See folder for Ltr. to Wright frm. Olson 11-2-84

STRATEGY AND PRELIMINARY PLANS FOR LARGE-SCALE HYDRAULIC STRESS TESTING OF SELECTED HYDROGEOLOGIC UNITS AT THE RRL-2 LOCATION

DRAFT

Basalt Waste Isolation Project
Richland, Washington

R. Stone
P. M. Rogers
R. L. Jackson
A. H. Lu
D. J. Moak

October, 1984

ABSTRACT

DRAFT

This strategy and preliminary plan is prepared for the first large-scale hydraulic stress (LHS) test on the Hanford Site, Washington. The test will be centered near the exploratory shaft site at RRL-2B. Tests will be designed and implemented to stress selected hydrogeologic ~~hydrologic~~ units (i.e., Rocky Coulee, Cohassett, Grande Ronde No. 5, and the Umtanum flow tops) in the Grande Ronde Basalt formation. The types of tests associated with this plan include constant rate pumping, injection, pulse, hydrochemical sampling, and tracer tests. During the constant rate pumping tests, water level fluctuations are expected to be observed in the hydrogeologic unit being pumped at DC-19, DC-20, DC-22, as well as other observation points several thousand feet from the pumping well. The injection and pulse tests will be used to stress relatively low conductivity flow tops, if encountered. Hydrochemical sampling will be performed prior to injection or pulse testing as well as during pumping tests. Tracer tests will be conjunctive with the pumping tests. Expected results of these tests are quantitative estimates of vertical and horizontal hydraulic conductivity, storativity, porosity, dispersivity, and information on hydrologic boundaries. The results will also be useful for the design of additional LHS tests at other locations on the Hanford Site, and will provide hydrologic data for input into the design of the proposed repository and groundwater control measures for exploratory shaft construction.

CONTENTS

DRAFT

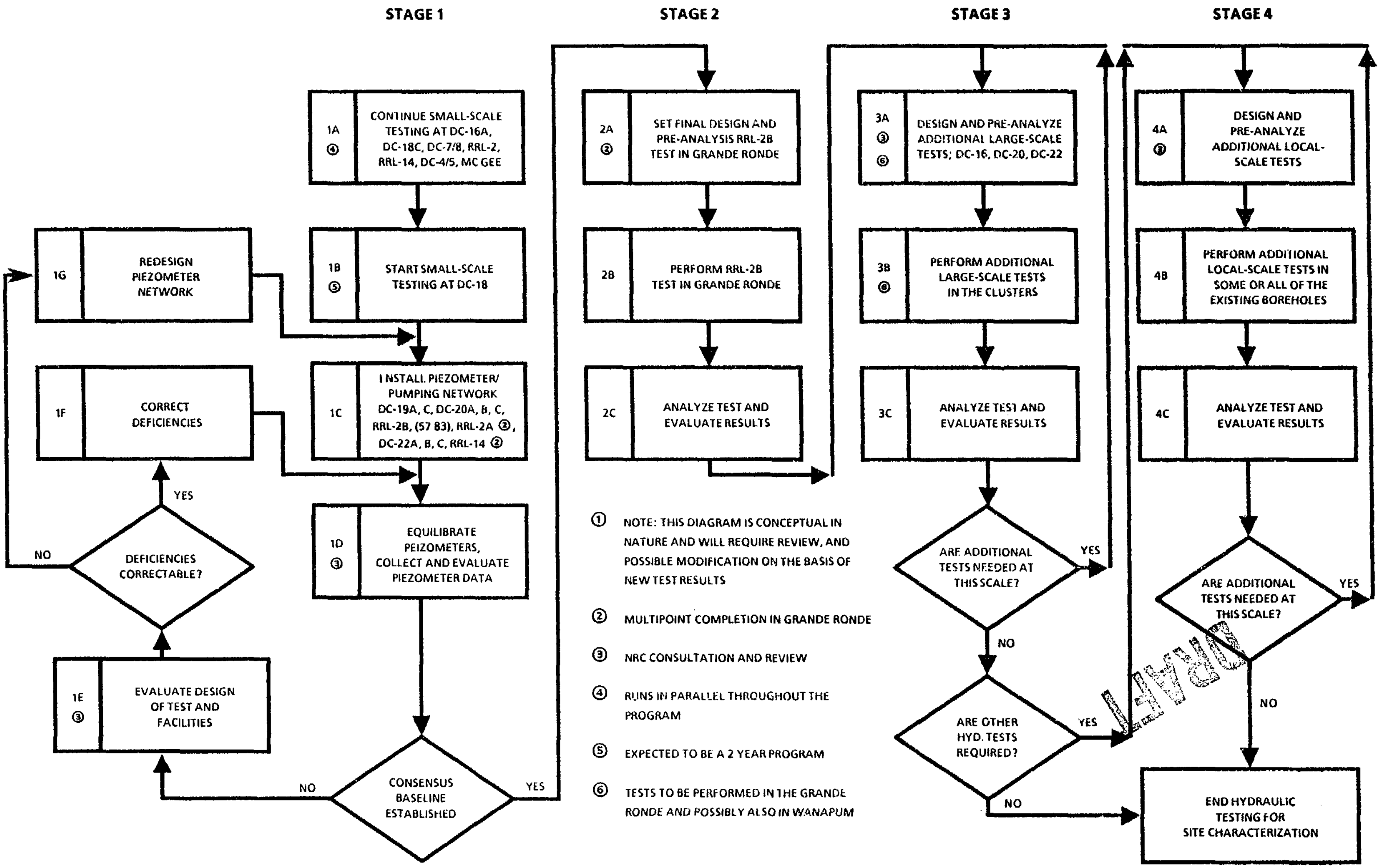
INTRODUCTION

This report documents a strategy and preliminary plan for performing large-scale, multiple-well hydraulic tests in the Grande Ronde Basalt at a specific location on the Hanford Site. The large-scale hydraulic stress (LHS) tests, will be performed at several selected locations on the Hanford Site; however, this document deals only with the first site which will be at the location of RRL-2 for reasons discussed below. Testing will be achieved by applying a stress such as withdrawal of groundwater, injection of water, or pressure pulsing and then observing resultant changes in groundwater level and/or pressure at several observation points. These stresses will be applied to selected basalt interflow zones (these zones may be referred to as either a flow top or flow bottom) of the Grande Ronde Basalt formation.

The general purposes of the LHS testing at RRL-2 are to evaluate the hydraulic characteristics of the selected interflow zones and adjacent hydrogeologic units, and to characterize the composition of dissolved substances in groundwater collected from the interflow zones. From this strategy and preliminary plan will evolve detailed plans, specifications, and procedures for hydraulic testing at well RRL-2B.

The planning for large-scale, multiple-well hydraulic testing of selected hydrostratigraphic units above and below the Cohassett flow interior (the preferred repository horizon) within the reference repository location (RRL) is part of the overall strategy for hydraulic testing at the Hanford Site. As shown in Figure 1, this strategy and plan is the initial step of stage 2 for the overall hydrologic site characterization. Data collection for establishment of background groundwater level trends at various locations at the site, a major part of stage 1 of this plan, is currently in progress. This strategy and plan is prepared only for stage 2, large-scale hydraulic stress (LHS) testing at the RRL-2 location. A strategy and plan will be prepared for stage 3 based on the data and experience gained in testing at RRL-2 and program needs identified at that time. Implementation of stages 2, 3, and 4 will provide data from several long-term pumping tests using several pumping wells at different locations at and near the RRL. This will facilitate more extensive evaluation of hydraulic characteristics, and will provide the opportunity to investigate and identify hydraulic boundaries in the groundwater systems that could not otherwise be studied. Testing using several pumping wells, pumped individually in separate tests, may also provide insight into the character and mechanism of vertical flow across basalt flow interiors that could not be obtained with a single test. The results of testing at well RRL-2B will aid in planning subsequent long-term multiple well tests.

FIGURE 1. LOGIC DIAGRAM FOR BWIP BOREHOLE: HYDROLOGIC TEST STRATEGY ①
(AFTER NUCLEAR REGULATORY COMMISSION, 1983)



PA841016-2

During the reconnaissance stage of hydraulic investigation at the Hanford Site, most hydraulic tests have been small-scale tests in single boreholes (Strait and Mercer, 1984). These tests have provided good estimates of hydraulic conductivity however, the areal extent and thus the representativeness of these data has been speculated upon and remains unknown (Nuclear Regulatory Commission, 1983). In addition to the single well tests, two tracer tests in flow tops have been completed (Leonhart, 1982) and a two well test of vertical hydraulic conductivity across a flow interior (Spane, et al., 1983). At the present, the Basalt Waste Isolation Project (BWIP) hydraulic investigation program is advancing from the reconnaissance stage. Large-scale, multiple-well hydraulic tests are required in this advanced stage to supplement the small-scale information hitherto collected. Some parameters such as aquifer storativity, porosity, and dispersivity are best estimated from multi-well tests. Further, these data are required to satisfy the needs for performance assessment of the proposed repository site.

The predictive models employed in performance assessment and other models used to portray the features of groundwater flow on the scale of the RRL and the Hanford Site deal with the heterogeneous nature of hydrogeologic units by use of areally averaged values of hydraulic characteristics. It is important that the characteristic parameter values input to the models be representative of the actual average site conditions on the scale of the models. Large-scale, multiple-well hydraulic tests will help assure that hydraulic parameter values used in modeling meet this requirement.

RATIONALE FOR TESTING AT RRL-2 LOCATION

The candidate repository horizons and the preferred repository horizon are contained within the Grande Ronde Basalt Formation (Long, 1983). Representative hydraulic parameter values of these and adjacent horizons are necessary for repository performance assessment. Thus, large-scale, multiple-well hydraulic testing of selected hydrostratigraphic units in the Grande Ronde Basalt Formation is given a high priority.

Well RRL-2B will be located within 500 feet of the Exploratory Shaft (ES) site which is fairly centrally located within the RRL. Testing at well RRL-2B would therefore provide the opportunity to evaluate hydraulic characteristics for the central portion of the RRL and the ES site. The evaluation will be of value and applicability in predicting the amount of groundwater inflow to the mined region during construction of the underground test area after ES completion. It may also help detect any geologic structures that could have mine safety significance.

It is important to test units of the Grande Ronde at the ES site prior to construction of the shaft because of possible alteration of the groundwater regime in the vicinity of the shaft. For example, potential alterations may occur when the shaft is grouted. Grout may migrate into relatively permeable flow tops. Another possibility is incomplete sealing of the ES annulus which may allow intercommunication of groundwater between flow tops. Also, the observation wells prepared for the LHS testing near the ES may be incorporated into future plans for monitoring during ES construction to assess the hydraulic effects of construction. For these reasons, stage 2 (Figure 1) specifies the first LHS testing to be at RRL-2 and in the Grande Ronde Basalt formation.

OBJECTIVES OF THE TESTING

Several general objectives of the LHS testing at well RRL-2B have been identified. These include:

- Facilitate design of additional LHS tests at other locations on the Hanford Site.
- Identification and classification of hydrologic boundaries. These boundaries may later be correlated to rock inhomogeneities that influence groundwater flow in the RRL.
- Characterization of the nature of dissolved substances in groundwater removed from the Grande Ronde Basalt through well RRL-2B.
- Assessment of the areal representativeness of hydraulic characteristic values obtained by previous single-well testing.
- Assessment of the degree of leakage into the test interflow zones from adjacent flow interiors.
- Evaluation of the hydraulic continuity of flow tops (and flow "bottoms") in the Grande Ronde Basalt in the RRL.

Specific requirements for evaluation of hydraulic characteristics of units of the Grande Ronde translate into a series of specific test objectives for the hydraulic testing at well RRL-2B. These test objectives include:

1. Evaluation of lateral hydraulic conductivity, storativity, effective porosity, and dispersivity of interflow zones.
2. Evaluation of vertical hydraulic conductivity of flow interiors using parameter variation and analytical techniques.

Another specific requirement is the measurement of the dissolved chemical and gas content and chemical characterization of groundwater samples collected from selected interflow zones.

Most of the details of how the testing objectives will be fulfilled by the proposed testing program at well RRL-2B are discussed below. A brief synopsis of the methods to be used in fulfilling the test objectives is presented here as a preview. Identification of hydraulic boundaries will depend largely on the analysis of drawdown and recovery hydrographs and the recognition of hydrograph shapes diagnostic of a variety of possible aquifer hydraulic boundaries. Water samples will be collected from the water pumped from well RRL-2B. These samples will be analyzed to provide a characterization of their dissolved chemical and gas content. The hydraulic characteristic values estimated from the results of pumping well RRL-2B will be compared with mean values of the same hydraulic characteristics as determined in single well tests to provide an assessment concerning the representativeness of the latter. The degree of leakage into the flow tops and flow "bottoms" of the Grande Ronde will be qualitatively assessed by inspection of drawdown hydrographs. Departure of drawdown records from the theoretical confined aquifer drawdown (as in the case of a leaky aquifer) may be quite obvious and easy to recognize. Hydraulic continuity of flow tops can be evaluated by observing water levels in wells other than the pumping well. Where drawdown occurs in an observation well in a particular unit that is being pumped, it can be inferred that some hydraulic connection exists between the pumped well and the observation well, in the pumped aquifer. Evaluation of lateral hydraulic conductivity, storativity, effective porosity and dispersivity of interflow zones will be accomplished using responses to the pumping from well RRL-2B and the results of tracer tests between observation wells and well RRL-2B as described in the section on data analysis and evaluation. Vertical hydraulic conductivity of flow interiors will be estimated using pumping test data as described in the same section.

SITE DESCRIPTION

Geologic Setting

The RRL lies within the Cold Creek syncline (Figure 2), which is part of the Pasco Basin. The Pasco Basin is one of several structural and topographic basins located within the Yakima Fold Belt Subprovince on the Columbia Plateau. The Pasco Basin extends to the Saddle Mountains on the north and to the Rattlesnake Hills on the south, both of which are anticlinal ridges of the Yakima Fold Belt. The western margin of the Pasco Basin is formed by the Naneum Ridge-Hog Ranch Anticline. The Palouse Slope defines the eastern margin of both the Pasco Basin and Yakima Fold Belt.

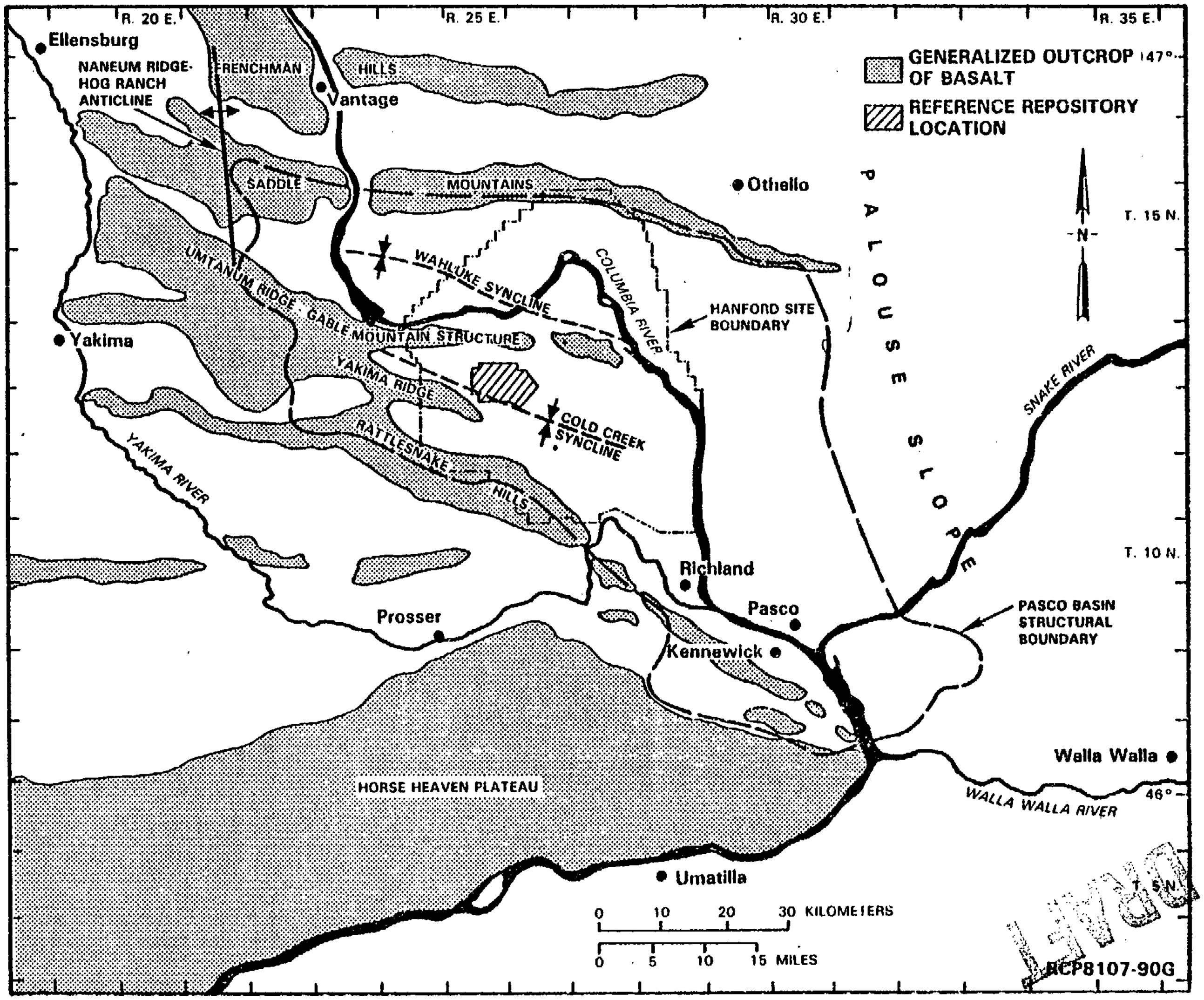


FIGURE 2 GENERAL LOCATION MAP SHOWING THE REFERENCE REPOSITORY LOCATION, COLD CREEK SYNCLINE, AND THE PASCO BASIN

The bedrock in the Pasco Basin is comprised of basalt flows of the Columbia River Basalt Group (Figure 3). The upper flows are interbedded with sediments of the Ellensburg Formation. Overlying the basalt are the fluvial-lacustrine Miocene-Pliocene Ringold Formation and catastrophic flood deposits of the Pleistocene Hanford Formation.

Within the RRL, the basalt flows can be grouped into three formations, listed oldest to youngest: (1) Grande Ronde, (2) Wanapum, and (3) Saddle Mountains Basalts (Figure 3). Of the three formations, the Grande Ronde Basalt accounts for more than 85 percent of the total volume of the Columbia River Basalt Group of the Columbia Plateau (Swanson and others, 1979; Reidel and others, 1982). Four horizons within the Grande Ronde Basalt Formation (Untanum, McCoy Canyon, Cohassett and Rocky Coulee Flows) have been identified as candidates for the reference repository horizon (Long, 1983).

The Grande Ronde Basalt in the Pasco Basin and RRL is divided informally into two basalt sequences (Myers, Price, and others, 1979). The lower sequence, the Schwana sequence, consists primarily of low-Mg chemical type flows. However, a small number of high-Mg chemical type flows and a very high-Mg chemical type flow are also found in the Schwana sequence,. The Umtanum flow is the uppermost flow in the Schwana sequence except in the northeast and northwest Pasco Basin where flows of low-Mg and intermediate-Mg chemical type have been found above it (Long and Landon, 1981; Price, 1982). The upper sequence, the Sentinel Bluffs, consists entirely of high-Mg chemical type flows. The lowermost flow in this sequence is the McCoy Canyon flow. The Cohassett flow is found near the middle of the Sentinel Bluffs sequence and the Rocky Coulee flow overlies the Cohassett flow. The boundary between the Schwana and the Sentinel Bluffs sequences is termed the Mg horizon (ARHCO, 1976).

Hydrologic Setting

Groundwater beneath the Hanford Site occurs in the sediments of the Hanford and Ringold Formations, and in the underlying basalt sequence of the Columbia River Basalt Group. Aquifers within the Hanford and Ringold Formations exist primarily under unconfined conditions. Groundwater in the layered basalt sequence is held under confined conditions.

Values of hydraulic conductivity for the Hanford and Ringold groundwater systems range from about 10^{-6} to 10^{-1} ft/s. The greatest hydraulic conductivity values occur in glaciofluvial sand and gravel deposits associated with buried paleochannels in the vicinity of Gable Mountain and Gable Butte (Gephart and others, 1979 DOE, 1982).

Period	Epoch	Group	Subgroup	Formation	K-Ar Age Years X 10^6	Member or Sequence	Geologic Mapping Symbol	Sediment Stratigraphy or Basalt Flows	
QUATERNARY	Pleistocene/ Holocene					SURFICIAL UNITS	Ql	LOESS	
							Qd	SAND DUNES	
							Qa, Qaf	ALLUVIUM AND ALLUVIAL FANS	
							Qld	LANDSLIDES	
							Qt	TALUS	
							Qco	COLLUVIUM	
	Pleisto- cene			Hanford		TOUCHET BEDS/ PASCO GRAVELS	Qht/Qhp		
								PLIO-PLEISTOCENE UNIT	
TERTIARY	Pliocene			Ringold			Trs	UPPER RINGOLD	FANGLOMERATE
							Trc	MIDDLE RINGOLD	FANGLOMERATE
							Trls	LOWER RINGOLD	FANGLOMERATE
							Trg	BASAL RINGOLD	
	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	8.5	ICE HARBOR MEMBER	Ti: Tig	GOOSE ISLAND FLOW	ELLENSBURG FORMATION Tel
							Tim	MARTINDALE FLOW	
							Tib	BASIN CITY FLOW	
								LEVEY INTERBED	
					10.5	ELEPHANT MOUNTAIN MEMBER	Tem: Tem_2	UPPER ELEPHANT MOUNTAIN FLOW	
							Tem_1	LOWER ELEPHANT MOUNTAIN FLOW	
								RATTLESNAKE RIDGE INTERBED	
					12.0	POMONA MEMBER	Tp: Tp_2	UPPER POMONA FLOW	
							Tp_1	LOWER POMONA FLOW	
								SELAH INTERBED	
						ESQUATZEL MEMBER	Te: Te_2	UPPER GABLE MOUNTAIN FLOW	
								GABLE MOUNTAIN INTERBED	
							Te_1	LOWER GABLE MOUNTAIN FLOW	
								COLD CREEK INTERBED	
						ASOTIN MEMBER	Ta	HUNTZINGER FLOW	
						WILBUR CREEK MEMBER	Tw	WAHLUKE FLOW	
						UMATILLA MEMBER	Tu: Tu_s	SILLUSI FLOW	
							Tu_u	UMATILLA FLOW	
								MABTON INTERBED	
				Wanapum Basalt	13.6	PRIEST RAPIDS MEMBER	Tpr: Tpr_l	LOLO FLOW	
							Tpr_r	ROSALIA FLOWS	
								QUINCY INTERBED	
						ROZA MEMBER	Tr: Tr_2	UPPER ROZA FLOW	
							Tr_1	LOWER ROZA FLOW	
								SQUAW CREEK INTERBED	
						FRENCHMAN SPRINGS MEMBER	Tf: Tf_a	APHYRIC FLOWS	
							Tf_p	PHYRIC FLOWS	
								VANTAGE INTERBED	
				Grande Ronde Basalt	15.6	SENTINEL BLUFFS SEQUENCE	Tsb	UNDIFFERENTIATED FLOWS	
								ROCKY COULEE FLOW	
								UNNAMED FLOW	
								COHASSETT FLOW	
								UNDIFFERENTIATED FLOWS	
								McCOY CANYON FLOW	
								INTERMEDIATE-Mg FLOW	
						SCHWANA SEQUENCE	Ts	LOW-Mg FLOW ABOVE UMTANUM	
								UMTANUM FLOW	
								HIGH-Mg FLOWS BELOW UMTANUM	
								VERY HIGH-Mg FLOW	
					16.1			AT LEAST 30 LOW-Mg FLOWS	

RCP8108-1G

FIGURE 3 PASCO BASIN STRATIGRAPHY

The confined aquifer system includes the basalt flows and associated sedimentary interbeds within the Grande Ronde, Wanapum and Saddle Mountains Basalts. Groundwater occurs primarily in interbed and flow-top zones.

For interbed and flow-top zones in the Saddle Mountains and Wanapum Basalts, measured hydraulic conductivities range primarily between 10^{-10} to 10^{-2} ft/s and average about 10^{-7} to 10^{-5} ft/s. The larger values are associated with flow tops within the Wanapum Basalt (Gephart and others, 1979; Strait and others, 1982; DOE, 1982).

Measured values of hydraulic conductivity for flow-top zones of the Grande Ronde Basalt range primarily between 10^{-10} to 10^{-3} ft/s. The geometric mean is approximately 5×10^{-7} ft/sec assuming an average flow top thickness of 10 ft. (Clifton et al., 1983). For the dense flow interior zones, the measured hydraulic conductivity ranges from about 10^{-10} to 10^{-12} ft/s (Gephart and others, 1979; Strait and others, 1982; DOE, 1982)

Groundwater flow within the Columbia River Basalt Group is influenced by a number of factors including topography, structure, lithology, recharge and discharge distribution and hydraulic properties of aquifers. Within the Cold Creek Syncline (beneath the RRL), the hydraulic heads in the confined system are estimated to range from 395 to 420 ft above mean sea level (MSL).

FACILITIES

Large-scale hydraulic tests conducted at the RRL-2 site in the Grande Ronde Basalt formation will utilize one pumping well and two observation wells near the Exploratory Shaft site and eight observation wells located at 1.4 miles or further from the pumping well (Table 1 and Figure 4). The facilities near the exploratory shaft site consist of borehole RRL-2A (existing), well RRL-2B (to be constructed) and piezometer nest RRL-2C (to be constructed). Both RRL-2A and RRL-2C will be used as multiple-level observation wells each capable of monitoring several selected hydrogeologic units. The pumping well for the large-scale hydrologic tests at RRL-2 is designated RRL-2B. This well will be constructed in stages, to be described in the next section, so that each horizon to be tested can be stressed discretely and then sealed before proceeding to the next horizon. The general location of the RRL-2 wells in relation to the ES is shown in Figure 5.

	PRINCIPLE OBSERVATION POINTS FOR LSH TESTS AT RRL–2									
	RRL–2C	RRL–2A	RRL–6	RRL–14	DC–16	DC–20	DC–22	DC–4/5	DC–19	M^c GEE
DISTANCE FROM RRL–2B (miles)	250 FT.	800 FT	1.4	1.4	1.6	1.6	1.5	1.8	3.4	4.4
UNCONFINED										
SADDLE MOUNTAINS BASALT					X	X	X		X	
WANAPUM BASALT					X	X	X		X	
ROCKY COULEE FLOW TOP	X	X		X		X	X	X	X	X
COHASSETT FLOW TOP	X	X	X	X	X	X	X	X	X	X
GRANDE RONDE No. 5 FLOW TOP	X	X	X	X	X			X		X
UMTANUM FLOW TOP		X	X	X	X	X	X	X	X	X
GRANDE RONDE COMPOSITE										

	OBSERVATION POINTS TO BE MONITROED AS PART OF THE GROUND WATER MONITORING PROGRAM																				
	DB–14	DB–11	DB–12	ENYEART	FORD	O'BRIAN	DB–9	DB–8	DC–2	DC–1	DC–12	DB–13	DB–15	DB–4	DC–14	DC–7/8	DB–7	DB–2	DB–1	DC–15	DDH–3
DISTANCE FROM RRL–2B (miles)	2.9	3.6	4.9	5.5	5.8	6.2	6.7	6.8	7.0	7.0	8.0	8.1	8.1	10.1	12.8	14.1	15.6	18.9	18.8	21.8	26.5
UNCONFINED																					
SADDLE MOUNTAINS BASALT							X	X				X		X			X				
WANAPUM BASALT	X		X	X	X	X				X			X					X	X		X
ROCKY COULEE FLOW TOP																X					
COHASSETT FLOW TOP																X					
GRANDE RONDE No. 5 FLOW TOP															X	X					
UMTANUM FLOW TOP											X				X	X					X
GRANDE RONDE COMPOSITE									X												

TABLE 1 BOREHOLES, WELLS, AND PIEZOMETERS AND ASSOCIATED HYDROGEOLOIC UNITS WHERE WATER LEVEL OBSERVATIONS CAN POTENTIALLLY BE MADE

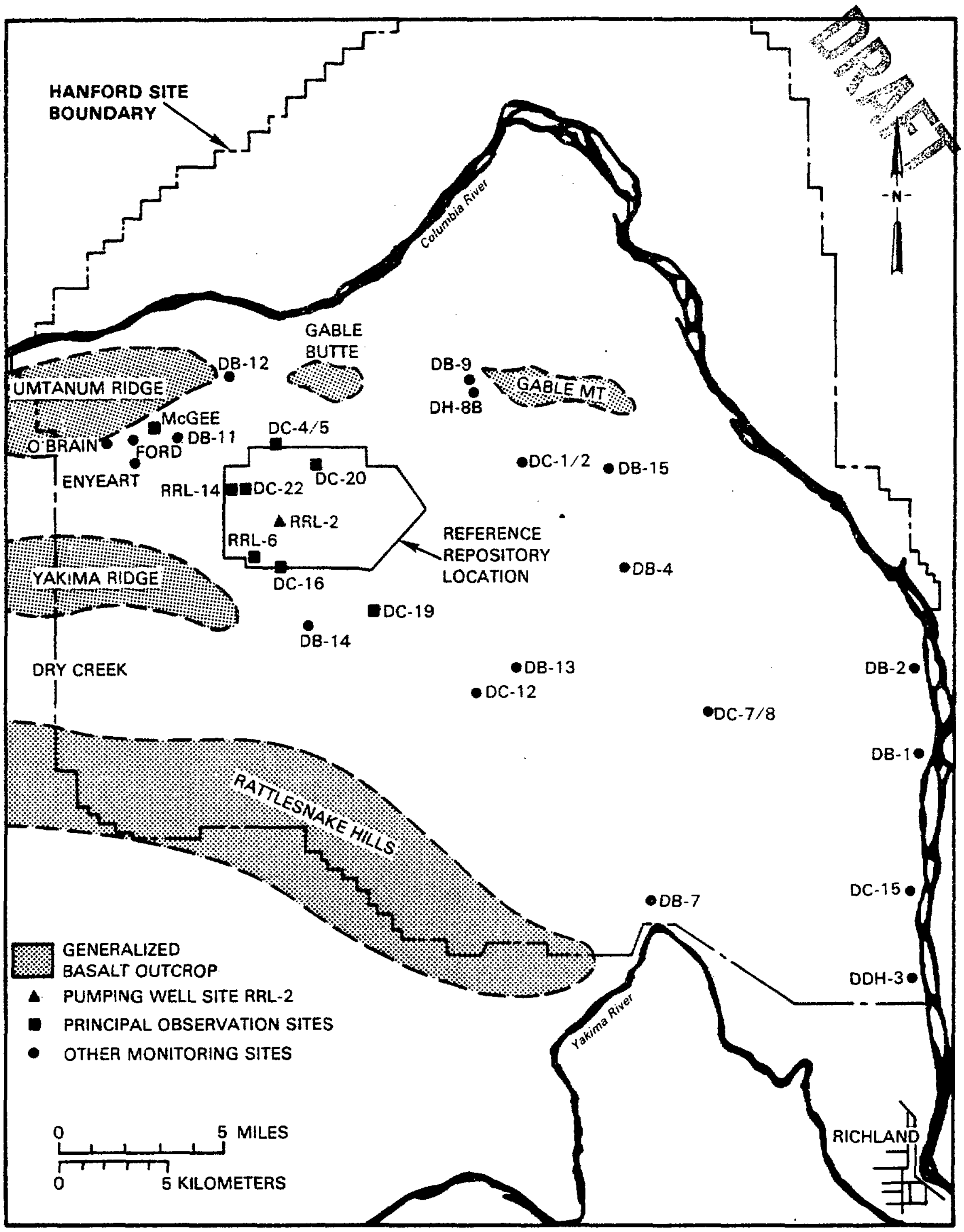


FIGURE 4 LOCATION OF BOREHOLES, WELLS, AND PIEZOMETERS ON THE HANFORD SITE WHERE WATER LEVEL DATA FROM HYDROGEOLOGIC UNITS IN THE COLUMBIA RIVER BASALT ARE CURRENTLY BEING OBTAINED

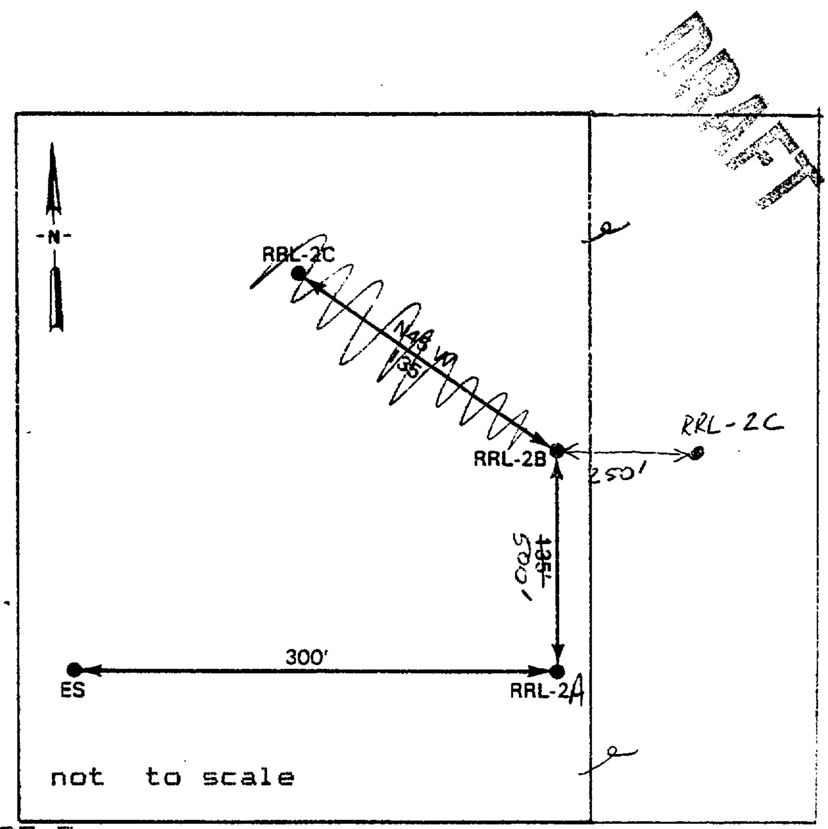


FIGURE 5 GENERALIZED RRL-2 CONFIGURATION

NOTE: Locations of wells RRL-2B and RRL-2C are approximate and subject to minor change.

The other principle facilities completed in the Grande Ronde Basalt Formation that will be monitored during the LHS tests at RRL-2 include: (1) piezometer clusters DC-19, DC-20, and DC-22; (2) boreholes DC-16A, RRL-6 and RRL-14; (3) dual borehole site DC-4/5; and (4) McGee well. These sites are located within 1.4 to 4.5 miles of RRL-2B. In addition to these observation boreholes, ongoing head monitoring will continue during LHS testing for distant observation boreholes which are part of the Hanford Site groundwater monitoring network. A more detailed discussion of the principle facilities 1.4 miles or further from RRL-2B can be found in Appendix A.

Pumping Well RRL-2B

Pumping well RRL-2B will be constructed so that a stress (induced by pumping, injection or pulsing) can be imposed on selected hydrogeologic units [Rocky Coulee flow top, Cohassett flow top, Cohassett flow bottom (Grande Ronde No. 5 flow top), and Umtanum flow top] within the Grande Ronde Basalt using a drill-test staged approach. This approach allows for hydraulic testing of a single horizon, i.e., the Rocky Coulee flow top, prior to deepening the well to other horizons for testing. Upon completion of hydraulic testing in each horizon, the well will be lined and cemented before drilling to the next test horizon. This procedure will be repeated for the deeper Cohassett flow top and Cohassett flow bottom. The lowermost test horizon (Umtanum flow top) will not be lined or cemented.

Design

The general design for pumping well RRL-2B is shown in Figure 6. As shown, three strings of casing will be installed from ground surface to approximately 2,820 ft. The lowermost string of 13.375-in. O.D. casing will be set above the Rocky Coulee flow top at a depth of approximately 2,820 ft. In addition to these three strings of casing, liners will be grouted across the flow tops of the Rocky Coulee and Cohassett, and the flow bottom of the Cohassett. The final designed depth and diameter of the borehole will be approximately 3,755 ft and 5.875-in., respectively. The uppermost portion of each liner overlaps the casing or liner immediately above it by about 100 feet. This is illustrated in Figure 6 but may not be readily apparent because the figure is not to scale.

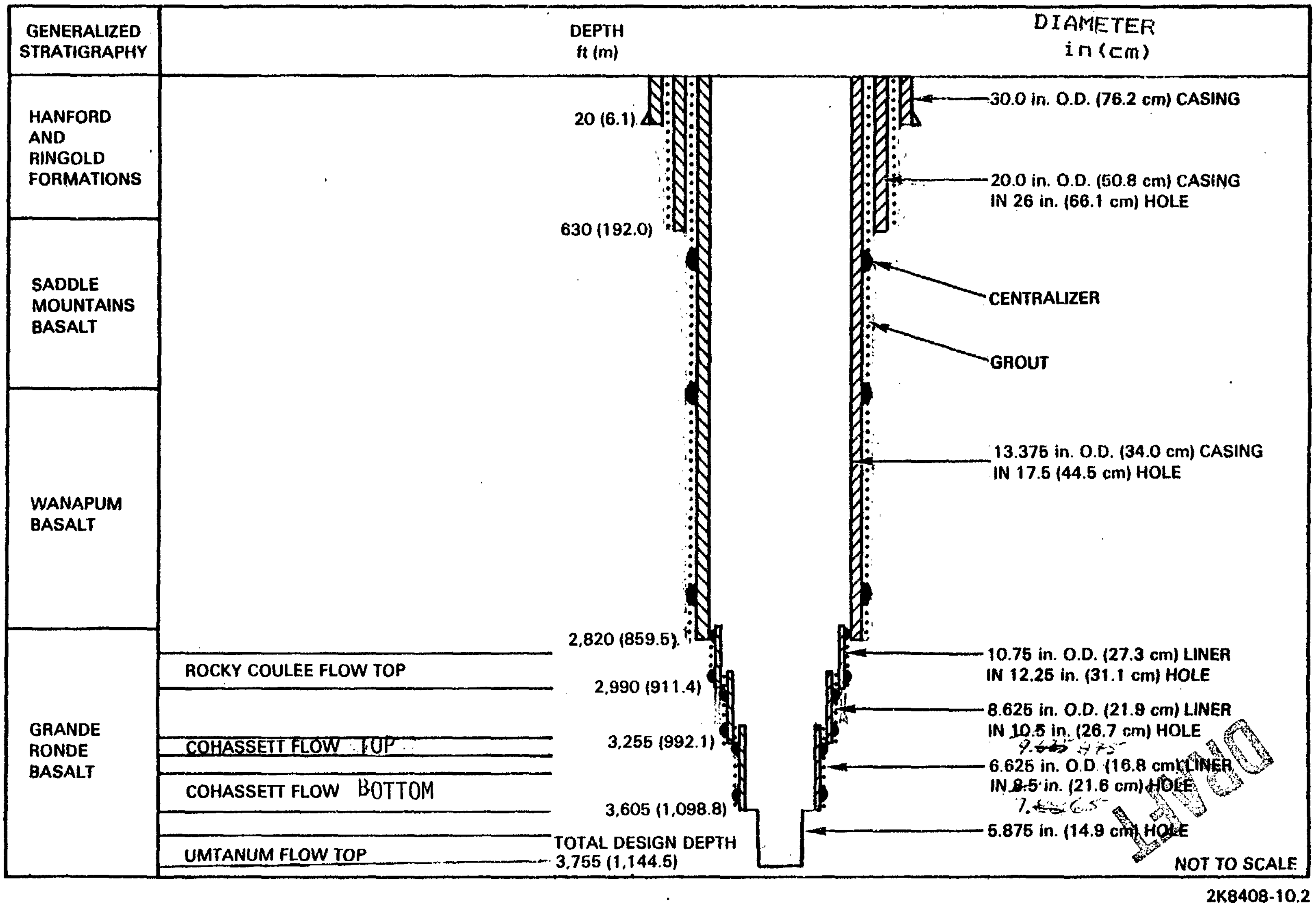


FIGURE 6 PROPOSED CONCEPRUAL DESIGN OF WELL RRL-2B

14

Drilling Requirements

Pumping well RRL-2B will consist of a 30-in. O.D. steel cased entry hole, installed by a cable tool drill to approximately 20 ft below the surface. A subcontracted rotary drill will then be set up over this hole and a 26-in. hole will be mud rotary drilled into the basalt to a depth of approximately 630 ft below land surface. Twenty-inch O.D. casing will then be installed and the annulus grouted with neat cement. Well RRL-2B will then be mud rotary drilled with a 17.5-in. bit to approximately 2,820 ft, which is just above the flow top of the Rocky Coulee flow. Then centralized 13.375-in. O.D. casing will be installed and the annulus grouted with neat cement. The well will then be advanced across the Rocky Coulee flow top with a 12.25-in. bit to approximately 2,860 feet using clear water as the drilling fluid. The bit and drilling tools will be pulled from the well and hydraulic testing will begin.

After testing the Rocky Coulee flow top, it will be sealed with neat cement and the borehole will be advanced with a 12.25-in. bit to approximately 2,990 ft. This is just above the Cohassett flow top. The open hole from approximately 2,820 to 2,990 will then be geophysically logged to determine the actual hole size and to verify that at least a 1-inch annular space will exist between the borehole and the 10.75-inch liner to be installed. If it is found that a 1-inch annular space is not available mitigating measures such as underreaming the hole or downsizing the liner diameter will be employed. A 10.75-in. O.D. centralized liner will be set from approximately 2,720 to 2,990 ft and grouted in place. A 9.875-in. hole will be drilled with water across the Cohassett flow top. The drilling tools will then be pulled from the well and hydraulic testing will begin.

After testing the Cohassett flow top, it will be sealed with neat cement and the well will be drilled with a 9.875-in. bit to just above the flow bottom of the Cohassett at a depth of approximately 3,255 ft. The open hole from approximately 2,990 to 3,255 will then be geophysically logged to determine the actual hole size and to verify that at least a 1-in annular space will exist between the borehole and the 8.625-inch liner to be installed. If it is found that a 1-inch annular space is not available mitigating measures such as underreaming the hole or downsizing the liner diameter will be employed. A centralized 8.625-in. O.D. liner will them be set from 2,890 (100 ft inside the Cohassett flow top liner) to 3,255 ft and grouted into place. A 7.865-in. hole will then be drilled across the flow bottom of the Cohassett flow. The drilling tools will be pulled from the well and hydraulic testing will begin.

After testing the Cohassett flow bottom, it will be sealed with neat cement and will be drilled with a 7.865-in bit to just above the Umtanum flow top at a depth of approximately 3,605 ft. The open hole from approximately 3,255 to 3,605 will then be geophysically logged to determine the actual hole size and to verify that at least a 1-inch annular space will exist between the borehole and the 6.625-inch liner to be installed. If it is found that a 1-inch annular space is not available mitigating measures such as underreaming the hole or downsizing the liner diameter will be employed. A centralized 6.625-in. O.D. liner will then be set from 3,155 to 3,605 ft and grouted into place. A 5.875-in. hole will then be drilled across the Umtanum flow top to a completed well depth of 3,755 ft. The drilling tools will be pulled from the well, the drill demobilized and hydrologic testing of the Umtanum flow top will begin.

Cementing and Casing Requirements

Construction of well RRL-2B will require three strings of casing and three liners:

1. From ground surface to approximately 20 ft, 30-in. O.D. butt welded casing will be installed.

2. From ground surface to approximately 630 ft, 20-in. O.D. casing will be installed with appropriately spaced centralizers and grouted in place.

3. From ground surface to approximately 2,820 ft,. 13.375-in. O.D. casing will be installed with appropriately spaced centralizers and grouted in place.

4. From approximately 2,720 (100 feet inside the 13.375-in casing) to 2,990 ft, a 10.75-in. O.D. liner will be set with appropriately spaced centralizers and grouted in place.

5. From approximately 2,890 (100 feet inside the Rocky Coulee flow top liner) to 3,255 ft, an 8.625-in. O.D. liner will be set with appropriately spaced centralizers and grouted in place.

6. From approximately 3,155 (100 feet inside the Cohassett Flow top liner) to 3,605 ft, a 6.625-in. O.D. liner will be set with appropriately spaced centralizers and grouted in place.

During the drilling of well RRL-2B, trouble zones above a depth of 2,820 ft, such as unstable sedimentary interbeds or lost circulation zones, may be cemented off to allow drilling activities to continue. Zones that will be tested will be cemented upon completion of hydraulic testing.

Observation Well RRL-2C

Observation well RRL-2C will monitor fluid pressures in selected flow tops and flow interiors within flows of the Grande Ronde Basalt. This multi-level piezometer design differs from other piezometer configurations, i.e., DC-19C, in that the RRL-2C design focuses on pressure monitoring of flow interiors as well as flow tops. Pressure measurements (using shut-in transducers at formation depth) will be obtained in the interiors of the Rocky Coulee, Cohassett, and Grande Ronde #5 flows (Figure 7). Pressure and depth-to-water measurements will be obtained in the Rocky Coulee flow top, Cohassett flow top and Cohassett flow bottom (grande Ronde #5 flow top). Figure 5 shows the approximate location of well RRL-2C. Well RRL-2C, with its piezometers completed in flow interiors, and flow tops provides an opportunity to estimate vertical hydraulic conductivity of flow interiors using the ratio method of Neuman and Witherspoon (1972).

Design

Each of the piezometer strings will consist of a tailpipe, one or more screened section(s), a seating nipple, a riser tube, a multiple gradation filter pack, and a neat-cement seal. Each piezometer string will be partially centralized to achieve stand-off of the screen section(s) from the borehole wall and the adjacent piezometer strings in the borehole. The six piezometer strings are isolated from each other and the next overlying hydrologic horizon by neat-cement seals. The three piezometers that will monitor fluid pressure in the flow interiors will have pressure transducers located at the formation depth. These transducers will be shut-in with a packer immediately above the piezometer screen. The other piezometers will also have transducers at formation depth however, they will not be shut-in.

Drilling Requirements

Well RRL-2C will consist of a 30-in. O.D. steel-cased entry hole to be installed by a cable tool drill to approximately 20 ft. A subcontracted rotary drill will be used to mud rotary a 26-in. hole into the basalt to a depth of approximately 630 ft. Twenty-inch O.D. steel casing will then be installed and the annulus grouted with neat cement. Well RRL-2C will then be mud rotary drilled with a 17.5-in. tricone bit to approximately 2,820 ft, which is just above the flow top of the Rocky Coulee flow. The 13.375-in. O.D. centralized steel casing will be installed and the annulus grouted with neat-cement. A 12.25-in. hole will then be rotary drilled using an areated water rotary system to a final depth of approximately 3,380 ft. Six 2-1/16-in. O.D. piezometer tubes with sand packs and neat-cement seals will be installed utilizing a workover rig. Piezometer tubes will be installed in the Rocky Coulee flow top, Rocky Coulee interior, Cohassett flow top, Cohassett flow interior, Cohassett flow bottom, and Grande Ronde # 5 flow interior.

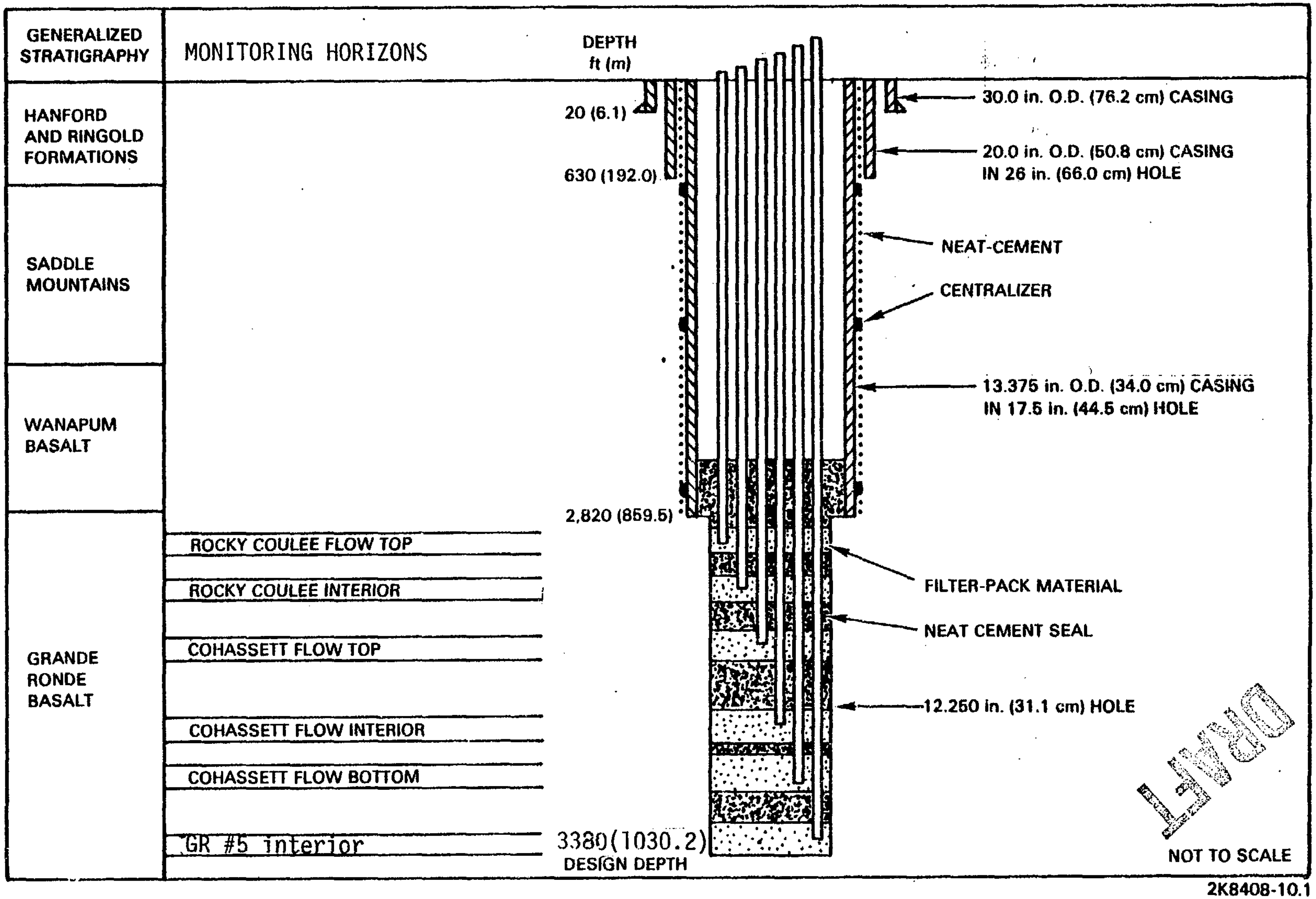


FIGURE 7 PROPOSED CONCEPTUAL DESIGN OF WELL RRL-2C

Cementing and Casing Requirements

Well RRL-2C will require three strings of casing:

1. From ground surface to approximately 20 ft, 30-in. O.D. butt welded casing will be installed.

2. From ground surface to approximately 630 ft, 20-in. O.D. casing will be installed with appropriately spaced centralizers and grouted in place.

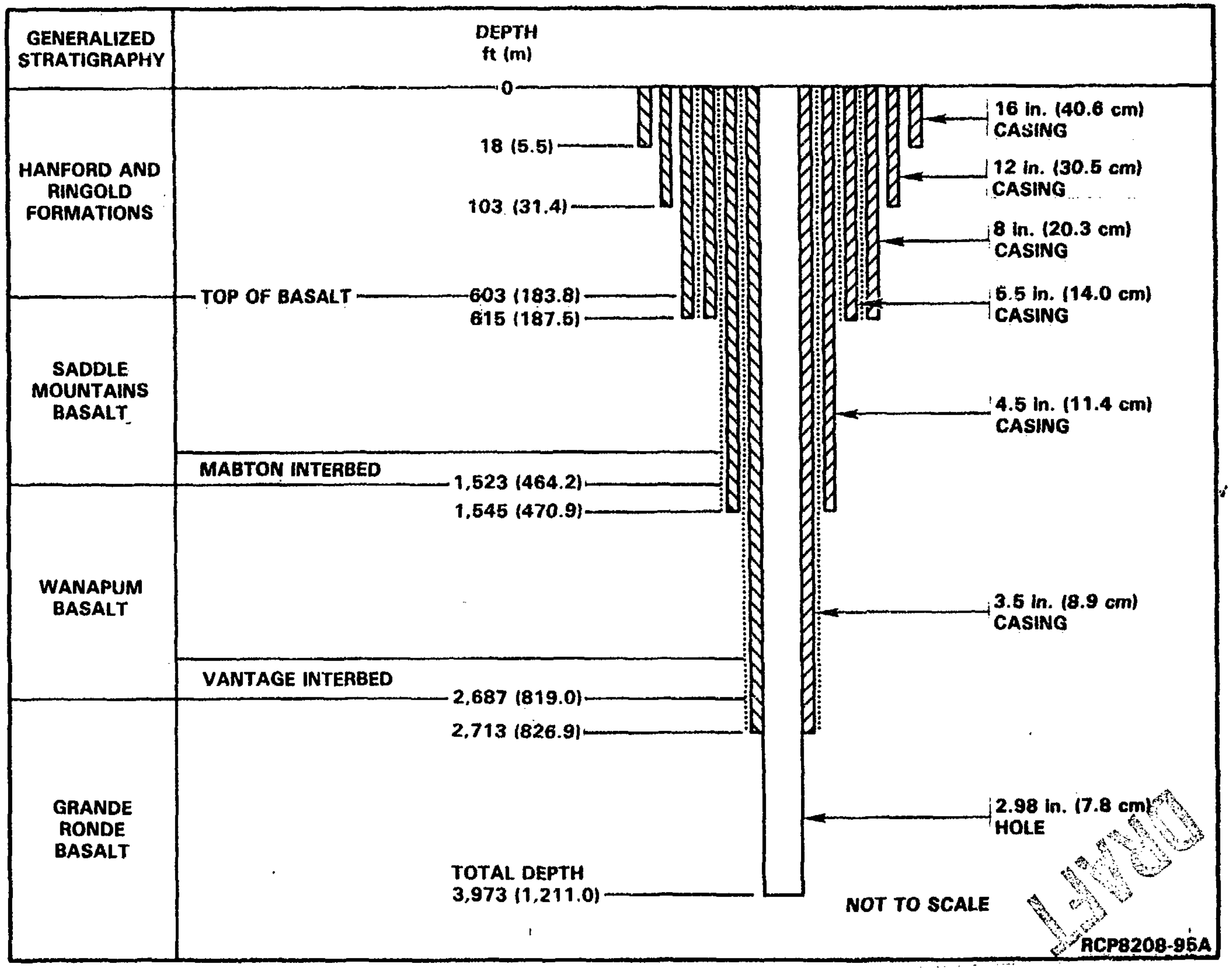
3. From ground surface to approximately 2,820 ft, 13.375-in. O.D. casing will be installed with appropriately spaced centralizers and grouted in place.

Existing Borehole (RRL-2A)

Borehole RRL-2A is completed as a 2.980-in.-diameter borehole. It was drilled in 1982 to acquire a wide range of subsurface information for assessing the overall suitability of the ES site, and for the design and selection of porthole locations. Wintczak (1983) presents the results of the drilling, core and geophysical logging, and hydrologic, geomechanical and hydrofracture tests performed at RRL-2A. The borehole was temporarily completed with water-inflatable bridge plugs (packers) to isolate selected flow tops. The bridge plugs thus prevent the movement of groundwater vertically in the borehole between flow tops. The temporary bridge plugs are installed from approximately 2,800 to 4,000 ft. These bridge plugs isolate the following hydrogeologic horizons: Umtanum flow top, McCoy Canyon flow top, Cohassett flow top, and Rocky Coulee flow top (cemented during construction). These bridge plugs will be replaced in early 1985 with a straddle packer system capable of isolating several horizons and measuring hydraulic pressures in them. Borehole RRL-2A will be used as a multi-level observation well during hydraulic testing at the RRL-2 location.

Current Configuration

An as-built of borehole RRL-2A is shown in Figure 8. As shown in this figure, several strings of casing were used to case off the formations above the Grande Ronde Basalt. The deepest string of casing (3.5-in. O.D. diameter) was cemented at a depth of 2,713 ft. Below the 3.5-in. casing, the 2,980-in. borehole is open between the depths of 2,713 to 3,973 ft.



NOTE: During construction the Rocky Coulee flow top was cemented to control drilling fluid loss.

FIGURE 8 AS-BUILT OF BOREHOLE RRL-2A

Borehole Preparation

Some remedial preparation will be required prior to installing the straddle packer monitoring system below the 3.5-in. casing at RRL-2A. The borehole preparation activities will include: (1) removing and placing bridge plugs, (2) flushing the borehole with clear water to remove particulate matter that may have entered the boring, (3) brief hydraulic tests of zones in the Cohassett flow interior that have been hydraulically fractured (for in situ stress measurements) to determine if conductivity in the vicinity of the borehole was materially changed as compared to estimates of conductivity from tests conducted prior to hydraulic fracturing, and (4) confirming the conditions of the borehole utilizing a caliper log, camera survey and running a 2.5-in. by 4.0-ft cylindrical rod over the open hole interval. During construction of borehole RRL-2A the Rocky Coulee flow top was cemented to control drilling fluid loss. However, at this time remedial measures that might remove some of the cement are not a part of the scheduled borehole preparation because of the difficulties and uncertainties associated with any of the available remedial measures. The previous cementing, however, did not completely seal the Rocky Coulee flow top as is indicated by observed water level fluctuations. Therefore, this flow top may be functional for the stress test; however, RRL-2A will not be used for tracer testing because of the potential effects the cementing may have had on the flow top porosity and dispersivity.

COMPLETION AND INSTRUMENTATION OF RRL-2A AND RRL-2C

Existing Borehole (RRL-2A)

A straddle packer monitoring system will be installed in borehole RRL-2A prior to conducting large scale hydraulic tests at well RRL-2B. This system is designed to isolate and measure hydraulic pressures in horizons in the 2.98-in. basalt core hole at depths ranging from 2,800 to 3,400 feet. The monitored horizons will initially be the Rocky Coulee flow top, Cohassett flow top, and Cohassett flow bottom. The Umtanum flow top can also be monitored, however, to do so will require removing the straddle packer system and bridge plugs and reinstalling them as described below. The inflatable packers will be installed in flow interiors. These zones are identified on the basis of information such as core data, geophysical logs (i.e., caliper, neutron-epithermal) and downhole camera surveys. Considerations also will be given to locate packers outside zones of hydraulic fracturing.

Bridge plugs isolating the rocky Coulee and cohassett flow tops will be removed and a bridge plug in the Grande Ronde #5 flow interior will be added. A straddle packer system will be installed and used to measure pressure in and isolate the Cohassett flow bottom and top and the Rocky Coulee flow top. Measurement of pressure in the Umtanum flow top will require the removal of the straddle packer system and bridge plugs, placement of a bridge plug in the Umtanum flow ~~top~~ interior and reinstallation of the straddle packer system. This arrangement will allow the measurement of pressure in the Umtanum flow top. However, several significant trade-offs must be considered. Pressure measurements above the Umtanum flow top would represent the composite pressure of several interflows. Data of this nature would ~~be~~ have limited quantitative use. Many of the locations for packer installation have

been hydrofractured (for determination of in situ stress). Also, the open borehole above the straddle packers would allow groundwater of the various interflows to mix. On the other hand, a pressure measurement in the Umtanum flow top at this location is important because there will not be an opportunity to obtain pressure measurements in the Umtanum at the nearby piezometer cluster, RRL-2C. The next closest observation well is about 1.4 miles from the pumping well, RRL-2B.

The strategy presented herein assumes pressure measurements at RRL-2A in the Umtanum flow top will be obtained during the LHS test of the Umtanum. It is expected that some uncertainty will be associated with the data collected from RRL-2A, especially those data from the Umtanum flow top. Prior to testing of the Umtanum, evaluations of the inherent negative aspects of the available system will be performed. Given these evaluations and the evaluations of the test data from LHS tests of the selected hydrogeologic units above the Umtanum, the decision to monitor the Umtanum flow top will be revisited.

By design, the straddle packer system is capable of monitoring absolute pressure in three horizons. Tracers can also be injected into the interval straddled. Pressures from each horizon are recorded simultaneously as rapidly as one minute intervals on to floppy disks for data transfer, data reduction and interpretation.

Observation Well RRL-2C

The six level multiple piezometer (see Figure 7 for design) will be instrumented with temperature compensated pressure transducers set at approximate formation depth. Both pressures and depth to water measurements will be made in piezometers completed in flow tops. Only pressure measurements will be made in piezometers conmpleted in flow interiors, because the pressure transducers, which will be located within the piezometer screen, will be shut-in with a packer located immediately above the piezometer screen. The downhole transducer and recording system planned at this site is similar to the system presently used at the borehole cluster sites DC-19, DC-20, and DC-22.

TEST SEQUENCE

Selected hydrogeologic units (e.g., Rocky Coulee flow top, Cohassett flow top, Cohassett flow bottom, and the Umtanum flow top which are also referred to as interflows) are of interest for reasons discussed in the section titled Rationale For Testing AT RRL-2 Location. The transmissivities of these interflows, based on hydrologic tests in RRL-2A (Wintczak, 1984), are several orders of magnitude higher than those in the adjacent flow interiors. Except for the Cohassett flow top, these interflows can be pumped in conventional pumped discharge well tests. At the present, it is assumed that the Cohassett flow top will not be stressed by pumping but by some other means such as injection and/or pulsing because of the very low estimated transmissivity of this interflow as indicated by hydrologic testing in RRL-2A. However, a brief step-drawdown pumping test will be performed in well RRL-2B to verify the pre-test assumptions prior to installation of injection equipment. The Cohassett flow top will be stressed with a conventional pumped discharge test if it is feasible based on the evaluation of the step-drawdown test.

DRAFT

The planned test sequence is to test the four horizons of interest in RRL-2B, Rocky Coulee flow top, Cohassett flow top, Cohassett flow bottom, and Umtanum flow top, in that order, as discussed in the section on facilities near the ES site. The staged construction of the well RRL-2B allows each interflow to be pumped or stressed individually. The staged construction requires that each interflow zone be sealed (using cement and casing) after it is tested, except for the last interflow, the Umtanum flow top, which will be the only interflow open in the well at the end of testing. In the future, it may be desired to re-test or utilize for other purposes the sealed interflow zones. However, it will be difficult to open up these zones and may not be possible to do so adequately. The alternative to this approach is to use a straddle packer arrangement to isolate the test intervals in the pumped well. This alternative is not acceptable for reasons that include the problem of leakage around packers and interconnection of aquifer zones in the open borehole.

Prior to, during and after the pumping tests of the Rocky Coulee flow top, Cohassett flow bottom and Umtanum flow top, provisions will be made to obtain water samples from the well for field and laboratory analyses. Convergent tracer tests will also be initiated during the pumping tests. At RRL-2C a tracer will be injected into the interflow being pumped at well RRL-2B (except for the Untamum flow top which will not have a piezometer) including the Cohassett flow top if it is indeed stressed by pumping. A tracer, distinguishable from the tracer injected into RRL-2C, will also be injected into the appropriate interflow at RRL-2A except for the Rocky Coulee flow top. A tracer experiment will

not be performed on the Rocky Coulee flow top using RRL-2A as an injection point because of the uncertainties that would arise related to the effects cementing may have had on the porosity and dispersivity of the Rocky Coulee flow top in the vicinity of RRL-2A. As discussed in an earlier section, the Rocky Coulee was cemented during construction of RRL-2A to control drilling fluid loss.

TEST DESIGN

The overall design of the large-scale test at RRL-2 is most easily discussed as a series of logical steps (Figure 9). The first step, parametric analysis, has been initiated and is discussed herein. Test conceptual design includes the planning for the installation of the test well, observation wells, and instrumentation based on the results of the parametric analysis. The step-drawdown tests will be a field test performed using temporary pumping equipment to verify the test design. If necessary, modifications can be made to the test pumping equipment and instrumentation at this time prior to initiating the long term test.

Test design is dependent on the objectives of the testing. These have already been listed but for clarity will be restated at this point. The objectives of the large-scale testing at RRL-2B are to:

- Facilitate the design of subsequent LHS tests.
- Maximize the areal extent of test influence.
- Quantify flow top hydraulic parameters (conductivity, storativity, effective porosity, dispersivity).
- Quantify leakance (analytically).
- Quantify vertical hydraulic conductivity (Kv) of flow interiors (using numerical model inverse techniques).
- Obtain representative hydrochemical samples.
- Quantify point values of Kv analytically using observations of pressure change in the flow interiors and flow tops using well RRL-2C.

Accomplishing the test objectives requires a plan that has the proper number of facilities at the proper locations, each with the appropriate design. One of the first tasks is to determine what existing observation points might be affected (e.g., within the measureable cone of influence) and then determine that these observation points are of configuration and design consistant with LHS test objectives. Part of this pre-test planning and design has been initiated by way of implementation of a parametric study, described more fully in the appendix. Preliminary results for the Rocky Coulee flow top are presented therein. Similar parametric studies for the Cohassett flow bottom and Umtanum flow top are under way.

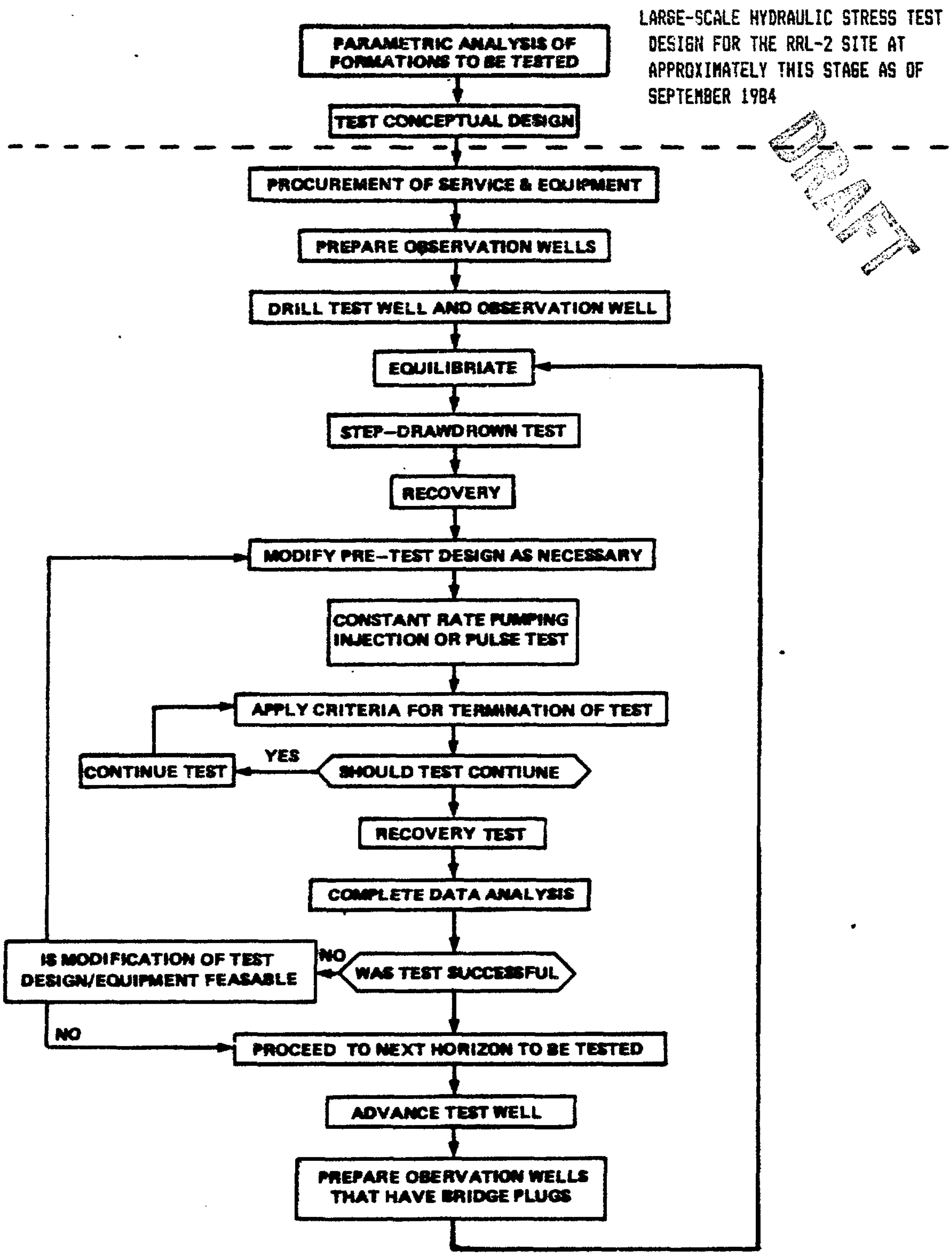


FIGURE 9 LOGIC DIAGRAM FOR DESIGN AND IMPLEMENTATION OF LARGE-SCALE HYDRAULIC STRESS TESTING AT THE RRL-2 SITE

The parametric studies are based primarily on the range of values of hydraulic parameters estimated from single-hole testing on the Hanford Site (Strait and Mercer, 1984). A quasi-three-dimensional model (Trescott, 1975) was used to evaluate the effects that the ranges of parameter values would have on a simulated pumping test. Twenty model runs were performed for the Rocky Coulee flow top. Some of the results of these runs are presented as a series of distance vs. drawdown curves and time vs. drawdown curves in the appendix.

Certain conclusions can be drawn from inspection of the above referenced results, relative to the test objectives. These conclusions, relative to testing the Rocky Coulee flow top, are:

- Substantial drawdown will occur in the Rocky Coulee flow interior within a radius of about 500 feet from the pumped well for most combinations of parameter values used in the model runs.

- The radius of influence, based on a drawdown of 5 feet in the pumped formation, will intercept the DC-20 and DC-22 piezometer clusters within a 30 day pumping period for all variations of parameters except those used in case 2. Drawdown in the Rocky Coulee flow top may not be measurable at the DC-19 piezometer cluster.

The first conclusion is important for the quantification of point values of Kv which, for an analytical determination, depends on observations of water level change within the dense basalt flow interiors. The inverse modeling technique, using the finite difference numerical model by Trescott (1975), requires that for the determination of K_v a measureable response be observed in the flow tops over and underlying the pumped flow top. This response should be discernable in the observation points within a few hundred feet of the pumped well however, for the next closest observation points at 1.4 miles, the response may not be discernable given either very low Rocky Coulee flow top transmissivity and/or very low interior Kv. The likelihood of measuring response at the more distant observation points can be increased by using more sensitive transducers to measure water pressures and by increasing the stress (e.g., increasing the drawdown) in the pumped flow top.

Quantification of porosity and dispersivity requires that a tracer test be performed concurrent with the pumping tests. A parametric study incorporating the expected range of these parameters will be performed. Also, prior to final tracer selection, tracer effect on water sample analyses and effects on tracer mobility due to reaction with the ground water will be evaluated.

Test conceptual design has also been initiated. The preliminary design and location of the test well, and all of the observation wells has been completed and is discussed in the section on facilities. The test well, to be designated RRL-2B, and one observation well, RRL-2C, have not yet been constructed. Therefore, both their designs and locations can still be modified should it be warranted based on the evaluation of the remaining parametric studies. The vertical locations of the transducers in the dense interiors in RRL-2C are yet to be determined. Most likely, the placements will be heavily weighed on constructability. The parametric study for the Rocky Coulee indicates that transducer installation in the upper two thirds of the Rocky Coulee flow interior will be acceptable.

The step-drawdown test will, as mentioned above, provide a way to verify the parametric analysis and the test conceptual design (Harrill, 1970). Also, it will provide information useful in evaluating well efficiency (Walton, 1970) and in selecting the optimum pumping rate for the long term test. The step-drawdown test will utilize temporary pumping/well development equipment installed to a depth of about 1,000 feet which will allow a maximum drawdown in the pumped well of about 800 feet. Basically, the test begins with relatively small discharge rates designed to result in only a few tens of feet of drawdown after a few hours of constant rate pumping. The flow rate is then increased by an increment designed to perhaps double the drawdown of the first step. The test will then continue in the same fashion, increasing the flow rate of each successive step to achieve about twice the drawdown of the proceeding step. The duration of each step is kept approximately equal until the available drawdown has been exhausted. Five steps are anticipated which would be followed by a recovery period of at least 48 hours duration. The flow rates for these steps will be determined in advance of the test however, both flow rates and step durations may be modified in the field. Following the step-drawdown test, the temporary pumping/development equipment will be removed from the well and the long-term test pump and equipment will be installed. Because of schedule constraints, the test pumps must be ordered prior to the step-drawdown test. The pumps ordered will be based on the parametric analysis and the test conceptual design steps. There are few field modifications that can be made to the test pumps should the step-drawdown test not verify prior test design. In this event, available equipment modifications and test design changes would have to be compared with potential schedule perturbations that would result in procuring other equipment.

The long-term pumping test would then begin after the test pumping equipment is installed, pre-test checks have been completed and pre-test water level trends have been established. In the Rocky Coulee flow top, Cohassett flow bottom, and Umtanum flow top, the long-term tests will be constant discharge rate pumping tests. The discharge rates and test durations will be determined through the stepwise process described herein consistent with the test objectives. A preliminary evaluation of the Rocky Coulee parametric study indicates a test duration of about 30 days culminating with a drawdown at the test well of between 1,000 and 1,500 feet assuming a 100 percent efficient well. The effect that this stress may have on cement seals used in well construction and the geologic material itself will be further evaluated prior to test implementation.

INSTRUMENTATION AND DATA COLLECTION

Observations and measurements associated with hydraulic testing of hydrostratigraphic units in well RRL-2B will fall into the following general categories:

- o Hydraulic pressure measurements.
- o Discharge volume measurements (discharge from well RRL-2B).
- o Discharge rate measurements.
- o Tracer concentration measurements.
- o Barometric pressure measurements.
- o Discharge water temperature measurements.

Hydraulic Pressure Measurements

Hydraulic pressure measurements in the wells and piezometers at DC-19, DC-20, and DC-22 will be made using quartz pressure transducers emplaced at near formation depth. These transducers are energized by a unit known as a signal conditioner/multiplexer. The signal conditioner/multiplexer also receives the output from the transducers and feeds it to a frequency counter which measures the oscillation frequency of the quartz transducers. Data flow is from the frequency counter to a desk-top computer where the frequency information is written onto floppy disk. Pressure values will be calculated, using the transducer manufacturer's calibration, then displayed and printed for immediate use. The floppy disk frequency data will be transmitted to Richland on a phone line where it will be converted to pressure values (again using the manufacturer's calibration). The pressure data will be retrieved from Richland by phone line for display, interpretation, and manipulation in the field office.

Hydraulic pressure measurements at well RRL-2C would be similar to that at DC-19, DC-20, and DC-22. The Rocky Coulee flow top at RRL-6, RRL-14, and DC-4/5 will be monitored using a pressure measurement system similar also to that at DC-19, DC-20, and DC-22. The type of pressure measurement system to be used at DC-16A has not been determined.

Various methods of telemetry are currently being considered for up to 10 other sites. The sites will be prioritized based on proximity to the pumping well, geologic horizons that can be monitored and density of other similar observation points. The primary objective of any telemetry application will be to allow real time analysis of the pumping test data. Other objectives relating to the ongoing groundwater monitoring program will also be considered but have not yet been identified.

The Rocky Coulee flow top at the McGee Well should be monitored using a pressure measurement system similar to that at DC-19, DC-20, and DC-22.

Where possible, checks on the pressure measurements will be made periodically by water-level measurements. These measurements will not constitute a complete record by themselves.

Discharge Volume Measurements

Total discharge from pumping well RRL-2B will be recorded using flow meters. Four meters will be used in a series-parallel arrangement so that water always flows through one set of two meters in series. If problems with one or both of these meters develop, the flow can be quickly valved to the other two meters, which are plumbed together in series, but in parallel with the first two meters. A record of discharge volume with time will be kept. Preference will be given to water meters that have an automatic recording capability. Records will be manually retrieved and delivered to the field office.

Discharge Rate Measurements

Discharge rate from the pumped well will be regulated by an automatic flow controller. Discharge rate will be measured using recording inline flow meters. Two flow meters will be plumbed into the discharge piping from the well. They will be in parallel so that one can be inspected or repaired as needed. Discharge rate records will be manually retrieved and transported to the field office.

Tracer Concentration Measurements

Tracer concentration in the water discharged from pumping well RRL-2B will be measured in the field using an ultra violet absorption spectrophotometer and a liquid chromatograph. The organic acids being considered for use in convergent tracer testing can be easily detected and their concentrations are readily determined with such equipment. The tracer content of the discharge water will be monitored continuously in the field. Time integrated samples of discharge water will be collected for laboratory analysis. A field record of tracer concentration as a function of time will be produced from the continuous monitoring.

Barometric Pressure Measurements

Atmospheric pressure is measured at the DC-19, DC-20, and DC-22 sites with a 15 psi quartz pressure transducer system at the surface. This system is essentially the same as that used at the sites to measure and record hydraulic pressure in the piezometers. A similar 15 psi surface transducer system will be employed at RRL-2A to obtain a record of atmospheric pressure variation there.

Discharge Water Temperature Measurements

A thermocouple, suitably calibrated, will be mounted in the discharge line from well RRL-2B to measure the temperature of water as it is pumped from the well. Records from these thermocouple measurements will be collected on a daily basis.

GENERAL TEST PROCEDURES

The test procedures are designed to assure that the test conditions are controlled and well measured. They provide a framework within which the tests will be conducted. A detailed test procedure or protocol will be prepared in the future. A generalized set of procedures is presented here.

Test procedures are differentiated into those followed before pumping (or pulsing), during pumping (or pulsing), and after pumping (or pulsing).

Preparation (Before Pumping or Pulse Testing) Procedures

Prior to initiation of the pump and pulse tests preparatory actions will include:

1. Calibration or checks on the calibration of all measuring devices to include transducers, flow meters, spectrophotometers, etc.

2. Hydraulic tests of critical borehole seals in piezometers and wells. The packer seals in the straddle packer system in RRL-2A would be tested, for example.

3. Preliminary pumping of well RRL-2B to determine a sustainable pumping rate for the pump test and to develop the well.

4. Establishment of near-equilibrium water levels and pressures in monitoring wells, boreholes, and piezometers and determination of any long-term pressure or water level trends.

5. Provisions to start timers and data recording devices simultaneously at the beginning of the tests.

6. Obtaining a pressurized water sample from the interval to be tested in the pumped well.

Pump (Pulse) Test (During Pumping) Procedures

Procedures to be followed during pumping tests will include:

1. More intense (dense) data collection in the first several hours of the test. The early parts of pumping tests are generally the busiest for those involved and in some ways are the most critical.

2. Careful monitoring of the performance of the discharge flow regulator, particularly in the early part of the test.

3. Collection of data at least on a daily basis from various data loggers/recorders.

4. Daily update of hydrographs for each well/borehole/piezometer.

5. Injection of tracer slug into appropriate interval in RRL-2A and RRL-2C after quasi-steady flow is noted between RRL-2A and RRL-2B.

6. Sampling water from discharge stream for laboratory analysis.

Procedures to be followed during pulse tests are somewhat simpler than for pump tests. The tests generally are only a few minutes to several tens of minutes in duration, essentially no volume flow into or out of the test well is involved, and no tracer test or water sampling is required. The most important element in a successful pulse test, aside from sensitive pressure transducers at observation wells, is the generation of a distinct and easily recognized pressure pulse.

Procedures Following Cessation of Pumping

Actions after cessation of pumping should include:

1. Reading the final water volume to allow calculation of cumulative volume pumped and average discharge rate.
2. More intense (dense) data collection in the first several hours of the recovery.
3. Collection of data at least on a daily basis from various data loggers/recorders.
4. Daily update of hydrographs for each well/borehole/piezometer.
5. Sampling of water in tested zone in well RRL-2B using the pressurized sampler, after the pump is pulled.

TEST DATA ANALYSIS AND EVALUATION

General

Analysis of the results of pumping well RRL-2B will be simplified by controlling test conditions and limiting the number of variables. Conversion of pressure measurements to equivalent hydraulic head values will be accomplished as a first step in data reduction. Hydrograph records of drawdown and pulse responses and tracer concentration graphs will be kept current during the testing and will serve to aid in determining test length. It is planned to continue the pumping tests until steady conditions are approached, if possible.

The analysis of the test results will proceed first using appropriate analytical techniques. If responses indicate that test conditions diverge from those required to apply certain analytical techniques, numerical techniques of data analysis will be used.

Analytical Techniques

The Cohassett flow top will likely be tested using constant head injection or pulse testing techniques. Theoretical bases for these tests and their interpretation are given by Jacob and Lohman (1952) and Johnson, et al. (1966), respectively.

DRAFT

The Rocky Coulee and Umtanum flow top and the Cohassett flow bottom will be tested using constant discharge pumping techniques. Analytical interpretive techniques such as those given by Theis (1935), Cooper and Jacob (1946), and Hantush (1956) will be used to derive estimates of the values of hydraulic characteristics of the flow tops. The method of Hantush (1956) and the ratio method (Neuman and Witherspoon, 1972) will be used to derive estimates of the values of hydraulic characteristics of flow interiors. A completely satisfactory analytical method to treat the convergent tracer test results is not yet available, but presumably can be obtained for our use. Hydraulic boundaries may be approximately located using techniques described by Ferris, et al. (1962).

Numerical Techniques

Axially symmetric and quasi-three-dimensional groundwater flow codes are available to analyze the test results by parameter variation techniques. In addition to these two finite difference codes, a fully three-dimensional, finite element groundwater flow code is available for data analysis. These codes are being used in test design and can serve in test analysis as well.

SCHEDULE

The schedule presented herein is predicated on the following:

- A sufficient groundwater level baseline will be established by March 1, 1985.
- ES drilling will begin January 1986.
- Two shafts will be constructed sequentially.
- Tests in the Rocky Coulee flow top, Cohassett flow bottom, and Umtanum flow top will each require 90 days.
- The test in the Cohassett flow top will require 40 days.
- A straddle packer monitoring system will be installed and operating in RRL-2A by March 1, 1985.

- LHS testing can proceed in the Grande Ronde at RRL-2 until the shaft approaches the top of the Grande Ronde.

- The test configuration for RRL-2 will consist of the test well RRL-2B, nearby observation wells, RRL-2A and RRL-2C, and several other observation points at 1.4 miles or farther from RRL-2B.

Implicit in the above listed assumptions is the availability of resources necessary to accomplish all of the stated objectives. The schedule, based on the above planning assumptions, is presented in Figure 10. If the plans go according to schedule, a pumping test of the Rocky Coulee flow top and pulse test of the Cohassett flow top should be performed in FY 1985 followed by pump tests of the Cohassett flow bottom and Umtanum flow top in FY 1986, all done prior to ES penetration of the Grande Ronde. Furthermore, both the Rocky Coulee and Cohassett flow top tests would be performed prior to the start of ES construction.

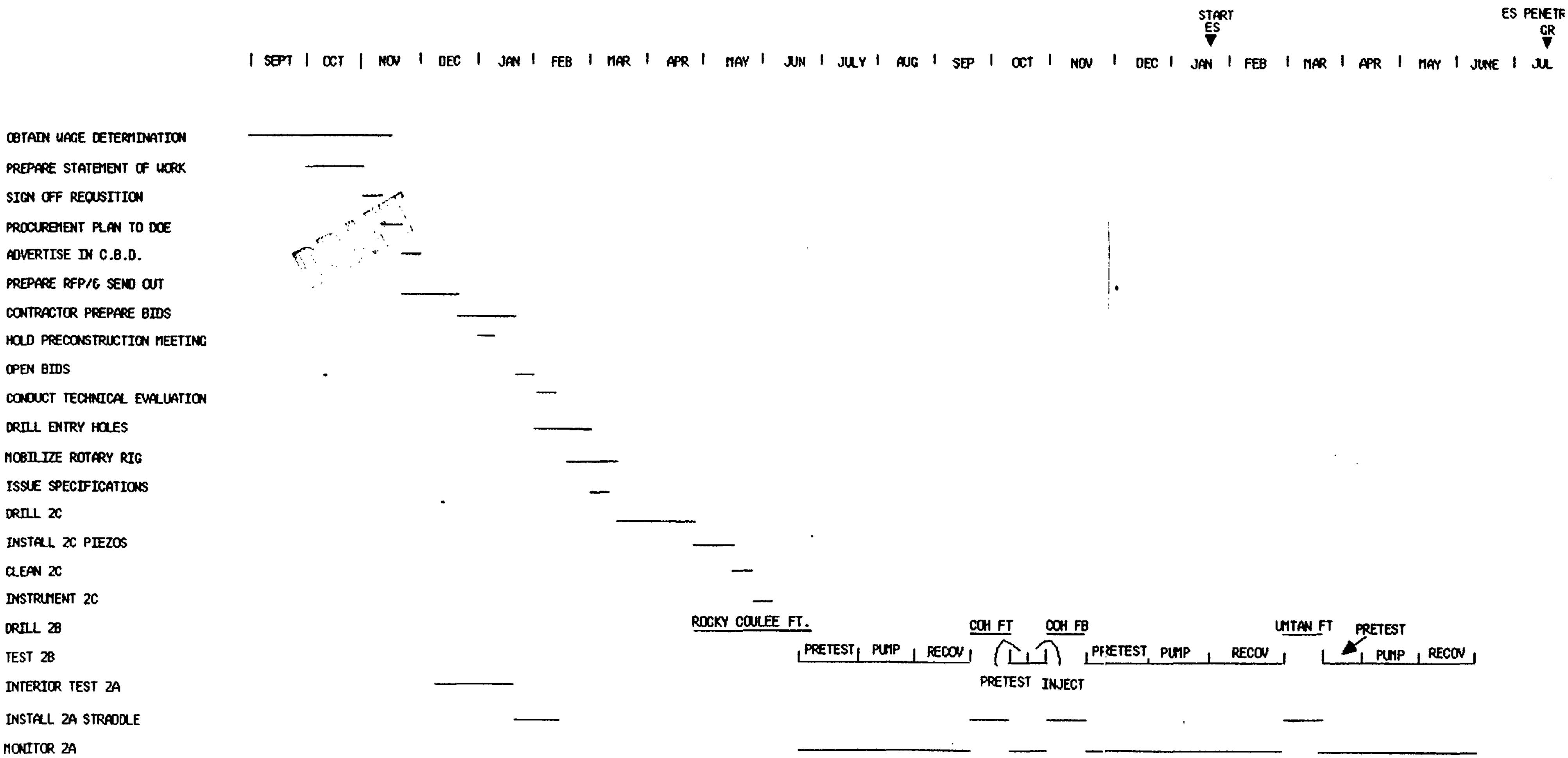
The plan presented herein allows for the achievement of the stated objectives. Possibly the most critical data need of the BWIP program at this time is representative estimates of basalt flow interior vertical hydraulic conductivity (Kv). Of particular interest are the vertical hydraulic conductivities of the Rocky Coulee and the Cohassett flow interiors. The current plan and schedule allows for the evaluation of data leading to estimates of Kv via the following applicable approaches:

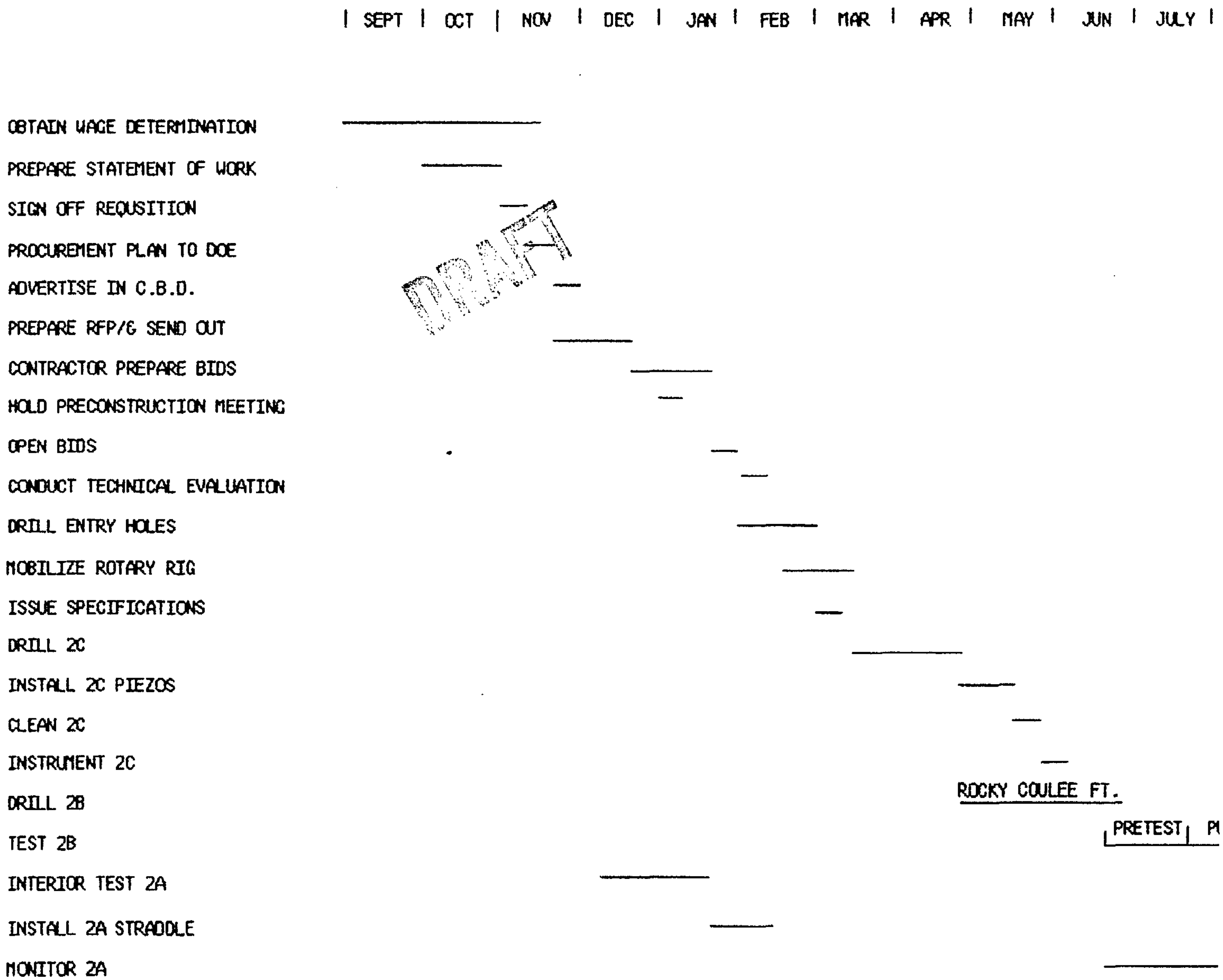
- Theis-Hantush method, relying on head measurements in the pumped formation.

- Numerical modeling to "back out" Kv based on head measurements in the pumped formation and flow tops subjacent and superjacent to the pumped formation.

- Ratio method, relying on head measurements in the pumped formation and the adjacent flow interior.

Currently, the ability does not exist to measure water levels in flow interiors at any location on the Hanford Site. RRL-2A, because of its close proximity to RRL-2B, would be well suited for use with the ratio method except that 1) it has been hydraulically fractured in the process of in situ stress measurement, 2) the Rocky Coulee flow top was grouted during drilling to control drilling fluid loss, and 3) the small nominal three-inch diameter borehole makes it impossible to instrument this boring with anything but temporary packers or experimental small hole multiple packer systems. For these reasons, head measurements in flow inteiors and in the Rocky Coulee flow top from borehole RRL-2A are not easily supported and may not be accurate. However, with a straddle packer system and placement of appropriate bridge plugs, this borehole is suitable for head measurements of other flow tops in the Grande Ronde. These data are useful for evaluation of Kv by both the Theis-Hantush and modeling methods.


START ES
ES PENETR GR
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JULY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JUL
OBTAIN WAGE DETERMINATION
PREPARE STATEMENT OF WORK
SIGN OFF REQUSITION
PROCUREMENT PLAN TO DOE
ADVERTISE IN C.B.D.
PREPARE RFP/6 SEND OUT
CONTRACTOR PREPARE BIDS
HOLD PRECONSTRUCTION MEETING
OPEN BIDS
CONDUCT TECHNICAL EVALUATION
DRILL ENTRY HOLES
MOBILIZE ROTARY RIG
ISSUE SPECIFICATIONS
DRILL 2C
INSTALL 2C PIEZOS
CLEAN 2C
INSTRUMENT 2C
DRILL 2B
TEST 2B
INTERIOR TEST 2A
INSTALL 2A STRADDLE
MONITOR 2A
ROCKY COULEE FT.
PRETEST
PUMP
RECOV
COH FT
COH FB
PRETEST
INJECT
PRETEST
PUMP
RECOV
UMTAN FT
PRETEST
PUMP
RECOV


SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JULY
OBTAIN WAGE DETERMINATION
PREPARE STATEMENT OF WORK
SIGN OFF REQUSITION
PROCUREMENT PLAN TO DOE
ADVERTISE IN C.B.D.
PREPARE RFP/6 SEND OUT
CONTRACTOR PREPARE BIDS
HOLD PRECONSTRUCTION MEETING
OPEN BIDS
CONDUCT TECHNICAL EVALUATION
DRILL ENTRY HOLES
MOBILIZE ROTARY RIG
ISSUE SPECIFICATIONS
DRILL 2C
INSTALL 2C PIEZOS
CLEAN 2C
INSTRUMENT 2C
DRILL 2B
TEST 2B
INTERIOR TEST 2A
INSTALL 2A STRADDLE
MONITOR 2A
DRAFT
ROCKY COULEE FT.
PRETEST

Well RRL-2C forms an intrinsic part of this strategy. It will be designed and constructed with emphasis on head observations in the flow interiors and will also provide head observations in selected flow tops. The observations from this nested piezometer will allow the estimation of Kv by the ratio method.

Measurement of head response in flow tops at other distant points can be used to estimate areally averaged vertical hydraulic conductivity of flow interiors with both the Theis-Hantush and modeling methods of analysis. These estimates may be dominated by a few major fractures or discontinuities in the intervening flow interiors (Gephart et al., 1983). Integration of the results of the three evaluations (Theis-Hantush, modeling, and ratio method) may provide evidence on the nature of vertical flow, e.g., fracture dominated vs. diffuse flow through the rock matrix.

REFERENCES

ARHCO, 1976, Preliminary Feasibility Study on Storage of Radioactive Waste in Columbia River Basalts, ARH-ST-137, Atlantic Richfield Hanford Company, Richland, Washington.

Clifton, P. M., Baca, R. G., Arnett, R. C., 1983, Stochastic Analysis of Groundwater Traveltime for Long-Term Repository Performance Assessment, RHO-BW-SA-323 P, Rockwell Hanford Operations, Richland, Washington.

Cooper, H. H., Jr., and Jacob, C. E., 1946, A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History, Transactions, Amer. Geophysical Union, Vol. 27, No. 4, pp. 526-534.

Diediker, L. D., 1984, Borehole DC-16A, SD-BWI-TI-135, Rockwell Hanford Operations, Richland, Washington.

DOE/EA-0048, 1978, Exploratory Borehole Drilling Activities, Wells, AR4--DC-4, -5, -6, -7, and -8, Hanford Reservation, Benton County, Washington.

DOE/RL 82-3, 1982, Site Characterization Report for the Basalt Waste Isolation Project, Office of Terminal Waste Disposal and Remedial Action, Washington, D.C.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R.W., 1962, Theory of Aquifer Tests, U.S. Geological Survey, Water Supply Paper 1536-E.

Gephart, R. E., Arnett, R. C., Baca, R. G., Leonhart, L. S., and Spane, F. A., Jr., 1979, Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge, RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Gephart, R. E., Price, S. M., Jackson, R. C., Myers, G. W., 1983, Geohydrologic Factors and Current Concepts Relevant to Characterization of a Potential Nuclear Waste Repository Site in Columbia River Basalt, Hanford Site, Washington, RHO-BW-SA-326 P, Rockwell Hanford Operations, Richland, Washington.

Hantush, M. S., 1956, Analysis of Data from Pumping Tests in Leaky Aquifers, Transactions, Amer. Geophysical Union, Vol. 37, No. 6, pp. 702-714.

Hantush, M. S. and C. E. Jacob, 1955, Non-steady Radial Flow in An Infinite Leaky Aquifer, Transactions of the American Geophysical Union, v. 36, pp. 95-100.

Harrill, J. R., 1971, Determining Transmissivity from Water-Level Recovery of a Step-Drawdown Test, (In Geological Survey Research), U.S. Geological Survey Professional Paper 700-C.

Jackson, R. L., Diediker, L. D., Ledgerwood, R. K., and Veatch, M. D., 1984, Piezometer Completion Report for Borehole Cluster Sites DC-19, DC-20, and DC-22, SD-BWI-TI-226, Rockwell Hanford Operations, Richland, Washington, Rev. 1.

Jacob, C. E. and Lohman, S. W., 1952, Nonsteady Flow to a Well of Constant Drawdown in an Extensive Aquifer, Transactions, Amer. Geophysical Union, Vol. 33, No. 4, pp. 559-569.

Johnson, C. R., Greenhorn, R. A., and Woods, E. G., 1966, Pulse Testing: A New Method for Describing Reservoir Flow Properties Between Wells, Soc. Petroleum Engineers, Transactions, Vol. 237, pp. 1599-1604.

Leonhart, L. S., 1982, Analyses of Two-Well Tracer Tests With a Pulse Input, SD-BWI-TI-073, Rockwell Hanford Operations, Richland, Washington.

Long, P. E. and Landon, R. D., 1981, "Stratigraphy of the Grande Ronde Basalt" in Myers, C. W. and Price, S. M., eds., Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Lu, A. H., 1984, "Opportunistic Use of Drilling-Stress Data to Estimate Aquifer Parameters", NWWA Symposium on Practical Applications of Groundwater Models, Columbus Ohio, August 15-17.

Myers, C. W., Price, S. M., Caggiano, J. A., Cochran, M. P., Czimer, W. J., Davidson, N. J., Edwards, R. C., Fecht, K. R., Holmes, G. E., Jones, M. G., Kunk, J. R., Landon, R. D., Ledgerwood, R. K., Lillie, J. T., Long, P. E., Mitchell, T. H., Price, E. H., Reidel, S. P., and Tallman, A. M., 1979, Geologic Studies of the Columbia Plateau: A Status Report, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

Neuman, S. P. and Witherspoon, P. A., 1972, Field Determination of the Hydraulic Properties of Leaky Multiple Aquifer Systems, Water Resources Research, Vol. 8, No. 5, pp. 1284-1298.

Nuclear Regulatory Commission, 1983, Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project, NUREG-0960, Office of Nuclear Safety and Safeguards, Washington, D.C.

Nuclear Regulatory Commission, 1983, BWIP SITE TECHNICAL Position No. 1.1: HYDROGEOLOGIC TESTING STRATEGY FOR THE BWIP SITE, Division of Waste Management, Washington, D.C.

Patterson, J. K., 1983, Borehole RRL-6 Report, SD-BWI-TI-167, Rockwell Hanford Operations, Richland, Washington.

Patterson, J. K., 1984, Borehole RRL-14 Report, SD-BWI-TI-186, Rockwell Hanford Operations, Richland, Washington.

Price, E. H., 1982, Structural Geometry, Strain Distribution, and Tectonic Evolution of Umtanum Ridge at Priest Rapids and a Comparison with other Selected Localities Within Yakima Fold Structures, South-Central Washington, Ph.D. Thesis, Washington State University, Pullman, Washington.

Prickett, T. A. and G. C. Lonquist, 1971, Selected Digital Computer Techniques for Groundwater Resource Evaluation, Bulletin 55, Illinois State Water Survey.

Reidel, S. P., Long, P. E., Myers, C. W., and Mase, J., 1982, New Evidence for Greater than 3.2 Kilometers of Columbia River Basalt Beneath the Greater Columbia Plateau, Transactions, Amer. Geophysical Union, Vol. 63, No. 8, p. 173.

Spane, F. A., Jr., Thorne, P. D., and Chapman, W. H., 1983, Results and Evaluation of Experimental Vertical Hydraulic Conductivity Testing at Boreholes DC-4 and DC-5, SD-BWI-TI-136, Rockwell Hanford Operations, Richland, Washington.

Strait, S. R., Spane, F. A., Jr., Jackson, R. L., and Pidcoe, W. W., 1982, Hydrologic Testing Methodology and Results from Deep Basalt Boreholes, RHO-BW-SA-189P, Rockwell Hanford Operations, Richland, Washington.

Strait, S. R. and Mercer, R. B., 1984, Hydrologic Property Data from Boreholes on the Hanford Site, SD-BWI-DP-051, Rockwell Hanford Operations, Richland, Washington (in preparation).

Swanson, D. A., Wright, T. L., Hooper, D. R., and Bentley, R. D., 1979, Revisions in Stratigraphic Nomenclature of the Columbia River Basalt Group, U.S. Geological Survey Bulletin 1457-H.

Theis, C. V., 1935, The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage, Transactions, Amer. Geophysical Union, Vol. 16, pp. 519-524.

Trescott, P. C., 1975, Documentation of Finite-Difference Method for Simulation of Three-Dimensional Groundwater Flow, U.S. Geological Sruvey, Open File Report 75-438.

Walton, W. C., 1970, Groundwater Resource Evaluation, McGraw Hill, New York.

Wintczak, T. M., 1984, Principal Borehole Report, Borehole RRL-2, SD-BWI-TI-113, Rockwell Hanford Operations, Richland, Washington.

Wood, T. J., Pidcoe, W. W., Mack, G. S., and Cline C. S., 1984, McGee Well Report, SD-BWI-TI-227, Rockwell Hanford Operations, Richland, Washington.

DRAFT

APPENDIX A

OTHER EXISTING FACILITIES

In addition to the observation wells and boreholes described in the text, on-going head monitoring will continue during the pumping test at distant observation boreholes which are part of the Hanford Site monitoring network. Tables 1 through 4 summarize the status of the observation boreholes which are presently part of the RRL and Hanford Site monitoring network.

Borehole Cluster Sites DC-19, DC-20, and DC-22

Borehole cluster sites DC-19, DC-20 and DC-22 are facilities for multi-level monitoring across the RRL for potentiometric baseline prior to ES drilling and for large-scale hydraulic testing. The borehole cluster sites DC-19, DC-20, and DC-22 are located about 3.4, 1.7, and 1.6 miles from RRL-2B, respectively (Figure 4 in text) three series of piezometer nests (A-, C-, and D-series) were installed at each site to monitor pressures within the basal Ringold sediments and flow tops of the Priest Rapids I (Rosalia), Sentinel Gap, Ginkgo, Rocky Coulee, Cohassett, and the Umtanum. In addition to these piezometers, a B-series pumping well was installed at DC-20 and DC-22. Design configuration for the piezometer and pumping facility and the borehole site plans are shown in Figures 1 and 2, respectively. Piezometer completion details are described by Jackson, et al. (1984).

Borehole Cluster Site DC-16

Borehole cluster site DC-16 is located 1.5 miles south of RRL-2B. The site consists of boreholes DC-16A, DC-16B, and DC-16C. Figure 3 shows the layout of the borings.

Borehole DC-16A is completed as a 3.937-in. core hole which is presently open between a depth of 1,569 and 4,398 ft in the Wanapum and Grande Ronde Basalt. Details of the borehole completion are described by Diediker (1983). Figure 4 shows the as-built configuration of DC-16A.

Well DC-16B is a pumping well with a 7.5-in. well screen installed in the Mabton interbed between the depths of 1,368 and 1,600 ft. Construction aspects for this boring are shown in Figure 5.

TABLE 1. Status of Selected Unconfined Monitoring Sites.

Borehole	Completion	Monitoring Horizon	Monitoring Interval	Monitoring Equipment
25-70	Perforations	Unconfined	Monthly	Steel Tape
32-70	Perforations	Unconfined	Monthly	Steel Tape
32-72	Perforations	Unconfined	Monthly	Steel Tape
43-88	Perforations	Unconfined (Upper)	Monthly	Steel Tape
49-79	Perforations	Unconfined (Upper)	Monthly	Steel Tape
50-85	Perforations	Unconfined	Monthly	Steel Tape

TABLE 2. Status of Saddle Mountains Head Monitoring Boreholes.

Borehole	Completion	Monitoring Horizon	Monitoring Interval	Monitoring Equipment
DC-16B	Pumping Well	Mabton Interbed	Continuous Weekly	Stevens Recorder Steel Tape
DC-19A, DC-20A, DC-22A	Multi-Piezometer	Rattlesnake Ridge Interbed and Basal Ringold	1-hour Daily	Downhole Pressure Transducer Steel Tape
DC-19D, DC-20D, DC-22D	Single Piezometer	Mabton Interbed	1-hour Daily	Downhole Pressure Transducer Steel Tape
DB-4, DB-7, DB-13	Single Piezometer	Mabton Interbed	Weekly	Steel Tape
DB-9	Single Piezometer	Mabton Interbed	Continuous Weekly	Stevens Recorder Steel Tape
DH-8B	Open Borehole	Asotin/Mabton Interbed	Continuous Weekly	Stevens Recorder Steel Tape

TABLE 3. Status of Wanapum Head Monitoring Boreholes.

Borehole	Completion	Monitoring Horizon	Monitoring Interval	Monitoring Equipment
DC-1	Multi-Level Piezometer	Wanapum Composite	Weekly	Steel Tape
DC-16A, DC-16C	Bridge Plugs	Priest Rapids Flow Top	1-hour Weekly	Downhole Pressure Transducer Steel Tape
DC-19C, DC-20C, DC-22C	Multi-Level Piezometer	Sentinel Gap and Ginkgo	1-hour Dialy	Downhole Pressure Transducer Steel Tape
DB-1	Open Borehole	Priest Rapids Flow Top	Weekly	Steel Tape
DB-2	Open Borehole	Priest Rapids Roza Flow Top	Weekly	Steel Tape
DB-11	Open Borehole	Priest Rapids	Weekly	Surface Pressure Transducer
DB-12	Open Borehole	Priest Rapids	Continuous Weekly	Stevens Recorder Steel Tape
DB-14	Single Packer	Priest Rapids	Daily	Steel Tape
DB-15	Open Borehole	Composite Wanapum	Weekly	Steel Tape
Ford, Enyeart, O'Brian	Open Borehole	Priest Rapids	Continuous Weekly	Stevens Recorder Steel Tape
DDH-3	Single Packer and Cement Plug	Ginkgo Flow Top	Weekly	Steel Tape

TABLE 4. Status of Grande Ronde Head Monitoring Boreholes.

Borehole	Completion	Monitoring Horizon	Monitoring Interval	Monitoring Equipment
DC-1	Multi-Piezometer	4 Zones	Weekly	Steel Tape
DC-2	Open Borehole	Composite	Weekly	Steel Tape
DC-4/5	Bridge Plugs	Rocky Coulee Flow Top	Weekly	Steel Tape
DC-7/8	Open Borehole	Composite Grande Ronde	Weekly	Steel Tape
DC-12	Open Borehole	Composite Grande Ronde	Weekly	Steel Tape
DC-15	Open Borehole	Composite Grande Ronde	Weekly	Steel Tape
DC-19C, DC-20C, DC-22C	Multi-Level Piezometer	3 Intervals	1-hour Daily	Downhole Pressure Transducer Steel Tape
RRL-2	Bridge Plugs	Rocky Coulee Flow Top	Weekly	Steel Tape
RRL-6	Bridge Plugs	Rocky Coulee Flow Top	1-hour Weekly	Downhole Pressure Transducer Steel Tape
RRL-14	Bridge Plugs Plugs	Rocky Coulee Flow Top	1-hour Weekly	Downhole Pressure Transducer Steel Tape

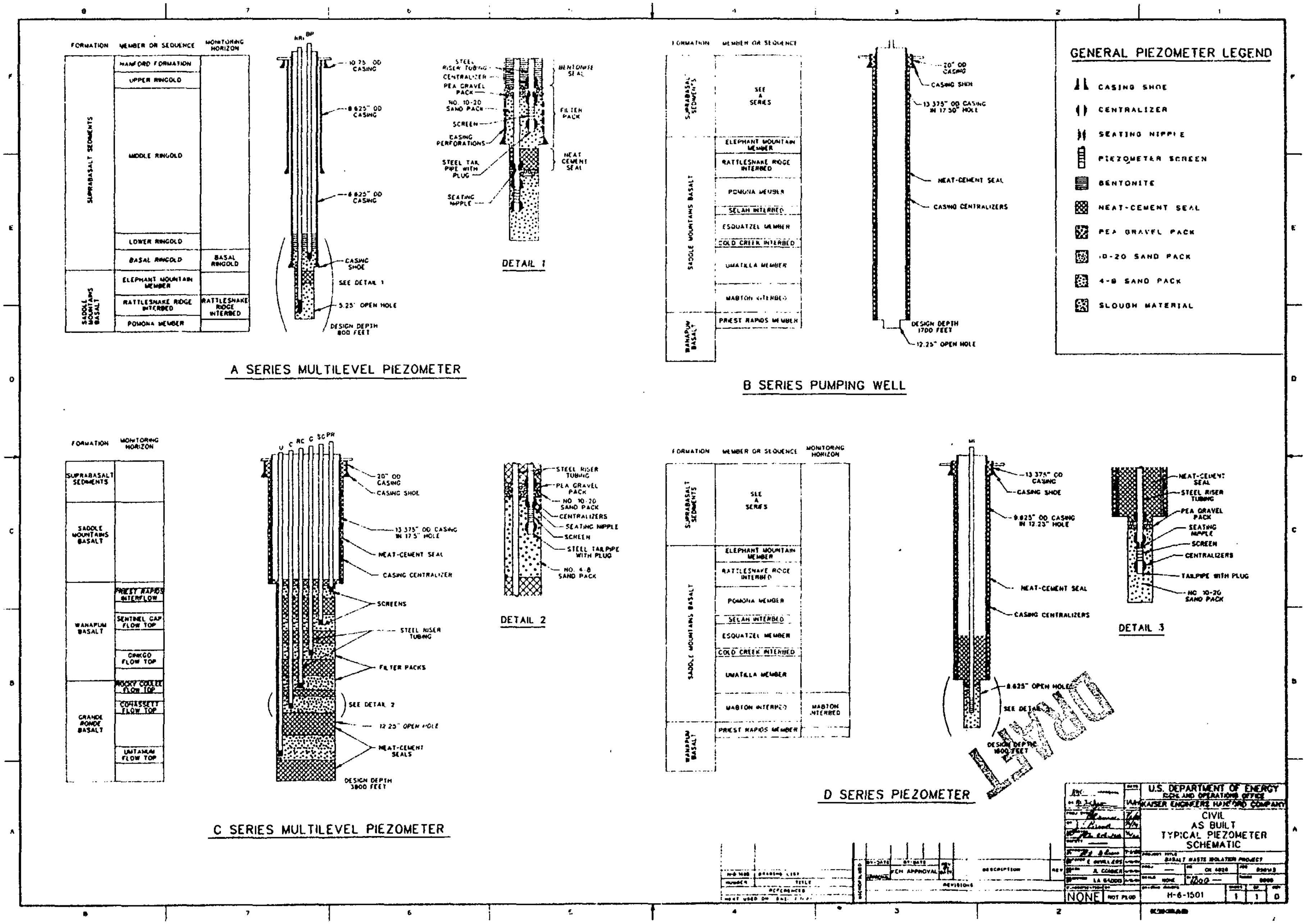
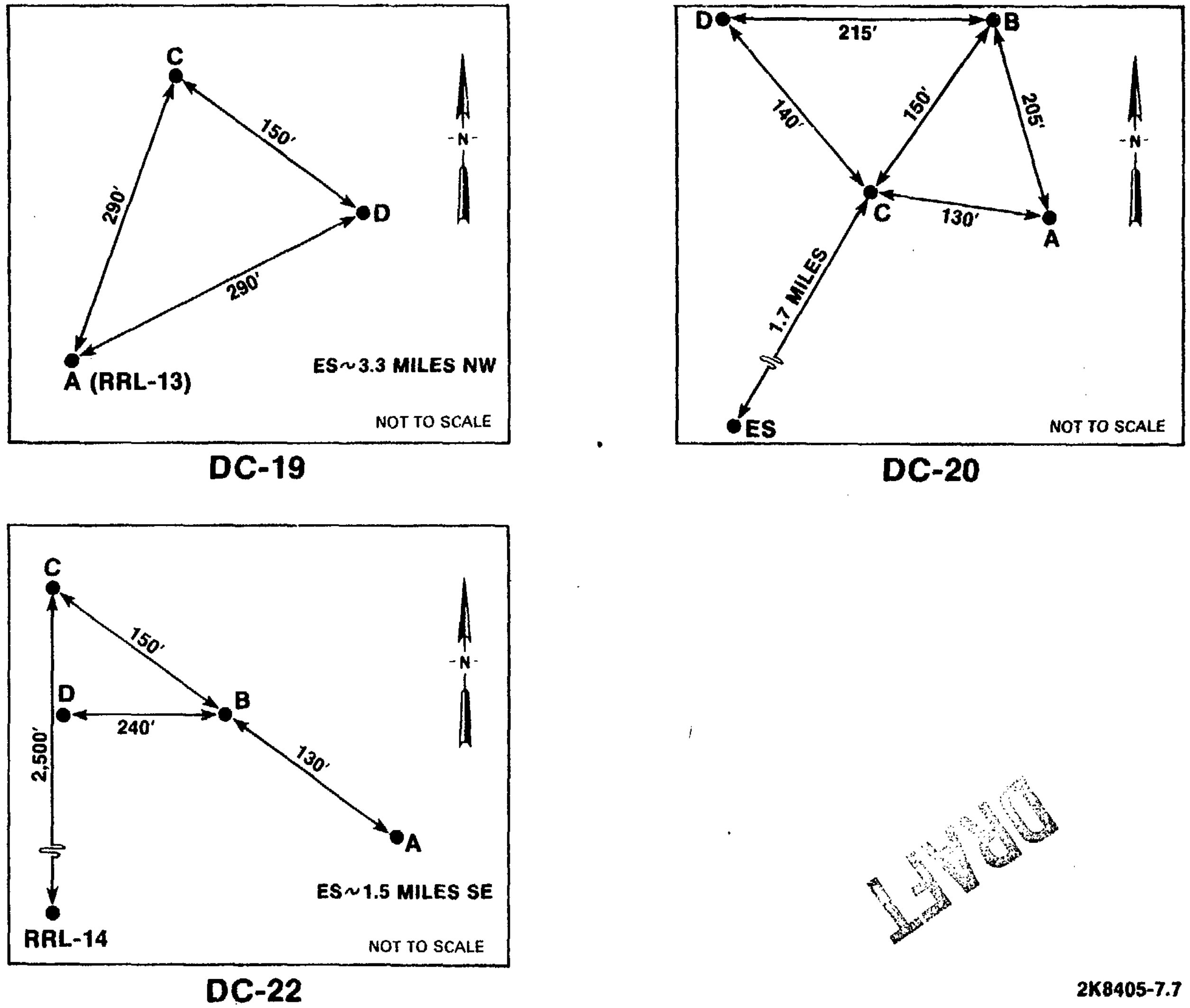


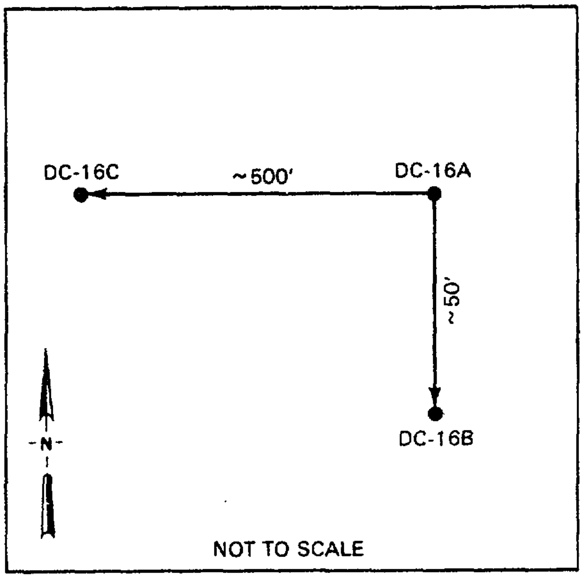
Figure 1 Configuration of wells and piezometers at DC-19, DC-20, and DC-22.

46



2K8405-7.7

FIGURE 2 CLUSTER BOREHOLE SITE PLANS



2K8408-10.3

FIGURE 3 DC-16 BOREHOLE SITE PLAN

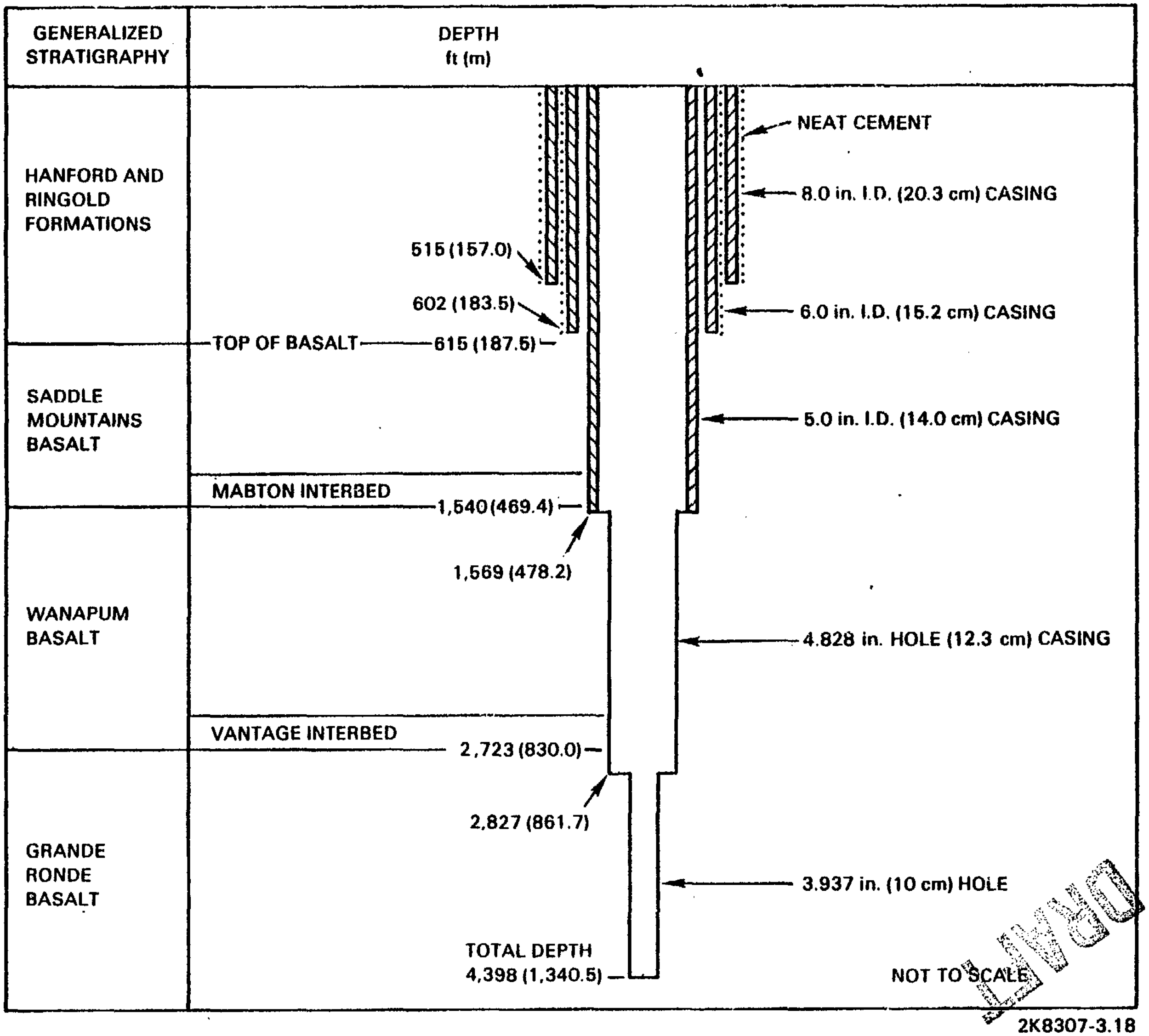
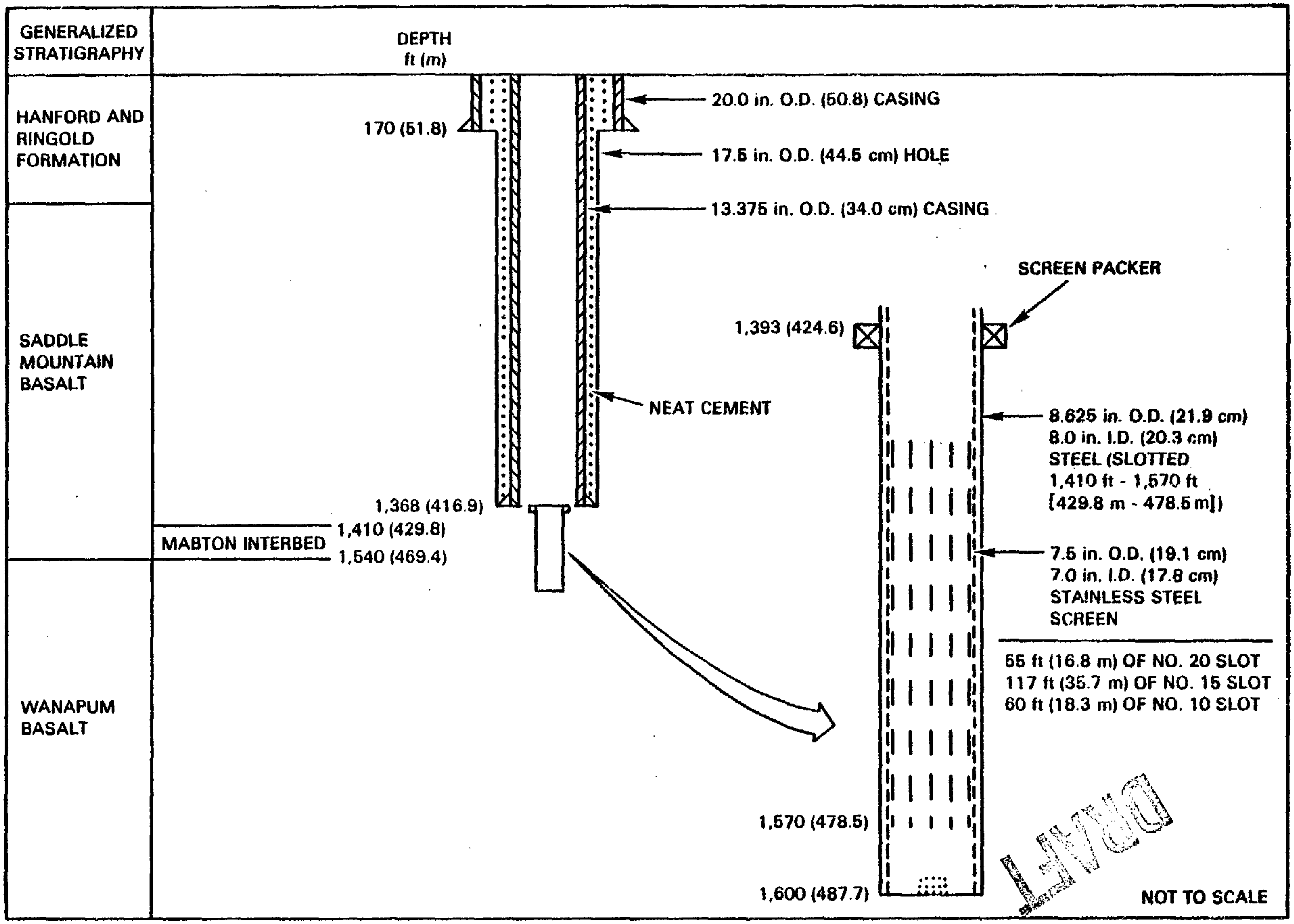


FIGURE 4 As-built drawing of borehole DC-16A.



2K8408-10.7

FIGURE 5 As-built drawing of well DC-16B.

50

Borehole DC-16C is completed as a 8.625-in. rotary hole which is open between a depth of 1,644 and 3,859 ft. This borehole was whipstocked at a depth of 3,762 ft to obtain core in the Umtanum flow. Figure 6 shows this as-built configuration of DC-16C.

Temporary bridge plugs and associated cement plugs isolate the following horizons in DC-16A and DC-16C: Priest Rapids I flow top (Rosalia), Sentinel Gap flow top, Ginkgo flow top, Rocky Coulee flow top, Cohassett flow top, and the Umtanum flow top. Under this multiple packer arrangement only the uppermost Priest Rapids flow top can be monitored with downhole pressure transducers at DC-16C. No pressure monitoring of the Priest Rapids at DC-16A is planned, because this horizon was cemented during the drilling operations.

Boreholes RRL-6 and RRL-14

Boreholes RRL-6 and RRL-14 are located about 1.4 miles from RRL-2B. Both boreholes are completed as small-diameter core holes in the Grande Ronde Basalt. As-built drawings of RRL-6 and RRL-14 are shown in Figures 7 and 8, respectively. Patterson (1983, 1984) describes construction details for both boreholes.

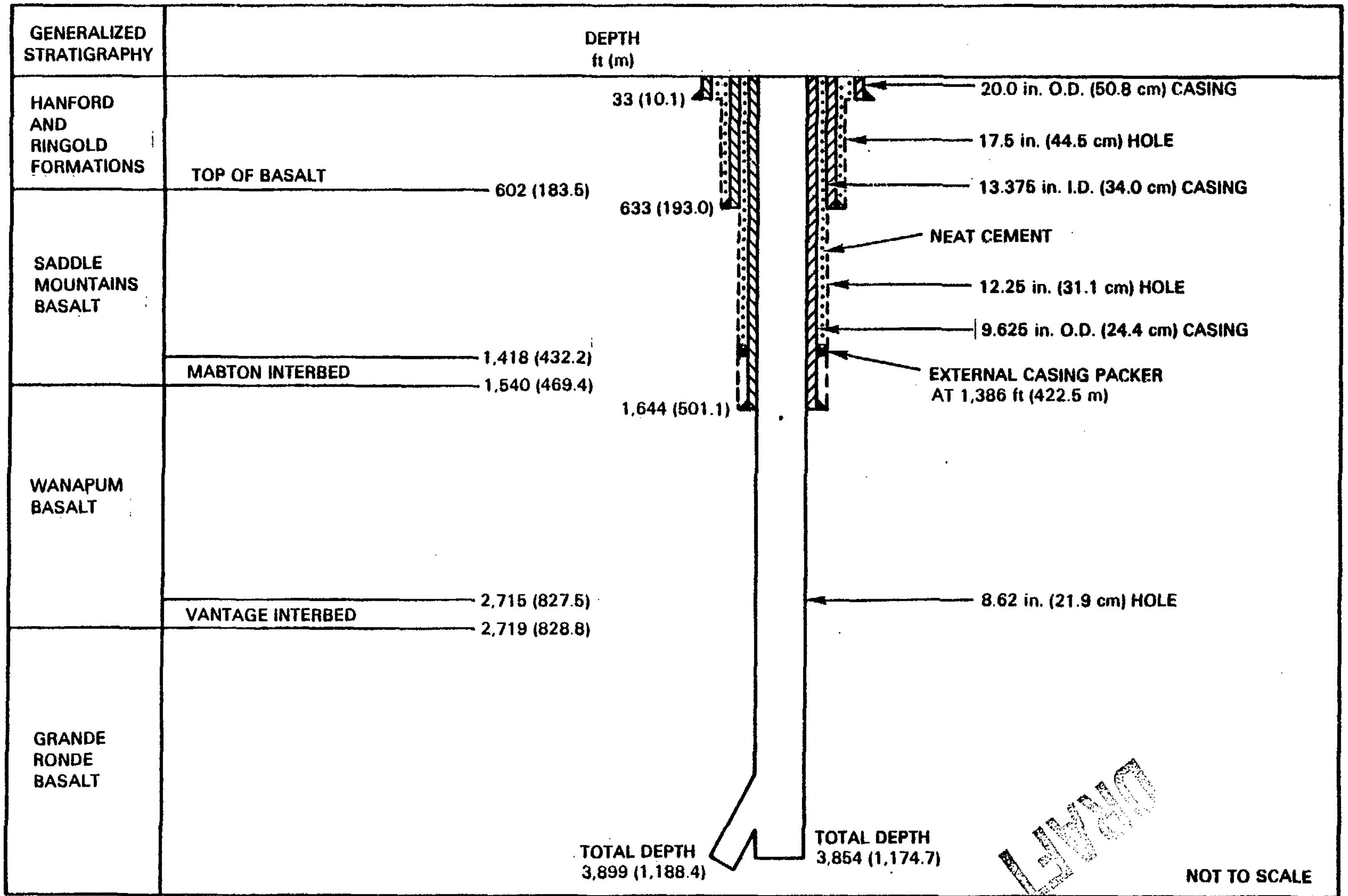
Temporary bridge plugs and associated cement plugs have been installed at both boreholes. They isolate the following horizons: Umtanum flow top, Cohassett flow top, and the Rocky Coulee flow top. With this system, the Rocky Coulee is presently being monitored with a downhole pressure transducer.

McGee Well

McGee Well is located about 4.5 miles northwest of RRL-2B and is on the west side of the Cold Creek flow impediment. The well was originally drilled in the early 20th century for irrigation-water supply. At that time the well was completed in the Priest Rapids interflow at a depth of 978 ft. Recently the BWIP Drilling and Testing Group deepened the well to acquire additional geologic and hydrologic information in the Wanapum and Grande Ronde Basalt. The 2.98-in. core hole is open in the Grande Ronde Basalt from 1,942 ft to the total depth of 3,123 ft. Figure 9 shows an as-built of the McGee Well.

Dual Borehole Site DC-4/5

Dual borehole site DC-4/5 is located about 2 miles north of RRL-2B. Both boreholes were drilled in 1978. Details of the construction aspects for both sites are described in DOE/EA-0048, 1978. Figures 10 and 11 show the as-builts for these two boreholes.



2K8408-10.6

FIGURE 6 As-built drawing of borehole DC-16C.

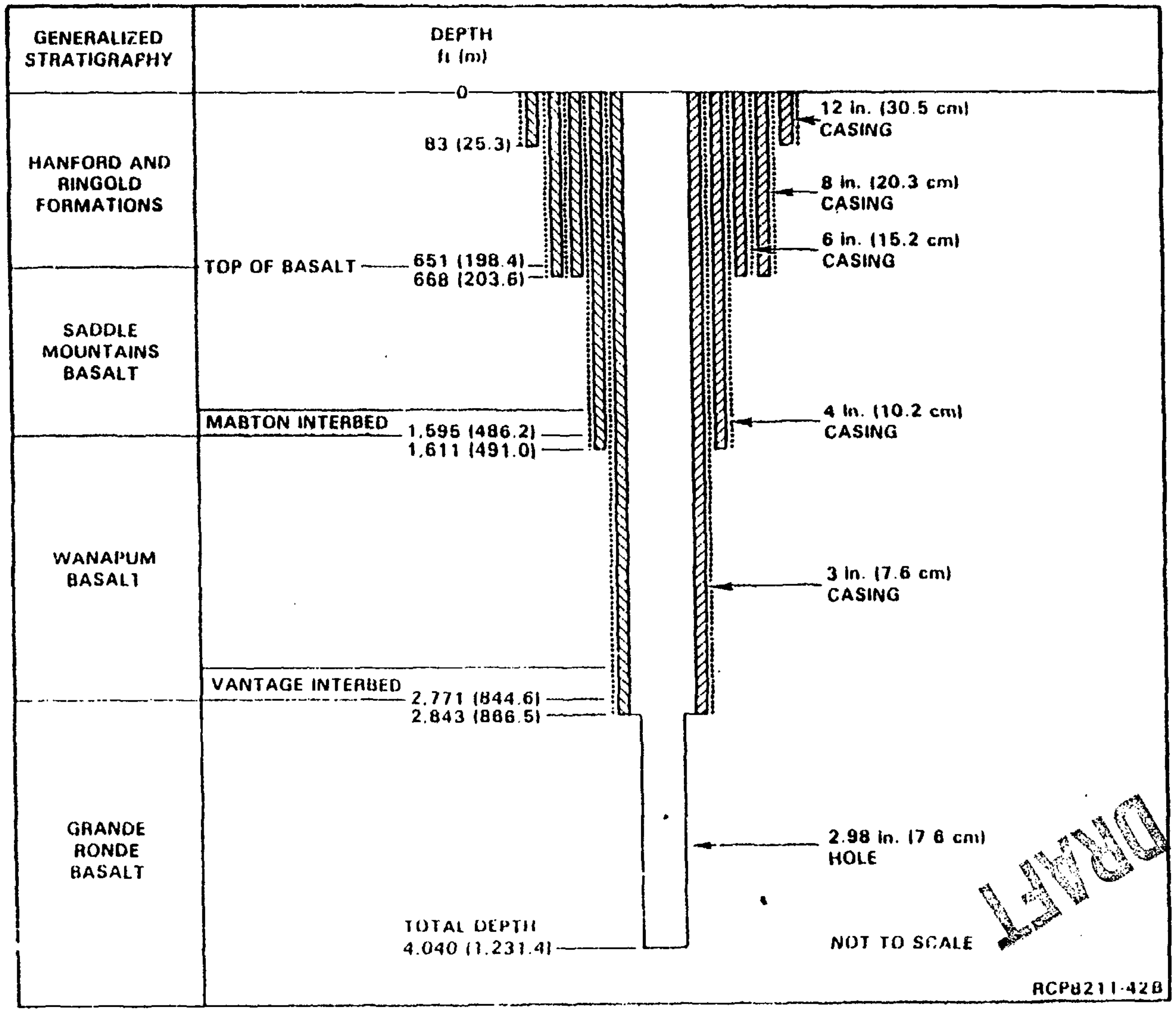


FIGURE 7 Borehole RRL-6; As-Built Drawing

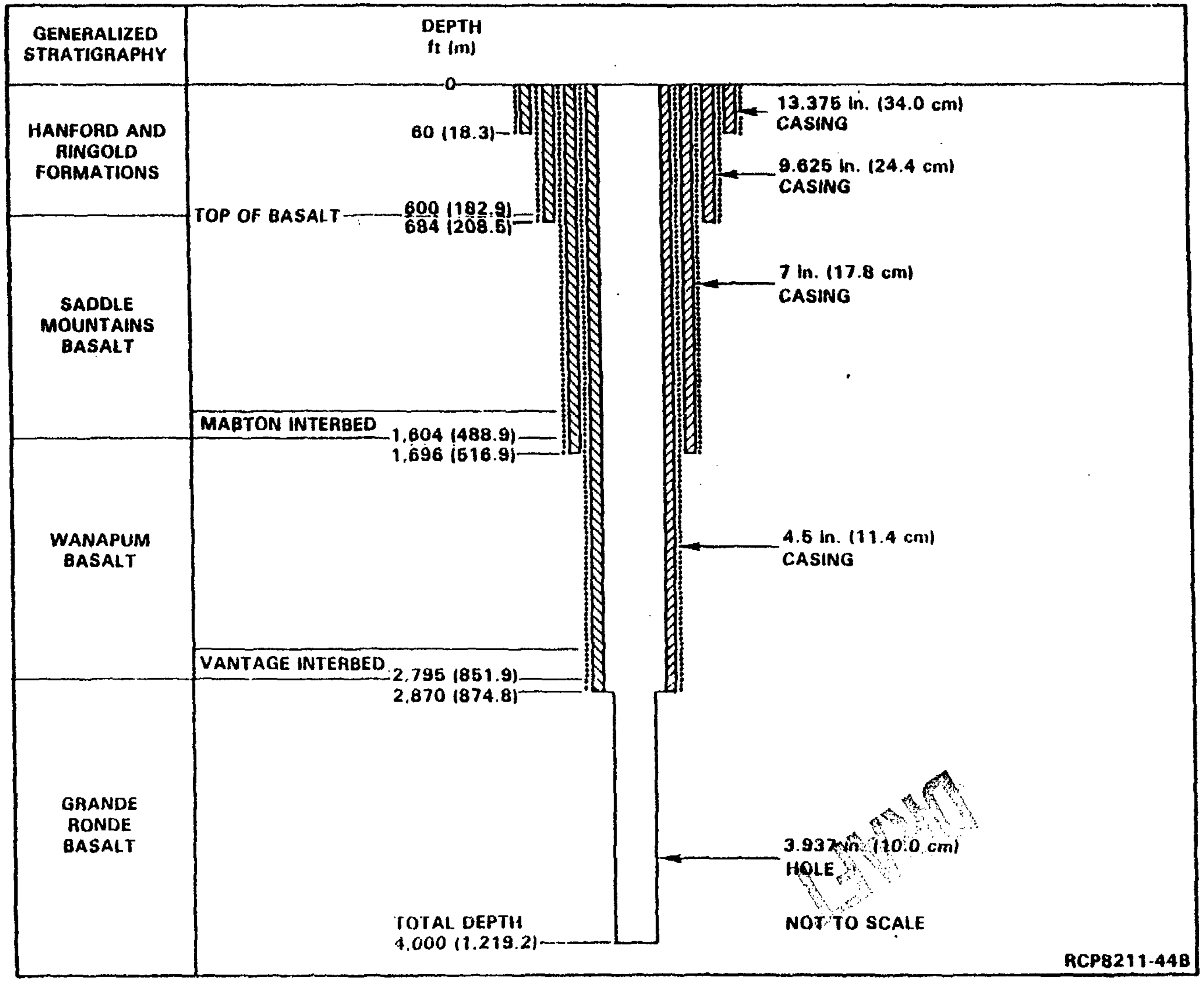


FIGURE 8 Borehole RRL-14, As-Built Drawing

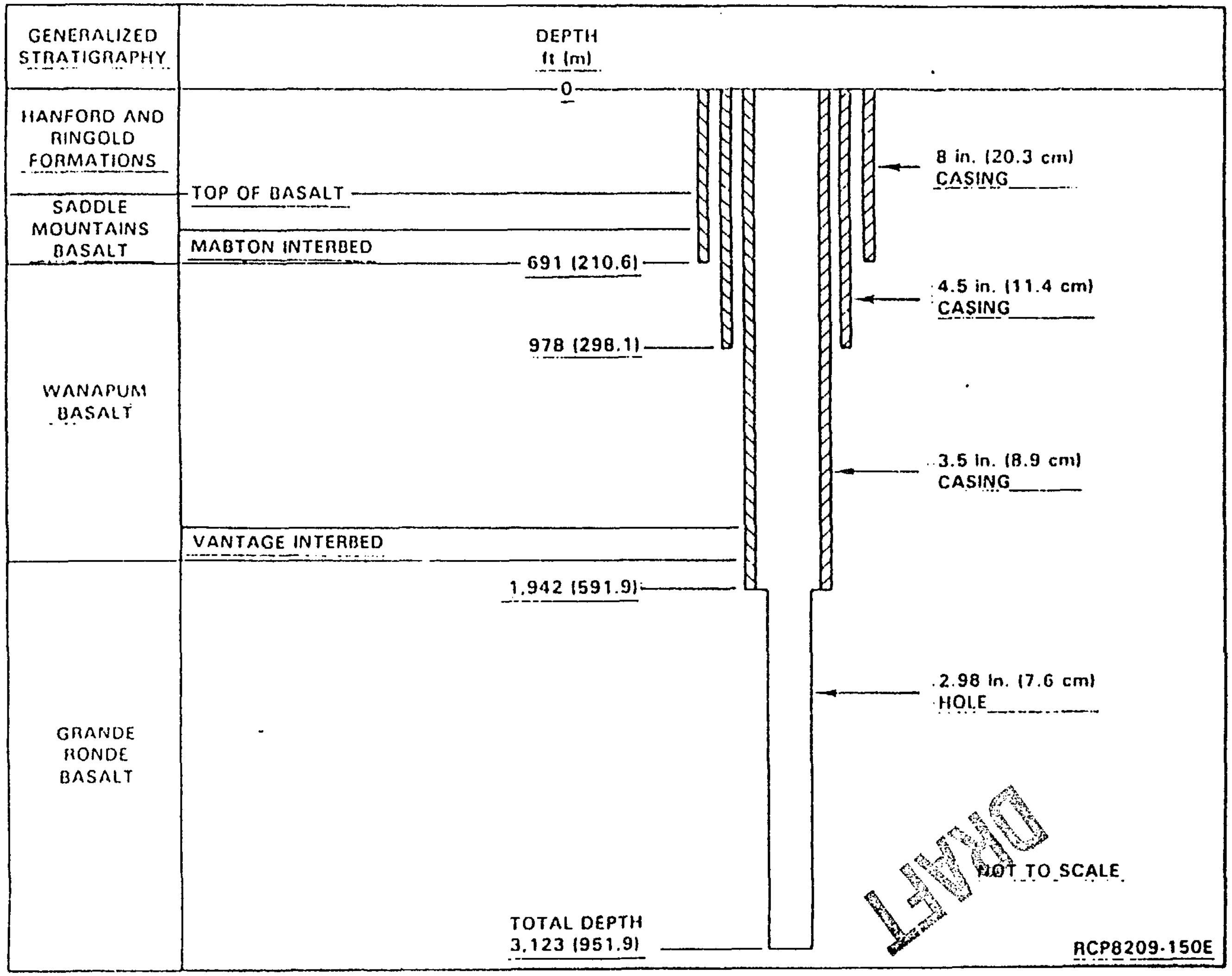


FIGURE 9 As-Built for the McGee Borehole.

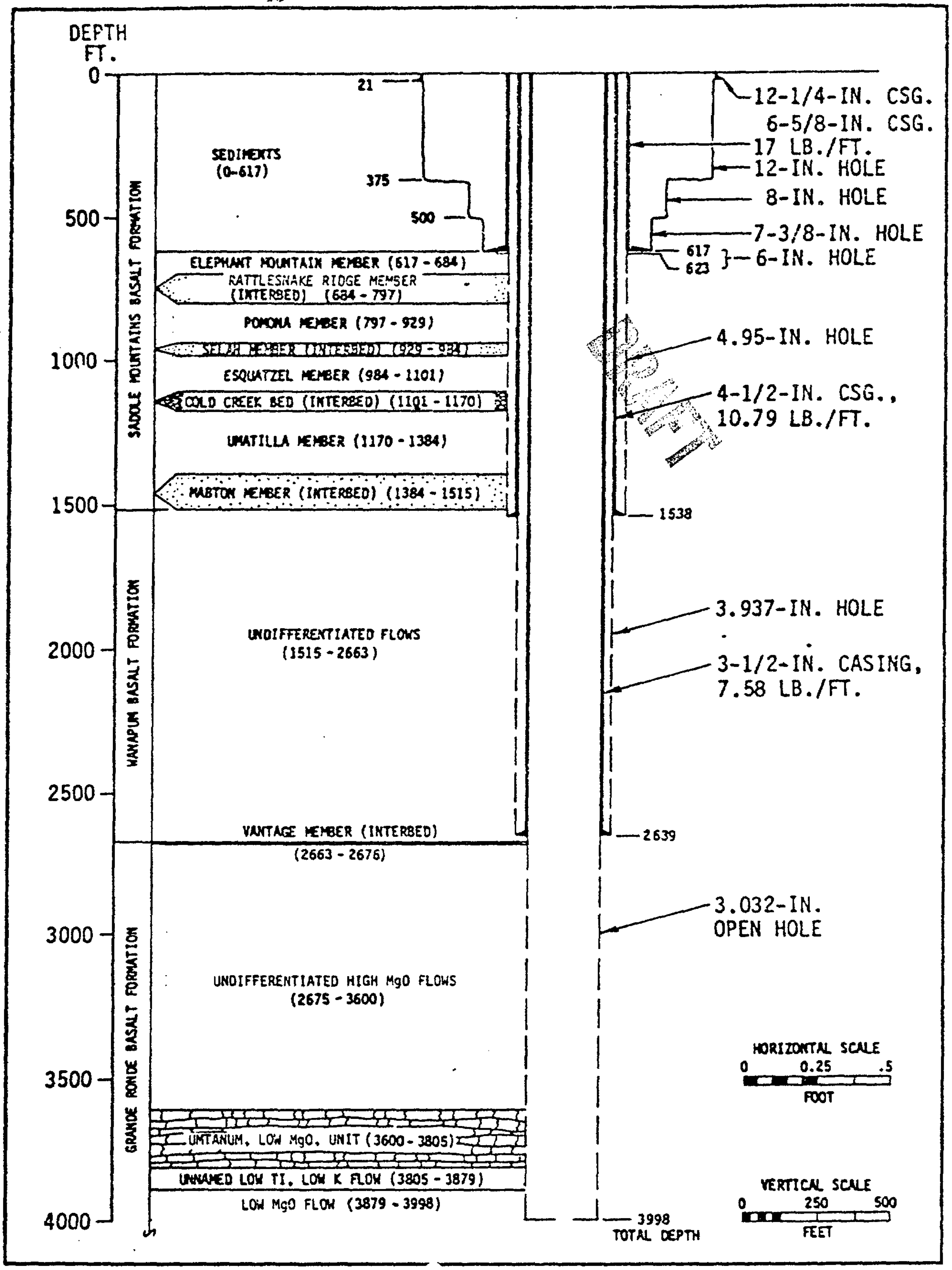


FIGURE 10 AS-BUILT DIAGRAM, CORE HOLE DC-4

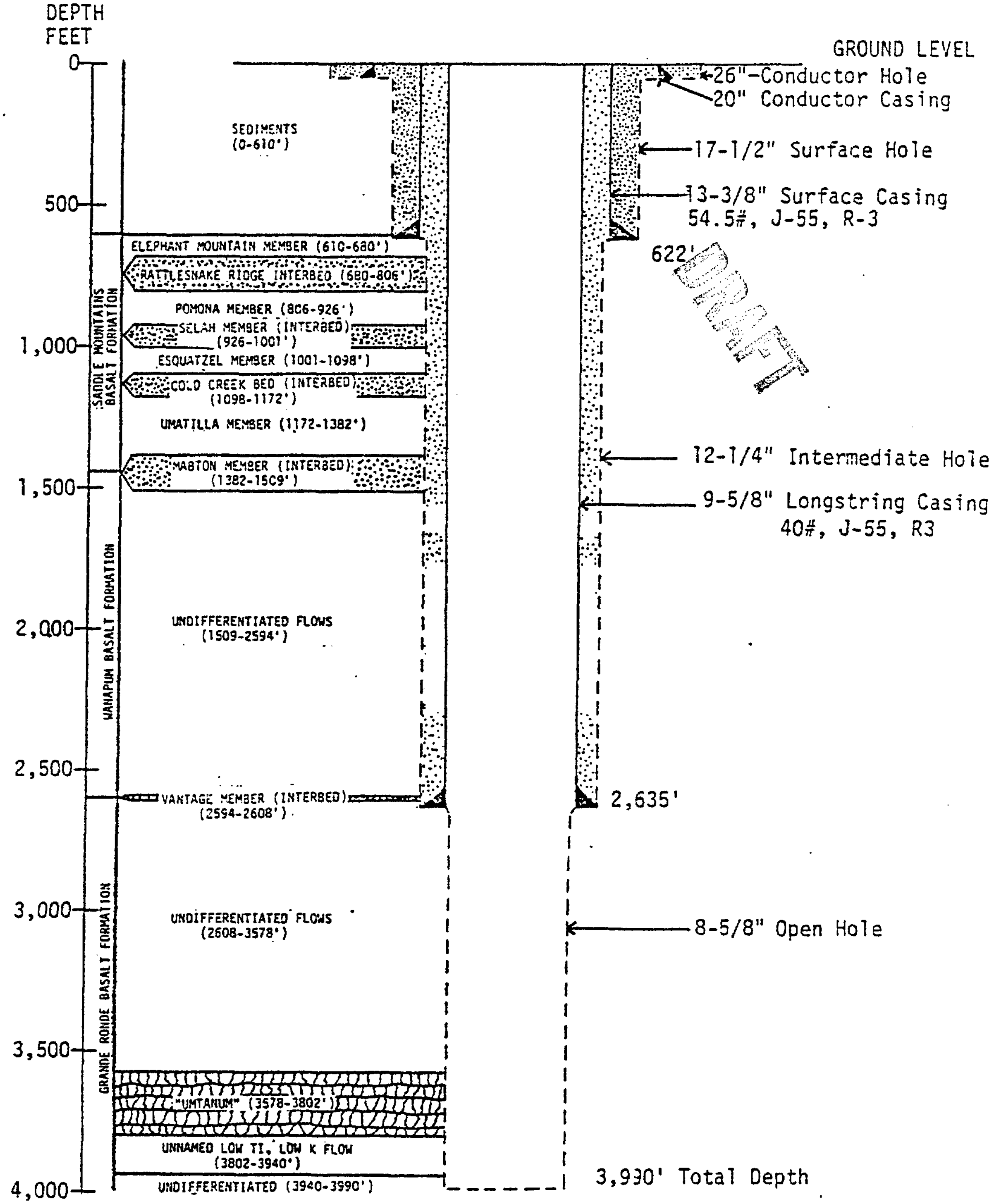


FIGURE 11 AS-BUILT DIAGRAM HOLE DC-5

Borehole DC-4 is a 3.032-in. core hole which is open between 2,639 and 3,998 ft in the Grande Ronde Basalt. Borehole DC-5 is a 8.625-in. rotary borehole and is open between a depth of 2,635 and 3,990 ft.

Both of these boreholes contain bridge plugs used to isolate the Rocky Coulee flow top, Cohassett flow top, and Umtanum flow top. In addition, downhole pressure transducer measurements are being taken in the Rocky Coulee flow top.

Other Hanford Site Monitoring Facilities

In addition to the boreholes and wells previously described, on-going monitoring will be continued for the distant network of boreholes and wells on the Hanford Site during all testing activities. These boreholes and wells include: O'Brian, Ford, Enyeart, DB-1, DB-2, DB-4, DB-7, DB-9, DB-11, DB-12, DB-13, DB-14, DB-15, DC-1/2, DC-7/8, DC-15, DDH-2, and DB-8A (Figure 4 in text). Status of these observation boreholes and wells is summarized in Tables 1 through 4.

OBSERVATION WELL/PIEZOMETER COMPLETION AND INSTRUMENTATION

Borehole Cluster Site DC-19, DC-20, and DC-22

Downhole pressure monitoring at these sites commenced in April to establish baseline head conditions prior to exploratory shaft drilling and large scale hydraulic tests. The data acquisition system consists of highly sensitive quartz pressure transducers and associated recording equipment that is capable of monitoring pressures on a continuous basis. The pressure transducers are set at approximately formation depth.

Borehole Cluster Site DC-16

Boreholes DC-16A and DC-16C contain several bridge plugs and associated neat cement plugs that serve to hydraulically separate the Wanapum and Grande Ronde horizons that are monitored at borehole cluster sites DC-19, DC-20, and DC-22. The uppermost horizon isolated, i.e., Priest Rapids interflow is being monitored with a TAM/Seling pressure transducer packer system at borehole DC-16C. The Mabton interbed at DC-16B is instrumented with a Stevens Recorder. In order to monitor several horizons during pump testing it is recommended that DC-16A be fitted with a multiple packer monitoring system.

Borehole RRL-6, RRL-14, and DC4/5 Sites

At these sites, bridge plugs and/or associated neat cement plugs are used to isolate the Rocky Coulee flow top, Cohassett flow top, and the Umtanum flow. Under this packer configuration only the uppermost isolated interval, i.e., Rocky Coulee is being monitored with a TAM/Seling data acquisition system. This system uses dual downhole pressure transducers to monitor interval pressures and annulus pressures above the TAM packer. If head measurements are needed in horizons below the Rocky Coulee, these boreholes may require a multiple packer monitoring system.

McGee Well

This well will be fitted with bridge plugs to isolate the Rocky Coulee flow top, Cohassett flow top, Cohassett flow bottom. It will be configured at a minimum to allow downhole pressure monitoring in the Rocky Coulee with the TAM/Seling equipment. It is recommended that the McGee well ultimately be fitted with a multiple packer monitoring system.

APPENDIX B

TEST EQUIPMENT REQUIREMENTS

The general requirement of all test equipment is that it be suitable for achieving the objectives and purposes of the tests as stated above with a high degree of reliability in a cost effective manner. The equipment required for the large-scale pumping tests is grouped into the following categories:

- Pumping equipment
- Injection equipment
- Tracer equipment
- Water and gas sampling equipment

The Rocky Coulee flow top, Cohassett flow bottom, and the Umtanum flow top will be stressed by withdrawing (pumping) groundwater. Submersible electric motor and centrifical turbine pump assemblies will be used to withdraw groundwater from the above three horizons. Preliminary calculations indicate that there are standard submersible motors and pumps available for the anticipated combinations of head and capacity. The Cohassett flow top, because of anticipated low yield, will be stressed by injection and/or pulsing test methods.

Three major considerations of the pumping system are: the type of pump, motor, and ancillary downhole mechanical equipment; power requirements; and water handling/disposal at the surface. The pump and motor will be, as stated above, submersible. Common considerations for the pump and motor, regardless of required head and capacity, are discussed next.

Pumping Equipment

Pump and Motor

The pump and motor assembly must be rated for high temperature operation (140 degree F.). A dynamic gas separator must also be used to remove free gas in the groundwater that will evolve with depressurization. The gas separator is installed in place of the standard pump intake. It uses centrifical force to remove gas from the groundwater. The gas is then vented into the annular space in the well near the pump discharge. Motor power required can vary from about 5 horsepower to 300 horsepower. The following motor characteristics are recommended:

Horsepower Range	Motor Diameter Inches	Voltage
3-40	6	480
40-100	6	900
100-225	6	2,400
225-340	7.5	2,400

The strategy is to keep the pump cable to a maximum of size #2 copper conductor. The #4 size conductor, which has a smaller cross-sectional area, is preferred and should be attainable in most cases depending on motor HP and length of cable. Only single, as opposed to tandem, type submersible motors will be used. Also, all motors will be three phase.

The parametric study described in Test Design considers two extreme values of water level drawdown, 500 and 2,000 feet, for a constant rate pumping test of 30 days duration. The static water levels in all of the test horizons are approximately 200 feet below ground surface. Planned pumping levels in the test well will be about 100 feet above the pump suction. Therefore, the pump suction will be located between 800 feet and 2,300 feet below ground surface for water level drawdown between 500 and 2,000 feet. The materials used in construction of the downhole mechanical equipment will be industry standard where consistent with test purposes and objectives. Special construction materials are at this time not necessary to safisfy hydrochemistry requirements. Additional planning and studies may however indicate otherwise. In that event special materials may be provided subject to the constraints of overall objectives, schedule, and budget.

Power Requirements

Because of the range of anticipated hydrologic parameters two or more sizes of electric submersible motors will be required. The overall range may be from 3 to 300 HP. The corresponding supply power kilovolt-amphere (KVA) requirement for this range in horsepower is 10 to 350 KVA. Currently, at the RRL-2 site, interruptible electrical power is available up to 6000 KVA. Standby generators will be employed during the test with automatic start and switch gear should there be an interruption in the primary electrical supply. The strategy employed herein is to minimize the number of different sized pumping units. Opportunity to make pump and motor size selections will come during the evaluation of the parametric study. The final opportunity will be during the evaluation of the step-drawdown data.

Electrical transformers corresponding to motor horsepowers and voltages will be required. Required ancillary electrical equipment includes motor protection devices and switchboards. The motor protection devices will guard against low and high voltages, phase unbalance, and phase reversal.

Discharge Piping and Groundwater Disposal

Discharge pipe from the pump discharge to ground surface must be designed to 1) limit friction loss to no more than 50 feet of head per 1,000 feet of piping and 2) to be able to safely withstand pump discharge pressure. Check valves will be located at the pump discharge and at 200 feet intervals in the pump discharge line to prevent rapid pump rotation reversal in the event of power failure and to minimize water level pertubations in the pumping well during recovery.

Near the well head on ground surface, yard piping will consist of redundant flow measuring devices, a flow control device, and ancillary piping to accommodate groundwater time series sampling and continuous tracer monitoring. One of the flow measuring devices will be equipped to provide instantaneous flow rate measurements. The other device will provide cumulative volume measurements. Both of the flow measuring devices will be equipped with a data interface that will provide a continuous record of the measurements. The flow control device will maintain the discharge at a selected rate with a minimum accuracy of least five percent.

Groundwater discharged will be conveyed away from the test site in pipes. The disposal of the groundwater will be on ground surface where it will be allowed to evaporate and infiltrate into the ground. The location of the discharge point will be such that it does not cause flooding of facilities or other nuisances. The location must also be far enough removed from the test site that it does not interfere with water level measurements in the basalt formations. The effects of disposal location on water levels in both the unconfined sediments and the confined basalt formations will be evaluated prior to test implementation.

Injection Equipment

One horizon, the Cohassett flow top, will be tested using an injection and/or a pulsing technique unless the evaluation of the step-drawdown test in RRL-2B indicates that it is feasible to pump. Injection flow rates are expected to be on the order of a few gallons per minute based on the estimated transmissivity of this interflow from testing at RRL-2A. If an injection test were performed the following basic equipment would be required:

- o A packer system to isolate and confine the test interval in the injection well.
- o Pressure transducers within and above the test interval.
- o Injection supply tubing from ground surface to the packer system capable of withstanding at least 2,000 psi.
- o Two pumps capable of supplying up to about 10 gpm at 2,000 psi.
- o Water supply for injection make-up water.
- o Two injection water conditioning/filtration units.
- o Yard piping which includes flow measuring devices and injection pressure gauges.
- o Primary electric power supply and backup power supply both with minimum capacity of 30 KVA.

The pulse test technique is preferred over the injection technique because of simpler equipment requirements. The pulse test does not mix a substantial quantity of water into the formations thus reducing uncertainties that may arise from the reactions that can occur with the mixing of two dissimilar waters. The basic equipment required for the pulse test is as follows:

- A packer system to isolate and confine the test interval in the test well.
- Pressure transducers within and above the test interval.
- Supply tubing capable of transmitting a hydraulic pulse.
- A system for inducing the pulse through the supply tubing to the test interval.

The induced pulse may be either a sudden increase or a decrease in pressure. This can be accomplished in a number of ways such as by raising or lowering a column of water or by applying a gas pressure pulse to the water surface in the packer tubing.

Tracer Equipment

A convergent, radial flow tracer test will be carried out in conjunction with the hydraulic testing in the Rocky Coulee flow top (tracer injection from RRL-2C only), Cohassett flow bottom, and Umtanum flow top (tracer injection from RRL-2A only). As discussed in the facilities section, the Rocky Coulee flow top at RRL-2A was cemented during construction therefore, for the Rocky Coulee flow top, RRL-2A will not be used as a point of tracer injection. A tracer test may be carried out in the Cohassett flow top if evaluation of the step-drawdown test in RRL-2B indicate the feasibility of pumping. Otherwise a pulse or injection test is planned for the Cohassett flow top which will preclude conjunctive tracer testing. A tracer will be injected into both RRL-2A and RRL-2C for tracer tests of the Cohassett flow top (should it prove feasible to pump) and the Cohassett flow bottom~~, and Umtanum flow top~~. For the Umtanum flow top a tracer will be injected into RRL-2A only as there will not be a piezometer completed in this flow top at RRL-2C. As discussed in the facilities section, there are several significant trade-offs associated with monitoring the Umtanum flow top at RRL-2A. If, after further evaluation, it is decided that the Umtanum flow top will not be monitored at RRL-2A then there will not be a tracer test in the Umtanum flow top.

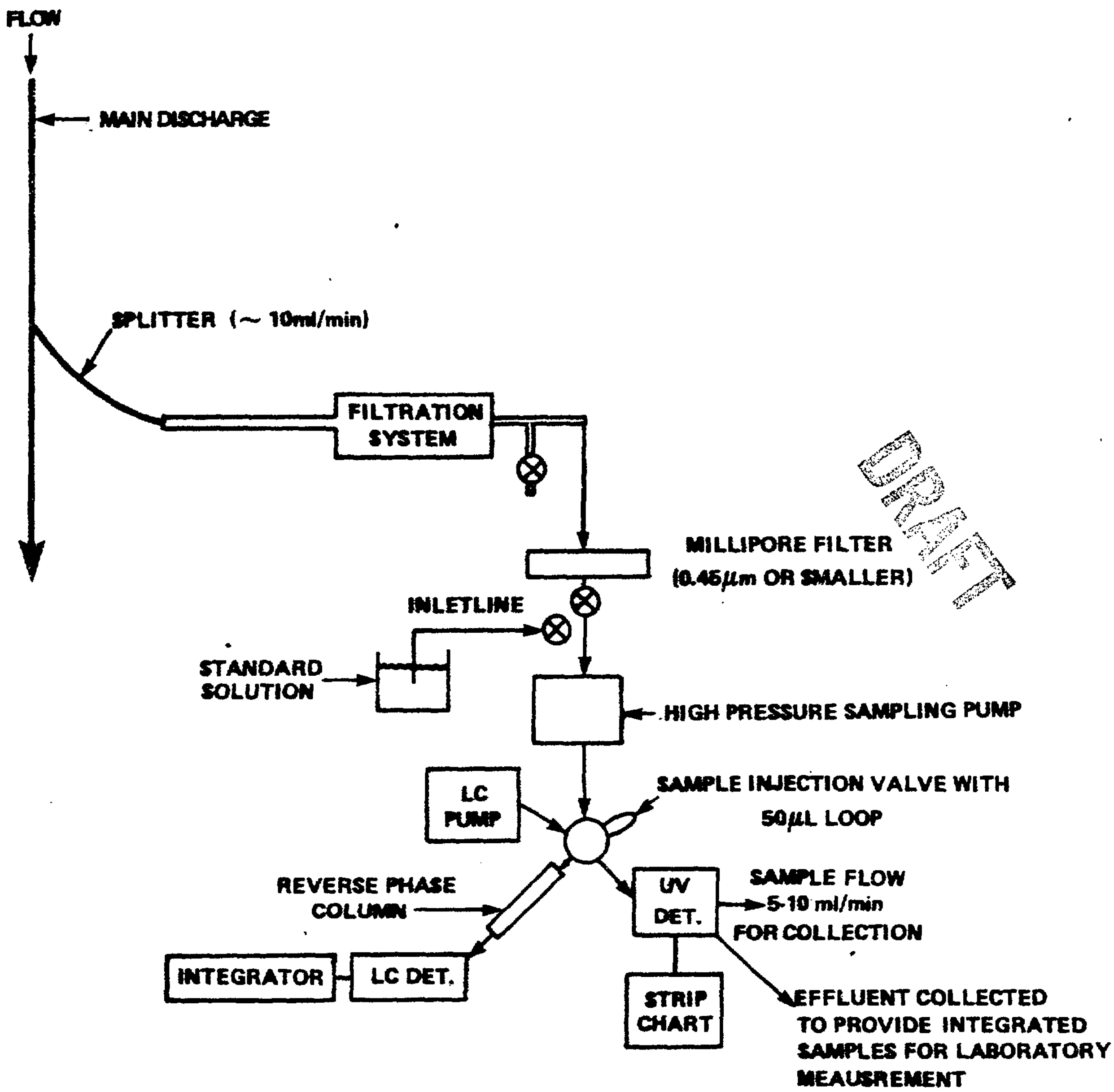
The tracers will be conservative, non-reactive tracers such as m-trifluoromethylbenzoic acid or pentafluorobenzoic acid. They will be pre-injected into the appropriate test intervals in borehole RRL-2A and RRL-2C. Pre-injection of the tracers will be done so that the tracer can move slightly out into the formation thus avoiding long borehole flushing times and the uncertainties that may arise from tracer dilution during borehole flushing.

Tracer concentration will be monitored continuously from the discharge at the test well at ground surface. Two methods will be used to monitor the tracer concentration. A water splitter, located on the inlet side of the main line flow meter, will divert approximately 10 mL/min from the main discharge line. This flow will then pass through a filter, through a high-pressure injection valve, and through an ultraviolet (UV) absorption detector (Figure 12). Effluent from the UV absorption detector will be continuously collected to provide integrated samples for subsequent laboratory analyses. In parallel with the UV detector will be a standard liquid chromatograph (LC) that will provide tracer concentration measurement continuously. Both the UV detector and the LC units will be provided with data interfaces that will record all measurements on magnetic tape or diskettes and strip charts. The plumbing and tracer detector equipment will be insulated and where necessary will be located inside of a heated and conditioned shelter to protect the instruments from variations in environmental conditions.

Water and Gas Sampling Equipment

Representative samples of groundwater will be collected from the discharge at the test well for contemporary and subsequent laboratory analyses. A sample splitter, located downstream of all of the main discharge line flow meters, will divert approximately 1 gpm from the main discharge line. This flow will then be piped into the mobile chemistry laboratory. Discrete time series groundwater samples will be provided from this flow. The sample splitter and plumbing will be made of standard carbon steel. Insulation will be installed on the main discharge line and the sample line to reduce the effects of variations in temperature.

The submersible pumps used in these tests will be equipped with dynamic gas separators submerged with the pump. Most of the free gas in the groundwater will be removed from the water and vented into the annular space between the pump and the well bore therefore gas analyses taken from surface collected water samples will not be representative. This may be somewhat mitigated by measuring gas flow rates and collecting gas samples at the well head. The well head will be sealed. A gas sampling port will be provided for continuous gas sampling and flow measuring. Also, vacuum and pressure gauges will be provided and a vacuum release valve to prevent vacuum in the well which could cause pump cavitation.



NOTE: REFER TO TEXT FOR EXPLAINATION OF ABBREVIATIONS

FIGURE 12 TRACER CONCENTRATION MONITORING APPARATUS

In situ samples of groundwater will be collected both before and after hydraulic testing. This will be accomplished by lowering a 2 liter sample canister to test interval depth. The sample canister will remain closed until it reaches sample depth at which time it will be opened to collect the sample and then closed again. In this fashion a water sample can be collected at ambient temperature and pressure. The sample canister must be able to safely withstand internal and external pressures of at least 1,500 psi. The pre-test sample will be collected after well development but before the test pump is installed. The post-test sample will be collected after the test pump has been removed from the well.

As the test well (RRL-2B) and observation well (RRL-2C) are being drilled, samples of the drilling fluids will be collected frequently and analyzed for subsequent evaluation of groundwater sample representativeness. Required equipment will consist of common sample containers and the mobile chemistry trailer.

START NEW Page

APPENDIX C

PARAMETRIC STUDY OF AQUIFER RESPONSE

INTRODUCTION

The purposes of the pre-test modeling analyses described herein are to provide:

1. A basis for estimating hydrologic behavior on large scales.

2. A tool for planning and design of large scale pumping tests.

3. Various potential scenarios by which a decision regarding test time periods and pumping rates can be made.

The analyses considered were based on the range of values of hydraulic parameters which were estimated from small scale test data (Strait and Mercer, 1984). The results of a parametric study of pumping the Rocky Coulee flow top are summarized herein. The other horizons to be tested at RRL-2B will be analyzed in a similar manner during detailed test design.

MODEL USE FOR STUDY

A quasi-three-dimensional model (Trescott, 1976) was used to evaluate the sensitivity of drawdown to parameter variation. The code utilizes a block-centered, finite difference grid in which variable grid spacing is permitted. The iterative numerical technique is the strongly implicit procedure. Three dimensions are simulated by a two-dimensional model, with an inter-aquifer transfer coefficient (TCF) determining the flow between layers (see Figure A). The TCF is a quantity that, when multiplied by the vertical head difference, yields the flow quantity

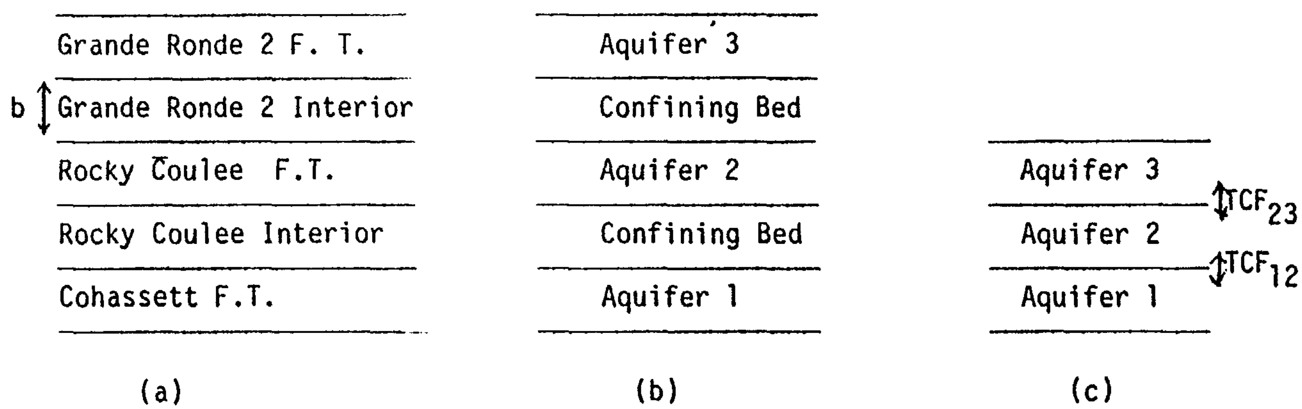


FIGURE A STRATIGRAPHY OF ROCKY COULEE FLOW TOP AND ADJACENT UNITS (A), CLASSIFICATION OF UNITS (B), AND MODEL LINKAGE OF UNITS (C)

being transferred between the layers. The TCF can be derived from Darcy's law and continuity. The TCF may be expressed in a simple way for our study as, Kv/b, where Kv and b are the vertical conductivity and the thickness of the dense interior of basalt, respectively.

insert to page 70

The boundary condition use in this study do not necessarily represent an unique selection. However, the effect of varied boundary conditions on the predicted drawdown at the observation wells is believed to be small in comparision the effects due to the range of parameters used in the study. Also, any error that may arrise due to an incorrect boundary is insignificant for the purpuses of this study because the cone of depression either does not or barely intercepts the model boundary during the simulation period (30 days).

DRAFT

MODEL SET-UP

The study area includes the Reference Repository Location (RRL) which lies within the central portion of the Cold Creek syncline. The area is bordered by geological structures on the north and southwest and an apparent impediment to groundwater flow on the northwest. Specified potential boundaries were imposed on the east and southeast (Figure B). These constant potential boundaries provide equivalent storage flow from the rest of the aquifer. ~~The error caused by these boundaries is insignificant because the cone of depression either never reached the boundaries or barely reached them during the simulation period.~~ Insert here

The model grid consisted of 30 rows and 35 columns (Figure B), with variable grid spacing. The size of grid varied from 158 feet to 1 mile. Three layers were used for simulation and the pumping was conducted at the central layer. The outermost nodes are impermeable boundaries assigned automatically by the computer code and represented by the symbol "O". These boundaries were suppressed if recharge or specified head valves were assigned to the immediate inner nodes. The symbol "Δ" indicates a constant potential boundary. The boundary conditions for this model were a combination of no-flow and specified head values based on geologic features and drilling-stress data (Lu, 1984). Figure B-1 is an enlargement of a portion of the variable grid near the pumping well.

NUMERICAL VERIFICATION OF THE MODEL

The abilities of the numerical model to simulate transient flow systems and the adequacy of the grid size and time steps used have been verified by comparing numerical simulation with pertinent idealized analytical solutions. The comparison with the Theis (1935) solution was done on an aquifer with hydrological properties and stress conditions similar to the Priest Rapids interflow but with an extended study area so that the cone of depression never reaches the boundaries during the simulation period. The comparison with the Hantush and Jacob (1955) leaky aquifer was made by assigning a high transmissivity in the upper aquifer to reproduce the Hantush and Jacob condition. The head in the upper aquifer remained nearly constant and the TCF became the simple ratio of vertical hydraulic conductivity to the thickness of the aquitard. The simulation used the same parameters in the pumping aquifer as were used for the nonleaky aquifer while adding vertical hydraulic conductivity $K_v = 1 \times 10^{-4}$ ft/d, and aquitard thickness b = 178 ft. The results of both comparisons are presented in Figure C and show that the model adequately defines the following:

- The drawdown in an ideal confined aquifer.
- The drawdown in a leaky aquifer.

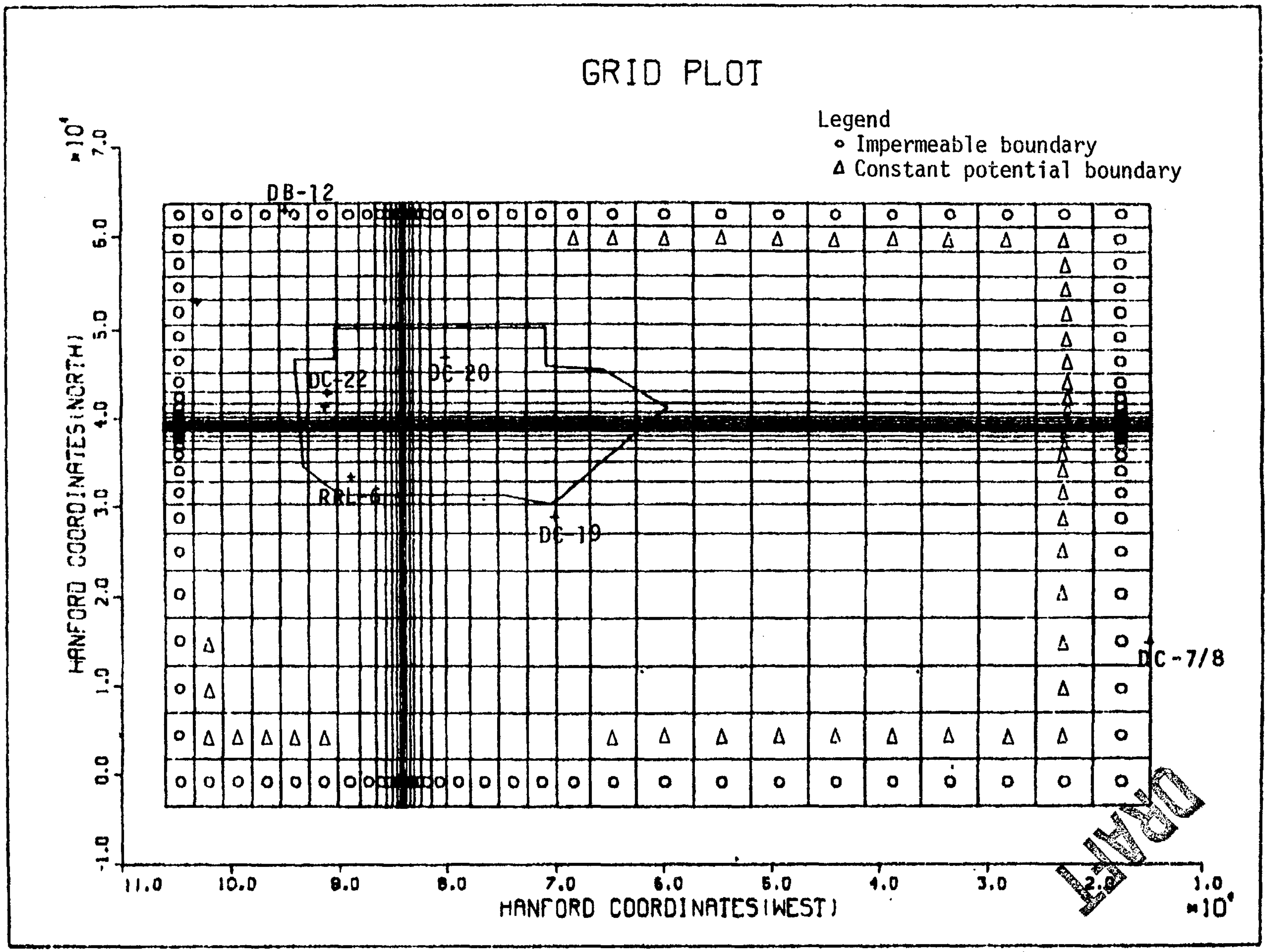


Figure B. Finite difference grid used to discretize the area including the reference repository location.

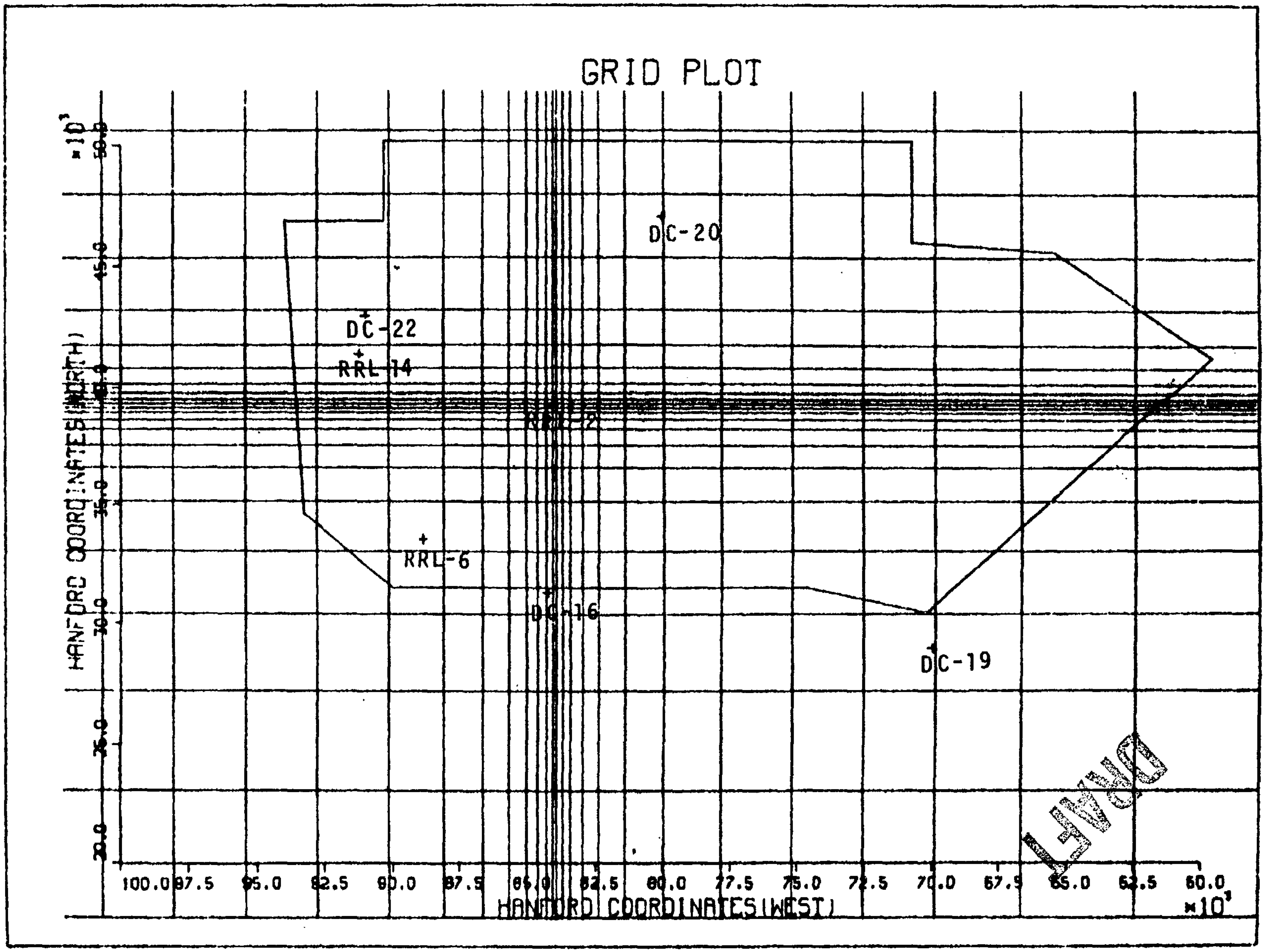
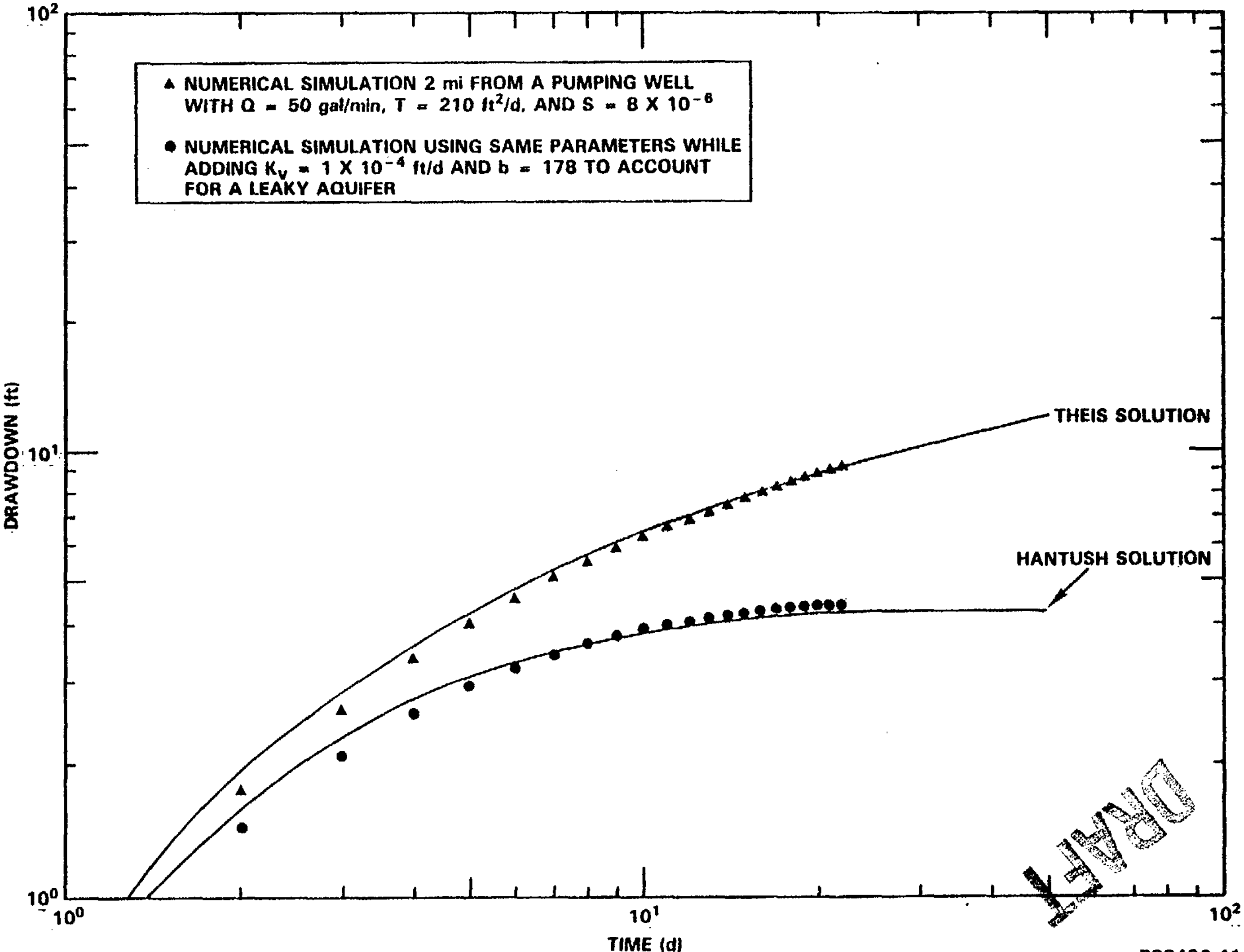


Figure B-1. Finite difference grid of the RRL and immediately surrounding area.

Figure C.
COMPARISON OF THEIS AND HANTUSH AND NUMERICAL SIMULATIONS



PS8406-41

73

PARAMETERS USED IN PLANNING LARGE SCALE TESTS

Small scale test results provide a basis for estimating hydrologic behavior on large scales, and therefore can be used in the planning and design of larger scale tests. Table 1 lists the transmissivities in ft^2/day estimated from small scale tests in the Rocky Coulee flow top, Cohassett flow top, Cohassett flow bottom, and Umtanum flow top. Transmissivities from single well tests are reported three ways in Table 1: as a range from high to low and a best estimate of the value based upon the professional opinion of the hydrologist conducting the test. Averages were then calculated for the high, low, and best transmissivity estimates and used to provide a range of transmissivity values for each of the formations to be stressed. Standard deviations associated with the averages are also presented in Table 1 to provide some idea of the variability of the transmissivities.

DRAFT

The calculated averages of transmissivity are listed in Table 2, Column 2. These numbers are brought over directly from Table 1 except where changes are made as explained in the footnotes of Table 2; the changes are based upon the consensus of hydrologist opinion. Also listed in Table 2 are the n and σ values for the best estimate of transmissivity. These two symbols are defined as follows:

n number of test valves used for calculating the average and standard deviation of the "best" estimate.

σ standard deviation of best estimates.

Storage coefficients and vertical conductivity values are found in Table 2, Column 4. These values represent the range of interest found in studies by Lu (1984).

PARAMETRIC STUDY RESULTS FOR ROCKY COULEE

Table 3 shows results of the parametric study performed using the Trescott model to simulate pumped withdrawal from the Rocky Coulee flow top. Transmissivities of the Rocky Coulee layer (layer 2, the middle layer) were varied from high to low to best values while those of the superadjacent and subadjecent layers (Grande Ronde 2 and Cohassett flowtop, respectively) were fixed in their "best" values (as per Table 2). In addition, storage coefficient and vertical conductivity values were stepped through their Table 2 high/low values. The result of these combinations as described above would be only 3x2x2 = 12 cases or runs.

TABLE 1 **sheet 1 of 2**

Transmissivity estimated from small scale tests (in ft^2/day)

BOREHOLE NUMBER/ NAME	High	Low	Best
ROCKY COULEE FLOW TOP			
McGee	1000	10	230
RRL-2A	100	10	10
DC-19C	1	0.1	0.5
DC-22C	10	0.001	0.1
	n=4 Ave=280 σ=484	n=4 Ave=5.0 σ=5.7	n=4 Ave=60.15 σ=113.3
COHASSETT FLOW TOP			
DC-16A	100	0.01	2.8
DC-4	1	0.1	0.12
McGee	280	80	200
RRL-14	10	1	5.
RRL-2			0.042
RRL-6	0.001	0.00001	0.005
DC-19C			
DC-20C			
DC-22C	1	0.1	
	n=6 Ave=65 σ=112	n=6 Ave=13.5 σ=32.6	n=6 Ave=34.7 σ=81
COHASSETT FLOW BOTTOM			
DC-16A	0.01	0.001	0.05
McGee	1.7	0.6	1.0
RRL-14	100	3.1	5.0
RRL-2			830
RRL-6	0.1	0.01	0.05
	n=4 Ave=25 σ=50	n=4 Ave=0.18 σ=0.29	n=5 Ave=17.82 σ=36

DRAFT

UMTANUM FLOW TOP

	High	Low	Best
DC-19	100	10	50
DC-6	1	0.1	10
RRL-2			480
DC-15			25
DC-16A	100	10	50
RRL-6	1	0.1	0.5
RRL-14	10	1.0	5.0
DC-20C	1	0.1	0.5
	n=6 Ave=36 σ=50	n=6 Ave=3.6 σ=5.	n=8 Ave=78. σ=164

sheet 2 of 2

Notes:

n= number of test values
σ= standard deviation
Estimates of transmisssivity are from summary of test results by Strait and Mercer (1984).

TABLE 2 PARAMETER VALUES USED IN SIMULATED PUMPING TEST OF ROCKY COULEE FLOW TOP

HYDROSTRATIGRAPHIC UNIT	Transmissivity, ft²/day					Thickness, ft			Storage Coef.		Over and Underlying Vertical Hydraulic Conductivity Flow Interior (K_v)	
	Average C) High	Average C) Low	For Best Value Best	N	σ	Interior Above	Flow Top	Interior Below	High	Low	Feet/Day D) High	Feet/Day D) Low
Grande Ronde 2 *Flow Top*			35 F)				23 E)	75 E)	10^{-5}	10^{-6}	$1x10^{-4}$	$1x10^{-6}$
Rocky Coulee Flow Top	280	5	60	4	113	75 E)	38 E), 50 B)	125 B)	10^{-5}	10^{-6}	$1x10^{-4}$	$1x10^{-6}$
Cohassett Flow Top	65	0.042 A)	35	6	81	125 B)	40 B) 21 E)	243 E)	10^{-5}	10^{-6}	$1x10^{-4}$	$1x10^{-6}$

A) The best estimate of transmissivity at RRL-2A, based on testing at this borehole, is T=0.042 ft²/day. This value is lower than the average "low" value for all tests in the Cohassett flow top therefore, T=0.042 ft²/day is used in this study as the "low" value.
B) Best estimated value based on compilation of interval reports.
C) See Table 1 for supporting VALUES
D) Range of K_v values used in this study is assumed based on one test value of approximately 10^{-5} ft/day (Spane, F. A., Thorne, P. D., et al., 1983).
E) Based on drilling log of borehole RRL-2A.
F) A transmissivity of the Grande Ronde 2 is not known based on composite testing of the Grande Ronde 2 and Rocky Coulee flows at RRL-2A. For this study, it is assumed that the transmissivity of the Grande Ronde 2 flow top is about the same as the Cohassett flow top which has been tested as a discrete unit in RRL-2A.

RUN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
T_2 (ft^2/day)	280	5	5	60	60	280	5	5	60	60	280	5	5	60	60	280	5	5	60	60	Transmissivity in Rocky Coulee F.T.
T_1, T_3 (ft^2/day)	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	Tr. in Grande Ronde 2 and Cohassett F.T.
S_1 S_2, S_3	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	Storage Coefficients
K_v (ft^2/day)	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-4}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	Vertical Conductivity
TCF_{12}					6×10^{-6}										6×10^{-8}						Inter-Aquifer Transfer Coefficients
TCF_{23}					1×10^{-5}										1×10^{-7}						
Q (gpm)	410	9.8	39	102	410	398	8.6	33	91	366	410	9.8	39	102	410	361	7.6	29.9	79.9	326	Pumping Rate
s (ft.)	188	251	1001	218	875	182	221	846	194	782	188	251	1001	218	875	165	196	766	171	697	Additional Drawdown in Pumping Well
dd (ft.)	308	257	1023	302	1213	332	231	887	301	1209	346	323	1288	347	1394		296	1156	320		Pumping Grid Drawdown
dd_{tot}=s+dd (ft.)	496	508	2024	520	2088	514	452	1733	495	1991	534	574	2289	565	2269		492	1922	491		Total Drawdown at Pumping Well after 30 days
s (ft.)	51.8	6.6	26.5	28.4	114	90.8	11.1	42.6	57.3	230.6	1.5	0.23	0.02	0.82	3.3		1.7	6.8	6.3		Maximum Drawdown in Cohassett F.T. after 30 days pumping in Rocky Coulee F.T.

TABLE 3. Parametric Study Results for Rocky Coulee and Adjacent Flow Tops

Twenty runs were made however, as seen in Table 3, because for cases of T_2 = 5 or 60 ft^2/day, it was desired to make separate runs for different pumping rates which would yield drawdowns of near 500 and 2,000 feet. These eight "added" cases are the runs 3, 5, 8, 10, 13, 15, 18 and 20, thus yielding a total of 20 runs. Runs are not reported for the four cases where T = 280 ft^2/day and drawdown is about 2,000 feet because the required pumping equipment would not be practical.

The inter aquifer transfer coefficients (TCF's) shown in Table 3 are obtained directly from the K_v and b values as follows:

$$\text{Run 1:} \quad TCF_{12} = Kv/b = \frac{10^{-4}}{125}(7.48\ gal/ft^3) = 6 \times 10^{-6}$$

$$TCF_{23} = Kv/b = \frac{10^{-4}}{75}(7.48) = 1 \times 10^{-5}$$

Drawdowns at the pumped well were computed in a two step process. First, the drawdown at the pumped node of the model from the Trescott run was obtained (denoted by dd in Table 3). Next, an "additional" drawdown(s) was computed. The two were then added, yielding the dd or total drawdown result of Table 3. The "additional" drawdown term was computed using the following equation from Prickett and Lonnquist, 1971, p. 61:

$$s = 0.3665\ (W/T)\ \log\ (a/4.81\ r)$$

where:

s = Additional drawdown or head decline to be added to calculated value from pumped well node of the digital model, ft.

T = Transmissivity of the pumped layer in the vicinity of the well, ft^2/day.

Q = Pumping rate, gpm.

a = Finite difference grid interval in vicinity of well, ft.

r = effective radius of the simulated pumping well, ft.

The values of T and Q are given in Table 3. The values of r and a used for all of the calculations are 0.5 feet and 158 feet, respectively.

insert to page 80

However, inspection of the model output indicates that the drawdown at equal radii from the pumped well and at various angles were substainally the same i.e. the cone of depression is approximately semetrical. This is expected because the pumped unit is assumed to be isotropic and homogeneous and, for most of the cases, the cone of depression did not intercept the model boundaries.

Case 16 and 20 were the only ones not showing results from the Trescott model runs. They failed at the 200 iteration maximum setting. The high number of interactions was due to numerical instability. Therefore, the Run 16 and 20 results are not included.

Four graphs were prepared for each model run. For example, the results of model run number 1 are presented in Figures D, E, F, and G. A brief description of each of these figures follows:

DRAFT

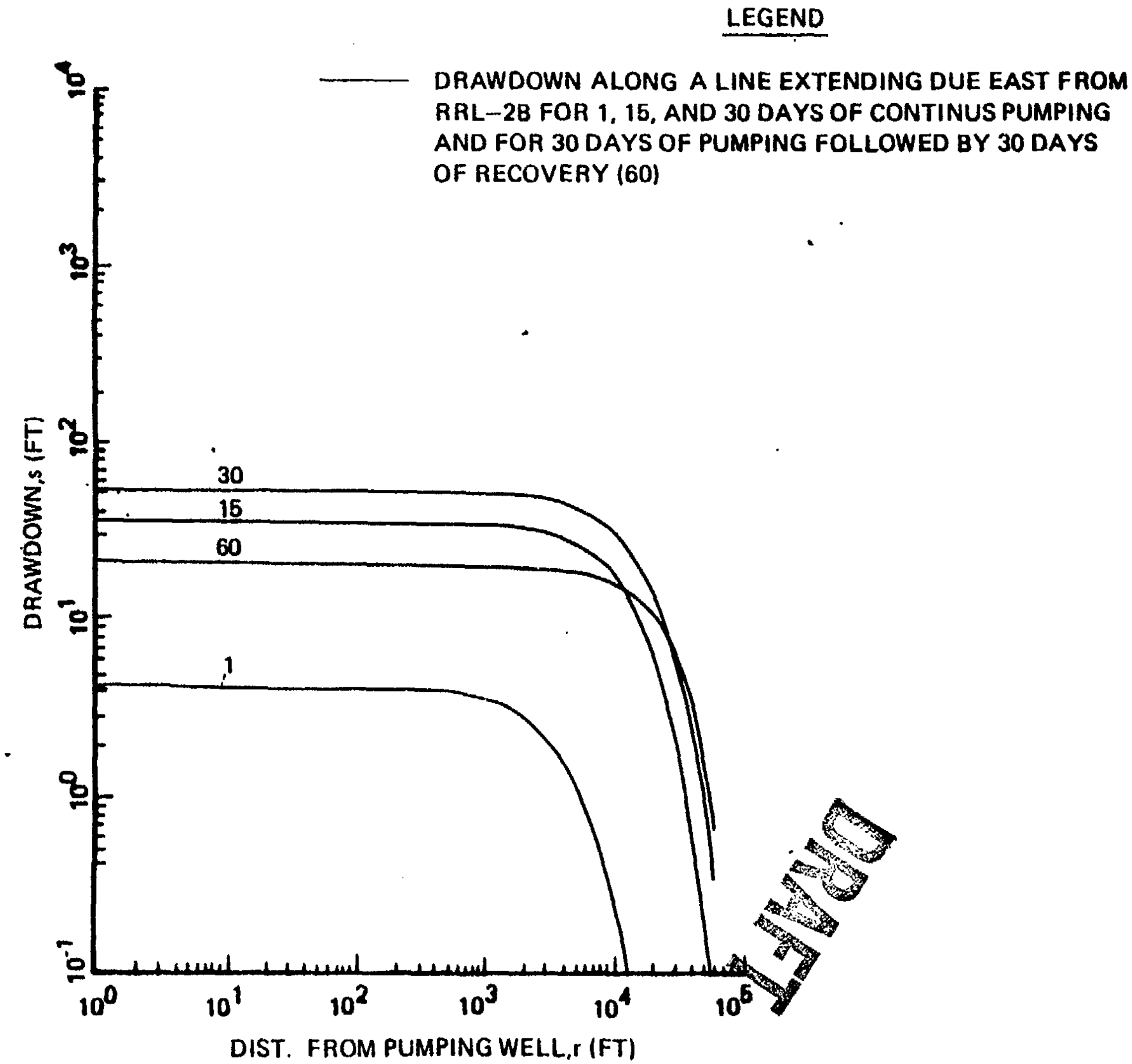
Figure D (Cohassett flow top): Drawdown in the unpumped unit vs. distance from pumping well is shown for pumping at days 1, 15 and 30 as well as day 60 for a 30 day recovery. These pressure drops are the continuous lines. In addition, markers are superimposed corresponding to the pressure drops at the wells DC-16, DC-20, DC-22 and DC-19.

The continuous curve represents hypothetical drawdown calculated at points east of the pumping well (see Figure B-1). Due to boundary conditions, observation wells at points in a non-easterly direction but of equal distance might yield different drawdown. ~~Thus, the markers may or may not fall directly on the continuous curves.~~ insert here from attached sheet

Figure E (Rocky Coulee flow top): Same concept as Figure D except this figure shows the simulated drawdown in the pumped formation.

Figure F (Grande Ronde 2 flow top): Same as Figure D except that it is the layer above the pumped layer.

Figure G Shows drawdown in pumped formation as a function of time at different wells. The discontinuity on the right side of the figure results from termination of pumping at day 30.

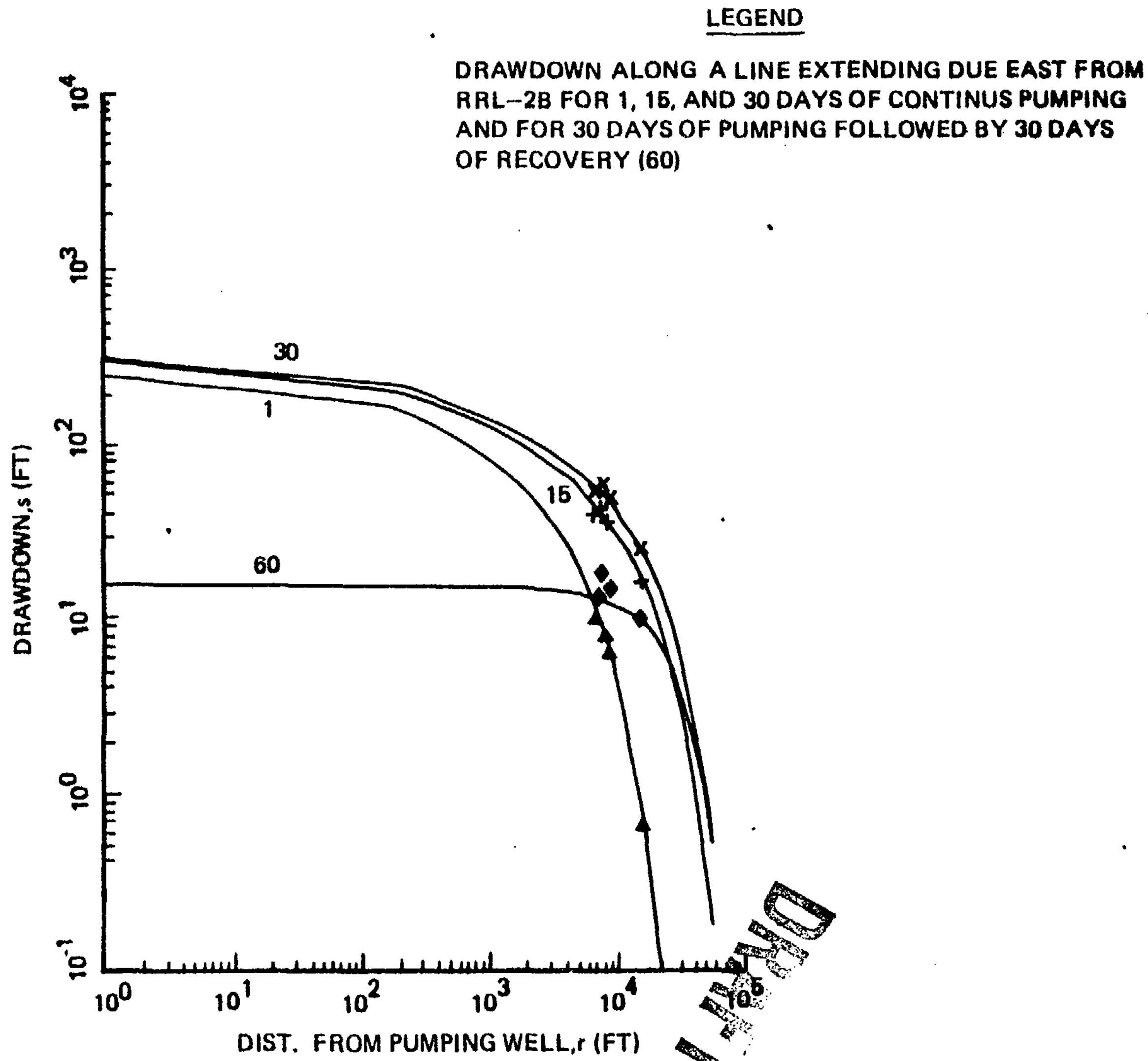


NOTE.

1) PUMPIMG IS FROM ROCKY COULEE FLOW TOP ONLY.

FIGURE D WATER LEVEL DRAWDOWN VERSUS DISTANCE IN THE COHASSETT FLOW TOP

18



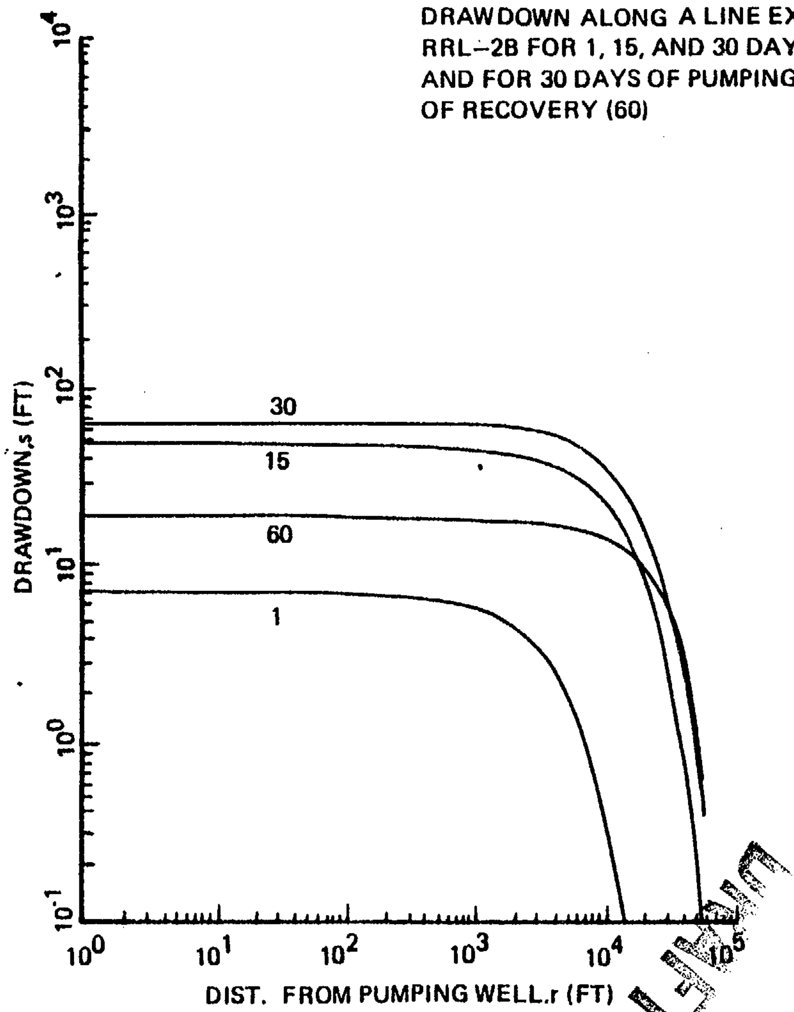
NOTE:

1) PUMPING IS FROM ROCKY COULEE FLOW TOP ONLY.

FIGURE E WATER LEVEL DRAWDOWN VERSUS DISTANCE IN THE ROCKY COULEE FLOW TOP

LEGEND

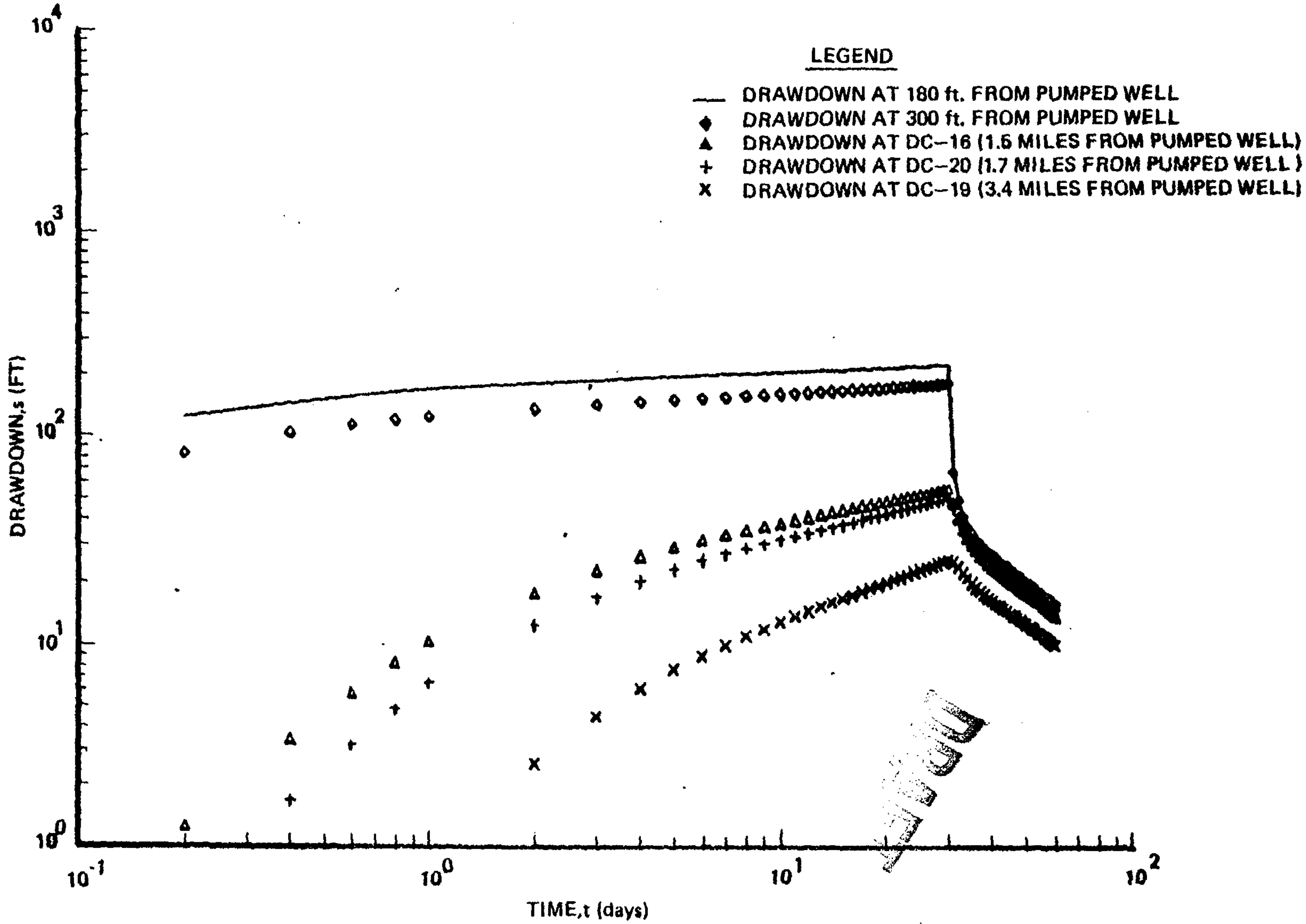
DRAWDOWN ALONG A LINE EXTENDING DUE EAST FROM RRL–2B FOR 1, 15, AND 30 DAYS OF CONTINUS PUMPING AND FOR 30 DAYS OF PUMPING FOLLOWED BY 30 DAYS OF RECOVERY (60)



NOTE:

1) PUMPING IS FROM ROCKY COULEE FLOW TOP ONLY.

FIGURE F WATER LEVEL DRAWDOWN VERSUS DISTANCE IN THE GRANDE RONDE 2 FLOW TOP



NOTE:
1) PUMPING IS FROM THE ROCKY COULEE FLOW TOP ONLY.

FIGURE 6 WATER LEVEL DRAWDOWN VERSUS TIME IN THE ROCKY COULEE FLOW TOP