See Pocket for encl.

NUCLEAR WASTE CONSULTANTS INC.
8341 So. Sangre de Cristo Rd., Suite 6
Littleton, Colorado 80127
(303) 973-7495

July 21, 1986

009/2.3/REV.005
RS-NMS-85-009
Communication No. 77

U.S. Nuclear Regulatory Commission
Division of Waste Management
Geotechnical Branch
MS 623-SS
Washington, DC 20555

Attention: **Mr. Jeff Pohle, Project Officer**
Technical Assistance in Hydrogeology - Project B (RS-NMS-85-009)

Re: **Comments on BWIP Final Environmental Assessment**

Dear Mr. Pohle:

Please find attached review comments on the BWIP Final Environmental Assessment from Terra Therma Inc. and Nuclear Waste Consultants. The review was performed under Subtask 2.3 of the current contract.

The review addresses each of the detailed and general comments of the NRC in the area of hydrogeology and related aspects of geochemistry. The reviewers find that, in general, the Final EA has not addressed the NRC comment or concern in the area of hydrogeology. Typically, the FEA text is virtually unchanged from the DEA text. A major exception is the DOE response to the solubility comment in the geochemistry area, which is very complete, detailed, and, to the TTI/NWC reviewer, both responsive and technically convincing. The review refers to TTI/NWC's earlier document review on the BWIP Groundwater Travel Time analyses for more detail on data limitations and consequent uncertainties that NWC considers to exist in the DOE methodology for evaluating pre-emplacement groundwater travel time.

If you have any questions about this review, please do not hesitate to contact me.

Respectfully submitted,
NUCLEAR WASTE CONSULTANTS

Mark J. Logsdon

Mark J. Logsdon, Project Manager

cc: US NRC - Director, NMSS (ATTN PSB)
DWM (ATTN Division Director)
Mary Little, Contract Administrator
WMGT (ATTN Branch Chief)

bc: M. Galloway

See D1021 7/21/86
TO: J. Pohle
Communication No. 77

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TERRA THERMA Date: 7/17/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 1 DOE Comment No: _____ Comment Topic: GWTT

Location of Comment Address: _____

How Was Comment Addressed? (Circle)
New Information (New Analysis) Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
__X__ Other (explain) ~~INCOMPLETE RESPONSE~~

Manner in Which Comment is Inadequately Addressed:

__✓__ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__✓__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

~~DETAILED REVIEW~~ SEE ATTACHED

The Final Environmental Assessment states that

> "there is no reason to believe, based on current information, that the ground-water travel time is not well in excess of 10,000 years." (DOE, 1986, p. 16).

This echoes a similar statement in the Site Characterization Report (DOE, 1982), and is identical to the statement made in the Draft Environmental Assessment (DOE, 1984).

It has been NRC staff's consistent position that this statement cannot be supported. In response to the Site Characterization Report, the NRC stated that

> "... some of the assumptions used in the estimation (of ground-water travel time) appear biassed in favor of long travel time" (NRC, 1982, p. xiii);

and that:

> "Calculations of travel times for three alternative conceptual models of groundwater flow in the Pasco Basin at the Hanford site yield estimates of pre-emplacement travel times that range from 20 years to greater than 40,000 years" (NRC, 1982, p. D-16);

and that:

> "...the NRC staff concludes that it is possible to contest the validity of the two key assertions of the DOE (that the flow is horizontal, and that the minimum ground-water travel time is in the range of 10,000 years or greater)." (NRC, 1982, p. D-16..D-17).

In response to the similar conclusion of the Draft EA, the NRC stated that the results of a re-evaluation of the groundwater travel time by the NRC staff:

> "...raise significant questions regarding the defensibility of the DOE's conclusion that the ground-water travel times can preliminarily be inferred, based on the existing data, to be well in excess of 10,000 years, or that there is a high probability that the travel times would be greater than 1,000 years." (NRC, 1985).

Following the release of the Final Environmental Report, the NWC review team was asked to review the report by Clifton (1986) which forms the basis for the current assertions on ground-water travel time (NWC,1986). This detailed review concluded that:

> "...the results obtained in the actual computation of GWTT are incorrect, and that there is a low probability that the GWTT will

> exceed 1,000 years (between 20% and 50%), and a lower probability that the GWTT will exceed 10,000 years (between 2% and 7%). The differences in the DOE result and the review result stem mainly from the interpretation of porosity, both with respect to the "best estimate" value, and the nature of its distribution around this estimate." (NWC, 1986, p. 8).

The failure of the DOE to acknowledge or respond to the continued supported criticism of a major licensing and siting evaluation cannot be explained.

REFERENCES

Clifton, P.M., 1986. "Groundwater Travel Time Analysis for the Reference Repository Location at the Hanford Site", SD-BWI-TI-303, Rockwell Hanford Operations, Richland, Washington, January.

Codell, 1985. Draft Generic Technical Position on Groundwater Travel Time (GWTT), U.S. Nuclear Regulatory Commission, November.

DOE, 1982. Site Characterization Report for the Basalt Waste Isolation Project, Report DOE/RL 82-3, prepared by Rockewell Hanford Operations for the U.S. Department of Energy, Assistant Secretarey for Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, November.

DOE, 1984. Draft Environmental Assessment Reference Repository Location, Hanford Site, Washington, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, December.

NRC, 1983. Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project, NUREG-0960, U.S. Nuclear Regulatoratory Commission, Office of Nuclear Materials and Safeguards, March.

NRC, 1985. NRC Comments on DOE Draft Environmental Assessment for the Hanford Site, U.S. Nuclear Regulatory Commission, March.

Nuclear Waste Consultants, 1986. "Review of "Groundwater Travel Time Analysis for the Reference Repository Location at the Hanford Site - SD-BWI-TI-303", submitted to J. Pohle by letter of June 13, 1986.

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 2 DOE Comment No: ____ Comment Topic: Thermal Loading

Location of Comment Address: ____

How Was Comment Addressed? (Circle)
(New Information) New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

___ DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) ____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
X Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) ____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
X Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) ____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 2 DOE Comment No:

Comment Topic: Thermal Loading

Location of Comment Address:

Additional Comments:

DOE considers that thermal effects caused by the repository are not significant in evaluating GWTT and the EPA Standard for the following reasons:

1. "The expected extent of the disturbed zone [temperature effects on rock permeability] is a very small portion of the total distance separating the repository from the accessible environment".

2. "The magnitude of these [thermal induced] gradients will also decrease as a function of time, because the rate of heat production diminishes with time. The magnitude of these gradients will also decrease as a function of distance from the waste due to temperatures decreasing with distance."

3. "Preliminary modeling studies of coupled heat transport and ground-water flow suggest that travel times through the proposed candidate horizons could be sufficiently long for the magnitudes of the thermal-induced gradients to decline to a point where they have no significant effect on the ground-water flow paths and travel times in the basalt flow tops overlying the candidate horizons (Long and WWC, 1984)."

4. "..... shorter travel times obtained with any of the conceptual models represent those trials in which the flow path was totally within the flow top immediately above the Cohassett flow interior. This is convenient ..... because, with no vertical legs in the path, the pre-emplacement travel times ..... do not have to be adjusted for the buoyant gradients induced by heat in the stored waste."

Terra Therma's response to DOE's above technical justifications are given below (note consistent numbering):

1. Terra Therma agrees with DOE that the extent of thermally-induced physical changes (e.g., rock permeability) are likely to represent only a small proportion of the total distance to the accessible environment. However, item no. 3 (above) suggests that travel time through the flow interior of the candidate horizon, under natural (pre-emplacement) conditions, represents a significant portion of the total

travel time. This would also imply that properties the candidate horizon are also significant in limiting cumulative radionuclide flux reaching the first interflow above the repository. Thus, processes effecting the physical hydraulic properties of the candidate horizon could have a substantial impact on GWTT and the EPA Standard. Since dense basalt within the candidate horizon will certainly be within the region of thermal changes, it is possible that the thermal effects associated with the waste may affect travel time and cumulative flux at the accessible environment.

2. Because the thermal response has a limited extent and apparently does not reach any thermal boundaries within several thousand years after emplacement, it cannot necessarily be assumed that the magnitude of temperature changes will decrease in direct proportion to the rate of heat production. Simple thermal modeling conducted by Terra Therma suggests that elevated temperatures will persist long after the rate of heat production has decreased to a very small value.

   Thermal effects will decrease with distance from the repository. However, thermally-induced processes occurring near the repository (e.g., within the candidate horizon) may affect travel time and flux beyond the region of the thermal disturbance.

3. The "preliminary" modeling studies described in Long and WWC (1984) assume that (1) the flow interior has extremely low vertical hydraulic conductivity, (2) can be modeled as an equivalent porous medium, and (3) is composed of relatively homogeneous material. Since there are no credible in situ measurements of bulk vertical hydraulic conductivity at the BWIP site, the first assumption cannot be substantiated. Also, unless the second and third assumptions can be substantiated by site characterization activities, they must be considered nonconservative from the standpoint of performance assessment. Thus, conclusions based on these modeling studies must be assessed a high degree of uncertainty.

4. Buoyancy <u>directly</u> affects only the vertical component of hydraulic gradient. However, if thermally-induced (buoyancy) gradients increase ground water flux rates through flow interiors, then by continuity, horizontal flux rates within interflows must also be affected to a certain extent. The magnitude of changes in horizontal gradients occurring within interflows depends on the hydraulic conductivity contrast between interflows/flow interiors and the planimetric cross-sectional area within the flow interior(s) affected by buoyancy. Thus, Terra Therma feels that it is incorrect to assume that horizontal hydraulic

gradients within interflows will not be affected by thermal loading.

In summary, Terra Therma feels that DOE has not provided sufficient support to justify their contention that thermal effects are not significant in evaluating GWTT and the EPA Standard.

.2.3.5 Site subsystem performance

The performance measures for the site subsystem are pre-waste-lacement ground-water travel time, and post-waste-emplacement tonuclide release to the accessible environment. This section presents analysis of these two performance measures. The stochastic analyses of und-water flow provides a range of ground-water travel time in basalt t are possible, as well as their probabilities. The stochastic lysis is limited to consideration of a single conceptual model for ul-water flow paths. Other conceptual models (see Subsection 3.3.2.2) phart et al., 1984) of ground-water flow through the basalts will be sidered by future studies. Additional details of the stochastic lysis of ground-water travel time is presented in Clifton (1984).

Ground-water travel times. Ground-water travel time along a given hline is a function of (1) transmissivity (or hydraulic conductivity), effective thickness (or effective porosity), and (3) hydraulic dient. Ground-water travel time will also be a function of storage fficient (or specific storage) if the flow regime is time dependent. less these geohydrologic parameter fields and hydraulic gradients are fectly known within the ground-water flow domain, there will be some ertainty associated with a ground-water travel time predicted by a el. The amount of uncertainty in a predicted travel time depends on well the spatial variability of the hydrogeologic parameters and raulic gradients are known, which, in turn, depend on the amount of hydrologic data within the ground-water flow domain. Recognizing that round-water travel time predicted by a model can be uncertain, it then omes useful to quantify this uncertainty by presenting an estimated bability distribution for predicted ground-water travel times rather an one specific travel time for which the likelihood may or may not be wn.

This section presents a stochastic analysis of pre-waste-emplacement und-water travel times in the deep basalts beneath the reference ository location and vicinity. The product of the analysis is an imated probability distribution of ground-water travel times from the inity of the repository to the accessible environment. Justification r the use of the stochastic modeling approach for ground-water travel el calculations is presented in Arnett and Sagar (1984); this report esents an example calculation that illustrates the limitations of ditional deterministic approaches.

Modeling approach. The method used to stochastically model und-water travel times is based on a Monte Carlo technique. This hnique is used to generate a suite of random spatial fields or boundary ditions (e.g., transmissivity, effective thickness, and regional raulic gradient) for the ground-water flow domain of interest. These lds are subsequently input to numerical models of the ground-water flow l travel time equations. The solution of these equations provides the responding suite of ground-water travel times that is subsequently used determine ground-water travel time statistics. A detailed description this methodology is in Clifton (1984).

DEA

Solution of the ground-water flow equation was accomplished by means of the two-dimensional finite-element computer code MAGNUM-2D (Baca et al., 1984a). For the purposes of this analysis, a Monte Carlo version of MAGNUM-2D (called MAGNUM-MC) was used to stochastically model ground-water flow. The output from MAGNUM-MC was used to calculate a suite of ground-water travel time simulations that were subsequently used to construct a travel time probability curve.

The U.S. Nuclear Regulatory Commission performance objective governing pre-waste-emplacement ground-water travel times states, "pre-waste-emplacement travel time along the fastest path of likely radionuclide travel from the disturbed zone around the repository to the accessible environment. . .be at least 1,000 years" (NRC, 1983b). Disturbed zone is defined in 10 CFR 60 (NRC, 1983b) as follows:

> "Disturbed zone means that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or from heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository."

Changes in the disturbed zone may occur as a result of mechanical, thermal, or chemical damage to the host rock near the waste packages. Therefore, determination of the location and extent of the disturbed zone is site specific and is best defined in terms of significant effects on the performance of the isolation system. Determination of such effects require detailed subsurface site characterization. Physical changes, induced either by excavation or by thermal stresses imposed by the emplaced waste, are likely to modify the permeability of the host rock in localized areas. The extent and magnitude of this effect are dependent on several factors, including drilling method and induced temperature. The drilling methods and temperatures anticipated and the changes in permeability that are expected to occur are not likely to significantly affect repository isolation performance (Cottam, 1983). The expected extent of the disturbed zone is a very small portion of the total distance separating the repository from the accessible environment.

In addition, thermal-induced hydraulic gradients (i.e., buoyancy) will develop during the postclosure period in the vicinity of the repository. The significance of buoyancy effects decreases both with time and distance from the repository (due to decrease of heat produced by radionuclide decay and in heat transfer losses as a function of host-rock distance). The effects of buoyancy driving force could be used to define the outer boundary of the disturbed zone. This would require a criterion defining the magnitude of bouyancy force that is to be considered significant and the future time at which this magnitude is to be calculated. These factors have not been specified by the U.S. Nuclear Regulatory Commission. Preliminary computer simulations of heat transport coupled to ground-water flow (Long and WCC, 1984) suggest that ground-water travel time through the candidate horizons could be

A

B

sufficiently long that a buoyancy driving force would have no significant effect on ground-water flow paths and travel time in the basalt flow tops overlying the candidate horizons.

Because of factors discussed in the preceeding paragraphs, no attempt was made to explicitly define the physical extent of the disturbed zone. Such a definition is dependent on data and analyses that will be available after characterization of the site. Instead, the origin of the pathlines used to calculate ground-water travel time was assumed to be a point in the candidate horizon flow top immediately overlying the downstream edge of the repository. Ground-water travel time from the repository horizon to the overlying flow top was not taken into account to introduce conservatism in this analysis. However, if this vertical component of ground-water flow were considered, travel time estimates would be longer. At this time, the U.S. Department of Energy is maintaining the future option of taking partial credit for the isolation characteristics of the flow interior of the preferred candidate horizon. A preliminary calculation of the potential for vertical flow paths through the basalt is presented in Clifton et al. (1984b).

The accessible environment in this analysis was defined to be a boundary 10 kilometers (approximately 6.2 miles) down gradient from the origin of the pathlines. This definition of accessible environment is consistent with the definition in Working Draft 4 of the U.S. Environmental Protection Agency standards (EPA, 1984). The term accessible environment is defined in draft 40 CFR 191 (EPA, 1984)as a summation of the:

> "(1) atmosphere, (2) land surfaces, (3) surface waters, (4) oceans, (5) portions of the lithosphere that are beyond the controlled area and the designated area, and (6) major sources of ground water that are beyond the controlled area or that are more than 2 kilometers (approximately 1.2 miles) in a horizontal direction from the original location of any of the radioactive wastes in a disposal system, whichever distance is greater."*

As shown in Figure 6-21, certain aspects of this definition of accessible environment are unequivocal:

1. Surface waters and the atmosphere are part of the accessible environment at all distances.

2. The lithosphere is part of the accessible environment at all depths for distances beyond 10 kilometers (approximately 6.2 miles) from the repository.

*See the referenced regulation for definitions of specialized terms used within this defined term.

DEA

The predicted results, shown in Figures 6-25 through 6-28, are dominated by the releases of nonadsorbed radionuclides, carbon-14 and iodine-129. Within the ranges of values currently expected for solubility, retardation coefficients, and ground-water travel time, adsorbed radionuclides are not likely to contribute significantly to cumulative releases.

The results of these stochastic simulations are presented in graphical form. The vertical axis of each graph is the cumulative probability, which expresses the level of certainty that the value of the radionuclide release is less than or equal to values on the horizontal axis. The horizontal axis of each graph consists of the possible range of radionuclide release in fractions of the proposed U.S. Environmental Protection Agency limit.

The calculated cumulative radionuclide release for a potential repository in basalt, as shown in Figures 6-25 to 6-28, shares the following three basic features.

- A number of Monte Carlo trials computed radionuclide travel times that exceeded the isolation period (e.g., 10,000 or 100,000 years). For these trials, the cumulative releases are zero. The effect of very long radionuclide travel times is reflected in the horizontal portion of the probability curves.

- The near-vertical portion of each curve shows the release of the total iodine-129 inventory.

- Adsorbed (and relatively insoluble) radionuclides are either totally absent from radionuclide release at the accessible environment or are evident in only a few of the 5,000 Monte Carlo simulations.

Discussion. The analyses presented provide useful insights into bounding conditions and sensitivities for the site isolation subsystem behavior. These analyses must, however, be viewed in the context of their stated limitations in order to properly interpret the results. The representation of a physical system by a numerical model has two principal sources of uncertainty: (1) simplistic, albeit conservative, representation of the actual physical system and (2) limited data. The computer code used in this analysis does not provide a detailed numerical representation of the complex hydrologic, chemical, and thermal processes involved in radionuclide transport. Instead, the inputs to the computer code are derived primarily from the outputs of other more detailed models. The results of the present analysis do, however, provide a good perspective on the potential isolation capability of the site subsystem and are believed to reasonably represent the potential isolation performance of the site subsystem.

C

6.4.2.6.1 Pre-waste-emplacement ground-water travel time

FEA

The objective of this subsection is to establish preliminary estimates of pre-waste-emplacement ground-water travel time for the proposed repository beneath the Hanford Site to assess how well this repository system can comply with the travel-time criteria defined in 10 CFR 960 (DOE, 1984a). To accomplish this objective, a suite of travel-time models, based on data and interpretations of the deep ground-water flow system beneath the Hanford Site, has been developed. These models are used to examine the sensitivity of the predicted ground-water travel times to variations in some of the model inputs and results in a range of predicted travel times. All analyses have been conducted in a stochastic framework, which allows a probability of occurrence to be associated with a predicted travel time. This subsection presents an abbreviated discussion of the travel-time model that best accounts for the current conceptual understanding of the deep ground-water flow regime beneath the Hanford Site. This model is used as a basis for evaluating the basalt sequence in the reference repository location and vicinity against the travel-time criteria in 10 CFR 960. The reader is referred to Clifton (1986) for a detailed discussion of the method of analysis, model inputs and assumptions, and results of the suite of ground-water travel-time models developed in support of this environmental assessment.

Pre-waste-emplacement ground-water travel time to the accessible environment is used by the U.S. Nuclear Regulatory Commission and U.S. Department of Energy as a measure for screening potential high-level nuclear waste repository sites. Both agencies require that the travel time be calculated along a pathline (or pathlines) beginning at the edge of the disturbed zone around the repository. The definition of disturbed zone provided by the U.S. Nuclear Regulatory Commission in 10 CFR 60 (NRC, 1985a) is

> ". . . that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or from heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository."

Creation of a disturbed zone may occur as a result of mechanical, thermal, or chemical processes acting on the host rock around the repository. Therefore, determination of the location and extent of the disturbed zone is site specific, and might best be defined in terms of any significant effects on the performance of the isolation system. Determination of such effects requires detailed subsurface site characterization. Physical changes, caused either by excavation or by thermal stresses induced by the emplaced waste, are likely to modify the permeability of the host rock out to lateral distances of no more than a few times the radius of the excavation. The extent and magnitude of the permeability change are dependent on several factors, including excavation method and temperature change due to waste emplacement. These changes are not likely to affect significantly the repository isolation performance (Cottam, 1983). Hence, the expected extent of the disturbed zone is a small portion of the total distance separating the repository from the accessible environment.

A

FEA

One characteristic of the repository in the postclosure period is the elevated temperature field produced by the decaying nuclear waste. This temperature field induces dominantly upward hydraulic gradients (i.e., buoyant gradients) above the repository. The magnitude of these gradients will decrease as a function of time, because the rate of heat production diminishes with time. The magnitude of these gradients will also decrease as a function of distance from the waste due to temperatures decreasing with distance. Preliminary modeling studies of coupled heat transport and ground-water flow suggest that travel times through the proposed candidate horizons could be sufficiently long for the magnitudes of the thermal-induced hydraulic gradients to decline to a point where they have no significant effect on the ground-water flow paths and travel times in the basalt flow tops overlying the proposed candidate horizons (Long and WCC, 1984).

B

In all the analyses of pre-waste-emplacement ground-water travel time presented in Clifton (1986) and in this subsection, the boundary of the disturbed zone is not rigorously defined, because of the factors discussed in the preceding paragraphs. It is implicitly assumed that the boundary of the disturbed zone lies between the repository excavations and the starting location of pathlines used to calculate ground-water travel times. Defining the extent of the disturbed zone is dependent on data and analyses that would be available, if the reference repository location were recommended for site characterization.

Site description

The deep basalts beneath the Hanford Site form a layered sequence consisting of dense, fractured basalt flow interiors overlain by brecciated and vesicular flow tops (see Section 2.1.1 and Subsection 3.3.2.1). Some of the basalt flows are relatively thick (greater than 40 meters (130 feet)) and continuous for many kilometers (miles) (Myers, Price et al., 1979). The permeability of flow interiors is lower than flow tops, because of their much smaller volume of interconnected fracture and pore space. In addition, most of these fractures are filled or lined with secondary minerals. The lithostatic load, in situ stress, and secondary minerals are thought to contribute to the lower permeability of deep flow interiors compared to shallower basalts (Spane, 1982). Thus, the flow interiors tend to act as confining units for ground water contained in the flow tops. The permeability contrast between basalt flow tops and flow interiors promotes two-dimensional horizontal movement of ground water along flow tops and one-dimensional vertical movement of ground water through flow interiors.

Various concepts of the ground-water flow regime in the deep basalt sequence beneath the Hanford Site are discussed in Subsection 3.3.2.2. These concepts depict four flow regimes that range between an essentially confined ground-water flow system with low vertical leakage across dense interiors and a system with high vertical leakage across flow interiors and along discrete structural discontinuities. Recent analyses of hydrochemical data from the deep ground waters beneath the reference repository

FEA

Data set for cumulative radionuclide-release analysis

The ground-water travel-time distribution used in EPASTAT (Fig. 6-28) approximates the collection of analytical results presented in Clifton (1986). Very long travel times tend to yield zero or low releases to the accessible environment, so the portion of Figure 6-28 important to EPASTAT is the short travel-time (lower left) portion of the curve.

The exceedance probabilities for 1,000- and 10,000-year travel times reported in Clifton (1986) were reasonably constant for all of the conceptual models at exceedance probability values of 97 percent (-1.88σ) and 78 percent (-0.77σ), respectively. Independence of these results from the particular conceptual model is a result of the fact that the shorter travel times obtained with any of the conceptual models represent those trials in which the flow path was totally within the flow top immediately above the Cohassett flow interior. This is convenient insofar as defining a travel-time input distribution for the EPASTAT analysis, because, with no vertical legs in the path, the pre-emplacement travel times reported in Clifton (1986) do not have to be adjusted for buoyant gradients induced by heat in the stored waste.

C

From the exceedance probabilities, and assuming that a lognormal travel-time distribution is a reasonable representation of the detailed analytical results for the purpose of estimating radionuclide releases,

$$\log M - 0.77\sigma = \log 10{,}000 = 4 \qquad (6\text{-}6)$$

$$\log M - 1.88\sigma = \log 1{,}000 = 3 \qquad (6\text{-}7)$$

where:

M = median travel time
σ = log standard deviation.

Solving for M and σ yields:

$M = 49{,}400$ years
$\sigma = 0.90$.

Because releases to the accessible environment, particularly in the first 10,000 years after repository closure, are dominated by the low end of the travel-time distribution, the selected representation is considered adequate for this preliminary analysis.

The release rate is computed in EPASTAT (Eslinger and Sagar, 1986) by a simple expression representing radionuclide solubility times solvent (water) flow rate:

$$\text{release rate} = mMSW \qquad (6\text{-}8)$$

Bassa

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/14/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME Possible

NRC Comment No: 2 DOE Comment No: _____ Comment Topic: Climatic Changes

Location of Comment Address: 6.3.1.4

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP [Other]

Not addressed

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

__X__ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: Major Comment #2

Comment Topic: Possible Climatic Changes

Location of Comment Address: 6.3.1.4

Additional Comments:

The DOE has stated in both the Draft Environmental Assessment (DEA) and the Final Environmental Assessment (FEA) that significant climatic changes are not expected during the next 10,000 years and therefore DOE concludes that the potentially adverse condition of significantly increased radionuclide transport caused by climatic changes is not present at Hanford (10 CFR 960.4-2-4(c)(2)). The NRC believes that climatic changes may significantly alter the geohydrologic regime, inducing changes in the hydraulic gradient, hydraulic conductivity, effective porosity, or the ground-water flux and consequently might affect repository performance. The NRC also felt that due to the significant changes that could occur, the possible climatic changes should be addressed further in the FEA.

The NRC also commented on the possibility of smaller-scale climatic variations which could result in future channel migrations of the Columbia River and its tributaries . The possibility of future channel migration is addressed in the FEA; however the probable causes for such small scale climatic variations are not addressed in the FEA.

No attempt is made in the FEA to further address the potential for significant warming, as either a warmer period during the next glaciation phase or as a possible warming trend in the environment as we know it today. Human-induced environmental influences are also not mentioned.

Significant climatic changes over the next 10,000 years are not expected as is stated by DOE in the FEA. No further supporting material has been added to this information as was suggested by the NRC with regard to their comments on the draft EA.

BASSE

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI/NWC Date: 7/15/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 2 DOE Comment No: _____ Comment Topic: Human Induced Changes

Location of Comment Address: _____

How Was Comment Addressed? (Circle)
(New Information) New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

___ DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
_X_ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
___ Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: Major Comment #2

Comment Topic: Possible Human Interference

Location of Comment Address:

Additional Comments:

The NRC Major Comment #2 states that human-induced conditions may significantly alter the geohydrologic regime and consequently affect rates of radionuclide transport to the accessible environment. These human-induced conditions could be caused by onsite wastewater disposal activities, offsite ground-water withdrawals or injections, dam construction, and irrigation practices. These changes could cause a potentially adverse condition as is stated in 10 CFR 960.4-2-1(c)(1).

The DOE does not consider these possibilities at any great length in the draft EA, but they have added considerably more detail in the final EA. There does exist, as is stated in the final EA, the potential for forseeable human activities to cause an adverse change to the ground-water flow system. However, as stated in the final EA, these activities are not expected to significantly impact the deep ground-water system.

The NRC Major Comment #2 also points out an apparent disparity in the draft EA. This conflict is solved by careful reading of either of the EAs.

Two comments from TTI: Further study is needed (1) with respect to the geologic boundary structures to ensure that human activities which occur away from the immediate vicinity will not adversely affect that portion of the ground-water flow system important to waste isolation and (2) with respect to vertical ground-water travel paths and travel times which could also affect that same portion of the ground-water flow system.

Hydrology Detailed Comment Resolution Form

NRC/Contractor: NWC-Logsdon Date: 7/15/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3 DOE Comment No: ____ Comment Topic: Geochem - Stability

Location of Comment Address: 6.3.1.2, p. 6-106 - 109 + C.5.81-88

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP (Other)
Better statement of position

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
(1)(2) X DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
____ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

(1) DOE acknowledges NRC concerns + proposes ongoing experimental program

(2) I find the DOE response compelling, ~~not~~ the DOE approach appropriate, and the wording of 6.3.1.2.1 very appropriate

(3) Final resolution requires site characterization

Hydrology Detailed Comment Resolution Form

NRC/Contractor: ITI/NWC Date: 7/15/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 1-4 DOE Comment No: ____ Comment Topic: Recharge/Discharge

Location of Comment Address: 1.3.2.2

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
__X__ Other (explain) Comment adequately addressed

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
____ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)
The "current" state of knowledge is presented in several places within both the draft and final EA. DOE realizes a need for greater understanding of ground-water flow patterns both near and away from the RRL. Details for research activities will be included in the SCP. (Vol III, C.4-80)

Basse

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TI/NWC Date: 7/15/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 2-6 DOE Comment No: _____ Comment Topic: Regional Groundwater Hydrology

Location of Comment Address: _____

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP (Other)
Not addressed

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

X Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
____ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

No changes/additions/further explanations are given in the Final EA to respond to NRC comment 2-6 criticism of the draft EA.

7/11/86 F. Marinelli

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 2-11 DOE Comment No: _____ Comment Topic: Selection of Candidate Horizon

Location of Comment Address: Sec 2.2.3.2; Pag 2-71; Par 3.

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP (Other)

No changes in FEA

Manner in Which Comment is Adequately Addressed:

___ DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

X Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
X Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 2-11 DOE Comment No:

Comment Topic: Selection of Candidate Horizon

Location of Comment Address: Sec 2.2.3.2; Page 2-71; Par 3

Additional Comments:

No changes were made in the FEA in response to this NRC comment.

Preliminary modeling results are subject to considerable uncertainty because:

1. There are no reliable measurements of bulk vertical hydraulic conductivity of flow interiors at the site.

2. No comprehensive modeling efforts have been performed which account for the effects of thermal induced gradients on radionuclide transport.

3. No comprehensive modeling efforts have been performed which account for potential heterogeneities within flow interiors.

Thus, conclusions regarding the absolute confinement capability of the Cohassett, based on "preliminary modeling results", is open to question.

The affected sentences in the DEA might be restated as follows:

> Preliminary performance modeling was conducted to assess the containment capabilities of candidate horizons in preventing significant contamination of the overlying, relatively high permeability zones in the Wanapum and Saddle Mountains Basalts (Long and WCC, 1984). This modeling was based on assumed values of vertical hydraulic conductivity and generally did not account for thermally induced gradients or flow interior heterogeneity. Thus, conclusions regarding the <u>absolute</u> confinement capability of the candidate horizons were subject to considerable uncertainty. However, if was felt that modeling results could be used in a sensitivity manner to assess the <u>relative</u> confinement capabilities of the different horizons. This assessment indicated that overall confinement provided by the Cohassett Flow Interior was not significantly different from the other candidate horizons.

believed that the probabilistic ranking best represented the comparison of horizons. In addition, the Cohassett flow ranked highest under a variety of assumptions about the relative importance of the ranking measures. Moreover, the highest rank for the Cohassett flow was not sensitive to wide variations in levels of the measures.

2.2.3.2 Application of expert judgment to the proposed candidate horizons

Members of the U.S. Department of Energy-Richland Operations Office Basalt Waste Isolation Project Overview Committee and their consultants (Bartlett, 1983) in conjunction with the Basalt Waste Isolation Project staff assessed the proposed candidate horizons based on the technical data available (Long and WCC, 1984). The assessment presupposed identification of the four proposed candidate horizons and was mainly deductive.

The principal conclusion from this review was that the Cohassett flow, with few exceptions, had characteristics that appeared to be more favorable for a repository than those of the other proposed candidate horizons. The main exception was that the Cohassett flow, because of its stratigraphic position, did not confine radionuclides to as great a depth as the McCoy Canyon or Umtanum flows. However, the Cohassett flow still provided vertical confinement that, based on preliminary modeling results, prevented significant contamination of the overlying, relatively high-permeability zones in the Wanapum and Saddle Mountains Basalts (Long and WCC, 1984). Vertical confinement thus appeared adequate. Consequently, the other two performance comparisons (radionuclide release and groundwater travel time) for which the Cohassett flow showed better performance than the other proposed candidate horizons, tended to offset its lesser performance on vertical confinement.

In summary, based on the recognized differences among the proposed candidate horizons, application of expert judgment identified the Cohassett flow as the preferred candidate horizon for a nuclear waste repository. This result corroborated the result obtained using the decision analysis approach.

It was recognized that the selection of the preferred candidate horizon was subject to review and revision as new data were acquired and analyzed. Based on the Long and Woodward-Clyde Consultants (Long and WCC, 1984) study, all four proposed candidate horizons identified were considered to be suitable as a host rock. In June 1985, the preferred candidate horizon, the Cohassett flow, was designated as the candidate horizon for a nuclear waste repository in basalt at the reference repository location.

7/11/86 F. Marinelli.

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-18 DOE Comment No: _____ Comment Topic: Ground Water Flow Directions

Location of Comment Address: Sec 3.3.2, Page 3-97; Par 1

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP (Other)
No significant changes in FEA

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
__X__ Other (explain) TTI disagrees with NRC comment

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 3-18 DOE Comment No:

Comment Topic: Ground Water Flow Directions

Location of Comment Address: Sec 3.3.2; Page 3-97; Par 1

Additional Comments:

In the FEA text associated with this comment, the word "bulk" should be inserted in front of "hydraulic conductivity".

TTI disagrees with the NRC comment. On the regional scale, the apparent contrast in bulk hydraulic conductivity between flow tops and flow interiors indicates that the ground water flow is primarily horizontal within flow tops and vertical within flow interiors. This conclusion pertains only to flow direction and is not related to the relative total fluxes occurring within these hydrostratigraphic units. Since the FEA text is concerned only with flow direction, TTI is in agreement with DOE.

However, NRC's recognition of potential heterogeneities within flow interiors is an important point which should be stated in the FEA. TTI recommends that an additional "bullet" on this subject be added to the FEA text. This addition might be worded as follows:

- An unknown degree of heterogeneity within flow interiors. If such heterogeneities are significant, flux rates through flow interiors may be locally increased.

- The existence of the Cold Creek barrier and Umtanum Ridge-Gable Mountain structure. These nearby structures may tend to isolate the reference repository location from hydraulic influences to the west and north by forming hydraulic boundaries of low lateral hydraulic conductivity. Such a situation exists across the Cold Creek barrier in which the reference repository location appears isolated from the major influences of ground-water pumpage in the Cold Creek Valley. These structural boundaries might also identify areas of increased vertical ground-water leakage between deep and shallow ground-water systems compared to areas of structurally less-deformed basalt. However, ground-water movement near geologic structures is not well understood at this time. The eastern extension of the Yakima Ridge anticline may also influence the geohydrologic setting of the reference repository location.

- A large contrast in hydraulic conductivity between flow tops and flow interiors. This feature promotes lateral ground-water movement in flow tops (aquifers) and vertical flow across basalt flow interiors (aquitards or, possibly, aquicludes). Actual flow directions depend on hydraulic head distributions.

- Local flow-top heterogeneities. This will contribute to hydrodynamic dispersion (mixing) and tortuous ground-water flow paths.

Hydraulic heads are monitored in 35 wells across the Hanford Site in support of basalt studies (Swanson and Wilcox, 1985). Through the use of multiple piezometers, some wells monitor more than one stratigraphic horizon. Overall, there are 11 monitoring points in the unconfined aquifer, 25 in the Saddle Mountains and upper Wanapum Basalts, and 25 in the lower Wanapum and Grande Ronde Basalts. Seven wells monitor composite water levels across the Wanapum or Grande Ronde Basalts. Hydraulic head data are summarized in Swanson and Leventhal (1984), Swanson and Wilcox (1985), and in monthly and quarterly issued reports. The following paragraphs outline available head information from several of these wells. The preliminary nature of these data is recognized and additional monitoring facilities are planned (Subsection 4.1.1.4).

In general, data indicate hydraulic head changes of approximately plus or minus 1 meter (3 feet) in the Mabton interbed of the lower Saddle Mountains Basalt at boreholes DB-1 and DB-2 (Fig. 3-34). These holes are located near the Columbia River in the eastern portion of the Cold Creek syncline. The monitored record extended from 1978 to 1981. Both boreholes later were deepened to monitor the Priest Rapids Member of the upper Wanapum Basalt. Following equilibration in the Priest Rapids Member, water levels stabilized at an elevation of approximately 120 meters (394 feet) in both holes. North of the Umtanum Ridge-Gable Mountain structure, hydraulic heads in the Priest Rapids Member, as measured in borehole DB-12, showed seasonal fluctuations of approximately plus or minus 2.5 meters (8 feet). The monitored period extended from 1980 to 1985. Mean head elevations are approximately 122 meters (400 feet).

7/11/86 F. Marcell.

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-17 DOE Comment No: _____ Comment Topic: Ground Water Flow Direction

Location of Comment Address: Sec 3.3.2; Page 3-96; Par 3,4

How Was Comment Addressed? (Circle)
[New Information] New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
__X__ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 3-17 DOE Comment No:

Comment Topic: Ground Water Flow Directions

Location of Comment Address: Sec 3.3.2; Page 3-96; Par 3,4

Additional Comments:

On the regional (Columbia Plateau) scale, there is a correspondence between topographic elevation and ground water flow directions. This is because regional recharge generally occurs in areas of high elevations and regional discharge is considered to occur along major rivers (which occupy topographic lows). Within the Columbia River Plateau, basalt structure generally conforms (in a subdued manner) to topography. Thus, on the gross regional scale, ground water flow directions are similar to structural dip. However, it is Terra Therma's opinion that topography is the controlling factor that affects regional ground water flow directions and not stratigraphic dip.

While the idea of a correspondence between regional flow and structural dip may be valid on the regional (Columbia Plateau) scale, application of this concept to a local or site specific scale is much more tenuous. This is because smaller scale flow systems may be superimposed on the regional trend. Since the reference repository location represents a very limited area within the Pasco Basin, Terra Therma feels that application of a regional concept regarding flow directions to a site specific area is subject to uncertainty. Our main concern is that this section of the FEA might be interpreted to mean that in order to determine flow directions within the RRL, one simply needs to measure the structural dip. We would have strong reservations on any conclusions regarding ground water flow directions based on this supposition.

Baseline piezometric monitoring tends to refute the concept that ground water flow within the RRL is in the direction of structural dip. Structural dip within the RRL is generally to the southeast. However, hydraulic heads measured in the Mabton Interbed at DC-19, 20 and 22 suggest a lateral flow direction to the west. Also, the extremely low horizontal gradients in Wanapum and Grande Ronde Basalts would not appear consistent with the magnitude of dip occurring in these strata (up to 5 degrees).

In summary, Terra Therma feels that a correspondence between structure and flow direction may be cautiously applied to the regional (Columbia Plateau) scale. However, application of this concept to a small scale area such as the RRL is over-simplistic and may lead to erroneous conclusions regarding local ground water flow directions.

Ground-water exchange between the unconfined and shallow confined aquifers beneath the Hanford Site also has been reported (Gephart et al., 1976; Graham et al., 1984). This exchange occurs near Gable Mountain Pond and West Lake located along the southwestern side of Gable Mountain (see Fig. 3-24). Here, the shallow basalts are folded and eroded.

Although specifics are currently unavailable, it has been proposed that the shallow basalt ground waters beneath the Hanford Site are locally recharged and discharged, while deeper flow systems are part of a more regional ground-water system. This would be consistent with the concepts of local, intermediate, and regional ground-water flow systems as proposed by Toth (1963) in his generic studies of ground-water flow patterns. The specific hydraulic effect of major geologic structures on ground-water flow patterns, such as anticlines crossing portions of the Columbia Plateau, is currently unanswered but is being addressed (Section 4.1).

At present, regional recharge to deep basalts is thought to result from a combination of factors, including (1) interbasin ground-water movement, (2) leakage along structural and stratigraphic discontinuities, and (3) leakage across nondeformed basalt flow interiors. The significance of each factor would vary depending on location. For example, in the eastern portion of the Columbia Plateau and Hanford Site, no major anticlines exist that could significantly impede or redirect interbasin ground-water movement from the Palouse subprovince (see Subsection 2.1.1.2). Here, the basalts (and overall ground-water flow directions) conform to the southwestern dip of the regional paleoslope. On the other hand, several anticlines exist in the western Columbia Plateau and Hanford Site areas that can influence vertical and lateral ground-water movement. These ridges belong to the Yakima Fold Belt subprovince. In such areas where major topographic relief exists, more complex local and regional flow system development probably occurs.

With the above ideas in mind, the geohydrology of the reference repository location appears to be most influenced by the following:

- A gently dipping (less than or equal to 5 degrees) and structurally uncomplicated bedrock of the Cold Creek syncline (east of the Cold Creek barrier and south of the Umtanum Ridge-Gable Mountain structure). This is believed to promote development of a ground-water flow system in which broad areal flow patterns are roughly in the direction of bedrock dip (i.e, toward the lowest elevations in the basin). (Tanaka et al. (1979) present structure-contour and water-level maps illustrating the general correspondence between structural dip and hydraulic gradient directions across the Columbia Plateau. In the plateau, the combination of pressure head and elevation of head-monitoring points describe a three-dimensional flow system in which ground water moves from high to low head and from high to low rock elevations.)

7/11/86 F. Marinelli.

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-19 DOE Comment No: _____ Comment Topic: Vertical K Test DC-415

Location of Comment Address: Sec 3.3.2.1.1; Page 3-114; Par 3

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP (Other)

No significant changes in FEA

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

__X__ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 3-19 DOE Comment No:

Comment Topic: DC-4/5 Vertical K Test

Location of Comment Address: Sec 3.3.2.1.1; Page 3-114; Par 3

Additional Comments:

The FEA text states the following:

> An initial ratio test conducted in boreholes DC-4 and DC-5 ..... suggests a vertical conductivity of less than approximately 10^{-10} meter per second (10^{-5} foot per day) for a test zone in the Rocky Coulee flow interior. Since this is the first test of its kind in basalt, an uncertainty cannot yet be assigned to the measured value.

The above text might lead an uninformed reader into believing that the only source of uncertainty in the DC-4/5 test is the fact that additional testing has not yet been performed to provide corroborative results. The implication is that there are no other substantial reasons to doubt the validity of this test.

TTI has reviewed and evaluated the DC-4/5 test in considerable detail. We concur with conclusions reached by Golder Associates (1984) and Brown (1984) that the DC-4/5 test results are invalid. This is because (1) the test was improperly designed and performed and (2) the analytical model used by DOE to calculate vertical K did not correspond in any way to the actual test conditions. Unless DOE can substantiate the their test results using rigorous technical arguments, it is TTI's recommendation that the DC-4/5 test should be omitted from the site characterization database, regardless of the results of future testing.

3.3.2.1 Potential ground-water pathways

Ground-water movement in basalt most likely occurs along pathways found in three groups of features: (1) Discontinuities within flow interiors, (2) flow contacts and sedimentary interbeds, and (3) bedrock structures (Gephart et al., 1983). These features are illustrated in Figure 3-35, as is the hypothetical location of a repository within the central part of a generic flow interior; as noted in Figure 3-35, no horizontal or vertical scale is intended. This figure simply illustrates the range of possible interbasalt and intrabasalt flow features that might exist and influence ground-water movement. The figure does not imply that all or any specific combination of features are expected to occur in a given area, or that a geohydrologic significance is assigned to these features. The existence of any one or combination of features may or may not be important to site characterization or waste isolation. Each of the above three categories is discussed below in regard to possible ground-water and solute pathways near a repository.

3.3.2.1.1 Flow interiors

Ground water moving from a repository would travel through fractures in the flow interior before reaching flow contacts or bedrock structures. The most ubiquitous discontinuities within the flow interior are cooling fractures found in the entablature and colonnade portions of a flow (see Fig. 3-35, features A and B).

Seventeen hydrologic tests (using a variety of test methods as described in Strait et al., 1982) have been conducted across the dense entablature and colonnade portions of the individual flow interiors. These tests were done at depths from approximately 360 to 1,200 meters (1,200 to 3,900 feet) beneath the Hanford Site. The horizontal hydraulic conductivities measured ranged from 10^{-10} to 10^{-16} meter per second (10^{-5} to 10^{-11} foot per day) with a median of 10^{-13} meter per second (10^{-8} foot per day). (The lower limit of detection is considered to be approximately 10^{-13} to 10^{-14} meter per second (10^{-8} to 10^{-9} foot per day).) These tests straddled flow interiors not containing vesicular zones. Low hydraulic conductivities for flow interiors have also been reported or suggested by other investigators (e.g., LaSala and Doty, 1971; Luzier and Burt, 1974; Newcomb, 1982). Such values in a fractured medium are attributed to a high degree of secondary mineral infilling and dead-end space in cooling fractures, in addition to lithostatic loading (DOE, 1982b). Field tests quantifying vertical conductivities and evaluating test methodologies within flow interiors are in progress. An initial ratio test conducted in boreholes DC-4 and DC-5 (see Fig. 3-7) by Spane et al. (1983) suggests a vertical conductivity of less than approximately 10^{-10} meter per second (10^{-5} foot per day) for a test zone in the Rocky Coulee flow interior. Since this is the first test of its kind in basalt, an uncertainty cannot yet be assigned to the measured value. Other test methods are under investigation (Section 4.1.1).

7/11/86 F. Marinelli

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTT Date: 7/11/86

Site: NNWSI BWIP DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-19 DOE Comment No: _____ Comment Topic: Flow Interior Anisotropy

Location of Comment Address: Sec 3.3.2.1.1 ; Page 3-116 ; Par 2

How Was Comment Addressed? (Circle)
New Information New Analysis [Revised Conclusions] Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
____ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
__X__ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 3-19 DOE Comment No:

Comment Topic: Flow Interior Anisotropy

Location of Comment Address: Sec 3.3.2.1.1; Page 3-116; Par 2

Additional Comments:

DOE appears to agree with the NRC comment but provides an inconsistent implementation of the resolution.

The revised FEA text states that:

> Estimates [of anisotropy] ..... range from 3.5 to 1 and 10 to 1. Thus, once several field measurements become available, it is believed vertical hydraulic conductivity of undeformed flow interiors will likely be within a factor of 10 of horizontal hydraulic conductivity values currently reported.

This statement assumes that horizontal hydraulic conductivities measured by single borehole tests are reliable bulk parameter values.

Considerable uncertainty exists in the use of single borehole tests to measure bulk properties dense basalt. Discussions of the limitations of this testing method at BWIP are well documented. While the anisotropy ratio for bulk hydraulic conductivity may very well be less than a factor of ten, this does not necessarily indicate that bulk vertical K will be within a factor of 10 of horizontal K values currently reported (based on single hole tests).

TTI recommends that the FEA text be reworded as follows:

> "Thus, once several field measurements become available, it is believed that the hydraulic conductivity anisotropy ratio for flow interiors will be within a factor of 10."

Tanaka et al. (1974) performed a digital model study of the ground-water hydrology in the Columbia Basin Irrigation Project area. This was a cooperative study between the State of Washington Department of Ecology and the U.S. Geological Survey. One data set need was for vertical hydraulic conductivity. On pages 23 and 24 of Tanaka et al. (1974) it is stated: "In the absence of reliable field data on the vertical hydraulic conductivity of basalt in the project area, several hydraulic conductivity values were estimated indirectly by analysis of the head response in basalt to application of known amounts of irrigation water, and these values were tested as model parameters. After repeated trials on the model, comparing different values of hydraulic conductivities to head response in the upper and lower aquifers, an average value of 0.00002 foot per day (within a range of 0.000001 foot/day to 0.000037 foot/day) gave computed heads that were similar in response to measured heads in both aquifers." In metric units, the above range equates to 3×10^{-12} to 1×10^{-10} meter per second. In MacNish and Barker (1976, p. 5), vertical hydraulic conductivity was said to be "as small as 0.00000005 ft/s." This is equivalent to 1×10^{-8} meter per second. (These computer-model-generated values for hydraulic conductivity are approximately two orders of magnitude larger than that suggested by available field test data for basalt flow interiors.) The representativeness of the above estimates for vertical hydraulic conductivity will be examined during large-scale stress tests and research conducted from within the exploratory shaft facility.

Field-derived values of the anisotropy ratio of vertical-to-horizontal hydraulic conductivity within basalt flow interiors are not available. Estimates based on ground-water model simulations and statistical analysis of fracture data are reported in U.S. Department of Energy (1982b) to range between 3.5 to 1 and 10 to 1. Thus, once several field measurements become available, it is believed vertical hydraulic conductivity of undeformed flow interiors will likely be within a factor of 10 of horizontal conductivity values currently reported. This concept is based on the representativeness of the previously noted ratios. The present uncertainty of these ratios is recognized; planned research (Subsection 4.1.1.3) will address this uncertainty.

Uncertainty in hydrologic test results, such as those outlined in this and the following section, is related to the extent that analytical assumptions are satisfied, as well as related to the relative hydraulic conductivity of the rock tested. For example, an uncertainty of approximately 2 or 3 times might apply to a rock of higher hydraulic conductivity (greater than approximately 10^{-6} meter per second (10^{-1} foot per day)) when data interpretations from several accepted analytical solutions are compared. On the other hand, when a single solution (e.g., Theis, 1935; Cooper and Jacob, 1946; Papadopulos and Cooper, 1967) is used, results of multiple tests in the same rock zone can be nearly identical. Equipment compliance and test system unknowns increase uncertainties in test results for rocks of low hydraulic conductivity. Such test uncertainties are common to all rock types. Overall, an uncertainty of approximately two to three times the hydraulic conductivity value measured is assigned for the flow top and interbed. For flow interiors, the upper range of values reported is considered high because equipment compliance results in an

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Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-21 DOE Comment No: _____ Comment Topic: Umtanum Fracture Zone

Location of Comment Address: Sec 3.3.2.1.1; Page 3-117; Par 7

How Was Comment Addressed? (Circle)
New Information New Analysis [Revised Conclusions] Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

X DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
___ Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

overestimation of the true hydraulic conductivity (i.e., if a flow interior test results in a 10^{-10} meter per second (10^{-5} foot per day) horizontal conductivity, the actual in situ value of the zone stressed is probably lower).

Preliminary single hole tests have been conducted on the possible effects of drilling fluid (mud) invasion on hydraulic conductivity estimates within a basalt flow interior. Results suggest that no discernible impact occurred from the use of drilling fluids under the test conditions examined (Spane and Thorne, 1984).

Few examples are formally available for comparing test interpretations conducted by different organizations. One brief comparison is given in Table 3-16. These calculations by Jackson (1982) and Wilson (1983) are essentially identical.

Besides entablature and colonnade joints, other discontinuities potentially present within flow interiors include vesicular zones, platy zones, and localized fracture zones. These features are illustrated as features C, D, and E in Figure 3-35.

Within the Cold Creek syncline, a vesicular zone in the entablature of the Cohassett flow (see Fig. 3-12) was hydrologically tested at four borehole sites. The hydraulic conductivity values calculated were 10^{-8} to 10^{-9}, 10^{-12} to 10^{-14}, 10^{-13} to 10^{-16}, and 10^{-14} to 10^{-16} meter per second (10^{-3} to 10^{-4}, 10^{-7} to 10^{-9}, 10^{-8} to 10^{-11}, and 10^{-9} to 10^{-11} foot per day). Whether such hydraulic conductivity values are typical of vesicular zones within flow interiors is not known.

The hydraulic conductivity of the Cohassett flow interior typically ranges from 10^{-10} to 10^{-14} meter per second (10^{-5} to 10^{-9} foot per day). These test results included straddling the vesicular zone of the flow. At borehole DC-16, the hydraulic conductivity of the Cohassett flow vesicular zone was tested at 10^{-8} to 10^{-9} meter per second (10^{-3} to 10^{-4} foot per day). The larger than normal conductivity reported at borehole DC-16 is believed to represent a local hydraulic heterogeneity. This is because the hydraulic conductivity of the vesicular zone is much lower at other boreholes in the reference repository location and its geologic characteristics are similar throughout the reference repository location (see Subsection 3.2.2.3).

A fracture zone approximately 2 meters (6 feet) thick was identified in the entablature near the base of the Umtanum flow in one borehole located in the reference repository location. A hydraulic conductivity of 5×10^{-4} meter per second (147 feet per day) was calculated from pump and slug tests (Strait and Spane, 1983). This is the highest hydraulic conductivity measured in a flow interior on the Hanford Site. Hydrologic tests across the Umtanum flow entablature-colonnade contact in other boreholes on the Hanford Site indicate values of approximately 10^{-13} meter per second (10^{-8} foot per day). Although the extent of this fracture zone is unknown, it is presently considered a localized feature (symbolically shown as feature E in Figure 3-35) that may be interconnected to the

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Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-22 DOE Comment No: ____ Comment Topic: Use of Geometric Mean

Location of Comment Address: Sec 3.3.2.1.2; Page 3-119; Par 5

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
__X__ Other (explain) TTI disagrees with NRC comment

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
__X__ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form (cont.)

NRC Comment No: 3-22 DOE Comment No:

Comment Topic: Use of Geometric Mean

Location of Comment Address: Sec 3.3.2.1.2; Page 3-119; Par 5

Additional Comments:

NRC's proposed resolution might be valid if the variabilities between flow tops are greater than those existing within flow tops. Compilations of site data suggest that this is not the case. For example, in Appendix H of the BWIP Draft SCA, statistical tests of differences showed that the variability in hydraulic conductivity between adjacent flow tops was generally not sufficiently great to define unique hydrostratigraphic units. Furthermore, histograms of hydraulic conductivity, constructed by TTI for all flow tops within the major basalt formations, are generally log-normally distributed and show little tendency multi-modal distributions. We therefore conclude that individual basalt flow tops are not sufficiently unique with regard to hydraulic conductivity to justify NRC's method of resolution.

However, it is TTI's opinion that the FEA statement justifying the use of geometric means is stated too strongly. Geometric means commonly provide a reasonable and efficient means of integrating hydraulic conductivity. However, it is not necessarily the best means of accomplishing this in all hydrogeologic settings. TTI recommends that the statement in the FEA be reworded as follows:

> "In heterogeneous media (e.g., basalt), the use of geometric mean values generally is considered to provide a reasonable integration of hydraulic conductivity over a large area (Neuman, 1982; Snow, 1965). Depending on local hydrogeologic conditions, the use of alternative methods to integrate hydrologic data may also be appropriate."

basalt flow top or bottom. At other borehole sites tested, this same stratigraphic zone possesses a much lower hydraulic conductivity typical of other basalt flow interiors studied.

3.3.2.1.2 Flow contacts and sedimentary interbeds

After ground water travels through joints or other pathways within a basalt interior, it may enter a flow contact. Commonly, these contacts represent the closest zones of higher hydraulic conductivity near the reference repository location. Flow contacts may contain features F through K as shown in Figure 3-35.

A flow top (see features F and G in Fig. 3-35) may form a more or less continuous layer atop the flow interior. The flow top of an areally extensive basalt flow may cover several thousand square kilometers (square miles) while its thickness, internal characteristics, and hydrologic properties spatially vary. Flow termination (pinch outs), such as feature H in Figure 3-35, represents places where ground water could move from one flow top to another without traversing a basalt interior.

Associated with some flow tops are sedimentary interbeds (see feature I in Fig. 3-35). Most interbeds within the Pasco Basin vicinity are located in the Saddle Mountains Basalt, approximately 500 meters (1,600 feet) above the Cohassett flow (see Fig. 3-6).

In excess of 200 single-hole hydrologic tests have been conducted in flow tops and interbeds in some 35 separate boreholes across the Hanford Site. These data indicate that within both the Saddle Mountains and Wanapum Basalts, the hydraulic conductivities of most individual flow tops and interbeds range between approximately 10^{-4} and 10^{-7} meter per second (10^{1} and 10^{-2} foot per day) with a geometric mean of approximately 10^{-5} meter per second (10^{0} foot per day). Some hydraulic conductivity values as large as 10^{-2} to 10^{-3} meter per second (10^{3} to 10^{2} feet per day) and as small as 10^{-8} to 10^{-10} meter per second (10^{-3} to 10^{-5} foot per day) are also reported for selected flow tops in the Saddle Mountains and Wanapum Basalts (Long and WCC, 1984). Large hydraulic conductivity values are commonly associated with the Priest Rapids Member of the upper Wanapum Basalt. Most hydraulic conductivity values within Grande Ronde Basalt flow tops range between approximately 10^{-5} and 10^{-9} meter per second (10^{0} and 10^{-4} foot per day) with a geometric mean of approximately 10^{-7} meter per second (10^{-2} foot per day) (Long and WCC, 1984). A few hydraulic conductivity values as large as 10^{-3} to 10^{-4} meter per second (10^{2} to 10^{1} feet per day) and as small as 10^{-10} to 10^{-11} meter per second (10^{-5} to 10^{-6} foot per day) are also reported (Long and WCC, 1984). In heterogeneous media (e.g., basalt), the use of geometric mean values generally is considered to provide the best integration of hydraulic conductivity over a large area (Neuman, 1982; Snow, 1965).

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Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-23 DOE Comment No: _____ Comment Topic: Use of term "effective thickness"

Location of Comment Address: Sec 3.3.2.1.2 ; Page 3-120 ; Par 1

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP [Other]

Re-definition of terms

Manner in Which Comment is Adequately Addressed:

X DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
___ Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

Existing hydrologic data, based on single-hole tests stressing localized rock volumes, suggest that flow-top hydraulic conductivities are heterogeneous across the reference repository location. For example, the hydraulic conductivity of the Rocky Coulee flow top changes only slightly, from 10^{-6} to 10^{-7} meter per second (10^{-1} to 10^{-2} foot per day), while that of the Cohassett flow top ranges between 10^{-6} to 10^{-11} meter per second (10^{-1} to 10^{-6} foot per day). Furthermore, borehole fluid-temperature and flow-velocity surveys performed during air-lift pumping tests sometimes indicate the presence of ground-water inflow zones within individual flow tops. Such zones can be thin (i.e., less than 1 to 3 meters (3 to 9 feet)), and may possess higher local hydraulic conductivities than the equivalent hydraulic conductivity assigned to the entire effective test interval (i.e., flow-top thickness). Zones of high permeability within flow tops appear as localized features and are not laterally continuous. For large-scale performance, the entire effective test interval is believed involved in ground-water movement. Additional information on the actual thickness of basalt flow tops involved in ground-water transport will be obtained by planned large-scale interference and tracer tests mentioned in Subsections 4.1.1.3.1 and 4.1.1.3.3.

Two tracer tests have been conducted in the flow top of the McCoy Canyon flow (Bakr et al., 1980; Gelhar, 1982; Leonhart et al., 1982). Dispersivity values reported were 0.45 and 0.85 meter (1.5 to 2.8 feet) with an effective thickness of 2×10^{-3} and 3×10^{-3} meter (6×10^{-3} and 1×10^{-2} foot).

Hydraulic heads measured across flow tops and interbeds by piezometers and also on a progressive drill-and-test basis suggest that the areal hydraulic gradient in the Cold Creek syncline is approximately 10^{-4} meter per meter (10^{-4} foot per foot). Vertical head measurements across the deep basalts reveal upward gradients of 10^{-3} to 10^{-4} meter per meter (10^{-3} to 10^{-4} foot per foot). It has been suggested that in structurally undeformed areas, ground-water movement is predominantly lateral with the general flow direction semiconforming to bedrock dip (Newcomb, 1982).

Because pillow breccia zones (see feature J in Fig. 3-35) have not been penetrated by boreholes in the Hanford Site, none have been hydrologically tested. Their existence, however, as well as spiracles or spiracle-like features (see feature K in Fig. 3-35), should be anticipated based on field observations in the Columbia Plateau. These features represent rock zones of possibly high hydraulic conductivity that may locally influence ground-water movement.

3.3.2.1.3 Bedrock structures

Bedrock structural discontinuities represent zones of potentially significant fracture anisotropy (shown symbolically as features L and M in Fig. 3-35) that may hydraulically connect flow systems above and below a

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Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-24 DOE Comment No: _____ Comment Topic: Locations of tracer tests

Location of Comment Address: Sec 3.3.2.1.2; Page 3-120; Par 2

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

____ DOE agreed with problem, basis, and suggested resolution
____ DOE disagreed with suggested resolution; alternative resolution accepted
____ DOE disagreed with problem and basis; DOE response accepted
____ Comment resolved pending NRC review of new information/analysis
__X__ Other (explain) EA is correct as stated. Supporting reference cited by NRC apparently is in error.

Manner in Which Comment is Inadequately Addressed:

____ Lack of recognition of NRC comment
____ Lack of understanding of the NRC stated problem and basis
____ Lack of agreement with NRC stated problem and basis
____ Lack of adequate support for disagreement with NRC stated problem and basis
____ Lack of agreement with NRC stated suggested resolution
____ Lack of adequate support for disagreement with NRC stated suggested resolution
____ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
____ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

____ Defer to SCP
____ Precipitate FEA Comment
____ Unresolved but not significant to siting or characterization
____ Other (explain) _____

Additional Comments: (use back if needed)

Hydrology Detailed Comment Resolution Form

NRC/Contractor: NWC - Logsdon Date: 7/15/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 3-25 DOE Comment No: ____ Comment Topic: Water Chem - Bedrock Structures

Location of Comment Address: 3.3.2.1.3 p. 3-122, 123

How Was Comment Addressed? (Circle)
New Information New Analysis (Revised Conclusions) Deferred to SCP Other

Manner in Which Comment is Adequately Addressed:

(1) X DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
(1) X Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
___ Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

(1) Closest answer - modified statement/conclusion, but did not include data or reference for data. However, this is quite minor, since NRC has seen the data and at least two NRC contractors (WMA and TTI) have reviewed the data in several letter reports and concurred with the DOE interpretation.

Mark J Logsdon 7/15/86

7/11/86 F. Marinelli

Hydrology Detailed Comment Resolution Form

NRC/Contractor: TTI Date: 7/11/86

Site: NNWSI (BWIP) DEAF SMITH DAVIS CANYON RICHTON DOME

NRC Comment No: 4-1 DOE Comment No: _____ Comment Topic: Use of term "vertical transmissivity"

Location of Comment Address: Sec 4.1.1.3.1 ; Page 4-6 ; Par 4

How Was Comment Addressed? (Circle)
New Information New Analysis Revised Conclusions Deferred to SCP [Other]

Redefinition of terms

Manner in Which Comment is Adequately Addressed:

X DOE agreed with problem, basis, and suggested resolution
___ DOE disagreed with suggested resolution; alternative resolution accepted
___ DOE disagreed with problem and basis; DOE response accepted
___ Comment resolved pending NRC review of new information/analysis
___ Other (explain) _____

Manner in Which Comment is Inadequately Addressed:

___ Lack of recognition of NRC comment
___ Lack of understanding of the NRC stated problem and basis
___ Lack of agreement with NRC stated problem and basis
___ Lack of adequate support for disagreement with NRC stated problem and basis
___ Lack of agreement with NRC stated suggested resolution
___ Lack of adequate support for disagreement with NRC stated suggested resolution
___ Assuming agreement with NRC suggested resolution, lack of, inadequate, or inconsistent implementation of resoultion through changes to appropriate sections of the FEA
___ Other (explain) _____

Status of Unresolved Comments: (Either adequately/inadequately addressed)

___ Defer to SCP
___ Precipitate FEA Comment
___ Unresolved but not significant to siting or characterization
___ Other (explain) _____

Additional Comments: (use back if needed)

Basin, Cold Creek syncline, and reference repository location. The relationships between earthquakes and their causal mechanisms would be studied. Contemporary deformation data also would be provided by periodic resurveying of existing and newly established trilateration arrays and leveling stations within the Pasco Basin area.

4.1.1.2.3 Tectonic modeling

This item includes work to integrate all geological, geophysical, geodetic, and seismic data collected for site characterization. Work would involve a review and assessment of structural and tectonic models with specific application to the Pasco Basin and the reference repository location. Pertinent models would be evaluated in terms of their impact on preclosure and postclosure repository performance. Interpretations would serve as the basis for input to seismic design of a repository.

4.1.1.3 Hydrologic parameter testing

The objective of this work is to complete the hydrologic tests needed for evaluating those ground-water flow characteristics within and surrounding the reference repository location critical to understanding ground-water movement and possible effect of radionuclide migration to the accessible environment. Test facilities specifically designed for hydrologic testing would be used for characterization within and in the vicinity of the reference repository location. Elsewhere on the Hanford Site existing and planned boreholes would be tested. A limited number of wells located off the Hanford Site also may be drilled and (or) tested. These would be located in areas considered important to understanding the regional geohydrologic setting.

4.1.1.3.1 Large-scale hydrologic stress tests

Multiple-hole tests would be designed to stress selected flow tops and interbeds across large distances (several thousand meters (feet)). These tests would provide large-scale measurement of transmissivity and storativity. By monitoring hydraulic heads above, below, and within basalt flows, vertical leakage across basalt flow interiors may be estimated.

4.1.1.3.2 Small-scale hydrologic tests

Single borehole hydrologic tests stress rock volumes in the immediate vicinity of the borehole. Such tests are reconnaissance in nature and would provide small-scale measurement of transmissivity and hydraulic head measurements recorded on a progressive drill-and-test basis or following borehole completion.