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VISIT TO THE BASALT WASTE ISOLATION PROJECT (BWIP) HANFORD, WASHINGTON

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General

As of September 1981, the BWIP field investigations can be described as evolving from a site screening mode to a site characterization mode. The Reference Repository Location has been designated; the Exploratory Shaft for in situ testing has been sited; substantially all the information for the site characterization report (SCR) is in hand; and preparation of the SCR has begun.

Much of the material discussed during the site visit is representative of the contents of the SCR. Based on this "foretaste" we conclude that the SCR, when completed, may be inadequate. Three specific anticipated shortcomings are noteworthy. These are discussed in following pages.

The primary concern relates to the development of plans for hydrologic investigations at the site. There are two points to make on this:

1. There are currently several widely different views on the general pattern of groundwater flow in the Pasco Basin. These have been put forth by Rockwell Hanford Operations (RHO) and other groups working in and having expertise in the Pasco Basin and surrounding region--viz., the U.S. Geological Survey (USGS) and Pacific Northwest Laboratories (PNL) of Battelle. The RHO program suffers from a lack of vigorous interaction with the other groups to understand the basis for the differing views and to work to assure that they are resolved, so that the whole matter is not left to be litigated as a licensing issue. The questions of hydrogeology are complex and will take some time to sort out. It is important that development of the specific investigations intended to resolve these questions (as presented in the SCR) includes close interactions with the USGS and others having the expertise and experience discussed above.

2. It appears the five year hydrology test program will not result in sufficient data to answer basic questions about groundwater movement.

We also attach considerable importance to two other concerns.

1. The conceptual repository design is inadequate because it ignores the consequences of the indicated high stress field. (After the site visit, during preparation of the trip report, we were informed that the design implications of the stress field are under study).

2. The in situ testing program that was discussed with NRC (i.e., Phase I of the Exploratory Shaft), is insufficient to characterize the site at depth, determine site suitability, and determine design parameters for the repository.

1. Hydrology

The importance of hydrology to the evaluation of the performance of a repository at BWIP is generally recognized. However, the data base is inadequate to support, or refute, any of the travel path models for possible nuclide release that have been developed to date. This partly results from reliance on single-well testing in small diameter boreholes, which provides point hydrologic values and is not well suited to characterizing multilayered hydrogeologic units in three dimensions. Further, no reliable determinations of vertical permeability or storativity have been made; these parameters are essential for developing groundwater flow models that predict travel time.

From our understanding of the testing progress and the five year plan for site characterization, we are concerned that the data base may be inadequate to support a construction authorization application, if this is advanced by the late 1980s. Two remedies can be seen:

a. Speed up data collection by drilling additional boreholes in the near term.

b. Optimize the drilling for hydrologic testing through a change in drilling strategy.

Drilling Strategy

A shift in emphasis of the drilling program appears needed. Up to the present moment the emphasis has been on collection of core for geologic purposes. This is understandable in the light of geologic needs for site screening. Now, however, the screening process is largely concluded, with location of the exploratory shaft.

Although placement of the recent holes - DC 12, DC 14 and DC 15 - was determined mainly for hydrologic needs, the practice of obtaining continuous core restricts the usefulness of these holes for hydrologic testing. With an urgent need for hydrologic data, future drilling should be tailored to hydrologic testing.

The change in drilling strategy would include the following:

a. Eliminate coring.

b. For geologic information, place greater reliance on geophysical well logs.

c. Consider conventional hydrologic testing practice, eg. drilling wells for large-volume pump tests paired with observation wells.

Modeling

The modeling of the ground-water flow system in the Pasco Basin is based on limited deep hydrologic data. Reliable values of vertical permeability and storativity are lacking, and boundary conditions are speculative. Under these circumstances, the efforts to develop groundwater flow paths and travel times should be considered preliminary and unverified. There is understandable disagreement between RHO and PNL models on location of discharge areas and travel times.

The RHO modeling effort could be enhanced by constructive cooperation with PNL and the USGS on regional hydrology. The regional models developed by both PNL and USGS could be put to greater use by RHO to improve confidence in boundary conditions for the Pasco Basin.

The modeling efforts could be used more effectively in the planning of hydrologic testing wells by use of sensitivity analyses of input parameter and boundary conditions. Such work can be used to identify locations where new hydrologic data would be particularly beneficial, and thus assist in placement of future boreholes.

2. Stress Field

Discing of drill core has been identified in most holes drilled into the Umtanum (proposed host rock). This condition suggests that the horizontal compressional stress is numerically greater than one-half the compressive strength of the basalt. At repository depth, the indicated horizontal stress is more than twice the vertical stress. In such a high stress field, it is probable that difficulties will be encountered in excavating openings and maintaining stability. This affects the selection of the opening size, extraction ratio, support methods, and orientation of the workings.

The BWIP Functional Design Criteria and Conceptual Design Reports have ignored the implications of core discing and have assumed a normal, lithostatic (one-to-one) ratio between the horizontal and vertical stresses. The appropriateness of this assumption has been questioned by the Bureau of Mines and by the National Academy of Sciences peer review. Careful, conservative engineering analysis is needed, now, as to the possible effect of the stress field on repository design and constructability. At the time of issuance of the present trip report (December, 1981), this analysis is understood to be in progress.

3. <u>Geochemical Retardation</u>

Research suggests that the basalt appears to offer the potential of a stable, reducing geochemical environment because (a) iron-bearing minerals tend to limit changes in Eh, and (b) the glass in the basalt tends to limit changes in pH. These conditions appear favorable for radionuclide retardation. However, attention needs to be given to the development of data on particulates, colloids, and complexes (as required in draft 10 CFR 60.122(g)).

Further, the form of retardation data developed by RHO is a multi-factor sorption function; in contrast, the performance assessment codes of ONWI presently use a single factor input (Kd). This suggests that development of code capability should be accelerated. Also, the data base necessary to evaluate geochemical retardation needs to be determined and compared with the data expected to be developed by the field testing program during site characterization.

4. <u>Geophysics</u>

Although aeromagnetics have been useful in site screening, other geophysical methods have not realized full utility. For example, a large amount of seismic refraction data, obtained in FY 81, has not been interpreted, and additional processing may significantly improve the high resolution seismic reflection data. If completed soon enough, evaluation of seismic data might assist in location of the exploratory shaft by identification of structures in the Cold Creek Syncline.

On a separate matter, calibration of nuclear in-hole logging equipment needs to be accelerated for maximum contribution of borehole logs to the understanding of geology and hydrology.

5. Content of the Site Characterization Report

Under DOE's present plan, only that portion of future investigations that are planned through Phase I of the Exploratory Shaft will be presented in the site characterization report. There appears to be no plan for presentation of the follow-on program of investigations, which would be done in Phase II and in expanded facilities at a second shaft. Under this scheme, NRC will receive a partial picture of the in situ testing program. NRC will, therefore, be handicapped in its review of the testing plans for appropriateness to resolve site suitability and design licensing questions by the time of construction authorization application.

Such a site characterization report would be incomplete. The first phase of the exploratory shaft testing will not generate all of the in situ testing information that is needed for a complete evaluation of site suitability and design. Therefore, the first phase does not constitute the full program of site characterization that must be covered in the SCR. Without a minimal presentation of follow-on in situ testing it would be impossible for NRC to evaluate the appropriateness of the Phase I work or the total in situ test effort. Furthermore, the conceptual repository design, in the SCR, could not be analyzed as to its physical relationship to the exploratory shafts and testing excavations. The linkage between design parameters and the planned tests could not be identified. Due to these gaps in information, it is unlikely that NRC could develop assurance that the in situ investigations can be expected to yield, during site characterization, the information needed to evaluate site suitability and design.

INTRODUCTION

From September 22 through September 25, 1981, staff members of the Nuclear Regulatory Commission and NRC advisors held meetings in Hanford, Washington with personnel from the Department of Energy Richland office and from the Rockwell Hanford Operations office. These meetings concerned the present status and future plans for the major investigative efforts of the Basalt Waste Isolation Project. Specifically, discussions were held concerning repository design, hydrology, hydrologic modeling, geochemistry, tectonics, geophysics, remote sensing, and quality assurance.

This trip is the third in the ongoing review by the NRC of the DOE Basalt Waste Isolation Project.

The present status of the Project is as follows.

A Reference Repository Location (RRL) has been designated on the northern limb of the Cold Creek syncline in the 200 West area. An Exploratory Shaft (ES) has been sited 300 feet from borehole RRL-2 (Figure 1). Early in 1982, borehole RRL-2 will be cored and tested hydrologically to a depth 500 feet below the repository level. RRL-2 will be redesignated DC-22 when this work commences. DC-22 will act as a pilot hole for the ES, and preshaft testing will be accomplished in DC-22.

During the next five years, six exploration holes are planned (including DC-22), and these will be numbered DC-17 through DC-22. These six test holes, with some paired hole testing in DC-4,5 and/or DC-7,8 and data from tests in the ES, are expected to provide data needed for the detailed hydrologic modeling required for hydrologic characterization of the proposed repository. A document (ST-14) that details the present geologic and hydrologic knowledge of the Cold Creek syncline is due to be released by the end of December 1981.

RHO is planning to start construction of the ES early in 1983, with completion in late 1984. Phase I of testing in the ES is scheduled for completion in

September 1985. The design of the ES, as well as the conceptual design for the repository, has been completed.

A major effort at the BWIP, now and for the next six months or so, is the writing of the site characterization report (SCR). A discussion of the SCR and what the NRC expects to receive was a part of the visit.

Attached as appendices are trip reports by the following participants:

Appendix A Geotrans Inc.[1]
Appendix B Golder Associates Inc.[1] (hydrology)
Appendix C Golder Associates Inc.[1] (rock mechanics)
Appendix D U.S. Bureau of Mines[2]
Appendix E U.S. Corps of Engineers[2]
Appendix F Roy Williams[3]

Appendix G provides the names of participating individuals.

[1]NRC Contractor or subcontractor.
[2]NRC Adviser under interagency agreement.
[3]NRC Consultant.

HYDROLOGIC TEST SITES IN THE GRANDE RONDE BASALT

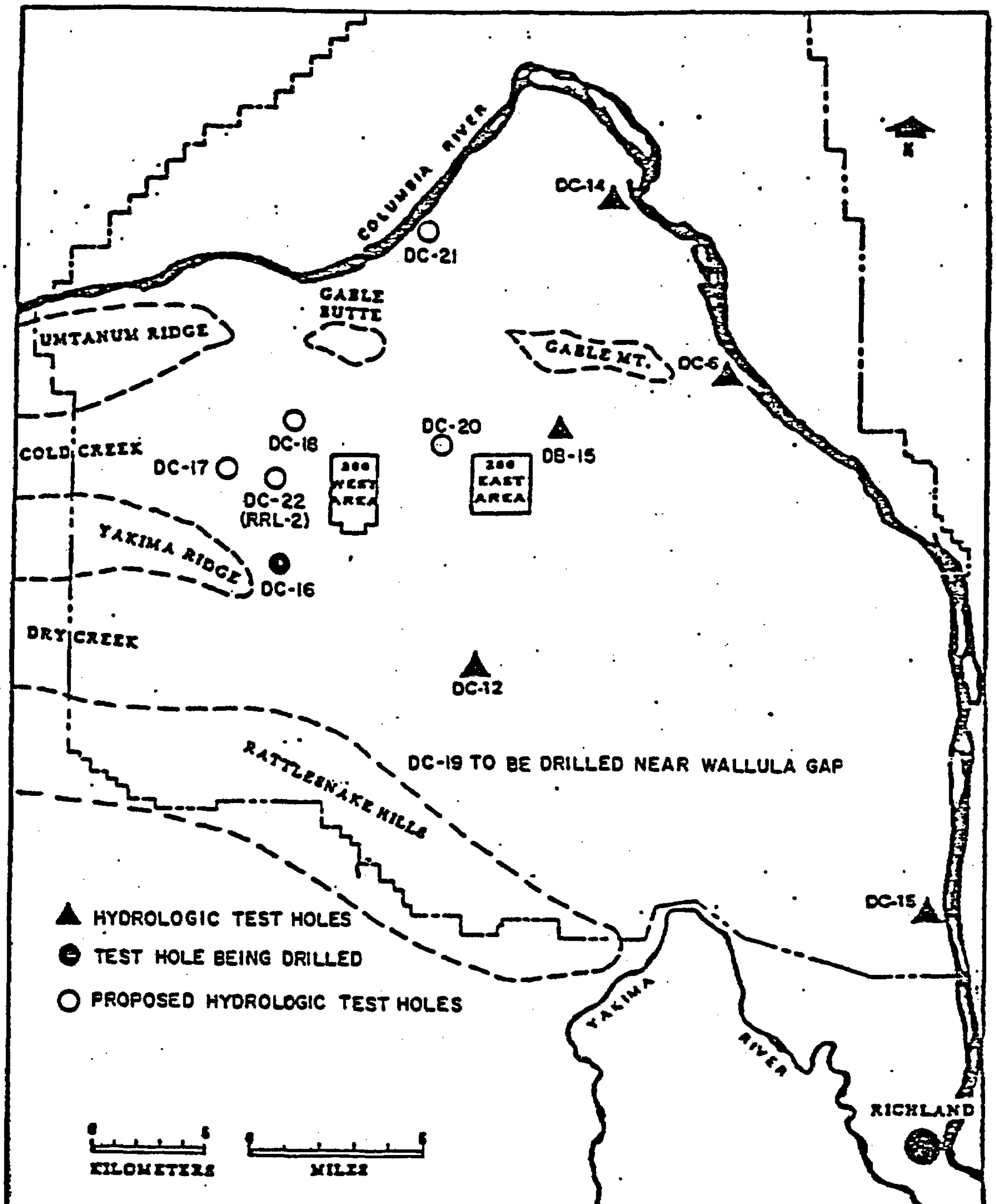


Figure 1

REPOSITORY DESIGN

The conceptual design report for BWIP is complete and is in the process of review by DOE and the Office of Nuclear Waste Isolation (ONWI). A copy of the design was not made available to NRC, although approximately 60 sheets of design drawings were provided during the design discussion. The total sheet count is approximately 500, including supporting analysis. DOE has scheduled the conceptual design report to be submitted to NRC in September 1982, as a document to be referenced in the site characterization report. The work on the design of waste packages and engineered barriers, including borehole and shaft sealing, has been transferred from Rockwell International to ONWI contractors.

Stress Field

We believe that a potential problem with the proposed repository host rock, the Umtanum basalt, has been inadequately handled in development of the conceptual repository design. The problem is the likelihood of a high horizontal stress field, as indicated by discing of drill core. The discing indicates that the horizontal stress at depth is high, probably greater than one-half the unconfined compressive strength of the rock. High stress conditions can present problems in developing and maintaining the stability of excavated openings.

In the conceptual design the horizontal stress/vertical stress ratio in the Umtanum is assured to be normal, i.e. 1 to 1. However, the discing suggests a ratio of 2:1 or greater in that unit (Appendix C, page 8).

A description of the core discing was presented in the RHO 1979 Geology Report (RHO-BWI-ST-4). The importance to design of a high stress field was pointed out in the Bureau of Mines review of the conceptual design done in April 1981 for the NRC. Since then, the National Academy of Sciences has noted the significance of the condition. Nevertheless, it appears that Rockwell/Kaiser, in development of the BWIP repository design, did not consider the indicated stress problem or analyze the consequences thereof.

Exploratory Shaft (ES)

The objectives of the ES (Phase 1) are to: (1) provide information for shaft design; (2) demonstrate that a shaft can be sunk to the repository horizon; (3) verify that the shaft can seal off the groundwater; (4) measure hydrologic properties; (5) conduct geomechanical tests.

The ES, as now planned, consists of a bored, 9-foot diameter shaft to a depth of 4200 feet. The shaft will be lined with steel and the annulus grouted. The finished dimension is 6 or 7 feet I.D. The annulus will be grouted in stages using the "TREMIE" method. Five GPM of water is the maximum planned inflow into the shaft after it is grouted.

At the 3700 foot level the steel liner will be cut away to permit excavation of a 30 foot diameter test area within the Umtanum. Here, hydrologic, rock mechanics and stress tests will be conducted, and two 50-foot holes are planned. Portholes will be constructed in the liner of the shaft, at various levels above the Umtanum, to allow coring and hydrologic testing after the shaft is complete. Drill hole DH22, 300 feet from the shaft collar, will provide information for locating the portholes.

The confined space of the shaft will limit the testing program in the shaft and this work will limit access to the test area at the 3700 foot level. It is not clear whether the tests can produce meaningful results in the time allowed for testing (about 10 months). Nor is it clear how the test results will be applied to repository design, which is frozen (under present plans) until 1987 (Appendix D, page 9).

The design of the Phase II test area and related tests, was not discussed by DOE and Rockwell. The reason given was that this phase had not yet been budgeted, planned or designed. For the same reason, the At-Depth Test Facility (with two shafts) and the Test Experimental Facility were not discussed.

Comment

There appear to be several gaps among the activities of repository design, rock mechanics, testing in the exploratory shaft, and site characterization.

- The consequences of a high stress field were not considered in repository design. However, at the time of completion of the present trip report (December 1981), such a study is understood to be in progress.

- Testing during Phase I of the Exploratory Shaft has apparently been planned without integration into the follow-on in situ testing effort.

- Only part of site characterization information needs can be accommodated by Phase I testing.

HYDROLOGY

At the start of the BWIP investigations there was considerable knowledge of shallow groundwater conditions at the Hanford Reservation, but little was known about groundwater conditions at the proposed repository depth (3700 feet).

The BWIP hydrologic investigations particularly address the deep hydrology. The work has been undertaken in two stages. During 1979, seven previously drilled core holes were reentered, and limited tests were conducted. However, due to the inherent restrictions of the approach, the data developed in this first stage--while usable for some purposes--are considered by RHO hydrologists to be less than reliable.

Then, beginning in FY 1980, five holes (DC-12, DC-14, DC-15, DB-15, and DC-16, located on Figure 1) were drilled so that core was obtained, and hydrologic tests were performed at selected levels. In addition, core hole DC-6 was developed and tested. These six holes provide most of the present data base for the deep hydrology at BWIP.

The hydrologic investigations are based on "single well" tests: that is, both tests and observations are run in the same hole. The holes are small, completed to a diameter of less than 4 inches and are cored throughout. For such holes, the testing techniques used by RHO are conventional; the equipment is first class; and the work appears to be done in a conscientious manner.

However, single well tests, in holes of small diameter, do not appear suitable for site characterization for several reasons:

- The pump tests are conducted at low volumes (less than 60 gpm). While this rate may be adequate for low permeability zones (say less than 10^{-8} meters/second), such pumping rates are apt to be inadequate for medium to high permeability zones.

- Single well tests are not suitable for measurement of two important parameters: storage coefficient (S) and vertical hydraulic conductivity (Kv). One of the major unknowns in understanding the ground-water travel paths is the extent to which an individual basalt flow permits, or inhibits, communication between the more permeable zones above and below. This problem has been raised by various reviewers of the BWIP work, including the NRC review in July 1980, but no progress has been made in investigation of vertical permeability.

- Single hole tests investigate the properties of a limited volume of rock; namely, a cylinder that is one or two feet in diameter, surrounding each hole. It is unlikely that this form of exploration can produce data that are representative of large volumes of rock so as to be applicable to the Pasco Basin as a whole.

Plans for the next five years call for the drilling and testing of six small diameter core holes (Figure 1). Paired hole testing of the Umtanum by low volume pumping is planned in DC-4 and DC-5 and/or DC-7 and DC-8. The distances between these pairs of holes is less than 150 feet, and the holes are more than 5 miles from the RRL. While the data from the planned paired hole testing will be helpful, the value will be limited for several reasons. (1) Because of the close spacing of hole pairs (less than 150 feet) only a limited volume of rock will be tested. (2) Casing presently in the holes restricts testing to the Grande Ronde; no properties of higher units will be measured. (3) In view of the distance between the holes and the RRL, and the expectable lateral variation within the Umtanum, it is questionable whether the test values for the Umtanum can be applied to the RRL.

Using the present information in the Pasco Basin, RHO has constructed a model of the deep ground-water flow. As discussed in the following section, "Hydrologic Modeling," the RHO model differs from those of PNL and the U.S. Geological Survey.

The practice of drilling holes to obtain core from top to bottom was appropriate to an earlier state of BWIP investigations, when the emphasis was correctly placed on collection of geologic data for site screening. Hydrologic testing was an adjunct to drilling for core recovery. However, now that the Reference Repository location has been designated, a shift in drilling strategy may be in order. The drilling techniques should be optimized for hydrologic testing. The hydrologic properties of major hydrostratigraphic units, both in the Grande Ronde and in higher formations, should be investigated.

A conventional approach to such investigations is to use multiple wells with long-term, high-volume pump tests. By this approach hydrologic parameters would be determined for large rock volumes by locating monitor and test wells so there is significant spacing in both lateral and vertical dimensions. Such testing can produce the following determinations:

- o Vertical hydraulic permeability (not known at present).
- o Storage coefficient (imperfectly known at present).
- o Horizontal permeability of medium and high permeability zones (imperfectly known at present).
- o Hydrologic parameters of a large volume of rock, which may be representative of the Pasco Basin as a whole. (Presently known parameters are for small rock volumes).

The NRC is concerned that the hydrologic site characterization program, as planned, will not produce reliable vertical permeability and storativity data (Appendix B, pages 5, 11, and 13; and Appendix E, pages 4 and 5). Without this information, the data base may not be adequate to support a full evaluation of site suitability and design that will be contained in a construction authorization application, if this document is advanced in the late 1980s.

HYDROLOGIC MODELING

Groundwater flow modeling is divided into two main categories: (1) far-field modeling of the Pasco Basin and (2) near-field modeling. The far-field effort is further subdivided into a three-dimensional approach and a two-dimensional approach.

Far-Field Three-Dimensional Approach

The three-dimensional approach uses the finite element flow code MAGNUM with three active layers: the Saddle Mountains formation, the Wanapum formation and the Grande Ronde formation. Layering is composited, i.e., very transmissive zones are averaged together with non-transmissive zones to form an equivalent transmissivity. Hydraulic properties are assumed to be homogeneous and anisotropic in each layer.

Conclusions drawn by RHO from the study are: (1) flow from the Saddle Mountains formation and possibly from the upper Wanapum formation discharges to the Columbia and Snake Rivers; (2) lower formations may discharge at Wallula Gap or beyond, with no apparent connection with the Columbia River outside of Wallula Gap (This may be due solely to choice of boundary conditions); and (3) the composited layering scheme is not conservative and more layers are needed to accurately calculate travel times. Figure 2 shows the layering scheme proposed for the multilayer model.

Far-Field Two-Dimensional Approach

The two-dimensional approach consists of choosing a streamline and pressure boundaries from the three-dimensional model and setting up a cross-section running from the Reference Repository Location to Wallula Gap, and crossing under both the Columbia and Snake Rivers (Figure 3). The simulation also uses the MAGNUM finite element flow code. Composite layering is used, but interest is focused on the Grande Ronde in order to estimate the travel time for a

PROPOSED VERTICAL LAYERING FOR MULTI-LAYER MODEL

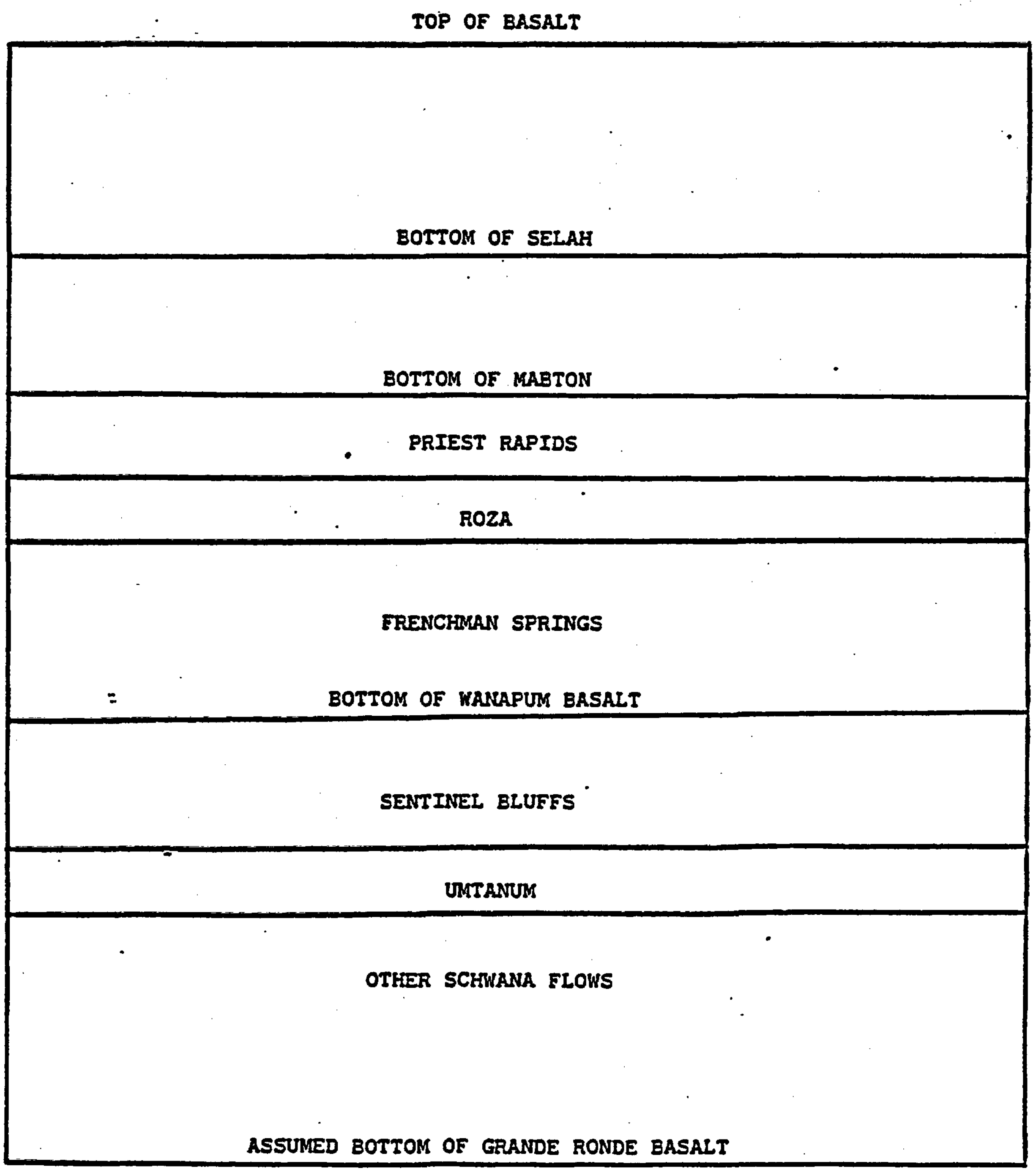
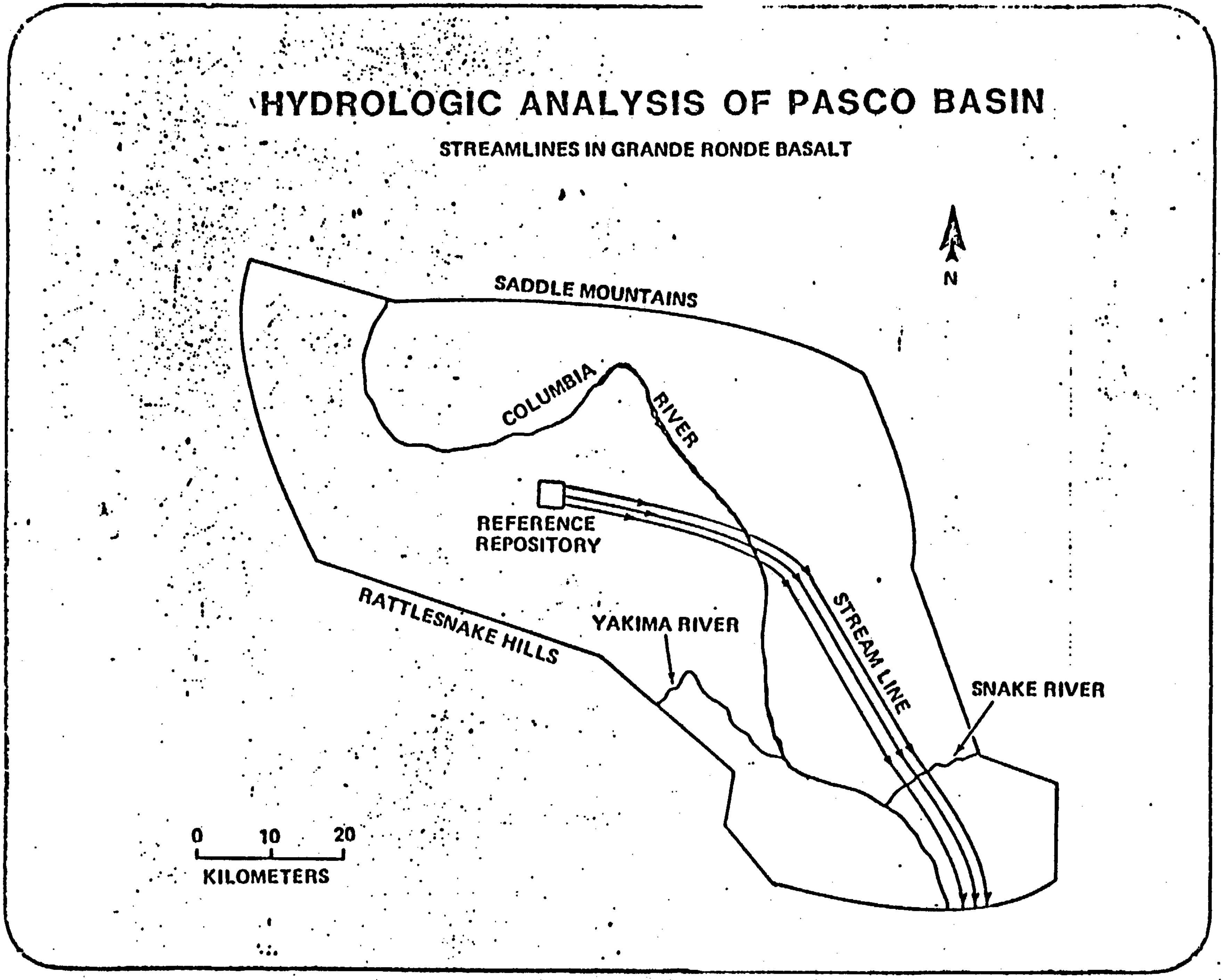


Figure 2

Figure 3



STREAMLINES IN GRANDE RONDE BASALT (From RHO slides) particle leaving the repository and going to the accessible environment. Since composited layering would yield non-conservative results, RHO increased the horizontal conductivity by a factor of 1000 in a small portion of the upper Grande Ronde formation. This small section represents the flow top breccia of the Umtanum flow unit.

The results of this calculation yield a travel time greater than 10^5 years. This figure is much larger than previous calculations performed by RHO, Los Alamos Technical Associates/Intera, and Pacific Northwest Labs.

Near-Field Approach

Conclusions reached from the near-field modeling effort are as follows: pathline and travel-time calculations done with and without thermal loadings (40KW/acre) indicate that the thermal loading significantly increases the travel-time. This is contrary to what was expected, because other studies have shown that an increased heat load would increase both horizontal and vertical hydraulic conductivity, thereby decreasing travel times. The present explanation is that the vertical bouyancy forces become so much larger than the horizontal velocities, that water is driven upward, higher into the section through areas of lower hydraulic conductivity, thus not allowing horizontal movement until the thermal gradient flattens out. Only then can the flow move horizontally into the more transmissive zones.

Comment

The modeling of the groundwater flow system at Hanford is based on limited deep hydrologic data; therefore, the presently indicated groundwater travel times and flow paths should be considered preliminary and unverified. Future modeling efforts will become more refined and could develop acceptance after calibration by accepted methods such as history matching and correlation with present day water table contours.

To date, there is no consensus between RHO and PNL regarding important basic concepts, e.g. flow patterns and location of discharge areas.

Internal inconsistencies exist in the most recent modeling attempts by RHO. RHO has taken the hydraulic head data obtained from the deep wells and constructed a model of the Pasco Basin by setting boundary conditions which preserve the head data from the wells. However, the resulting boundary conditions do not agree with the RHO conceptual model. For example, the conceptual model indicates that discharge is occurring in the Wallula Gap area. When boundary conditions are examined in detail, they are, in fact, recharge boundaries, i.e., head is decreasing with depth. This type of inconsistency should be resolved before model results can be considered credible.

The modeling studies could be used more effectively in the planning of hydrologic investigations by using sensitivity analyses on input parameters and boundary conditions to determine effects on the flow direction. This information can be used to identify areas where certain data would be most beneficial, and boreholes can be located accordingly.

The RHO modeling effort would be enhanced by constructive cooperation among RHO, PNL and the USGS regarding the regional hydrology of the Columbia Plateau. Regional models developed by both PNL and the USGS could help to provide boundary conditions and other insights into the Pasco Basin. The extensive data of the USGS regarding the Columbia Plateau could assist in the general understanding of groundwater flow in the Pasco Basin.

In conclusion, there are currently several widely different views on the general pattern of groundwater flow in the Pasco Basin. These have been put forth by RHO and other groups working in and having expertise in the Pasco Basin and surrounding region--viz., the USGS and PNL. The RHO program suffers from a lack of vigorous interaction with other groups to understand the basis for the differing views and to work to assure that they are resolved so that the whole matter is not left to be litigated as a licensing issue. The questions

~~of~~ hydrogeology are complex and will take some time to sort out. It is important that development of the specific investigations intended to resolve these questions (as presented in the SCR) includes close interactions with the USGS and others having the expertise and experience discussed above.

GEOCHEMISTRY

The geochemical research is aimed at examining both near-field and far-field processes. This work includes studies to bound Eh, pH, radionuclide solubility and repository temperature conditions. Single-phase experiments involving waste/water/rock interactions under the anticipated environmental conditions are under way. Basic radionuclide solubility data are being integrated into the sorption experiment program. The sorption experiments are conducted using bentonite (possible backfill material) and typical basalt fracture-filling material. In addition, substrate surface area per unit mass is being associated with the sorption measurement. This is important because the traditional use of sorption per unit mass does not adequately characterize the available sorption sites provided by the substrate.

It has been assumed by some that fracture-filling clays will swell when in contact with water, and the fractures, therefore, will become sealed to flow. However, under thermal loading, high temperatures could cause dehydration, which could result in the opening of "clay sealed" fractures to flow. The RHO group is addressing this controversial issue. A related question that still has to be resolved is the possible change in the mechanical properties of the fractured host rock in response to hydration and dehydration of the infilling material which could cause changes in friction between joint surfaces.

The systematic characterization of the mineralogy and petrology of the Umtanum flow is continuing. The results to date show that petrographic textures can be related to the cooling history of intraflow structures. Based on such evidence, it is apparent that the Umtanum is composed of several cooling units. The significance of this is that the Umtanum is not simply "massive," as it is usually described; rather, it may be texturally and structurally heterogenous and, thus, more difficult to characterize.

It appears that no work has been conducted to characterize the role that particulates, colloids and complexes might play in radionuclides transport, as called for in draft 10 CFR 60.122(g).

The geochemical work suggests that the Reference Repository Location may provide a naturally reducing environment that is favorable for nuclide retardation. This reducing environment is due to reduced iron-bearing minerals which limit changes in Eh, and the basaltic glass which limits changes in pH.

Comment

The geochemical research appears to reflect the general needs of 10 CFR 60, and the work should be able to characterize some important aspects of the geochemical environment and its retardation properties. However, new research efforts (including in situ tests) will be needed to develop the data that will ultimately be used to characterize the site and satisfactorily bring geochemical issues to closure by licensing time. Three examples of research initiatives follow. One - in addition to the characterization of single phase retardation geochemistry, attention needs to be given to multiphase retardation geochemistry. This is important because the formation of aqueous complexes could affect retardation. Two - attention needs to be given to the effect on mechanical properties of the fractured host rock due to hydration/dehydration of fracture-filling minerals. Three - attention needs to be given to the role of particulates, colloids and complexes in radionuclide transport (as called for in draft 10 CFR 60).

In addition, since the correlation of laboratory data to the Reference Repository Location are of obvious importance, the transferability of data must be clearly established. Finally, reconciliation is needed between the type of information under development by the RHO geochemical group and the capabilities of the codes, under development in ONWI, to use the information. At present, ONWI performance assessment codes are oriented toward the use of Kd look-up tables. However, the RHO geochemical research is working toward a multifactor measure of retardation. It is not clear how this measure will be accommodated in available or planned performance assessment computer programs.

TECTONICS

Geologic studies show that the Umtanum Ridge and Saddle Mountains are old structures that are growing slowly. In the area of the Cold Creek syncline there is north-south compression expressed as reverse faulting and thrusting along asymmetric anticlines. To the east of the Pasco Basin, east-west extension is present, associated with dikes from where the basalts in the basin originated. Although a décollement at depth has been proposed, there does not seem to be much evidence for it. The fold pattern can be explained by clockwise rotation with a rigid buttress in the western part of the Pasco Basin. A clay model yielded results that are very similar to the existing features.

Seismic records show that earthquakes occur in swarms, are shallow (1-3 km depth), and have Richter magnitudes up to 3 but are usually less than 2. Earthquakes below the basalt at (> 6 km) also have magnitudes up to 3. Focal mechanism solutions indicate north-south compression in the area of the syncline.

In is concluded by RHO that there is a low strain rate, and the strain pattern has been in existence for some time. The uplift rate is 0.003-0.07mm/yr.

Comment

The area chosen for the repository is apparently one of the least disturbed areas in the Pasco Basin. What needs to be done now is to make a better use of regional tectonic data outside the Pasco Basin, for example in northern Oregon. Some of the Tertiary grabens north of the Basalt area show trends that may extend into the Pasco Basin (Appendix E, page 2).

While is it now concluded by RHO that the earthquake data show no trends, and it seems that there are no strong trends, less apparent trend directions may exist in the data and could be revealed by further analysis.

GEOPHYSICS

At the present time, the major geophysical effort is the interpretation of magnetotelluric data collected in the third and fourth quarter of FY 1981. Magnetotelluric data are being used to interpret the gross structure of the sediments beneath the basalts and, hopefully, to gain an insight into the structure of the deep basalts (Grande Ronde and Pre-Grande Ronde).

A seismic refraction grid was shot over the RRL (Reference Repository Location) in FY 1981, to determine the structure of the sediments overlying the basalts. However, the refraction data will not be interpreted until FY 1982 because of budgetary limitations.

A seismic reflection program was recorded in the vicinity of the RRL, Gable Mountain and Gable Butte, and the Columbia River north of Gable Mountain. The BWIP investigators were hopeful of recording a reflector in the Grande Ronde, preferably the top of the Umtanum unit. This was not achieved; however, the top of basalt and (probably) the Mabton interbed were recorded. The data quality is good, particularly the reflection from the top of basalt. We believe that the top-of-basalt reflection could be sharpened through additional processing with improved weathering corrections, thus making these data more useful. This could provide recognition of top-of-basalt faulting, if present. Improved weathering corrections should also clean up the Mabton reflector.

Calibration of the nuclear borehole logging tools should be provided in the near future so that quantitative information on porosity, density and permeability of the basalts may be obtained. This will lessen reliance on core information, thus allowing greater freedom in drilling strategy. Otherwise, the geophysical logging program appears to be in acceptable condition (Appendix B, page 10).

Comment

Aeromagnetics has been the geophysical tool of greatest use to BWIP investigations for site screening. Magnetotellurics have been used primarily to help gain an understanding of deep regional structure. Little use has been made of the seismic reflection information and, since ~~it~~ has not been interpreted, the seismic refraction data have been of no use. There still may be time to process the data and apply the structural information thus obtained to siting of the ES and to groundwater modeling.

QUALITY ASSURANCE

In general, the QA program appears to be in place and workable. The program relating to hardware (labs, drill rigs) is working with little difficulty. However, the procedures relating to geotechnical investigations are still experiencing growth pains. RHO appears to be aware of the problems inherent in imposing QA procedures on geotechnical investigations and is attempting to deal these problems.

RHO-BWI-MA-4, Operating Procedures, RHO-BWI-MA 150, Quality Assurance Manual, and RHO-BWI-MA 115, Engineering Procedure Manual are the three basic documents issued by BWIP concerning QA. In addition there are some 105 QA manuals directed at specific activities. These are all living documents with updates as needed. None of the documents have been reviewed by the NRC for completeness or accuracy.

The entire QA program is presently being revised in preparation for the Site Characterization report. No publication of QA related documents is planned before submission of the SCR.

REMOTE SENSING

RHO researchers are using high-sun-angle, high altitude, aerial (U-2, Skylab and Landsat) imagery to assist in the analysis of surface features and the mapping of 35,000 square miles of Columbia River Plateau geology. To date, the bulk of the work has involved analysis of lineaments. These features are mapped at a scale of 1:250,000. Up-to-date computer techniques are employed to integrate and compare these data with other sources of geologic information. A substantial report on the results of this work (along with maps, imagery and overlays) is in draft form and will be released in early 1982.

A preliminary comparison of the remote sensing data with available geologic and topographic maps of the region show that seventy percent of the photo lineaments/features correlate with the known geology. The remaining thirty percent are being reviewed, and only those photo features that are most likely to be of geologic origin and significance will be checked in the field.

Comment

To date, lineament trends and patterns apparently have not been analysed. Trend analysis is often used to infer regional stress fields and suggest resulting crustal movements. RHO should proceed to analyze the data.

GEOCHEMISTRY

The geochemical research is aimed at examining both near-field and far-field processes. This work includes bounding Hanford Eh, pH and temperature conditions and experiments involving waste/water/rock interactions under Eh, pH, and temperature conditions anticipated at BWIP. The general nature of the program seems to be to:

- characterize the maximum release rates of radionuclides from a waste package,
- characterize the retardation properties of the waste package,
- characterize the requirements for waste package material imposed by the "10^{-5}" criteria in 10 CFR 60, and that imposed by the geochemistry of the site,
- characterize the retardation properties of the host rock fracture filling material,
- relate the retardation properties of the waste package to the 1000 year containment criteria in 10 CFR 60, and
- integrate site specific geochemistry and the retardation properties of the waste package, and the near-field and far-field environment into performance assessment models.

These efforts appear to be expeditions for BWIP site characterization because basic radionuclide solubility data are being integrated into sorption experiments. These experiments are being or will be conducted using bentonite and typical Hanford basalt fracture filling material. Sorption and desorption, and irreversible reactions are determined. By combining these factors, RHO is beginning to characterize the retardation properties of the Hanford site.

To date, RHO solubility and sorption experiment have only single phase analyses. In addition, substrate surface area per unit mass is being associated with the sorption measurement. This is important because the traditional use of sorption per unit mass does not adequately characterize the available sorption sites provided by the substrate.

Further, RHO workers seem to have identified the primary and secondary phases of fracture filling materials through which escaped radionuclides would have to pass. Also, the retardation properties of these mineral phases are under investigation.

It has been assumed by some that fracture-filling days will swell when in contact water and fractures will become sealed to flow. However, dehydration could result in the opening of "clay sealed" fractures to fluid flow.

The RHO group seems to be directly addressing the resolution of this controversial issue. Preliminary work indicates that the fractures would be self-sealing in the presence of water and that dehydration would not occur at temperatures below 100°C. In addition, dehydration would be reversible up to 300°C thereby resealing the fractures if water were reintroduced.

A related question that still has to be resolved involves change in the mechanical properties of the host rock and host-rock stability in response to dehydration and the opening of fractures, or hydration and clay-swelling and the "natural" sealing of fractures.

The systematic characterization of the mineralogy and petrology of the Umtanum flow is continuing. The results to date show that petrographic textures can be related to the cooling history of intraflow structures. Based on this evidence, it is apparent that the Umtanum is a complicated Type II basalt flow composed of several cooling units. The significance of this is that the Umtanum is not simply "massive" as it is usually referred to, but may be texturally heterogenous and will be more difficult to characterize than expected.

No work is being conducted to characterize the rate that particulates, colloids and complexes might play in radionuclides transport at BWIP (as called for in 10 CFR 60).

Finally, work at RHO suggests that the geochemical nature of the Hanford site will provide a stable and naturally reducing environment. The supporting evidence is that iron bearing minerals limit changes in Eh, and the local basaltic gloss limits changes in pH.

Comments and Conclusions.

The geochemical research pursued by RHO investigations appear to reflect the general needs of 10 CFR 60 and should be able to characterize some important aspects of the geochemical environment and retardation properties of the Hanford site. However, continued research and new research efforts (including in situ tests) may be needed to develop the quantitative data that will ultimately be used to fully characterize the site and satisfactorly bring geochemical issues to closure by licensing time.

At some point, in addition to the characterization of single phase retardation geochemistry, attention needs to be given to multiphase retardation geochemistry. This is important because the formation of aqueous complexes could effect retardation.

Attention needs to be given to how the mechanical properties of the host rock might be influenced by hydration/dehydration of fracture-filling minerals.

Further, attention needs to be given to the role of particulates, colloids and complexes in radionuclide transport at Hanford (as called for in 10 CFR 60).

In addition, there is a critical need for the economic integration of critical geochemical data into performance assessment models.

Appendix A

Geotrans Incorporated

Trip Report

MEMORANDUM

To: L. Lehman, NRC | Subject: TRIP REPORT--BWIP Site Visit

From: J. Mercer, GeoTrans, Inc. | Date: September 30, 1981

The purpose of this memorandum is to describe meetings, discussions, and impressions concerning the BWIP Site Visit. This trip report is part of a combined effort, and as such, only the following items are discussed: (1) a September 21, 1981, meeting with Pacific Northwest Laboratories (PNL), (2) a September 28, 1981 meeting with the U.S. Geological Survey, and (3) general comments on the overall trip. Detailed meeting notes are also attached.

The modeling of PNL was divided into two parts: (1) a regional model and (2) a Pasco Basin model. The regional model covered 21,000 square miles and had two active layers. The code VTT was used and two-dimensional flow was assumed in the layers, which were connected through the use of transfer coefficients between layers. The Pasco Basin model covered 2,000 square miles. The three-dimensional model, FE3DGW, was used with three active layers. Both models had the following major assumptions: (1) porous flow equivalent of composite transmissive zones and confining zones, and (2) the Grande Ronde Formation is similar hydrologically to the Wanapum Formation. The latter assumption was made because most wells are less than 400 feet in depth and only a few wells penetrate the Grande Ronde Formation.

The major conclusions from the local model include: (1) large scale vertical hydraulic conductivity is of order 0.001 ft/day; (2) supports vertical upward leakage in the Pasco Basin (what PNL calls distributed discharge); (3) supports ground-water divide for Rattlesnake - Hog Ranch - Table Mountain; (4) supports Saddle-Mountains as only permeability barrier; (5) pathway analysis indicates that radionuclides will move primarily vertically, with average ground-water travel time to the Columbia River calculated as about 15,000 years; and (6) in 10,000 years, only ^{129}I and ^{14}C will reach the accessible environment (1 mile boundary). These radionuclides have distribution coefficients close to zero. Recommended additional data requirements include (1) tests to determine the nature of the vertical permeability; (2) porosity measurements; and (3) deep potential measurements.

The approach taken by PNL, that of using a regional model to help define the local boundaries and boundary conditions, is a good one. Since limited data are available, this modeling effort is considered preliminary, and a simple model with few layers is justified. In fact, because of the scale of the regional model and the limited data, a one layer model probably would have been adequate. This is supported since they had to lump the Saddle Mountains and Wanapum Basalts into one layer, while for the Grande Ronde layer, they had to assume similar hydrologic properties to those of the Wanapum Formation. Why not treat all as one layer with leakage? For the local model, more layers are justified since the goal is to calculate travel times.

Four modeling studies have been or are currently being made by the USGS in the Columbia Plateau. These include: (1) a two-dimensional (areal) modeling study by J.E. Luzier and J.A. Skrivan in the Odessa-Lind area, (2) a three-dimensional coarse grid model of the entire Columbia Plateau, part of which was done by Bill Meyer, (3) a three-dimensional model of the Quincy Basin, Henry Buyer's project, and (4) a three-dimensional model of the Horse Heaven Hills area, Frank Packard's area. In addition to these studies, in 1983, a regional aquifer study is planned to be initialized by the USGS dealing with the entire Columbia Plateau. This is to be a four year study.

In summary, the U.S.G.S. presents several ideas and observations that are different from those of PNL and/or Rockwell. One important observation is the large amount of pumpage that occurs in the areas surrounding the Hanford location. These are producing drawdowns that average ten feet per year and extend into the Grande Ronde. And, at least in some locations, these drawdowns are thought to cause interbasin flow. The possible long-term effects of this pumpage on a repository need to be evaluated. Second, under pre-man conditions, no interbasin flow is thought to have occurred; discharge is to the low points, i.e., the rivers. Third, flow is structurally controlled. This helps lead to the conclusion that the interbeds control vertical flow and the vertical hydraulic conductivity is generally higher for areas with anticlines. They also feel that considerable vertical flow occurs in the basalts, which is contrary to Rockwell's beliefs. Finally, the main conclusion is that there is not enough data to adequately calibrate most models of the Columbia Plateau.

Other general impressions or comments are included below:

(1) The Columbia Plateau models, by virtue of the data limitations, should be considered preliminary, with results that are likely to be changed or modified, as more data are obtained. Hopefully, the various models will converge to similar results with the acquisition of this data.

(2) As a consequence of the above, obviously more data should be collected to help define the hydraulic system.

(3) More interaction among the various groups performing modeling at the Columbia Plateau is recommended, as well as among the geologists, hydrologists and modelers at the Hanford location.

(4) I suggest that as part of the sensitivity analysis, the Rockwell modeling should allow for a free surface at the top boundary.

(5) Can the different geochemistry of the water near the Columbia River be explained by mixing with water originating east of the river?

(6) The near-field work seems to be lagging behind the far-field work. The field work is considering only thermal-mechanical and ignores flow, while the modeling, at this point, considers only thermal and flow, but no mechanical. To complicate matters even more, certain stresses observed in the field heater experiments cannot be explained. A more integrated approach is needed for this very complicated problem.

(7) In order for the NRC to adequately evaluate modeling work performed at the Hanford location, it is important that all codes and data used be fully documented and incorporated into the quality assurance program.

JWM:dye

cc Nancy Finley, Sandia
Mark Reeves, Intera

DETAILED MEETING NOTES

PLN Meeting

On Monday morning, September 21, 1981, a meeting was held at Pacific Northwest Laboratories (PNL), Richland, Washington to discuss modeling performed by PNL on the Columbia Plateau. In attendance at the meeting were L. Lehman (NRC), N.C. Finley (Sandia), F.B. Nimick (Sandia), M. Reeves (Intera), F.H. Dove (PNL), C. Cole (PNL) and J.W. Mercer (GeoTrans). The meeting consisted of presentations by F.H. Dove and C. Cole. Mr. Dove, manager of the AEGIS Program, gave an overview of the project, while Mr. Cole discussed modeling activities. The remainder of this section will be used to summarize the PNL modeling activities.

The modeling of PNL was divided into two parts: (1) a regional model and (2) a Pasco Basin model. The regional model covered 21,000 square miles and had two active layers. The code VTT was used and two-dimensional flow was assumed in the layers, which were connected through the use of transfer coefficients between layers. The Pasco Basin model covered 2,000 square miles. The three-dimensional model, FE3DGW, was used with three active layers. Both models had the following major assumptions: (1) porous flow equivalent of composite transmissive zones and confining zones, and (2) the Grande Ronde Formation is similar hydrologically to the Wanapum Formation. The latter assumption was made because most wells are less than 400 feet in depth and only a few wells penetrate the Grande Ronde Formation.

The regional model was constructed to estimate flows and boundaries for the local or Pasco Basin model. It is similar to a modeling study performed by the U.S. Geological Survey, known as a coarse grid model that is used to estimate interbasin transfer. The region included in this study is shown in Figure 1. The finite-difference grid of the regional model had two active layers. The lower-most layer represented the Grande Ronde Formation (the Umtanum unit in the middle of this formation is the site of the proposed repository). The next layer represented two formations: the Saddle Mountain Basalts and, primarily, the Wanapum Basalts. An upper third layer was used in the model, but was not active (not part of the solution). Its purpose was to represent the alluvium (Ringold Formation). Where the alluvium was present or

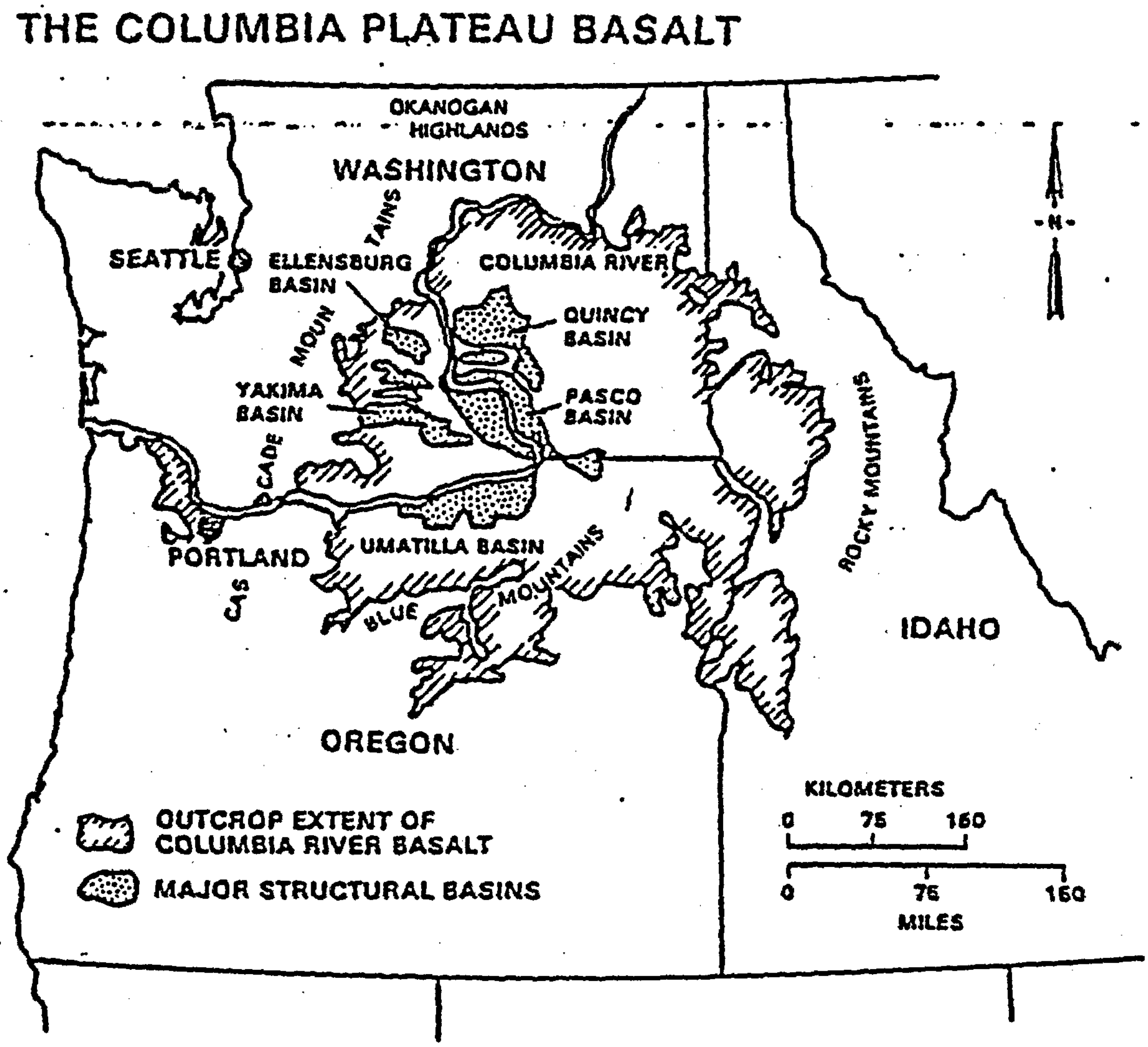


Figure 1. Regional features at the Columbia Plateau (from PNL slides).

where lakes and surface water bodies existed, this layer was considered constant head (a Dirichlet boundary). The lateral boundaries of the regional model were (see Figure 2): toward the north and east, the basalt edge (treated as constant head); toward the south, structural boundaries, such as the Craigmont Monocline, Limkiln Fault, Blue Mountains and Horse Heaven Hills Anticline; and toward the west, structural boundaries, such as Rattlesnake Hills Anticline. These latter boundaries were treated as no-flow because of structural evidence and the evidence of a ground-water divide. The regional model was a steady-state model that included sources and sinks, such as wells, recharge, etc.

There was little data for which to calibrate the model against; this was especially true for vertical characteristics and for the deeper, Grande Ronde Formation. It was also felt that discharge to the rivers was too small to provide a meaningful calibration quantity. This was decided after extensive recharge calculations were made using Land Sat Imagery (see Table 1). The primary observed data that was used for calibration was the potentiometric surface. However, this data was limited to primarily the following units: (1) water table, (2) Rattlesnake Ridge, and (3) Mabton. In order to match this surface, they had to decrease the horizontal permeability and increase the vertical permeability near anticlines. Geologically, this would be expected. Details of the calibration are summarized in Table 2. In general, the Saddle Mountain-Wanapum layer was recharging both the alluvium and the Grande Ronde Formation. An exception to this was the Pasco basin, where the Grande Ronde recharged the Saddle Mountain-Wanapum layer. PNL referred to this as distributed discharge.

The regional model was used to help define the local model of the Pasco Basin. The model used in this case was a three-dimensional finite-element code. There were three active layers, where again, the alluvium was treated as a Dirichlet boundary. The local model boundaries were somewhat arbitrary and are shown in Figure 3. The finite-element grid is shown in Figure 4. The boundary conditions for the boundaries that are common to both the local and regional models are treated as described before in the regional model. For the other boundaries, the Rattlesnake Hills were treated as no-flow (a

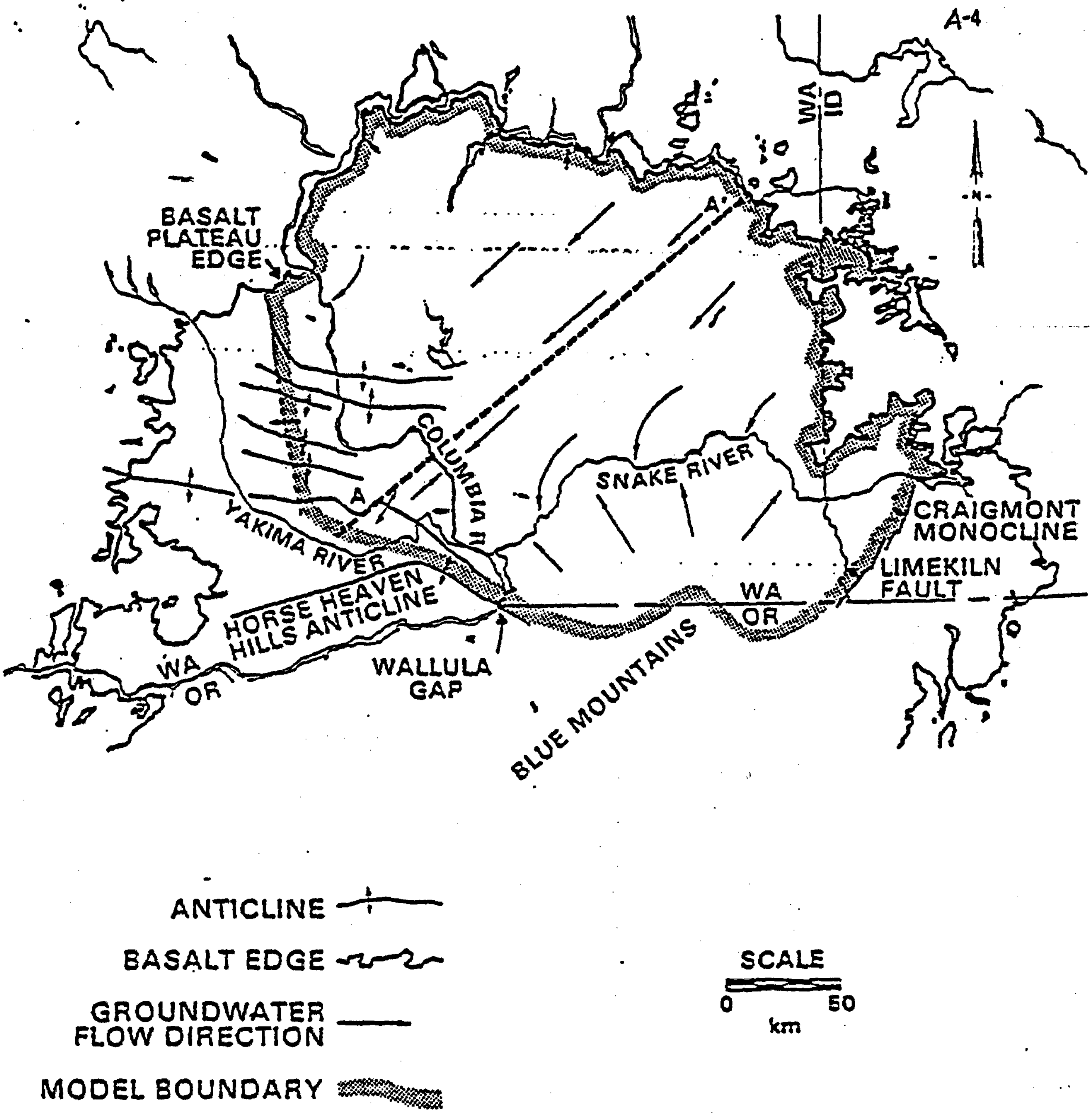


Figure 2. Boundaries of regional model (from PNL slides).

Table 1. Recharge data for regional model (from PNL slides).

RECHARGE ESTIMATES MADE ON REGULAR GRIDS.
REGIONAL 3 MILE, 55 X 55, 21,000 SQUARE MILES
LOCAL 1 MILE, 78 X 67, 2,000 SQUARE MILES

GEOSTATISTICAL INTERPLOATION METHOD USED TO FIT PRECIPITATION AND PET DATA FROM WEATHER STATION MEASUREMENTS.

* ACCOUNTS FOR PRECIPATION CORRELATION WITH ELEVATION.
* UNBIASED ESTIMATOR TO DETERMINE OPTIMUM INTERPOLATION PARAMETERS.

REGIONALLY WE MOVE INTO AND OUT OF THE CASCADE RAIN SHADOW AS WE MOVE FROM WEST TO EAST.
PRECIPITATION CORELATION WITH ELEVATION A MORE GLOBAL FUNCTION OF ELEVATION.

* COLFAX IN NARROW VALLEY-PRECIPITATION FUNCTION OF SURROUNDING PLATEAU.

FOUR VEGETATION TYPES:
DRY LAND WHEAT, IRRIGATED, FOREST, SAGE BRUSH-CHEAT GRASS

REGIONAL RUNOFF FROM USDA DATA.

SPRINKLER EFFICENCY AND FALLOWING OF WHEAT ACCOUNTED FOR.

ESTIMATES	REGIONAL	LOCAL
PRECIPITATION	12.2 MAF/YR	772,000 AF/YR
AET	12.2	1,394,000
PUMPING	0.204	27,000
RECHARGE	2.66	287,000 (55,000) PREMAN
	1.22 IRRIGATION	
	0.93 SAGE-CHEAT	
	0.15 FOREST	
	0.36 DRY LAND WHEAT	

Table 2. Parameter for regional model (from PNL slides).

REGIONAL MODEL CALIBRATION
* TRANSMISSIVITY
(INITIAL)FINAL GPD/FT

SM-WP (25,000)-85,000
GR (60,000)-51,000
INCREASE IN CALIBRATED TRANSMISSIVITY NOT UNLIKELY
* INTERAQUIFER TRANSFER
(INITIAL)FINAL FT/DAY
SM-WP TO GR (.001) .00101 MAX.=.007
UPWARD FLUX 0.32 MAF/YR
DOWNWARD FLUX 0.64 MAF/YR (LOSS = 0.32MAF/YR)
ALLUVIUM TO SM-WP (.01) .0069 MAX.=.36
UPWARD FLUX .71MAF/YR
DOWNWARD FLUX 0.11MAF/YR (LOSS = 0.60MAF/YR)

LOSSES TO:	FROM SM-WP	FROM GR
RIVERS	.13MAF/YR	.59MAF/YR
	8.0 CFS/MILE	0.8-5.5 CFS/MILE(COLUMBIA-SNAKE)
LAKES	0.035MAF/YR	0.12MAF/YR
SEEPAGE FACES	0.011MAF/YR	0.015MAF/YR

LAKE LOSSES ABOUT EQUAL TO 40 INCHES/YR

INITIAL COMPARISONS WITH WELLS (UNCALIBRATED)

1958 246, 1968 402, 1978 367, INTERPRETED 701 FINAL INTERPRETED 214

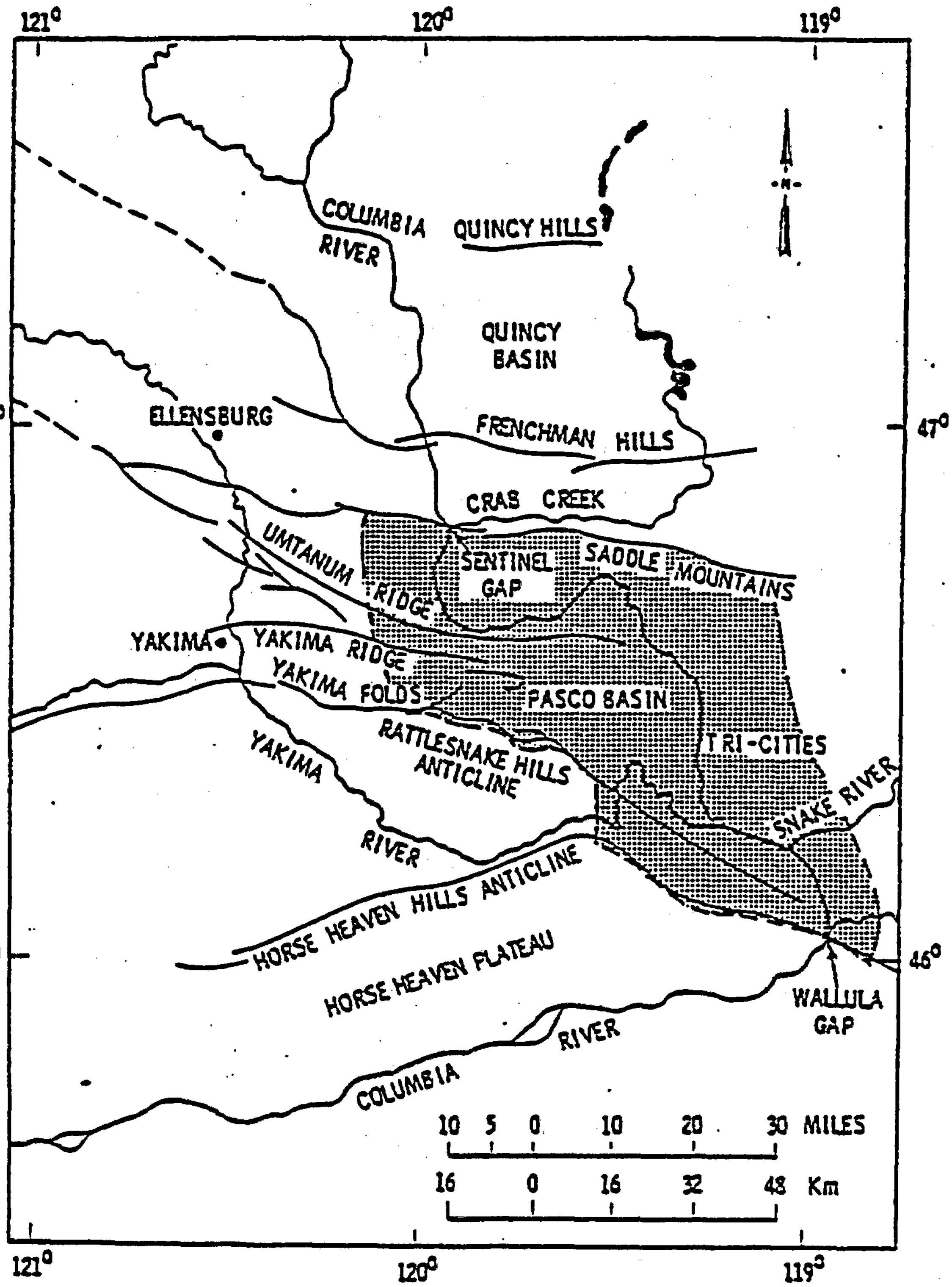
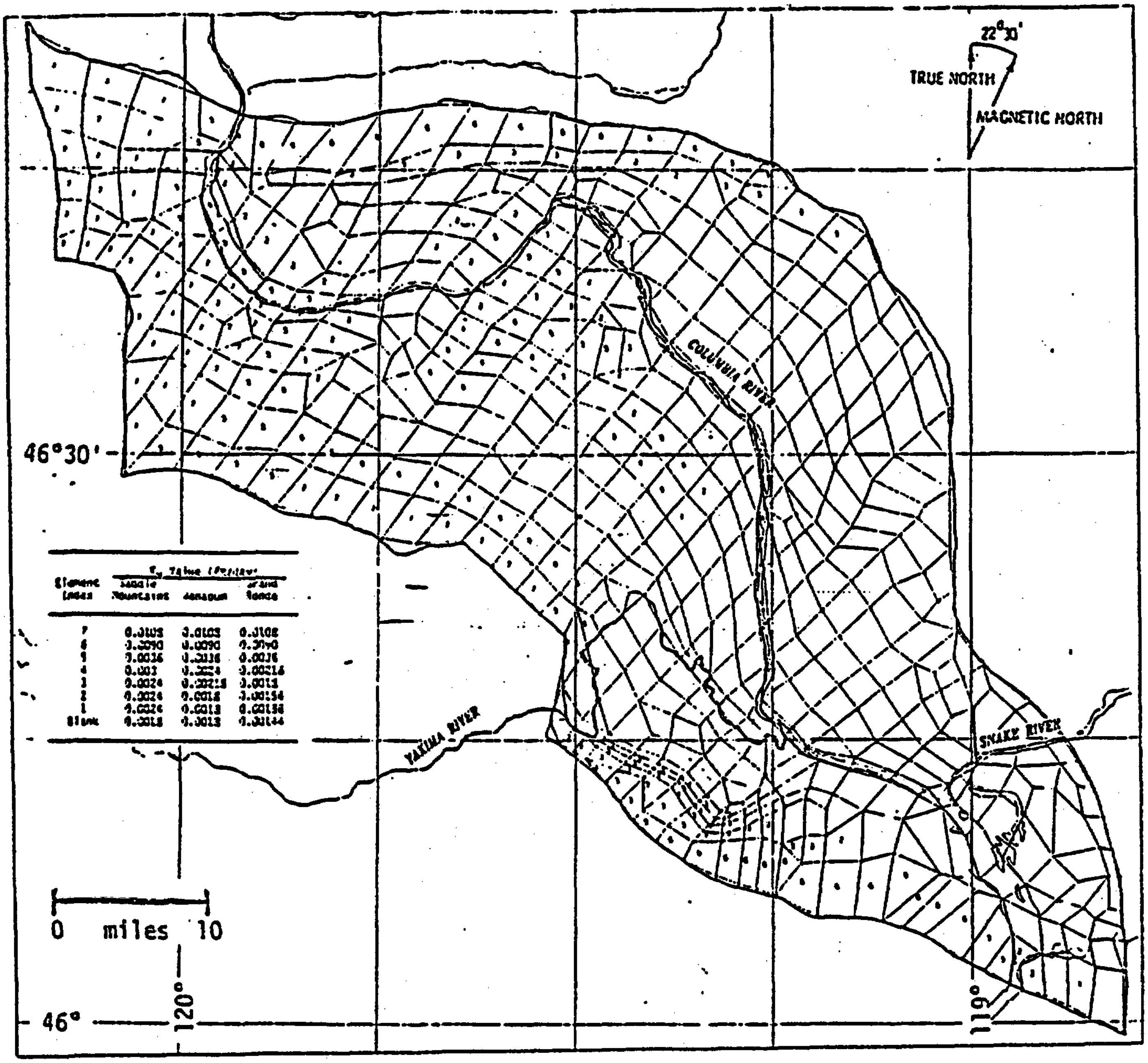


Figure 3. Pasco Basin boundaries (from PNL slides).



Element Index	Value [illegible]: Saddle Mountains	Wanapum	Grande Ronde
7	0.0105	0.0105	0.0108
6	0.0090	0.0090	0.0090
5	0.0036	0.0036	0.0036
4	0.003	0.0024	0.00216
3	0.0024	0.00216	0.0013
2	0.0024	0.0018	0.00154
1	0.0024	0.0013	0.00138
Blank	0.0018	0.0013	0.00144

Figure 4. Pasco Basin finite element configuration (from PNL slides).

ground-water divide), whereas the remaining boundary was treated as constant head, determined from the regional model. Since the regional model was a two-layer, finite-difference model, and the local model was a three-layer, finite-element model, some type of extrapolation had to be used to obtain the appropriate head values for the constant head boundaries. Several approximations were used, with all being fairly insensitive to the computed travel time, since the path line was mainly in the vertical. As part of the modeling, anticlines were assigned a higher vertical hydraulic conductivity and a lower horizontal hydraulic conductivity than the surrounding rock. Details of the parameters used in the local model are given in Table 3 and on Figure 4.

The major conclusions from the local model include: (1) large scale vertical hydraulic conductivity is of order 0.001 ft/day; (2) supports vertical upward leakage in the Pasco Basin (what PNL calls distributed discharge); (3) supports ground-water divide for Rattlesnake - Hog Ranch - Table Mountain; (4) supports Saddle-Mountains as only permeability barrier; (5) pathway analysis indicates that radionuclides will move primarily vertically, with average ground-water travel time to the Columbia River calculated as about 15,000 years; and (6) in 10,000 years, only ^{129}I and ^{14}C will reach the accessible environment (1 mile boundary). These radionuclides have distribution coefficients close to zero. Recommended additional data requirements include (1) tests to determine the nature of the vertical permeability; (2) porosity measurements; and (3) deep potential measurements.

The approach taken by PNL, that of using a regional model to help define the local boundaries and boundary conditions, is a good one. Since limited data are available, this modeling effort is considered preliminary, and a simple model with few layers is justified. In fact, because of the scale of the regional model and the limited data, a one layer model probably would have been adequate. This is supported since they had to lump the Saddle Mountains and Wanapum Basalts into one layer, while for the Grande Ronde layer, they had to assume similar hydrologic properties to those of the Wanapum Formation. Why not treat all as one layer with leakage? For the local model, more layers are justified since the goal is to calculate travel times.

Table 3. Parameter for Pasco Basin model (from PNL slides).

LOCAL OR PASCO BASIN MODEL SELECTION

* FE3DGW, 3-D, FINITE ELEMENT, STEADY STATE
* HANDLES MULTIPLE LAYERS AND VERTICAL MOVEMENT
* IRREGULAR SUBDIVISIONS FOR BETTER BOUNDARY DEFINITION
* INHOMOGENEITY AND ANISOTROPY

LOCAL MODEL DATA REQUIREMENTS

* LOCAL BOUNDARY
  - NORTH AND EAST ARE HELD FROM REGIONAL
  - SOUTH AND WEST ARE RECHARGE-STRUCTURAL
    NO FLOW GROUNDWATER DIVIDES (SAMES AS REGIONAL)
* GRID CONSTRUCTION
  - 606 SURFACE NODES
  - 555 SURFACE ELEMENTS
  - 4 LAYERS (ALLUVIUM, SM, WP, GR)
* STRUCTURE TOPS FOR EACH LAYER
* EQUIVALENT POROUS MEDIA K_H, K_V AND POROSITY (SCALE, COMPOSITING, HETEROGENEITY IMPORTANT)
  - INITIAL K_H 4.0 FT/DAY (SM)
  - INITIAL K_V/K_H RATIO 0.1 ALLUVIUM, 0.01 OTHERS
  - INITIAL POROSITY 0.1 AL, 0.095 SM, 0.07 WP, 0.06 GR
* STRESS (RECHARGE-PUMPING)
  - PUMPING 27,000 AF/YR (13000 AF/YR LOW YIELD WELLS IN CIRCLED AREA)
  - RECHARGE 287,000 AF/YR (55,000 PREMAN)
    (DISTRIBUTION OF STRESS IMPORTANT)

USGS Meeting

On Monday afternoon, September 28, 1981, a meeting was held at the U.S. Geological Survey, Tacoma, Washington, to discuss their modeling associated with the Columbia Plateau. In attendance at the meeting were Bob Wright (NRC), Paul Prestholt (NRC), Linda Lehman (NRC), Nancy Finley (Sandia), Fran Nimick(Sandia), Mark Reeves (Intera) Jim Mercer (GeoTrans), Bill Meyer (USGS), Frank Packard (USGS), and Henry Buyer (USGS). Four modeling studies have been or are currently being made by the USGS in the Columbia Plateau. These include: (1) a two-dimensional (areal) modeling study by J.E. Luzier and J.A. Skrivan in the Odessa-Lind area, (2) a three-dimensional coarse grid model of the entire Columbia Plateau, part of which was done by Bill Meyer, (3) a three-dimensional model of the Quincy Basin, Henry Buyer's project, and (4) a three-dimensional model of the Horse Heaven Hills area, Frank Packard's area. In addition to these studies, in 1983, a regional aquifer study is planned to be initialized by the USGS dealing with the entire Columbia Plateau. This is to be a four year study.

The two-dimensional model study of the Odessa-Lind area is the only published study:

Luzier, J.E. and J.A. Skrivan, 1975. Digital-simulation and projection of water-level declines in basalt aquifers of the Odessa-Lind area, east central Washington, Water Supply Paper 2036.

This area was chosen because it is the most developed, in terms of ground-water use, on the Columbia Plateau. This area is northeast of the Hanford site, including parts of Adams, Grant, and Lincoln Counties. The maximum usage of ground water is tending to move south toward the City of Pasco. It is interesting to note that the drawdown in the Grande Ronde/Wanapum combined units was similar to the drawdown in the Wanapum/Saddle Mountain combined units. Also, this rate of drawdown is controlled by state law to be less than ten feet per year.

The coarse grid model study was designed to evaluate data needs. As part of this study, the U.S.G.S. was supposed to evaluate Gupta's model, but because the model did not contain a mass balance, the Survey opted to use its own three-dimensional flow code. The study was terminated prematurely when the U.S.G.S. interpretation of the flow system differed from that of Rockwell; however, a report summarizing the study is in the review process. The coarse grid model simulated steady-state conditions and consisted of two layers. The Saddle Mountain and Wanapum Basalts were lumped into one layer and the second layer consisted of the Grande Ronde Basalt. Calibration was to the potentiometric surface prior to development. This lead to a leakance (K'/ℓ') for the Vantage of 1.3×10^{-11}/s. After considerable sensitivity analysis, the main conclusion was that there was not enough data to adequately calibrate the model. The upper boundary of the U.S.G.S. model was treated similarly to the PNL model, that is, constant head where surface water occurs, recharge elsewhere. It is interesting to note that, unlike PNL, they do not believe that any interbasin flow is occurring (except possibly due to pumpage). The rivers are the lowest points and discharge occurs along them. Data for this model was obtained from the GWSI and subsequently corrected by Lynn Popinka. The final report will be a Washington Department of Ecology report.

The Quincy Basin model is a current project working with one of the subbasins in the Columbia Plateau. The model consists of three layers: (1) the Ringold Formation, (2) Wanapum Basalt, and (3) the Grande Ronde Basalt. The main emphasis of the study is on the shallow system, comprised of the unconsolidated material. In this area, the unconsolidated material is about 300 feet thick and the Wanapum is about 400 feet thick, with the Wanapum considered to have a permeability that is an order of magnitude less than the unconsolidated material. For the Grande Ronde in this subbasin, they believe recharge is from irrigation and discharge is to the Columbia River.

The Horse Heaven Hills study is a current project and actually considers two models: (1) a vertical cross-sectional model and (2) a three-dimensional model. This area is just north of and adjacent to an area in Oregon known as the Columbia Slope, which is also being modeled by the U.S.G.S. They believe that pumpage in Oregon may be causing underflow beneath the Columbia River. The cross-sectional model consisted of five layers: (1) Saddle Mountains, (2) Mabton, (3) Wanapum, (4) Vantage, and (5) Grande Ronde. The two lateral boundaries were associated with an anticline and the Columbia River, and were considered no-flow. The purpose of the model was to examine the vertical connection between layers. They believe that much vertical movement occurs in the basalts, while the interbeds, such as the Mabton and Vantage, offer resistance to vertical flow. Data for the model included the following transmissive data:

Saddle Mountains	$T = 10^{-3} - 10^{-5}\ ft^2/s$	(lateral)
Wanapum	$T = 10^{-2} - 10^{-4}\ ft^2/s$	(lateral)
Interbeds	$K_v = 10^{-9}$ ft/s	(under river)
	$K_v = 10^{-12}$ ft/s	(under anticline)

Note that, unlike PNL, the vertical hydraulic conductivity associated with the anticline is not the highest. The highest hydraulic conductivity, under the river, is attributed to sand beds found there. Also, from their results, the vertical gradient in hydraulic head in the Grande Ronde was almost negligible. The flow in the Grande Ronde comprised about 25 percent of the flow in the entire sequence modeled in the cross section.

The three-dimensional model of the Horse Heaven Hills area extended south to approximately the Columbia River, east to Wallula Gap, north to the Yakima River, and west to several deeply entrenched streams. The enclosed area included an anticline and two large pumping centers. The model consisted of three layers: (1) Saddle Mountain, (2) Wanapum, the main aquifer, and (3) the Grande Ronde. These were connected through leakance coefficients. Even though the Grande Ronde was included as an active layer, only two wells penetrate the Grande Ronde in this study area, and they were drilled by the Department of Ecology. The model is considered preliminary and again, the purpose was to determined data availability and adequacy. They feel that the hydrology is structurally controlled. For example, the interbeds are believed to control the vertical flow. The Mabton interbed, an ash fall, is thick in synclines and thin on anticlines. Therefore, leakance associated with anticlines should be higher than that of the surrounding area. As pointed out earlier, this rule is violated in this area because of the sand beds under the river. They expect the Vantage to behave similarly to the Mabton. Other observations on this study include: (1) the wells are cased such that good head data are obtained, as opposed to composite heads (this is generally not the case), (2) the Saddle Mountain Basalt generally has a permeability that is an order of magnitude less than that in the Wanapum Basalt, and (3) the rate of drawdown within the Wanapum is about 10-15 feet per year.

In summary, the U.S.G.S. presents several ideas and observations that are different from those of PNL and/or Rockwell. One important observation is the large amount of pumpage that occurs in the areas surrounding the Hanford location. These are producing drawdowns that average ten feet per year and extend into the Grande Ronde. And, at least in some locations, these drawdowns are thought to cause interbasin flow. The possible long-term effects of this pumpage on a repository need to be evaluated. Second, under pre-man conditions, no interbasin flow is thought to have occurred; discharge is to the low points, i.e., the rivers. Third, flow is structurally controlled. This helps lead to the conclusion that the interbeds control vertical flow and the vertical hydraulic conductivity is generally higher for areas with anticlines. They also feel that considerable vertical flow occurs in the basalts, which is contrary to Rockwell's beliefs. Finally, the main conclusion is that there is not enough data to adequately calibrate most models of the Columbia Plateau.

Appendix B

Golder Associates Incorporated

Hydrology Trip Report

Appendix G

List of Participants

AGENDA FOR NUCLEAR REGULATORY COMMISSION
VISIT TO BASALT WASTE ISOLATION PROJECT
RICHLAND, WASHINGTON

September 22-26, 1981

Attendees

NRC

Jared Davis (Management, Research)
Donald Alexander (Geochemistry, Petrology)
George Birchard (Geochemistry)
David Brooks (Geochemistry, Remote Sensing)
John Greeves (Civil Engineering)
Ludwig Hartung (Engineering Geology)
Linda Lehman (Hydrologic Modeling)
Paul Prestholt (Hydrology, Geophysics, Quality Assurance)
Robert Wright (Senior Technical Advisor)
Ernst Zurflueh (Geophysics, Tectonics)

Golder Associates

Adrian Brown (Hydrology)
Richard Gates (Rock Mechanics)
Eileen Poeter (Hydrology)
Jerry Rowe (Hydrology)
Tod Schrauf (Hydrology)
Richard Talbot (Mining Engineering)

Sandia National Laboratories

Nancy Finley (Geochemistry, Quality Assurance)
Fran Nimick (Hydrologic Modeling, Quality Assurance)

U.S. Bureau of Mines

Ernie Corp (Mining Engineering)

U.S. Corps of Engineers

Richard Galster (Structural Geology)

Intera Environmental Consultants

Mark Reeves (Hydrologic Modeling)

Geotrans

Jim Mercer

University of Idaho

Roy Williams (Hydrology)

B-i

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

G/81/811
October 9, 1981

U.S. Nuclear Regulatory Commission
High Level Waste Technical Development Branch
Division of Waste Management
Washington, D.C. 20555

Attention: Mr. Lud Hartung, Project Manager

Subject: Contract No. NRC-02-81-037, Letter #19

Gentlemen:

This letter report is submitted in accordance with the subject contract, Task 6, Project #10 with our comments on BWIP Site Visit for Hydrology - Hanford, Washington, September, 1981.

The Golder Associates' hydrologists were Adrian Brown, Jerry Rowe, Eileen Poeter and Todd Schrauf. Some management input was provided the first two days by Richard Gates. No list of attendees or agenda are provided since NRC was so well represented.

Our technical comments are provided in the enclosed memo. Up to the date of this review we believe the approach taken by Rockwell to investigate the hydrology of the BWIP site has been good. They have acquired and assimulated a vast amount of hydrologic data over a relatively short time period.

The philosophical basis of the program appears to be that of establishing the broad geohydrological system framework parameters for the system using short duration localized tests of the geohydrology. We feel that this approach is useful for initial site selection and characterization at Hanford. However, the Hanford material allows areal testing, and we believe this to be an essential part of site characterization. The conceptual model currently being used has, in our opinion, been prematurely formalized. We feel that a wide range of hypotheses should be formally examined and that testing should be designed to distinguish between them.

We hope you find this report helpful in your continued monitoring of DOE progress at Hanford, Washington.

Sincerely,

GOLDER ASSOCIATES, INC.

Richard H. Gates, Ph.D., P.E.
Project Manager

RHG:lw

Enclosure - 1

cc: J. B. Martin, Division of Waste Management
M. J. Mattia, Contracting Officer

MEMORANDUM

TO: Richard Gates
FROM: Adrian Brown
SUBJECT: Trip Report--Basalt Waste Isolation Project
September 21 through 26, 1981
DATE: October 2, 1981

1.0 INTRODUCTION

This memorandum describes the findings of the trip to the Hanford Basalt Waste Isolation Project (BWIP) in Richland, Washington, undertaken by Jerry Rowe and Eileen Poeter of Golder Associates in Seattle, and Adrian Brown and Todd Schrauf of Golder Associates in Denver. This report summarizes the objective, findings, and conclusions of the hydrology review.

2.0 REVIEW OBJECTIVE

The objective of the review was to make a progress review of the site characterization activities being undertaken at the Basalt Waste Isolation Project, particularly with respect to the extent to which the completed and planned activities conform to 10-CFR-60*, both enacted and proposed.

3.0 ACTIVITIES REVIEWED

The project items which were reviewed by the hydrology team were primarily as follows:

- Overall hydrology strategy
- Geological interpretation
- Borehole geophysics
- Hydrologic testing and data analysis
- Hydrogeochemistry evaluation
- Conceptual hydrology model building
- Numerical modeling of geohydrology
- Future plans--testing and shaft.

3.1 OVERALL HYDROLOGY STRATEGY

3.1.1 Objectives

The major objectives of Rockwell's BWIP hydrology program are:

- To investigate and characterize the hydrologic conditions at the BWIP site
- To develop a conceptual model of groundwater flow in deep basalts of the Pasco Basin and to a lesser extent the Columbia River Plateau
- To develop hydrologic computer models capable of predicting repository performance
- To calibrate the computer models using field data
- To predict repository performance in terms of potential flow paths, travel times, and release rates of nuclides entering the biosphere via groundwater.

3.1.2 Approach

Rockwell has conducted hydrologic investigations for BWIP since 1977. In that time the following approach has been developed:

- A review of existing geologic, geohydrologic, geophysical, geochemical and surface hydrology data in the Columbia River Plateau with emphasis on the Pasco Basin

- The development of a conceptual model of groundwater flow in the deep basalts

- The acquisition of additional regional hydrologic information in the Columbia River Plateau from data sources such as USGS wells, irrigation wells, LANDSAT photographs and other ongoing regional studies

- The acquisition of hydrologic data from deep basalt wells drilled and tested by Rockwell on the Hanford Reservation

- The refinement of the conceptual hydrologic model of the Pasco Basin groundwater system based upon new data

- The development and calibration of both near field and far field computer models of groundwater flow and nuclide transport

- Simulations of repository performance including flow paths, travel times and release rates of nuclides into the biosphere.

3.1.3 Current Status

As of September, 1981 we understand that the following work has been completed or is underway:

- A review of existing hydrologic data in the Columbia River Plateau was presented in RHO-BWI-ST-5

- A preliminary conceptual model of groundwater flow in the deep basalts has been developed

- o A target repository location (RRL site) and horizon (Umtanum Basalt) has been chosen
- o Five deep drillholes into the Wanapum and Grande Ronde Basalts have been drilled and hydrologically sampled and tested and one hole is currently being drilled. The primary hydrologic data acquired pertains to horizontal hydraulic conductivity, hydraulic head and hydrochemistry
- o Preliminary computer simulations have been conducted as part of conceptual model development and as an aid in the selection of sites for further field testing in drillholes.

3.1.4 Future Studies

We understand that the following hydrologic studies are envisioned in the future.

- o Drilling and testing of approximately six deep holes into the basalt to yield additional hydrologic data on hydraulic conductivity, hydraulic head and hydrochemistry
- o Testing of existing paired boreholes at two locations to determine horizontal and vertical hydraulic conductivity, storage coefficient, effective porosity and dispersion coefficient. Emphasis will be placed on obtaining vertical hydraulic conductivity of the Umtanum Flow (repository horizon)
- o Continued refinement of the conceptual hydrologic model
- o Further simulations of repository performance.

3.1.5 Assessment and Recommendations

Up to the date of this review we believe the approach taken by Rockwell to investigate the hydrology of the BWIP site has been good. They have acquired and assimulated a vast amount of hydrologic data over a relatively short time period.

Field testing has been conducted almost exclusively within single boreholes. For initial investigations, this approach has been useful in defining the basic geometry and hydrologic parameters governing the groundwater flow system in the deep basalts of the Pasco Basin. However, the adequacy of this approach is questioned as a strategy for basalt hydrogeology. Basalt is characterized by low permeability sections (flow colonnades and entablature zones) interlaid with high permeability sections (flow breccias, flow tops, and vesicular zones). The low permeability material (10^{-8} meters per second or lower) can only be tested by this approach, but the medium and high permeability materials can and should be evaluated utilizing the standard hydrology methods for high permeability units: multiple hole, long term, relatively high stress pump testing.

Tests lasting from a few seconds to a few hours creating a stress of a fraction of a pound per square inch, involving a flow of a few gallons per minute or less and creating an effect reaching only a few hole diameters into the formation cannot be considered adequate for characterization of the higher permeability portions of this site under the 10-CRF-60 regulations.

Such tests tend to yield spot values of horizontal hydraulic conductivity and are not suitable for determining parameters such as vertical hydraulic conductivity of the low permeability horizons and storage coefficient. The intent of 10 CFR 60 Section 60.21 is clearly to define bulk values of hydrogeologic properties. The existing testing methods do not provide a means of simultaneously measuring hydraulic heads at various horizons within a single drillhole or measuring long term head variations. The bulk hydrogeologic characteristics of the aquifer systems and possible transient effects upon hydraulic heads are essential to understanding and predicting the flow system.

We believe that such testing can be performed within the intent of 10-CFR-60.10(d) which requires that testing not comprise the long term performance of the repository.

The scope of the detailed investigation has been limited primarily to the Pasco Basin and particularly to the area surrounding the target repository site. Because the Pasco Basin is part of a larger regional flow system it is important to understand the interrelationships between the Pasco Basin and the surrounding Columbia River Plateau. Currently this interrelationship is handled in the computer models by establishing boundary conditions; either no-flow or constant head at the limits of the Pasco Basin. We believe more work is needed before adequate boundary conditions can be established. This is important since the selection of boundary conditions within a predictive groundwater model will largely determine the predicted flow pathways and travel times.

The performance of a few high flow pump tests, observed at a network of points in the three-dimensional flow system is recommended in order to produce the following information:

- Bulk horizontal permeability values for the flow system
- A measure of the hydrologic continuity and interconnection of flow top zones
- Bulk vertical permeability values for the flow system
- Storage parameters for the system
- A major change in the system for use in calibrating numerical flow models (as required by 10-CFR-60.21 (e)(1)(ii)(E).

3.2 GEOLOGICAL INTERPRETATION

3.2.1 Objectives

The objective of the geological investigation being conducted which pertain to the hydrological aspects of the BWIP program are:

- To determine the degree of lateral continuity or variation of the stratigraphic units (flows, interflows, and interbeds) within the Pasco Basin and surrounding areas
- To determine the location and magnitude of significant structural features (folds, faults, etc.) within the basin.

3.2.2 Approach

The geology of the site is being interpreted using a combination of surface geological mapping, geophysical tools (both surface and down hole), and a limited number of core holes. Data collected from core holes include core descriptions and tests, geochemical analysis of core, and downhole geophysics.

3.2.3 Assessment and Recommendations

Generally speaking, the reviewers are in agreement with the approach which has been taken. Geological characterization has been thorough. Almost everything which could be reasonably asked to evaluate site geology is being done.. One criticism which we would make is that there appears to be a lack of emphasis on rock structure, particularly in the low permeability units. Joint information seems to have been largely ignored in the evalution to date, and there appears to have been little attempt to obtain oriented core. As joints are the primary flow path in the colonnade and entablature sections, this appears to be a significant oversight. We would recommend that much more emphasis be given to this aspect of the study.

3.3 BOREHOLE GEOPHYSICAL LOGGING PROGRAM

3.3.1 Objectives

- Obtainment of information to aid in selection of test intervals during drilling
- Obtainment of information to aid in design and evaluation of borehole completion
- Procurement of temperature data to discern geothermal gradient and/or zones of water inflow and movement
- Definition and correlation of stratigraphic units
- Determination of formation properties.

3.3.2 Approach

Development of the program is converging on a set of standard procedures. The procedure includes logging of each section of hole as drilling proceeds and logging of the entire hole before casing emplacement if possible. Data is collected on hard copy-form and on magnetic tape. Quality control is maintained by having a Rockwell hydrologist/geophysicist present during the logging process to monitor the proceedings and approve the final log copy. Further quality control measures include recording a repeat section of each log in each borehole and logging a reference borehole every three months to correct for drift. The reference borehole is also used for testing tools after repair and maintenance operations.

At present, log processing includes digitizing the hard copy data, correcting count rates for casing shifts and cable stretch, and plotting of data in the form of a log suite.

Quantitative calibration has been achieved for the following logs:

- o Fluid temperature (°C)
- o Caliper (diameter inches)
- o Sonic velocity (microsec/foot)
- o Apparent Resistivity (ohms)
- o Flow meter (ft/sec).

Nuclear and magnetic logs are collected for qualitative interpretation with respect to the relative response of the tool within the borehole.

3.2.3 Future Plans

A program for calibrating the nuclear logging tools is presently underway, with the necessary contracts open for bid. The program involves drilling a telescoping core hole on the Hanford Reservation through a section of the basalts. Analysis of the core will include information on porosity, density, acoustic velocity and permeability. An attempt will be made to develop empirical relationships between porosity and neutron-epithermal neutron count rate and density and gamma-gamma count rate. In addition, the calibration hole will provide empirical relationships describing the effect of borehole diameter on tool reponse.

The possibility of modeling the behavior of the logging tools is being considered. If such work is undertaken, the empirical relationships will provide verification of the models.

Improvements in data processing will include using the magnetic tape data in place of hand digitizing data, applying corrections for borehole environment, and assigning empirically derived values for porosity and density of material forming the borehole wall.

3.2.4 Assessment and Recommendations

- The borehole geophysical logging program is in excellent condition.

- Calibration of nuclear logs and empirical relationships describing the response of tools to borehole environment is essential if quantitative information is desired. It is possible that quantitative information on the formation material forming the borehole wall is not as valuable in the basalt environment as it is in more homogeneous environments. For example, porosity as detected by the neutron-epithermal neutron tool has little relationship with the effective porosity of interflow zones.

- The possibility of relating bulk field permeability measurements to geophysical logs should be explored although it is quite possible no relationship exists. The sonic velocity and resistivity logs (as they relate to fracturing) used in conjunction with the remaining log suite (as it relates to lithlogy) would be one possible approach to developing a relationship.

- Geophysical logs from some of the deeper boreholes (e.g., DC6 and DH4) indicated a zone below the Umtanum which appears to have similar properties as the Umtanum and yet is much thicker. This observation leads to the general question of "Why has the Umtanum unit been selected as the host rock for the repository?" The rationale for selecting the Umtanum was not discussed at the review meeting. A better repository site might be overlooked if study is limited to one horizon.

- Rockwell personnel inquired about Nuclear Regulatory Commission (NRC) criteria concerning geophysical logs. Such information was obtained from Paul Prestholt and it was reported to Rockwell that no criteria were specified by NRC, however it was expected that industry standards would be maintained in the logging program.

3.3 HYDROLOGICAL TESTING AND DATA ANALYSIS

3.3.1 Objectives

- To measure the bulk hydraulic properties of the basalt units within the Pasco Basin for input to modeling efforts.
- To determine the hydrostatic head distribution within the basin for model calibration and assessment of the region groundwater flow field.

3.3.2 Approach

Hydrological testing at the Hanford site has been mainly limited to single hole tests to measure static piezometer heads and horizontal point hydraulic conductivities of both low and high conductivity zones. In general, the testing effort has been limited to a concentrated drill and test effort over the last 2 years. Testing prior to this has consisted essentially of re-entering open holes eliminating the potential for reliable static head measurements prior to 1979. Also due to early testing difficulties much of the pre-1979 permeability data is subject to question according to Rockwell. For these reasons, current efforts must be viewed as essentially a reconnaissance.

3.3.3 Assessment and Recommendations

Although the current testing techniques employed at the Hanford site are rather standard (particularly in terms of current oilfield methods) and have been consciencíously per-formed, the exactness of the values obtained is somewhat questionable due to difficulties with the techniques as discussed below:

- Static water head--This is measured by necessity following initial development of the well and hence subject to the influences of residual drawdown effects (which are almost certainly very small). Of far more importance, is the temporal variation of these measurements which has not been significantly examined at Hanford and could result in improper conclusions about small magnitude spatial head variations.

- Air lift tests--Essentially a constant discharge test, the evaluation of test data is limited particularly in the more permeable zones due to the time delay between the cessation of the air lift pumping and the first recovery measurement. In at least one case this recovery was missed all together.

- Submersible pump tests--Again principally a constant discharge test, the evaluation of data within the more permeable zones is questionable due to the extremely low pumpage rates resulting in generally very small magnitude drawdowns and hence reduced sensitivity of analysis. Drawdowns as low as 1 foot after 24 hours of pumpage were recorded.

- Slug tests--These tests involve both damped and undamped pressure pulses induced within the formation through the drill string. Considering that the observed magnitude of the induced pressure pulses were on the order of 0.5 psi, for the test results we reviewed, these tests do not considerably stress the formation.

- Constant drawdown tests--These involved some of the larger volume tests performed on the more permeable zones but were limited in practice to flowing artesian wells. This was perhaps one of the better tests conducted of the single hole test sites.

- Pulse test--These were used for the measurement of extremely low permeability zones. The test results were probably not sufficiently accurate due to the extremely gradual pressure drops observed relative to the large compliance of the test system.

- Constant head injection test--These were also used for the measurement of extremely low permeability zones. The test result accuracy is affected by the uncertainty of potential packer leakage and the ability to measure such low flows.

The current hydrological testing program being conducted at Hanford is not sufficient to completely characterize the bulk hydrological properties of the proposed host medium nor to adequately understand the regional flow system as required by 10-CFR-60. This is mainly attributable to inadequacies in the overall hydrology strategy (Section 3.1), however, there are certain aspects of the current testing procedures which could be improved.

Drilling of larger diameter holes for the single hole tests would allow the following:

- A larger sample rock volume measured under each test technique.

- Larger submersible pumps or shaft driven turbine pumps to be used during constant discharge tests to create a more reasonable stressing of the system (this could be accomplished even if only the upper few hundred feet of the hole were kept at a large diameter).

Another proposed revision of the current procedures is to make use of downhole instrumentation to the full extent possible. Examples include:

- The current low stress levels obtained during slug tests could be increased significantly by performing a standard drill stem test instead. In such a test a downhole pressure transducer is placed below the set packer and a shut in valve is used to isolate the test interval from the drill stem.

  The drill is then swabbed or filled to create a significant pressure difference between the static (shut in pressure) and the applied head (drill string pressure).

- The low permeability tests are conducted with what must be a very compliant (soft) system in comparison to the flow volumes involved. This is particularly critical for the pulse test where pressure changes are monitored. Much of the compliance could be eliminated by simply shutting in the test interval and relying on the downhole pressure measurement.

Packer compliance may also be a critical aspect of low permeability measurement. This should be examined by setting the packers in a cased section of hole and measuring the pressure volume responses.

3.4 HYDROCHEMISTRY

Our review of hydrochemical data was brief and centered primarily on how hydrochemical studies can be used to evaluate the flow system. We did not review work relating to the chemical reactions affecting nuclide transport in the groundwater system.

3.4.1 Objectives

The objectives of the hydrochemical investigations being conducted to evaluate the flow system are:

- To investigate and characterize the hydrochemistry of groundwater in the deep basalt
- To provide hydrochemical evidence which can be used to aid in the development of the conceptual hydrologic model
- To provide groundwater age dates.

3.4.2 Approach

Rockwell is collecting and analyzing water samples from high hydraulic conductivity test zones in the deep basalts.

3.4.3 Future Studies

Hydrochemical sampling will continue to be conducted from drillholes in the high hydraulic conductivity test intervals. Work will continue on characterizing hydrochemical types and their origins. Various methods of isotope age dating of groundwater will be used.

3.4.4 Assessment and Recommendations

Water samples indicate that groundwater is generally a sodium-bicarbonate type in the Saddle Mountains basalt, a sodium-bicarbonate to sodium-chloride-bicarbonate type in the Wanapum basalt and a sodium-chloride type in the Grande Ronde. Groundwater age dates based on Carbon-14 generally range from 20,000 to greater than 30,000 years in the deep basalts. Age dating is difficult due to the low concentration of environmental isotopes upon which age-dating is based. There is some evidence to suggest mixing of deeper groundwater with shallower groundwater in the vicinity of Gable Mountain, possibly inferring higher vertical hydraulic conductivities associated with the anticlinal structure.

The quality of the water sample collected is likely to be compromised by the following changes:

- Pressure change from aquifer to surface
- Temperature change from aquifer to surface
- Contamination by contact with drill string and pump
- Contamination by drilling fluid

These changes will likely have a significant impact on eH, pH, gas concentration, trace elements, carbonate/bicarbonate balance, and possibly silicate level. As a result, the test results can only be regarded as second order data.

The other significant problem which reviewers identified was the perennial difficulty of age dating of the water. The difference in age estimates using tritium, carbon, uranium, and chlorine dating are large enough to suggest real doubt on the utility of water age dating in the context of site characterization.

Our current feeling is that hydrochemical data neither confirm nor deny the conceptual flow model of the Pasco Basin. There is evidence that distinct hydrochemical facies exist within the three deep basalt formations. Whether this is indicative of limited vertical mixing due to low vertical hydraulic conductivity and/or low vertical gradients or whether it is the result of different chemical composition of the various basalt formations is not clear.

While we recommend a continuation of the hydrogeochemical testing program, we would make a parallel recommendation that the data not be relied on as heavily as it is at present for the interpretation of regional flow patterns in the Pasco Basin. We feel that the uncertainty about the mechanisms of pre-emplacement rock/water interaction, reduce hydrogeochemistry to a second order tool for regional characterization, especially with respect to vertical flow.

3.5 CONCEPTUAL HYDROLOGY MODEL BUILDING

3.5.1 Objectives

Rockwell has clearly attempted to formulate a conceptual model of groundwater flow in the Pasco Basin which is consistent with existing data. The objectives of a conceptual model are:

- o To provide a framework in which observed hydrologic data can be explained in terms of an overall flow system
- o To provide a rational means by which sites for further data acquisition can be chosen in an optimal manner to prove or disprove the conceptual model
- o To provide a physical model which can be incorporated into a numerical computer model and simulated.

3.5.2 Approach

Rockwell has logically formulated a conceptual model of groundwater flow in the Pasco Basin and used the model to determine areas for further investigation. Based upon the conceptual model they have formulated a computer model of groundwater flow within the Pasco Basin.

The present DOE model fundamentally involves the following concepts:

- o High permeability, high porosity units interlayed with very low permeability, low porosity units.
- o Generally declining horizontal permeability with depth.
- o Low overall vertical permeability of the system, although in any given unit, higher vertical than horizontal hydraulic conductivity.
- o Generally upward vertical flow potential in the Hanford reservation area.
- o Lateral flow potential to the south and east.

- o Generally little faulting effect within the reservation.
- o General separation of the Columbia River from the deep groundwater flow system.
- o Very low permeability in the Umtanum flow (the target repository horizon).
- o System discharge from deep flow at Wallula gap or beyond.

This model is based primarily on geology, horizontal permeability, static head, water quality, water age, and preliminary numerical modeling results.

3.5.3 Future Studies

The current conceptual model of the Pasco Basin is considered preliminary and will evolve as more data becomes available. Future exploration work is being designed to attempt to prove or disprove the existing conceptual model.

Rockwell will continue to refine the conceptual model or formulate different models depending upon new data.

3.5.4 Assessment and Recommendations

Based upon the current data we believe Rockwell has formulated an appropriate conceptual model. However, there is some question as to the extent to which the future exploration and testing program will provide information to prove or disapprove the model. A major assumption in the existing model of the Pasco Basin is that a high degree of vertical isolation exists between the various basalt aquifers. We believe that a major thrust of the future investigations should be towards demonstrating that the assumed vertical isolation exists on a regional scale within the Pasco Basin. This requires that a low regional vertical hydraulic conductivity be demonstrated. Because the future testing program relies primarily upon single borehole tests it is questionable whether a regional vertical hydraulic conductivity can be determined.

The existing conceptual model depends heavily upon assumed boundary conditions at the edges of the Pasco Basin. We believe more study is required to establish boundary conditions. In particular, the effects of the shallow groundwater system and proposed recharge/discharge zones lying outside of the Pasco Basin should be evaluated. Sensitivity studies using relatively simple computer models of the conceptual flow system may prove very useful in identifying these effects.

We strongly recommend that the conceptual model of the area be kept as flexible as possible at this stage and that the several hypotheses about overall flow systems be formalized and considered in parallel. This will encourage testing efforts in the future which are designed to resolve the differences between models.

3.6 COMPUTER MODELING OF REGIONAL GEOHYDROLOGY

3.6.1 Objectives

1. Develop quantitative understanding of the natural ground water flow regime

2. Predict long term performance of waste isolation system under a variety of conditions

3.6.2 Approach

Experimentation with existing three dimensional finite element ground water models presented logistics problems, so an "in house" model was developed with the assistance of an outside contractor. Areal extent of the model has been limited to the boundaries of the Pasco Basin. Modeling efforts have progressed from a simple one layer model to a composite three layer model.

Preliminary predictions of flow paths and travel times are determined in the framework of the three layer model. Vertical head profiles from individual boreholes are applied over the entire region and the resulting flow pattern is predicted. Data points comprising such profiles were collected at different points in time and may not represent the prevailing vertical gradient at any given point in time. Vertical hydraulic conductivity, bulk horizontal hydraulic conductivity and storativity of the hydrostratigraphic units are unknown at this time, hence best estimates of such parameters are utilized in the model.

Calibration of the model against known head distribution within the basin has not been carried out because the required data is not available. Data describing the phreatic surface is available but has not been utilized to calibrate the model.

3.6.3 Future Plans

Future plans include increasing the quantity of point horizontal conductivity data, incorporating data from single hole vertical permeability tests and incorporating additional head data collected at points in space and time.

3.6.4 Assessment and Recommendations

The numerical modeling appears to be somewhat decoupled from the rest of the program, particularly the hydrogeochemistry and hydrological testing portions. Model building presently leans heavily on geological interpretation which is usually a somewhat poor indicator of regional flow systems.

Specific criticisms include:

- o Unreasonably low ranges of vertical permeability ascribed to entablature sections.
- o Unappropriate fixing of the head in the unconfied groundwater system rather than using it as a calibration/ validation factor.
- o Unreasonably close location of lateral boundaries (all DOE modeling appears to have been confined to the Pasco Basin).
- o Lack of explicit inclusion of known and possible fault lineaments.

We, therefore, make the following recommendations:

- o Expansion of the areal extent of the modeling effort to include a bulk scale model of a larger portion of the Columbia Plateau would enhance the understanding of the groundwater flow regime at the boundaries of the Pasco Basin. Such an effort would aid in selection of boundary conditions for a more detailed model representing the Pasco Basin.
- o Increased communication between modelers and hydrologists and geologists might aid the modeling effort.
- o Position of the phreatic surface and distribution (vertical and horizontal) of head at a point in time within the basin are valuable data for calibrating a groundwater model. Adjustment of model parameters to force the model to mimic actual field potentials can be used to "fine tune" the geohydrologic data (i.e. hydraulic conductivity; structural control of flow).

- As required by the proposed rules for 10CFR60.21(c)(1)(ii)(E) the model shall be verified by using "field tests, in situ tests, field-verified laboratory tests, monitoring data or natural analog studies."

  If credence is to be given to predictions made by a model, the model must be able to reproduce the initial known position of the phreatic surface and known values of the head distribution within the basin at a given point in time. In addition, the model should accurately simulate a stress on the system of similar magnitude to that which will be applied by repository emplacement. One method of making such verification is to greatly stress the system (for example by a large scale pump test) and accurately simulate the resulting head distribution throughout the basin.

For the present, the numerical modeling effort should continue to be general rather than specific, and all items which can be kept flexible should not be permaturely fixed. In our opinion, the flow of the modeling effort should be kept at the level of parametric studies until data is obtained from the field which would allow a reasonable validation of the models.

3.7 FUTURE FIELD TESTING PLANS

3.7.1 Summary

The future plans for the project to the submission of the site characterization report and into the next 5 years include:

- Continuation of core hole testing program with holes placed south of the Reference Repository Location (RRL) (hole DC16 already in progress) west of the RRL (DC-17), northeast of the RRL (DC-18), near Wallula Gap (DC-19), and on the Columbia River near Reactor N (DC-21). The full suite of tests now being used will be used in these holes.

- o Initiation of dual hole testing in two sets of paired holes, mainly for vertical permeability and tracer tests.

- o Deepening and testing of Hole RRL-2 for shaft location evaluation.

- o Single hole testing of the material penetrated by the shaft.

- o Observation and testing of the shaft station.

3.7.2 Assessment and Recommendations

The shaft testing and near RRL testing activities appear to be an essential part of site characterization and are entirely appropriate in this context. However, we do not believe the proposed dual hole testing will be effective in providing useful vertical permeability data, or in defining areal hydraulic characteristics, nor do we believe that the remote holes (DC-19, DC-21) will materially assist in defining the regional hydrogeology.

Elements which appear to be missing in the future plans are:

- o Development of credible water quality sampling data at depth.

- o Development of accurate head data at depth against which models can be calibrated.

- o Development of an adequate understanding of bulk horizontal and vertical permeabilities particularly for the materials above the respository horizon.

- o Development of system changes which can be used to verify numerical models.

We believe that these elements can and should be addressed in this geologic setting.

Based on the above, we recommend that:

- The shaft program be pursued with all haste so as to allow evaluation of the Umtanum layer.
- The near RRL core hole program be performed as planned.
- The far field program be modified to place more emphasis on permanent well completion and areal high stress testing of the geohydrology system.

4.0 OVERVIEW

Our review conclusions can be broken down into three areas: philosophy of program, field execution, and development of conceptual model.

4.1 PHILOSOPHY OF PROGRAM

The philosophical basis of the program appears to be that of establishing the broad geohydrological system framework parameters for the system using short duration localized tests of the geohydrology. We feel that this approach is useful for initial site selection and characterization at Hanford. However, the Hanford material allows areal testing, and we believe this to be an essential part of site characterization.

4.2 FIELD EXECUTION

The review of the method of execution of those tests being performed is an essential part of our assessment. We find that with some exceptions, the current testing is being performed in a technically acceptable manner.

4.3 CONCEPTUAL MODEL

The conceptual model currently being used has, in our opinion, been prematurely formalized. We feel that a wide range of hypotheses should be formally examined and that testing should be designed to distinguish between them.

We find that the team at Rockwell is well trained, enthusiastic, and is producing with a high quality. We believe that the time has come to diversify the program, but excepting that one general criticism of the future plan we conclude that the project is in excellent condition.

Respectfully submitted,

GOLDER ASSOCIATES

EP for Adrian Brown

Adrian Brown
Group Leader, Hydrology

EP for Jerry Rowe

Jerry Rowe
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Appendix C

Golder Associates Incorporated

Mining Engineering Trip Report

C-i

Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

G/81/808
October 9, 1981

U.S. Nuclear Regulatory Commission
High Level Waste Technical Development Branch
Division of Waste Management
Washington, D.C. 20555

Attention: Mr. Lud Hartung, Project Manager

Subject: Contract No. NRC-02-81-037, Letter #18

Gentlemen:

This letter report is submitted in accordance with the subject contract, Task 6, Project #3, with our comments on BWIP Site Visit for Mining Engineers - Hanford, Washington, September, 1981.

The Golder Associates' mining engineer was Richard Talbot and some management and rock mechanics input was provided the first two days by Richard Gates. No list of attendees or agenda are provided since NRC was so well represented.

Our technical comments are provided in the enclosed memo. We feel that Rockwell International and their contractors are technically sound in their approach at BWIP. The programs (schedules and budgets) are continually changing at the DOE level and this does impact on the technical soundness, but the job is being well done with these constraints. The Near Surface Test Facility is proving to be a valuable asset for the development of in-situ testing of basalt.

We hope you find this report helpful in your continued monitoring of DOE progress at Hanford, Washington.

Sincerely,

GOLDER ASSOCIATES, INC.

R. H. Gates, Ph.D., P.E.
Project Manager

C-ii

RHG:lw

Enclosure - 1

cc: J. B. Martin, Division of Waste Management
M. J. Mattia, Contracting Officer

Re: NRC/BW~~IP~~ Site Visit, September 21-25, 1981, by R. Talbot

1. EXPERIMENTAL SHAFT TESTING FACILITY (ESTF)

(a) Design Plan for ESTF

The current version of the design for the ESTF was not made available to either NRC or Golder Associates. The following comments are based on information obtained during discussions with DOE/Rockwell/Kaiser personnel.

The ESTF as planned consists of two phases. Phase I includes:

- An exploratory borehole located some 300 feet from the proposed shaft site.
- An exploratory shaft to a depth of 4200 feet, some 500 feet below the repository horizon.
- A belled-out test chamber at the repository horizon.

Phase II includes an additional 200 feet of tunnel development from the shaft.

The shaft will be bored to a diameter of 10 feet with a finished diameter of 6 to 7 feet.

The objectives of Phase I are stated to be:

- Obtain data for shaft design.
- Demonstrate that a shaft can be sunk to the required depth at this location and evaluate boring as a shaft construction method.
- Verify that the groundwater system can be effectively sealed and evaluate the effects of construction on the rock.
- Determine the hydrologic properties of the reference repository horizon.
- Complete geomechanical tests and rock mass characterization of the repository horizon.

The key issues identified by Rockwell are:

- Hydrologic containment
- Tectonics
- In situ stresses, thermomechanical response and the ability to model repository performance.

The overall schedule of activities is as follows:

• Start exploratory borehole:	January 1982
• Complete exploratory borehole:	March 1983
• Complete shaft boring demonstration:	April 1984
• Equip shaft for access:	December 1984
• Complete hydrologic testing from shaft:	April 1985
• Complete belling and geomechanics testing:	May 1985

An area of 18 square miles has been identified (A-H block) as a potential area for the repository. A provisional site selection within this area has been made based on pre-existing land use and geological criteria. The ESTF will be located within the proposed repository area.

(b) Location of ESTF

The proposed repository layout incorporates a substantial shaft pillar between two main storage areas. This pillar, 7800'x2730', will contain the five main repository shafts, the contact waste storage panel, and the ESTF (Figure 1). The exact location of the ESTF within the shaft pillar has not been specified. It is our opinion that this is the correct decision, and that the shaft pillar is sufficiently large to contain the ESTF without jeopardizing the performance of the repository. Information obtained from this initial entry into the repository horizon will provide a base with which to compare and evaluate the results of ongoing exploration drilling and development activities, which are an essential part of repository design verification.

This raises an important issue. DOE/Rockwell are of the opinion that the ESTF is not subject to licensing procedure, yet, because the ESTF will be located within the proposed repository, the construction and subsequent decommissioning of that facility must be shown to meet repository design criteria. Construction methods are discussed below. The sealing of the shaft during construction has been addressed quite thoroughly in the report by Cobbs Engineering, "A Review of Drilled Shaft Sealing for the BWIP, September 1981." No information was available on decommissioning or the effect of the ESTF on long-term containment.

It was stated by Kaiser Engineers that a program for decommissioning the exploratory shaft will be included in the conceptual design report to be published in September 1982. (Not currently available to NRC.) This will generally consist of grout curtains above and below aquifer zones, placed from inside the shaft. The shaft liner will be left in place. It is our assumption that the shaft will also be backfilled in a manner similar to that proposed for the main repository shafts.

(c) Shaft Construction

The proposed method of shaft construction is full-face drilling. This position is supported and justified in RSD-BWI-TP-007, Appendix A, "Identification of a Preferred Shaft Sinking Method for a Nuclear Waste Repository in Basalt, December 1980." The primary reasons for selecting boring were stated to be:

- Control of groundwater and ground conditions
- Shorter sinking time
- Safety
- Reduced damage to rock wall.

The shaft would be lined by grouting behind a steel liner that is floated into place. This liner would be fitted with a number of ports to allow subsequent drilling, sampling and hydrologic testing of the aquifers overlying the repository horizon.

It has been suggested that boring the shaft will result in a loss of geological and hydrological data. The plan for the ESTF is that data sufficient for site characterization will be obtained, after completion of the shaft, from horizontal borings. This appears to be a reasonable position to adopt. The alternative approach, conventional shaft sinking, would allow a detailed examination of the shaft wall before lining, but it would be necessary to freeze and grout ahead of the shaft bottom. The effect of the construction on the hydrological system would therefore still not be observed.

The significant time advantage offered by fullface drilling and the minimized fracturing of the surrounding rock strongly recommend the use of this construction method for the ESTF. The conceptual design has been based on conventional drill and blast shaft construction, but Kaiser indicates that they would move toward shaft drilling when the technology is proven. The ESTF will provide significant data for this purpose.

The shaft drilling will be preceded by an exploratory borehole, based on deepening the existing RRL2 hole, which is presently 1500 feet deep. This work will include:

- Core logging
- Complete suite of downhole geophysical tests
- Full suite of laboratory physical property testing
- Hydrofracturing stress measurements.

The details of this test program were not spelled out. Geological, geophysical and physical property testing are intended to verify projected data for the site. The hydrofracturing may provide significantly new information on in situ stresses.

The shaft design and dimensions are adequate for the Phase I and II layout, as they are presently defined. If this program is extended to include the ADTF, a second shaft will have to be sunk to the repository horizon. A plan for the ADTF is not currently available.

(d) Testing Program for ESTF

The test program is defined only for Phase I of the ESTF. This is a very limited program, which includes:

- Hydrologic testing by means of horizontal holes drilled out into the shaft wall. This is intended to establish, among other things, the vertical conductivity of critical horizons.
- Coring and core logging from drillholes.
- Physical property testing using drill core.
- Measurement of in situ stresses at the repository horizon.

- Measurement of deformations (with extensometers) as the shaft is belled out.

Details of these tests, their scope, number, equipment and test procedures, were not available to us. While this work appears to meet the objectives of the ESTF Phase I program as defined, we are unable to assess the test program vis-a-vis repository design and site characterization, because:

- Phase II test program has not been defined at all
- Phase I physical property testing does not include any in situ tests.

In particular, we note that the time allotted for all of the hydrologic and geomechanical testing is extremely short (approx. 4 months) and it is not clear that the scope of testing laid out can be completed in that time.

The work that is being done, and planned, in this area is, we believe, of a high technical quality, and it may reasonably be assumed that data would be satisfactorily developed in those areas where it is determined to be required. We consider, however, that the ongoing test program and its application to the site characterization/design process should be outlined in more detail, so that the orderly acquisition of relevant data and the application of the test results to the planned design of the repository can be evaluated. This should include a clear definition of the scope of work for:

- Phase I ESTF
- Phase II ESTF
- ADTF

We believe that the site characterization plan should include this information, and the Phase I/Phase II work might typically be assumed to include the suite of tests currently defined by Golder in our Technical Assistance Task 2. Rockwell requested that NRC firm up their plans for any R&D testing at depth at Hanford since early coordination is required.

At this stage we can conclude that the ESTF Phase I work will determine the feasibility of blind drilling a deep shaft in basalt, the in situ state of stress at the repository horizon, and, possibly, some data on the rock mass deformation characteristics at the repository horizon.

2. CONCEPTUAL DESIGN

(a) Functional Design Criteria

Golder Associates did not participate in discussions of RHO-BWI-CD-38 Rev. 3, and have no further comments in this area.

(b) Site Investigations and Repository Design

The interface areas between site investigation and repository design can be considered as:

- Geology
- Hydrology
- Rock Mechanics

All site investigation activities are limited by the imposed constraint to minimize the number of penetrations to the repository level, and it is beyond the scope of this report to discuss what will constitute an acceptable minimum. The Rockwell program therefore was reviewed in terms of the sequence of data acquisition and its scope.

Geology

The candidate repository site has been selected after consideration of the regional geology, based on detailed outcrop mapping, deep drilling, and cross hole correlation. This work has not been reviewed in depth by Golder, but the scope appears to justify further exploration at the selected site.

The ongoing preconstruction data acquisition program includes:

- Deepening RRL2 to 4200 feet
- Blind drilling an exploratory shaft to 4200 feet to gain access to the repository horizon
- Horizontal core drilling (+50 feet) from the shaft at specified locations, primarily for hydrological testing
- Belling out the shaft at the repository horizon (Phase I, ESTF)
- Approximately 200 feet of linear development at the repository horizon (Phase II, ESTF)

- A currently undefined development program for the ADTF/TEF, but which will almost certainly include one additional shaft and connecting development.

In addition, Kaiser Engineers has an exploration program contained in their conceptual design which includes:

- Approximately 20,000 feet of linear development as the repository horizon.

- Horizontal core drilling between development.

It is not clear at this point whether or not these two elements would precede construction authorization. As this development work provides a substantial part of site verification, the timing is crucial. This is an issue that should be discussed further with DOE. This total program of work will provide fairly detailed geological data over an area of 5 storage panels (equivalent to 5 years of waste storage), the experimental storage panel and the shaft area (Figure 2).

This overall program of data acquisition appears to be well thought out and provides increasing confidence in the level of geological data. The repository construction development and exploratory drilling, in particular, provide detailed data over an area almost one-quarter of the total storage area, before full panel development and waste storage is started. This work should satisfactorily address the questions related to the proper location of the repository horizon within the Umtanum flow and anticipate major structural defects within that specific area. Our only comment here is that this type of advance development should be continued over the life of the repository, to precede full panel development at all times.

Hydrology

The conceptual design currently provides for an average pumping capacity of 2500 gpm. As we have previously indicated in our review of CD-35 and CD-38, the validity of this assumption must be verified. Clearly, the exploration program previously outlined should provide some opportunity to investigate potential problems at the repository horizon. Detailed comments on the hydrological program are provided in our letter number 19.

Rock Mechanics

The work done by Kaiser on the rock mechanics design is based on the concept of the Rock Stress Safety Factor, as described in CD-38. This is, in our view, a rather simplistic approach, which may be adequate for conceptual design but needs to be upgraded for final design. In discussions with Kaiser, they generally agreed with this conclusion.

A basic weakness of the design studies, and hence the integration of site investigations with the design process, is the lack of definition of an acceptable design procedure for the final repository design. It is our view that the scope of site investigations and testing should be clearly tied in to the design process, and this link has not as yet been demonstrated by Rockwell/DOE for the Hanford site.

(c) Conceptual Design

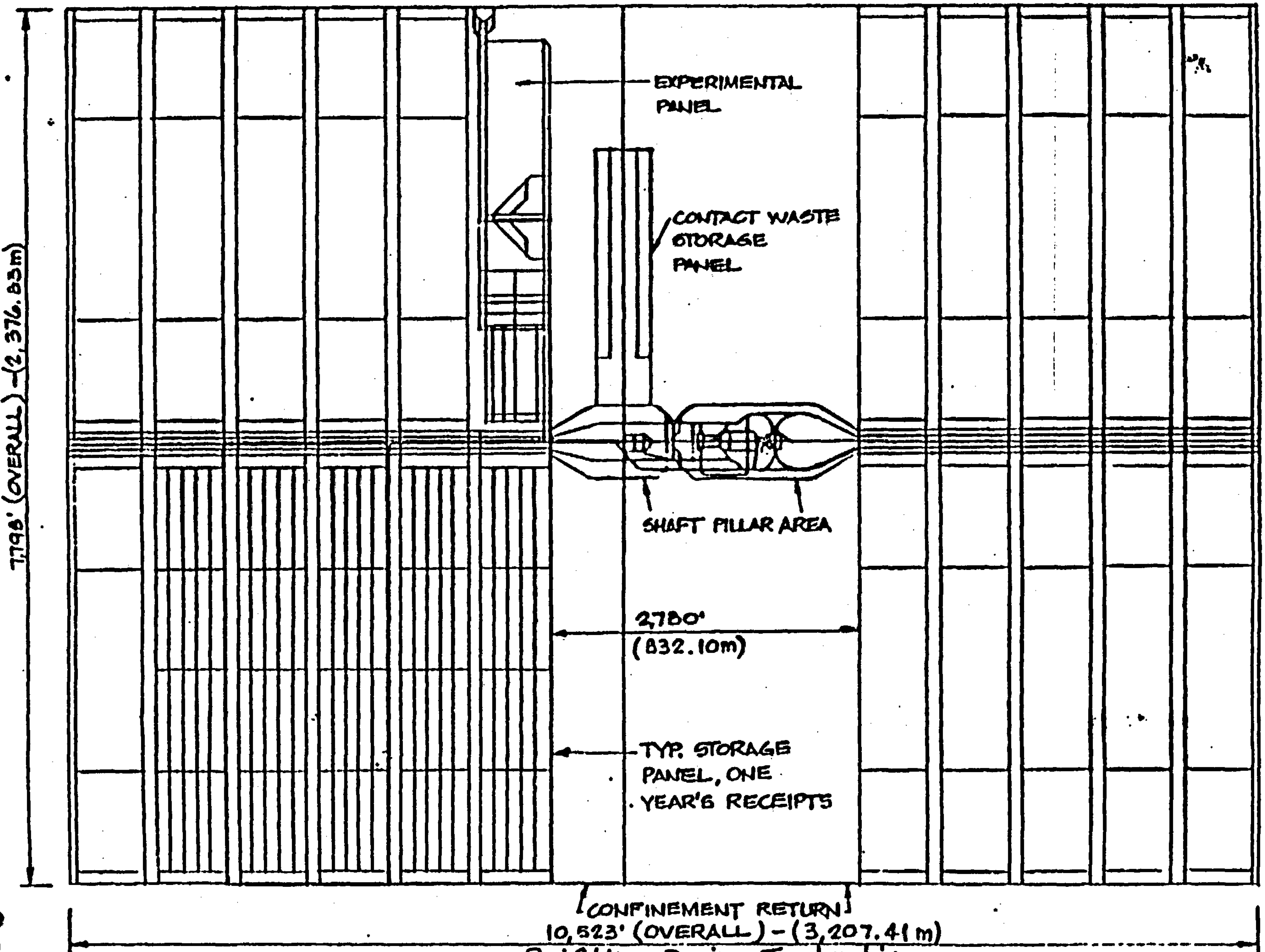
The current version of the Kaiser Engineers conceptual design is not available to us, and it will not be released until September 1982. We have, however, obtained outline data from Kaiser, either in discussions or on paper. Clearly it is an improvement on the previous design document (CD-35) and generally appears to meet the design criteria specified in CD-38.

It is not clear that the design incorporates an evaluation of long-term containment or any performance modeling. We again emphasise that this is an area that must be addressed at some stage, and it would be reasonable to expect that a strategy for doing this should be established at an early date.

3. NEAR SURFACE TEST FACILITY (NSTF)

The near surface test facility was visited, and some discussion was held with K.S. Kim and A. Krug of Rockwell concerning the test program and ongoing work. The concept of the NSTF is that it not only provides useful data in some areas, particularly thermal effects, but also provides an evaluation of test procedures and data monitoring methods.

It was stated by Rockwell that the primary usefulness of the NSTF was to develop technologies and procedures for repository evaluation at depth. While some of the data (thermal effects and in situ block tests) may be useful in predicting effects at depth, an evaluation of the repository horizon must be made on the basis of the rock conditions that exist at that depth. We believe that the general program of exploration at depth provides ample opportunity to make that evaluation.



— Drifting During Exploration

NWRB REPOSITORY LAYOUT (FIGURE 1)

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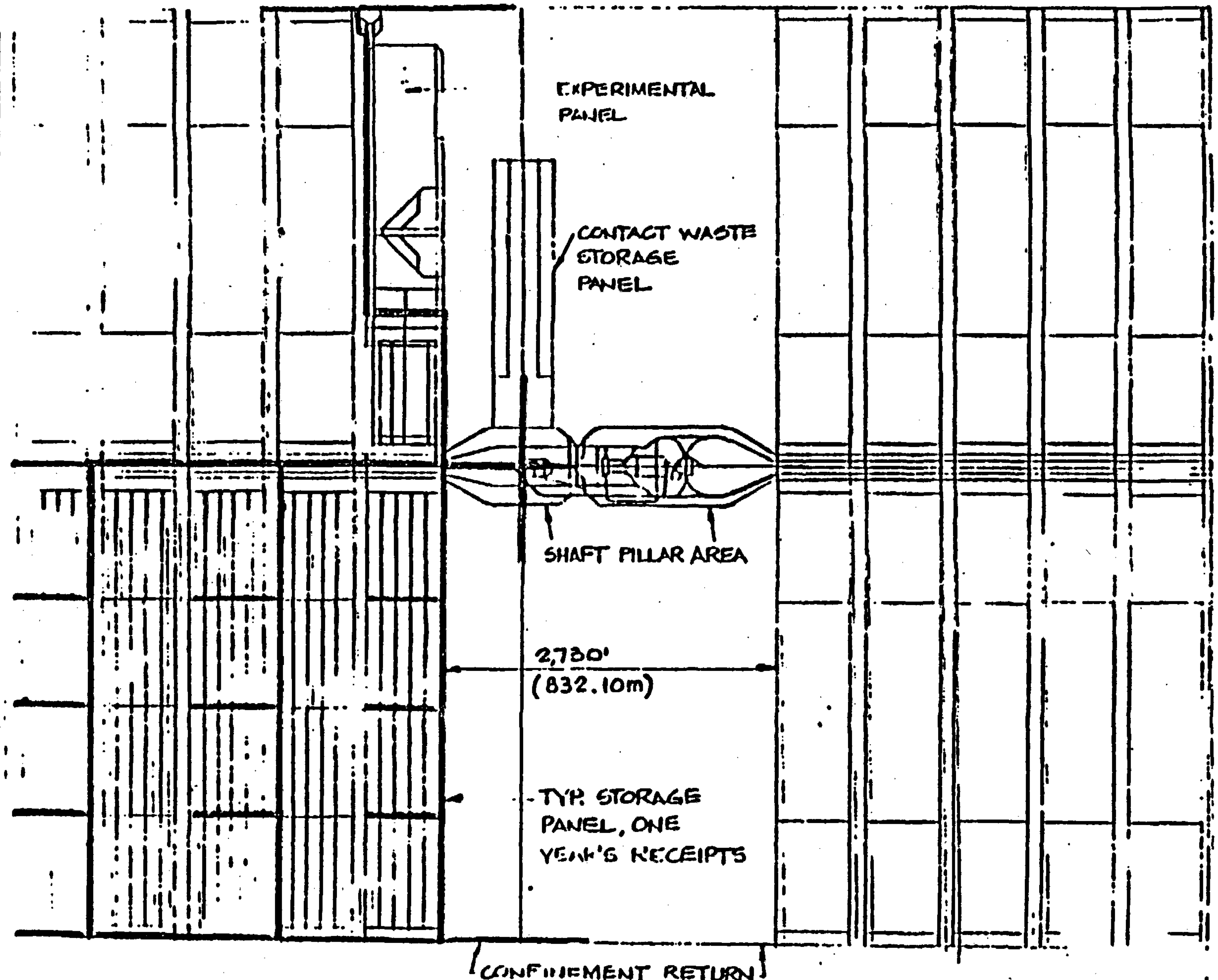

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Drill holes - Exploration Program

NWRP REPOSITORY LAYOUT (FIGURE 2)

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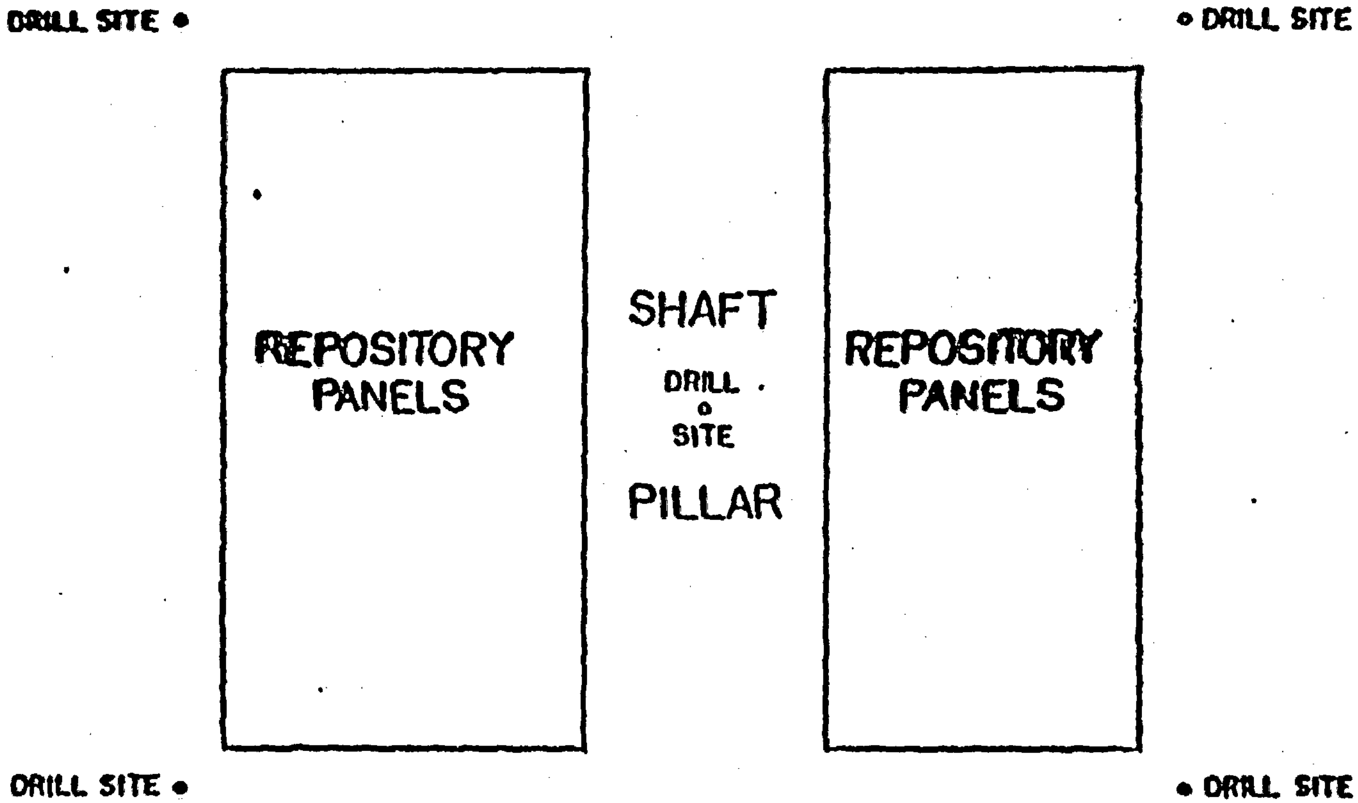

REPOSITORY SURFACE EXPLORATION

208.

DATA OBTAINABLE ONLY FROM AN UNDERGROUND EXPLORATION PROGRAM

- MINING-INDUCED POTENTIAL FOR RADIONUCLIDE MIGRATION
- PHYSICAL RESPONSE OF THE HOST ROCK TO THERMAL LOADING
- HOST ROCK GEOLOGY (DETAIL)
- GROUND CONDITIONS
- SCHEDULES
- MINING METHODS FOR OPENING, OPERATING AND DECOMMISSIONING

UNANTICIPATED OCCURRENCES LEADING TO CONSTRUCTION CANCELLATION

1. DURING SINKING OF EXPLORATION SHAFT
   - o EXCESSIVE WATER
   - o EXPLOSIVE OR TOXIC GAS
   - o EXCESSIVE ROCK PRESSURES

2. DURING HORIZONTAL EXPLORATION
   - o EXCESSIVE WATER
   - o EXPLOSIVE OR TOXIC GAS
   - o EXCESSIVE ROCK PRESSURES
   - O UNACCEPTABLE FAULTING OR FOLDING
   - o LARGE AREAS OF BAD GROUND

CONCLUSIONS

1. UNDERGROUND EXPLORATION PROVIDES DATA NEEDED AND NOT AVAILABLE FROM SURFACE
2. UNDERGROUND EXPLORATION PROVIDES STATISTICAL CONFIDENCE FOR EXPENDITURE OF LARGE FUNDS
3. UNDERGROUND EXPLORATION AND TESTING IS COMMON IN THE MINING INDUSTRY FOR GRASS ROOTS PROJECTS

Appendix D

Bureau of Mines

Trip Report

TRIP REPORT

BASALT WASTE ISOLATION PROJECT

REVIEW MEETING

September 21-25, 1981

Ernest L. Corp

U.S. Bureau of Mines

BACKGROUND

Under an interagency agreement between the Nuclear Regulatory Commission and the Bureau of Mines, BOM has agreed to provide mining engineering consultants to NRC to assist them in their role as a review and certification authority for an underground nuclear waste repository. BOM assigned Ernest L. Corp from the Spokane Research Center to serve as a consultant to NRC on the Basalt Waste Isolation Project (BWIP).

Initial support was provided to NRC in April 1981 with BOM's review of the Preconceptual Design Report for a Nuclear Waste Repository in Basalt, Project B-301 (RHO-BWI-CO-35). Written comments on this review were provided to NRC in April.

During the week of September 20-24, 1981, a joint meeting was held in Richland, Washington between NRC and their consultants, Rockwell (DOE's prime contractor) and their subcontractors to review progress on BWIP. Topics covered included hydrogeology, waste package design, exploratory shaft and repository design, quality assurance, geophysics, and remote sensing. This trip report will critique principally the group discussions involving design of the Exploratory Shaft Test Facility, Near Surface Test Facility test results, borehole and shaft sealing, and conceptual design of the repository.

GENERAL COMMENTS

The September 20-24 meeting provided me with my first opportunity to obtain specific facts concerning BWIP, thereby enabling some assessment of the program's objectives, planned work, and results to date. Information released in last year's Preconceptual Design Report (CD-35) was very general and provided no decision logic or criteria as to what constitutes an acceptable or unacceptable site or repository design.

The meeting also impressed me with the fact that there are numerous capable people working on the project, and if certain programmatic problems can be overcome, the project can achieve its intended objectives.

The first of these objectives is to assess the feasibility of siting, constructing, and operating a repository in the basalts underlying the Hanford site. Assessment of siting feasibility should be a prerequisite to any other objectives in the program, particularly objective No. 2 which is to provide engineering technology needed for detailed design of a basalt repository. However, in none of the published material or meeting discussions has a criteria been presented that permits a policy decision to be made on the acceptability or unacceptability of the site. Acceptance/rejection criteria should have been established at the beginning of the project so that a site suitability decision becomes a continuing consideration as characterization data is collected. If, at any time, the criteria are not met, a rejection decision can be made and efforts can be concentrated on alternative sites. This is the principal use of systems engineering; a use that appears to be omitted from the system's objectives of BWIP. It seems imperative that some acceptance/rejection criteria be established now, even if it is after-the-fact. Without such criteria, site characterization can continue indefinitely or until some arbitrary institutional deadline is reached that requires making a decision on the information accumulated thus far. This does not represent a wise use of resources.

Complicating the problem of inadequate selection criteria is a tendency or philosophy that contravenes the need to assess site feasibility. This philosophy produces two results: 1) an avoidance to attack the heart of the issue--the repository horizon--and to concentrate research and development and data collection on peripheral efforts such as the Near Surface Test Facility; and 2) establishment of fixed guidelines concerning minimum penetrations into the repository which seriously restrict or even disallows the collection of critical data. Although an unintentional by-product of multi-level management and programmatic constraints, this philosophy gives an appearance that the longer the problem is studied, the greater the assurance that the site will be an acceptable repository.

There are basically only two critical issues that must be addressed in a policy decision as to site acceptability: Are the hydrologic conditions suitable for a repository, and are the rock properties and stress conditions at the repository level (Umtanum flow) suitable for waste isolation from the biosphere? Data necessary to address the latter of these issues are almost nonexistent, and, in fact, will not be obtained until an exploratory borehole(s) and an exploratory shaft (ESTF) are sunk to the repository horizon and insitu tests are conducted. Site characterization, therefore, cannot be considered complete until the repository horizon is penetrated, explored, and tested. The final Site Characterization Report should include these findings.

As to the hydrologic suitability of the site, there is much information still lacking. There has been a concerted effort by Rockwell to accelerate the hydrologic testing and obtain a better understanding of the groundwater flow field in the basin. This catch-up effort may not be completed by the 1985 site selection deadline. It seems imperative, therefore, that more effort be concentrated in the repository area, and, again, definite acceptance/rejection criteria be established for hydrologic suitability. Additional boreholes, other than the one confirmatory borehole for the Experimental Shaft Test Facility (ESTF), should be considered. This is particularly important with regard to measuring vertical permeability, which requires at least two boreholes. The vertical permeability data obtained from horizontal holes in the ESTF may not be representative of actual insitu values because of fracturing and stress redistribution around the borehole.

Again, hydrologic conditions, rock properties, and insitu stress at the repository site are major factors controlling site acceptability. They should be confronted directly with go/no-go criteria established apriori.

NEAR SURFACE TEST FACILITY (NSTF)

The September 22 visit to the NSTF was my second. The stated objectives of the NSTF are to: 1) test basalt insitu, 2) qualify basalt as a repository medium, 3) provide a design basis for key repository elements, and 4) demonstrate placement, storage, and retrieval of waste. At present only full-scale heater tests and large-scale rock-properties tests are being conducted.

As stated previously, I consider the NSTF a peripheral effort that avoids the principal issue--the repository horizon. It is not clear how the testing and data obtained at the NSTF relates to the testing and data needs of the ESTF, the Test Evaluation Facility (TEF), or the At Depth Test Facility (ADTF). The insitu heater and rock properties tests conducted in the Pomona basalt may or may not be representative of conditions in the Umtanum basalt. Different fracture patterns, porosities, mineral types, degrees of saturation, etc., can significantly alter the data. It is almost certain that the same type of tests will have to be conducted again at the repository horizon to provide a design basis for key repository elements (objective 3), and to qualify Umtanum basalt as a repository medium (objective 2).

To demonstrate the placement, storage, and retrieval of waste (objective 4) does not require an underground facility. This a materials handling problem that can be solved in a surface mockup. In fact, there is little value in even conducting such tests until more precise information is obtained on the size and shape of the repository, the type of canister, and its mode of emplacement. This information is dependent on the properties of the Umtanum basalt (the thickness of the entablature), the insitu stress field, retrieval procedures, etc.

It appears that the principal function of the NSTF is to provide a practice area for evaluating different test procedures and training personnel in their use. Its use, therefore, does not seem to fall on the critical path for determining repository acceptability or repository design. It would seem more prudent at this point in time to redirect resources allocated to the NSTF to the ESTF and TEF.

EXPERIMENTAL SHAFT TEST FACILITY (ESTF)

The proposed exploratory shaft scheduled for sinking in May of 1983 represents the first effort in BWIP to assess the feasibility of siting and constructing a repository in the Umtanum. It is also the first project that mentions the use of decision logic for location confirmation, sinking procedure, and sealing verification. Although the criteria or bases for the decision logic are somewhat general or yet to be determined, it is encouraging to see recognition of the fact that there indeed may be circumstances whereby the site will not make a suitable repository. Continuation of this effort to develop more specific decision (acceptance/rejection) criteria will make it much easier to develop a meaningful testing program in the ESTF.

Objectives of the exploratory shaft are to: 1) determine the suitability of the proposed location and obtain information for shaft design; 2) demonstrate that a shaft can be sunk and assess the construction method; 3) verify shaft seal-off and sinking effects on the surrounding rock; 4) measure hydraulic conductivity of the repository horizon for isolation capability; and 5) characterize the rock mass at the repository horizon.

Objective No. 1 is to be satisfied in part by a single confirmatory borehole drilled through the repository horizon. The borehole will provide geologic data, flow depth and thickness, temperature, hydraulic conductivity, and rock strength. The single borehole idea versus multiple boreholes originates from the concept of minimum penetrations into the repository horizon. In my opinion the one-borehole concept represents an error in sound engineering judgment. How many mines, dams, buildings, or other engineering projects would ever be undertaken on the basis of one borehole. The thought is unthinkable. Two boreholes at least are needed for proper hydrologic testing, and at least four additional ones should be drilled into the four quarters of the proposed repository area. There is no guarantee that the thickness, quality, fracturing, or conductivity of the basalt is uniform throughout the Umtanum. If borehole sealing is even a concern in terms of groundwater intercommunication, then shaft sealing must border on the impossible. It is suggested that a more realistic viewpoint be adopted concerning exploration of the Untanum layer.

The decision logic for a confirmatory borehole provides two alternatives: 1) proceed with shaft drilling, and 2) abandon location. Although the latter alternative is offered, discussions with rock mechanics personnel revealed that there were no conceivable circumstances whereby borehole findings would stop shaft drilling. Thus, there seems to be no rejection criteria to back up the intent of using decision logic.

Plans to blind bore a 7- to 8-foot-diameter exploratory shaft instead of sinking with conventional drill and blast have caused considerable controversy. However, with four major acquifers overlying the site, and one of these possibly capable of producing 173,000 gpm, conventional sinking can only be accomplished with freezing. Freezing to 2,000 feet is an extremely time-consuming and costly endeavor that could delay a site selection decision by three to four years. Considering the following advantages and disadvantages of boring versus conventional sinking, I feel that boring is a wise choice.

Advantages--Bored Shaft With Grouted-Steel Casing:

1. Shaft can be completed in 18 months versus three to four years (possibly 6 years) providing an early opportunity to view and test the Umtanum.
2. Less fracturing of wall rock from blasting or freeze expansion.
3. Increased safety and greatly reduced cost.
4. A seven- to eight-foot-diameter bored shaft may be considered state of the art.
5. Rock permeability tests can be conducted through portholes in the steel liner permitting an analysis of vertical flow outward from the shaft. No permeability tests can be conducted in frozen ground.
6. May indicate feasibility for boring the five repository shafts.

Disadvantages--Bored Shaft:

1. Cannot observe exposed rock while sinking. With freezing, only geologic fracturing could be mapped. Basalt is already known to be highly fractured and mapping will serve very little purpose.
2. Permeability tests through the liner portholes will be non-standard and may not provide any data on the vertical conductivity of undisturbed basalt. This provides more justification for a second confirmatory borehole.

3. May not achieve an adequate grout seal between the steel liner and shaft wall. Can be minimized by special inspection techniques.

4. Will not achieve exploratory shaft objectives 2 and 3 if it is determined that conventional sinking with freezing is still required for the repository shafts.

The large acquifers overlying the proposed repository site are a major engineering obstacle to site suitability. The ability to seal these acquifers is a critical unknown that may never be completely resolved. This problem can conceivably be minimized if all repository shafts were bored rather than conventionally sunk through frozen ground. Freezing can solve a multitude of problems during shaft sinking, but may create a multitude of unsolvable problems after the thaw. Bored shafts, if they can be sunk in large diameters, may be the only salvation for a Hanford repository location.

Once the exploratory shaft is completed, there appears to be some confusion as to what types of testing will follow. Proposals include: a bell-out at the repository horizon; driving several hundred feet of drift, driving four miles of drift, boring off the drifts, and sinking a second exploratory shaft; and no plans at all until Phase II is formulated. The bell concept seems to be based on the idea that there is some restriction to exploring the Untanum. After the large investment in sinking an exploratory shaft, I would hope there are no restrictions to looking at the area it was intended to service. It seems prudent, therefore, to drive as much drift as possible and obtain as much information as possible on the Umtanum layer. This should all be in the same work phase as shaft sinking (Phase I), and not in a second phase (TEF or ADTF) to be determined later. This is analagous to chewing your food in Phase I, and swallowing in Phase II. If Phase I wasn't executed properly, you choke in Phase II.

The completion of the exploratory work at the Umtanum represents the most crucial decision point in BWIP. At this point, the extent of the Umtanum will be known, its physical and hydrologic properties and insitu stresses will have been measured, and some knowledge will be available on the overlying strata and the ability to seal it. It is of utmost importance, therefore, that specific acceptance/rejection criteria be established before the shaft is sunk. If the criteria are acceptable, additional exploratory drifting (with a second shaft) should be done to completely delineate the repository horizon, and perform any long-term testing that is needed. If the criteria are unacceptable, it is time to stop spending money and look elsewhere for a site.

Discussions were held regarding the types of rock mechanics tests that would be conducted at the repository horizon and what information was critical to repository design. It was implied that the standard battery of rock mechanics tests would be conducted, but very little thought has been given to how the resulting data will be used for design, or how it may critically affect design. These scenarios are a necessary prerequisite to developing decision logic on site acceptability.

There also appears to be some programmatic conflicts that could seriously impair data collection from the ESTF. The schedule allows only 6 months for rock mechanics testing. A minimum of 10 months is required, If management has already decided that there will be a repository at Hanford, and crucial rock mechanics data has no influence on this decision, then the ESTF should be eliminated and resources diverted to repository construction. The approach that no repository site is unacceptable is not an undeniable one providing an unlimited construction budget is available.

REPOSITORY DESIGN

The updated repository design is a vast improvement over that presented in the original Preconceptual Design Report. This is particularly true for the design of the access shafts where lining thickness (18" max) and shaft diameters (16' max) have been greatly reduced. The question was raised as to why all 5 shafts were centralized at the center of the repository versus having the ventilation exhaust shafts at the periphery. The disadvantages of the centralized arrangement are that increased ventilation pressures are required to bring air back through returns from the peripheral areas, escape is limited in case of a centralized disaster, and the complexity of the centralized area is increased (added returns, crossovers, bulkheads, etc). It was pointed out, however, that exhausting from two peripheral points requires an additional shaft which violates the constraint of minimum penetrations. Separation of the shafts can also pose security problems.

These considerations are probably valid as long as the shaft diameters remain the same as proposed. However, if boring appears to be a feasible alternative to conventional sinking, then shaft diameters may have to be scaled down and the number of shafts increased. If this occurs, the only argument in favor of shaft centralization is security. This should not outweigh the other advantages. Also, if boring is feasible, BOM's April 1981 comments regarding standardization of shaft sizes should be considered. This would greatly reduce the cost of sinking, operating, and maintaining the repository shafts.

The question was asked about the 6 1/2 year time frame required for sinking a conventional shaft by freezing. A time breakdown was not readily available so the accuracy of the estimate cannot be evaluated. Offhand a three-year time frame sounds more plausible.

There were many other comments concerning repository design contained in BOM's April review. Time did not permit discussions on all of these items, and many may still be applicable.

The greatest shortcoming in the proposed repository design is in the actual rock mechanics design work itself. Kaiser's design assumes a hydrostatic stress condition at the repository level, and all openings were designed based on a minimum rock stress safety factor (RSSF) of 2.0. RSSF is essentially a theoretical number arrived at by hand calculation that gives a qualitative indication of stress levels around an opening. It should by no means be considered a quantitative design tool for predicting repository rock behavior. Additionally, discing found in some of the cores taken from the Umtanum indicates that a hydrostatic stress condition does not exist. In fact, there may be a high, nonuniform component of horizontal stress that could significantly alter the present design. It is apparent at this point in time that no final decision can be made on a repository design until testing in the exploratory shaft is complete. Rock properties, insitu stress conditions, and hydrologic conditions in the Umtanum are a prerequisite.

When site properties are obtained, it is hoped that a more sophisticated design procedure will be used. An approach using numerical modeling (i.e. finite-element analysis) is recommended. For short-term stability, an elastic-plastic constitutive relationship should be used, and for longer-term stability viscoelastic behavior should be considered. Displacement may become a more critical design parameter than stress.

Even without rock properties and insitu stress information, the use of hypothetical design scenarios should not be precluded. These scenarios are almost a necessity to obtain a feeling for what rock mechanics information is critical and how it is to be used in design. Not only can the critical rock mechanics parameters be delineated, but their realm of acceptability can be determined before measurements are ever taken. This, in fact, is the only basis for formulating decision logic as to site acceptability. The scenarios can also provide an insight into the range of support requirements, and the type and method of backfilling.

Creep (time-dependent strain under constant stress) in basalt has evidently been determined to be negligible, and will not be a design consideration. This may be true over the short term, but when one considers the fracturing in the overall rock mass and a time frame of 1,000 years, creep (viscoelastic) behavior may not be negligible. Closure of a backfilled opening could amount to about 30 percent of the original dimension. The effect of this closure or subsidence on overlying strata should be considered.

Retrievability of waste from the repository for a period of 25 to 50 years was discussed briefly. There appears to be some confusion as to the interpretation of the requirement or the need for it. The apparent intention of retrievability is to retain a capability to remove the emplaced canisters should a problem develop within the retrieval time frame. There are several problems with the requirement: 1) it increases the severity of the design requirements for the repository openings; 2) it increases the potential for long-term creep because of the delay in backfilling; and 3) the time period specified is probably not long enough to allow problems to develop. It is BOM's position, therefore, that the retrievability requirement, in addition to being very costly, is detrimental to long-term repository stability. If there is that much uncertainty as to long-term integrity of the waste package, it would probably be more prudent to look for a shallower repository that was above the water table, where surface runoff could be controlled, where post-closure monitoring could be employed, and where serious problems could be more easily rectified.

Based on the limited discussions concerning backfilling of the repository, it appears that plans for a backfill system are not fully formulated as yet. The idea of using bentonite and bentonite nodules appears good. The swelling effects of the bentonite should reduce backfill permeability as well as providing added opening support. The effects of high temperatures on moistened bentonite should be considered in terms of producing subsequent decreases in volume.

Also, it would seem beneficial to add some ion-exchange capabilities into the backfill to provide an additional isolation barrier. This was suggested in the April 1981 BOM review. If NRC requires any expert assistance in the area of ion exchange, I suggest they contact Donald E. Shanks of BOM's Reno Research Center.

The latest repository layout incorporates vertical storage of the waste canisters. This seems like a much more preferable arrangement than the original horizontal storage scheme. It is suggested, however, that some consideration be given to an overall layout that incorporates something other than right-angle intersections. Right-angle intersections are very restrictive for materials handling and may require that opening sizes be larger than needed, and shapes be other than optimum. Even the bored canister holes in the floor can be inclined from the vertical to reduce headroom. The benefits of reduced headroom, however, must be weighed against the added difficulties in off-vertical canister handling.

SUMMARY

The principal issues in assessing the feasibility of siting a repository at Hanford are the suitability of hydrologic conditions, rock characteristics, and stress conditions at the repository level. To date these issues have not been addressed directly, and will not be addressed until exploratory boreholes and an exploratory shaft are drilled. Before this work is started, decision logic must be formulated as to what constitutes acceptable or unacceptable conditions for a site. The fact that conditions discovered at depth are within the limits of what was predicted does not constitute acceptable decision logic.

To obtain the necessary information for site characterization and site-feasibility decision making, it is recommended that:

1. Acceptance/rejection criteria be established immediately. Information on the four major acquifers overlying the site should be incorporated in this decision logic in terms of the need to isolate them from the repository, our ability within the state of the art to do so, and the economic effects of the acquifers on site construction.
2. Efforts be concentrated on exploring the repository horizon at the expense of experimental work at the NSTF and complete basin hydrologic definition.
3. Additional boreholes (5 or 6) be drilled to the Umtanum to provide data on vertical permeability, horizon extent, and rock properties. The requirement for minimum penetrations should be reconsidered.
4. The experimental shaft be bored only if borehole data are within pre-established limits of site acceptability.

5. If the experimental shaft is bored, considerable exploratory drifting be done to delineate the repository area, collect rock properties information, and determine insitu stresses. These efforts can be considered all in the realm of exploration, and a second shaft should not be required until long-term experiments are started (i.e. heater testing).
6. Information from the shaft and initial exploratory work should be incorporated as part of the Site Characterization report.
7. A decision should be made as to what rock mechanics information is critical to repository design, exactly how it will be used, and how it will be collected.
8. Ample time be provided in the ESTF schedule to collect the necessary data.
9. Various scenarios be run using elastic-plastic finite-element models to determine the sensitivity of rock properties, water, and insitu stress on repository design. Viscoelastic (creep) tests be performed on Umtanum basalt to model long-term opening closure.
10. The retrievability-of-waste requirement be reconsidered in the light of its detrimental effect on long-term stability, and its cost of implementation.
11. The use of backfills with ion-exchange capability should be considered to provide an additional barrier.

A lifetime of study will neither improve nor impair Hanford's acceptability as a repository site. What is there is there, and only good decision logic established early in the program can determine if what is there is acceptable.

Appendix E

U.S. Corps of Engineers

Trip Report

DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX C-3755
SEATTLE, WASHINGTON 98124

NPSEN-FM

4 NOV 1981

SUBJECT: Site Visit, Basalt Waste Isolation Program (BWIP), September 1981

THRU: Commander, North Pacific Division
ATTN: NPDEN-GS

TO: Nuclear Regulatory Commission
Washington D.C. 20555

1. Reference Interagency Agreement (IA) No. NRC-02-81-031 dated 7 June 1981, and Task Order dated 25 August 1981. Further reference our letter to you dated 10 August 1981 which summarizes our review of ST-4 and ST-5. Attached, are findings and comments by Mr. Richard Galster, Chief of our Geology Section, resulting from his participation in the BWIP Site Screening Review Visit in September 1981.

2. Our review of the present status of site characterization leads us to question the adequacy and timing of obtaining a data base which would support characterization under the requirements of 10 CFR 60. Given the 7- to 10-year time frame prior to anticipated licensing of a nuclear waste repository, the present and planned rate of data acquisition with respect to answering the key issues of hydrology, rock stress and thermal mechanical behavior at proposed repository depth, together with establishing tectonic stability may not be accomplished. We note a considerable amount of preliminary repository design work being accomplished with a less than adequate emphasis on site characterization.

3. While, at the present time, we see nothing to disagree with the selection of the reference candidate repository site, we have nowhere found a rational technical basis for the selection. We would hope that this may be rectified in the Site Characterization Report.

4. We feel that a tectonic model can be developed which will adequately explain the past, present and predicted tectonic setting. However, in order to establish the tectonic and structural stability of the setting, considerably more field analysis on a broad regional base, with detailed analysis in specific areas, will be necessary. The relationships of the interior plateau setting with the plate boundary need to be shown.

E-1

Review of Status of Basalt Waste
Isolation Program (BWIP)
September 1981

1. General.

a. The discussions and comments covered in this report are generated as a result of a five day meeting at Richland, Washington during the week of 21-26 September 1981. The purpose of the meeting was to field the Nuclear Regulatory Commission (NRC) team which will review the BWIP Site Characterization Report (SCR) and to discuss the status of the work with the investigators. The team included staff from the NRC lead by Mr. Robert J. Wright, Senior Technical Advisor and technical consultants from Golder Associates; Sandia National Laboratory; University of Idaho; U.S. Bureau of Mines; U.S. Army Corps of Engineers; Lawrence Livermore Laboratory; Intera Environmental Consultants and Geotrans. The meeting included presentations by staff of Rockwell Hanford Operations (RHO), working in smaller discussion groups with RHO and Department of Energy staff, field trips and executive sessions of the NRC Review Team.

b. During a team organization meeting Mr. Wright emphasized that the visit was to be clearly focused on the demands of the SCR review and that the team was not there to make recommendations to RHO; the team is working for NRC. He noted that some features of site characterization would be completed at the time of SCR submittal (probably in the fall of 1982), other features may not, indicating that some 88 items in 10 CFR 60 need to be addressed and that characterization investigation would probably continue for 7 to 10 more years before licensing. He noted further that one of the purposes of the team review was to examine quality of data being obtained.

c. While the tasking order which included the Corps of Engineers on this team visit tasked the Corps principally with evaluating the geologic and tectonic stability investigations, the hydrology studies cannot logically be separated from the other geologic studies. Thus, with the approval of the NRC staff members, this report includes comments of the hydrology, testing methods and ground water modeling presently being conducted and planned for the future.

2. Geology and Tectonic Stability.

a. Findings:

(1) Work accomplished by RHO since submittal of ST-4 (status report on Geology of the Columbia Plateau) has been toward developing a tectonic model and determining contemporary strain rates. The stated approach has been to integrate geologic, geophysical and geodetic data from published sources with that being generated by RHO. Geologic studies include regional geologic studies, time and rate of deformation

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5. The hydrogeology of the candidate repository, together with the state of stress at depth, can be appropriately characterized at the lowest cost by a reasonable array of quality borings. Present plans appear inadequate to accomplish this, and additional quality borings should be considered.

6. We question the timing and purpose of the proposed exploratory shaft. The expense of the shaft with respect to the data which may be obtained from it does not appear cost effective. The indicated purpose of the shaft is to show constructability. Technology is presently available within the heavy construction industry to handle construction difficulties posed by ground water and rock stresses, which appear to us to be the critical items.

NORMAN C. HINTZ
Colonel, Corps of Engineers
Acting District Engineer

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studies and structural analysis. Regional geologic studies have been accomplished through the U.S. Geological Survey and State of Oregon staffs and have not yet been compiled by RHO into a usable form. Timing and rate of deformation studies are being accomplished by a thorough study of the lava flow and sediment distribution, thickness and character of the Saddle Mountains Basalt together with similar analyses of supra-basalt sediment units. The thickness and distribution of the Saddle Mountains Basalt flows suggest an uplift rate of about 0.05 mm/year for the period 13 to 6 million years ago. Structural analysis work has been concentrated largely on a detailed study of the Umtanum structure near Priest Rapids in order to better understand the mechanics of the Yakima folds and develop a temporal and spatial model in the Pasco Basin area.

(2) Geophysical studies include an ongoing program of seismic monitoring together with acquisition and evaluation of magnetotelluric data as a tool in determining crustal structure and thickness. The seismic studies have recognized the appearance of very shallow (< 3 km) low magnitude earthquake swarms which cannot be attributed to any major geologic structures. Moreover, they do not appear as a series of foreshocks building to a main event nor do they have any temporal or spatial consistancy. Earthquake focal mechanism studies suggest that the region is presently in low level N-S compression.

(3) Geodetic work has included reoccupation of Hanford, Wallula Gap, Warm Springs and Milton-Freewater trilateriation networks and a first order level survey across the Pasco Basin. These efforts expect to yield data on contemporary changes in horizontal and vertical deformation. Estimates of strain rate from these data suggest 0.04 mm/year compression in a northeast direction and 0.02 mm/year compression in a northwest direction.

(4) Golder's work in the Gable Mountain area has documented 0.2 foot thrust displacement in sediments of the same age as the St. Helens S ash (13,000 years).

(5) RHO is presently publishing a definitive work on the "Subsurface Geology of the Cold Creek Syncline" (ST-14) to be available late in 1981. The purpose of this document is to present geologic knowledge which relates to the suitability of the Umtanum flow within the Cold Creek Syncline for use as nuclear waste repository host rock.

b. <u>Comment:</u>

(1) RHO has not completed a good regional geologic-tectonic base map of an area sufficient to characterize a region appropriate for the requirements of 10 CFR 60. This was one of our comments during review of ST-4. This compilation is very much needed during the development of the tectonic model so that all geologic, geophysical and geodetic data may be related on the same scale with a structural background.

The entire Columbia Plateau should be included with adjacent area such as the map area covered by Newcomb (1970). The compilation is a basic step in understanding and presenting the total structural-tectonic fabric of the region.

(2) Detailed work in understanding the distribution and thickness of the Saddle Mountains Basalt flows and associated interbeds appear to have been valuable in determining time and rates of deformation within portions of the Yakima Fold Belt. Additional effort appears to be required to understand similar features in the supra basalt sediments. This may require a more thorough stratigraphic analysis of the Ringold and younger sediments to note any change in the deformation rate through Pleistocene and Holocene time.

(3) The detailed study of the Umtanum structure appears to have been most worthwhile. Major pronouncements regarding tectonic model and the development of the Yakima fold belt without the support of more regional data, however, are inappropriate.

(4) Time was not available to review the quality of the geophysical or geodetic data or RHO's synthesizing of it. "A priori" one might expect contemporary deformation to be manifest largely in the anticlines and along faults, with less effect in the structural low areas. Whether this is supported by data is not known.

3. Hydrology.

a. Findings:

(1) In the wake of ST-5 (report on Hydrologic Studies, 1979) RHO continues to attempt to define the flow system in the deeper basalts. ST-5 did not include borehole hydrology data in which RHO has confidence. Earlier (pre-1979) holes, most of which bottomed in or near the bottom of the Saddle Mountains Basalt or in the Mabton Interbed, obtained little hydrologic data. The few holes drilled to the top of the Grande Ronde Basalt obtained insufficient head information. The hydrologic data in which RHO has a measure of confidence, at least in Wanapum and Grande Ronde, is limited to three newer borings (DC-12, 14, 15), reentry into DC-6 and a deepened DB-15.

(2) A potentiometric surface developed from data within the Mabton Interbed is used as a general guide for flow patterns in deeper aquifers.

(3) No efforts have been made to obtain, either by calculation from head losses or from pumping tests, a realistic vertical permeability for the various hydrogeologic units. RHO has assumed a vertical permeability one to two orders of magnitude greater than borehole measurements of horizontal permeability.

(4) At the present time geologic formational units are used as hydrostratigraphic units.

(5) An area of anomalous hydraulic gradient with an abrupt head drop of about 400 feet has been identified in the Cold Creek Syncline area along the western margin of the reservation. This area generally lies between the dying ends of Yakima and Umtanum ridges (anticlines) and is adjacent to an area of heavy irrigation. This is most noticeable in wells completed in the Saddle Mountains Basalt. Deepening of one irrigation well into the Wanapum suggests that the head differential may become less in deeper units.

(6) Borehole temperature gradient measurements show a consistent rise in the range of 10-13°C/1,000 feet of depth.

b. Comment:

(1) Investigation of the hydrology of the Wanapum and Grande Ronde appears to be just beginning. The rate of data acquisition is very slow considering the present schedule of proposed repository licensing. A greater number of data points are required both around the general area of the candidate repository and in the region around the periphery of the Pasco Basin. No plans were presented which would lead to obtaining an adequate data base for understanding the hydrology to depths below the candidate repository as required under 10 CFR 60.

(2) The importance of obtaining realistic hydraulic conductivities, both horizontal and vertical cannot be over estimated. The methods presently in use are inadequate in that low pumping rates and minor drawdowns do not stress the hydrologic system. Higher capacity pumping tests with observation wells in the area of test influence would provide more appropriate data.

(3) Present hydrostatigraphy is based on formational units which from a head and hydrochemical standpoint has little basis. Formational changes are not generally reflected in the heads. Frequently in the borings with more reliable data, the heads show no change with depth or the change is reflected at other than formational boundaries. The suggestion that the hydrochemical break occurred at the top of the Grande Ronde, is not substantiated in the borings with better data. Frequently the break is in the Frenchman Springs and there are examples of decrease in total solids at levels below the Umtanum. The data base is small and validity of some data may be questioned because of sampling and testing methods.

4. Drilling and Hydrologic Testing.

a. Findings: Since 1979 drilling methods and sequence generally consist of coring with PQ wireline (5.25-inch hole) to the top of the Wanapum, extending the boring with NC wireline coring (3.93-inch hole) to the Vantage Interbed and drilling NX (3.032-inch hole) to the bottom within the Grande Ronde. This general procedure has been followed for borings DC-12, 14 and 15 and for DC-16 which is presently in progress in the vicinity of the candidate repository. Drilling mud is consistantly used as a circulatory fluid. Fluid losses during drilling are common, frequently 50 percent and locally total. Areas of apparent higher permeability are tested as the boring is advanced while zones of lower permeability are tested after boring has been completed. Individual tests in dense entablature and colonnade portions of flows sometimes take as long as two months. Disbursing agents are not generally used in cleaning borings prior to hydro testing; only washing with water. Geophysical logs (SP-resistivity, caliper, temperature, natural gamma, density, neutron and sonic) are routinely conducted. Hydrologic test methods include a suite of constant discharge, constant drawdown, slug, pulse or constant head injection methods depending on anticipated permeabilities. Maximum withdrawal rates are about 10 g.p.m. for pumping and 70 g.p.m. for air lift. Drawdowns are minimal, frequently less than a foot.

b. Comment: It may not be possible to maximize acquisition of both geologic and hydraulic information in single borings. Larger diameter (8-12-inch) borings with observation wells are necessary to obtain reliable hydraulic information. Borings might be cored, then enlarged in sequential stages so that more appropriate pumping tests could be conducted as the boring is advanced. The use of mud, while surely decreasing bit wear, casts a substantial question on the validity of conductivity data especially in less permeable zones. A biodegradable foaming agent might be an appropriate compromise between mud and water as a circulating fluid, even at the cost of setting additional diamond bits.

5. Future Exploration.

a. Findings: Plans for further investigation include DC-17 in the vicinity of the 400-foot head drop in the Northwest area of the reservation, DC-19 tentatively planned for Wallula Gap and the deepening of RRL-2 (reference repository location) which is 300 feet away from proposed exploratory shaft.

b. Comment: Planned investigation appears insufficient to characterize the regional hydrology picture appropriate to the requirements of 10 CFR 60. A series of borings around the periphery of the basin as well as additional borings in the general area of the Cold Creek Syncline seem warranted. Such borings should be carried below the Umtanum with attention to both hydrologic and geologic detail.

6. Exploratory Shaft (ESTF).

a. Findings: DOE/RHO are planning to blind bore a less than 10-foot diameter shaft into the Umtanum flow within the candidate repository.

Shaft would be cased and grouted. No geologic or hydraulic information would be obtained during drilling, but plans to cut "windows" in the casing to make observations and perform hydraulic testing are being considered for a later phase. The purpose of the shaft is to determine constructability of such a feature. A reference boring 300 feet from the site of the shaft will be used to select stratigraphic zones for future testing and observation points to be checked through casing "windows".

b. Comment:

(1) The shaft as presently envisioned will lend a measure of information to the constructability of the project, but will yield little to the hydrologic and geologic data so important to determining ground water flow directions and permeabilities of various zones.

(2) Shaft appears premature in the general scheme of site characteriztion. As envisioned it will not yield details of hydrogeology which are critical to site characterization. While we agree that eventually an exploratory shaft is desirable, its construction after final site selection seems more appropriate. At this stage, placement of borings around the candidate site periphery and around the basin in general to answer questions critical to regional and site characterization seem more warranted.

(3) The stated purpose of the shaft is to show constructability. We believe that techniques are presently available within the heavy construction industry to construct a repository including handling of groundwater flows and overcoming problems resulting from the "in situ" state of stress at depths under consideration.

(4) If a shaft is constructed, the use of a boring 300 feet away from the shaft to base selection of shaft casing "windows" may result in inappropriate selection. Given the present state of knowledge regarding changes in flow structure and flow contacts in the Wanapum and upper Grande Ronde basalts within the candidate repository area, important differences in location and character of jointing and thus hydraulic characteristics may be expected.

7. Hydrologic Modeling.

a. Findings: Both near field and far field hydraulic models will be constructed. The near field will encompass only the area around the candidate repository subject to repository induced thermal change. The far field model will include all else from the points of intake to points of discharge. At the present time the ground water model will consider four layers using major formational subdivisions (Grande Ronde, Wanapum, Saddle Mountains and unconfined), but ultimately the model can include many layers. The model assumes a vertical permeability less than horizontal and permits both upward leakage and downward flow.

Present assumption is that discharge from both Wanapum and Grande Ronde basalts is in the vicinity of Wallula Gap.

b. Comment:

(1) The potentiometric maps used for model input are based on very little data especially within the Grande Ronde Basalt. Heads are arbitrarily set and do not necessarily agree with what data is available. While it probably is a useful exercise to make the model work, it should be remembered that considerable change will be required as control data from deeper geologic units becomes available. There is real danger in modeling without realistic data.

(2) The free water surface and unconfined water table should be used as the upper boundary for the model. The lower boundary in the Grande Ronde, while arbitrary, should be deeper than presently assumed.

8. Conclusions.

a. Compilation of regional geologic structure over a broader area is believed a necessary requirement prior to developing a realistic tectonic model.

b. Considering the criticality of hydrologic characterization as emphasized in 10 CFR 60, the present study is inadequate, both in scope and timing, to fulfill requirements prior to licensing.

c. Present hydrologic testing methods are inadequate in that they do not stress the ground water system, a prime requirement for a test.

d. Hydrologic modeling is far ahead of the data base.

e. Site selection appears to be ahead of the regional data base in accordance with the requirements of 10 CFR 60. We have not been able to find, within the material we have been tasked to review, the reasons for selection of the Umtanum flow for a candidate repository or the candidate location, nor can we find the reasons for excluding other areas.

f. The construction of a bored shaft to repository depth appears premature considering the paucity of information available on the geologic and hydrologic characterization of the site, information required under 10 CFR 60.

Richard W. Galster
Chief, Geology Section

Richard W. Galster

Appendix F

Roy Williams

Trip Report

Roy E. Williams
P. O. Box 15
Viola, Idaho 83872

September 28, 1981

Mr. Paul Prestholt
High-level Waste Technical Development Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, Maryland 20910

Dear Mr. Prestholt:

This letter constitutes my comments with respect to our visit to the Hanford site during the week of September 20, 1981. All comments pertain to the Basalt Waste Isolation Project (BWIP). Some of the comments are based on information presented in document numbers RHO-BWI-ST-~~1~~4 and 5. Most of my comments pertain to the hydrology of the proposed BWIP site. However, a few of my comments pertain to scheduling of the project with respect to the acquisition of hydrologic data, past and future, along with the proposed ESTF.

INTRODUCTION

As I understand it, the current status of Rockwell International's proposed plan for the disposal of high-level radioactive wastes consists of the storage of the waste in mined out portions of the Umtanum basalt at 3,000 to 4,000 feet below land surface. It is clear that the characteristics of the occurrence and movement of ground water at the proposed site are a critical issue, if not the basic issue, in the decision making process that will be utilized in the judgement of the ultimate fate of the proposed project. Consequently, a considerable portion of my time and thoughts during the site visit was directed at the ground water issue. A considerable portion of the site visit was spent with the Rockwell hydrology group, particularly with Mr. Roy Gephart, Mr. Frank Spane, Mr. Steve Strait, Mr. Dave Graham, Mr. Ron Arnett and Mr. Leo Lenhart. My perception of the hydrology group assigned to the project is that these individuals have initiated a basic data collection program that ultimately will provide a basis for the characterization of the proposed BWIP site with respect to hydrology. The single hole test methods they have employed are state of the art. It is important to note however that the current status of the hydrologic investigative program should not be considered adequate for a normal comprehensive site characterization document. The SCR, if completed in one year, will constitute more of a plan than a site characterization. This statement is not intended to constitute a negative reflection of the capability of the aforementioned hydrology group. It is intended to reflect the fact that the scheduling of the investigative program is such that not enough will be known about the site hydrology to provide what would normally be called a comprehensive site characterization report within the next year. Any site characterization activity based on the current availability of hydrologic data should be considered as very preliminary. Any decisions made on the basis of such a preliminary site characterization report should be assigned a high risk factor. Investments based on it will be high risk investments. However, it is my opinion that these risks will be necessary if a delay in schedule is to be avoided.

EXPLORATORY SHAFT TEST FACILITY

It is my understanding that an exploratory shaft test facility (ESTF) is being designed and is destined for construction in a little over a year at the proposed BWIP site. This exploratory test shaft facility will extend to a proposed depth of some 4,200 feet. The design includes drifts off the bottom of the shaft into the Umtanum formation. The major basis for the decision making process leading to the design and construction of the ESTF consists of the aforementioned hydrologic studies of the area.

As mentioned above, it is important to realize that the current early status of the hydrologic investigation constitutes a high risk basis for the decision to proceed with the shaft. An effort is being made to minimize this risk by extending the depth of drill hole RL2 approximately 300 feet from the site of the proposed shaft to a depth of approximately 4,000 feet. Single hole hydrologic testing will occur in this test hole. If the shaft were delayed until the hydrologic site characterization studies reached their proper stage, a major time increment would be added to the project.

DATA BASE FOR MODELING

In the normal course of the development of a mine (shaft plus drifts off the bottom of the shaft), a hydrologic testing program would have been scheduled that would have facilitated the mathematical modeling of the hydrologic environment in the vicinity of the mine to the extent that mine water inflow and its impact on the hydrologic regime could be predicted. This will not be the case at the BWIP. Insufficient data are available for reliable modeling. For this reason the ESTF definitely should be viewed as a part of the site characterization procedure. The studies proposed by the aforementioned hydrologic group should be allowed to continue and expand during and after the development of the exploratory shaft. Eventually, sufficient data can be collected so that predictive, reliable mathematical models of the potential movement of radionuclides that might escape from the disposal site can be developed and validated. At present the major gap in the data base required for proper model construction consists of the veritable absence of vertical saturated hydraulic conductivity data and of data on hydraulic continuity. All the testing of hydraulic properties conducted to date has been based on analyses in single drill holes. Pumping rates have been very low as a consequence of the fact that all holes are small diameter core holes. Their major purpose has not been hydrologic testing. No standard pump tests have been conducted on paired holes in the appropriate hydrostratigraphic units at the site. Standard multiple well pump tests are necessary for the determination of vertical saturated hydraulic conductivity and for the delineation of hydraulic continuity of leakage characteristics among the hydrostratigraphic units in the column of aquifers, aquitards and aquicludes above the Umtanum formation. It is my understanding that the aforementioned hydrology group has proposed the implementation of such multiple well pump tests but that approval for the tests has not been granted in the past. Additional data also are absent under the present schedule as will be discussed below. Some of the absent data will be collected in the future under current plans presented during the site visit. The data gap on vertical saturated hydraulic conductivity, on leakage and on lateral hydraulic continuity should be eliminated as soon as possible via multiple drill hole testing.

In the absence of a data base that can be used for the construction of, validated mathematical models, it is speculative at this stage to predict the travel times and flow paths of radionuclides or other dissolved ions that might escape from the Umtanum formation if it is used as a repository. Consequently, the exploratory shaft should be installed with the philosophy that, under the existing state of knowledge, the Umtanum formation is being viewed essentially as an absolute container for wastes stored in it. The very limited amount of existing single hole transmissivity data suggest that the Umtanum formation is very low in permeability. Consequently, this may not be an unreasonable philosophy on which to proceed if the point data sources prove to be extrapolable areally. However, it should be understood at the outset that under the existing status of the hydrologic investigations being conducted at the site that it is not possible to predict the flow paths of escaping dissolved constituents if the Umtanum formation proves not to be a reliable absolute container. This statement is consistent with my previous statement that the exploratory shaft and the drifts proposed for construction at its bottom be viewed as a part of the site characterization process and not as the first step in the construction of a permanent facility.

RISKS PERTINENT TO ESTF

The above observations are important to the consideration of the risk of the financial investment required for the ESTF. It should be understood by all agencies at the outset that on the basis of the available hydrologic information, it may be necessary to sacrifice the investment in the shaft if (1) the shaft produces unexpected, uncontrollable vertical leakage into the Umtanum formation (along the shaft), (2) if the drifting into the Umtanum formation reveals that the Umtanum formation does not constitute a container for the radioactive wastes proposed for disposal in it, and (3) that the shaft drilling process encounters unforeseen conditions that make drilling impossible. Such unforeseen conditions could constitute faults or interbeds that could cause unacceptable loss of mud or make it impossible to maintain a straight hole. It should be pointed out that the information obtained from drill hole RL2 (new number DC22) could shed considerable additional light on the risks inherent in item 3.

In this light it is noteworthy that the drill hole proposed at RL2 is intended to be a continuation of the existing core hole. As I understand it, the existing core hole extends to a depth of 1,800 feet at PQ diameter (5.25 inches). However, several alternatives are available in addition to simply deepening the drill hole and continuing to collect core and the same types of hydrologic data that have been collected on the other existing core holes. As noted previously, the types of data that have been collected to date apply primarily to the immediate vicinity of the drill hole. Alternative number 1 consists of pursuing the present planned course of action. That is, the drill hole at RL2 (future number DC22) will be deepened as a small diameter core hole and transmissivity data collected by recovery tests or slug tests depending on which technique is successful. Alternative number 2 consists of reaming the hole to its present depth and continuing at a larger than PQ drilling diameter to total depth. This procedure would enable the hole to be pumped at higher rates in confining beds and a limited amount of hydrologic information will be obtained under a stress system that is greater than that applied previously. Alternative number 3 consists of continuing the hole as planned but simultaneously initiate the drilling of an additional hole located approximately one mile from drill hole RL2 (preferably on the opposite side of the proposed ESTF site). This hole would be a larger diameter rotary drill hole, preferably air-rotary but mud-rotary if necessary. Its purpose would not be to collect core. Its purpose would be to provide the opportunity to: (1) collect geophysical logs so that hydrostratigraphic units could be delineated and (2) to provide a mechanism whereby standard pump tests could be run using this hole in combination with drill hole RL2. Drill hole RL2 would be the observation well. Careful planning would be required in order to assure that correlatable hydrostratigraphic units could be pumped and monitored simultaneously in the two drill holes. The rotary drill hole would permit a large scale standardized two hole pump test to be conducted at the site so the saturated hydraulic conductivity of hydraulically continuous hydrostratigraphic units could be obtained on a large scale, higher stress, reliable basis. The tests would need to be designed according to the Hantush Method and according to the Witherspoon-Neuman Method. The hydrology staff at Rockwell is familiar with both methods. The vertical hydraulic saturated hydraulic conductivity of the Umtanum formation could be tested more reliably with these two bore holes. The Witherspoon-Neuman Method probably would be necessary although the modified Hantush Method might be applicable. The first aquifer above the Umtanum formation would be pumped at as high a rate as possible. Several hundred gallons per minute would be advisable. Instrumentation could be installed in this unit, in the observation well, and in the Umtanum unit below the aquifer both in the observation well and in the pumped well. This approach would add the cost of one additional rotary well to the project. However, it would fill a significant gap that exists currently in the data base. If a step of this dimension is not undertaken at the site, this gap in the data base will continue to exist and it will be a continuing weakness in the project investigative process for the site characterization report.

SPECIFIC GAPS IN THE DATA BASE THAT NEED TO BE ELIMINATED

As I stated above, any site characterization report based on currently available hydrologic information should be viewed as preliminary. I also stated above that as a consequence of this circumstance the proposed ESTF should be reviewed as a part of the site characterization procedure in the context of the rule that was published in July. Specific technological gaps in the existing data base that constitute the rationale for this conclusion are as follows. Some of these points are redundant relative to the above but they cannot be overemphasized.

1. None of the pump tests conducted to date in any of the hydrostratigraphic units at the Hanford site allow the measurement of storage coefficient or vertical saturated hydraulic conductivity (K_V). The explanation for this conclusion rests on the fact that all tests have been preformed on single drill holes. Even the single drill hole injection or withdrawal tests have been conducted at very low pumping rates. These low pumping rates are a consequence of the fact that the major emphasis of management has been to obtain core rather than standard hydrologic data on hydraulic properties. Core holes are slow to drill and expensive. Hydrologic testing in them is slow and limited also. Furthermore, the tests that are performed in a bored hole (as opposed to a pair of bored holes) produce properties of the porous medium immediately in the vicinity of the well only. For purposes of project scheduling it would have been better for management to have designated some holes as core holes and other holes as hydrologic data holes. Project planning should be altered to correct this situation as soon as possible. Nevertheless, as things stand now, no values of K_V have been obtained and it is unlikely that values will be obtained prior to the initiation of shaft sinking. If values are obtained prior to shaft sinking, they will be restricted to the Grande Ronde formation because available paired holes have been cased through all hydrostratigraphic units above the Grande Ronde. The absence of K_V values hampers greatly the construction and validation of reliable mathematical models of the area during the characterization process. The hydrology staff has requested and does plan to obtain K_V values in the future. They are completely aware of the necessary procedures for obtaining such parameters.

2. The decision to place emphasis on core holes also has placed restrictions on the aereal applicability of the transmissivity values that have been obtained for the various hydrostratigraphic units. Without the ability to conduct standard pump tests, the available values of transmissivity must be viewed as indicative of T values only in the immediate

vicinity of the drill holes. Consequently, the testing procedure that has been available to the hydrology staff to date has not facilitated the identification of hydraulic boundaries such as faults or stratigraphic pinchouts. In order for a pumping test to identify such features, a large cone of depression, relatively high pumping rates, and observation wells are necessary. It is not possible to return to existing wells and conduct such tests above the Grande Ronde because existing wells above the Grande Ronde have been cased off. Therefore, the shaft must be sunk without the benefit of such standard hydrologic information. This situation does not preclude the success of the shaft; it simply increases the risk of unforeseen difficulties, cost overruns, and delays.

3. It appears that the hydrology of the unconfined aquifer is reasonably well understood. Standard pumping tests and boundary condition measurements apparently have been made in the unconfined aquifer over the past several years. However, the hydraulic continuity between the unconfined aquifer and the confined aquifers in the hydrostratigraphic section at the site is not well understood. This circumstance is a consequence of the absence of drill holes that are capable of defining boundary conditions around the periphery of the unconfined aquifer and along the topographic highs around the basin. This makes difficult the definition of recharge areas under current conditions. This problem can be solved in the future by proper site selection of new drill holes but probably not in time for the preparation of a comprehensive site characterization report prior to the planned date of sinking of the ESTF.

4. The small diameter of cored drill holes limits the pumping rate by submersible pump to about 10 to 15 gallons per minute and the rate by air-lift pump to something slightly above this rate. Consequently, the hydraulic properties that have been measured in the cored drill holes are severely restricted with respect to areal distribution.

5. Hydrogeochemical data at the site are just beginning to be obtained in quantities that may prove usable in delineating the degree of hydraulic connection among aquifers and aquitards. In the absence of the aforementioned standardized pump tests, using multiple wells, it would be advisable to treat these data statistically as soon as possible. The hypothesis that various groups of water quality samples derive from different or identical populations should be tested in as many horizons as possible at as many drill holes as possible. Such analyses may quickly shed valuable light on the question of hydraulic connection between hydrostratigraphic units of considerable importance to the NRC's evaluation of the site characterization report.

6. None of the models presented to us during the site visit showed faults that have been incorporated into the models. The absence of faults that are hydrologically significant may be a perfectly legitimate omission from the modeled structures. However, this fact should be

demonstrated by what ever means are available. The NRC should scrutinize carefully the mapping and analysis of faults in the site characterization report because of their potential importance in the transfer of dissolved constituents that might escape from the repository. The accurate delineation of faults cannot be overemphasized with respect to mining risks. High resolution reflection seismology could be useful at the site to attempt to delineate the faults that may be significant with respect to the hydrology of the site, particularly as regards the risk of potential releases from the repository, to shaft and drift excavation risks, and to mathematical modeling of travel times and flow paths. Seismic data commonly are used for the purpose of mapping faults. I did not receive sufficient information during the site visit to be able to judge whether existing data could be used to map hydrologically significant faults. I did receive information to the effect that the geophysics staff has been diminishing as a result of resignations and that budget cuts have curtailed the analysis of existing geophysical data. These factors may be limiting with respect to the ability of the hydrology staff to pursue this line of investigation. However, if this is not the case, the use of geophysical data should be considered in terms of delineating structural features, particularly faults, that are hydrologically significant with respect to modeling of the ground water flow system at the site.

7. As I understand it, the thermal expansion tests and thermal stress tests being conducted at the near surface test facility are being conducted on dry basalt. While there is no cause to criticize such experiments, the NRC should realize that the heat generated by radioactive wastes will interact with rock whose pore spaces are saturated with water no matter how low the saturated hydraulic conductivity or the porosity. The expansion characteristics of the saturated rock may not be the same as the expansion characteristics of the unsaturated rock. Care should be taken to ascertain that the site characterization report recognizes that the thermally stressed rock will be saturated and may expand at rates greater or less than that of dry rock.

8. The status of mathematical modeling of hydrologic systems at the site is extremely general in nature. This is an inevitable consequence of the scheduling of the hydrologic data base testing program at the site. Boundary values that are necessary for the construction of a mathematical model framework for a ground water flow system simply are not available to the mathematical modelers in sufficient quantity for model validation. Consequently, the output of mathematical models at the present time should be viewed as broad guidelines and subject to change as additional data come in. It is apparent that the personnel involved in mathematical modeling are capable of producing valid mathematical models of the site and its vicinity. However, they should

not be expected to produce reliable results when they are so far ahead of the data base. Their results are bound to differ because of the limited data on boundary conditions and hydraulic properties.

RECOMMENDATION

As discussed above, the status of the hydrologic data base collection system is considerably behind with respect to other proposed activities on the BWIP. The most important of these other proposed activities is the ESTF. This is not to say that the ESTF should not be attempted. It simply means that management is willing to take considerable risks that would not be necessary if the hydrologic data base collection system were more advanced. Assuming that the shaft sinking into the Umtanum formation is successful, it also means that the hydrologic data base collection system designed for the drifts in the Umtanum formation will need to be extremely comprehensive. Without the ability to predict accurately the migration paths of potentially releasable dissolved constituents from the repository, it will be necessary to show that the respository itself is essentially a container and that the risk of release of radionuclides is essentially zero. Consequently, it is very important for the hydrology group and the NRC to ascertain that the site characterization process test thoroughly the hydralic transport properties and the distribution coefficient properties of the Umtanum formation during the construction of the drifts. I recommend that this effort constitute a major interdisciplinary effort on the part of the hydrology group and design group during the site characterization process as related to the research conducted in the drifts at the bottom of the proposed ESTF shaft.

Sincerely,

Roy E. Williams/sl

Roy E. Williams

REW:sl

Appendix G

List of Participants

AGENDA FOR NUCLEAR REGULATORY COMMISSION
VISIT TO BASALT WASTE ISOLATION PROJECT
RICHLAND, WASHINGTON

September 22-26, 1981

Attendees

NRC

Jared Davis (Management, Research)
Donald Alexander (Geochemistry, Petrology)
George Birchard (Geochemistry)
David Brooks (Geochemistry, Remote Sensing)
John Greeves (Civil Engineering)
Ludwig Hartung (Engineering Geology)
Linda Lehman (Hydrologic Modeling)
Paul Prestholt (Hydrology, Geophysics, Quality Assurance)
Robert Wright (Senior Technical Advisor)
Ernst Zurflueh (Geophysics, Tectonics)

Golder Associates

Adrian Brown (Hydrology)
Richard Gates (Rock Mechanics)
Eileen Poeter (Hydrology)
Jerry Rowe (Hydrology)
Tod Schrauf (Hydrology)
Richard Talbot (Mining Engineering)

Sandia National Laboratories

Nancy Finley (Geochemistry, Quality Assurance)
Fran Nimick (Hydrologic Modeling, Quality Assurance)

U.S. Bureau of Mines

Ernie Corp (Mining Engineering)

U.S. Corps of Engineers

Richard Galster (Structural Geology)

Intera Environmental Consultants

Mark Reeves (Hydrologic Modeling)

Geotrans

Jim Mercer

University of Idaho

Roy Williams (Hydrology)