Lawrence Livermore National Laboratory

NUCLEAR SYSTEMS SAFETY PROGRAM

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Ms. Kristin Westbrook
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Geotechnical Branch
Division of Waste Management ,
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: Site Technical Position on BWIP Geologic Stability Issues

REFERENCE: NRC FIN A0294, "Technical Assistance in Seismo-Tectonic Impacts in Repositories"

Dear Ms. Westbrook:

This is to transmit the subject Site Technical Position (STP) report with discussion. This STP report is under four general headings as follows:

- What are the structural discontinuities in the Pasco Basin under present conditions?
- What are the stratigraphic discontinuities of the Pasco Basin under present conditions?
- What are the probabilities and nature of natural changes that would affect repository performance?
- What are the probabilities and nature of human-induced changes, excluding repository construction, that would affect repository performance?

Don O. Emerson, H. Larry McKague, D. Burt Slemmons, and Robert A. Whitney contributed generously to this report.

It is essential that the Department of Energy (DOE) and their contractors have sufficient time for studying the questions in our STP report prior to the forthcoming joint workshop meeting in Richland, WA.

If you have any questions, please let met know.

Sincerely,

Dae H. Chung
Project Manager

DHC/lw

Enclosure

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SITE TECHNICAL POSITION

Geological Stability Issues for the Basalt Waste Isolation Project

By

Lawrence Livermore National Laboratory

1. BACKGROUND

In review of an application for a Construction Authorization for any high-level waste geologic repository, the NRC staff is required to make a determination if the site and design meet the technical criteria of 10 CFR Part 60. The NRC staff determination will be based on the answers to, and supporting analyses of, technical questions concerning groundwater flow, geochemical retardation, waste form and waste package, geologic stability, and facility design. During the process of Site characterization, the Department of Energy (DOE) performs the laboratory and field investigations that develop the information needed to address these basic technical questions.

Investigations needed to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1982 (The Act) has established a schedule for site characterization and selection. Specifically, The Act requires publication of Site Characterization Plans (SCPs) by DOE at an early stage of the process. This process includes preparation of formal Site Characterization Analyses (SCAs) by NRC staff. Supplementing and preceding the SCAs are documented site reviews and technical meetings, and single-issue site technical positions.

Because of the complexity and long lead times for site characterization investigations, it is essential that activities be organized to make possible an NRC determination of site acceptability. Proper organization necessitates early identification of technical questions relevant to the specific site. Therefore, this document establishes from the present data the NRC position as to the essential technical questions (specific issues) relevant to the Geologic Stability Issues of the Basalt Waste Isolation Project (BWIP) site. Future Site Technical Positions relevant to geologic stability will address both potential NRC staff concerns regarding selected specific issues and acceptable technical approaches for addressing those specific issues.

Terminology used by NRC staff to describe issues may require clarification:

SITE ISSUES are defined as questions about a specific site that must be answered or resolved to complete licensing assessments of the site and design suitability in terms of 10 CFR 60. Site issues are not necessarily controversial questions. Site issues can be divided into performance issues and specific issues.

PERFORMANCE ISSUES are broad questions concerning both the operational and long-term performance of the various elements of the overall geologic repository system (e.g., waste form, waste package, geologic setting). Performance issues are derived directly from performance objectives in 10 CFR 60 (including environmental objectives of 10 CFR 51). Development of performance issues for a geologic repository is explained in detail in Appendix C of NUREG-0960, "Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project," March 1983.

SPECIFIC ISSUES are, generally, questions about conditions and processes (information needed) that must be considered in assessing the performance issues. Therefore, performance issues include the integration of numerous specific issues thus establishing the relationship between specific issues discussed in this Site Technical Position and the performance objectives of 10 CFR 60.

Performance issues for a geologic repository, as developed in NUREG-0960, are:

1. How do the design criteria and conceptual design address releases of radioactive materials to unrestricted areas within the limits specified in 10 CFR 20?

2. How do the design criteria and conceptual design accommodate the retrievability option?

3. When and how does water contact the backfill?

4. When and how does water contact the waste package?

5. When and how does water contact the waste form?

6. When, how, and at what rate are radionuclides released from the waste form?

7. When, how, and at what rate are radionuclides released from the waste package?

8. When, how, and at what rate are radionuclides released from the backfill?

9. When, how, and at what rate are radionuclides released from the disturbed zone?

10. When, how, and at what rate are radionuclides released from the farfield to the accessible environment?

11. What is the pre-waste emplacement groundwater travel time along the fastest path of radionuclide travel from the disturbed zone to the accessible environment?

12. Have the NEPA Environmental/Institutional/Siting requirements for nuclear facilities been met?

Because geologic stability affects both pathways for radionuclide migration and repository design, information on the geologic setting collected during site characterization at BWIP will be part of the total repository system information needs of the NRC staff required to assess the performance issues. Specific issues identified in the following section indicate, in a broad but complete manner, information on geologic stability at BWIP needed by the NRC staff to assess adequately the performance issues. The sequential order in which issues are identified should not be interpreted as the relative order of importance.

2. TECHNICAL POSITION

To properly assess the Technical Criteria of 10 CFR 60 based on the current information available for the BWIP site at least the following specific issues concerning the geologic stability of the site should be addressed. The issue numbers are from the Geology section (5.0) of Table C-2 of the NRC Draft Site Characterization Analysis NUREG-0960. The (*) indicates that the issues are listed in Table C-2. The un-asterisked issues are herein added to the original issues.

GEOLOGY

1.0* What are the structural discontinuities in the Pasco Basin under present conditions?

1.1* What is the significance of the aeromagnetic and gravity anomalies that define intact blocks in the Cold Creek Syncline?

1.1.1 What is the significance of the N-96 and N-84 anomalies?

1.2* What is the character of faults delineated in the Pasco Basin and adjoining areas?

1.2.1 Does low-angle thrust faulting occur in the Cold Creek Syncline?

1.2.2 Are there local or regional decollements in the Pasco Basin area?

1.2.3 What is the impact of the Rattlesnake-Wallula Alignment (RAW) on the RRL site?

1.2.3.1 Does RAW have splays, branches, conjugate faults or an enechelon pattern which could intersect the site of the RRL?

1.2.3.2 What are the earthquake recurrence intervals on RAW?

1.2.3.3 What are the maximum credible earthquakes for nearby parts of RAW?

1.3* What is the probability and nature of undetected faulting in the controlled area?

1.3.1* East-west trending faulting?

1.3.2* North-west to south-east trending faulting?

1.3.3 What is the cause and orientation of the tectonic breccias in boreholes in the Cold Creek Syncline area?

2.0* What are the stratigraphic discontinuities of the Pasco Basin under present conditions?

2.1 What is a generalized stratigraphic column for the Pasco Basin area and how do the data from all boreholes and geophysical surveys correlate with the generalized stratigraphic column?

2.1.1 Why is the error in RHO (1983) top-of-basalt maps (Figures 5-8, 5-9, and 5-10) so great?

2.1.2* What is the lateral continuity and variation in thickness of the interaflow structures of the Umtanum Flow and Middle Sentinel Bluffs Flow?

3.0* What are the probabilities and nature of natural changes that would affect repository performance?

3.1* What is the probability of earthquake activity in or near the Pasco Basin affecting repository performance?

3.1.1* What is the seismic hazard and risk to surface and subsurface facilities within the controlled zone?

3.1.1.1 What are the sources or source areas for earthquakes that could produce maximum accelerations at the site?

3.1.1.2 What is the maximum size (magnitude) of the largest earthquake expected from sources or source areas that could affect the site?

3.1.1.3 Are there secondary hazards from earthquake accelerations at the site?

3.1.1.4 What are the paths followed by seismic waves from the defined sources/source areas to the RRL and how do these affect attenuation?

3.1.1.5 Are seismic focusing effects possible in the Cold Creek Syncline which could increase significantly the accelerations at RRL from certain sources/source areas?

3.2* What is the nature and probability of renewed volcanism in or near the Pasco Basin affecting repository performance?

3.2.1* Flood basalt?

3.2.2* Air fall tephra?

3.2.3* Ash flows?

3.2.4* Flooding with water (damming Wallula Gap)?

3.3* What is the probability of glaciation in or near the Pasco Basin affecting repository performance?

3.3.1* What is the probability that differential loading caused by glaciation can result in a change in the state of stress?

3.3.2* What is the probability that water loading from ice melt flooding will cause a change in the state of stress?

3.4* What is the probability and nature of structural deformation in the Pasco Basin that would effect repository performance?

3.4.1 What is (are) the conceptual tectonic model(s) of the Cold Creek Syncline and surrounding areas?

3.4.1.1 What are the plate motions in the Pacific Northwest in adjoining northeast Pacific Ocean basin with respect to absolute hot-spot movement, and how does this relate to regional and local tectonics in the vicinity of RRL?

3.4.1.2 What is (are) the regional tectonic model(s) for the Pacific Northwest and how do regional geophysical, geological, and seismological data correlate with this (these) model(s)?

3.4.1.3 What are the geographic and spatial relationships of all structural features in and near the Pasco Basin?

3.4.1.4 Do geophysical data bases fit with local structural interpretations?

3.4.2 What is the direction and rate of deformation both at the surface and with depth at the RRL site?

3.4.2.1 The level line data (RHO-BW-ST-19 P, p. 6-21 - 6-29) was noted as being inconsistent, i.e., E-W shortening, with the axis of compression as indicated by the geology (N-S shortening). Does this mean a change in tectonic styles in the last 13,000 years? How does this fit with focal mechanism data?

3.4.3* What is the probability and nature of future faulting in the controlled zone?

3.4.3.1 Is rupture due to faulting at or below the surface at the RRL a possibility?

3.4.3.2* What is the probability of future faulting in the repository shearing the backfill or waste package?

3.4.4 What is the source of the microearthquake swarms in the Cold Creek Syncline area?

3.5 Is there hazard to the site from a seismic deformation?

4.0* What are the probabilities and nature of human-induced changes, excluding repository construction, that would affect repository performance?

4.1* What are the probabilities that groundwater withdrawals would affect repository performance?

4.1.1* What is the probability that groundwater withdrawals for irrigation would trigger micro-earthquake or earthquake swarms?

4.2* What are the probabilities and nature of groundwater recharge that would affect repository performance?

4.2.1* What is the probability that fluids injected into the confined aquifer at the 200W area will trigger earthquake swarms in the controlled zone?

4.2.2* What is the probability that water impoundments behind possible future dam construction (Ben Franklin Dam) will cause micro-earthquakes or earthquake swarms?

4.2.3* What is the probability that flooding due to upstream dam failure will cause micro-earthquakes or earthquake swarms?

4.3 Are there possible geologic hazards to RRL that could be generated by problems or accidents with other nearby nuclear facilities?

DISCUSSION

In this discussion, the rationale for each issue is described.

1.0* What are the structural discontinuities in the Pasco Basin under present conditions?

What are the geographic and spatial relationships of all structural features in and near the Pasco Basin? A structural map at a reasonable scale of the Pasco Basin is needed which depicts all structural features indentified in the area. This map should also show the location of all boreholes, and cross-sections, and should be compatible with geological, geophysical and seismological data. Areas of structures identified by geophysical and hydrological methods should be labeled, such as the Nancy lineament (USNRC, 1983) and the May Junction monocline (USNRC, 1982a).

1.1* What is the significance of the aeromagnetic and gravity anomalies that define intact blocks in the Cold Creek Syncline?

Do geophysical data bases fit with local structural interpretations? Present discussions on local geophysical anomalies do not fit descriptions of structures. RHO (1983) states in Table 4-1 that anomaly #1 "corresponds with Rattlesnake Hills structure." From a geographical standpoint this is certainly true but from a hypsometric or isopachic standpoint the anomaly opposes the topography of Rattlesnake Mountains, as shown by the association of anomalies opposite to #1 with other ridges in the study area. Gradients shown between the negative anomaly #1 and positive anomalies numbers 5, 8, and 10 should be given.

A comparison of geophysical anomalies with known or inferred structures needs to be accomplished. This should include features within Cold Creek Syncline such as the Nancy lineament and the May Junction monocline.

RHO (1983) states "Several minor anomalies between the observed and theoretical top-of-basalt maps (Figures 5-10) occur in Cold Creek Syncline." Examples shown are true but give anomalies of about plus 500 feet and minus 200 feet differences. If the Rattlesnake Mountain data were included, between DC-8 and the Mountain an anomaly in excess of plus 2000 feet may exist if the trend of contours toward Rattlesnake Mountain continue. There is now about 3000 feet of difference; this is not a minor anomaly.

Within the area chosen to plot, anomalies as great as 1000 feet exist, twice what is shown by the examples in the text (i.e., Yakima Ridge to Cold Creek Valley Depression).

1.1.1* What is the significance of the N-96 and N-84 anomalies?

1.2 What is the character of faults delineated in the Pasco Basin and adjoining areas?

A fault map which depicts all known faults in the Pasco Basin and adjoining areas needs to be compiled. A discussion of each fault with regard to mechanism, activity, total movement, interrelationships with other faults, and compatibility with the regional tectonic model(s) needs to accompany the map. For example, the normal faults on Toppenish Ridge less than 50 km from the site are associated with reverse faults (USNRC, 1983 and Slemmons, 1983 in USNRC, 1983). These scarps may be associated with large Holocene earthquakes and suggest that part or all of Yakima fold belt is tectonically active.

1.2.1 Does low-angle thrust faulting occur in the Cold Creek Syncline area?

Low-angle faults, which are not obvious from surface investigations, may occur in areas with tectonic expressions like the Pasco Basin and surrounding areas. Evidence from geophysical studies or subsurface geologic investigations is necessary to understand this potential problem.

1.2.2 Are there local or regional decollements in the Pasco Basin area?

Avoiding the classification of thin- and thick-skinned tectonics in the RHO (1983) report does not preclude dismissal of the question of regional or at least large-scale local decollements, either between basalt flows or between the basalt and underlying rocks. The question of decollements, whether shallow or deep, should be addressed. Models such as Bruhn (1981) shown in Figure 7-3 (bottom) and Price (1982) shown in Figure 7-4 (bottom) of RHO (1983) indicate decollement at a shallow depth (to a few thousand feet) may not only be present, but prevalent. Decollements below unthrust anticlines help geometric relationships at shallow depths to avoid plastic deformation of brittle material (basalt) without significant geopressure. Caggiano (RHO 1983) states on page 8-1 (2nd paragraph) that some slip may occur along layer boundaries. If this slip extends outside of the fold, this is a decollement, and present data is insufficient to rule out this possibility. Disking of borehole cores in synclinal areas indicates sufficient horizontal stresses exist in flat lying strata to accomplish decollement. Hypocentral depth of earthquakes appears to decrease as a log function down fault plane dip on some faulted anticlines, which may indicate a decreasing dip in the fault planes as they approach a decollement.

1.2.3 What is the impact of the Rattlesnake-Wallula Alignment (RAW) on the RRL site?

This is the closest major geologic feature that appears to be a possible source of major ground motion and fault offset at the site. The potential for damage to the containment capability of BWIP from this structure needs to be studied. The field fault and fold relationships along the Rattlesnake-Wallula Alignment has not been assessed by RHO (1983) and definitive data to support the position of no associated seismicity for RAW has not been evaluated by both geologic and seismologic data. This is a critical geologic (and possibly seismologic) structure that bounds the southern edge of the Reference Repository Location. The lack of a complete evaluation precludes the possibility of making definitive judgements on the stability at the Site. This RHO (1983) position has not been closely integrated with the tectonic model(s).

1.2.3.1 Does RAW have splays, branches, conjugate faults or an _en echelon_ pattern which could intersect the site of the RRL?

Faults often exhibit complex surficial traces including splays, branches, _en echelon_ patterns, and conjugate patterns. The possibility of these patterns intersecting the RRL from RAW (and other active faults) needs to be assessed.

1.2.3.2 What are the earthquake recurrence intervals on RAW?

If RAW is a seismogenic structure, it is necessary to determine earthquake recurrence intervals, especially for the segment closest to the RRL in order to understand the potential for strong ground motion at the site. The presence of deeper earthquakes suggests that there is tectonic activity in this area. The activity is low, which is compatible with the geologic data. This low rate, with the long recurrence intervals shown by the geologic data indicate that the historical seismological events may have limited use for delineation of earthquake structures and recurrence intervals.

1.2.3.3 What are the maximum credible earthquakes for nearby parts of RAW?

This information is part of that needed to determine the potential for strong ground motion at the RRL.

1.3* What is the probability and nature of undetected faulting in the controlled area?

Fault rupture through the RRL site is an obvious hazard to containment of radionuclides.

1.3.1* East-west trending faulting?

1.3.2* North-west to south-east trending faulting?

1.3.3 What is the cause and orientation of the tectonic breccias in boreholes in the Cold Creek Syncline area?

Because these may be related to faulting, the cause and orientation of the tectonic breccias found in some of the boreholes need to be determined.

2.0* What are the stratigraphic discontinuities of the Pasco Basin under present conditions?

Cross-sections need to be constructed at a reasonable scale with sufficient vertical exaggeration to enhance the visual representation of structural features. These cross-sections should contain all available borehole, geophysical, geological, hydrological and seismological data. Cross-sections such as figure 2-4 of RHO (1983) do not have sufficient vertical exaggeration, are not constructed on all available borehole data, and follow paths that tend to minimize the visual representation of geologic structures. For example, borehole RSH-1 is very near to the south ends of sections A-A' and B-B', but data from this borehole is not used. This in turn requires that extrapolation be used in depicting the structure of the Rattlesnake Mountain and does not define the extent on faulting on the northeast flank of the structure.

Other cross-sections, such as the fence diagram of Figure A-9 of USNRC, 1982a, are not compatible with geophysical and hydrological data as this diagram intersects both the Nancy lineament and the May Junction Monocline, but does not show them. Figure A-9 also skirts the site area but figures showing some borehole locations (fig. A-8) indicate data through the RRL is available.

2.1* What is a generalized stratigraphic column for the Pasco Basin area and how do the data from all boreholes and geophysical surveys correlate with the generalized stratigraphic column?

A generalized stratigraphic column for the Pasco Basin needs to be developed that is compatible with all borehole and geophysical data in the basin. Diagrams correlating all boreholes available need to be constructed. This compilation is necessary to support conclusions reached by RHO (1983). Following is a quote from RHO (1983):

> "Thickness variations and the lateral extent of all Wanapum and Saddle Mountains basalt flows and some Grande Ronde basalt flows indicate that the present Yakima folds were actively growing throughout much of Miocene time (Rudd and others, 1980; Rudd and Fecht, 1981, 1982). Deformation was concentrated along present first-order structural trends, as shown by areas of maximum thinning consistently corresponding to anticlinal axes and areas of maximum thickening corresponding to synclinal troughs."

The following table is from measured section boreholes shown in Plates 11-5, 1 and 2 of RHO-BSI-ST-4. Because of the small vertical exaggeration the measurements are probably only correct to about ± 20 feet.

Borehole Number	Thickness of Saddle Mtns. basalt flows (and interbeds of Ellensburg Formation)	Thickness of Wanapum basalt flows	Thickness of interbed of Ellensburg Formation between Saddle Mtns. and Wanapum flows	Structure on which borehole is located
DC-4/5	748'	1142'	118'	Cold Creek Syncline
DB-11	472'	not measured	157'	
DC-3	709'	1102'	157'	
DC-7/8	827'	1102'	79'	
DB-14	826'	not measured	118'	Yakima Ridge
RSH-1	591'	1260'	118'	Rattlesnake Hills
DC-6	669'	1023'	79'	Umtanum Ridge
DH-4	433'	1023'	-0-	Saddle Mtns.
(average)	657'	1126'		

An interpretation of this data could be minor thinning of Wanapum basalts except in Rattlesnake Hills, minor thinning to thickening of the Ellensburg Formation interbed between the basalt formations except at Saddle Mountains where it is pinched out, and no discernable change in Saddle Mountains basalt (the youngest unit) except at Saddle Mountains, where it thins somewhat.

This certainly is not "consistent" thinning, and in fact may show thickening over some structures (e.g. 134' of thickening over Rattlesnake Hills).

RHO (1983) states "On Gable Mountain, the eastern continuation of Umtanum Ridge, the earliest suggestion of deformation is in the post-Umattila time as evidenced by thinning of the Salah interbed (Fitch, 1978)." Elsewhere in the text interbeds are characterized as being of variable thicknesses in synclinal and undeformed areas. Thus the Gable Mountain evidence may suggest timing of deformation but not conclusively. A discussion of the thickness data of flows and interbeds above the Selah interbed would clarify this issue, and this discussion should be centered on the compilation of all borehole data to conclude that the "suggested" timing of deformation is compatible with the data base.

This compilation should also clarify the data bases shown in Figures 2-3 and 5-2 of RHO (1983) which are not consistent with respect to basalt flows or interbeds.

2.1.1 Why is the error in RHO (1983) top-of-basalt maps (Figures 5-8, 5-9, and 5-10) so great?

Substantial error exists in the theoretical top-of-basalt figure, especially in areas of ridges where observation over large areas is possible and the data base should closely match the theoretical value if the proper modeling was accomplished. RHO (1983) states that "Due to better data density (borehole locations) in synclinal areas, the residual map is most valuable for interpretation of features within the Cold Creek Syncline." Actually the availability of data on ridges, where the basalt is exposed for large areas, should cause a much denser data availability in ridge areas.

2.1.2* What is the lateral continuity and variation in thickness of the intraflow structures of the Umtanum Flow and Middle Sentinel Bluffs Flow?

3.0* What are the probabilities and nature of natural changes that would affect repository performance?

3.1* What is the probability of earthquake activity in or near the Pasco Basin affecting repository performance?

3.1.1* What is the seismic hazard and risk to surface and subsurface facilities within the controlled zone?

An estimate of the magnitude and frequency of strong ground motion at the RRL is necessary to determine the safety during the operational phase of the project and to evaluate if these motions will have any deleterious effects on the containment potential of the site during the post-closure phase.

RHO (1983) does not evaluate the issue of the character of RAW, i.e., seismogenic capability, fault geometry, fault parameters, and design earthquake values. The potential for "floating" earthquakes from local or regional decollements needs to be addressed. A comparison of the hazard vs. deformation style between the site and the Coalinga, California, area needs to be made.

3.1.1.1 What are the sources or source areas for earthquakes that could produce maximum accelerations at the site?

These are essential for determination of the earthquake hazard.

3.1.1.2 What is the maximum size (magnitude) of the largest earthquake expected from sources or source areas that could affect the site?

This information is needed to determine the earthquake hazard at the RRL site.

3.1.1.3 Are there secondary hazards from earthquake accelerations at the site?

Loess has been reported at some sites in the Cold Creek Syncline area (U.S.N.R.C., 1982). The liquefiability of these deposits and effect on construction and operation of BWIP needs to be assessed.

3.1.1.4 What are the paths followed by seismic waves from the defined sources/source areas to the RRL and how do these affect attenuation?

Seismic waves from different sources/source areas will have variable geologic conditions along their paths to the RRL. How do these geologic differences affect accelerations and frequencies at the site?

3.1.1.5 Are seismic focusing effects possible in the Cold Creek Syncline which could increase significantly the accelerations at RRL from certain sources/source areas?

Seismic focusing can greatly increase accelerations in some areas. As focusing is a function of the geometry of geologic structures and topography, focusing from buried structures in the Cold Creek Syncline could affect accelerations at the site. Structures such as the buried eastern end of the Yakima Ridge structure, the Nancy lineament and the May Junction monocline need to be assessed for this possibility.

3.2* What is the nature and probability of renewed volcanism in or near the Pasco Basin affecting repository performance?

In the last 17 MY two types of volcanism have occurred within 100 miles of the RRL. These are the Columbia River basalts and the andesitic cascade volcanos. Although they appear to be separated in time, i.e., the Columbia River basalts, and distance, i.e., the Cascade Volcanics, the potential threat of renewed volcanic activity needs to be evaluated in terms of current tectonic models of the Pacific North.

3.2.1* What is the possibility of renewed eruption of flood basalts?

Do the last Columbia River lava flows represent a termination of activity or the beginning of a hiatus in the activity? Are there tectonic models which may or could predict renewed basaltic volcanism?

3.2.2* What is the potential for a large ashfall in the RRL such that the repository would be affected?

Are there, in the geologic record, eruptions of Cascade volcanos large enough that the ash fall associated with them would affect long term repository performance? For example, such ash falls could result in increased surface runoff. Could these affect repository performance in any way?

3.2.3* Is there any evidence for the eastward migration of cascade volcanism in Washington, similar to that in Oregon? If such evidence exists what is the probability that the RRL could be covered by an ash flow?

Although the RRL is beyond the longest known distance traveled by an ash flow (Also Japan, 73 km; in Sheridan, 1979), would eastward migration of the cascade volcanic belt put the RRL within range of an ash flow?

3.2.4* Flooding with water (damming Wallula Gap)?

3.3* What is the probability of glaciation in or near the Pasco Basin affecting repository performance?

3.3.1* What is the probability that differential loading caused by glaciation can result in a change in the state of stress?

3.3.2* What is the probability that water loading from ice melt flooding will cause a change in the state of stress?

3.4 What is the probability and nature of structural deformation in the Pasco Basin that would effect repository performance?

The character, timing, and style of deformation in the Pasco Basin should be compatible with the regional tectonic model(s) and the geological, geophysical, and seismological data. Influence of basement structures needs to be clarified. For example in RHO (1983) basalt layer 3 can be shown to be high in some structures (Gable Mountains) and low in others (southeast Rattlesnake Mountain). How this affects basement influence on Yakima Fold structures needs to be clarified.

Better delineation of the timing and extent of the Palouse paleoslope is necessary. Extrapolation of the paleoslope into the Pasco Basin may be in error if deformation at Rattlesnake Mountain was occurring in the Miocene, as indicated by isopach maps of layer 2 and top of layer 3 (figure 4-3 and 4-5 of RHO, 1983).

The deformational history of each fold (anticlinal and synclinal) which affects the site needs to be delineated. This need is shown by the RHO (1983) discussion of folding in the Pasco Basin. The use of Umtanum Ridge as a "typical" Yakima fold does not address differences in fold attitudes (such as the southeast extension of Rattlesnake Mountain and the north-south trending May Junction monocline), and great differences in deformational history are indicated by the data. For example RHO (1983) states "the initiation of deformation of Columbia River basalt at widely separated localities in the Columbia Plateau in late Grande Rhonde time suggests that the process was regional and penecontemporaneous, but it has not been established that all ridges began to develop at this time" and later "...folding in Rattlesnake Mountain south of Snively Basin cannot be demonstrated until early Wanapum time,...".

In fact, the data suggest that in Wanapum time the area of southeast Rattlesnake Mountain was synclinal in nature, with thicker deposits of Wanapum besalt than in other areas (see Table in question 2.1). Deletion of data from borehole RSH-1 does not allow an interpretation of the structure in Saddle Mountain times but Figure 2-4 of RHO (1983) does not indicate substantial thinning of the Saddle Mountain basalt over this structure. Thus, anticlinal folding at southeastern Rattlesnake Mountain can be inferred to have been initiated in post-Saddle Mountain basalt times.

For the Snively Basin RHO (1983) states that the basement structures correlate to surface structures, but not in other parts of the Yakima fold belt, yet the RHO (1983) report uses Snively Basin as a "typical" basin in the Yakima fold belt. This further exemplifies the need for an individual structure description.

Gravity surveys of the northern portion of RAW indicate no lateral movement across the zone with an accuracy of 2 km. More detailed work needs to be done to ascertain if there is some lateral displacement on the structure.

3.4.1 What is (are) the conceptual tectonic model(s) of the Cold Creek Syncline and surrounding area?

Conceptual tectonic model(s) of the Cold Creek Syncline and surrounding area are necessary for testing the geologic and seismologic observations that have been or will be documented. More than one model may need to be developed for further discussion of the viability of each model. The following sub-discussions represent some subject areas in which problems arise in development of a conceptual tectonic model or models.

3.4.1.1 What are the plate motions in the Pacific Northwest and adjoining northeast Pacific Ocean basin with respect to absolute hot-spot movement, and how does this relate to regional and local tectonics in the vicinity of RRL?

Previous discussions (RHO, 1983) have depicted only plate motion with respect to a fixed North American plate. This, at a minimum, obscures a visual interpretation of plate motion diagrams. A diagram showing both direction and velocity at all plates with respect to the hot-spot or absolute movement needs to be developed.

3.4.1.2 What is (are) the regional tectonic model(s) for the Pacific Northwest and how do regional geophysical, geological and seismological data correlate with this (these) model(s)?

Many regional tectonic models for the Pacific Northwest have been presented in studies for the Hanford Reservation and in the general literature. As the "tectonic stability" of the RRL is dependent upon which model represents actual conditions in the region, a regional tectonic model(s) must be characterized. This model needs to correlate available geophysical, geological and seismological data. Comparisons of the model(s) with models of other regions of better understood seismicity (e.g. - southern California, northern Baja, Kansas, the

Basin and Range Providence, the Rocky Mountain front in Colorado) can help develop a perspective of "tectonically stable" regions.

3.4.1.3 What are the geographic and spatial relationships of all structural features in and near the Pasco Basin?

3.4.1.4 Do geophysical data bases fit with local structural interpretations?

3.4.2* What is the direction and rate of deformation both at the surface and with depth at the RRL site?

The type and amount of potential fault displacement depends on the direction and rate of deformation in the area. Although these rates are suspected to be low, their effect on the geologic stability of the RRL needs to be understood.

RHO (1983) states "Folding in other ridges of the Yakima fold belt was probably developing penecontemporaneously with the Saddle Mountains. However, the aerial distribution and thickness of stratigraphic units known from the present degree of detailed study do not allow this hypothesis to be demonstrated." Data as shown in Question 3.4 indicates in fact that this is not the case, and all deformation on Rattlesnake Mountain may be post-Saddle Mountain Time, while Saddle Mountain is believed to have begun deformation in pre-Wanapum Times. As strain rates are calculated on this assumption, a re-evaluation of southeast Rattlesnake Mountain should be accomplished.

Within the RHO (1983) report there is some disagreement about strain rate. On page 8-4 the strain rate is given as less than 1 mm/year for the Pasco Basin. On page 8-2, strain is given as 0.02 to 0.04 mm/km/year. As the Pasco Basin is about 60 km north to south (direction of compression), this gives about 1.2 to 2.4 mm/year strain across the basin. Thus figures presently vary from less than 1 mm/year to 2.4 mm/year.

RHO (1983) indicates that Price (1982) concludes that "...folding strain should be concentrated in areas of steeply dipping strata..." yet borehole cores in horizontal strata show disking from in situ strain. Does this indicate steeply dipping strata will have more accumulated strain than in the synclinal area that produced the "disked" core (see Figure A-12 of USNRC, 1983)? The in situ stress needs to be evaluated with respect to the Mohr's envelope of brittle fracture for basalts. As assessment of strain distribution across the basin should be made to determine if low deformation on one fold can be extrapolated across synclines to other folds.

3.4.2.1 The level line data (RHO-BW-ST-19 P, p.6-21 - 6-29) was noted as being inconsistent, i.e., E-W shortening, with the axis of compression as indicated by the geology (N-S shortening). Does this mean a change in tectonic styles in the last 13,000 years? How does this fit with focal mechanism data?

These inconsistancies between different data sets could result from several sources, i.e., accuracy and precision of data or changes in tectonic style. Barrash (1982) suggested we may be in the midst of a tectonic transition interval. The discrepancy noted above could support this conclusion.

The recent 1983 earthquake, borehole drill measurements, and seismologic focal mechanism data contributes other sources of information on the current stress axes. How does this fit the above conclusion?

3.4.3 What is the probability and nature of future faulting in the controlled zone?

3.4.3.1 Is rupture due to faulting at or below the surface at the RRL a possibility?

3.4.3.2 What is the probability of future faulting in the repository shearing the backfill or waste package?

3.4.4 What is the source of the microearthquake swarms in the Cold Creek Syncline area?

Because these swarms may yield clues to the mechanics of deformation in the area, it is important to understand as much as is possible about their location and sense of motion. Hill (1977) has discussed fluid (magma or groundwater) as causes for swarms of earthquakes. How does his model fit with observed seismicity in the Pasco Basin?

A complete epicenter map for the Pasco Basin and surrounding regions needs to be presented with a discussion of the relationships between seismicity and geologic structures within the basin. For example, the alignment of epicenters between the Yakima Ridge structure and RAW may link these two major structures (see Figure 6-3, RHO, 1983). Epicenter maps need to be completed and updated to the present (see differences between RHO (1983) Figure 6-3 and USNRC (1983) Figure N-1).

The absence of or crude alignment of epicenters (RHO, 1983) may be attributable to the low dip angle on faults within the

4.2.2* What is the probability that water impoundments behind possible future dam construction (Ben Franklin dam) will cause micro-earthquakes or earthquake swarms?

4.2.3* What is the probability that flooding due to upstream dam failure will cause micro-earthquakes or earthquake swarms?

4.3 Are there possible geologic hazards to RRL that could be generated by problems or accidents with other nearby nuclear facilities?

Excessive heat release may result in drastic hydrologic changes and induced seismicity. Radioactivity release may affect the construction and operation phases of the RRL.

Pasco Basin. Looking downdip, in cross-sections, or at three dimensional stereoplots of hypocenters may show stronger fault definition from the seismic data.

The lack of major seismicity is common before many large earthquakes but may be well-expressed during aftershock or creeping phases of activity, thus, the apparent lack of historical activity may not indicate absence of tectonic activity in the area. Better fault definition by seismic methods may modify the present position on seismicity in the Pasco Basin.

3.5 Is there hazard to the site from aseismic deformation?

Aseismic deformation such as fault-creep, bedding plane slippage, fold formation, and isostatic adjustment needs to be assessed for possible hazard to the site.

4.0* What are the probabilities and nature of human-induced changes, excluding repository construction, that would affect repository performance?

4.1* What are the probabilities that groundwater withdrawals would affect repository performance?

4.1.1* What is the probability that groundwater withdrawals for irrigation would trigger micro-earthquake or earthquake swarms?

4.2* What are the probabilities and nature of groundwater recharge that would affect repository performance?

4.2.1* What is the probability that fluids injected into the confined aquifer at the 200W area will trigger earthquake swarms in the controlled zone?

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