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O. L. Olson, Project Manager
BWIP Project Office
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Box 550
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FOLLOW-UP COMMENTS ON MAY 22, 1985 BWIP/NRC HYDROLOGY MEETING: CHANGES IN TESTING PLANS SINCE DECEMBER 1984

Dear Mr. Olson:

1.0 INTRODUCTION

During the May 22, 1985 BWIP/NRC Hydrology Workshop, DOE unveiled a number of changes in the BWIP hydrologic test plans from those presented at the previous meeting in December 1984. During the May 1985 meeting, NRC agreed to review these changes and provide comments to DOE within a month of the meeting. The following pages contain our comments on the revised test plans.

The most significant planned or potential changes in the test plan described by DOE at the May 22 meeting were:

a) a reduced scale hydraulic stress test at the RRL-2 cluster prior to Exploratory Shaft (ES) drilling;

b) the potential deletion of the previously-planned large scale hydraulic stress (LHS) test prior to ES penetration of the Grande Ronde;

c) a number of additional planned boreholes outside of the reference repository location (RRL);

d) postponement of the first pump test until at least November 1985;

and e) a program to perform independent regional modeling.

The changes in the test plan are directly related to the observations made during the baseline monitoring program. These changes have been evaluated by NRC in terms of the objectives of testing and in terms of the information on site hydrologic conditions collected to date. In particular, the timing, location and scale of the stress test (items a, b, and d) were considered with respect to its coordination with, and impact on, the hydrologic baseline monitoring program. Our evaluation of the hydrologic baseline data we have

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seen thus far is outlined in the following section. Section 2.0 provides the background information necessary to understand the purpose of Changes a, b, and d, and to support our position on the changes as presented in Section 3.0.

2.0 DISCUSSION OF OBSERVATIONS FROM HEAD MONITORING PROGRAM

NRC considers that the overall objective of the test plan, including hydrologic baseline monitoring activities and both small- and large-scale testing activities, is to develop a more accurate model of the site hydrogeology. The test plan should therefore include evaluation of hydrologic boundary conditions, hydrologic structures controlling or affecting ground-water flow, hydrologic parameters (including hydraulic gradients, hydraulic conductivities, effective porosities, storativities, and dispersivities), and system dynamics (i.e., degree and nature of transience), as described in draft BWIP ISTP 1.0 (NRC (1984)). We have questioned in the past (cf., NRC (1983); Wright (1984)) the validity of the drill and test data collected prior to 1984 in terms of both individual measurement reliability, and in the extrapolatability of the local-scale data to repository-scale modeling. The strategy proposed in draft STP 1.1 was designed to address the issues of repository-scale horizontal and vertical hydraulic conductivities, storativities, identification and evaluation of hydrologic structures, pre-emplacement hydraulic gradients, and system dynamics.

NRC and DOE have agreed (BWIP/NRC (1983)) that a critical part of the test strategy is the establishment of a hydrologic head baseline. This baseline would ideally represent an undisturbed snapshot of the pre-emplacement ground-water flow system. Prior to the baseline monitoring activities it was anticipated that the Grande Ronde flow system beneath the site would reveal itself to be isolated from the Wanapum and Saddle Mountains flow systems, and that a steady- or quasi-steady-state picture of the flow system from the repository horizon to the accessible environment would emerge within about a year after initiation of monitoring. A second aspect of the hydrologic baseline monitoring program would be the identification of short-term head trends that could be simply and explicitly accounted for in hydrologic test interpretation.

The NRC staff and contractors have examined the head monitoring data from DC-19, -20, and -22 collected between April and December of 1984. We have also examined in less detail the head monitoring data from BWIP's deep borehole monitoring network up to September 1984. Based on the limited data we have seen from DC-19, -20, and-22, it would appear that 1) quasi-steady-state heads at these particular locations can probably be projected for the monitored Saddle Mountains and Wanapum units; 2) final steady- or quasi-steady-state heads can not be projected for the Grande Ronde units monitored; 3) the trends

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ATTACHMENT 1

May 31, 1985
Contract No. NRC-02-82-044
Fin No. B7372-3
Communication No. 128

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

Dear Matt:

The purpose of this letter is to provide you with our team's assessment of the change in large-scale stress tests proposed by DOE at the meeting of May 22, 1985, in Washington, D.C. We believe the testing program as discussed by Steve Baker is a significant departure from the NRC's position as stated in STP 1.1.

It is evident from Steve Baker's discussion that DOE recognizes the trade-offs between collection of additional water level data to establish a quasi steady-state head configuration near the RRL and the initiation of a large scale hydrologic stress test (LHS) prior to boring the exploratory shaft. Steve Baker indicated that they are planning the first multiple well stress test to include only the RRL-2 wells without achieving significant drawdown at cluster well sites DC-19, 20, and 22. Maurice Veatch and Steve Baker described the proposed test as follows. The pumping well would be RRL-2B, completed in the Rocky Coulee flow top. Well RRL-2C would have multiple level piezometers installed similar to the DC-19C, 20C and 22C. RRL-2C would be 250 feet away from the pumping well. Mr. Veatch indicated that the pumping of RRL-2B would be implemented utilizing the maximum pumping rate possible without depleting the available drawdown to the level of the Rocky Coulee flow top. The stress test would continue until measurements of water level decline were detected in DC-19C, 20C or 22C or until the test period of approximately 60 days had been exceeded. Mr. Veatch stated that only a small drawdown would be allowed to occur in wells DC-19C, 20C and 22C in order to minimize the perturbation on the fluid potential (head) distribution within the RRL. Essentially, he indicated that DOE believes it to be more important to continue to collect baseline fluid potential data than to collect large scale hydraulic property data. The test proposed would constitute a relatively small-scale test with the primary information on aquifer hydraulic properties derived from data collected in RRL-2C.

Steve Baker indicated two objectives for this test. The first objective is related to mine safety during the breakout from the exploratory shaft. The second objective is to provide data on the hydrogeologic characteristics of the RRL-2 area prior to the construction of the exploratory shaft. A second stress test is planned at the RRL-2B site after the completion of the exploratory shaft to evaluate any hydrologic changes because of shaft construction. In response to a question, DOE-Rockwell personnel indicated that the before and after tests probably would be similar in length and rate of pumping in order to evaluate the hydraulic effects of shaft construction. The testing program outlined by DOE on May 22 suggests that the large-scale stress test in the RRL-2 area outlined in STP 1.1 will be delayed until 1988 at the minimum.

The present design of the aforementioned smaller scale stress test utilizing RRL-2B does not facilitate evaluation of two important hydrogeologic characteristics: lateral boundary-hydraulic continuity and vertical leakage-hydraulic continuity. The test program described would stress a portion of the aquifer whose maximum extent is the radial distance from RRL-2B to DC-19, DC-20 or DC-22. This scale would not permit the detection or evaluation of lateral boundaries-hydraulic continuity on a repository scale as addressed in STP 1.1. The major observation well for the hydraulic stress test would be RRL-2C. The nearness of this observation well to the pumping well (250 feet) limits the application of the Hantush and Jacob (1955) method and Hantush (1960) method of leaky aquifer analysis. Both methods require observation wells at considerable distance from the pumping well in order to identify leakage utilizing type curve analyses. The construction of RRL-2C with monitoring zones in the Rocky Coulee flow interior and the Cohassett flow interior may allow evaluation of vertical hydraulic conductivity utilizing the Neuman and Witherspoon (1972) ratio method. The required length of the test to get water level responses in the flow interiors might not be achieved because of the limitation of having minimum water level decline in the Rocky Coulee flow top at cluster sites DC-19C, 20C and 22C. Similarly, a fairly long-term test might be required to allow measurement of water level response in the Cohassett flow top in RRL-2C.

DOE personnel indicated that repository scale stress tests would be conducted in the Wanapum Formation where well yields are considerably higher. These results certainly will be valuable in evaluating the overall hydrogeologic characteristics of the RRL site. However, the large-scale stress testing results derived from the Wanapum Formation may not be transferable to the Grande Ronde flow tops. The structural characteristics present in the Grande Ronde basalt may not be identical to those present within the Wanapum Formation. The presumption of transferability of results from the Wanapum to the Grande Ronde is contrary to the intent of STP 1.1.

We believe that one of the advantages of the BWIP site is the in-situ testability of the hydraulic properties of the hypothesized multiple flow tops above and below the repository horizon. The test plan as presented by DOE-Rockwell on May 22 is not consistent with testing this hypothesis and the concomitant hydraulic properties as addressed in STP 1.1

Please contact us if you have questions.

Sincerely,

Roy E. Williams

Roy E. Williams

REW:sl

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ATTACHMENT 2

MEMORANDUM FOR: Robert J. Wright
Repository Projects Branch
Division of Waste Management

THRU: Myron Fliegel, Section Leader
Hydrology Section
Geotechnical Branch
Division of Waste Management

FROM: Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

SUBJECT: LEONHART, ET AL., (1984): "ANALYSIS AND INTERPRETATION OF A RECIRCULATING TRACER EXPERIMENT PERFORMED ON A BASALT FLOW TOP"

The subject document was received by NRC in November of 1984 as an enclosure to a letter from Olson (DOE/BWIP) to Wright (NRC/WMRP). The document is a pre-copy of a Rockwell document (RHO-BW-SA-300P), a final copy of which has not been received by NRC to date. The document describes a dual-well recirculating tracer test and its analysis. The analysis yields a value of flow top effective thickness (effective porosity times interval thickness) and dispersivity. These parameters, especially effective thickness, are critical for hydrogeologic performance assessment.

Enclosed please find a review of the subject document. The main conclusions of the review are that 1) the document is responsive to concerns about a precursor document (Gelhar et al. 1982); 2) certain aspects of the described test warrant further examination, e.g., the small magnitude and irregularity of drawdown/buildup; 3) additional documentation of the lag time analysis and discussion of potential dispersion in the boreholes would have been helpful in the document; 4) the low effective thickness measured can be explained based on a consideration of fracture flow; 5) the representativeness of this effective thickness value for larger scales than the scale of the test, and the validity of the equivalent porous-medium continuum assumption at the scales of testing and modeling, are important questions which warrant additional research; and

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6) BWIP is clearly a leader in advancing the state of the field practice.

I recommend that this review be transmitted to BWIP and other interested parties, subsequent to peer review as appropriate.

Matthew Gordon

Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

Enclosure:
As stated

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WMGT DOCUMENT REVIEW:

"Analysis and Interpretation of a Recirculating Tracer Experiment Performed on a Deep Basalt Flow Top," by L. Leonhart, R. Jackson, D. Graham, L. Gelhar, G. Thompson, B. Kanehiro, and C. Wilson, 1984

Review by Matthew Gordon, Hydrology Section, WMGT

1. INTRODUCTION AND GENERAL COMMENTS

The subject document was received by NRC in November of 1984 as an enclosure to a letter from Olson (DOE/BWIP) to Wright (NRC/WMRP). The document is a pre-copy of a Rockwell document (RHO-BW-SA-300P), a final copy of which has not been received by NRC to date. The document describes a dual-well recirculating tracer test performed at the Hanford site, and its analysis. The analysis yields a value of flow top effective thickness (effective porosity times interval thickness) and dispersivity.

The test analysis utilizes the same methodology employed in a previous document Gelhar (1982). The Gelhar (1982) document has been reviewed previously by NRC (Gordon and Coleman (1984)). NRC's review of the Gelhar (1982) document did not question the analytical methodology, but noted deficiencies in the test documentation, and questioned whether adherence to the analytical assumptions of Gelhar (1982) was maintained during the test, which was performed several years earlier (1978) by Science Applications Inc. (SAI).

The new document (Leonhart et al. (1984)) evidences a large measure of responsiveness to NRC's concerns regarding the previous document (Gelhar (1982)). The documentation is superior: the assumptions and limitations of the test are clearly presented. The analysis appears sound, and a discussion of the test results and its implications is well-presented. The test itself was run under better-controlled conditions, which more closely adhere to Gelhar and Collins (1971) analytical approach. The analysis appears to have been successful in terms of producing an excellent type curve match (Figure 8 of the report). The superiority of the Gelhar and Collins (1971) type curve approach to tracer test analysis to the simpler and more common two-point analysis is clear. BWIP, in its application of the Gelhar and Collins (1971) method, is leading the state of the field practice into the state of the art, for which they deserve commendation.

A few questions and comments regarding the test and test documentation have been identified during the review of this document. These questions and comments are discussed below, followed by a discussion of the test result and its implications.

2. COMMENTS REGARDING TEST AND TEST DOCUMENTATION

One puzzling aspect of the documented tests is the the observed development of a head buildup at DC-8 of only two feet (0.61 m) during the test, while the drawdown at DC-7 reached a magnitude of 77 feet (23.5 m). Leonhart et al. note that, "theoretically, a mirror-image symmetry should develop between the cones of impression and depression at the recharge and discharge wells under conditions of ideal homogeneity and isotropy within the flow top, and equivalent well efficiencies [apparently meaning wellbore damage or improvement (c.f. Earlougher, 1977) in this context] and under conditions of equal flow" (p. 28). Leonhart et al. reason that lateral heterogeneities in the vicinity of the two boreholes, e.g., a local pinch-out of a more highly transmissive horizon within the flow top may be responsible for the observed asymmetry.

Assuming constant flow rates and an ideal homogeneous isotropic aquifer, the head impression and depression within the aquifer, but not necessarily within the well, would be expected to be symmetrical. The expected head distribution in the aquifer is illustrated in Figure 1, using the aquifer properties of Leonhart et al. (the figure and calculation is based on output from a numerical model, SWIFT, and a contouring post-processor; heads very close to the well are averaged across a larger grid block). However, a difference in the magnitude of drawdown/buildup within the boreholes themselves would in fact be expected due to the differing radii of the two wells: DC-7 being 0.11 m radius, and DC-8 being 0.04 m radius. (We note that inches have been inaccurately converted to centimeters on page 6 of the document.) The inequality in the observed borehole drawdown/buildup is, however, opposite to what would be expected theoretically, i.e., DC-8 (the smaller hole) had less buildup than DC-7 had drawdown. Assuming the value of aquifer transmissivity as noted in Leonhart et al., the expected drawdown in DC-7 would be about 67.3 meters at steady state, while the buildup in DC-8 would theoretically be about 81.5 meters (based on a calculation using equation 8-155 from Bear (1979)) for the 1 gal/min pumping/injection rates). Both of the observed drawdown/buildup magnitudes are less than would be expected theoretically; and the 0.61 m observed buildup at DC-8 is particularly inconsistent with the expected value. This could possibly be due to the aquifer having a higher transmissivity than assumed, with a local low transmissivity zone or wellbore skin near DC-7. Alternatively, a very conductive fracture or other heterogeneity may intercept DC-8 and not DC-7; however, this would seem inconsistent with the reasonably high recovery of tracer (60%) at DC-7. Similarly, a local pinch-out of a more transmissive horizon may also explain the observed drawdown/buildup, as reasoned by Leonhart et al. The presence of a wellbore skin at DC-7 is discounted by Leonhart et al., although no clear justification for doing so is presented in the document. During an attempted pump test at DC-7 prior to the tracer test, "excessive drawdown" (p. 7) was developed at DC-7; this may be consistent with what was observed during the tracer test, and suggests that a skin effect or the presence of lateral heterogeneities are affecting the ground-water flow near DC-7. Another explanation could be that the flow top has a higher transmissivity than assumed, with a less permeable boundary or borehole skin effect near DC-7, causing a higher drawdown at DC-7 than the impression at DC-8. At any rate, given the irregularities in the observed drawdown and buildup, it is surprising that such an excellent fit to the type curve was obtained (Figure 8 of the report).

It is not clear whether steady-flow conditions were attained during the test; on page 11, it is stated that "the drawdown at DC-7 stabilized at about 77 ft and the groundwater mound at DC-8 built up 2 ft". If steady flow conditions were not attained, the test may require reevaluation.

Leonhart et al. note that lag time, i.e., the time that the tracer spent traveling down DC-8 and up DC-7 between injection and detection, is one of the most sensitive parameters in the analysis. The results of the analysis of the lag time are not presented in the report. An analysis of the tracer front, using the method of Muskat (1937) which assumes no dispersivity, would result in a travel time of the non-dispersed front of 139 minutes. The dispersion accounted for by the Gelhar and Collins (1971) solution apparently causes a delay in the arrival of the peak to 178 minutes according to figure 8 of the report. Assuming that the time axis in figure 6 of the report represents the time since the pulse injection, the inferred total lag time is apparently 1242 minutes. Thus, the tracer peak took 178 minutes to travel in the aquifer and spent about 1242 minutes in the boreholes. At the December 1984 BWIP/NRC hydrology meeting in Silver Spring, MD, Dr. Gelhar indicated that, based on his calculations, the dispersion within the boreholes does not adversely affect the dispersivity calculation, since the Taylor-type dispersion in the boreholes is insignificant compared to dispersion in the aquifer. While this appears reasonable, it would have been helpful to have included these calculations in the report, as well as the calculations of lag time, especially given the sensitivity of the analysis to this parameter.

3. DISCUSSION OF TEST RESULT AND ITS IMPLICATIONS

The test yielded a very low value of effective thickness (effective porosity of interval times interval thickness), yielding an effective porosity for the test interval of 1.6×10^{-4}. Assuming the tracer movement in the brecciated flow top to be dominated by movement along the ubiquitous fractures and joints, this value of effective porosity for the "equivalent porous-medium continuum" can be shown to be reasonable. In a fractured medium, where the fractures dominate the flow, the effective porosity of the equivalent continuum may be very small compared to the volumetric fraction of total void space (including the intact matrix block void space). Assuming:

- flow to be dominated by the fractures;
- that the cubic law for flow within fractures is valid in this case;
- the noted interval transmissivity value of .065 m^2/day; and
- the derived effective thickness value of 1.8×10^{-3} m,
- the interval thickness value of 11.3 m,

an average fracture aperture of 2.3×10^{-5} m with a frequency of 7.1 fractures per meter for the interval can be inferred (see Appendix A). These values are consistent with the ranges of values observed in the field (c.f., Long and WCC, 1984).

This test was performed in the McCoy Canyon flow top between boreholes DC-7 and DC-8 which are laterally separated by 55 ft at the test interval. The validity of the calculated effective porosity value at the larger scales of interest for repository performance assessment depends on the degree to which the flow at those scales is dominated by fractures and joints. This will depend in turn on the continuity or "connectedness" of the fracture network on these scales, as explored (in a different context) by Smith and Schwartz (1984). If the fracture network is interrupted on these larger scales by intact rock, the effective porosity will be affected more by the effective porosity of the matrix rock, and could be significantly higher than the effective porosity on the smaller scales at locations dominated by fracture flow. If, on the other hand, groundwater flow at the larger scales is also dominated by fractures, or if the tests are performed within isolated unfractured zones, the large-scale effective porosity could be larger, equal, or smaller than the value measured on the test scale. This scale-dependence of effective porosity is an area of great technical interest which requires more research. It is of significant programmatic interest as well, since the representativeness of this low effective porosity value at larger scales is a key question in assessments of the suitability of the site for a HLW repository. An important related question is whether the medium may validly be assumed to act as an equivalent porous medium at the scale of testing or modeling, or whether the geometry of the individual fractures must be taken into account at these scales.

4. SUMMARY

The most important points of the review above are listed below:

1) The Leonhart et al. (1984) document is responsive to NRC's concerns regarding previous tracer test, test analysis and documentation (Gelhar (1982)).

2) The test result is not unreasonable assuming the flow in the flow top breccia to be dominated by the secondary permeability, i.e., of the fractures and joints, as opposed to the primary permeability, i.e. of the matrix blocks.

3) More research, both generic and site specific, is needed to determine whether the effective porosity value derived at the 55 ft test scale is representative of the effective porosity at larger scales. This is especially important if the fracture network is discontinuous at the larger scales or if the frequency of continuous or connected fracture sets is different at the larger scales. The large-scale testing program planned at BWIP may offer insight into this question. The related assumption that the flow top acts as an equivalent porous-medium continuum also warrants further examination.

4) The irregularity of the observed drawdown/buildup in the boreholes warrants additional examination by BWIP to determine its impact on the tracer test, and on the estimate of the transmissivity of the zone.

5) For completeness, the lag time analysis should have been included in the report, as well as an analysis of dispersion in the borehole.

6) It is not clear whether steady state flow conditions were attained during the test.

7) The test and the analysis by Leonhart et al. (1984) reflects the status of BWIP's hydrology program as a leader in the state of the field practice.

FOLLOW-UP ACTIVITY

This review should be transmitted to BWIP and other interested parties. NRC should obtain the drawdown and recovery data from the DC-7 pump test described in Leonhart et al. NRC should also obtain the drawdown and buildup data that may have been collected during the tracer test, if in fact the flow conditions were not steady during the test.

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STEADY STATE FLOW FIELD

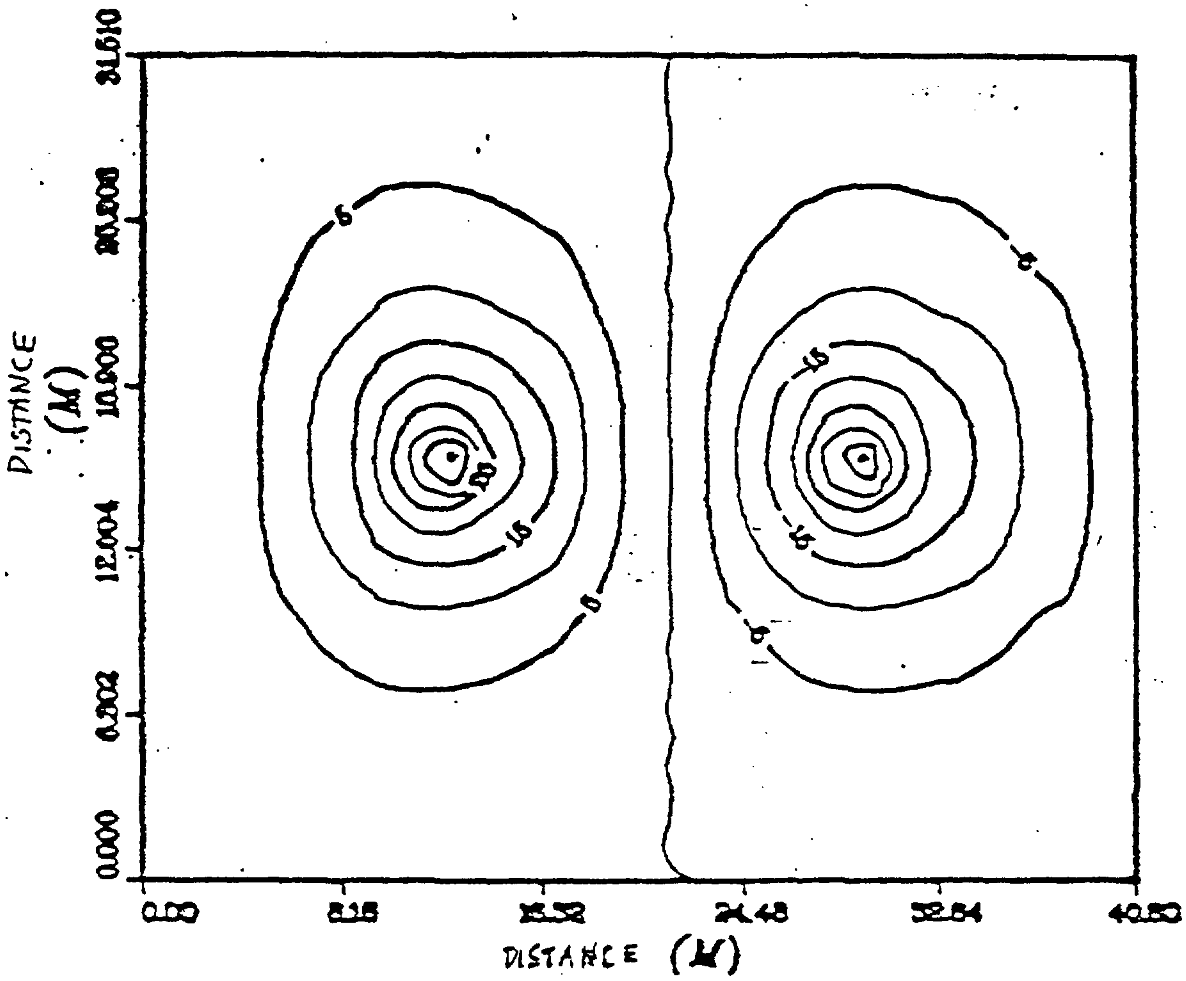

FIGURE 1. CONTOURS OF EQUAL HEAD BUILDUP, IN METERS, FOR HOMOGENEOUS AQUIFER AS DESCRIBED IN TEXT. PUMPING RATE 1 GAL/MIN. NEGATIVE BUILDUP IMPLIES DRAWDOWN. (DC-8 ON LEFT, DC-7 ON RIGHT). THEORETICAL RESULT, FROM NUMERICAL MODEL.

APPENDIX A:

Estimation of Fracture Properties Based on Transmissivity and Effective Thickness Measurements

Assuming prismatic blocks, with flow taking place between parallel fractures and all fractures having equal apertures (2d), the Poiseuille cubic law identifies the transmissivity of each fracture (T_f):

$$T_f = \frac{(2d)^3 \rho g}{12\mu} \tag{1}$$

where ρ is the fluid density and μ is the fluid viscosity. The total transmissivity of the aquifer is equal to the sum total transmissivity of all the fractures in the interval plus the transmissivity of the matrix. However, the transmissivity of the matrix is generally much lower than the transmissivity of the fractures, and can be neglected for fractured media. The total global interval transmissivity is thus

$$T_g = \frac{(2d)^3 \rho g}{12\mu} \times N \tag{2}$$

where N = number of fractures in interval
= B/(2a) (3)
where 2a = separation distance between fractures
and B = interval thickness

This global transmissivity applies to the equivalent porous-medium continuum.

The effective porosity within each fracture is, of course, unity. The effective thickness (n_eB) of the interval (i.e., the global effective thickness), which would apply to the equivalent porous-medium continuum, is equal to (c.f., Huyakorn et al., 1983)

$$n_eB = \frac{2d\ B}{2d + 2a} \tag{4}$$

Since 2d << 2a, n_eB can be approximated as

$$n_eB = B(2d)/(2a) \tag{5}$$

For the McCoy Canyon flow top, the effective interval thickness (B), global transmissivity (T) and global effective thickness (n_eB) are known (11.3 m, .065

m^2/day and .0018 m respectively). Therefore, equations (2), (3) and (5) are three equations in three unknowns (2d, N, and 2a) and the solution of these equations is:

$$2d = 2.3 \times 10^{-5} \text{ m}$$
$$N = 79.8 \text{ fractures}$$
$$2a = 1.4 \times 10^{-1} \text{ m}$$

FEB 28 1985

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ATTACHMENT 3

Dr. Robert M. Cranwell, Supervisor
Waste Management Systems
Division 6431
Sandia National Laboratories
P. O. Box 5800
Albuquerque, NM 87185

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Dear Dr. Cranwell:

I have received and reviewed your January monthly progress report for FIN A1757, dated February 1, 1985. This monthly report included Paul Davis' trip report covering the DOE/NRC meeting during the week of December 11-14, 1985. The work performed during January has been fully satisfactory.

Attached is my preliminary review of a modeling scenario regarding the possible effects of Hanford Site wastewater disposal activities on the system of confined basalt and interbed aquifers. This is one of the four ground-water modeling scenarios described in my letter to you dated February 12, 1985. I suggest that we add to and modify this review as part of the development of a set of modeling scenarios to be numerically evaluated in future under subtasks 1.3 and 1.4.

As a reminder, in your next monthly progress report please address my questions regarding expenditures as described in my letter to you dated February 12, 1985. Specifically, this refers to 2 K for ADP Support (NOV 84 monthly report) and 11 K for Direct Manpower (DEC 84 monthly report).

The action taken by this letter is considered to be within the scope of the current contract FIN A1757. No changes to cost or delivery of contracted services and products are authorized. Please notify me immediately if you believe that this letter would result in changes to cost or delivery of contracted products.

Sincerely,

Neil M. Coleman, Project Manager
Hydrology Section
Geotechnical Branch
Division of Waste Management, NMSS

Attachment:
As stated

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Preliminary Modeling Scenario:

Possible Effects of Hanford Site Wastewater Disposal Activities On the System of Confined Basalt and Interbed Aquifers

Beginning in the mid-1940's, and continuing up to the present time, industrial activities at Hanford have generated large volumes of radionuclide-bearing wastewaters. These contaminated waters have been released to surficial geologic deposits (Hanford and Ringold Formations) via infiltration cribs and swamps, resulting in artificial recharge to the unconfined aquifer system. Most of the disposal activities have occurred at locations in or near the 200 West and 200 East Areas. The 200 West Area is fully contained within the perimeter of the defined Reference Repository Location (RRL) of the Basalt Waste Isolation Project (BWIP)(see Figure 1).

Newcomb et al. (1972) quote Belter (1963) in reporting that volumes of liquid waste discharged onsite from 1945 to 1959 were:

	Effluent Volumes		
	Gallons	Acre-Ft	Meters^3
Cribs (72)	4.0×10^9	1.2×10^4	1.5×10^7
Trenches (18)	2.8×10^7	8.6×10^1	1.1×10^5
Swamps	3.8×10^{10}	1.2×10^5	1.4×10^8
Totals:	4.2×10^{10}	1.3×10^5	1.6×10^8

Additional information regarding disposed volumes of wastewater was reported by CRWM (1978). A total of 177 infiltration cribs had been built during the period of Hanford Operations. As of the mid-1970's, 144 of these had been retired, 8 were unused, 10 were on standby and 15 were in active use. As of January, 1975 about 1.3×10^{11} gallons (4.0×10^5 acre-ft or 5.0×10^8 meters^3) of effluent had been percolated, largely in and near the two 200 Areas (see Figure 1). Pronounced recharge mounds were created on the water table surface. At 200 West (within the RRL) the generated mound was about 25 meters above the natural water-table level of 1944 ;at 200 East, about 9 meters above (CRWM, 1978). The movement and shapes of these ground-water mounds during the earlier period from 1948 to 1961 were reviewed by Newcomb et al. (1972). Figures 2 and 3 show the approximate areal patterns of these mounds and their recharge loci as determined during the years 1948, 1953, and 1961 (Newcomb et al., 1972). For comparison purposes, see Figure 4 which is intended to illustrate the water table at the Hanford Site as of January 1944 (although it is based on data collected during 1948-1952) (CRWM, 1978). Figure 5 depicts the shape, areal

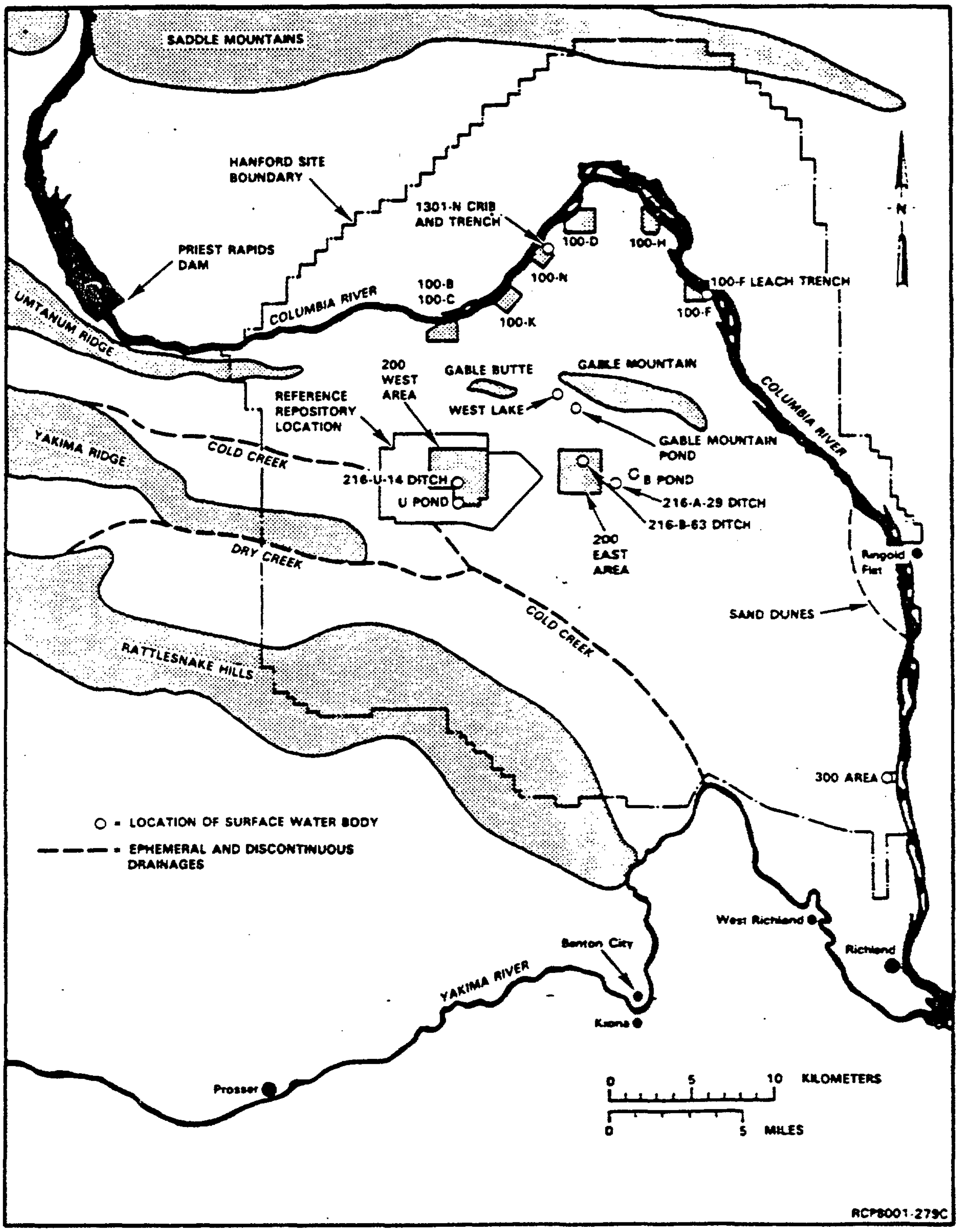


Figure 1 — Surface-water bodies including ephemeral creeks on the Hanford Site.

(Source - Figure presented without modification from page 3-59 of DOE [1984]).

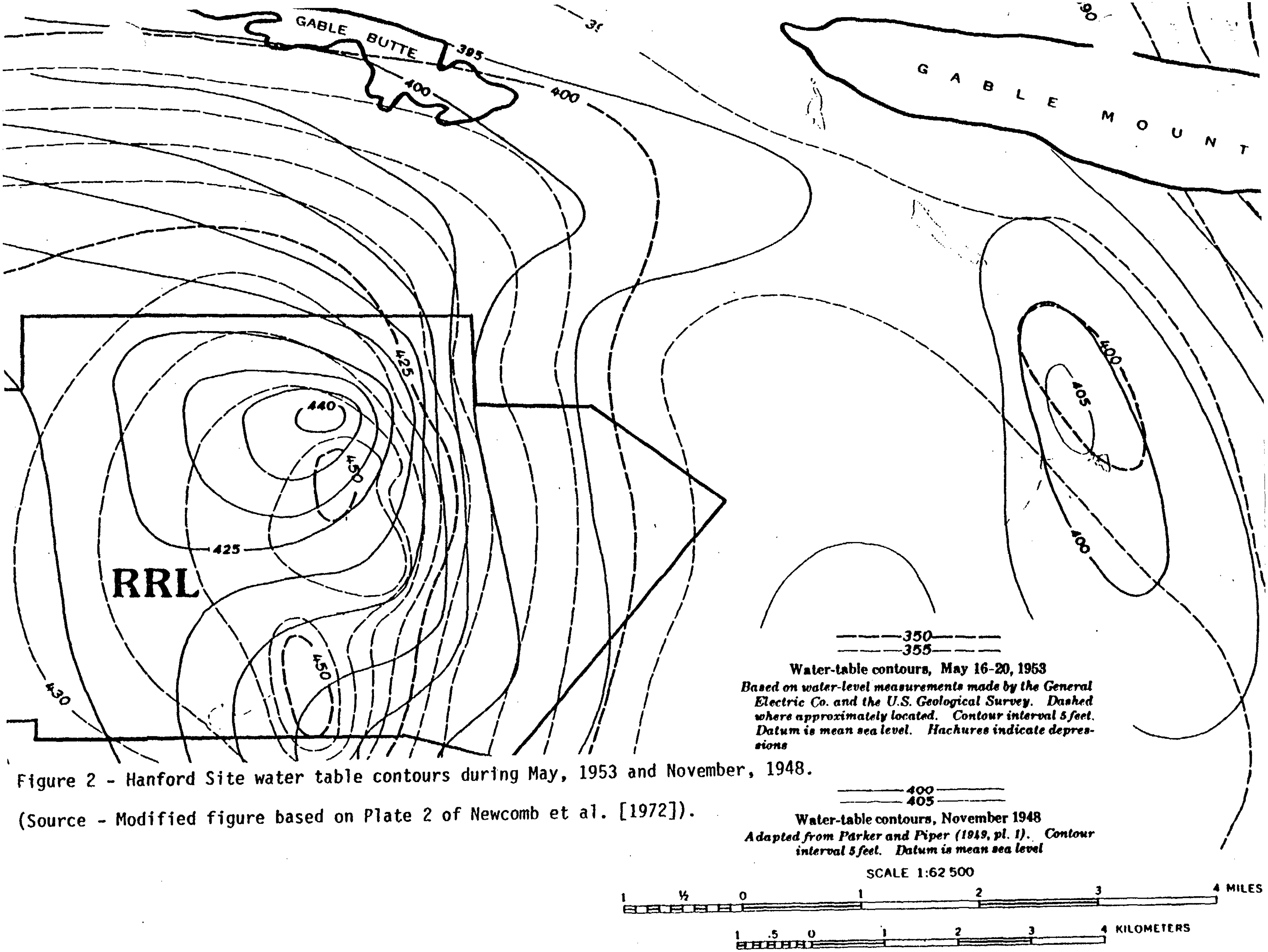


Figure 2 - Hanford Site water table contours during May, 1953 and November, 1948.

(Source - Modified figure based on Plate 2 of Newcomb et al. [1972]).

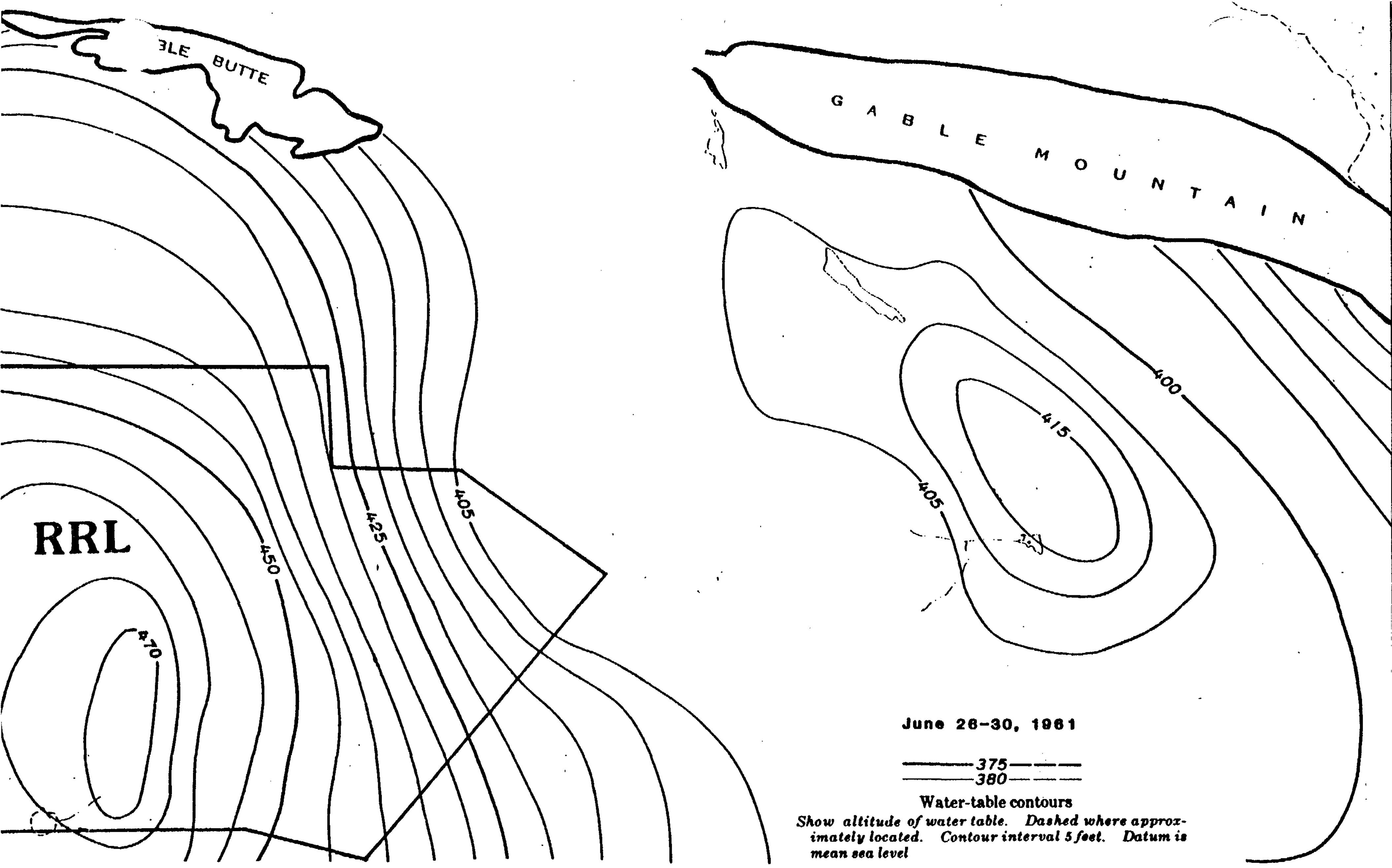
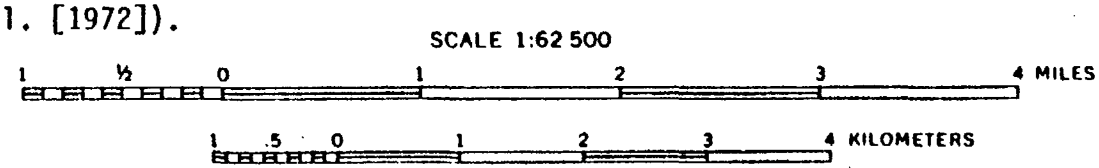
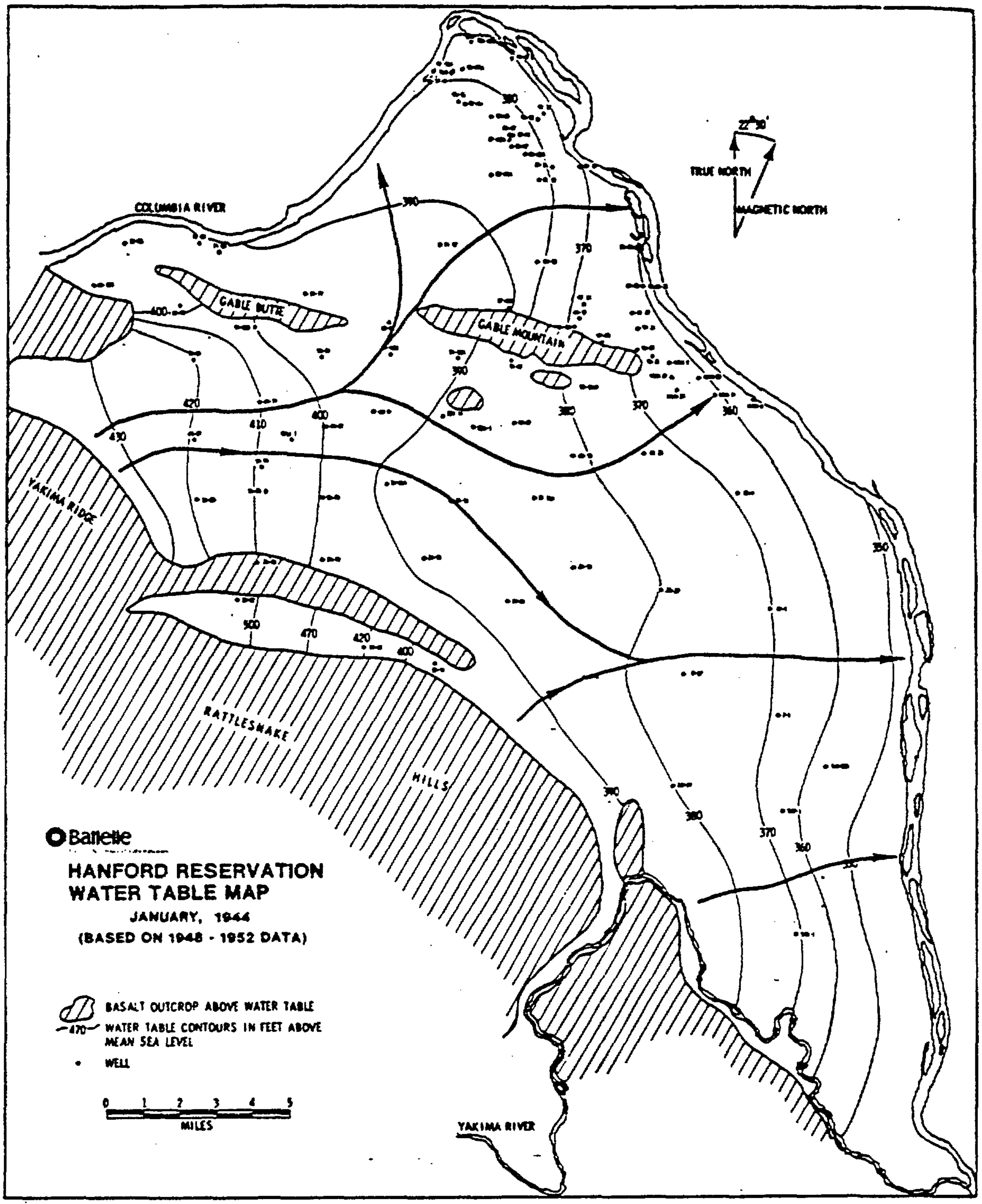


Figure 3 - Hanford Site water table contours during June, 1961.

(Source - Modified figure based on Plate 3 of Newcomb et al. [1972]).

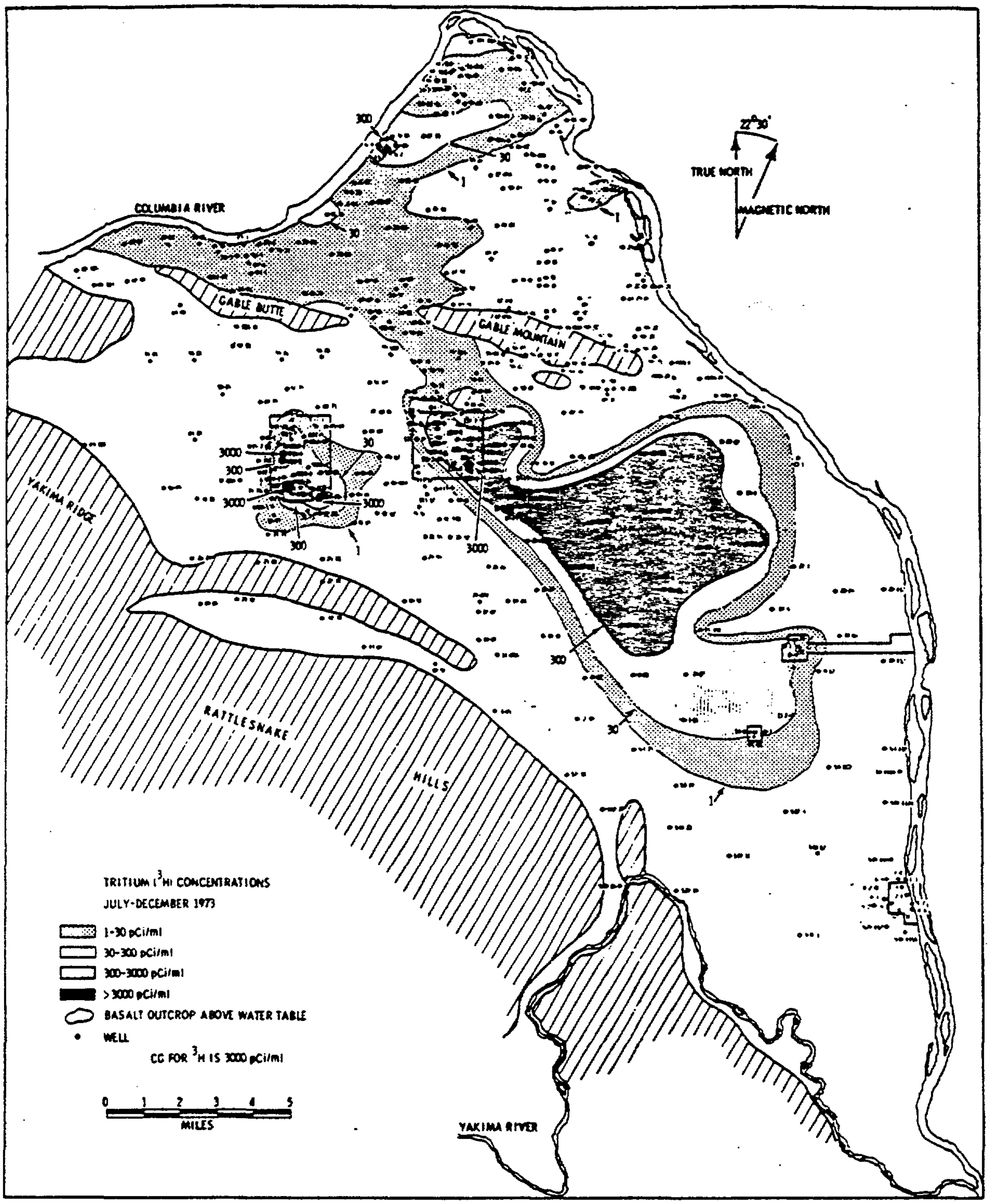




SOURCE: ERDA-1538:II.3-D-25, Figure II.3-D-14 (streamlines added).

FIGURE 4 – Water table at the Hanford Reservation under natural conditions as of January, 1944.

(Source - Figure presented without modification from page 154 of CRWM [1978]).



SOURCE: ERDA-1538:II.3-29, Figure II.3-20.

FIGURE 5—Distribution of tritium (^3H) in the unconfined water body of the Hanford Reservation, July-December 1973. (Drinking water standard: 3000 picocuries per milliliter.)

(Source - Figure presented without modification from page 66 of CRWM [1978]).

extent, and approximate direction of migration of the tritium plume in the unconfined aquifer as of 1973 (CRWM, 1978).

The NRC staff is concerned that these disposal activities may possibly have caused significant changes in the geohydrologic regime, including the confined basalt and interbed aquifers that underlie the RRL. Figure 5-41 of the SCR (1982) shows 10 hydraulic head measurements collected using drill and test techniques in borehole RRL-2, located in the heart of the RRL. As depicted in Figure 6, hydraulic heads decrease with depth from the Mabton Interbed down to the upper Grande Ronde basalts, then increase with depth down to the Umtanum Basalt (see Figure 7). As shown in Figure 5-40 of the SCR (1982) a similar trend reversal appears to exist in data from borehole DC-16A (see Figure 8). As shown in Figures 9-11, data from each of the newly constructed (1984) piezometer clusters at DC-19,20,22 show decreasing heads with depth down to the Priest Rapids Member of the Wanapum Basalt. These figures are based on data from Jackson et al. (1984) which are summarized in Table 1. Relative to the RRL, locations of boreholes discussed above are shown in Figure 12.

The pattern of these head variations with depth suggests transient hydrologic responses which constitute significant anomalies in the confined aquifer system. At present, we consider downward recharge to be the most likely explanation for these gradient changes at depth. It is entirely possible that we are observing a downwardly-progressing change in hydraulic heads in response to four decades of onsite liquid waste disposal. In other words, heads measured near the RRL, and perhaps at other locations on the Hanford Site, may not be representative of pre-1944 steady-state conditions.

With regard to potentiometric measurements of deep aquifers, the NRC has previously stated concerns regarding the effects of variations in fluid temperatures and dissolved solids within wellbores (Wright et al., 1984). Two relevant figures presented by DOE in a recent meeting (DOE/NRC, 1984) are attached as Figures 13 and 14. According to the DOE staff, these figures show head measurements from the borehole clusters DC-19 and DC-22 and compare uncorrected heads with those corrected for fluid density variations ("environmental heads"). Based on these figures, it appears that "environmental heads" and uncorrected heads are similar because the corrections for temperature and dissolved constituents tend to cancel each other out. However, we cannot verify this phenomenon because the data used to perform the head corrections were not presented during the stated meeting. If the corrections used to obtain "environmental heads" prove to be valid and correct, then the measured vertical head profiles would provide greater confidence in the existence of the hydrologic anomalies discussed above.

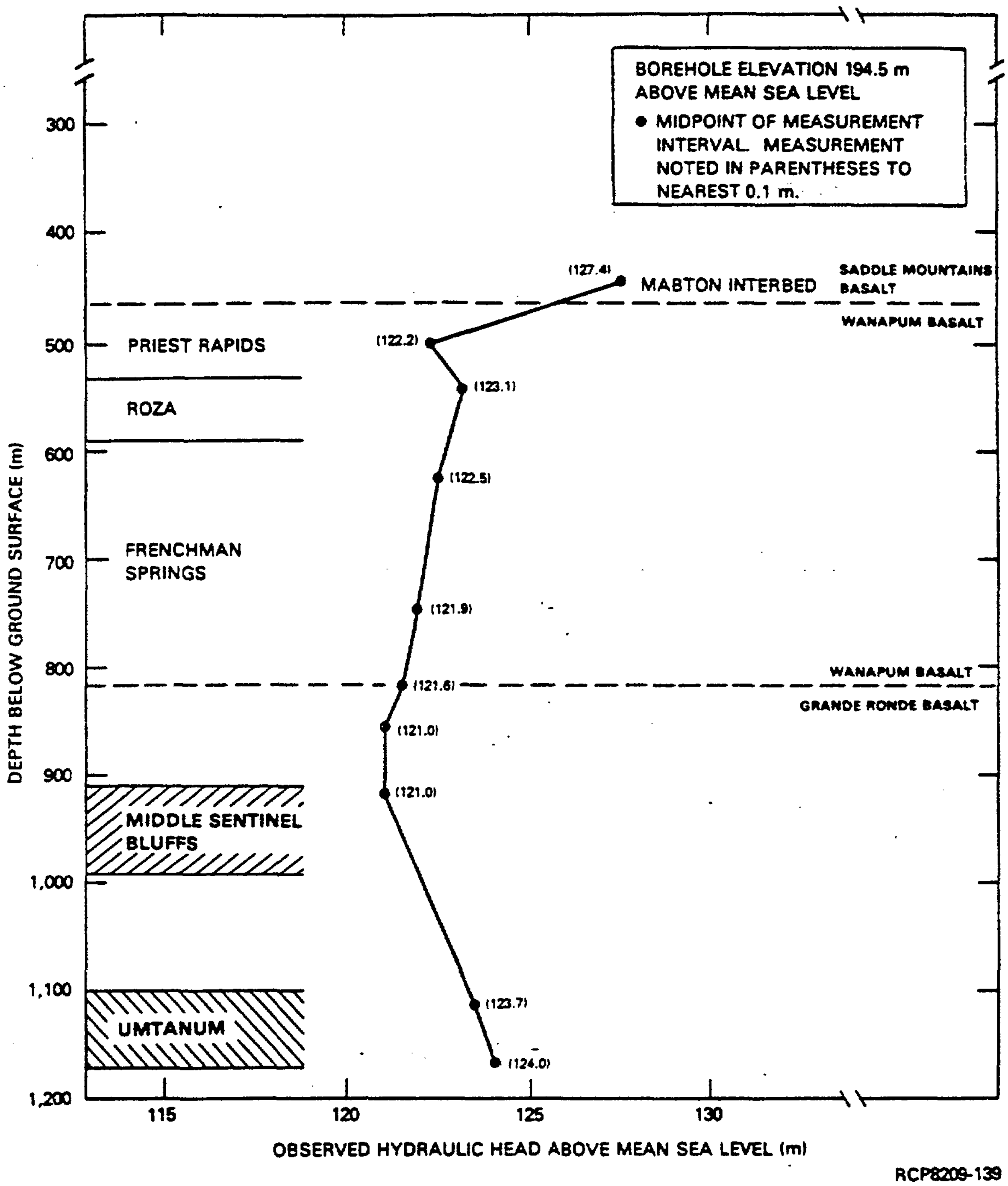


FIGURE 6 — Hydraulic Head Measurements Within the Columbia River Basalts at Borehole RRL-2.

(Source - Figure presented without modification from page 5.1-72 of USDOE [1982]).

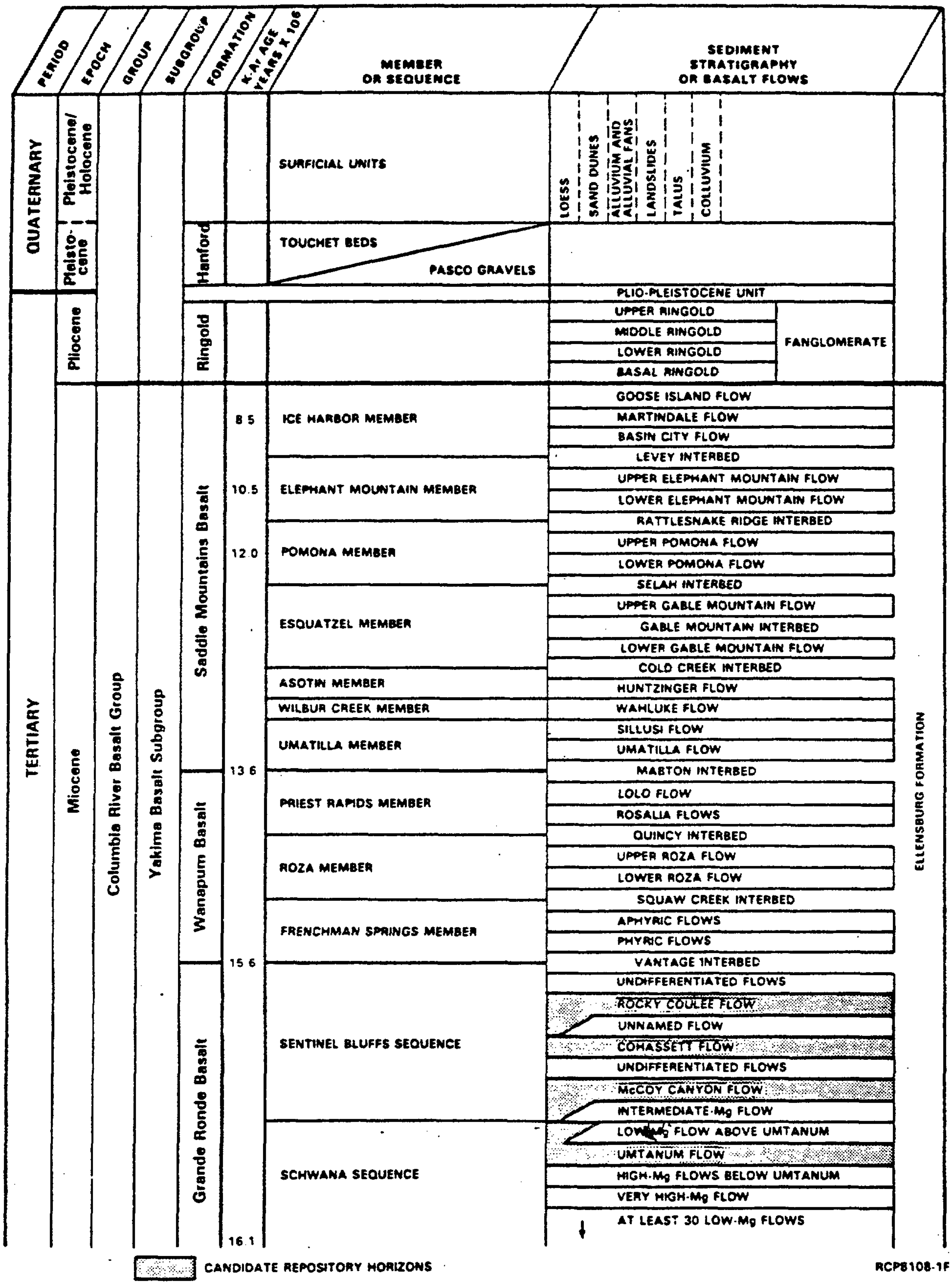


FIGURE 7 – Stratigraphic Nomenclature of the Columbia River Basalt Group, Pasco Basin.

(Source - Figure presented without modification from page 4 of RHO [1984]).

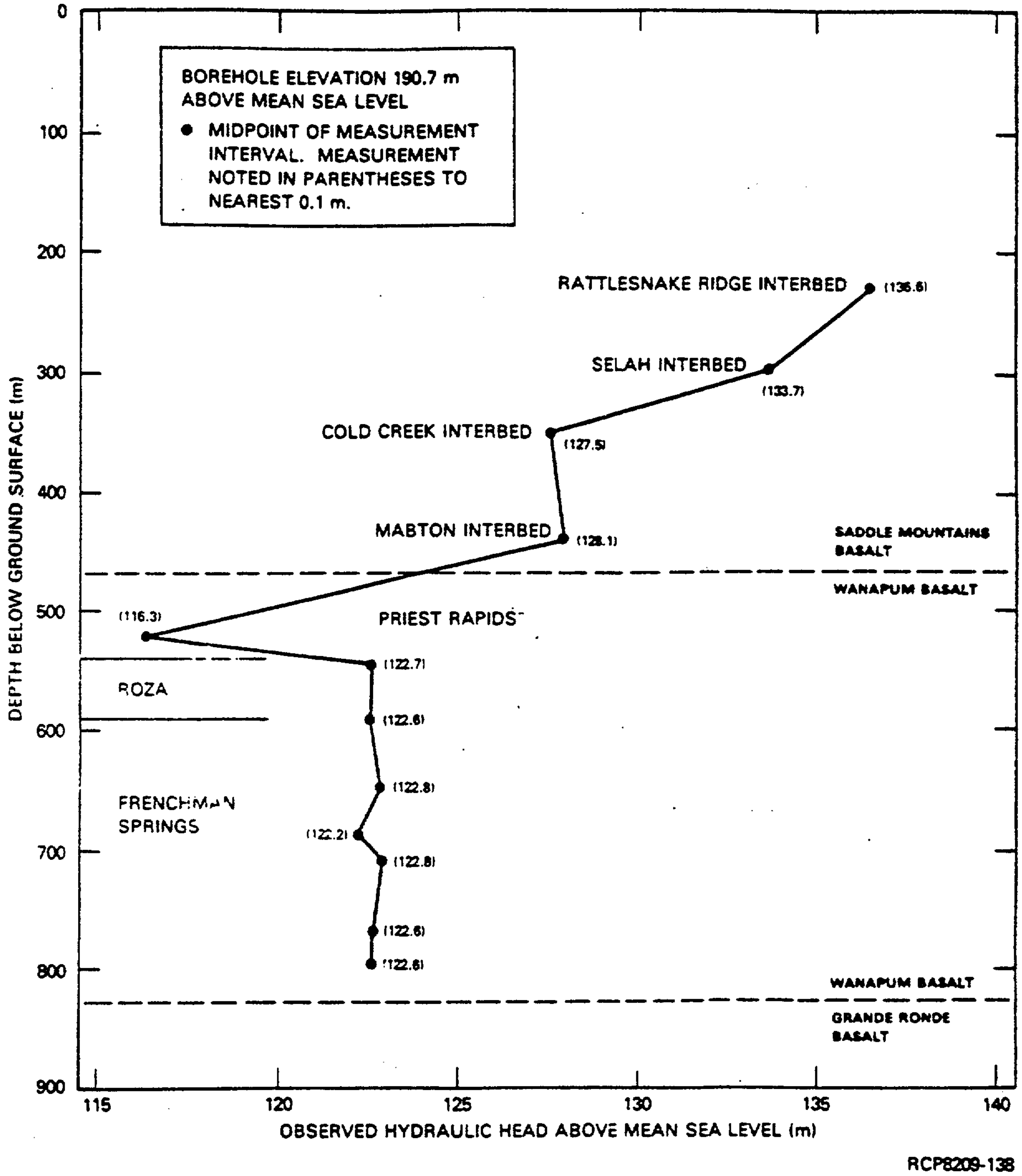


FIGURE 8 — Hydraulic Head Measurements Within the Saddle Mountains and Wanapum Basalts at Borehole DC-16A.

(Source - Figure presented without modification from page 5.1-71 of USDOE [1982]).

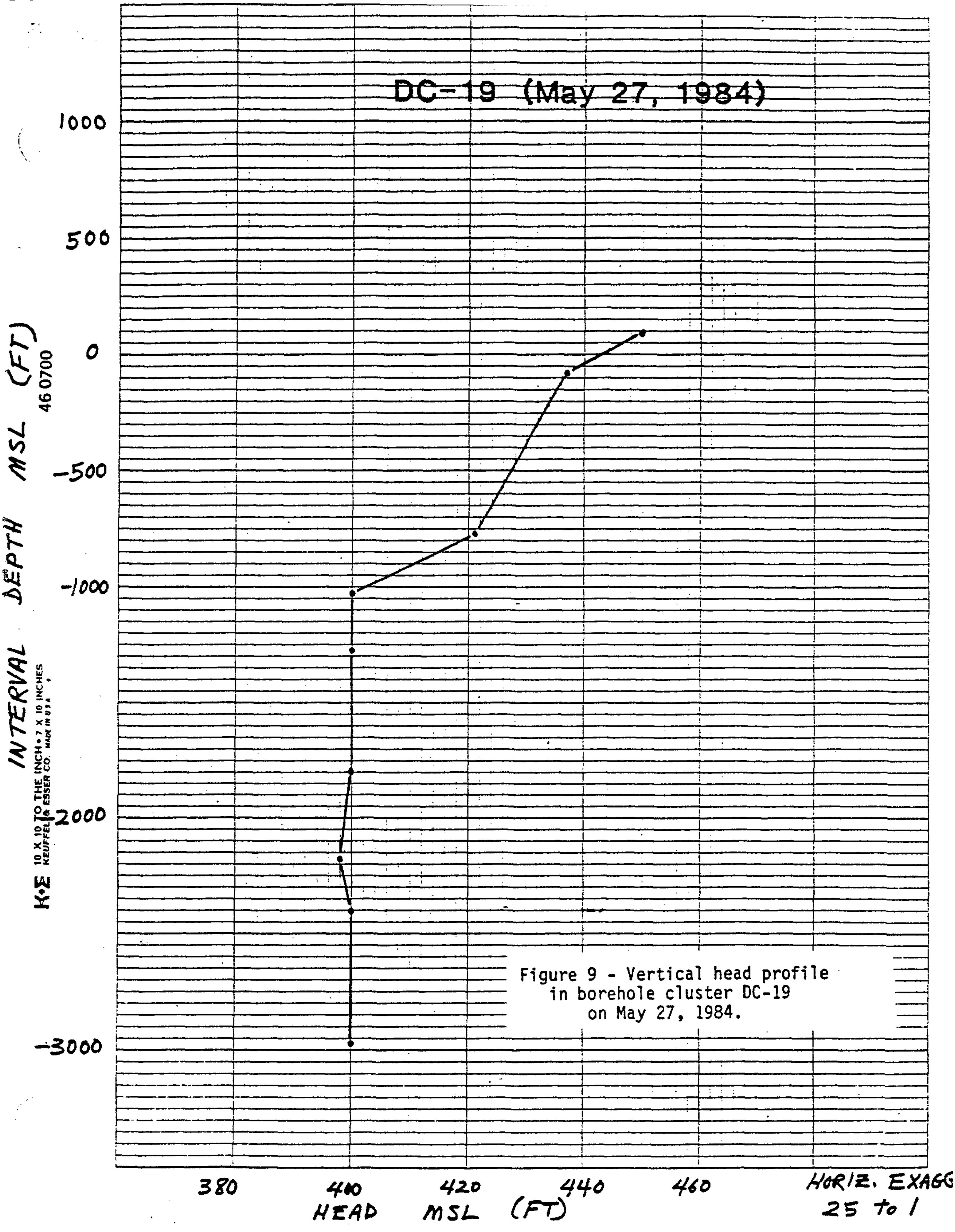


Figure 9 - Vertical head profile
in borehole cluster DC-19
on May 27, 1984.

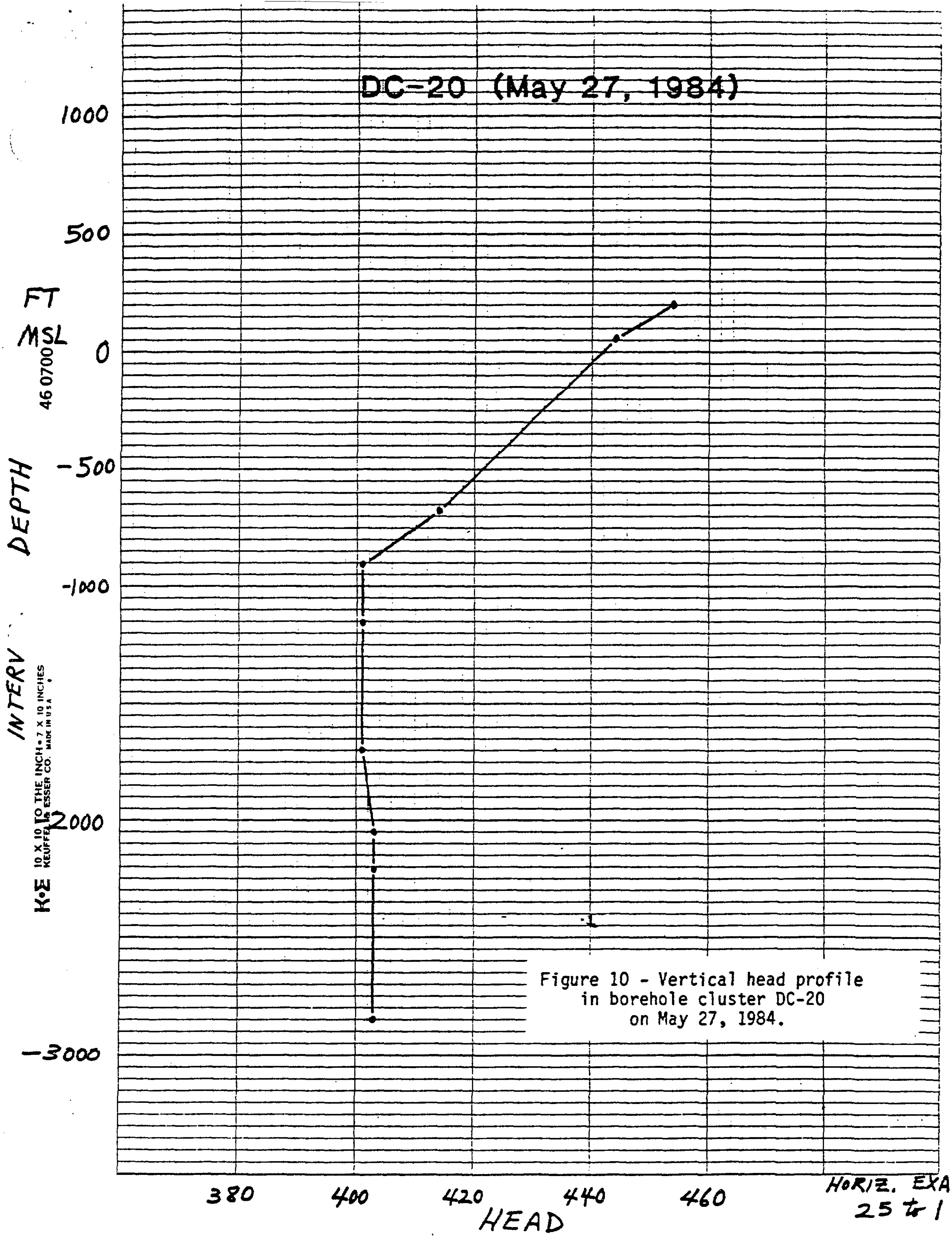


Figure 10 - Vertical head profile in borehole cluster DC-20 on May 27, 1984.

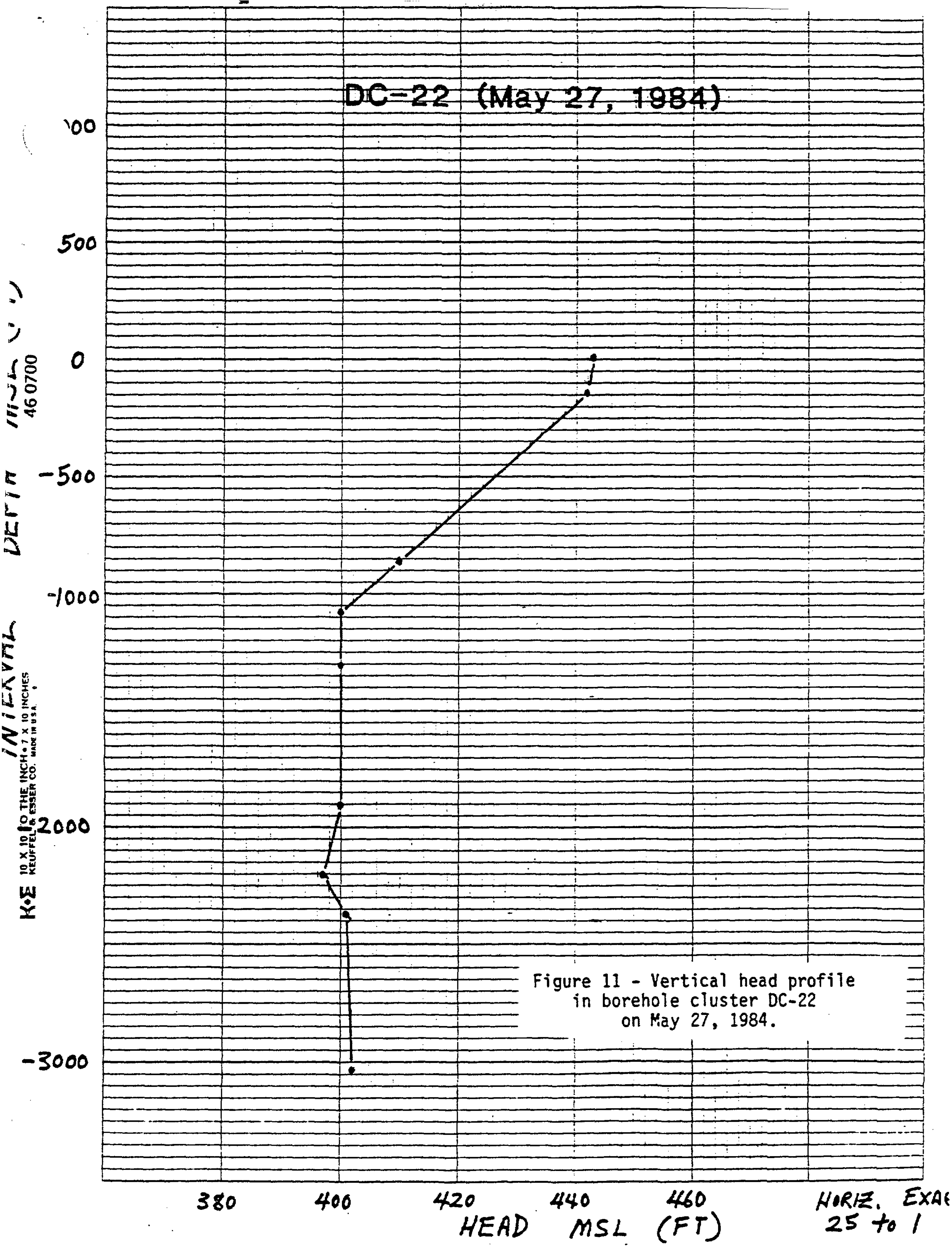


Figure 11 - Vertical head profile in borehole cluster DC-22 on May 27, 1984.

	DC-19		DC-20		DC-22	
	Mean Head Elev.	Elev. MSL Screen Top	Mean Head Elev.	Elev. MSL Screen Top	Mean Head Elev.	Elev. MSL Screen Top
Basal Ringold	450	97.2	454	207.5	443	5.3
Rattlesnake Ridge	437	-87.6	444	60.0	442	-143.2
Mabton	421	-774.4	414	-675.1	410	-860.1
Priest Rapids IF	400	-1034.8	401	-907.8	400	-1083.0
Sentinel Gap FT	400	-1274.1	401	-1160.4	400	-1320.4
Ginkgo FT	400	-1803.1	401	-1705.3	400	-1908.5
Rocky Coulee FT	398	-2183.0	403	-2045.2	397	-2212.6
Cohassett FT	400	-2406.3	403	-2220.0	401	-2378.1
Umtanum FT	400	-2976.7	403	-2856.5	402	-3039.5
		Screen #1 Top		Screen #1 Top		Screen #1 Top

Table 1 - Potentiometric data for all piezometers in the borehole clusters DC-19, DC-20, and DC-22. All elevations reported in feet.

(Data source: Jackson et al. (1984))

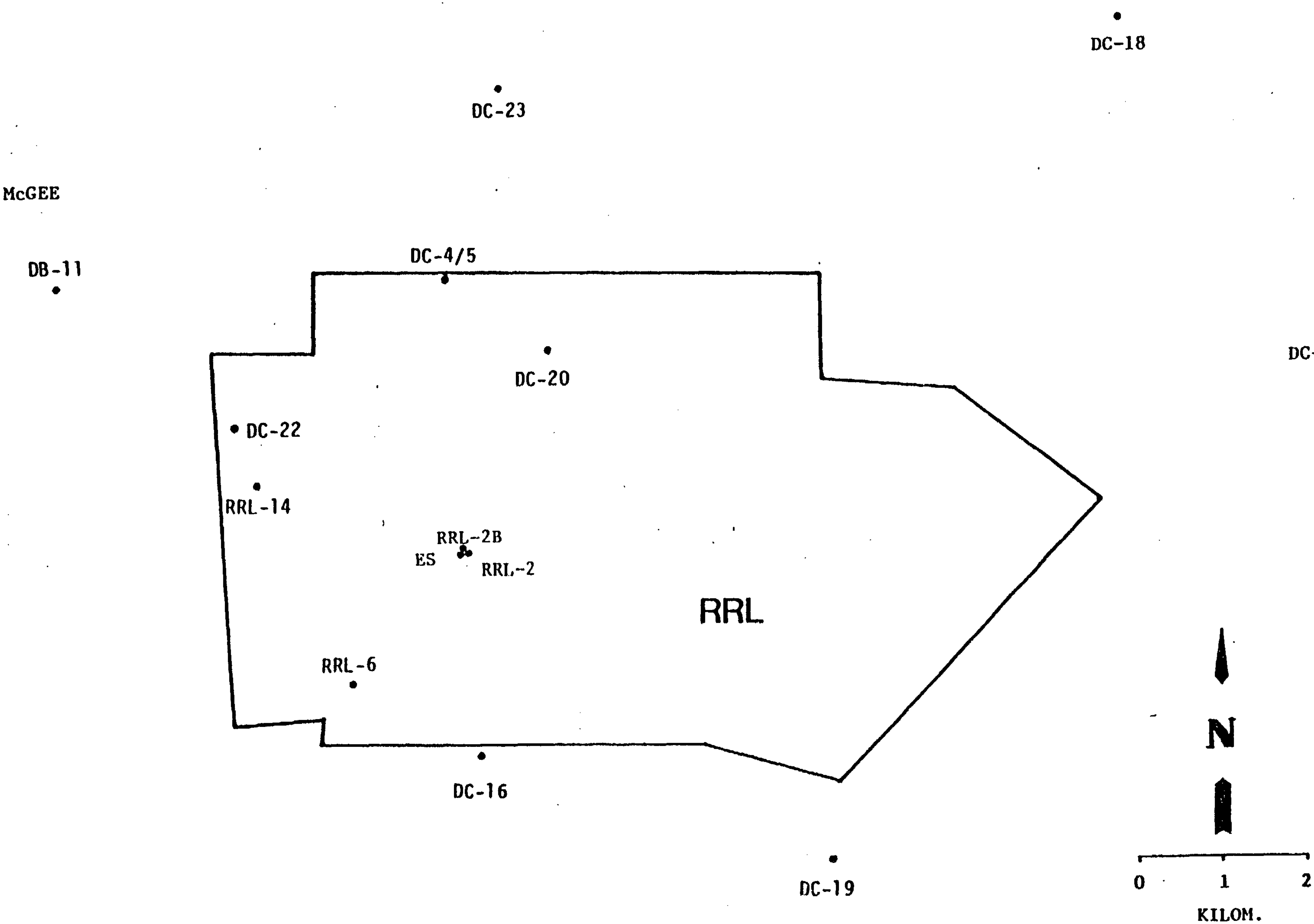


Figure 12 - Distribution of major wells and well clusters in the vicinity of the Reference Repository Location.

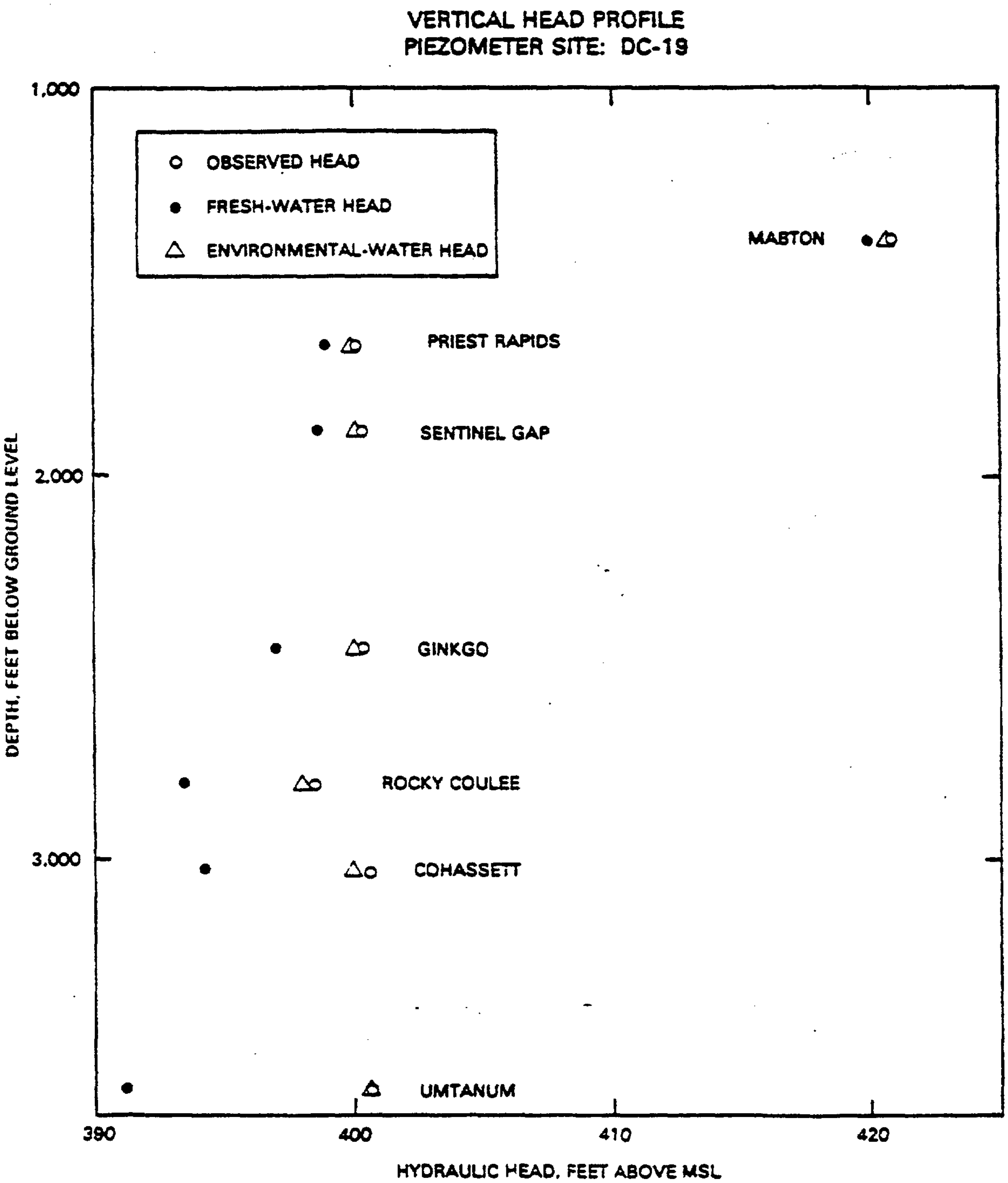


Figure 13 - Vertical head profile at piezometer site DC-19.

(Source - Figure presented without modification from DOE/NRC [1984]).

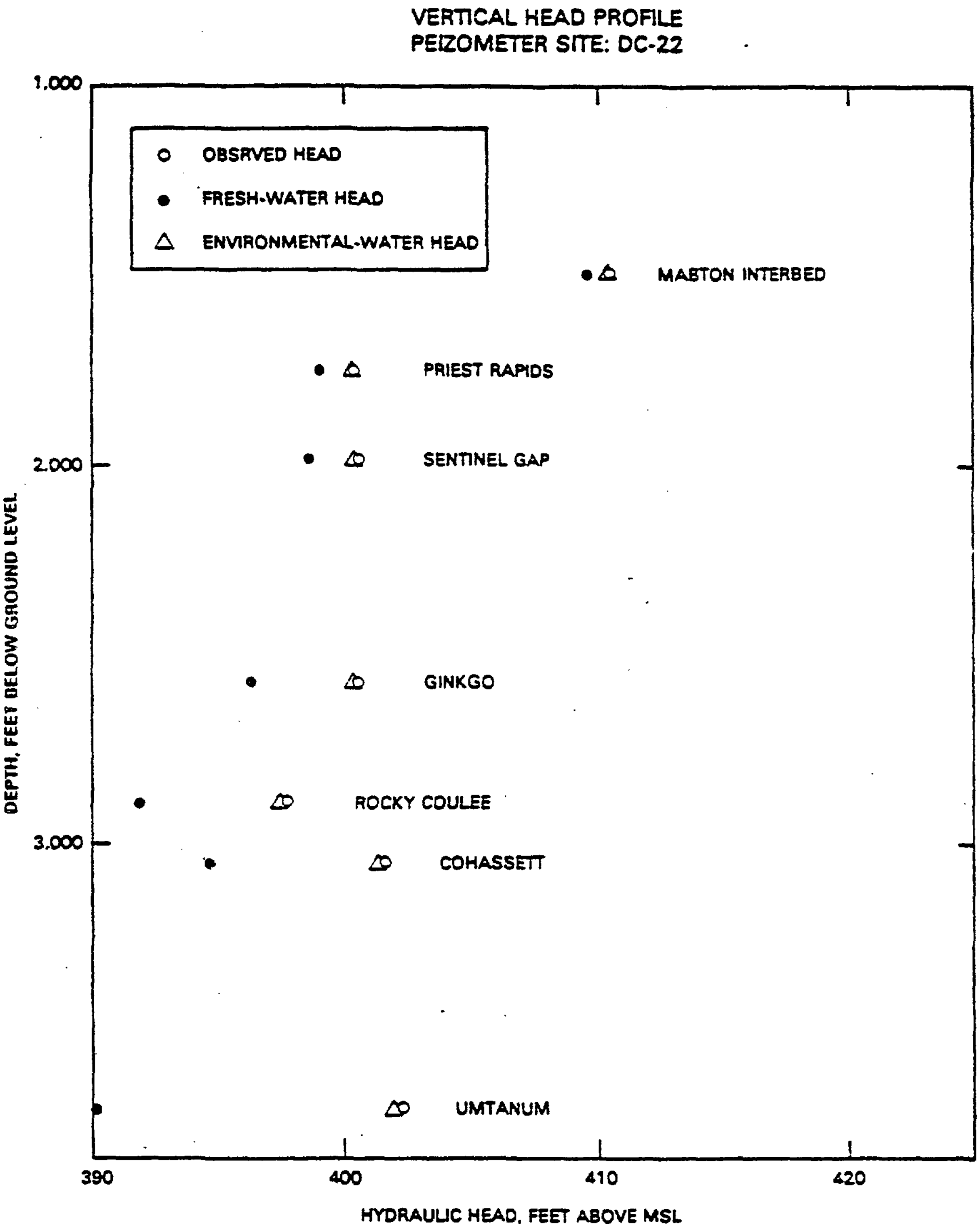


Figure 14 - Vertical head profile at piezometer site DC-22.

(Source - Figure presented without modification from DOE/NRC [1984]).

I have assembled a preliminary reference list that includes those sources mentioned in this attachment and others that contain relevant geologic and hydrologic data for the unconfined aquifer system at the Hanford Site. These references should be added to a master bibliography used in support of project work under A1757.

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