Yucca Mt.

Draft Environmental Assessment

Comment

HYDROLOGY DOCUMENT NUMBER 447

O.E.A. Comments

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MAJOR COMMENTS

YUCCA MOUNTAIN MAJOR COMMENTS

COMMENT 1 -- FAULT ACTIVITY

Guideline on Tectonics (10 CFR 960.4-2-7): (d) Disqualifying Condition

Guideline on Preclosure Tectonics (10 CFR 960.5-2-11): (a) Qualifying Condition; (b) Favorable Condition; (c) Potentially Adverse Conditions 2, 3

The preclosure and postclosure tectonics guidelines (960.5-2-11 and 960.4-2-7, respectively) require that the nature and rates of tectonic processes, such as faulting, be evaluated for their impacts on repository construction, operation and performance. In the evaluation of faulting and the potential for ground motion due to seismicity at Yucca Mountain, the DOE has made the unsupported assumption that active faulting is not present at Yucca Mountain. The DOE has utilized this assumption in its findings on 960.4-2-7(d), that the evidence does not support disqualification of the site on the basis of likely loss of waste isolation due to fault movement or other ground motion; and in its findings on 960.5-2-11(c)(2 and 3), that potentially adverse conditions related to the possibilities of ground motion in excess of reasonable design limits or of higher magnitude earthquakes than predicted from historical seismicity are not present.

To assess the potential for future fault activity at Yucca Mountain, an analysis of the local stress environment and its relationship to the regional tectonics is necessary (see detailed comment 3-3). The DOE has incorporated an analysis of data from DOE investigators (Carr, 1984) on regional tectonics into their assessment of Yucca Mountain fault activity. From this, the DOE finds that "At present, a preliminary conclusion can be made that <u>the north-trending faults at Yucca Mountain should be considered potentially active</u> (emphasis added) even though the absence of fault scarps and the near absence of seismic activity suggest that they are not active." (page 6-226, 2nd paragraph) (see detailed comment 6-92). The NRC is concerned because the DOE makes findings "Under the assumption that the <u>Yucca Mountain faults are not active,</u>..."(emphasis added) (pages 3-21, paragraph 2; 6-231, paragraph 4; 6-286, paragraph 2; 6-288, paragraph 3; and 6-289, paragraph 3).

The potential for future activity of faults at Yucca Mountain should be the basis of estimates of seismic activity and associated ground motion at the site. Ground motion estimates are needed in the evaluation of the preclosure tectonic guidelines 960.5-2-11(a); 960.5-2-11(b); 960.5-2-11(c)(1), (2), and (3); and the postclosure tectonic guideline 960.4-2-7(d). The draft EA states

on page 6-288 that "the most likely peak deterministic ground acceleration at Yucca Mountain is approximately 0.4g" resulting from movement on the Bare Mountain fault, 14 kilometers west of the site, assuming Yucca Mountain faults are not active. If the faults at Yucca Mountain are assumed to be active, then the maximum expected ground acceleration would be significantly higher than 0.4g (see detailed comment 6-92). This may have an impact on some of the findings under those guidelines that require ground motion estimates.

The DOE should consider whether the assumption that Yucca Mountain faults are not active is warranted or conservative in light of the presently available data and to incorporate those considerations into a re-evaluation of the findings with respect to guidelines 960.4-2-7(d), 960.5-2-11(c)(2 and 3), and other guidelines mentioned above as appropriate.

COMMENT 2 -- VOLCANISM/HYDROTHERMAL ACTIVITY

Guideline on Tectonics (10 CFR 960.4-2-7): (b) Favorable Condition

To make a finding with regard to Guideline 960.4-2-7(b) requires that the probability for disruption of the repository by igneous or tectonic activity (with which hydrothermal activity is associated) be estimated for the 10,000 year post-closure period. The mean probability estimate presented in the draft EA is not supported by the information provided in the draft EA or in the supporting references. Furthermore, the determination does not take into account geologic controls, such as fault zones, and the potential for hydrothermal activity.

The favorable condition under 960.4-2-7 requires that there be less than one chance in 10,000 (1.0×10^{-4}) of releases of radionuclides to the accessible environment due to igneous activity over the first 10,000 years after closure. In the draft EA (page 6-222, paragraph 3) and the supporting reference (Crowe et al., 1982) the range of probabilities for basaltic eruptions at Yucca Mountain for a 10,000 year period is given as 3.3×10^{-6} to 4.7×10^{-4}. The DOE concludes that "the mean value of this range is less than one chance in 10,000 over the next 10,000 years" but does not provide the mean value or how it was determined. In the absence of such information, and considering that the range of probabilities provided in the draft EA extends to as high as 4.7 chances in 10,000 of volcanic eruptions in the next 10,000 years, it appears that the favorable condition may not be met at Yucca Mountain.

In addition, DOE investigators (Crowe et al., 1982) state that their values are solely statistical and do not incorporate geologic controls such as fault zones

(preferential pathways). The draft EA does not discuss these limitations or factor such considerations into its probability estimates.

The probability of hydrothermal activity, which is often associated with volcanic activity, is also not considered in the draft EA. There are several lines of evidence that suggest hydrothermal systems have existed and may possibly still exist in the Yucca Mountain region: elevated water temperatures in boreholes around Yucca Mountain (page 3-22); high temperature zeolites in tuff units at Yucca Mountain (page 6-161); and potential hydrothermal deposits (travertine and opal) in fault zones on either side of Yucca Mountain (NRC staff trip report, Rice, 12/28/84). A feature of hydrothermal activity such as upward-moving warm or hot ground water migrating along fractures which may intersect the repository, poses potential problems for waste isolation capabilities of the repository. It should be noted that in 1979 the DOE eliminated the Wahmonie site on the NTS from consideration partly due to warm springs deposits and hydrothermal alteration (draft EA, page 2-14) (see detailed comment 6-88).

The DOE should reconsider its finding with respect to Guideline 960.4-2-7(b) in light of the above observations. In addition, the DOE should consider presenting a more thorough discussion of the probability of disruption of the repository at Yucca Mountain by igneous activity, including: (1) why the mean probability is an appropriate approach to addressing the guideline; (2) the mean probability value and how it was determined; and (3) the limitations and uncertainities in that determination due to exclusion of certain geologic features from the determination. The DOE should also consider factoring in the potential for hydrothermal activity at Yucca Mountain while addressing this guideline.

COMMENT 3 -- GROUNDWATER TRAVEL TIME CALCULATIONS

Guideline on Geohydrology (10 CFR 960.4-2-1): (d) Disqualifying Condition

Guideline on Geohydrology (10 CFR 960.4-2-1): (b) Favorable Condition 1

Guideline on Geohydrology (10 CFR 960.4-2-1): (b) Favorable Condition: 5 (iii)

The DOE has concluded that the evidence does not support a finding that the site is disqualified under the condition that groundwater travel time is less than 1,000 years (960.4-2-1(d)) and that the favorable condition of a 10,000 year travel time (960.4-2-1(b)(1)) is present because the calculated

pre-waste-emplacement travel time exceeds 20,000 years. Furthermore, the DOE has concluded that a geohydrologic unit that would divert the downward infiltration of water beyond the limits of emplaced waste (favorable condition 960.4-2-1(b)(5)(iii)) is present. This condition is related to the groundwater travel time guidelines because it limits the flux that will pass through the host rock. The DOE's conclusions for the above mentioned guidelines are not supported adequately by information presented in the draft EA. While the DOE does recognize the need to be conservative and account for uncertainties, many of the assumptions and approaches used in the DOE's analysis are in fact not conservative and do not incorporate uncertainties associated with the available data. For example, the DOE, in some sections (e.g., 6.4.2.4 and 6.4.2.5), recognizes that fracture flow could occur and result in greatly reduced travel times; however, this possibility was not incorporated into the DOE's assessment of the geohydrology guidelines. Finally, data used by the DOE to support its conclusion may also be interpreted to support alternative hypotheses of water migration through the unsaturated zone. A brief description of the specific problems which bear upon the DOE's findings is given below. The detailed rationale for these concerns can be found in detailed comments 6-17 through 6-50.

1. There is no reference to or discussion of how values of effective porosity used in travel time calculations through the unsaturated zone were estimated nor is there any discussion of the technique used to estimate effective porosity for travel time calculations in the saturated zone. Effective porosity is important in groundwater travel time calculations because it represents the amount of interconnected pore space (or fractures) available for transmitting water. Because the DOE has not provided the basis for its estimates, it cannot be assumed that these values are either reasonable or conservative.

2. The degree of saturation, a measure of the amount of water in the voids of a rock, was omitted from groundwater travel time calculations through the unsaturated segment of the flow path. This parameter needs to be accounted for in both the hydraulic conductivity and effective porosity parameters. Failure to include the degree of saturation when using effective porosity in travel time calculations results in non-conservative travel time estimates.

3. The DOE has used single values for the key hydrogeologic parameters in the travel time calculations rather than a range of values. The few data that are available are either estimated or based on limited measurements and suggest that many of these parameters are highly variable. Therefore, the use of a single value, rather than a range of values or a conservative value, could lead to nonconservative travel time estimates.

4. The DOE's conceptual model of flow through the unsaturated zone is based on some assumptions which are not supported by the available data. The DOE assumes that matrix flow through the unsaturated zone will predominate. Therefore, the flux through the host rock will be limited to a value that is equal to or less than the saturated matrix hydraulic conductivity of the host rock (Topopah Spring welded unit). The DOE has used the geometric mean saturated hydraulic conductivity of 1 mm/year as the "maximum" flux for the travel time calculations through the unsaturated zone. However, measurements have been obtained by the DOE investigators which are two orders of magnitude higher than 1 mm/year (Montazer and Wilson, 1984). Therefore, the flux through the matrix is probably quite variable, and a higher flux could be supported by the available data.

5. The assumption that matrix flow will predominate through the host rock largely depends upon the hypothesis that excess recharge is both diverted away from the host rock and retarded by capillary and permeability barriers at the contacts between the Tiva Canyon welded unit and the underlying Paintbrush tuff nonwelded unit; and between the Topopah Spring welded unit and the overlying Paintbrush nonwelded unit. This hypothesis is questionable for reasons discussed in detailed comment 6-31. A brief summary of these reasons is given below.

   A. According to the DOE's hypothesis, recharge from intense and short-lived events would move laterally, down dip at the contact between the fractures of the Tiva Canyon welded unit and the matrix of the Paintbrush nonwelded unit because a permeability contrast exists between these two units and because entrapped air would further reduce the permeability of the Paintbrush nonwelded unit. However, this lateral movement would be short-lived because the entrapped air would be dissolved or displaced, thereby allowing the recharge to move downward. No data have been provided in the draft EA which indicate that saturated or nearly saturated conditions have been observed at this contact. It is unlikely that water will move laterally over any significant distances until the rock is almost completely saturated. Furthermore, the DOE states that downward flow would occur under saturated conditions (draft EA, page 6-129).

   In addition, the DOE states that lateral flow would continue until structural features with high permeability were encountered (page 6-129). However, existing data on known faults, such as the Ghost Dance fault and other possible subsurface faults, indicate that there are potential conduits for downward flow within the primary repository block. Therefore, even if lateral flow were to occur in

the units overlying the host rock, it is unlikely that water would be diverted beyond the emplaced waste.

B. The DOE also states that a capillary barrier is probably formed between the matrix of the Paintbrush nonwelded unit and the fractures of the underlying Topopah Spring unit where the pores of the nonwelded unit are smaller than the apertures of the fractures in the welded unit (draft EA, page 6-126). There is no evidence presented in the draft EA that this is a general condition across the site. In addition, there is no evidence presented in the draft EA that perched water is present at this contact. Therefore, there is no reason to assume that any excess recharge has been stored or that significant lateral flow is occurring within this unit. Furthermore, if saturated conditions did exist in the Paintbrush nonwelded unit, the capillary barrier of the fractures would be overcome (draft EA, page 6-129) and flux in excess of the saturated hydraulic conductivity of the matrix of the Topopah Spring welded unit would be allowed to pass downward, possibly including fracture flow.

The above mentioned concerns could substantially reduce confidence in the DOE's calculated 20,000 year groundwater travel time. The presence of the favorable condition for diversion of water from emplaced waste also is questioned. The DOE should consider the existing field and laboratory data and experiments, as well as spatial and temporal variability of the hydrologic system at Yucca Mountain, and other sources of uncertainty in their assessments. The conclusions reached for the guidelines on groundwater travel time (960.4-2-1(d) and (b)(1)) and for the favorable condition of infiltration diversion (960.4-2-1(b)(5)(iii) should be re-evaluated in consideration of the revised analysis.

COMMENT 4 -- FREE DRAINAGE OF HOST ROCK

Guideline on Geohydrology (10 CFR 960.4-2-1): (b) Favorable Condition 5 (iv)

The DOE concludes that the host rock (Topopah Spring Member) is freely draining and thus favorable condition 960.4-2-1(b)(5)(iv) is present. Free drainage is not defined in the draft EA; the NRC infers it to mean that the host rock drains so freely as to be unsaturated. However, observations of water under positive pressure within the Topopah Spring Member, reported during and after drilling some boreholes, can reasonably lead to the conclusion that saturated conditions are locally present within the proposed host rock.

Evidence of perched water (local zones of water under positive pressure in the unsaturated zone) has been observed at well USW H-1 as reported by DOE investigators (Rush et al., 1983) wherein down-hole television camera observations in the Topopah Spring Member recorded fractures that produced water under positive pressure. In addition, based on past discussions with the DOE, free-standing water was observed in the bottom of test hole UZ-1. Furthermore, based on these discussions, there are no definitive explanations for the source of water in either UZ-1 or USW H-1. Previous discussions have suggested that these waters originated from drilling fluids; however, it has not been demonstrated clearly that this is the case. An alternative explanation for the source of these waters is naturally occurring waters either held or migrating in the fracture system of the unsaturated zone. Regardless of the origin, observed water under positive pressure demonstrates the fact that perched zones can prevail for at least short periods of time (month(s) to year(s)) in localized portions of the Topopah Spring Member.

The evidence presented above suggests that localized saturated zones may be present in the host rock. Therefore, the DOE should reconsider the assumptions and evaluations pertaining to this favorable condition. In doing so, the DOE should determine whether or not evidence of local saturation implies absence of free drainage. The DOE should then revise the EA to convey more accurately the available information and how this information supports conclusions relative to this favorable condition.

COMMENT 5 -- GROUNDWATER CHEMISTRY OF THE UNSATURATED ZONE

Guideline on Geochemistry (10 CFR 960.4-2-2): (b) Favorable Conditions 2, 3; (c) Potentially Adverse Condition 1

Based upon its assessment of unsaturated zone groundwater chemistry at Yucca Mountain; the DOE has concluded that favorable conditions relative to radionuclide retardation and to mineral stability (960.4-2-2(b)(2 and 3)) are present at Yucca Mountain and that the potentially adverse condition regarding reactivity of the engineered barrier system, especially the waste package, to the host rock ground water (960.4-2-2(c)) is not present. In making these findings the DOE has treated ground water from well J-13 in the saturated zone as similar to ground water from the unsaturated zone (see page 6-165). This approach is questionable (see detailed comments 6-58, 6-62, and 6-70) in light of available data which suggest that (1) water in the unsaturated zone may have a short residence time and therefore be unable to equilibrate with the host rock (Drever and Smith, 1978; Henne, 1982), and (2) vadose zone water may have a composition controlled by near-surface leaching processes (Drever and Smith,

1978; Henne, 1982; Oversby and Knauss, 1983; Oversby, 1984). Hence, whereas groundwater composition in the saturated zone is primarily influenced by the host rock, the groundwater composition of the unsaturated zone may be controlled primarily by soil chemistry and near-surface leaching processes.

The DOE noted in Section 6.3.1.1. (page 6-130) that if the groundwater flux exceeds 1 mm/yr, fracture flow could occur. If fracture flow predominates (this cannot be discounted; see major comment 3), the ground water of the unsaturated zone may not have sufficient time to equilibrate with the host rock, but rather, may reflect the soil or alluvium chemistry. In arid regions, deposition of salts at or near the surface during evaporation followed by partial re-solution during heavy rains may produce ground water in the unsaturated zone with a high content of soluble salts (Drever and Smith, 1978), which may be significantly different from ground water in the saturated zone. This is supported by the findings of DOE investigators (Oversby and Knauss, 1983; and Oversby, 1984) that there is a significant component of readily soluble salts in outcrop samples of both the Bullfrog and Topopah Spring Member tuffs. Based on these findings, the vadose zone ground water may be higher in ionic strength, dissolved solids, dissolved gases, colloids, and/or organics than J-13 water, obtained from the saturated zone.

The soluble salts of the vadose zone ground water may eventually precipitate near the repository where the temperature reaches 100°C and the water is driven off. Upon cooling of the region near the repository, a pulse of fresh ground water could contact the salts, producing a brine or at least a ground water considerably more concentrated in soluble salts than J-13 ground water. Changes in ground water chemical composition as the result of waste emplacement or differences in vadose zone water will affect radionuclide release to a degree not predicted based on the results of tests using J-13 water.

Groundwater composition has a profound influence on radionuclide speciation, which affects solubility and sorption and is important to determine stability of sorptive minerals such as zeolites. All of these are factors which determine the rate of radionuclide release and transport. For example, the presence of ligands such as carbonates can lead to the formation of radionuclide-carbonate-complexes with increased solubility as well as neutral or anionic species with decreased retardation due to sorption. Groundwater composition is also an important factor in determining stability of sorptive minerals such as zeolites and clays.

A ground water with a pH outside the 6-8 range or with increased sodium content, for example, may help to reduce the sorptive capacity of the host rock by increasing the reaction rates of the metastable zeolites, clinoptilolite and

NRC COMMENTS

ON

DOE DRAFT ENVIRONMENTAL ASSESSMENT

FOR

THE YUCCA MOUNTAIN SITE

March 20, 1985

(Dec 12, 1984)." Because of the limited time available for review and the vast amount of data and information existing for the nine sites, the staff had prepared for the draft EA reviews well before their receipt. Preparation included: 1) broad familiarization with the overall existing data/information base for each site; 2) selected detailed reviews of data; 3) development of a clear understanding of the guidelines; and 4) development of preliminary views and issues through reviews of existing data and scoping reviews of preliminary EA drafts. This early preparation and familiarization with the existing data base has allowed the staff to determine if the conclusions and findings in the EAs are consistent with the available data.

In its review, the staff has sought to identify potential safety issues through a review of DOE's application of the siting guidelines. The staff has focused on the analyses and technical evaluations that are made on individual guidelines which constitute the factual basis upon which the site comparisons are made by DOE. The staff reviewed the available data, interpretations, assumptions and performance assessments in the EA and its references that DOE used to substantiate its evaluation of a site against the guidelines. In commenting on the EAs, the staff has recognized that the level of information which exists on each site is not equivalent to what will be necessary to make findings about the suitability of the one site that is proposed for development as a repository. The staff has reviewed the evaluations and conclusions which are called for at the EA stage by the siting guidelines. These guidelines recognize the inherent uncertainties that will face any site before detailed site characterization.

The staff's review and comment on the evaluations and conclusions on the siting guidelines effectively identified issues which are relevant to potential safety issues. In its concurrence action on the siting guidelines, the Commission found that the guidelines are consistent with the requirements of its own regulations on geologic repositories (10 CFR Part 60). Therefore, while the staff has not identified in each case how its comments relate to the specific requirements of 10 CFR Part 60, we feel that they serve to identify those issues which are relevant to potential licensing of each site based on information currently available and which will need to be resolved during site characterization.

The staff also commented on the analyses of environmental impacts of site characterization activities and repository operation with the intent of assisting DOE's preparation of the final EAs. However, the staff has not performed a detailed review with regard to the site characterization plans in Chapter 4 or the repository descriptions in Chapter 5 of the EAs. The staff only commented on those aspects of site characterization plans, such as the need for characterizing the geohydrological regime beneath Canyonlands Park,

which need to be considered to evaluate the site against the siting guidelines, at this time. Site characterization plans will be reviewed upon receipt of such plans in accordance with the NWPA and in other consultations with the DOE under the interagency agreement governing repository prelicensing matters (48 FR 38701); the staff's review and positions will be documented in site characterization analyses at that time.

NRC Staff Comment-Summary

In no case did the staff conclude that a disqualifying condition was clearly present or a qualifying condition clearly absent at the sites being investigated. To a large extent the EAs recognize that uncertainties exist at each site. However, in some instances, the full range of uncertainty that exists about certain factors affecting site suitability is not recognized in the discussion supporting the EA findings. The staff noted that in a number of instances the EAs make conclusions and findings which are not supported by existing data or which existing data indicate are not conservative. In these instances, the staff points out specific data and other information which indicate that EA conclusions are not realistically conservative as required by 10 CFR Part 960 (10 CFR Part 960.3 requires that assumptions made in EA evaluations be... "realistic but conservative enough to underestimate the potential for a site to meet the qualifying condition of a guideline..."). For example, we point out information on hydrologic conditions at several sites which is not fully documented in the EAs and which could realistically support less optimistic conclusions about groundwater travel time than those presented in the EA.

In each comment, the staff has attempted to describe the significance of the comment and to recommend what DOE might do to resolve the comment. Ultimately, it may be found unnecessary to completely eliminate all of the uncertainties about site features that are identified in the comments. It is expected that through further investigation it can be shown that some of these uncertainties are compensated for by other site features which assure overall system guidelines are met. (For example, some questions about geochemical properties may be mooted or lessened in importance by development of information indicating that there are very favorable and compensating groundwater conditions.) Nevertheless, it is essential that all potential problems and uncertainties about sites be explicitly identified at this stage so that site-screening decisions are based on complete assessment of the facts and that future site characterization work is complete.

In pointing out deficiencies in DOE's evaluations of individual sites, the staff has commented on DOE's evaluations and findings with respect to the various individual factors which are important to site suitability (i.e., 10 CFR Part 960 guidelines on geohydrology, geochemistry, rock characteristics,

etc.). We expect that the DOE analyses in Chapter 1 through 6 will be revised in light of our comments. The staff therefore recommends that DOE reconsider its ratings and ranking analyses of sites in Chapter 7 so that the overall comparison of sites and resulting decisions are consistent with supporting evaluations and findings on individual factors.

It is the staff's view that by recognizing uncertainties identified in our comments and reexamining its assessments in light of the other technical concerns that we raise, the environmental assessments and related decisions will be strengthened.

Presentation of EA Comments

The staff presents its comments in two parts. First, it presents major comments. The order in which these comments are presented has no special significance; the order is governed by the fact that some comments, which help the reader understand others, come first. Second, detailed comments are presented on each of the chapters of the EA. The major comments are those comments which the staff considers may potentially lead DOE to a change in EA findings with respect to specific guideline or may affect the relative ratings of sites. In some of the detailed comments, the staff identifies areas where the discussions supporting the EA findings are more certain than we believe the data supports. If such supporting discussions were considered in the comparison and ratings of sites, these detailed comments could be as significant as those labeled major comments.

Many of the staff's comments appear identical for different sites because the information presented by DOE in the EAs was often identical and therefore would result in the same comment, particularly when sites are in the same geohydrologic basin. Similar comments do, however, take into consideration differences resulting from site specific information.

4. The DOE's conceptual model of flow through the unsaturated zone is based on some assumptions which are not supported by the available data. The DOE assumes that matrix flow through the unsaturated zone will predominate. Therefore, the flux through the host rock will be limited to a value that is equal to or less than the saturated matrix hydraulic conductivity of the host rock (Topopah Spring welded unit). The DOE has used the geometric mean saturated hydraulic conductivity of 1 mm/year as the "maximum" flux for the travel time calculations through the unsaturated zone. However, measurements have been obtained by the DOE investigators which are two orders of magnitude higher than 1 mm/year (Montazer and Wilson, 1984). Therefore, the flux through the matrix is probably quite variable, and a higher flux could be supported by the available data.

5. The assumption that matrix flow will predominate through the host rock largely depends upon the hypothesis that excess recharge is both diverted away from the host rock and retarded by capillary and permeability barriers at the contacts between the Tiva Canyon welded unit and the underlying Paintbrush tuff nonwelded unit; and between the Topopah Spring welded unit and the overlying Paintbrush nonwelded unit. This hypothesis is questionable for reasons discussed in detailed comment 6-31. A brief summary of these reasons is given below.

   A. According to the DOE's hypothesis, recharge from intense and short-lived events would move laterally, down dip at the contact between the fractures of the Tiva Canyon welded unit and the matrix of the Paintbrush nonwelded unit because a permeability contrast exists between these two units and because entrapped air would further reduce the permeability of the Paintbrush nonwelded unit. However, this lateral movement would be short-lived because the entrapped air would be dissolved or displaced, thereby allowing the recharge to move downward. No data have been provided in the draft EA which indicate that saturated or nearly saturated conditions have been observed at this contact. It is unlikely that water will move laterally over any significant distances until the rock is almost completely saturated. Furthermore, the DOE states that downward flow would occur under saturated conditions (draft EA, page 6-129).

   In addition, the DOE states that lateral flow would continue until structural features with high permeability were encountered (page 6-129). However, existing data on known faults, such as the Ghost Dance fault and other possible subsurface faults, indicate that there are potential conduits for downward flow within the primary repository block. Therefore, even if lateral flow were to occur in

the units overlying the host rock, it is unlikely that water would be diverted beyond the emplaced waste.

B. The DOE also states that a capillary barrier is probably formed between the matrix of the Paintbrush nonwelded unit and the fractures of the underlying Topopah Spring unit where the pores of the nonwelded unit are smaller than the apertures of the fractures in the welded unit (draft EA, page 6-126). There is no evidence presented in the draft EA that this is a general condition across the site. In addition, there is no evidence presented in the draft EA that perched water is present at this contact. Therefore, there is no reason to assume that any excess recharge has been stored or that significant lateral flow is occurring within this unit. Furthermore, if saturated conditions did exist in the Paintbrush nonwelded unit, the capillary barrier of the fractures would be overcome (draft EA, page 6-129) and flux in excess of the saturated hydraulic conductivity of the matrix of the Topopah Spring welded unit would be allowed to pass downward, possibly including fracture flow.

The above mentioned concerns could substantially reduce confidence in the DOE's calculated 20,000 year groundwater travel time. The presence of the favorable condition for diversion of water from emplaced waste also is questioned. The DOE should consider the existing field and laboratory data and experiments, as well as spatial and temporal variability of the hydrologic system at Yucca Mountain, and other sources of uncertainty in their assessments. The conclusions reached for the guidelines on groundwater travel time (960.4-2-1(d) and (b)(1)) and for the favorable condition of infiltration diversion (960.4-2-1(b)(5)(iii) should be re-evaluated in consideration of the revised analysis.

COMMENT 4 -- FREE DRAINAGE OF HOST ROCK

Guideline on Geohydrology (10 CFR 960.4-2-1): (b) Favorable Condition 5 (iv)

The DOE concludes that the host rock (Topopah Spring Member) is freely draining and thus favorable condition 960.4-2-1(b)(5)(iv) is present. Free drainage is not defined in the draft EA; the NRC infers it to mean that the host rock drains so freely as to be unsaturated. However, observations of water under positive pressure within the Topopah Spring Member, reported during and after drilling some boreholes, can reasonably lead to the conclusion that saturated conditions are locally present within the proposed host rock.

Evidence of perched water (local zones of water under positive pressure in the unsaturated zone) has been observed at well USW H-1 as reported by DOE investigators (Rush et al., 1983) wherein down-hole television camera observations in the Topopah Spring Member recorded fractures that produced water under positive pressure. In addition, based on past discussions with the DOE, free-standing water was observed in the bottom of test hole UZ-1. Furthermore, based on these discussions, there are no definitive explanations for the source of water in either UZ-1 or USW H-1. Previous discussions have suggested that these waters originated from drilling fluids; however, it has not been demonstrated clearly that this is the case. An alternative explanation for the source of these waters is naturally occurring waters either held or migrating in the fracture system of the unsaturated zone. Regardless of the origin, observed water under positive pressure demonstrates the fact that perched zones can prevail for at least short periods of time (month(s) to year(s)) in localized portions of the Topopah Spring Member.

The evidence presented above suggests that localized saturated zones may be present in the host rock. Therefore, the DOE should reconsider the assumptions and evaluations pertaining to this favorable condition. In doing so, the DOE should determine whether or not evidence of local saturation implies absence of free drainage. The DOE should then revise the EA to convey more accurately the available information and how this information supports conclusions relative to this favorable condition.

COMMENT 5 -- GROUNDWATER CHEMISTRY OF THE UNSATURATED ZONE

Guideline on Geochemistry (10 CFR 960.4-2-2): (b) Favorable Conditions 2, 3; (c) Potentially Adverse Condition 1

Based upon its assessment of unsaturated zone groundwater chemistry at Yucca Mountain; the DOE has concluded that favorable conditions relative to radionuclide retardation and to mineral stability (960.4-2-2(b)(2 and 3)) are present at Yucca Mountain and that the potentially adverse condition regarding reactivity of the engineered barrier system, especially the waste package, to the host rock ground water (960.4-2-2(c)) is not present. In making these findings the DOE has treated ground water from well J-13 in the saturated zone as similar to ground water from the unsaturated zone (see page 6-165). This approach is questionable (see detailed comments 6-58, 6-62, and 6-70) in light of available data which suggest that (1) water in the unsaturated zone may have a short residence time and therefore be unable to equilibrate with the host rock (Drever and Smith, 1978; Henne, 1982), and (2) vadose zone water may have a composition controlled by near-surface leaching processes (Drever and Smith,

1978; Henne, 1982; Oversby and Knauss, 1983; Oversby, 1984). Hence, whereas groundwater composition in the saturated zone is primarily influenced by the host rock, the groundwater composition of the unsaturated zone may be controlled primarily by soil chemistry and near-surface leaching processes.

The DOE noted in Section 6.3.1.1. (page 6-130) that if the groundwater flux exceeds 1 mm/yr, fracture flow could occur. If fracture flow predominates (this cannot be discounted; see major comment 3), the ground water of the unsaturated zone may not have sufficient time to equilibrate with the host rock, but rather, may reflect the soil or alluvium chemistry. In arid regions, deposition of salts at or near the surface during evaporation followed by partial re-solution during heavy rains may produce ground water in the unsaturated zone with a high content of soluble salts (Drever and Smith, 1978), which may be significantly different from ground water in the saturated zone. This is supported by the findings of DOE investigators (Oversby and Knauss, 1983; and Oversby, 1984) that there is a significant component of readily soluble salts in outcrop samples of both the Bullfrog and Topopah Spring Member tuffs. Based on these findings, the vadose zone ground water may be higher in ionic strength, dissolved solids, dissolved gases, colloids, and/or organics than J-13 water, obtained from the saturated zone.

The soluble salts of the vadose zone ground water may eventually precipitate near the repository where the temperature reaches 100°C and the water is driven off. Upon cooling of the region near the repository, a pulse of fresh ground water could contact the salts, producing a brine or at least a ground water considerably more concentrated in soluble salts than J-13 ground water. Changes in ground water chemical composition as the result of waste emplacement or differences in vadose zone water will affect radionuclide release to a degree not predicted based on the results of tests using J-13 water.

Groundwater composition has a profound influence on radionuclide speciation, which affects solubility and sorption and is important to determine stability of sorptive minerals such as zeolites. All of these are factors which determine the rate of radionuclide release and transport. For example, the presence of ligands such as carbonates can lead to the formation of radionuclide-carbonate-complexes with increased solubility as well as neutral or anionic species with decreased retardation due to sorption. Groundwater composition is also an important factor in determining stability of sorptive minerals such as zeolites and clays.

A ground water with a pH outside the 6-8 range or with increased sodium content, for example, may help to reduce the sorptive capacity of the host rock by increasing the reaction rates of the metastable zeolites, clinoptilolite and

mordenite, thereby enhancing the formation of less sorptive analcime + quartz or feldspar + quartz mineral assemblages.

Chemical processes affecting radionuclide release and transport, mineral stability, and integrity of the waste package are critically dependent on groundwater chemistry. Based on the foregoing discussion, it is not clear that J-13 water accurately represents unsaturated zone water. Therefore, the DOE should reevaluate the findings with respect to 960.4-2-2(b)(2 and 3) and 960.4-2-2(c), and consider a conceptual model in which ground water is a variable in order to address the potential effects of changes in chemistry on radionuclide release and transport, mineral stability, and waste package performance.

COMMENT 6 -- RETARDATION OF RADIONUCLIDES

Guideline on Geochemistry (10 CFR 960.4-2-2): (b) Favorable Conditions 2, 5

The DOE has used inappropriately large retardation factors in evaluating the retardation of radionuclides to make findings for the guidelines on geochemical processes (960.4-2-2(b)(2 and 5)). The DOE has calculated retardation factors based on the assumption of saturated, porous flow and equilibrium conditions. The assumption of porous flow is questionable because there is considerable uncertainty in the flux and flow mechanisms at Yucca Mountain (draft EA, page 6-147). Furthermore, retardation factors based on measurements from batch sorption experiments (the kind performed by the DOE on a crushed tuff under water-saturated conditions and relied upon in their analyses) may lead to unreasonably high estimates of the actual sorptive capacity of the host rock. Consequently, the estimates of radionuclide releases may be unreasonably low.

Although the draft EA clearly states that the nature and rates of flow are not well understood (draft EA, page 6-129), the DOE has assumed that matrix flow is the dominant means of transport through the unsaturated zone. As pointed out by DOE investigators (Scott et al, 1983) this assumption may only be valid for the non-welded, porous tuff units. As discussed in major comment 3, some of the assumptions made in the DOE's conceptual model of groundwater flow through the unsaturated zone are questionable. Furthermore, the uncertainty in this hypothesis is such that an alternative conceptual model which considers fracture flow cannot be discounted. It is possible that at times, and especially if climatic conditions change such that recharge increases (see major comment 8), fracture flow may be the dominant means of radionuclide transport through the welded, highly fractured units in the unsaturated zone.

Therefore, the radionuclides may not contact the mass of rock expected under matrix flow regimes. Under these conditions, the use of data from batch tests, which assume porous flow conditions, will yield high retardation factors and lead to underestimation of radionuclide releases.

The retardation factors calculated in the draft EA (equation 6-4, page 6-152) are applicable only to fully saturated, porous flow conditions where the total surface area of the solid (all the active sorption sites) is available to the radionuclide. Retardation factors calculated for those conditions represent an upper limit of the retardation capacity for unsaturated flow conditions. In unsaturated flow, generally fewer sites are available due to the limited amount of water, the dead-end pore space, and the channeling effects known to occur in unsaturated media. The calculation of retardation factors based on saturated flow without corrections for these effects may lead to erroneously high values for unsaturated media and lead to an additional degree of underestimation of releases.

The overestimate of the retardation factor for unsaturated flow coupled with the possible overestimate for fracture flow versus matrix flow in highly fractured welded tuff suggest that data presented are insufficient for the evaluation of guidelines 960.4-2-2(b)(2) and 960.4-2-2(b)(5). Assessments of the radionuclide retardation release rates under different possible flow regimes should be used in draft EA analyses in order to ensure that a reasonable estimate of release and transport are obtained. These new estimates should be used to re-evaluate the guideline findings cited above.

COMMENT 7 -- MINERAL STABILITY

<u>Guideline on Geochemistry (10 CFR 960.4-2-2): (b) Favorable Condition 3</u>

<u>Guideline on Rock Characteristics (10 CFR 960.4-2-3): (c) Potentially Adverse Condition 2</u>

<u>Preclosure Guideline on Rock Characteristics (10 CFR 960.5-2-9): (c) Potentially Adverse Condition 4</u>

In the draft EA, the DOE has concluded that favorable condition 960.4-2-2(b)(3) concerning the stability of potentially sorptive minerals under expected repository conditions is present at Yucca Mountain and that potentially adverse conditions concerning processes or phenomena which could affect waste isolation (960.4-2-3(c)(2)) or lead to safety hazards and difficulty with retrieval

(960.5-2-9(c)(4)) are not present. The draft EA does not adequately present or analyze all the available data on the location of minerals and their stability and therefore does not adequately support the DOE findings.

The draft EA recognizes that minerals such as zeolites and clays can be altered under repository-induced heat loads to phases which are less favorable to waste isolation. By concluding that favorable condition 960.4-2-2(b)(3) is present, the DOE implies that there are no minerals that would alter to less favorable minerals within the zone subject to significant thermal effects and important to constructability of the repository. However, other DOE reports (Bish et al., 1982; Vaniman et al., 1984) suggest abundant zeolites and clays are present in the central and lower Topopah Spring Member that may be subjected to changing conditions. Based on the few drill holes in the repository block (detailed comment 6-66), it is difficult to confidently characterize the amount of sorptive minerals at the repository horizon.

With respect to the potential for alteration of zeolites, which are being counted upon to provide sorption of radionuclides, the DOE states that there are minerals within the 100°C isotherm that will react, but that they "represent a very small proportion of total sorptive zeolites present..." (draft EA, page 6-161). The DOE considers (draft EA, page 6-161) that the only significant quantities of zeolitized tuff are located at depths below 650 meters or 300 meters below the repository, where temperatures are predicted to reach 60°C (which the DOE considers to be an insignificant temperature increase). However, there is evidence that zeolites and clays occur in abundances of 50 to 90% in portions of the Calico Hills tuff within 50 meters of the proposed repository horizon (Bish et al., 1984), where the DOE predicts temperatures to exceed 80°C (Braithwaite and Nimick, 1984). These temperatures may be sufficient to cause alteration of zeolites under certain geochemical conditions, that have not been adequately considered by the DOE.

The stability and rates of reaction of zeolites and clays are not well known, but available evidence indicates that zeolites react at temperatures of 100-120°C under groundwater conditions observed at the site (J-13 well water); with an increase in sodium due to dissolution of volcanic glass the zeolite reactions could occur at temperatures as low as 80°C (Bish et al., 1982). Higher pH's than are found in J-13 water, which could plausibly exist in the unsaturated zone, might cause the zeolite reactions to occur at even lower temperatures; zeolite reactions can proceed within hours in a ground water at ambient temperatures with a pH around 9.

When the zeolite reactions occur, the resulting mineral assemblages consist of phases such as analcime and quartz, which are far less sorptive than zeolites and clays. Also, there is a 20% volume reduction involved in the transition

from zeolite to analcime, which could affect rock stability near the repository, and the dehydration of clays can also be expected to result in some volume reduction.

In summary of the above information, it appears that there are zeolites and clays in unknown abundance along the expected flow paths from the repository horizon to the accessible environment and that the possibility exists of reactions, especially at elevated temperatures and/or unanticipated groundwater conditions, in which the zeolites and clays are altered to less sorptive phases occupying less volume.

The potential reduction in sorptive capacity of rocks along the flow path from the repository to the accessible environment and in fractures in the repository horizon--which are thought to be important to retardation--should be considered in the DOE's evaluation of the finding for 960.4-2-2(b)(3). Dehydration reactions of smectites lining fractures in the repository horizon (Vaniman et al., 1984) and reaction of zeolites in the tuffaceous beds of the Calico Hills would reduce the ability of the host rock to retard the migration of radionuclides which would affect the finding for guideline 960.4-2-3(c)(2). The volume reduction which accompanies mineralogical changes affecting the zeolites and clays (smectites) could adversely affect the finding for 960.5-2-9(c)(4).

Using the available information cited above, the DOE should reconsider the finding (960.4-2-2(b)(3)) that no mineralogical changes are to be expected that would adversely affect the sorptive qualities of the host rock and units directly below the repository. In addition, considering the lack of areal data on zeolite distribution and abundance in and directly below the repository horizon, the DOE should take the conservative position advocated in the EA (6-4 and 7-3) and reevaluate the guidelines on rock stability (960.4-2-3)(c)(2) and 960.5-2-9(c)(4)).

COMMENT 8 -- RADIONUCLIDE TRANSPORT INCREASE DUE TO CHANGES IN GEOHYDROLOGIC AND CLIMATIC CONDITIONS

Guideline on Geohydrology (10 CFR Part 960.4-2-1): (c) Potentially Adverse Condition 1

Guideline on Climate Changes (10 CFR Part 960.4-2-4): (c) Potentially Adverse Condition 2

The DOE concludes that the potentially adverse condition related to expected changes in geohydrologic conditions sufficient to cause significantly increased transport of radionuclides (960.4-2-1(c)(1)) is not present at the Yucca Mountain site. The DOE has also concluded that the potentially adverse condition related to climatic changes sufficient to increase significantly the transport of radionuclides to the accessible environment (960.4-2-4(c)(2)) is not present. Based on available information, the draft EA does not adequately support either conclusion.

Although the DOE implicitly acknowledges that groundwater velocities may be substantially increased as a result of plausible future changes in geohydrology and climate, the DOE appears to dismiss the significance of these changes because of the implied ability of geochemical retardation to limit radionuclide transport to the accessible environment. Climatological analyses by DOE investigators (Spaulding et al., 1984) indicate a potential increase of precipitation at the Yucca Mountain site of 40% or more, which in turn would greatly increase the present estimated recharge rates to the unsaturated units at the site. This increased recharge would probably increase water flux through the unsaturated zone which may increase groundwater velocities. In addition, transit time would also be reduced by water table rises which are also induced by increased recharge rates, because a larger portion of the travel path would then be through the saturated zone, where fracture flow would generally predominate.

Despite potential increases of water flux and velocity through the unsaturated zone, the DOE concludes that such changes will not significantly increase radionuclide transport to the accessible environment because of the ability of the geochemical characteristics of the site to retard radionuclide transport. Review of site geochemistry, however, indicates that the ability of the geochemical system to effect sufficient retardation is highly uncertain because the retardation estimates are currently based on the assumption that matrix flow will predominate along most of the unsaturated segments of the flow path (see major comment 6).

Based on the concerns discussed above, there is reasonable doubt that the potentially adverse conditions are absent at Yucca Mountain. The DOE should reevaluate its conclusions supporting the absence of these potentially adverse conditions at the Yucca Mountain site, specifically with regard to the plausible increases in groundwater velocities caused by climatic and geohydrologic changes and delineation of the uncertainties associated with strong reliance on site geochemistry to retard radionuclide transport to the accessible environment.

COMMENT 9 -- COMPARATIVE EVALUATION OF SITES AGAINST GUIDELINES ON SURFACE FLOODING

Guideline on Surface Characteristics (10 CFR 960.5-2-8): (c) Potentially Adverse Condition

Guideline on Hydrology (10 CFR 960.5-2-10): (b) Favorable Condition 2

In assessing the guidelines relating to surface water flooding (960.5-2-8(c) and 960.5-2-10(b)(2)) the DOE appears to be inconsistent among the nine sites. The DOE correctly concludes that at two sites (Deaf Smith and Swisher) the repository facilities are not subject to surface water flooding while at the other seven sites they are. The sites that are subject to flooding would have to be flood-protected in varying degrees through the use of engineering measures. At four of those sites (Davis Canyon, Lavender, Cypress Creek, and Vacherie) the DOE concludes that because flood protection would have to be provided the adverse condition (960.5-2-8(c)) is present and the favorable condition (960.5-2-10(b)(2)) is not. At the remaining three sites (Hanford, Yucca Mountain, and Richton) the DOE concludes that since flood protection could be provided, through engineering measures, the adverse condition is not present and the favorable condition is. The seven sites susceptible to surface flooding have not been treated equitably.

It is suggested that the DOE decide whether credit for flood protection through engineering measures be considered in applying guidelines 960.5-2-8(c) and 960.5-2-10(b)(2) and then implement the decision consistently. It should be noted that engineering measures, if properly designed and implemented, can be used to protect almost any site from almost any flood. Thus, a decision to allow credit for such flood protection may amount to eliminating the differentiation between sites with respect to these guidelines.

COMMENT 10 -- WASTE PACKAGE POSTCLOSURE PERFORMANCE

The Executive Summary states that (page 16) "...the lifetime of the waste packages ... is expected to be more than 3,000 years..." and "...the fractional rate of radionuclide release from the engineered barrier system is estimated to be within the NRC regulatory limits." However, these and several other statements (e.g., Section 6.3.2.2.1) in the draft EA do not adequately convey the uncertainties which exist with respect to potential failure mechanisms.

A preliminary performance analysis is presented in Section 6.4 for the reference waste package and engineered barrier system in terms of containment lifetime and radionuclide-controlled release rate limits. The range of estimated waste package lifetimes is presented on the assumption that failure would occur through uniform corrosion. In several instances (e.g. Section 6.4.2.1.1), the potential for failure by other mechanisms is recognized; but uncertainty on this point is not adequately carried through in the draft EA summaries. While the summary Section 6.4.2.2.1 acknowledges that other failure mechanisms have not been considered in lifetime estimates, it strongly implies that using the lower bound of the estimates based on uniform corrosion (i.e., 3,000 year lifetime) compensates. The statement of "expected" waste package performance in the Executive Summary is presumably based on this line of argument. However, assuming that 3,000 years is a lower bound may not be conservative. The waste canister material (austenitic stainless steel) is known to be very resistant to uniform corrosion but is, however, susceptible to forms of localized corrosion under conceivable metallurgical and repository conditions. If summary statements such as those cited from the Executive Summary are to be maintained, the supporting performance analysis should consider these potentially more serious failure modes and the associated uncertainties in containment lifetimes (see detailed comments 6-72 and 6-114) since localized mechanisms could result in canister breach at times far less than uniform corrosion.

In addressing the performance objective of the controlled release of radionuclides, the DOE assumes a simple model consisting of congruent dissolution of a canister-sized waste monolith controlled by the solubility limit of uranium oxide. The fractional mass-release rate was determined based on individual parameters, each of which has associated uncertainties, e.g., the water flux, the area of waste which would be exposed to the ground water, and even the solubility of the urania matrix. Furthermore, the draft EA acknowledges that there are radionuclides whose solubilities will not be controlled by the uranium oxide matrix, but there is no attempt to calculate the release rates of these radionuclides (see detailed comments 6-118 and 6-119). This becomes important to do if statements are to be maintained that

the engineered barrier system has been estimated to meet regulatory requirements at this time.

With respect to 10 CFR 960 Postclosure Guidelines 960.4-1, 960.4-2-1(a) and 960.4-2-2(a), the DOE has stated that the geologic setting at the Yucca Mountain Site will allow for the use of engineered barriers (using reasonably available technology) to permit compliance with 10 CFR 60.113. The preliminary performance analyses as currently presented in the draft EA to support the findings of a 3,000 year waste package lifetime and of a fractional radionuclide release rate within the NRC regulatory limits, rely on insufficiently supported assumptions regarding the failure mode of the canister and dissolution of the waste form.

The DOE should consider more realistic assumptions in the preliminary performance analyses and provide an estimate of the impact of model and input data uncertainties on the results of the analyses or reconsider the summary statements made in the draft EA.

COMMENT 11 -- COMPARATIVE EVALUATION OF SITES

The draft EA's describe in Chapter 7 and Appendix B the relative weights given to post-closure and pre-closure guidelines. As required by the guidelines, the DOE gave greater weight to post-closure guidelines (i.e., from 51% to 85% in applying the so-called utility estimation method). However, the staff notes that the spread of site ratings on individual guidelines (see, for example, Tables B-2 and B-3) is distinctly different between the post-closure and pre-closure analyses. The spread of ratings on pre-closure guidelines is much greater than it is for post-closure guidelines. The result of this wider spread is to have pre-closure guidelines dominate the overall ranking, notwithstanding the greater weight given to post-closure guidelines. It appears as if the ratings might be relative in nature as opposed to being an assessment of sites on an absolute scale. If ratings are indeed relative in nature, then inconsistent treatment of post-closure and pre-closure ratings may be interpreted as effectively going counter to the requirement that post-closure guidelines be assigned greater weight in site comparison.

The NRC recommends that the description of the rating methods in the final EA be expanded to explain the reason for the wider spread on pre-closure ratings and, in general, to describe more specifically the method of assigning ratings on individual factors.

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DETAILED COMMENTS

EXECUTIVE SUMMARY COMMENTS

E-1

Section 2.2.2, Grouping of Sites by Geohydrologic Setting, Page 5, Paragraph 4

The term "dry unsaturated zone" is used. "Dry" has no precise meaning and may convey the misconception to non-technical readers that there is no water in the unsaturated zone. It is suggested that the term "dry" be omitted because water saturations (see, for example, page 6-125, paragraph 4) may be from 40 to 90%.

E-2

Section 5, Regional and Local Effects of Repository Development, Page 13, Last Paragraph

This paragraph provides an explanation of the types of transportation effects from increased commuter traffic and the hauling of supplies and radioactive waste. The second sentence states that radiological risks result from routine waste shipments, but there is no mention of radiological risk from transportation accidents. It is suggested that this section discuss the radiological risk from transportation accidents.

E-3

Section 6.3.3, Ease and Cost of Siting, Construction, Operation, and Closure, Page 17, Last Paragraph

This paragraph makes the assertion that there is "adequate vertical flexibility for designing and constructing the repository" at Yucca Mountain. In reviewing the cross-sectional diagrams by Scott and Bonk (1984), it appears that there is limited flexibility in the vertical direction. The location of the repository has a maximum of 30 meters of upward flexibility (as constrained by the disqualifying condition under erosion, 10 CFR 960.4-2-5) and minimal downward flexibility due to increases in lithophysal cavity percentage and the basal vitrophyre of the Topopah Spring Member.

Since the potential for variations in stratigraphy exists in the welded portions of the Topopah Spring Member and because adverse structural features may be encountered during repository construction, vertical flexibility will be necessary in order to provide the necessary space for waste disposal. It is suggested that the DOE consider providing information to establish that there is adequate flexibility for designing and constructing the repository.

Executive Summary References

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CHAPTER 1 COMMENTS

No comments

CHAPTER 2 COMMENTS

2-1

Section, Introduction, Page 2-1, Paragraph 4

This paragraph refers to Figure 2-1 for the location of the Yucca Mountain site. 10 CFR Part 60 defines "site" as the location of the controlled area. Paragraph 2 on page 3-4 indicates that the land parcel under consideration includes the underground facilities, the surface facilities and the controlled area for the repository. It is not clear what area delineated on Figure 2-1 represents the Yucca Mountain site, i.e., the complete, estimated controlled area as defined in 10 CFR Part 60.

Both Preclosure and Postclosure Guidelines on Site Ownership and Control (10 CFR 960.5-2-2 and 960.4-2-8-2, respectively) as well as 10 CFR 60.121 (Requirements for Ownership and Control of Interests in Land) require areal delineation of the controlled area for complete evaluation. This is particularly pertinent to 10 CFR 60.121(b) and 10 CFR 60.121(c) which consider additional controls outside of the controlled area to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation. The EA should be revised to include delineation of the controlled area.

2-2

Section 2.1, Regional Setting of Yucca Mountain, Page 2-6, Figure 2-3a

Understanding the deeper structures beneath Yucca Mountain is an important part of evaluating the geologic stability of the area. Although cross sections shown in Figure 2-3a are schematic, they do not show the buried caldera beneath Yucca Mountain and Crater Flat as is indicated in Figure 3-3 on page 3-7. The DOE should consider modifying these figures to be consistent with others presented in the draft EA.

2-3

Section 2.3, Evaluation of the Yucca Mountain Site Against the Disqualifying Conditions of 10 CFR Part 960, Page 2-52, Paragraph 3

The DOE has not adequately addressed uncertainties inherent in travel time calculations. Many factors, both geological and geomechanical, within a complex fracture-dominated flow system impart measurable or unquantifiable uncertainties into travel time calculations. For example, the last sentence does not consider the key role of the "hydraulic connection" of the matrix with the fracture system, the adsorption capabilities of the matrix and fracture coatings or skin, or the areal changes in hydraulic gradient. It should be noted that uncertainties in calculating each of these parameters pose an

additive effect on the confidence of the final travel time estimate. Thus, overall confidence of travel time estimates has additional uncertainties not mentioned in this paragraph.

CHAPTER 3 COMMENTS

3-1

Section 3.2.1.1, Caldera Evolution and Genesis of Ash Flows, Page 3-9, Paragraphs 1 through 3

The DOE's discussion of the genesis of tuff at Yucca Mountain contains several inaccurate statements. The draft EA states that ash flows, after coming to rest, compact and weld together under their own weight and heat, forming the rock type known as welded tuff. Ash flow tuffs, however, are not always welded. Many small ash flow deposits contain nonwelded, partially welded, and densely welded members within a single or compound cooling unit. See for example the discussion of the Yucca Mountain Member of the Paintbrush Tuff on page 3-10.

Vitrophyre is a dense black glassy rock in which the glassy fragments have completely coalesced (welded) eliminating all pore space. The DOE states that this type of rock often occurs at the top and base of an ash flow. The vitrophyre zone or zone of dense welding does not occur at the top of an ash flow and only rarely at the bottom of flows emplaced at high temperatures (Smith, 1960, Page 154-155). Rapid cooling by the atmosphere or earth results in a vitric non-welded to partially welded tuff. Most single ash-flow cooling units have a nonwelded top and bottom (Smith 1960, p.154).

The DOE implies that ash falls form rock units known as bedded tuff. The term "bedded tuff" generally implies that volcanic material has been reworked, i.e., eroded and redeposited, after the initial deposition and may have originated as either an ash fall or an ash flow, or both, prior to erosion and redeposition: for example see Maldonado and Koether (1983, page 58). Ash falls are the more common source material for bedded material because of their nonwelded nature. However, ash falls can be identified and are commonly listed in USGS lithologic descriptions as such: for example see Maldonado and Koether (1983, Page 66). Thorough understanding of tuff units is essential to evaluation of the stability of the tuffs for construction of a repository.

3-2

Section 3.2.2, Structure, Page 3-13, Figure 3-4

Figure 3-4 shows major strike-slip fault zones in Nevada and California. Problems related to this figure have been identified and are listed below.

First, the draft EA does not adequately discuss the nature of faults presented in this figure; therefore their potential seismic hazard to the site cannot be evaluated. For example, a strike-slip fault approximately 80 kilometers long is shown at a distance of 15-20 kilometers southwest of the site. The fault's age, activity, and seismic hazard to the site is not discussed for possible impact on the seismotectonic characterization of the site.

Secondly, this figure also implies that the Walker Lane fault zone is much narrower than other authors show (Carr, 1974, Figure 1; Carr, 1984, Figure 3; and Smith, 1960, Figure 3). This is significant in view of the statement on page 3-14, paragraph 2, where it is acknowledged "...that seismic activity and surface displacements have occurred during this century within the Walker Lane shear zone." It is important to show the maximum width and extent of the Walker Lane fault zone in order to illustrate the maximum potential extent of seismic activity associated with this zone.

The DOE should consider modifying this figure accurately, including relocating Tonopah to its actual location, for their discussion of regional structure in the Yucca Mountain geologic setting.

3-3

Section 3.2.2, Structure, Page 3-14, Paragraph 2

Discussion of the tectonic setting in the draft EA is limited to Yucca Mountain and does not take into account nearby faults or faulting styles (e.g., the left-lateral offsets in the Spotted Range-Mine Mountain structural zone southeast and east of the site, activity in the Walker Lane fault zone north of Tonopah (Slemmons et al., 1977), and the faults in Yucca Flat and Pahute Mesa). Oversimplification of the regional stress regime results from the brevity and limited scope of the discussions.

The DOE should consider presenting a complete discussion of the regional and site-specific seismotectonic regimes at and around Yucca Mountain. This discussion is needed to adequately assess the seismic hazard to the repository site.

3-4

Section 3.2.2, Structure, Page 3-14, Paragraph 4

Identification of structural features at Yucca Mountain should be provided to assess the feasibility of a potential waste repository site. The draft EA mentions an area of very closely spaced faults that trend northeast. There is no discussion or reference to these features. Figure 3-8 shows several areas of closely spaced faults in the central block. However, these trend north-northwest. The DOE should consider defining the nature of these northeast trending faults, identify them in Figure 3-8, and discuss how they relate to other faults at Yucca Mountain.

3-5

Section 3.2.2, Structure, Page 3-19, Paragraph 1

The first sentence in this paragraph suggests that lateral displacement occurs only on northwest trending faults north of the repository area, yet evidence of lateral displacement, in the form of slickensides, occurs south of well G-2 in both wells G-1 (Spengler, et al., 1981, pages 40-41) and UE 25 a-1 (Spengler et al., 1979, page 29). G-1 is within the repository block and UE 25 a-1 is located approximately 500 m east of the block. The DOE should consider discussing lateral displacement on the faults within the region of the site in addition to those north of the site.

3-6

Section 3.2.2, Structure, Page 3-19, Paragraph 2

Dating of fault activity, especially on major block-forming faults, is crucial for determining the past tectonic activity and the potential future activity within the Yucca Mountain geologic setting.

The absence of Timber Mountain tuff on high-standing blocks can occur as the result of geologic processes other than non-deposition on topographically high-standing fault blocks. The most obvious one is erosion subsequent to faulting. Ekren et al. (1968) offer evidence that the topography was "very subdued during the eruption of the Timber Mountain tuff." Under this scenario, large block-forming faults could have occurred after, rather than before, the deposition of the Timber Mountain tuff. Thus, the initiation of significant faulting may be several million years more recent than implied in this report.

The DOE should consider all viable hypotheses for the age determination of major structural features in the Yucca Mountain region in evaluating past tectonic activity.

3-7

Section 3.2.2, Structure, Page 3-19, Paragraph 2

The draft EA states that the dating of materials gathered from trenches across faults with very small degraded scarps within 10-20 kilometers of the site, show "no unequivocal" evidence that movement has occurred in the last 40,000 years. This statement is ambiguous and may be misleading.

There are several specific concerns that arise from this statement. The term "no unequivocal" is confusing and can imply that there are multiple interpretations of fault movement, perhaps including movement younger than 40,000 years. There are faults within 10-20 kilometers of the site that display

movement in the last 10,000 years. The Bare Mountain fault lies approximately 15 kilometers to the west of the site, and portions of the Rock Valley fault zone lie within 20 kilometers of the site, both of which have had Holocene (10,000 year old) movement. Also, degraded scarps represent the surface expression of predominantly dip-slip or oblique-slip movement on faults. The existence of faults without scarps appears to have not been considered. No reference is made to the possibility of pure strike-slip fault movement that would produce surface displacement but would not produce a fault scarp on the surface.

The DOE should consider re-phrasing the statement referenced above to be very specific about the location of the faults being discussed, the accuracy of the dating of the faults, and the nature of movement on these faults.

3-8

Section 3.2.3, Seismicity, Page 3-19, Paragraph 3

Defining the seismic nature of the geologic setting is an integral part of assessing the Yucca Mountain site as a potential waste repository. The seismic activity along the northeast-trending left-lateral Pahranagat shear zone, the Mine Mountain, Rock Valley, and Frenchman Flat fault systems, is not discussed, although these are some of the most seismically active areas in the vicinity of the repository site (Rogers et al., 1983).

The DOE should consider including these potentially active fault zones in the assessment of the seismic nature of the Yucca Mountain geologic setting.

3-9

Section 3.2.3, Seismicity, Page 3-19, Paragraph 3

In this section, the DOE states that "Yucca Mountain lies in an area of relatively low historical seismicity, just south of the Southern Nevada East-West Seismic Belt" (SNEWSB). This is schematically illustrated in Figure 3-9 (Page 3-20) of the draft EA. The basis used to define the southern boundary of the SNEWSB is not presented in the draft EA.

The SNEWSB is characterized by seismicity in a region where north-south-trending normal-fault blocks are transected by east to southeast-trending zones of lateral faulting (Smith, 1978). Insufficient data or discussion is presented to evaluate whether the southern boundary of the SNEWSB has been properly delineated and the basis for excluding the site from this seismic belt. Two seismicity maps of the area around the NTS (Rogers et al., 1981, Figure 7 and Rogers et al., 1983, Figure 9) show a scatter of seismicity, with local areas of more concentrated seismic activity. From these seismicity maps, it seems that the southern boundary of the SNEWSB encompasses the Yucca Mountain site. At least one publication (Carr and Rogers, 1982, page 9)

delineates the extent of the "East-West Zone" to include the Yucca Mountain site. Another reference, Carr (1984), suggests the southern boundary of the SNEWSB be located further south of that which is presented in the draft EA. Algermissen et al., (1982) and Bucknam and Thenhaus (1979) estimate a maximum expected Richter magnitude earthquake in this region coincident with the SNEWSB on the order of 7.0 to 7.5. A higher degree of tectonic and seismic activity is implied if the site is included within the SNEWSB.

The NRC suggests the DOE identify how the southern boundary of the SNEWSB was determined and, if the site is indeed within the SNEWSB, how this will affect the estimated maximum ground acceleration at the site.

3-10

Section 3.2.3, Seismicity, Page 3-21, Paragraph 2

This paragraph states that "under the assumption that Yucca Mountain faults are not active", the peak deterministic ground acceleration computed for the site is 0.4g, resulting from an earthquake of magnitude 6.8 (this information is detailed in Chapter 6; see, for example, Section 6.3.1.7.5). According to the definition of active fault presented in the Glossary of the draft EA (page G-1) it cannot be assumed that the Yucca Mountain faults are not active. The Solitario Canyon fault, located within a kilometer of the western margin of the Yucca Mountain site, is approximately the same length as the Bare Mountain fault. The maximum magnitude computed for the Bare Mountain fault is 6.8. Should such an earthquake occur on the Solitario Canyon fault, the deterministic peak acceleration may exceed 0.4g. The Ghost Dance fault, which intersects the Yucca Mountain site, might also be considered active according to the Glossary definition. An earthquake on the Ghost Dance fault would most likely cause accelerations within the repository in excess of the 0.4g stated in the EA.

The NRC suggests the DOE assume the faults are active at Yucca Mountain and assess the seismic hazard accordingly.

3-11

Section 3.3.2.1, Groundwater Movement, Page 3-28, Paragraph 3

This section of the draft EA discusses potential recharge to the groundwater system at Yucca Mountain and concludes that probably less than 1 mm/yr percolates through the matrix of the unsaturated zone. The data base is inadequate to support the estimated percolation rate of 1 mm/yr suggested by Montazer and Wilson (1984). Therefore, the validity of the 1 mm/yr percolation rate used in the travel time calculations throughout the draft EA is questionable. In a subsequent section of the draft EA the method used to estimate the 1 mm/year flux rate is presented, but other values could be

defended. This statement is explained further under comments on Section 6.3.1.1. Data in support of the 1mm/yr flux through the unsaturated zone are critical to all travel time estimates.

3-12

Section 3.3.2, Groundwater, Table 3-3, Page 3-29

In Table 3-3, the stratigraphic order of the Pah Canyon and Yucca Mountain members were inadvertently reversed. This comment also applies to Table 6-16 on page 6-128.

3-13

Section 3.3.3, Present and Projected Water Use in the Area, Page 3-31, Paragraph 1; Section 3.6.3.3. Water Supply, Page 3-74, Paragraph 4

This paragraph states that the principal users of groundwater in the area of concern are in the Amargosa Desert south of the town of Amargosa Valley and in the Pahrump Valley. Subsequently, the paragraph indicates that the amount of water used in the Amargosa Desert is unknown although irrigated acreage was estimated at 2000 acres in 1969.

Given information on irrigated acreage, crop type, and irrigation techniques, estimates of water use can be made, albeit with uncertainties. Domestic water use can be estimated from the number of wells and accepted average daily use figures for domestic consumption.

Considering that: 1) the draft EA indicates that one of the principal uses of groundwater in the area of concern is within the Amargosa Desert; 2) the EA is to assess impacts resulting from site characterization and repository development; and 3) Chapter 3 of the draft EA is the source of information to identify and evaluate such impacts, Section 3.3.3 should be revised to include estimates of current and projected water use in the Amargosa Desert.

As an additional note, although the draft EA indicates that well J-13 (Section 5.2.2, Page 5-35, Paragraph 3) is so productive that all water requirements for the project can be met with minimal drawdown of the regional water table and thus no impact on off-site users, provision of present and projected off-site water use in the EA would help in assessing the validity of that position.

3-14

Section 3.4.3, Air Quality and Weather Conditions, Pages 3-44 and 3-46

No information is provided on the diffusion climatology and potential ambient air quality levels in the area of the Yucca Mountain site which should be utilized to assess air quality impacts. It is suggested that information on the expected joint frequencies of wind speed, wind direction and atmospheric stability, and on potential means and extremes of ambient air quality levels of criteria (regulated) air pollutants be provided.

3-15

Section 3.4.3, Air Quality and Weather Conditions, Table 3-4, Page 3-45

The climatic summary presented in this table is based upon data compiled at Yucca Flat from 1962 to 1971. Extrapolation of climatic conditions from Yucca Flat to topographically higher elevations at Yucca Mountain for present-day conditions may not be appropriate. Based on past discussions with the DOE it is the NRC's understanding that precipitation data have been collected at Yucca Mountain since 1983. In making an estimate of climatological conditions it is important to consider all available data. A correlation between climatic conditions recorded at Yucca Flat and conditions at Yucca Mountain has not been demonstrated.

3-16

Section 3.6.3.3, Water Supply, Page 3-74

There is no information provided in Chapter 3 indicating that a water well inventory was attempted. Information provided in Table 3-19 (page 3-75) indicates that utilities and/or water and sanitation districts were requested to provide data on numbers of wells serving communities and estimated total use. These data do not indicate well locations.

Impacts on regional water tables resulting from locating a repository at Yucca Mountain are assessed in Chapter 5. This assessment indicates that no significant effects on regional water tables are anticipated. However, estimated regional impacts may not reflect potentially significant local impacts for those communities or individuals whose wells are closest or adjacent to the site. Section 3.6.3.3 should provide pertinent well data at least for those wells in use closest to the site. Potential impacts to those users should be considered in Chapters 4 and 5.

Chapter 3 References

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CHAPTER 4 COMMENTS

4-1

Section 4.1.1.1, Exploratory Drilling, Page 4-3, Paragraphs 2 and 3

Descriptions of exploratory drilling activities state that drill site location preparation requires the disruption of the regolith for drill pads and that the access road would be 5 miles in length and 50 feet in width. A maximum of 30.3 acres would be disturbed for drilling pad locations. These estimates could be too low if borrow areas to build appropriately graded access roads are needed. If, as this section suggests, 20 new borehole locations are developed, over 600 acres of regolith could be disturbed. The potential for increased infiltration to the unsaturated zone should be evaluated.

4-2

Section 4.1.1.2, Geophysical Surveys, Pages 4-4 through 4-6

The geophysical surveys and techniques described indicate the use of off-road vehicles for site characterization activities; some shallow drillholes may also be required for seismic energy generation by use of explosives set off in drilled shotholes. Transportation and data acquisition efforts in a relatively arid area such as the Yucca Mountain site and vicinity will disturb the desert-type vegetation. For example, wheel tracks will be susceptible to gullying during periods of heavy rainfall, and may therefore be considered as an effect on the environment.

The DOE should consider discussing not only the plans for geophysical surveys, but also the impacts on the environment due to these surveys.

4-3

Section 4.1.2, Exploratory-Shaft Facility, Pages 4-7 through 4-20

Section 4.2 of the draft EA includes a description of the exploratory shaft facility that is planned for site characterization. However, no information is given on the lateral extent of the main underground testing facility. The size of this facility will determine the amount of excavated rock, equipment, labor, water consumed, excavated rock storage area requirements, etc. and will thus affect evaluation of several siting guidelines, including those in the area of environmental quality (960.5-2-5) and socioeconomic impacts (960.5-2-6). The draft EA does not adequately address the possible effects of the lateral extent of the main underground testing facility on the DOE's evaluation of those guidelines.

In planning the underground testing facility, the DOE should consider use of long drifts for site characterization (similar to that at WIPP, 1984) along with the use of small diameter drilled holes because (i) use of only the horizontal and inclined holes drilled from underground testing areas may not yield sufficiently detailed information about geology, hydrology, or geochemistry; short holes are not likely to have sufficient penetration into the formation; long holes are difficult to drill and hard to control or to provide sufficent exploration data, and (ii) lithophysae, faults, and brecciated zones may be better exposed in the surfaces of long drifts.

As stated above, the size of the main testing facility, including the length of drifts, may have an impact on the evaluation of several siting guidelines. Therefore, in discussing the assumptions for the preliminary design of the proposed underground testing areas, the final EA should verify that use of long drifts with relatively shorter boreholes has been considered for use in the underground testing facility and that the impact of such testing facility design has been considered in assessing the environmental impact. In addition, the final EA should include details of the underground testing areas design concepts that may have an impact on the environment.

4-4

Section 4.1.2.1, Surface Facilities, Page 4-9, Paragraph 4

The site plan (Figure 4-3) and preceding discussion (Section 4.1.2.1) indicate that diversion channels will be required during exploratory shaft construction to divert flood waters away from the shaft area, and that the diversion channels will be designed for a 100-year flood. Information and data that will be gathered during the construction of the shaft will be valuable in the design, operation, and closure of the repository. The validity and usefulness of in-situ test data in the exploratory shaft, particularly unsaturated zone data, could be jeopardized if a flood larger than a 100-year flood were to inundate or damage the shaft.

It may not be prudent to design protective features for an exploratory shaft of such unprecedented size, depth, and importance for only a 100-year flood. Based on the preliminary shaft location, it appears that the exploratory shaft will be located in an area likely to experience high flood velocities that may present design difficulties; the steepness of the natural and man-made channels appears to be such that very high flow velocities could be produced by fairly routine flood events (Squires and Young, 1984).

The NRC's experience with floods during the construction of important structures has indicated that the benefits of designing for a larger flood normally outweigh the costs of providing the necessary flood protection. In addition, if the exploratory shaft facilities are incorporated into the other surface facilities during repository operation, it is likely that a larger flood will be used for design purposes. It is therefore suggested that a

larger flood, such as the probable maximum flood (PMF), be used for the design of the exploratory shaft and its appurtenant facilities.

4-5

Section 4.1.2.1, Surface Facilities, Page 4-12, Paragraph 4; Page 4-13, Paragraphs 1 and 3

This section describes the proposed method for disposal of liquid wastes in the sewage lagoon and on the rock storage pile. The lagoon will be used for disposal of sewage, sewage makeup water, drilling fluids including air-water mist, bentonitic mud with water control agents, polymer foam, and washdown water. Also, any perched water or percolation seepages released to the underground facilities will be pumped to the surface and discharged on the rock storage pile with the excess ending in the lagoon. Water and wastes will be allowed to infiltrate into the alluvium below the rock storage area and lagoon. In the draft EA the DOE has not adequately considered the possible consequences of this infiltration. For example, no breakdown of the quantity and quality of liquid wastes potentially percolating into the alluvium is provided, nor is there a discussion of the likelihood of contamination of the local ground water by these waste fluids.

Another unanalyzed consequence of waste fluid infiltration is the potentially adverse effect it might have on the site characterization hydrologic monitoring program. The distance between the sewage lagoon and the exploratory shaft is not given in Figure 4-3; however, it appears possible that water from the lagoon could infiltrate into the region near the exploratory shaft and interfere with the accurate measurement of natural saturation of the tuff. If water from the sewage lagoon moves into the vicinity of the exploratory shaft where in-situ moisture content is to be measured, the measurements may not reflect natural conditions; in that case, it will not be possible to determine accurately the downward flux rate, which is necessary to determine the groundwater travel times. It is suggested that in the final EA the DOE present a discussion of possible consequences of liquid waste infiltration from the sewage lagoon and rock storage area into the subsurface and consider the desirability of lining the sewage lagoon and rock storage area in light of those consequences.

4-6

Section 4.1.2.2, Exploratory Shaft and Underground Workings, Page 4-14

The lithologic log of USW G-4 presented in a report by Bentley (1984) indicates the presence of several fault planes in and down hole of the Pah Canyon and Topopah Spring Members of the Paintbrush Tuff. The presence of these fault planes are not indicated in geologic cross sections such as the one shown on page 5-10 or those shown in Scott and Bonk (1984). The presence of these fault

planes should be addressed because the proposed exploratory-shaft facility will be located adjacent to USW G-4.

4-7

Section 4.2.1, Expected Effects on the Environment, Pages 4-22 through 4-30

There is no discussion of the expected effects of site characterization on mineral resources in this section leaving open the possibility of impacts. It is suggested that such a discussion be included in the final EA.

4-8

Section 4.2.1.1.2, Hydrology, Page 4-23, Paragraph 3

A complete breakdown of estimated water use during site characterization is not provided in Chapter 4. Water uses include consumption, equipment washdown, construction (concrete), drilling, and dust suppression (roads, shaft). Table 4-5 on page 4-36 indicates that these activities may have a local effect on quality and quantity of ground water. A more complete estimate of water use during site characterization activities should be provided to allow a more thorough assessment of possible impacts to any near-by (local) water users.

4-9

Section 4.2.1.1.2, Hydrology, Page 4-23, Paragraph 3

This paragraph indicates that neither the quality nor quantity of ground water would be affected significantly by site characterization activities. No basis for the conclusion is stated or referenced. In particular, no discussion is provided on potential impacts to local groundwater quality or quantity resulting from liquid effluent disposal on the rock-storage pile and sewage lagoon and subsequent infiltration. This section should be revised to include such analysis.

4-10

Section 4.2.1.2, Ecosystems, Page 4-24, Paragraph 4

It is stated that construction activities will displace animals, thus making the assumption that some of these displaced animals will survive. In most cases the species population will be reduced by the number of individuals the lost habitat supported (Kroodsma, 1985). Therefore, it is suggested that emphasis be placed on habitat loss and the associated permanent reduction in wildlife populations. For example, the uniqueness of the habitat and the

percentage of the species population which the habitat supports could be addressed.

4-11

Section 4.2.5, Summary of Environmental Effects, Page 4-39, Table 4-5; Section 5.2.8, Archeological, Cultural, and Historical Resources, Pages 5-53 through 5-55

The standard operating practice presented in Table 4-5 which is related to archeological, cultural, and historic resources omits reference to required consultation activities. It is recommended that the standard operating practice include provision for consultation with the State Historic Preservation Officer and when appropriate, contact with the keeper of the National Register of Historic Places and the Advisory Council on Historic Preservation to assure compliance with the National Historic Preservation Act of 1966 and 36 CFR 800.

Chapter 4 References

Bentley, C.B., 1984. Geohydrologic Data for Well USW G-4, Yucca Mountain Area, Nye County, Nevada, USGS-OFR-84-063, Open-File Report, U.S. Geological Survey, Denver, Colo.

Kroodsma, R., 1985. "In My Opinion..." Assessing the Loss of Wildlife Habitat in Environmental Statements, Wildlife Society Bulletin 13, pp. 82-87.

Panel on the Waste Isolation Pilot Plant, 1984. Review of the Scientific and Technical Criteria for the Waste Isolation Plant (WIPP), National Academy Press.

Scott, R.B. and J. Bonk, 1984. Preliminary Geologic Map of Yucca Mountain, Nye County, Nevada, with Geologic Sections, USGS-OFR-84-494, Open-File Report, U.S. Geological Survey, Denver, Colo.

Squires, R. R. and R.L. Young, 1984. Flood Potential of Fortymile Wash and Its Principal Tributaries, Nevada Test Site, Southern Nevada, USGS-WRI-83-4001, Water Resources Investigations Report, U.S. Geological Survey, Carson City, Nev.

CHAPTER 5 COMMENTS

5-1

Section 5.1.1.1, Surface Facilities, Page 5-7, Figure 5-4

A heliport is proposed for the repository as indicated on Figure 5-4 of the draft EA. No discussion about the heliport is provided. Information such as the size of the aircraft to be used, the number and frequency of flights to be scheduled, the approach angle and direction of takeoffs and landings, etc., is needed in order to evaluate the potential hazard helicopters may present to the site.

5-2

Section 5.1.2.2, Waste Emplacement, Page 5-24, Paragraph 3

It is stated that one of the proposed waste sources for the repository is transuranic wastes (TRU). However, the draft EA provides no discussion regarding the characteristics and the waste packaging for these wastes. The final EA should provide a discussion of the characteristics of the proposed TRU wastes, a description of the waste package, and an evaluation of the suitability of these wastes for disposal in the repository.

5-3

Section 5.1.3, Retrievability, Pages 5-24 and 5-25

The potential use of the long-hole horizontal waste emplacement/retrieval option may present retrievability problems and is questioned in terms of DOE's ability to meet the licensing criteria 10 CFR 60.133 (c) and 10 CFR 60.111 (b).

In the draft EA it is indicated that long-hole horizontal waste-emplacement is an option under consideration for the Yucca Mountain site (draft EA, pages 5-24, 6-296). In comparing this option with the vertical waste-emplacement method, a recent DOE study (Dravo 1984, page 32) has concluded that the long-hole horizontal emplacement method is the recommended option for the Yucca Mountain site, provided the required technology can be developed. The feasibility of this approach for waste emplacement and retrieval has been questioned by independent evaluations (USBM, 1984; USDOE, 1984a, page 5-25) on the basis that the technology to safely handle potential retrieval problems is not reasonably available. Furthermore, the highly fractured host rock at the Yucca Mountain site threatens retrievability from long-horizontal emplacement holes. For this option, the draft EA has given inadequate consideration to the problems of meeting the licensing design criterion for the underground facility

related to retrieval of waste 10 CFR 60.133(c) and the licensing criterion on the retrievability performance objective 10 CFR 60.111(b).

The long-hole horizontal waste emplacement concept referenced in the draft EA would consist of 600 to 700 foot long boreholes that would accommodate 30 to 60 waste packages (Jackson, 1984). Steel liners would be used to facilitate retrieval (draft EA, page 5-24, last paragraph). This option may pose difficulties in terms of retrievability for the following reasons:

- There exists the possibility of corrosion of the liners because the liners may contact minor quantities of water (seepage from potentially corrosive perched water zones or water-bearing shear zones) and the steel liners may make electrical contacts with the stainless steel waste canisters, resulting in galvanic corrosion of the liners (see detailed comment 5-4). This corrosion could jeopardize the integrity of the liners and thus cause difficulties in retrieval operations.

- Potential instability of the rock mass due to weakening along fractures from thermal, hydraulic, and mechanical effects could cause significant rock movement. Such movement could result in misalignment or rupture of the hole liner, which, if it occurred deep inside a 600 to 700 foot long hole, could create additional problems in retrievability. The rock block movement around the emplacement holes could also lead to potential binding of the waste packages in the liner, causing further complications.

- Retrieving breached canisters out of a long horizontal emplacement hole would pose major technical problems that may be insurmountable (USNRC, 1984a).

The long-term impact of the DOE's continued interest in the long-hole horizontal waste emplacement option could be that the DOE may pursue an approach that will not provide adequate confidence that the licensing criteria 10 CFR 60.133(c) and 10 CFR 60.111(b) will be met.

If, after due consideration of the above comments, the long-hole horizontal waste emplacement option is to be pursued further, the DOE should discuss the feasibility of waste emplacement and retrieval for this concept. (See detailed comments 6-105(1) and 6-107).

5-4

<u>Section 5.1.3, Retrievability, Page 5-24, Paragraph 5</u>

The draft EA indicates that steel liners would be used if the option of horizontal emplacement holes is chosen. The potential exists for galvanic corrosion of the steel emplacement hole liner as a result of electrical contact with the more noble stainless steel canister, which could jeopardize a retrievability operation.

Designs for the horizontal emplacement of waste packages indicate the annular gap between the stainless steel container and the steel borehole liner could be as little as 3 cm (Gregg and O'Neal, 1983) and similarly with the shorter borehole liner and the container in the vertical (reference) emplacement design (Dravo, 1984). Furthermore, the designs do not indicate how or if the gap is to be maintained. Therefore, physical or electrical contact between the dissimilar metals could create a galvanic corrosion cell. Assuming that the stainless steel is in a passive state, thereby increasing the electrical potential between the two metals, and that water is present as the electrolyte, the corrosion of the steel liner may be significantly rapid as to penetrate the liner within the retrieval period. If a substantial number of contacts exist among the liner and waste containers, the integrity of the liner for purposes of retrievability may be compromised.

5-5

Section 5.1.5, Alternative Repository Concepts, Pages 5-25 through 5-27

In the draft EA, the DOE has identified some of the alternate repository design assumptions that are being pursued. However, an adequate description of the impact of these alternatives on the environmental assessment and on the evaluations of the siting guidelines (e.g., 10 CFR 960.5-2-5, environmental quality and 10 CFR 960.5-2-9, rock characteristics) has not been provided.

On page 5-1 (paragraph 2) of the draft EA, it is stated that some of the design assumptions on which the preliminary repository concepts were based have been changed. However, the draft EA does not summarize all these changes. In addition, the impact of the intended design assumption changes on the environmental assessment has also not been adequately addressed. Some of these alternate design assumptions are: (a) single-stage vs. two-stage repository design; (b) use of off-site monitored-retrievable-storage vs. on-site waste handling facilities; (c) use of vertical shaft vs. ramp for men-and-materials access to the repository; (d) use of 5-year vs. 10-year-old spent-fuel; (e) backfilling of emplacement and access drifts vs. open rooms; and (f) revised accident analysis results.

Comments on these alternate assumptions are as follows:

(a) Single-Stage vs. Two-Stage Repository Design:

The draft EA has presented in Table 5-12 (pages 5-30 to 5-33) an estimate of the changes in projected impacts of using a two-stage repository. However, bases for these findings are not adequately discussed in the draft EA. Since it is likely that the DOE may further pursue the two-stage repository concept to meet the 1998 operation schedule (draft EA, page 5-27, last paragraph), its environmental impact should be evaluated and details included in the final EA.

(b) Use of Monitored-Retrievable-Storage Facilities:

It is stated in the draft EA (page 5-23, paragraph 2) that "After casks are unloaded, the spent-fuel assemblies will be packaged, or they may be disassembled and individual fuel rods consolidated into specially designed waste packages." This description assumes that the facilities for consolidating the spent-fuel assemblies would be located at the repository. However, this assumption is not consistent with statements made by Mr. Ben Rusche, Director of the Office of Civilian Radioactive Waste Management of the DOE, at the NRC commission meeting on November 15, 1984 (USNRC, 1984a) and at the Atomic Industry Forum meeting on November 12, 1984 (OCRWM Bulletin, 1984). At these meetings, Mr. Rusche stated that certain waste disposal functions such as packaging, handling, and lag storage of waste may be carried out at locations other than the repository site using an off-site monitored-retrievable-storage facility. If waste packaging, handling, and lag storage are not to be done at the site, it could affect the design of the surface facilities of the repository and may also have an effect on the evaluation of some of the siting guidelines (e.g., 10 CFR 960.5-2-5, environmental quality). The DOE should consider this potential design change in the final EA and discuss its impact on the environmental assessment.

(c) Vertical Shaft vs. Ramp

In paragraph 2, on page 5-8 of the draft EA, it is stated that either a shaft or a ramp access will be used for men-and-materials access to the repository. Further, it is also stated that for impact analyses, ramp access has been assumed. Thus, it appears that the DOE has not adequately evaluated the impact of using a shaft access for men and materials on siting guidelines related to environmental quality (960.5-2-5) and socioeconomic impacts (960.5-2-6). If the shaft access is retained as a viable option, the final EA should describe the potential effects of this alternative on the evaluation of pertinent siting guidelines.

(d) Use of 5-Year-Old Spent-Fuel

In paragraph 3, on page 5-27, it is stated that the draft EA has assumed the emplacement of 10-year-old spent-fuel. However, the September 1984 publication of the DOE, "Generic Requirements for a Mined Geologic Disposal System" (USDOE, 1984b) states that the repository design shall be capable of receiving and disposing of infrequent shipments of spent-fuel aged as little as 5 years out of the reactor. Potential use of this design assumption could influence the repository design, including the heat load, spacing of emplacement holes, and number of canisters per emplacement hole. Use of 5-year-old waste in the repository could, therefore, affect the amount of rock excavation, number of workers, and equipment. If disposal of 5-year-old waste is a possibility, then the final EA should evaluate and discuss the impact of emplacing 5-year-old spent-fuel at the repository, and its effect on the evaluation of siting

guidelines related to environmental quality (960.5-2-5), socioeconomic impacts (960.5-2-6), and transportation (960.5-2-7).

(e) Backfilling of Access and Emplacement Drifts vs. Open Rooms

From the discussion provided in paragraph 3, page 5-11 of the draft EA, it appears that the decision to backfill access and emplacement drifts or to maintain open rooms prior to closure and decommissioning has not been finalized. The environmental impact of each alternative is likely to be different, especially with regard to retrievability. Retrieval of backfilled rooms would possibly involve handling extremely hot muck, leading to potentially hazardous environmental conditions. Evaluation of the siting guidelines (e.g., 10 CFR 960.5-2-9(4)) could also be influenced by the decision to backfill the access and emplacement drifts. Therefore, the final EA should present the environmental impact resulting from both alternatives.

(f) Accident Analysis

In paragraph 3, page 6-15 and paragraph 3, page 6-35 of the draft EA, it is stated that the information used for assessments of accidental radiological releases is not the same as that contained in Jackson (1984), or in Section 3.4.7 and Section 5.2.9. The DOE should update the information given in Sections 3.4.7 and Section 5.2.9 to accurately reflect the assumptions made in assessing the environmental impact.

Much of the information on accidental radiological release used in assessing the environmental impact in Chapter 5 appears to have been taken from Jackson (1984, page 5-59, last paragraph). Since this analysis has been revised, the results of the revised analysis should be incorporated into the discussion of radiological effects in the final EA.

The final EA should evaluate and discuss the impacts of the above-mentioned assumptions and other alternate design assumptions.

5-6

Section 5.2.1, Geologic Impacts, Page 5-34, Paragraph 2

This section addresses the potential for induced seismicity due to the stress releases imposed by repository construction at Yucca Mountain. The statement, "excavation of the repository represents an insignificant disturbance to the overall competence of the rock units at Yucca Mountain." may be too optimistic in light of the available data on the Yucca Mountain structural and tectonic environment. The following list of interpretations presented in the draft EA suggests that faults may be near failure and could slip in response to human-induced stress changes:

1) "At present, a preliminary conclusion could be made that the north-trending faults at Yucca Mountain should be considered active even though the absence of fault scarps and the near absence of seismic activity suggests that they are not active." (6-226, last paragraph).

2) "...Interpretations of stress measurements at Yucca Mountain could indicate that certain faults may be near failure..." (page 6-227, first paragraph).

3) "...The accompanying aftershocks indicate that these faults (at Pahute Mesa) may have been tectonically stressed near the failure point, and slip was triggered by stress changes produced by the explosions (Underground Testing)." (page 6-227, First Paragraph).

The significance of this concern is that stress field changes imposed by the construction of an underground facility at Yucca Mountain may initiate slip on faults that may be at or near the failure point. Stress changes near the Solitario Canyon Fault, and perhaps the Ghost Dance Fault, are of particular concern. Major displacement on either of these faults has the potential to generate significant seismicity, which could have impacts on the integrity of the underground and surface facilities as well as the safety of repository personnel.

To resolve this concern, it is suggested that the in situ stress regime at Yucca Mountain and potential changes to that regime due to repository construction, including impacts on fault displacement and resulting seismicity for faults in and around the repository location, be critically evaluated.

5-7

Section 5.2.2, Hydrologic Impacts, Pages 5-35 and 5-36

This section identifies potential hydrologic impacts on the physical environment as a result of locating a repository at Yucca Mountain. Relative to groundwater, the following potential impacts have been identified in this section. They include: 1) The exclusion of any future exploitation of ground water in the area immediately surrounding the repository; 2) Regional draw-down effects from groundwater withdrawals at Yucca Mountain; and 3) Release of radionuclides into the groundwater. Comments relative to the these potential groundwater impacts follow below.

1. The exclusion of any future exploitation of groundwater in the area immediately surrounding the repository.

The discussion in this section indicates that development of a repository at Yucca Mountain would result in a controlled area within which groundwater exploitation would be prohibited (page 5-35, paragraph 2). Therefore, the exclusion of any future exploitation of groundwater in the area immediately

surrounding the repository is identified as a potential impact. Referencing a study by Sinnock and Fernandez (1982), the section concludes that future generations are more likely to drill for water in Jackass Flats to the east and Crater Flat to the west of Yucca Mountain than on the mountain itself. Therefore, it is concluded that no significant impacts are expected. The reason presented for the low probability of developing water resources on Yucca Mountain is because of additional expense in pumping water to the top of the mountain as well as the rugged terrain. Similar statements of this rationale are provided in Section 6.3.1.1.4 (paragraph 4, page 6-133; paragraph 2, page 6-134); Section 6.3.1.8.3 (paragraph 6, page 6-236) and Section 6.3.1.8.4 (page 6-242, continuing paragraph; paragraph 3, page 6-243).

Two additional factors not explicitly referred to in the discussion and which appear to support the conclusion that no significant impacts would be expected as a result of the exclusion of any future exploitation of groundwater in the area immediately surrounding the repository are contained in Section 6.3.1.1.4 (paragraph 1, page 6-134). The first is a statement that from the standpoint of the commercial value of groundwater, irrigation is not of major concern in the site area primarily because of poor characteristics of the alluvium, which make the site undesirable for agricultural use. The alluvium is coarse-grained and drains rapidly except in the playa areas where the concentration of salts makes it unlikely that crops could be grown. The second is that pressure to develop groundwater locally for human consumption is not likely because land use is restricted.

Although it appears qualitatively that any impacts resulting from the exclusion of any future exploitation of groundwater do not appear to be significant, the rationale presented in Section 5.2.2 to support that conclusion is not well developed, and lacks clarity and completeness for the following reasons:

A) It is assumed that the statement in Section 6.3.1.1.4 (page 6-134, paragraph 1) on suitability of alluvium for agricultural use implicitly supports the subject conclusion. No reference is provided for that statement in Section 6.3.1.1.4. Evaluation of soil types was not considered in Sinnock et al. (1984). Given that the only information provided is that alluvium (non-playa areas) is coarse grained and well-drained, conclusions on suitability for agricultural use seem unsupported.

B) It is not clear what specific areas are included within the zone in which future exploitation of groundwater will be excluded. The primary rationale for there being no impacts implicitly assumes that the area of exclusion will be the higher elevations and rugged terrain of Yucca Mountain. As noted in comment 2-1, the controlled area has not been delineated. Additional controls outside of the controlled area, which could include water rights, are a consideration in 10 CFR Part 121. It is not clear if there are areas beyond the controlled area in which: 1) additional controls may be necessary; and 2) are not now under government control and thus restricted use. If so, the potential impacts of

restrictions in those areas require evaluations. This is also relevant to various guidelines on site ownership/control and human interference as well as the statement on page 6-134 which indicates that pressure to develop groundwater locally for human consumption is not likely because land use is restricted.

C) This section did not consider potentially serious water shortages in the Las Vegas Valley in the near future.

D) The discussion centers solely on potential impacts to future generations. Potential impacts to existing users is not addressed explicitly in Section 5.2.2. It is not clear if any existing non-governmental water users and/or supply sources (wells) would be located within areas where restrictions or prohibitions would occur. This includes areas outside of the controlled area. Such potential impacts should be addressed.

In summary, the rationale presented in Section 5.2.2 supporting the conclusion that no significant impacts are anticipated as a result of the exclusion of any future exploitation of ground water should be revised to include adequate references for supporting information and to delineate clearly areas subject to controls.

2. Regional drawdown effects from groundwater withdrawals at Yucca Mountain

It is concluded in Section 5.2.2 that aquifers underlying Yucca Mountain can produce an abundant quantity of ground water for long periods of time without lowering the regional water table. It does not appear that any of the regional (Waddell, 1982) or subregional (Czarnecki and Waddell, 1984) models of groundwater flow are being used to predict drawdowns based on estimated repository withdrawals nor that any simplified analytical calculations are being done of distance-drawdown based on information contained in Young (1972) or Thordarson (1983). In addition, no evaluation of local drawdown effects as a potential impact is presented in Section 5.2.2. As noted in detailed comment 3-16 there is no accurate identification of local users (wells). Conclusions based on regional considerations may not be relevant in considering local impacts. Available data would allow at least a simplified quantitative assessment of potential regional or local impacts. Finally, as noted in detailed comment 5-8, a more accurate estimate of the volume of repository water requirements should be prepared and used to re-evaluate local and regional effects from groundwater withdrawals at Yucca Mountain.

3. Release of radionuclides into the groundwater

Based on preliminary assessments of the long-term performance of a repository at Yucca Mountain (Sinnock et al., 1984; Thompson et al., 1984) and preliminary performance analyses described in Sections 6.3.2 and 6.4.2 of the draft EA it is concluded that a repository at Yucca Mountain would meet the draft version of the EPA standards for radionuclide releases to the accessible environment. Those assessments are directed toward long-term post-closure performance, and

neither they nor any material in this section provide an analysis of the potential for release of radionuclides into groundwater as a result of a pre-closure accident. The only statement found in Chapter 5 relevant to such a situation is the unsupported statement on page 5-59 (paragraph 2) which states, "no significant water ingestion pathway was identified." The section should either be revised to incorporate a discussion, conclusions, and supporting rationale for this scenario or provide a reference to the discussion of this scenario contained in Section 6.2.2.1.3 (page 6-104).

5-8

Section 5.2.2, Hydrologic Impacts, Page 5-35, Paragraph 3

According to paragraph 3, it has been estimated that the water requirements for a repository at Yucca Mountain would average 220,000 cubic meters (180 acre-ft) per year over a 60-year period that includes the construction, operation, retrievability, and decommissioning phases. This same 180 acre-ft/year figure is presented again in Section 6.2.1.7.5 (page 6-84, paragraph 1). In both cases the reference cited is McBrien and Jones (1984). Pertinent comments are as follows:

1. Review of the report of McBrien and Jones (1984) does not indicate any relevant estimates of on-site water use. Only estimates of increased water demand on public utilities or municipalities resulting from increased population are presented.

2. Paragraph 3 indicates that the 180 acre-ft/year is calculated based on worker consumption only. Therefore, this is an incomplete estimate of the water requirements for all phases of the repository; for example, water use estimates for construction (concrete), dust suppression, equipment washdown, or possible decontamination have been omitted.

Because regional drawdown effects from groundwater withdrawals at Yucca Mountain have been identified as a potential hydrologic impact (page 5-35, paragraph 1), a more complete breakdown of repository water use volume estimates is a prerequisite for reaching conclusions on such an impact. Section 5.2.2 should be revised accordingly relative to re-evaluation of the origin and reasonableness of this water use estimate. If necessary, other sections of the draft EA making use of this estimate should be revised.

5-9

Section 5.2.2, Hydrologic Impacts, Page 5-35, Paragraph 5

This paragraph discusses climatic changes during the Quaternary period. According to the draft EA, "the evidence compiled to date suggests that climatic changes during the Quaternary period, the last 1.8 million years,

probably had a negligible effect on the hydrologic system at Yucca Mountain." This statement is in conflict with the finding related to favorable condition 2 of the guideline on climatic changes (960.4-2-4). This favorable condition relates to a geologic setting in which climatic changes have had little effect on the hydrologic system throughout the Quaternary Period. It is concluded in the draft EA that this favorable condition is not present at Yucca Mountain (Section 6.3.1.4.4, page 6-200, paragraph 1). The two parts of the draft EA should be made consistent.

5-10

Section 5.2.2, Hydrologic Impacts, Page 5-36, Paragraph 2

This paragraph states that runoff and possible leachates from the rock-storage pile would be retained by the storage-pile berm, as discussed in Section 5.1.1.3. There is no discussion of a rock-storage pile berm in Section 5.1.1.3, nor any other reference to a storage-pile berm in Chapter 5. However, discussion of a rock-storage pile and associated berm is included in Chapter 4 only as related to exploratory shaft construction. Table 4-5 (page 4-38) indicates that construction of a berm is a standard operating practice to mitigate potential impacts on vegetation resulting from fluid escape. No similar discussion of potential impacts to ecosystems (vegetation) is included in Chapter 5, in particular Section 5.2.4 (Ecosystems) and Table 5-57 (Summary Of Environmental Effects Associated With The Construction, Operation, Retrievability, And Decommissioning Phase Of The Repository). Chapter 5 should be revised to include discussion of the storage-berm in a manner similar to that used in Chapter 4, including consideration of potential effects on the quality of local ground water. In addition, estimates of the quantity and quality of liquid effluents should be provided. The potential for impacts would seem to be greater during repository construction than for site characterization activities.

5-11

Section 5.2.2, Hydrologic Impacts, Page 5-36, Paragraph 2

This paragraph indicates that runoff and possible leachates from the rock-storage pile would be retained by the storage-pile berm, as described in Section 5.1.1.3 (see previous comment). The paragraph also indicates that these liquids are not expected to infiltrate into the underlying formation because of the region's high potential evaporation rate. Therefore, because all liquid effluents would be disposed of in evaporation ponds or the rock-storage pile the repository is considered a zero-discharge facility (no liquid effluents would be discharged into the environment); thus, no hydrologic impacts are expected.

In light of other statements in the draft EA, the statement in paragraph 2 indicating that liquid effluents are not expected to infiltrate into the underlying formation is questionable. Based on Figure 5-7 (Section 5.1.1.1, page 5-6) the rock-storage pile as well as evaporation ponds would be built on alluvium. Considering the statement that alluvium is coarse-grained and drains rapidly (Section 6.3.1.1.4, page 6-134, paragraph 1) one would expect a considerable amount of infiltration to occur regardless of the evapotranspiration rate. Therefore, the conclusion that the storage-pile and evaporation ponds constitute a zero-discharge facility may not be valid, and a different rationale is necessary to support the conclusion of no significant impact. Section 5.2.2 should be revised accordingly.

5-12

Section 5.2.5.3, Operation, Page 5-45, Continuing Paragraph

The conclusion is reached by the DOE that, as a result of the operation of a nuclear waste repository at the Nevada site, no ambient air quality standards will be violated; however, only diesel emissions were utilized in this assessment. No fugitive dust emissions were presented and included, and background levels were not added to the calculated air quality levels resulting from plant operations. Therefore, the DOE conclusion may not be verified due to insufficient information. It is suggested that air quality impacts of operation be reevaluated including conservative air quality background levels and fugitive dust in the assessment.

5-13

Section 5.2.6, Noise, Page 5-47, Paragraphs 2 and 3

There is no indication in this section as to the need or intent to confirm the estimated ambient noise levels for the rural community and desert areas. If the estimates presented in the text are offered as being representative and no confirmatory monitoring is proposed, this section should so state.

5-14

Section 5.2.9.1, Construction, Page 5-56, Paragraph 4

No information is provided on the diffusion analyses utilized to obtain the man-rem resulting from construction activities. It is suggested that the details of the diffusion analyses be provided so that the validity of the DOE radiological impact of construction can be assessed.

5-15

Section, 5.2.9.2.3, Accidental Exposure During Operation, Page 5-59, Paragraph 1

The draft EA provides various accident scenarios (page 5-60, Table 5-27) that could lead to radioactive releases and exposure to the general public and repository personnel. However, one important accident scenario has not been considered, viz., the potential hazard associated with retrieval and subsequent disposal of breached waste-canisters. Some of the canisters may breach during the pre-closure period of repository life (USNRC, 1984a). In the event that retrieval becomes necessary, special equipment and safeguards may be required to extract the breached canisters from the emplacement holes, transport them through the repository, and send them off for repackaging. Considerable dose commitments to restricted and unrestricted areas may accompany such operations. Therefore, it is suggested that the final EA address this potential accident scenario and evaluate corresponding release probabilities and dose commitments.

5-16

Section 5.2.9.2.3, Accidental Exposure During Operation, Page 5-60, Table 5-27

No information is provided on diffusion analyses utilized to evaluate the radiological consequences of accidental releases during operation. It is suggested that the DOE provide the details of these diffusion analyses so that the validity of the DOE's radiological impact of accidents can be assessed.

5-17

Section 5.3, Expected Effects of Transportation Activities, Page 5-62

The impacts from transportation accidents, including the estimated dose to the maximally exposed individual and the estimated number of latent cancer fatalities, are not discussed. It is suggested that the final EA include either an explanation of the use of existing analyses and studies to substantiate the assertion that transportation accident impacts are small, or an analysis of the consequences, probabilities, risks, and cleanup costs for a severe transportation accident en route to the site.

5-18

Section 5.3.2.1, Radiological Effects of Nuclear Waste Transportation, Page 5-72, Paragraph 3

The paragraph states that under accident-free operating circumstances, no radioactive material would be released from the shipping containers during

transport. While this may be true for the contents of the package, there have been cases of contamination being released from the package surface during transport. It is suggested that the potential radiation doses to radiation workers involved in the close proximity decontamination efforts be addressed in the final EA.

5-19

Section 5.3.2.1, Radiological Effects on Nuclear Waste Transportation, Page 5-75, Table 5-36

This table provides estimated collective radiation doses associated with the 30-year operating lifetime of a repository. It is suggested that the table list the exposures for the occupational and non-occupational population subgroups.

5-20

Section 5.3.2.1, Radiological Effects of Nuclear Waste Transportation, Page 5-75, Continuing Paragraph

It is stated in this paragraph that if a transportation accident involving high-level radioactive waste were to occur, experimental evidence suggests that the consequences would not be great. The consequences of a transportation accident en route are not specifically analyzed in the draft EA or appendices. It is suggested that the cost of cleanup for transportation accidents be addressed in the EA.

5-21

Section 5.3.2.1, Radiological Effects of Nuclear Waste Transportation, Page 5-76, Table 5-37

This table provides total and average radiation doses to a maximally exposed individual (member of the general public) resulting from routine transportation to the repository. It is suggested that the table also include maximum exposure that is likely to occur in a transportation accident.

5-22

Section 5.3.2.1, Radiological Effects of Nuclear Waste Transportation, Page 5-79, Table 5-41

This table lists factors used to calculate non-radiological effects of transportation. It is suggested that an explanation of the factors used for rural and suburban area analyses be provided.

5-23

Section 5.3.2.3, Costs of Radioactive Waste Transportation, Page 5-80

Certain transportation corridors along the routes to the sites, for example, those with high accident frequency or high waste traffic volume, or adverse weather conditions are a potentially important issue. Although the radiological risks along these special corridors are estimated to be small, such corridors may be subject to increased state and local emergency response actions. This response may be costly and could be disruptive to communities. It is suggested that this type of consideration be included in the assessment of transportation impacts.

5-24

Section 5.3.2.1, Radiological Effects of Nuclear Waste Transportation, Page 5-80, Continuing Paragraph

This paragraph discusses non-radiological effects of transportation. The basis for the truck and rail fatality comparisons should be clarified.

5-25

Section 5.4.1.1, Labor, Pages 5-85 through 5-86

No indication is given of the uncertainties of the labor force estimates used in the socioeconomic analyses. The size of the labor force during construction, operation, and closure is a major determinant of socioeconomic impacts. Therefore, labor force size and uncertainty would be reflected in the magnitudes and uncertainties of estimates of socioeconomic impacts. It is suggested that the uncertainty in labor force estimates be assessed and if they are sufficiently large, the implications for the estimates of socioeconomic impacts be discussed.

5-26

Section 5.4.3.3, Water Supply, Page 5-101, Paragraph 1

Under the broader heading of expected effects on socioeconomic conditions expected effects of the repository on water supplies of municipal and private utility systems are discussed in Section 5.4.3.3. Only potential impacts to these water supplies resulting from increased population are discussed. It would be appropriate, based on information provided in Section 5.2.2 (Hydrologic Impacts), to provide summary statements and conclusions related to potential impacts on water supplies resulting from: 1) exclusion of any future exploitation of groundwater as a result of locating a repository at Yucca Mountain; 2) drawdown effects resulting from repository-related groundwater withdrawals; and 3) pre- or post-closure release of radionuclides into the groundwater.

5-27

Section 5.4.5, Fiscal Conditions and Government Structure, Pages 5-108 through 5-109

The discussion in this section on technical and financial assistance for planning and mitigation needs to consider how assistance will be provided to assure timely planning. Early planning is necessary to prevent impacts that can be mitigated. Many of the tax benefits cited in this section are during construction when it will be too late to mitigate the impacts of construction. More emphasis needs to be placed on preplanning potential of financial and technical assistance. Specifically, the DOE grants may be available during site characterization to assist in planning for economic, social, and public health and safety impacts of a repository. This planning would then identify potential impacts and requirements well in advance of the beginning of construction and allow timely mitigation. A detailed approach to impact mitigation is suggested, and plans for the timely implementation of studies should be considered. Mitigation planning is a lengthy process which should take place as early in the repository siting as possible. It is suggested that there be a full discussion of the timing of pre-impact assistance available for mitigation planning.

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CHAPTER 6 COMMENTS

6-1

Section 6.2.1.1, Postclosure Site Ownership and Control (10 CFR 960.4-2-8-2), Page 6-7

The qualifying condition for this guideline requires that the site shall be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR Part 60, ownership, surface and subsurface rights, and control of access that are required in order that potential surface and subsurface activities at the site will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in Section 960.4-1 of the siting guidelines. As stated in Section 6.2.1.1.2 (page 6-9, paragraph 1), the Yucca Mountain site is entirely located on federally owned land (Figure 3-1, page 3-2). Evaluation of the postclosure site ownership and control guideline (10 CFR 960.4-2-8-2) presumably is based on the site as delineated on Figure 3-1 and the plan developed by Richards and Vieth (1983).

As noted in detailed comment 2-1, an accurate delineation of the controlled area is not provided in the draft EA. It is not clear if the "site" discussed under this qualifying condition includes both the controlled area and any additional lands outside of the controlled area as needed in relation to 10 CFR 60.121 (b) and 10 CFR 60.121(c). Additional controls outside of the controlled area could include exclusion of any future exploitation of groundwater (obtaining water rights) if, for example, it could be shown that future groundwater withdrawals could be expected to induce migration of radionuclides to the accessible environment in amounts exceeding EPA standards. Because the qualifying condition of 960.4-2-8-2 references 10 CFR 60 specifically, clarification in this area is needed for complete evaluation of the qualifying condition.

6-2

Section 6.2.1.1.2, Data Relevant to the Evaluation, Pages 6-9 and 6-10

The discussion of land ownership is inadequate with respect to the description of existing rights and future acquisition activities. The term of the current withdrawal is not stated, and the extent to which the DOI's jurisdiction over specified resources may interfere with the DOE's exercise of control is not addressed. The Air Force's views regarding its need for lands at the Nellis Range should be presented; if their use is of sufficient importance, the DOE might not be able to obtain the required land interests. The referenced land acquisition report may contain the information needed to resolve questions arising under the land ownership guidelines; it would be helpful, however, if the required actions, as conceived by that report, were summarized in the final EA.

6-3

Section 6.2.1.1.2, Data Relevant to the Evaluation, Page 6-9, Paragraph 6

This section provides information on the jurisdiction and control of all land parcels relevant to the Yucca Mountain Site. This includes the Nevada Test Site segment, Nellis Air Force Range segment and the Bureau of Land Management segment. The section indicates that all these lands are currently free and clear of encumbrances arising under lease, right of entry, deed, patent, mortgage, appropriation, prescription, or otherwise (page 6-9, paragraph 5) although the DOE only has control of the NTS segment. However, in paragraph 6 within the discussion on assumptions and data uncertainties it is stated that although the DOE has control over water rights from points of extraction on the NTS, it is possible that superior rights to the water in the same underground source may exist with respect to some point of extraction outside the NTS boundaries. It is also stated that the significance of this issue would depend on superior rights, as well as on a comparison of the amount of water needed to construct and operate the repository to the amount available for extraction from the underground source. This particular discussion of possible superior rights to the water in areas outside the NTS boundaries appears to imply that water rights on repository site segments other than NTS could be held by non-governmental entities. This would not be consistent with other statements in the draft EA and should be clarified.

6-4

Section 6.2.1.4.2, Data Relevant to the Evaluation, Assumptions and Data Uncertainties, Page 6-27, Paragraph 3

This paragraph provides data relevant to the evaluation of the qualifying condition of the guideline on meteorology (10 CFR 960.5-2-3). As stated, much of the meterological data is not site specific to Yucca Mountain. The assumption is made that monitoring stations with long-term records (Yucca Flat and Beatty) are representative of conditions at the Yucca Mountain repository. There is no evidence of an attempt to validate, correlate, or compare the most recently compiled meteorogical data at Yucca Mountain with the long-term monitoring stations.

6-5

Section, 6.2.1.5.4, Potentially Adverse Conditions (1), Pages 6-37 to 6-40, Paragraphs All

The draft EA does not adequately discuss the potential effects of some of the present and future defense-related activities in the vicinity of the proposed site on the design, construction, operation and closure of the proposed repository facilities. Since the Yucca Mountain site is partly located on the

Nellis Air Force Range, the possible effects of vibratory ground motion and pressure waves resulting from "practice bombing" in the vicinity of the site should be considered in the design. In the draft EA, there is no mention of the conceivable consequences from misfired armament on board the aircraft in the event of flight or bombing errors. More information would be needed about the specific type of bombs or other armament on board the aircraft, or used at the range, in order to make a determination of the potential danger these overflights might have on the repository. It is suggested that the final EA also address the measures taken to avoid direct bomb hits on geologic repository surface facilities during the operating life of the repository. The effects of any design changes due to the above mentioned considerations on the environmental impacts should be evaluated and described in the final EA.

6-6

Section 6.2.1.5.4, Potentially Adverse Conditions (1), Pages 6-37 through 6-40

A portion of the Yucca Mountain site is proposed to be located on the Nellis Air Force Range. As shown in Table 5-27 on page 5-60 of the draft EA and in Table 16 of the report by Jackson et al. (1984), a potential aircraft crash appears to be the accident scenario leading to maximum population whole-body dose commitments ($< 1.1 \times 10^2$ man-rem) as compared to those from other postulated accidents. The draft EA states (page 6-37, paragraph 3) that for the military - aircraft flights to and from target areas, the probability of an airplane crash at the repository site has been estimated at less than 2.0×10^{-10} per year. The basis for this conclusion has not been sufficiently substantiated in the draft EA.

On pages 63 to 66 of the Jackson et al. (1984) report, typical calculations for aircraft crash probability are given. The aircraft crash probability is calculated for a very small area (4 X 4.9 x 2.9m) of the repository surface facilities which would contain an estimated four hot cells. Because a typical plane crash is likely to affect a much larger area due to its sliding along the ground upon impact, fire and flying debris, a much larger area should be considered for the aircraft crash probability calculations.

Also, in the last paragraph of page 65 (Jackson et al., 1984) the potential impact of many factors are not taken into account for probability calculations, but have been assumed to be negligible. It is recommended that the DOE further review its aircraft crash probability calculations, revise them by making more realistic assumptions, and evaluate and discuss their environmental consequences in the final EA.

6-7

<u>Section 6.2.1.5.5, Disqualifying Condition, Page 6-41, through 6-43</u>

The draft EA does not adequately support the conclusion (page 6-41, paragraph 5) that "The Yucca Mountain site is sufficiently distant from present and potential (future) test locations that collapse, or formation of fractures is highly unlikely". The following comments provide some of the specific examples of assumptions and data uncertainties which should be further considered in the final EA.

1. An adequate basis for the assumption that "The yield limit for Mid Valley, a future potential test area, is likely to be similar to that for Yucca Flat", (page 6-35, continuing paragraph) has not been provided in the draft EA. Because the Mid Valley testing area is the closest one to the proposed repository site (about 20 km versus about 30 km for Yucca Flat), a reliable estimate of the expected yield limits, along with adequate documentation, would be required to assess the possible impacts of weapons tests at this location.

2a. Considerable emphasis has been placed on the prediction capability of the "acceleration - production equation" developed by Vortman (1980) (page 6-38, paragraph 2 of the draft EA). Based on a review of Vortman (1980), it appears that the prediction equation is not based on fully reliable data. For example, on page 8 of Vortman (1980) it is stated that the data from large-yield events as early as 1966 have been used as a basis for the prediction equation, and that the measurement systems (viz., Pace Accelerometers, DX velocity gauges, and L-7 seismometers) used then did not havé characteristics (such as accuracy and stability of calibration with time) as good as those of systems in use today.

2b. The analysis results in Vortman (1980) are stated to be based on the assumption that data from current and past tests on Pahute Mesa are applicable to the Buckboard Area. However, due to probable differences in the geologic characteristics between these two areas, such an extrapolation may not be appropriate.

3. The draft EA states that no damage to off-site mines due to underground nuclear tests had been reported through 1977 (page 6-41). However, the time period of the surveillance program has not been reported. Since the repository openings need to be maintained for about 90 years, surveillance data for a short duration on temporary mines may not be directly applicable to repository openings. The final EA should focus on data that most closely correlate with expected repository conditions.

6-8

Section 6.2.1.6, Environmental Quality, Pages 6-44 through 6-73

Aesthetics of facilities including the supporting railroad are not commented on in this section. It is suggested that aesthetics of the railroad be explicitly discussed in the final EA.

6-9

Section 6.2.1.6.3, Favorable Conditions, Page 6-63, Paragraph 4

In this section the DOE concludes that the favorable condition relating to environmental quality standards is present at Yucca Mountain: "...no reason has been identified that would suggest that the Federal, state, and local environmental requirements applying to this project cannot be met..." (page 6-63, last paragraph). With respect to air quality, the DOE has not provided an adequate analysis of available information to substantiate that Federal and state air quality standards are unlikely to be exceeded during repository construction at Yucca Mountain.

According to Table 5-17 in the draft EA the estimated maximum 24-hour total suspended particulate (TSP) levels from repository construction at Yucca Mountain are 130 and 132 $\mu g/m^3$ (exclusive of current background TSP) for ridge and valley locations respectively. These values may exceed the secondary EPA and the Nevada air quality standards when the background TSP levels are added to them. Moreover, the reference upon which the draft EA's values is based states the estimated maximum 24-hour TSP concentrations to be 276 $\mu g/m^3$ (ridge) and 271 $\mu g/m^3$ (valley), both of which exceed the primary and secondary EPA and the Nevada standards (Bowen and Egami, 1983, page 9). No explanation of the discrepancy between the TSP values in the draft EA and in Bowen and Egami (1983) is provided in the draft EA.

It is suggested that the DOE include in the final EA an explanation of how and why the TSP estimates in the reference (Bowen and Egami, 1983) were modified to the levels presented in the draft EA. The DOE should also consider incorporating current background TSP levels into the analysis of TSP levels during repository construction at Yucca Mountain.

6-10

Section 6.2.1.6.3, Mitigation of Water Use Impact, Page 6-64

The document acknowledges that the scarcity of water in the region is of concern. The draft EA does not discuss any special efforts that will be made to minimize water use or to recycle water or otherwise mitigate the effect of

water use. It is suggested that conservation of water be included as an objective in further project planning.

6-11

Section 6.2.1.7.4, Potentially Adverse Conditions, Page 6-82, Paragraph 5

This paragraph provides the evaluation of potentially adverse condition 3 for the guideline on Socioeconomics (10 CFR 960.5-2-6). This adverse condition is on the need for repository-related purchase or acquisition of water rights, if such water rights could have significant adverse impacts on the present or future development of the affected area. Two points pertinent to the finding of the guidelines are as follows:

1. This paragraph indicates that according to preliminary analyses, the repository will require 220,000 m^3 (180 acre-feet) of water per year for 60 years. McBrien and Jones (1984) is used as a reference for this estimate. Review of the report of McBrien and Jones (1984) does not indicate relevant estimates of on-site water use. Only estimates of increased water demand on public utilities or municipalities resulting from increased population are presented. In addition, paragraph 3 on page 5-35 (Section 5.2.2) indicates that the 180 acre-ft/year figure is calculated based on worker consumption only. Therefore, this is an incomplete estimate of the water requirements for all phases of the repository. As examples, omitted are water use estimates for construction (concrete), dust suppression, equipment washdown or possible decontamination.

2. The evaluation concludes that the estimated repository water needs will not result in groundwater withdrawals which would impinge on known water rights and should not affect other water users in the region. Favorable condition 2 in Section 6.3.1.1 is referenced as support. The rationale presented may be speculative. First, favorable condition 2 in Section 6.3.1.1 is related to the nature and rates of hydrologic processes operating within the geologic setting during the Quaternary period and is not relevant to the subject discussion. The appropriate reference is potentially adverse condition 2, which is the presence of groundwater sources, suitable for crop irrigation or human consumption without treatment, along groundwater flow paths from the host rock to the accessible environment. As noted in Table 6-15 (page 6-117) this potentially adverse condition is present at Yucca Mountain although its relevance to the present discussion is not clear because the guideline on socioeconomics (960.5-2-6) and thus the potentially adverse condition on acquisition of water rights is relevant to preclosure only, while evaluations in Section 6.3.1.1 are relevant to postclosure conditions. Second, relative to the statement that no known water rights will be impacted by repository water withdrawals, on page 6-10 (continuing paragraph 1) and page 6-22 (paragraph 4) it is implied that ownership of

water rights other than that held by the DOE on the NTS is not known. Third, relative to the statement that groundwater withdrawals should not affect other water users, there is no information provided in Chapter 3 indicating that any water well inventory was attempted. Therefore, it is not clear just how close to the site some other users may be. While discussions provided in Chapter 5 (Section 5.2.2) and associated references indicate that the general conclusion that no significant lowering of the regional water table is expected is reasonable, albeit qualitative, conclusions based on regional considerations may not be relevant in considering local impacts. Consideration of local users is as relevant as is consideration of major developments or population centers.

In summary, in order to evaluate completely potentially adverse condition 3 for the guideline on socioeconomics (10 CFR 960.5-2-6), Section 6.2.1.7.4 should be revised to: 1. provide a more accurate estimate of repository water use; 2. identify existing off-site water rights; and 3. identify and consider potential effects to local users. In addition, references cited should be corrected as noted above.

6-12

Section 6.2.1.7.5, Disqualifying Condition, Page 6-84, Paragraphs 2 and 3

This disqualifying condition states that a site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures. Pertinent comments are as follows:

1. Competing requirements for groundwater use have been considered in evaluating this disqualifying condition. However, the projected repository water-use estimate is incomplete. Review of the referenced report (McBrien and Jones, 1984) does not indicate any relevant estimates of on-site water use. Only estimates of increased water demand on public utilities or municipalities resulting from increased population are presented. In addition, paragraph 3 on page 5-35 (Section 5.2.2) of the draft EA indicates that the 180 acre-ft/year figure is calculated based on worker consumption only. Therefore, this is an incomplete estimate of the water requirements for all phases of the repository. As examples, omitted are water use estimates for construction (concrete), dust suppression, equipment washdown or possible decontamination operations.

2. This section restates the conclusion that regional effects of withdrawing groundwater for a repository at Yucca Mountain are expected to be negligible (paragraph 2, page 6-84). Based on available information in referenced documents this appears to be a reasonable conclusion from a regional and qualitative context although there is some uncertainty

involved as indicated in Section 6.3.3.3 (paragraph 2, page 6-279). However, it should be noted that this is a qualitative conclusion. The NRC is not aware that any of the regional (Waddell, 1982) or subregional (Czarnecki and Waddell, 1984) models of groundwater flow are being used to predict drawdowns based on estimated repository withdrawals nor are we aware of any simplified analytical calculations of distance-drawdown based on information contained in Young (1972) or Thordarson (1983).

3. No evaluation of drawdown effects on local users is provided. Based on information provided in Chapter 3 it is not clear if there are any local users. However, if there are they would be as important a consideration as major developments or population centers in evaluating this guideline.

In summary, in order to evaluate completely this disqualifying condition, Section 6.2.1.7.5 should be revised to: (1) provide a more accurate estimate of repository water use; and (2) identify and consider potential effects to local water users. Available data would allow at least a simplified quantitative assessment of potential effects to regional and local water users.

6-13

Section 6.2.1.8.2, Data Relevant to the Evaluation, Page 6-91, Paragraph 1 and Section 6.2.1.8.3, Favorable Conditions, Page 6-93, Paragraph 1

The potential for flooding in the Yucca Mountain region is significant because the climatic conditions and topography there favor sudden cloud bursts and the concentration of runoff in arroyos. Because of the flood potential of Fortymile Wash to the east of Yucca Mountain and because of the proposed construction of either a railroad or auto bridge to cross the wash, it is a concern that design specifications for this bridge be evaluated with appropriate flood hazard analyses.

In addition, information presented in Section 6.2.1.8.3 does not consider the potential for damage resulting from flash floods crossing the alluvial fan at the base of Sheep Range and disturbing rail lines. This potential hazard is also not considered in Chapter 5, pages 5-71 and 5-72.

The DOE should consider evaluating flood potential (Squires and Young, 1984) and its effects on engineered structures including proposed railways and bridges in the geologic setting of Yucca Mountain related to the waste repository.

6-14

Section 6.2.1.8.3, Favorable Condition (9), Conclusion, Page 6-98, Paragraph 2

The DOE has not evaluated the transportation route potential disruption outside of Nevada and the routes from the bulk of reactor sites in the U.S., i.e., the midwest and northeast would have to be through the severe winter weather belt (Wyoming, Nebraska, Colorado, etc.), where there could be significant routine winter disruption of transportation through these regions. Only the severe weather conditions in the general region of Yucca Mountain were evaluated by the DOE. It is suggested that the DOE evaluate the potential transportation disruption outside the Nevada area and between the reactor sites and the Yucca Mountain site.

6-15

Section 6.3.1.1.2, Data Relevant to the Evaluation, Page 6-113, Paragraph 3

Emphasis provided in discussions in this paragraph concerning faults is on vertical displacement. However, strike-slip displacement has been observed on a number of historical faults at Yucca Mountain (Stewart, 1980, p. 117; Maldonado and Koether, 1983, p. 45). Without considering horizontal displacement faults, the structural setting of Yucca Mountain cannot be adequately described. The DOE should consider including a discussion of strike-slip (or oblique slip) faults at Yucca Mountain in this section.

6-16

Section 6.3.1.1.2, Data Relevant to the Evaluation, Page 6-113, Paragraph 3

The statement "the attitudes of faults and fractures at depth in drill holes are similar to those on the surface (Maldonado and Koether, 1983; Scott et al., 1983, 1984)." is made in this section. In reviewing the cross sections developed by Scott and Bonk (1984) based on surface mapping and borehole data, it appears that many of these faults are interpreted to change attitude with depth. Granted that it is often very difficult to be certain that a projected surface fault correlates with a borehole fault, the attitudes are different as evidenced by the curved nature of major faults on Scott and Bonk's (1984) cross-sections of Yucca Mountain. This change in attitude may play an important role in predicting radionuclide transportation via ground water, as well as in the constructability of the underground facility and flexibility in its location. It is suggested that the DOE consider indicating the degree of potential dissimilarity between the surface and subsurface fault and fracture attitudes at Yucca Mountain.

6-17

Section 6.3.1.1.2, Data Relevant to the Evaluation, Table 6-15. Summary of Analyses for Section 6.3.1.1, Geohydrology (10 CFR 960.4-2-1), Page 6-115, Condition (i), Second Column

Table 6-15 (pages 6-114 through 6-118) presents a summary of analyses for Section 6.3.1.1. This table presents a DOE finding that the hydraulic conductivity is less that 1 mm/yr in the host rock and surrounding geohydrologic units. This finding is overgeneralized and should be revised. For example, according to Table 3-3 on page 3-29 of the draft EA, the saturated matrix hydraulic conductivity of the Paintbrush nonwelded unit above the Topopah Spring Member is given as 3,300 mm/yr. The saturated matrix hydraulic conductivity of the tuffaceous beds of Calico Hills below the Topopah Spring Member ranges from 3 mm/yr for the zeolitic portion to 1,460 mm/yr for the vitric portion of this unit. Therefore, Table 3-3 indicates that the surrounding geohydrologic units have significantly higher saturated matrix hydraulic conductivities than the host rock (Topopah Spring Member).

6-18

Section 6.3.1.1.2, Data Relevant to the Evaluation, Table 6-15. Summary of Analyses for Section 6.3.1.1, Geohydrology (10 CFR 960.4-2-1), Page 6-115, Condition (ii), Second Column

The statement "Hydraulic conductivity is downward..." should probably read "Hydraulic gradient is downward...".

6-19

Section 6.3.1.1.2, Data Relevant to the Evaluation, Table 6-15, Summary of Analyses for Section 6.3.1.1, Geohydrology (10 CFR 960.4.2.1), Page 6-115, Condition (iv), Second Column

The statement "...hydraulic gradient is low in the tuffaceous beds of Calico Hills" should probably read "...hydraulic conductivity is low in the tuffaceous beds of Calico Hills."

6-20

Section 6.3.1.1.2, Data Relevant to the Evaluation, Page 6-119, Paragraph 2

This section presents a summary of the available data relevant to evaluating conditions of the guideline on Geohydrology (10 CFR 960.4-2-1). As stated in paragraph 2 (page 6-119), "Fracture frequency within the Calico Hills nonwelded unit is much lower than in the overlying Topopah Spring unit and the available

data indicate that porous flow through the matrix, rather than fracture flow, dominates the prevailing flux." Available data are insufficient to conclude that the hypothesis wherein matrix flow dominates the prevailing flux is a conservative hypothesis, particularly in the welded units. Although saturation data from samples of matrix materials suggest that matrix flow dominates over fracture flow the data are insufficient to evaluate adequately the potential for fracture flow in the unsaturated zone.

6-21

Section 6.3.1.1.2, Data Relevant to the Evaluation, Page 6-120, Continuing Paragraph

Blair et al. (1984) is referenced for "porosity values for the tuffaceous beds of Calico Hills"; however, this reference is not listed under References for Chapter 6. This reference should be added.

6-22

Section 6.3.1.1.3, Favorable Conditions, No. 1, Pages 6-120 through 6-121

This section evaluates favorable conditions with respect to the Geohydrology guideline (10 CFR 960.4-2-1). Favorable condition 1 relates to site conditions such that the pre-waste emplacement groundwater travel time along any path of likely radionuclide travel from the disturbed zone to the accessible environment would be more than 10,000 years. The DOE has concluded that this favorable condition is present at Yucca Mountain (page 6-121, paragraph 2).

Available data on groundwater age dates have not been considered in estimating travel times. The report by Thordarson (1983) suggests that the apparent age of ground water derived from carbon-14 age dating at well J-13 is 9,900 years. This apparent groundwater age is not discussed in the draft EA with respect to potential groundwater travel times. Discussions in Section 6.3.1.1.3, 6.3.1.1.5 and 6.3.1.1.6 should be re-evaluated with respect to such data.

Also, paragraph one (page 6-121) describes the hydraulic conductivity measurements from core samples in the unsaturated zone at Yucca Mountain. According to the draft EA, "hydraulic conductivity measurements of core samples from the Topopah Spring welded unit indicate that the average matrix flux may be as low as 0.003 mm/yr (Weeks and Wilson, 1984). Average matrix flux values this low would greatly increase the travel time in the unsaturated zone." According to Weeks and Wilson (1984), the results of their study are preliminary and should be used only as a guide for future studies. The final EA should indicate the preliminary nature of their results.

In addition, the DOE should provide the reference that supports the assumption (page 6-121, paragraph 2), "If the disturbed zone is conservatively extended to the base of the Topopah Spring welded unit." There are no discussions

concerning the anticipated thermal loadings or heat transport in this section. To demonstrate that this assumption is conservative, the rationale on how the disturbed zone was delineated needs to be provided. This rationale should consider other statements in the draft EA such as: 1. "Assuming a gross thermal loading of 57KW/acre, the maximum temperature experienced at 50 m (160 ft) below the repository horizon is predicted to be well below 100° C" (page 6-185) and 2. "Disturbed zone is assumed to be approximately 25 m wide for this calculation" (Table 6-44, footnote d, page 6-319). Therefore, there is no way to evaluate whether this assumption is conservative.

The NRC acknowledges that further clarification of the definition of the disturbed zone is needed, and currently is preparing further technical guidance on the calculation of the disturbed zone.

6-23

Section 6.3.1.1.3, Favorable Conditions, No. 1, Page 6-121, Paragraph 2

This section evaluates favorable conditions with respect to the Geohydrology guideline (10 CFR 960.4-2-1). The detailed analysis supporting the conclusion that favorable condition 1 is present is discussed in Section 6.3.1.1.5 (page 6-135) of the draft EA under the disqualifying condition for the geohydrology guideline. In the NRC's comments on Section 6.3.1.1.5 the NRC has delineated problems with the DOE's calculated minimum travel times. These comments are not repeated here; however, there is one additional consideration that is relevant to the presence or absence of favorable condition 1 but not relevant to the disqualifying condition related to the 1,000 year groundwater travel time. That consideration is the absence of data.

In the calculation of travel times, values of effective porosity are necessary to complete the calculation. In the EA there are no measured effective porosity data presented for either the unsaturated or saturated zones. It is noted on page 6-137 that "in the absence of data on tuffs from Yucca Mountain, data from pumping tests were used to estimate upper and lower bounds of .005 and .002 for effective porosity." Because no reference is provided for this estimate, effective porosity values for the saturated zone must be assumed to be estimates derived from professional judgment. In addition, there is no clear reference provided for the origin of effective porosity values for the unsaturated zone which are presented in Table 6-17 (page 6-139). Estimates of effective porosity for the Calico Hills nonwelded unit are presented on page 18 of Montazer and Wilson (1984). These estimates appear to be primarily judgemental. No estimates of effective porosity for other geologic units in the unsaturated zone were noted in Montazer and Wilson (1984). The basis for the effective porosity value assigned to the Topopah Spring welded unit (.1 as noted in Table 6-17 on page 6-139) is not presented.

Based on the evidence presented it appears that there are no measured effective porosity data available for either the unsaturated or saturated zone. Values

presented are based on professional judgment. It would appear that bounding estimates of effective porosity, based on professional judgment, would allow for effective porosity to vary by at least one order of magnitude across the site. This was not considered, thus upper and lower bounds of effective porosity in the unsaturated zone are not integrated into the quantitative analysis for this favorable condition. Therefore, there is no way to determine that these values are conservative. In addition, data developed to date for the unsaturated zone does not ensure that only matrix flow occurs, or that flux may not exceed the 1 mm/yr assumed in the draft EA. It is acknowledged in the draft EA that all data currently available permit that only conceptual models be postulated and that the favored conceptual model (Montazer and Wilson, 1984) has not been confirmed by field data, especially with respect to a capillary barrier hypothesis and the absence of significant fracture flow hypothesis described in the draft EA.

The basis for evaluating favorable and potentially adverse conditions requires that conservative assumptions be made and that in the absence of data no credit be taken (Section 6.1.2, pages 6-3 and 6-4). The DOE's conclusion that this favorable condition is present appears inconsistent with that approach.

6-24

Section 6.3.1.1.3, Favorable Conditions, No. 2, Page 6-122, Paragraph 1

The conclusion stated in this paragraph that the nature and rate of Quaternary processes if continued into the future would affect, but not significantly reduce, the ability of the geologic repository to isolate radioactive waste during the next 100,000 years is questionable.

The discussion recognizes the potential for shortened travel times due to increased water levels in the unsaturated zone but does not discuss the effects of increased flux due to increased precipitation/recharge as noted in a report by Czarnecki (1984). More importantly, the evaluation does not discuss what is assumed to be the key factor in the conclusion that such processes, if continued into the future, would not significantly reduce the isolation capability of the repository. That factor is geochemical retardation. In this evaluation as well as evaluations of site conditions on future changes in hydrologic processes and climatic changes the point is made clearly that the principal changes throughout the Quaternary pluvial periods included increased recharge, rising water table, increasing gradients and upgradient movement of groundwater discharge areas. In addition, it is concluded that pluvial conditions are likely to return, yet the DOE concludes that radionuclide transport will not be significantly affected. What is not discussed clearly in these evaluations is that the bounding studies by Sinnock et al. (1984) require a significant amount of credit for geochemical retardation in order to meet EPA release limits under a pluvial type scenario. This should be discussed explicitly in these evaluations.

6-25

Section 6.3.1.1.3, Favorable Conditions, No. 3, Page 6-123, Continuing Paragraph

This paragraph provides an evaluation of favorable condition 3 for the guideline on Geohydrology (10 CFR 960.4-2-1). From a hydrogeologic viewpoint, the statement, "...major surface structural features can be used to characterize the subsurface stratigraphy and geologic structures..." is unsupported and may lead to erroneous conclusions. As an example of how surface structural mapping was not reflected in the subsurface, consider USW G-4 which intercepted fault zones that were not predicted by Scott and Bonk (1984). This information, combined with the fact that large portions of the site have no subsurface information, would indicate the potential for other unidentified subsurface fault zones. This may impact downward flow of water.

6-26

Section 6.3.1.1.3, Favorable Conditions, No. 3, Page, 6-123 Paragraph 3, through Page 6-124, Paragraph 1

This section provides an evaluation of favorable condition 3 for the guideline on Geohydrology (10 CFR 960.4-2-1). The initial step in hydrologic modeling is the development of a conceptual model. This conceptual understanding provides a basis for the construction of a numerical or quantitative evaluation needed for travel time estimates. The technical discussions on these pages assume that the conceptual models developed for the Yucca Mountain system are representative of this hydrologic system. Detailed studies and testing of conceptual models have not been reported to date. Caution should be used in the application of quantitative tools for establishing confidence about conditions of the hydrologic system. That is, before "conservative properties" and "statistical sampling" are used, the applicability of the conceptual model of variably-saturated flow occurring only in the matrix of the fractured system needs to be demonstrated.

6-27

Section 6.3.1.1.3, Favorable Conditions, No. 3, Page 6-124, Continuing Paragraph

This section provides the evaluation of favorable condition 3 for the guideline on Geohydrology (10 CFR 960.4-2-1). The described statistical methods approach to the development of uncertainty estimates in data and models requires that field exploration and testing programs have collected representative subsets of the population for each parameter. Thus, the development of a "probability distribution for net flow conditions" by statistically sampling the expected distribution of values for a given hydraulic property is not useful unless the

compiled data are representative of the hydrologic system. It will be necesssary to substantiate that the sampling program will collect sufficient and representative data to be statistically correct. This is particularly important: (1) if the conceptual model guiding data collection changes significantly during site characterization; and (2) to be able to model the site with reasonable certainty. Well founded statistical applications must be based upon proper sampling design in order to characterize a given hydrologic property such as effective porosity.

6-28

Section 6.3.1.1.3, Favorable Conditions, No. 5(i), Page 6-126, Continuing Paragraph

This section provides the evaluation of favorable condition 5 (i) for the guideline on geohydrology (10 CFR 960.4-2-1). There are alternative interpretations for the wide variability in percent saturation values to that presented in this section.

The variation of saturation (40% to 90%) which has been measured in the Topopah Spring Member is discussed in this section. It is stated that "the wide variability in the percent saturation values is due mainly to the low porosity and permeability of the matrix of the Topopah Spring welded unit." An alternative explanation is that there are variations in pore size which produce variations in degree of saturation under steady downward flow. Capillary pressure or water tension must be a continuous function, but degree of saturation can vary in space under changes of pore size. Another alternative interpretation is that flow through the fractures distributes water non-uniformly to the porous matrix. Alternative explanations for the variability in saturation should be incorporated into the discussion in this section.

6-29

Section 6.3.1.1.3, Favorable Conditions, No. 5(i), Page 6-126, Continuing Paragraph

This section provides the evaluation of favorable condition 5 (i) for the guideline on geohydrology (10 CFR 960.4-2-1). The DOE's conclusion that evidence from paleohydrologic investigations indicates probable low and relatively long-term constancy of flux, thereby resulting in constancy of saturation over time, is questionable.

Paleohydrologic investigations (Section 6.3.1.4) indicate increased precipitation in late Wisconsin time. Other discussions in the draft EA indicate potential for near-term increases in summer precipitation as well as a potential for a pluvial period in 10,000 years. Therefore, it is unlikely that

a long-term constancy of flux, and thus a constancy of saturation would occur over time. In addition, long-term changes in climate and recharge are not relevant to this favorable condition. What is pertinent to this favorable condition is the constancy of saturation with respect to existing conditions (this is a pre-waste emplacement condition). Because no data on change in degree of saturation (temporal variation, not spatial variation) in response to recharge events are presented, the DOE's conclusion that this favorable condition should not be considered present is correct. If time variant data on degree of saturation are available they should be presented in the evaluation of this favorable condition. The discussion on paleohydrology and the inferred impact on saturation should be revised.

6-30

Section 6.3.1.1.3, Favorable Conditions, No. 5(iii), Page 6-126, Paragraph 2

This section provides the evaluation of favorable condition 5 (iii) for the guideline on geohydrology (10 CFR 960.4-2-1). The statement in this section which indicates that no evidence of fracture flow has been observed in the host rock is questionable.

The statement "no evidence of fracture flow has been observed in the host rock" appears to contradict observations in well USW H-1 by Rush et al. (1984) where it is reported from down-hole, television camera observations in the Topopoah Spring Member that fractures seep water, as well as past DOE/NRC discussions which indicate there was free-standing water in the bottom of test hole UZ-1. Previous discussions have suggested that these waters originated from drilling fluids; however, it has not been demonstrated that this is the case. Regardless of the source of these waters, the test hole camera logs and observed drilling conditions indicate fracture flow has been observed. This evidence should be discussed relative to fracture flow.

6-31

Section 6.3.1.1.3, Favorable Conditions, No. 5(iii), Page 6-126

This section evaluates favorable conditions with respect to the geohydrology guideline (10 CFR 960.4-2-1). Favorable condition 5 (iii) relates to a geohydrologic unit above the host rock that would divert the downward infiltration of water beyond the limits of the emplaced waste. The DOE has concluded that this favorable condition is present at Yucca Mountain (page 6-130, paragraph 2).

The DOE's conclusion is not supported adequately by information presented in the draft EA. Data used by the DOE to support its conclusion may also be interpreted reasonably to support alternative hypotheses of water migration through the unsaturated zone which are contrary to the DOE's conclusion.

In support of the conclusion that the Paintbrush non-welded unit would divert infiltration, the DOE presents four interrelated factors. These are: 1) that a permeability contrast exists between the upper boundary of the Paintbrush non-welded unit and the overlying Tiva Canyon welded unit; 2) that air trapped in the Paintbrush non-welded unit would result in decreased permeability; 3) that a capillary barrier exists between the pores of the Paintbrush non-welded unit and the fractures of the underlying Topopah Spring welded unit (the host rock); and 4) that a permeability barrier exists consisting of the low permeability matrix of the Topopah Spring welded unit.

The DOE presents data in the draft EA which support a permeability contrast between the fractures of the Tiva Canyon welded unit and the matrix of the Paintbrush non-welded unit. General theory accepts that entrapped air reduces permeability. However, there is no technical basis to support the DOE's hypothesis on how these two factors functionally interact at Yucca Mountain. Specifically, the DOE's hypothesis that these two factors combine to cause recharge from intense and short-lived events to move laterally, down dip, at the Tiva Canyon/Paintbrush contact resulting in a diversion of infiltration away from emplaced wastes is questionable for the following reasons:

A. As saturation increases above the entrapped air there would be a tendency for lateral movement of water toward areas of lower saturation. Prior to saturation, this movement would be driven by capillary forces. Such a condition would be short-lived in nature (until entrapped air is dissolved or displaced). To assume capillary-driven flow over any significant distance does not appear to be reasonable. No observations of this phenomenon occurring at the site are presented to verify the hypothesis.

B. There are no data presented in the draft EA which indicate saturated conditions have been observed at the Tiva Canyon/Paintbrush non-welded unit contact. Therefore, there is no basis for assuming either significant horizontal head gradients in the Paintbrush non-welded unit or that significant lateral flow occurs. However, the DOE concludes that flow would be downward when saturation occurs.

C. Existing data on known faults such as the Ghost Dance Fault and other possible subsurface fault zones within the primary repository area indicate that there are potential conduits for downward flow, making the assumption of lateral flow beyond the repository area unwarranted.

The DOE's hypothesis that factors 3 and 4 functionally interact to retard downward flow into the host rock is questionable for the following reasons:

A. There is no direct evidence indicating that the capillary barrier is functioning. Specifically, theoretical considerations indicate that a condition of steady state or equilibrium at the Paintbrush/Topopah interface would be characterized by pressure continuity at the interface, constant vertical Darcy velocity (flux) above and below the interface, and different moisture contents above and below the interface (Bear, 1972;

Corey, 1977). No evidence for perched water at this contact is discussed or presented in the draft EA, so there is no reason to assume that significant lateral flow is occurring within the Paintbrush non-welded unit. Montazer and Wilson (1984) describe the Paintbrush only as "moderately saturated". In addition, for this hypothesis to be operative it would have been necessary for excess recharge (above 1 mm/yr) to have been "stored" or moved laterally within Tiva Canyon and/or Paintbrush units for, presumably, the last thousands or tens of thousands years. As noted previously, no data are available which indicates this has happened. However, if such conditions did exist the vertical hydraulic gradient across the Paintbrush/Topopah contact would exceed unity allowing flux in excess of the saturated matrix hydraulic conductivity of the Topopah to pass through the Topopah, possibly including fracture flow. This would make the capillary barrier ineffective. Therefore, the capillary barrier does not appear to either cause lateral flow or limit downward flow on the basis of available data.

B. Lack of available data limits the acceptability of the capillary barrier hypothesis. Because there are no data presented on the pore size/fracture aperture relationships between the non-welded Paintbrush and Topopah Spring welded units, the assumption that water from the pores of the Paintbrush tuff will not enter the fractures of the Topopah Spring unit is questionable and may not be warranted. The amount of flux at which fracture flow begins is not known.

C. Uncertainty in available data limits the acceptability of the permeability barrier hypothesis. The DOE assumes that the flux passing through the Paintbrush/Topopah Spring contact will be limited to an amount equal to or less than the saturated hydraulic conductivity of the matrix of the Topopah Spring unit which is given as 1 mm/yr. The 1 mm/yr value is the geometric mean of measurements of the saturated hydraulic conductivity. Measurements that are two orders of magnitude higher have been obtained (Montazer and Wilson, 1984). Consideration of this heterogeneity would support spatial variation in fluxes through the matrix of the Topopah. Therefore, it would not seem appropriate to assume that the flux through the matrix of the Topopah is limited to a "maximum" of 1 mm/yr. In this case the flux would be continuous across the contact in the matrix and the permeability barrier would not be operative.

6-32

Section 6.3.1.1.3, Favorable Conditions, Table 6-16, Page 6-128

This section discusses the percolation of water down through the Paintbrush nonwelded unit into the Topopah Spring unit. Table 6-16 (page 6-128) presents a dual classification of Tertiary volcanic rocks at Yucca Mountain. An error occurs under the heading "comments" pertaining to the tuffaceous beds of the Calico Hills, Prow Pass and Bullfrog members of the Crater Flat Tuff.

According to the table, the bulk hydraulic conductivity of the tuffaceous beds of the Calico Hills, Prow Pass and Bullfrog members in the saturated zone was determined from pumping tests to be about 0.2 m/day (3 mm/yr). The conversion of 0.2 m/day to 3mm/yr is an error. The 3 mm/yr should be 73,000 mm/yr. This section should be revised accordingly. Also, a reference for the origin of the .2 m/day hydraulic conductivity value should be provided.

6-33

Section 6.3.1.1.3, Favorable Conditions, Table 6-16, Page 6-128

See detailed comment 3-12.

6-34

Section 6.3.1.1.3, Favorable Conditions, No. 5 (iii), Page 6-129, Paragraph 1

The statement "...because the pulse of water would trap air in the upper part of the nonwelded unit, thereby decreasing the permeability significantly" should probably read "...because the pulse of water would trap air in the upper part of the nonwelded unit, thereby decreasing the relative permeability to water significantly."

6-35

Section 6.3.1.1.3, Favorable Conditions, No.5 (iii), Page 6-129, Paragraph 1

It is possible the the statement "...or until saturated conditions developed within the welded unit" should read "...or until saturated conditions developed within the nonwelded unit." Both the sentence just quoted and the following two sentences in page 6-129, paragraph one, are not clear relative to intended meaning. The discussion is on the "upper" barrier and immediately shifts to a conclusion about the "lower" barrier. In addition, these sentences can be interpreted in more than one way. Because these sentences are important to understanding the hypothesis being presented they should be clarified.

6-36

Section 6.3.1.1.3, Favorable Conditions, No. 5 (iv), Evaluation for Free Drainage, Page 6-129, Paragraph 2

This section evaluates favorable condition 5 (iv) of the geohydrology guideline (10 CFR 960.4-2-1). This favorable condition relates to a host rock that provides for free drainage. The discussion in this paragraph cannot be evaluated because it is based on rock-mass permeabilities to air (Montazer and Wilson, 1984). The inference is made that the air permeabilities are representative of the fractures. Without a discussion related to the details

of the testing method, it is not possible to evaluate independently the validity of these permeabilities. For example, the permeabilities could be actually representative of the matrix instead of the fractures.

6-37

Section 6.3.1.1.3, Favorable Conditions, No. 5 (iv), Evaluation For Free Drainage, Page 6-129, Paragraph 2

This section evaluates favorable condition 5 (iv) of the geohydrology guideline (10 CFR 960.4-2-1). This favorable condition relates to a host rock that provides for free drainage. The DOE has concluded that this favorable condition is present at Yucca Mountain. Assuming "free-drainage" means the absence of saturated conditions, the DOE has not considered data which indicate that the condition of free drainage within the host rock might not be present.

Observations in well USW H-1 (Rush et al., 1984) from down-hole television camera observations in the Topopah Spring member indicate that fractures seep water. In addition, past discussions between the DOE and the NRC conveyed the impression that there was free-standing water observed in the bottom of test hole UZ-1. The NRC is not aware of any definitive analyses delineating the source of these waters although it has been suggested that they originated from drilling fluids. However, this has not been clearly demonstrated. An alternative explanation is that the water is naturally occurring and is either held or migrating within the fracture system of the unsaturated zone. If this is true, it is evidence of localized perched water. However, regardless of the origin of the water these observations demonstrate that "perched" water can be present in at least localized areas of the Topopah Spring Member for an uncertain period of time.

6-38

Section 6.3.1.1.4, Potentially Adverse Conditions, No. 1, Page 6-131, Paragraph 4

This section evaluates Potentially Adverse Condition 1 of the geohydrology guideline (10 CFR 960.4-2-1). This potentially adverse condition relates to expected changes in geohydrologic conditions sufficient to significantly increase the transport of radionuclides to the accessible environment as compared with pre-waste-emplacement conditions. The DOE has concluded that this potentially adverse condition is not present at Yucca Mountain. It is implicit in the DOE's conclusion, as evidenced in a report by Sinnock et al. (1984), that credit for geochemical retardation is necessary in order to meet EPA radionuclide release rates under a scenario of "expected changes". Evidence presented indicates that increased recharge rates, elevated water levels and decreased travel times are anticipated during a pluvial period whose occurrence in the next 10,000 years is plausible. In this evaluation the DOE

has not considered data which could impact significantly the effectiveness of geochemical retardation.

The paragraph states that "The geochemical barrier provided by the Calico Hills...would retard the transportation of radionuclides." This geochemical barrier concept assumes that retardation of radionuclides would occur through the presence of zeolitized zones in the Calico Hills. Geologic logs for test holes USW G-3, H-3, and H-5 do not exhibit the presence of zeolitized zones in the Calico Hills Unit. The areal distribution of the zeolitic facies is shown to be absent in the southern portions of the repository block (Montazer and Wilson, 1984). Thus, the effectiveness of this "geochemical barrier" for retardation of radionuclides may be reduced in selected areas underneath the repository horizon.

6-39

Section 6.3.1.1.4, Potentially Adverse Conditions, No. 1, Page 6-131, Paragraph 4

This section discusses the effects of an increase in the recharge rate on the elevation of the water table beneath Yucca Mountain. According to the draft EA, "the maximum amount of water table rise during a major pluvial is estimated to be 130 m (7,700 ft) (Section 6.3.1.4)." This is an error in the conversion from 130 m to 7,700 ft. The 7,700 ft in this sentence should be 426 ft.

6-40

Section 6.3.1.1.4, Potentially Adverse Conditions, No. 1, Page 6-132, Paragraph 1

This section evaluates Potentially Adverse Condition 1 of the geohydrology guideline (10 CFR 960.4-2-1). The DOE's evaluation of potential, shortened flow paths to the accessible environment as a result of future increased recharge rates is not complete relative to potential scenarios and available data. Some assumptions appear to be inconsistent relative to assumptions in other sections of the draft EA.

As stated in this paragraph, "no evidence of modern or Quaternary springs or seeps has been found. Water from any future springs or seeps that might develop on the flanks of Yucca Mountain during periods of increased recharge would not pass through the repository, because the flow would be perched and the repository would be at a lower elevation than such springs. Water moving through the repository would enter the saturated groundwater system locally and travel toward the regional discharge areas." What has not been considered in this evaluation includes:

1. Perching of water at the Tiva Canyon/Paintbrush contact or at the Paintbrush/Topopah Spring contact is only an assumption at this time. In a subsequent section of the draft EA (Section 6.3.1.4.3, page 6-198) it is assumed that perching of water is unlikely because fracture and matrix permeability generally is high enough to transmit water at the postulated much higher fluxes of pluvial times. These assumptions do not appear to be consistent.

2. As noted in previous comments, evidence exists which questions the assumption that perching of groundwater within the Topopah Spring Member would not occur. This assumption is implicit in the DOE's evaluation. Such perching could initiate a flow path that would pass through the repository to newly developed seeps or springs.

3. While discussing water which then enters the saturated groundwater system, the DOE indicates that the flow path would then be toward regional discharge areas. While this appears correct, the evaluation fails to consider the upgradient migration of these regional discharge areas as a result of increased recharge.

4. While there may be no evidence of springs or seeps on the flanks of Yucca Mountain there appears to be evidence of travertine and opal along alluvial fault traces in trenches adjacent to Yucca Mountain (NRC trip report, Rice, 12/28/84). This information needs to be considered relative to the potential for future groundwater discharge. Considerations should not be limited to the "flanks" of Yucca Mountain.

The points outlined in this comment should be considered before any final conclusion on the presence or absence of Potentially Adverse Condition 1 is made.

6-41

Section 6.3.1.1.4, Potentially Adverse Conditions, No. 1, Page 6-133, Paragraph 1

This section evaluates potentially adverse condition 1 of the geohydrology guideline (10 CFR 960.4-2-1). There are no data presented to support the DOE's conclusion that any future decrease in effective porosity by precipitation of minerals in the fractures would be more than offset by increased sorption.

This paragraph discusses the potential effects of variations in effective porosity. According to the draft EA, "in the saturated zone, effective porosity could increase by fracture formation or decrease by mineral precipitation. Retardation within the saturated zone probably would be minimally affected. On the other hand, a decrease in effective porosity by the precipitation of minerals in the fractures would be more than offset by

increased sorption; fracture coatings (zeolites, smectites, manganese oxides) have very reactive surfaces that greatly increase retardation." Data in support of the conclusion that a decrease in effective porosity would be more than offset by increased sorption are critical because the data are needed to evaluate potential changes in radionuclide release rates to the accessible environment. Data in support of the subject conclusion should be presented in the final EA.

6-42

Section 6.3.1.1.4, Potentially Adverse Conditions, No. 1, Page 6-133, Paragraph 2

This section evaluates Potentially Adverse Condition 1 of the Geohydrology Guideline (10 CFR 960.4-2-1). The DOE has concluded that this condition is not present at Yucca Mountain. Paleoclimatic and paleohydrologic evidence does not support that conclusion.

The DOE's conclusion with respect to this condition is summarized in Table 6-15 (page 6-117) wherein it is stated that "pluvial conditions in the future are not expected to cause (a) significant increase in transport of radionuclides." This conclusion is questionable based on the following:

Work by Spaulding et al. (1984) on climate change during late Wisconsin time indicates that a return to pluvial climates could result in an increase in average annual precipitation by as much as 40 percent. Statements in the draft EA indicate that "in the near future Yucca Mountain might experience summer temperatures at least 3°C (5°F) higher and summer rainfall not more than 50 percent higher than today's value" (Section 6.3.1.4.4., page 6-201, last paragraph). In addition, a scenario is discussed by which pluvial conditions could occur in approximately 10,000 years. Preliminary work by Czarnecki (1984) indicates that if precipitation increased by 100 percent, recharge would increase by an average of 13.7 times the presently estimated recharge. It can be reasoned that even if Czarnecki had simulated a scenario where precipitation increased by only 40 to 50 percent, recharge would still increase by a significant multiple. Based on assumptions implicit in the conceptual model of the unsaturated zone presented in the draft EA, such an increase in recharge would result in fracture flow in the unsaturated zone which would significantly reduce travel times through the unsaturated zone. As noted in Sinnock et al. (1984, page 130), an increase in recharge beyond the capacity of the matrix would result in an abrupt transition between matrix and fracture flow wherein flow times to the water table "discontinuously change from tens of thousands of years for matrix flow to tens of years for fracture flow." The preliminary work by Czarnecki (1984) also indicates that a 100 percent increase in precipitation would result in a rise in the water table as much as 130 meters, again reducing travel times through the unsaturated zone.

Based on preliminary work by Spaulding et al. (1984) and Czarnecki (1984) as well as discussions in the draft EA mentioned previously, a scenario in which precipitation increases resulting in an increase in recharge rates appears to be a plausible scenario. Although these studies are preliminary and should be subject to additional investigation due to the complexities and difficulties in assessing evidence of paleoclimatic and paleohydrologic processes, nevertheless they demonstrate the importance and potential magnitude of a pluvial impact on repository performance. Therefore, it seems appropriate to conclude that under such a scenario groundwater velocities would increase significantly over pre-waste-emplacement conditions with a potential concomitant impact on rate of sorption of radionuclides. Apparently, the conclusion made in the draft EA that no changes in geohydrologic conditions are expected that would significantly increase the transport of radionuclides to the accessible environment as compared with pre-waste-emplacement conditions is based implicitly on geochemical retardation. Clearly, bounding estimates of radionuclide releases provided in Sinnock et al. (1984) rely explicitly on geochemical retardation rather than travel times in order to meet EPA release rates under a scenario of increased recharge resulting in fracture flow. Review of site geochemistry indicates that this reliance on geochemical retardation under this scenario may not be warranted. (See geochemistry detailed comments 6-57, 6-58, 6-60, 6-61, and 6-69).

6-43

<u>Section 6.3.1.1.5, Disqualifying Condition (Infiltration-Percolation-Recharge), Page 6-136, Paragraphs 1 and 2</u>

This section discusses the movement of water through the unsaturated zone. According to the draft EA, "the study of water movement through the unsaturated zone requires the values of the percolation rate. At Yucca Mountain, the expected value for the percolation rate through the host rock is less than 1 mm/yr, probably less than 0.2 mm/yr (Weeks and Wilson, 1984)." According to Weeks and Wilson (1984), the results of their study are preliminary and should be used only as a guide for future studies. The uncertainty in this estimate should be clarified.

6-44

<u>Section 6.3.1.1.5, Disqualifying Condition (Infiltration-Percolation-Recharge), Page 6-136, Paragraph 3</u>

This section describes evidence for a low flux rate through the host rock. According to the draft EA, "the most direct evidence for low flux through the host rock is provided by preliminary data from borehole USW UZ-1 (personal communication from P. Montazer, USGS, 1984)." According to the draft EA, "the matric potential of the rock matrix indicated by the measurements would be

sufficient over a long period of time to pull any water into the matrix. As a result, fracture flow is not likely because water moving through fractures could travel only a few tens of meters at most before being drawn into the matrix by the high matric potential. This reasoning strongly indicates that very little, if any, water is moving through the fractures and that matrix flow dominates the water movement." According to the draft EA, data for borehole USW UZ-1 are preliminary. All conclusions based on preliminary data should be labeled preliminary conclusions. The statement in the draft EA that "this reasoning strongly indicates that very little, if any, water is moving through the fractures and that matrix flow dominates the water movement" is too definitive. Reasoning may suggest that very little, if any, water is moving through the fractures and that matrix flow dominates the water movement; however, reasoning alone (without data) cannot be relied upon for that conclusion. Very few data are available with respect to the characteristics of unsaturated flow through fractures in welded tuff. The saturation level at which water movement through fractures begins has not been documented. The effect of potential fracture coatings has not been considered. This section should be revised to more accurately convey the uncertainty associated with such conclusions.

6-45

Section 6.3.1.1.5, Disqualifying Condition (Infiltration-Percolation-Recharge), Page 6-136, Paragraph 4

This section provides the evaluation for the disqualifying condition of the Geohydrology Guideline (10 CFR 960.4-2-1). The estimate of downward groundwater flux through the unsaturated zone used in travel time calculations may not be conservative. Variability in the limited data base would allow a higher flux estimate to be used.

Estimates for the vertical matrix flux (assuming no fracture flow) through the host rock range from a low value of .003 mm/yr (Weeks and Wilson, 1984) to a high of 10 mm/yr (Sass and Lachenbruch, 1982). According to Montazer and Wilson (1984) data from borehole UZ-1 show a negative (upward) flux of approximately 1 to 2 mm/yr in the Topopah Spring Member. They also estimated the downward vertical flux through the Topopah Spring Member to be 1 mm/yr based on the geometric mean (about 1 mm/yr) of saturated matrix hydraulic conductivity measurements on core samples assuming a hydraulic gradient of one. Based on this information the DOE has concluded that for the purposes of their quantitative analyses, the "maximum" downward flux through the host rock is 1 mm/yr. However, Montazer and Wilson (1984) indicate that the measured saturated matrix hydraulic conductivity of two samples was two orders of magnitude greater than the geometric mean. If the downward flux through the host rock (Topopah Spring member) is limited to an amount equal to the saturated matrix hydraulic conductivity, then this range of values suggests that the assumed flux of 1 mm/yr may not be a conservative estimate.

Additional uncertainty on the estimated flux under present climatic conditions is introduced by recharge estimates of 4.5 mm/yr (Rush, 1970) to 5 mm/yr (Waddell et al., 1984). These estimates of recharge are inconsistent with the estimated 1 mm/yr matrix flux. Given that there is no evidence of spring-discharge points along the outcrop of the contact between the Paintbrush nonwelded unit and the Tiva Canyon welded unit which indicates, according to Montazer and Wilson (1984), lack of an extensive perched groundwater system in these two units, it is questionable whether any significant "diversion" of recharge occurs. The very nature of the "capillary barrier" requires that if recharge is greater than the saturated hydraulic conductivity of a lower unit the degree of saturation in the upper unit must increase until either complete saturation occurs or the saturation has increased to the point where the entire recharge is passed downward. Given that the water content of the Paintbrush non-welded unit is very large and the unit is moderately saturated (Montazer and Wilson, 1984) as well as the fact that little or nothing is known about the pore size/fracture aperture relationship between the Paintbrush non-welded/Topopah Spring welded units it could be argued that the entire recharge estimate of 4.5 to 5 mm/yr is a conservative estimate of flux through the host rock. If the saturated matrix conductivity of the Topopah Spring is limited to a maximum of 1 mm/yr as the DOE indicates, then the flux could pass through the host rock as fracture flow.

Given the uncertainties discussed above, it is questionable whether the estimated 1 mm/yr flux through the host rock is either a "maximum" or "conservative" estimate. Very few data are available with respect to the characteristics of unsaturated flow through fractures in welded tuff. The saturation level at which water movement through fractures begins has not been documented. This section should be revised to more accurately convey the uncertainty associated with this estimate of flux.

6-46

Section 6.3.1.1.5, Disqualifying Condition (Infiltration-Percolation-Recharge), Page 6-136, Paragraph 4

This section discusses the amount of flux moving through the matrix in the unsaturated zone. According to the draft EA, "the saturated matrix hydraulic conductivities of both the Topopah Spring welded unit and the zeolitic portion of the Calico Hills nonwelded unit are about 1 mm/yr (personal communication from P. Montazer, USGS, 1984). These values set an upper limit on the amount of flux moving through the matrix in the unsaturated portions of these units, where the hydraulic gradient is unity." The value of saturated matrix hydraulic conductivity given for the zeolitic portion of the Calico Hills nonwelded unit (1 mm/yr) is inconsistent with the value presented in Table 6-16. Table 6-16 on page 6-128 and paragraph 2 on page 6-137 indicate that the saturated matrix hydraulic conductivity of the Calico Hills is 3 mm/yr rather than 1 mm/yr as mentioned above. This inconsistency should be corrected.

6-47

Section 6.3.1.1.5, Disqualifying Condition (Travel Time Calculations), Page 6-137, Paragraph 3

This section provides the quantitative analysis for the evaluation of the disqualifying condition of the geohydrology guideline (10 CFR 960.4-2-1). The average saturated hydraulic conductivity for the tuffaceous beds of the Calico Hills presented in the draft EA appears to have been averaged incorrectly.

The DOE states that "the average saturated hydraulic conductivity (k_s) for the tuffaceous beds of the Calico Hills is assumed to be 5.8 X 10^4 mm/yr..., using values for bulk conductivity of .24 m/day... from UE-25b#1...(Lahoud et al., 1984) and 0.06 m/day ... from well J-13 (Thordarson, 1983)." However, Lahoud et al. (1984, page 39) report an average hydraulic conductivity of .26 m/day rather than .24 m/day for the rhyolitic tuffs of the Calico Hills. In addition, Thordarson (1983, page 23) reports 3 different values of hydraulic conductivity for just the tuffaceous beds of the Calico Hills (.094, .13, and .15 m/day). Therefore, the average of the range in Thordarson's values is .12 m/day, not 0.06 m/day as stated in the draft EA. Apparently, the DOE has incorporated values obtained from hydraulic tests which tested both the Calico Hills and Prow Pass Member (i.e., packers straddled portions of both units) into the average figure. The range in value of the saturated hydraulic conductivity for the tuffaceous beds of the Calico Hills should be based on tests run only in that specific unit. This value should be corrected and the travel time estimate through the Calico Hills segment of the saturated flow path revised. The effect of this change will be to reduce travel time through this segment of the flow path.

In addition, the rationale underlying the stated assumption that the hydraulic conductivity of the Paintbrush Tuff and welded Crater Flat Tuff is about 3.65 x 10^5 mm/yr should be delineated. It is not clear how this figure was derived or why this figure should be considered conservative.

6-48

Section 6.3.1.1.5, Disqualifying Condition (Travel-Time Calculations), Page 6-137 to 6-140

This section provides the quantitative analysis for the evaluation of the disqualifying condition of the geohydrology guideline (10 CFR 960.4-2-1). The estimates of effective porosity used in travel time calculations may not be conservative.

Estimates of effective porosity appear to be based on inductive reasoning or professional judgment rather than any on-site measurements or previous measurements in analogous environments. For example, in Table 6-17 (page 6-139) an effective porosity of .1 is assigned to the Topopah Spring welded

unit. No reference is given for this estimate. Also, in Table 6-17 an effective porosity of .2 is assigned to both the zeolitic and vitric portions of the Calico HIlls nonwelded units. Again, no reference is established for these estimates. Montazer and Wilson (1984) discuss a potential range of effective porosity from .016 to .232 for the Calico Hills non-welded unit. These values apparently were arrived at inductively and thus are speculative. However, no rationale is provided in the draft EA explaining why the chosen value of .2 represents a conservative value of the range of .016 to .232. Table 6-17 also provides estimates of effective porosity for saturated zone units. In this case the text indicates that data from oumping tests were used to estimate upper and lower bounds of .005 and .002 for effective porosity although there is no reference or rationale indicating the method by which these values were derived.

Because estimates of effective porosity are hypothetical and not supported by any real measurements these estimates may not be conservative. In addition, no attempt has been made to bound these estimates and thereby allow some indication that an appropriate lower bound of travel time through the unsaturated zone was provided. A conservative approach warrants that ranges of values be considered in flow velocity calculations to provide a more accurate representation of travel times likely to be encountered at the site. This section should be revised to more accurately convey the uncertainty associated with effective porosity estimates. The conclusion that the case presented is conservative needs to be re-evaluated.

6-49

Section 6.3.1.1.5, Disqualifying Condition (Travel Time Calculations), Pages 6-137 through 6-140

This section provides the quantitative analysis for the evaluation of the disqualifying condition of the geohydrology guideline (10 CFR 960.4-2-1). The use of mean values of hydraulic conductivity in travel time calculations may not represent a conservative approach.

Throughout this section of the draft EA, the DOE has provided mean values of the hydraulic conductivity for each of the hydrogeologic units along the interpreted flow path to the accessible environment. These mean values are then used in the travel time calculations. Use of mean values only does not reflect the possible heterogeneity of these units or the uncertainty associated with the available data base. Consideration of all available data in estimating input parameters to the flow velocity calculations for each hydrogeologic unit is important to site evaluation. A conservative approach warrants that ranges of values be considered in flow velocity calculations to provide a more accurate representation of travel times likely to be encountered at the site. This is important at Yucca Mountain because the flux term used in travel time calculations is based inductively on the mean saturated matrix hydraulic conductivity of the Topopah Spring Member coupled with a "capillary"

and permeability barrier hypothesis rather than on existing estimates of precipitation/recharge. Therefore, just as the use of mean values of hydraulic conductivity does not reflect heterogeneity of individual units neither does the assumed value of flux reflect the possible heterogeneity of flux across the site. This approach compounds the uncertainty associated with travel time calculations at this site.

6-50

Section 6.3.1.1.5, Disqualifying Condition (Travel Time Calculations), Pages 6-137 through 6-140

This section provides the quantitative analysis for the evaluation of the disqualifying condition of the geohydrology guideline (10 CFR 960.4-2-1). It appears that the DOE has not accounted for the degree of saturation in calculations of travel time through the unsaturated zone.

The expression used to calculate linear water-particle velocity in this section is given as

$$v_s = (k_s i)/n_e$$

where k equals the hydraulic conductivity, i equals the gradient, and n_e equals the effective porosity. In unsaturated media the degree of saturation needs to be accounted for in both the hydraulic conductivity (k) and effective porosity (n_e) terms. In the analysis provided the DOE has used saturated hydraulic conductivity rather than effective hydraulic conductivity. This is a conservative and acceptable approach because using saturated values results in faster velocities and lower travel times. However, the DOE has apparently failed to consider the degree of saturation relative to the effective porosity term. In Section 6.4.2.2.2 of the draft EA the DOE has used a different expression to calculate linear water-particle velocities

$$v_s = (k_s i)/\theta$$

where θ equals the moisture content which the DOE states is equal to the product of effective porosity and saturation.

There are no data on moisture content presented or discussed in this section. Therefore, there is no basis for assuming that the moisture content equals effective porosity, numerically, for either the Topopah Spring or Calico Hills units. It is stated in Section 6.4.2.2.2 (page 6-313) that the effective porosity is taken as equal to the moisture content in calculations presented in this section of the draft EA. However, the value of moisture content of the Calico Hills unit is given as .28 on Page 6-313, whereas the value of effective porosity of the Calico Hills unit is given as .2 on page 6-139.

It is not clear in any of the discussions in the draft EA what the reasonable ranges in effective porosity or moisture content are. What data are presented are inconsistent. No basis is provided for determining what conservative

values should be. Based on the presentation in the draft EA it appears that the DOE has not accounted for the degree of saturation in calculations of travel time through the unsaturated zone. When saturation is considered in the calculations, relative to effective porosity, travel times decrease proportionally to the degree of saturation.

6-51

Section 6.3.1.2.2, Data Relevant to the Evaluation, Page 6-143, Paragraph 3

The DOE has stated that the potential host rock, the Topopah Spring Member, is composed of 98 percent non-hydrous minerals. This statement seems to be contradicted by several recent DOE documents (Vaniman et al., 1984; Bish et al., 1982) which indicate that the Topopah Spring Member contains a higher percentage of non-hydrous mineral.

Data on the areal distribution and abundance of the secondary minerals are contradictory in the DOE literature. Several reports suggest abundant zeolites and clay minerals in the Topopah Spring Member (Bish et al., 1982, Vaniman et al., 1984) at the repository horizon. Sorptive minerals (zeolites and clays) appear to be found throughout portions of the repository horizon in varying amounts and it may be difficult to predict with any accuracy the absolute amount of these minerals at the repository horizon based on the few drill holes in the exploratory block. In drill holes USW G-1, G-2 and UE 24a-1 the groundmass of the central and lower Topopah Spring Member has a high clay (smectite) content (Bish et al., 1982). Smectite abundances may be as high as 6% in the repository horizon (Vaniman et al., 1984). Data from hydrological drill holes indicate that sorptive minerals are present in the repository horizon (Levy, 1984). Vaniman et al. (1984, page 19) also indicate that zeolites occur above the basal vitrophyre in the Topopah Spring Member in USW G-1 (10 to 20%) and G-2 (30 to 50%). "Even where zeolite abundances at this level are very small, as in USW GU-3, the zeolites are concentrated along fractures and voids...and therefore may be important for waste element sorption along potential flow paths."

The possible presence of more hydrous minerals (smectities and zeolites) in the Topopah Spring Member at the repository horizon and below in abundances greater than presented in the draft EA would suggest that they may have a significant effect on the performance under expected repository conditions. The amount of hydrous minerals present at the repository horizon should be evaluated in light of the effect of dehydration on repository performance and a more conservative position should be taken.

6-52

<u>Section 6.3.1.2.2, Data Relevant to the Evaluation, Summary of Available Data, Page 6-147, Paragraph 4</u>

The assumption of equilibrium chemical behavior in discussing precipitation and complex formation may lead to incorrect conclusions about the tuff-groundwater systems at Yucca Mountain because many rock/water reactions in those systems will be either controlled or influenced by kinetics. This point is tacitly acknowledged by the DOE inasmuch as the draft EA contains lengthy discussions of the possible effects of kinetics on the stability of zeolites and clay minerals in NTS tuffs. Furthermore, it has been demonstrated that supersaturation and redox disequilibrium (Lindberg and Runnells, 1984) can occur in many different types of rock/groundwater systems, including tuff-groundwater systems such as those at Yucca Mountain.

6-53

<u>Section 6.3.1.2.2, Data Relevant to the Evaluation (Assumptions and Data Uncertainties), Page 6-147, Paragraph 5</u>

According to the draft EA, "there is uncertainty in the flux and flow mechanisms of water at Yucca Mountain, and for conservatism the expected maximum flux was used in this analysis". Based on the discussion presented in the comment for page 6-135, a flux rate of 1 mm/yr may not be a conservative estimate of the expected maximum flux.

6-54

<u>Section 6.3.1.2.2, Data Relevant to the Evaluation (Assumptions and Data Uncertainties), Page 6-148, Paragraph 1</u>

This section discusses uncertainties in the estimated flux and the mechanisms of groundwater flow at Yucca Mountain. According to the draft EA, "another area of uncertainty involves the attributes of fractures. Important attributes that affect water flow, such as aperture size, fracture spacing, and connectivity, are sufficiently known to develop a hydrologic model for flow in the saturated zone." This statement is inconsistent with the statement on page 6-175 that "virtually no data are available on properties of individual fractures or the effects of fractures on rock matrix properties, although experiments to measure such properties are underway in the laboratory and planned for the exploratory shaft." Data pertaining to the hydraulic properties of fractures are important to the EA review process because very little is known about the characteristics of water movement through fractures in the tuffs at Yucca Mountain.

6-55

Section 6.3.1.2.3, Favorable Conditions (2), Page 6-151, Paragraph 2

While many of the oxides of radionuclides exhibit a minimum solubility in the pH range of 6 to 8, C, Cs, I, and Tc have large solubilities in that range.

These elements represent approximately 1.40 (10^4) ci/1000 MTHM 1000 years. Paragraph 2 (draft EA, page 6-151) implies that a neutral pH in the ground water of Yucca Mountain will favor minimum solubilities for many elements. Because three of the ten key radionuclides have large solubilities at that pH, the final EA should also discuss the elements with high solubilities.

6-56

Section 6.3.1.2.3, Favorable Conditions (2), Page 6-151, Paragraph 2 (see also Page 6-120, Paragraph 4)

The DOE states that since oxides of many waste elements, particularly the actinides, have high solubilities at low and high pH, with a minimum solubility in the pH range of 6 to 8, the nearly neutral pH of water from the Yucca Mountain area provides conditions that favor minimum solubilities for these elements.

This commentary refers only to oxides of waste elements, not silicates, carbonates, or phosphates, etc. The consequences of waste elements precipitating as either silicates, carbonates, etc. should also be addressed. It may be possible that silicate, carbonate, or phosphate solids will control the concentrations of some dissolved radionuclides. If so, the solubilities of waste elements may then be different from those of the oxides in the ground water with near-neutral pH. It may be worthwhile to consider the ramifications of these circumstances in which the concentrations of dissolved radionuclides are limited by the solubility of these other complexes.

6-57

Section 6.3.1.2.3, Favorable Conditions (2), Page 6-151 Paragraph 3, Page 6-160 Paragraph 4

It is unclear from this discussion whether matrix diffusion will effectively retard the movement of radionuclides at Yucca Mountain. Because Tc, I and C do not appear to be retarded by either precipitation or sorption, matrix diffusion could play an important role in controlling the release of these nuclides. Matrix diffusion is most effective when saturated fracture flow conditions exist. The projected repository horizon is in the unsaturated zone, where the effect of matrix diffusion in retarding radionuclides will be reduced. Blencoe and Grisak (1984) indicate that there is a linear relationship between saturation and the effectiveness of matrix diffusion to retard radionuclides.

The effectiveness will also be reduced by the presence of mineral fracture coatings (see detailed comment 6-64) and dead-end pore space. Even under saturated flow conditions the relative contribution of matrix diffusion to radionuclide retardation is dependent on the fracture aperture, abundance and nature of mineral coatings, and groundwater flux through the fractures. There is no evaluation in the draft EA of the uncertainties listed above. The DOE should consider the above uncertainties in its discussion of matrix diffusion.

6-58

Section 6.3.1.2.3, Favorable Conditions (2) Page 6-152, Page 6-160 Conclusion

In this section of the draft EA, the results of batch sorption measurements have been presented to support the finding that geochemical conditions at Yucca Mountain promote sorption of radionuclides. While most of the radionuclides (with the exception of Tc, I) appear to be adsorbed by the tuff under batch test methods, it is not clear to what extent these distribution coefficients will change and how applicable the retardation factor is under unsaturated flow conditions.

The composition of the ground water will directly affect radionuclide speciation and as a result radionuclide sorption (draft EA, page 6-150). The batch sorption measurements reported in Tables 6-21 and 6-22 were conducted using water from well J-13, which, as discussed previously, may have a different chemical composition from water in the unsaturated zone. The distribution coefficient for the various radionuclides may therefore be different if measured in a ground water of different chemical composition.

Although the draft EA clearly states that the nature and rates of flow are not well understood (draft EA, page 6-129), the DOE has assumed that matrix flow is the dominant means of transport through the unsaturated zone. As discussed in major comment 3, if fracture flow is the dominant means of radionuclide transport through the welded, highly fractured units in the unsaturated zone, the radionuclides may not contact the mass of rock expected under matrix flow regimes. Under these conditions, the use of data from batch tests, which assume porous flow conditions, will yield high retardation factors and lead to underestimation of radionuclide releases.

The retardation factors (R_f) calculated in the draft EA are applicable only to fully saturated, porous flow conditions where the total surface area of the solid (all the active sorption sites) is available to the radionuclide. Retardation factors calculated for those conditions may represent an upper limit of the retardation capacity for unsaturated flow conditions. In unsaturated flow, generally fewer sites are available due to the limited amount of water, the dead-end pore space, and the channeling effects known to occur in unsaturated media. The use of retardation factors based on saturated flow without corrections for these effects will lead to erroneously high values for

unsaturated media and lead to an additional degree of underestimation of releases.

The tuffs at Yucca Mountain may provide significant retardation by sorption for most radionuclides except Tc and perhaps U, C, and I. Because of the uncertainties in the measurement of batch sorption distribution coefficients and calculation of retardation factors based on assumptions of a saturated porous flow model, the retardation factors may differ significantly under fracture flow or unsaturated conditions. The DOE should consider the range of retardation factors that may be possible under these alternative conceptual flow models.

The correlation between sorption ratio and sorptive mineral content is good for alkali or alkaline earth elements, but there is little or no correlation for Tc, Ce, Eu, Am, Np, U. The wide variation in sorption ratios (often up to 4 orders of magnitude, see Heiken, 1982), and poor correlation for sorptive minerals to sorption ratio for most radionuclides, imparts a high degree of uncertainty in applying these values to retardation calculations. The DOE should include in their evaluation of this guideline a discussion of the uncertainties involved.

6-59

Section 6.3.1.2.3, Favorable Conditions (2), Pages 6-154 to 6-157

Tables 6-21a, 6-21b, 6-22a, and 6-22b of the draft EA present average sorption ratios (distribution coefficients from batch adsorption experiments on crushed tuff) rather than ranges of sorption ratios. According to footnotes for these tables, some data were rejected in averaging. Ranges of sorption ratios provide more meaningful data than do averages. The DOE should consider providing ranges of sorption ratios in the final EA. This would allow a more complete evaluation of the data.

6-60

Section 6.3.1.2.3, Favorable Conditions (2), Page 6-158, Paragraph 1

The assumption of equilibrium conditions and porous flow in this section may not be reasonable for all of the tuff units, e.g. the welded Topopah Spring Member, partially welded Prow Pass Member, and welded Bullfrog Member. In the welded and partially welded tuffs the fracture permeability may exceed the matrix permeability, thereby making fracture flow the most likely means of radionuclide transport for these units. The fluid flux through fractures may be as high as 10^{-5} m^3/sec (Henne, 1982). In this circumstance: (1) equilibrium conditions may not exist, and (2) calculations of retardation factors based on porosity and bulk density are liable to be erroneous. Under fracture flow conditions, sorption will occur principally along fracture

surfaces; therefore, for the welded units, the DOE should consider basing the retardation factor on a range of conditions including both fracture and matrix permeability (see for example, Haggblom, 1977).

6-61

Section 6.3.1.2.3, Favorable Condition (2), Page 6-158, Paragraph 2

The implication of the first two sentences in this paragraph is that precipitation or matrix diffusion will retard any radionuclides that are not retarded by sorption on tuff. No comparisons are made between the relative significance of each of the retardation processes--sorption, precipitation or matrix diffusion--for individual radionuclides. While some radionuclides are either precipitated out of solution, or adsorbed onto tuff, others (e.g Tc, C, and I) do not appear to be retarded by either of these means. For example, (according to Table 6-23) Tc is not retarded by sorption; however, it is one of the highly soluble radionuclides (Table 6-24), has one of the longest half-lives (Table 6-42), and is one of the radionuclides with the largest inventory after 1000 years (1.3 10^4Ci/1000 MTHM). It is not clear from any of the discussions in the draft EA if Tc, C, and I will be retarded. The DOE should address this apparent problem in the final EA.

Furthermore, the statement that engineered barriers be considered for retardation is contrary to the letter and intent of the guidelines (10 CFR 960.3-1-5 and FR 49(236)477290).

6-62

Section 6.3.1.2.3, Favorable Condition (2), Page 6-158, Paragraph 3

No data have been collected on the water chemistry of the unsaturated zone. Therefore, it may be premature to claim "organic concentrations of 1 x 10^{-6} moles per liter or less" because the data are based on water from well J-13 which is from the saturated zone. Episodic ground water in the unsaturated zone may be more typical of surface ground waters (Henne, 1982; Drever and Smith, 1978) which may contain higher organic concentrations (see detailed comment 6-70). A conservative line of reasoning must be used in evaluation of this condition.

6-63

Section 6.3.1.2, Favorable Condition (2), Page 6-144, Item(2) and Page 6-158, Paragraph 4; Page 6-169, Paragraph 4

It is questionable whether particulates and colloids will be filtered by tuffs, thereby inhibiting transport of radionuclides via these agents, if some of the ground water at Yucca Mountain migrates downward through the fractures in the

unsaturated zone rather than through the rock matrix. If fracture flow predominates in the unsaturated zone (because of local zones of saturation around fractures in welded units with low matrix permeability) at the Yucca Mountain site, a significant fraction of the particulates and colloids in groundwater may not be filtered out by the tuffs. Filtration would generally only be effective in fractures with an aperture width of less than 0.1 micrometer. This conclusion also applies to flow of ground water beneath the water table. The DOE should consider the possible transport of colloids and particulates under fracture and matrix flow regimes.

6-64

Section 6.3.1.2.3, Favorable Conditions (2), Conclusion, Page 6-160, Paragraph 4

The following statement: "The physical properties of the tuffaceous rocks at Yucca Mountain will promote the diffusion of radionuclides into the rock matrix," does not take into account the effect that fracture skin would have on the transport of radionuclides into this matrix. Fracture coatings may limit migration of both water and radionuclides into the rock matrix.

6-65

Section 6.3.1.2.3, Favorable Conditions (2), Page 6-160, Conclusion

The draft EA does not contain any discussions of geochemical conditions along the distal ends of potential radionuclide-release pathways (i.e., geochemical conditions along radionuclide-release pathways from the region immediately beneath the candidate repository horizon to points within the accessible environment). These conditions must be identified in order to conduct defensible assessments of the performance of rocks for radionuclide isolation in the far field. Where data are not cogent, the conclusions have to be supported by a conservative line of reasoning.

6-66

Section 6.3.1.2.3, Favorable Conditions (3), Page 6-161, Paragraph 3

The DOE has concluded that there are no minerals at or near the repository horizon that will alter to less favorable phases due to emplacement of the waste. The data may not adequately support this conclusion for the following reasons:

1) The DOE acknowledges that there are minerals present within the 100°C isotherm that will react, "but represent a very small proportion of total sorptive zeolites present...", (draft EA, page 6-161).

2) The supporting data on the location and amount of minerals present at the repository horizon, and in the tuffs below the repository horizon, is not conclusive and is in places contradictory.

3) The analysis of mineral stability does not adequately consider repository-induced conditions, the effect of the chemistry of the vadose zone ground water, and the potential changes in groundwater chemistry due to repository conditions.

The location and amount of minerals, and their stability, are important because sorptive minerals (zeolites and clays) may react to form less sorptive mineral assemblages which may decrease the retardation capacity of the host rock and surrounding media. These reactions are also accompanied by a volume reduction, which may affect the constructability of the repository and/or the permeability of the host rock.

Data on the areal distribution and abundance of the secondary minerals are contradictory if followed through the DOE literature. Several reports suggest abundant zeolites and clay minerals in the Topopah Spring Member (Bish et al., 1982, Vaniman et al., 1984) at the repository horizon. Other reports (Bish et al., 1984) indicate that sorptive minerals may not be abundant at the repository horizon and report less alteration, although the same secondary minerals are reported. Based principally on data from USW G-3, the DOE also claims (draft EA, page 6-161) that the only significant quantities of zeolitized tuffs occur at a depth below 650 meters (60°C isotherm), where the reaction rate will be so slow that it will be unaffected by the 23°C temperature increase expected as a result of waste emplacement. However, in other wells, zeolites and clays are found in the Calico Hills tuff in abundances of 50-90% (Bish et al., 1984) well above 650 meters, closer to the repository, and therefore at a position which may experience temperatures in excess of 80°C. Sorptive minerals appear to be found throughout portions of the repository horizon (and the underlying units) in varying amounts, and it is difficult to accurately predict the absolute amount of these minerals at the repository horizon based on the few drill holes in the exploratory block.

The stability and rates of reaction of zeolites and clays are not well known. The DOE concludes in the draft EA, however, that at temperatures above 100°C zeolites become unstable and will react to form less sorptive minerals, and that at the 60°C isotherm (at a depth of 650 meters, where the DOE claims most of the sorptive minerals exist) the reaction rates are too slow to be of any consequence. However, zeolite reaction rates are strongly influenced not only by temperature but also by water chemistry (e.g., pH, ionic strength, chemical composition). Reactions can proceed within hours in the laboratory (1) at elevated temperatures (under equilibrium conditions) and (2) at observed ambient temperatures in a ground water if the pH is increased to 9. Also, an increase in the sodium content of the water may cause reaction of clinoptilolite to more stable, less sorptive analcime at temperatures as low as 80°C (Bish et al., 1982). The reaction of glasses in the vitric zone can produce higher sodium in ground waters (Bish et al., 1982), which may encourage

reactions to less sorptive mineral assemblages in portions of the zeolitic Calico Hills tuff that are within 50 meters of the proposed repository horizon, where the DOE predicts the temperatures to exceed 80°C (Braithwaite and Nimick, 1984). Inasmuch as the groundwater composition is not accurately known, it is inappropriate for the DOE to assume that zeolites and clays will be stable to 100°C, or that the reactions will take tens of millions of years at a temperature of 60°C.

The recrystallization of clinoptilolite to analcime is accompanied by a volume reduction of approximately 20% (Bish et al., 1982). Dehydration of clays can also be expected to result in some volume reduction. The Calico Hills tuff (reported to contain 50 to 90% zeolites) is in some locations only about 50 meters below the repository horizon and could experience temperature changes--due to the waste emplacement--adequate for reaction of zeolites and clays. Also accompanied by a volume change (5%) is the α-β displacive transformation of cristobalite which occurs reversibly at about 223° ± 27°C (draft EA page 6-221). These volume changes could affect rock stability in and below the repository.

The potential reduction in sorptive capacity of rocks along the flow path from the repository to the accessible environment and in fractures in the repository horizon--which are thought to be important to retardation--should be considered in the DOE's evaluation of this finding.

In light of the available information cited above, the DOE should reconsider the finding that no mineralogical changes are to be expected that would adversely affect the sorptive qualities of the host rock and units directly below the repository.

6-67

Section 6.3.1.2.3., Favorable Conditions (4), Page 6-162, Paragraph 3

The assumption that release of elements with high solubilities will be limited by the dissolution of the bulk waste form (congruent dissolution) is questioned. Spent fuel rods will be buried as assemblies. It is possible that upon failure of the zircaloy cladding of the fuel rod and stainless steel canister, UO_2 pellets will be exposed to the ground water. Volatile fission products do diffuse through the UO_2 lattice and concentrate in cracks or in fuel-cladding gaps (Woodley, 1983). Experimental studies have shown that some radionuclides (e.g., Cs and I in spent fuel) are released into solution at a faster rate than the matrix dissolution rate (Johnson, 1982). The first stage in glass dissolution is often a leaching of alkali elements, which could release some radionuclides at a faster rate than the rate of the subsequent mechanism of matrix dissolution (Adams, 1984). Under such circumstances, a dissolution rate equal to that of the bulk waste form would not be conservative.

6-68

Section 6.3.1.2.3., Favorable Conditions (4), Page 6-164, Continuing Paragraph and Paragraphs 1 and 2

The implication that the ratio of release rate to inventory meets the guideline is questionable in light of the number of uncertainties and assumptions presented in Kerrisk (1984). Assumptions such as applying bulk waste form dissolution rates (See detailed comment 6-67) to calculations for both solubility- and diffusion-limited release can vary release rates by orders of magnitude depending on the radionuclide (e.g., C, Cs, Tc, and Np). Groundwater flux through the repository will increase the release rates by an order of magnitude for every two orders of increase in the flux. It has not been demonstrated that groundwater flow in the unsaturated zone at Yucca Mountain is predominantly matrix flow rather than fracture flow. If fracture flow is predominant, then it is possible that meteoric water will migrate down to, and through, an engineered HLW facility at a very rapid rate. If this possibility cannot be ruled out at the present time, then the assumption of matrix flow at 1 mm/yr may be an underestimation of flux. The present waste package design does not call for backfill around the canisters, yet both models assume porous media flow surrounding the canisters, which is an assumption that may reduce the groundwater velocity and thus yield non-conservative values. Kerrisk (1984, page 13) also states that there are large uncertainties in the calculated solubility values. These uncertainties can vary by several orders of magnitude (Ogard et al., 1984).

Based on the uncertainties and possible range in values for groundwater flux, the DOE should re-evaluate the finding in light of the uncertainties cited above.

6-69

Section 6.3.1.2.3, Favorable Conditions (5), Page 6-164, Paragraph 4

The statement, "All the radionuclides studied, except for technetium-99, have retardation factors well in excess of 10, and for porous flow, the effective velocity of radionuclides is found by dividing the flow rate by the retardation factor" may in fact apply for porous flow; however, there is some question about its validity for fracture flow. In addition, these retardation factors are for saturated, not unsaturated conditions. It has been stated previously in the draft EA that the flow at Yucca Mountain is not well understood. Under certain conditions and in certain units fracture flow may prevail. Haggblom (1977) has developed an expression for retardation under fracture flow conditions that can give significantly different values from those calculated on the basis of porous flow. The resulting retardation factors could vary by several orders of magnitude (see detailed comment 6-58). Such a decrease could have serious effects on estimates of retardation for elements such as Np and U, which have calculated retardation factors between 10^1 or 10^2. The possibility

exists that these elements may not be substantially retarded by sorption. The DOE should include a discussion in this section addressing the effect of fracture flow and unsaturated conditions on the calculation of radionuclide retardation factors.

6-70

Section 6.3.1.2.4, Potentially Adverse Conditions (1), Page 6-165, Paragraph 4

The comment that water in the unsaturated zone is expected to be similar to the chemical composition of ground water in the saturated zone is not supported by the available literature. It is not necessarily true that vadose-zone water will be "similar" chemically to the ground water in the saturated zone. A sizable fraction of the latter ground water may originate in regions far removed from Yucca Mountain, and thus may have a different chemical "signature." Furthermore, the rocks beneath the water table may be somewhat different from the rocks present in the vadose zone, and, therefore, different rock/water reactions in the two zones may result in ground waters with different chemistries. Finally, due to its closer proximity to the surface, vadose-zone water is more likely to contain hydrocarbons dissolved from decaying organic matter in the overlying soil zone.

The DOE noted in Section 6.3.1.1 (page 6-130) that if the groundwater flux exceeds 1 mm/yr, fracture flow could occur. If fracture flow predominates (this cannot be discounted completely--see major comment 3), the ground water of the unsaturated zone may not have sufficient time to equilibrate with the host rock, but rather, may reflect the soil or alluvium chemistry. A thesis (Henne, 1982) dealing with the chemistry of the ground water in the Rainier Mesa volcanic tuffs indicates that the groundwater chemistry in the unsaturated zone at Rainier Mesa is controlled by the soil chemistry, not by equilibration with the host rock. Henne maintains that groundwater velocity through the unsaturated zone by fracture flow could be as rapid as 4.4 m/day which corresponds to a groundwater retention time of 0.3 years. It would be difficult for the ground water to equilibrate with the tuffs at velocities this rapid.

In arid regions, deposition of salts at or near the surface during evaporation followed by partial re-solution during heavy rains may produce ground water in the unsaturated zone with a high content of soluble salts (Drever and Smith, 1978), which may be significantly different from ground water in the saturated zone. This is supported by the findings of Oversby and Knauss (1983) and Oversby (1984) that there is a significant component of readily soluble salts in outcrop samples of both the Bullfrog and Topopah Spring Member tuffs. Based on these findings, the vadose zone ground water may be higher in ionic strength, dissolved solids, dissolved gases, colloids, and/or organics than J-13 water, obtained from the saturated zone. Therefore, the DOE should consider in its findings the possibility that the composition of the ground

water in the unsaturated zone may be dissimilar to water from the saturated zone.

6-71

Section 6.3.1.2.4, Potentially Adverse Conditions (1), Page 6-166, Paragraph 2, Page 6-183, Paragraph 3, and Page 6-186, Paragraph 3

The draft EA concludes that there are no known groundwater conditions at Yucca Mountain that are expected to compromise the performance of the metal barrier. However, the basis for this conclusion has not included adequate consideration of some possible waste package-induced effects on the post-emplacement groundwater chemistry, which may result in an underestimation of the reactivity of the groundwater with the engineered barriers. For example, little is known quantitatively about the deleterious effects of (a) oxygen, nitrogen, and carbon dioxide introduced during excavation and operation, and (b) the formation of oxidants and nitric acid by gamma radiolysis effects (Bates and Oversby, 1984). These factors could cause increased container corrosion rates for several hundreds of years after repository closure.

Also, this conclusion is based on experiments conducted in a Teflon-lined reaction vessel in a closed system (Knauss, 1984). A more recent study (USDOE, 1984) indicates that when J-13 water is boiled (open system) and concentrated, the pH changes from 7 to 9.8, probably due to the loss of CO_2. Testing performed at the Brookhaven National Laboratory under NRC contract FIN A-3167 indicates a similar result. A preliminary test showed that when distilled water was added to crushed tuff and maintained at boiling water conditions for one month, the concentration of many ions in solution was almost an order of magnitude greater than in J-13 ground water (Soo, 1984). In addition, it is possible that a groundwater from the unsaturated zone would initially have a higher concentration of dissolved salts than J-13 ground water (Henne, 1982).

Also, the formation of steam from ground water in the repository during the period after closure may cause the precipitation of dissolved salts. Fresh cooler water entering the repository at a later time may redissolve a significant amount of these precipitates, leading to ground water with concentrations of Cl^-, F^-, and SO_4^{-2} much higher than those in J-13 well water or vadose-zone water. These ions may adversely affect metallic barrier performance, especially with respect to the likelihood of stress corrosion cracking (see detailed comment 6-114).

Therefore, until further studies of the possible effects of the post-emplacement environment on the performance of the waste package are completed, numerous uncertainties will remain concerning the performance of the waste package. The DOE should factor these uncertainties into the findings on the reactivity of ground water with the waste package.

6-72

Section 6.3.1.2.4, Potentially Adverse Conditions (3), Page 6-169, Paragraph 4.

The draft EA states that although the repository is in an oxidizing environment, the stainless steel container could react with oxygen to form a protective oxide layer and thereby effectively reduce the amount of this gas reaching the waste. It is stated that this layer is likely to enhance the container lifetime. However, this conclusion may be based on a transient condition which may not provide any overall enhancement of the waste package lifetime or reduction in the oxidation state of the water.

For example, it is possible that after a passive oxide layer has formed on the steel, the reaction rate with oxygen will become so slow that additional oxygen migrating into the waste package borehole, or oxygen generated by gamma radiolysis, is not significantly decreased in concentration by container interactions.

Also, the presence of a passive oxide layer on the container, while potentially beneficial with respect to the rate of uniform corrosion, could enhance local attack from stress corrosion cracking, crevice corrosion and pitting. Such mechanisms are encouraged by the presence of large passivated areas on the stainless steel which are cathodic with respect to crack tips, crevice and pitting regions. This could enhance metal dissolution in these anodic locations and reduce container life.

It is not clear, therefore, that the possible beneficial conditions resulting from the oxidizing environment (described in the draft EA) outweigh the associated adverse conditions. The DOE should consider all the uncertainties which currently exist in predicting waste package performance. In this regard, the passive oxide layer may reduce uniform corrosion while increasing the material's susceptibility to localized corrosion. Thus, the statement that the "pre-waste-emplacement oxidizing conditions may prolong the lifetime of the canister" may be premature based on the available data.

6-73

Section 6.3.1.2.4, Potentially Adverse Conditions (3), Page 6-170, Paragraph 1

The DOE states that the lifetime of Zircaloy cladding may be shortened under oxidizing conditions since UO_2 fuel can swell if oxidized and cause stress-rupture of the cladding. However, for the UO_2 to be oxidized, oxygen-bearing water would first have to penetrate the cladding to reach the fuel. Thus, inasmuch as the cladding would have already failed, additional breaching by stress-rupture mechanisms would seem insignificant. Clarification is needed on the logic for considering cladding stress-rupture failure under oxidizing conditions.

6-74

Section 6.3.1.3.2, Data Relevant to the Evaluation, Pages 6-172 through 6-175

The effects of various assumptions and data uncertainties on the evaluation of the post-closure siting guidelines on rock characteristics (10 CFR 960.4-2-3) do not seem to have been appropriately taken into consideration in the draft EA. The following comments provide some of the specific examples of assumptions and data uncertainties which should be further discussed in the final EA, especially with respect to their potential effects on the evaluation of pertinent siting guidelines.

1. (a) It is mentioned in the draft EA (page 6-175, 1st sentence) that "Many of the fracture attributes, such as orientation, frequency, length, and aperture, have not yet been measured." Also, it is stated (page 6-175, paragraph 2) that, "Virtually no data are available on properties of individual fractures or the effects of fractures on rock matrix properties." However, the effects of data uncertainties resulting from lack of data on fractures do not seem to have been appropriately taken into consideration in the evaluation of the postclosure siting guidelines. For instance, on page 6-175, paragraph 3 of the draft EA it is mentioned that in the computer programs, the fractures were conservatively modeled as planar, ubiquitous, and non-intersecting. However, the draft EA does not adequately justify the assumption that the simplified models would lead to conservative results. The computer analyses, which are based on averaged properties (page 6-175, paragraph 3 of the draft EA), should be recognized as preliminary and not necessarily conservative.

   (b) Data uncertainties related to geologic anomalies (e.g., lithophysal cavities, vitric zones, etc.) are not discussed in this section. The presence of anomalous zones within the rock mass may affect long-term stability and isolation capability of the host rock, thereby influencing the evaluation of the post-closure siting guidelines. The assumptions and effects of data uncertainties on these evaluations should be addressed in the final EA. The discussion should include the effects of fluids, fracture filling, varying stress field, elevated temperature, and vibratory events on rock mass stability.

2. It is stated in the draft EA (page 6-175, paragraph 2) that "Where specific properties for a particular unit were not available, the property was estimated by comparison with a similar rock unit." However, the data uncertainties resulting from this assumption have not been fully addressed. It appears that most of the host rock properties are estimated on the basis of the data from G-tunnel in Rainier Mesa. The exposed rock formation available for testing in G-tunnel is the relatively lithophysae-free Grouse Canyon Formation. There are only limited data available to make meaningful comparisons between the properties of the two

formations. The potential effects of assuming similarity between the engineering properties of the Topopah Spring Member and Grouse Canyon Formation on the evaluation of postclosure siting guidelines on rock characteristics (10 CFR 960.4-2-3) should be addressed in the final EA.

6-75

Section 6.3.1.3.3, Favorable Conditions (1), Pages 6-176 to 6-178

The draft EA does not provide a sufficient basis to conclude that significant vertical flexibility is available in the placement of the repository. Also, the draft EA provides inadequate substantiation for the conclusion that sufficient lateral extent is available for waste emplacement.

It is stated in the draft EA (page 6-178, first sentence) that there is approximately 749 ha (1850 acres) of area that is potentially usable for locating the underground repository facility at the Yucca Mountain site. In addition, it is concluded (page 6-178, paragraph 3) that this area has sufficient thickness to provide significant vertical flexibility in the placement of the repository. Additional substantiation is needed to support this conclusion and to verify that sufficient lateral extent is available for waste emplacement. The following comments should be considered in evaluating the available information and to re-evaluate conclusions given in the draft EA.

1. The draft EA states (page 6-178, first sentence) that the primary host rock area (area 1) consists of approximately 890 ha (2,200 acres), and that 15% of this area may not be suitable for the repository location because of the presence of minor faults and breccia. However, it should be noted that the excluded area is not likely to be concentrated at one location; rather, it may be distributed in segments throughout the host rock. The random location of these areas may deter complete utilization of the remainder of the area 1 host rock, and thus could further reduce the potentially available usable area. The EA should consider this possibility in terms of its effects on the availability of sufficient lateral extent of area 1 host rock for waste emplacement.

2. The draft EA states (page 6-176, paragraph 3) that emplacement in the Topopah Spring Member is proposed in the relatively lithophysae-free zone (containing less than 15 to 20 percent lithophysae). It is further stated that at low percentages, the lithophysae have little effect on mineability and ground support requirements; at high percentages (probably near 30 percent) it could affect mineability and ground stability. However, adequate basis to substantiate these conclusions is not provided in the draft EA or in the reference document (Mansure and Ortiz, 1984). In addition, no data are provided to support the contention that the so-called "lithophysae-free" zones have sufficient lateral continuity for the placement of the underground facility. If lithophysae-free zones are found to be intermingled with zones having a relatively high percentage of

lithophysae, the isolation capability and thermomechanical properties of the repository host rock would have to be further evaluated. The final EA should recognize this possibility and describe the measures to be taken in case a suitable lithophysae-free zone of sufficient lateral extent is not found within Area 1.

3. The draft EA concludes that sufficient host rock thickness is available to provide vertical flexibility in the placement of the repository (page 6-178, last paragraph). However, the basis for this conclusion is not clearly stated. The final EA should discuss the extent of possible restrictions on vertical flexibility due to lithophysae content. Data should be presented in the final EA to support the conclusion that a sufficiently thick lithophysae-free zone is available for repository placement and that this zone meets other requirements (e.g. sufficient rock strength, desirable thermal properties, limited fracture density, etc.) for locating the underground facility. (Also see detailed comments E-3 and 6-77).

6-76

Section 6.3.1.3.3, Favorable Conditions, Pages 6-177 and 6-179, Figures 6-5 and 6-6

Figures 6.5 and 6.6 identify the map locations of Area 1 "Primary area" for the underground facility and approximate area of the underground facility showing the overburden contours, respectively. Both diagrams show key features in evaluating the site against the siting guidelines, one for adequate area for waste emplacement and the other for the 200 meter overburden requirement. It is suggested that the DOE use one standard design area and scale for all such figures throughout the text. This should eliminate the potential for misinterpretation of design requirements imposed by the existing geologic setting.

6-7/

Section 6.3.1.3.3, Favorable Conditions, Page 6-178, Last Paragraph

Based on the stratigraphic features of the Topopah Spring Member (the repository host rock), the draft EA contains inadequate support for the statement "the potential host rock at Yucca Mountain is sufficiently thick to provide significant vertical flexibility in the placement of the repository to ensure isolation." Considering the nature of the host tuff unit inhomogeneities, there is limited construction flexibility available for repository openings in the host rock. Thus, the repository envelope (45 meters in diameter) can move only slightly up or down based on the previously mentioned restrictions. The highly variable nature of the lithophysal cavities and vitrophyre of the lower units limits the vertically downward flexibility of

the repository. Furthermore, the 200 meter overburden disqualifying condition limits the vertically upward flexibility.

It is suggested that the DOE reconsider their assessment of the amount of vertical flexibility available.

6-78

Section 6.3.1.3.3(2), Favorable Conditions, Pages 6-181 through 6-182

The draft EA conclusion (page 6-182, paragraph 2) that the repository host rock will accommodate the thermal and mechanical stresses developed during the period of peak temperatures with no adverse effect on waste containment and isolation is almost solely based on the near and far-field finite element thermal analyses conducted by Johnstone et al. (1984). However, the Johnstone et al. (1984) study was apparently done for the prime objective of ranking the tuff horizons. A definite conclusion based on this study alone may not be appropriate due to the preliminary nature and many inherent limitations of the study. Some of the limitations are identified below:

- Little is known about joint frequencies, orientations, joint infillings, and joint strengths (page 6-175, paragraph 2 of the draft EA).
- The computer model does not accommodate changes in mechanical properties of the host rock due to the expected elevated temperatures.
- The model thermal prediction has not been verified by any field data.
- The effect of lithophysal cavities in the Topapah Spring Member has not been adequately considered in the measurements of thermal properties. The thermal conductivity measurements utilized only two samples to define lithophysal effects, and the basis for thermal expansion results is not adequately described in the reference (Tillerson and Nimick, 1984) cited in Table 6-27 (page 6-182) of the draft EA.
- The in-situ stress field data used in the analyses (page 11 of Johnstone et al., 1984) may not be fully applicable to the reference repository horizon because the stress measurement data were obtained from the saturated zone only (Healy et al., 1982, Healy et al., 1984).
- The rock property data and analyses are based on results of laboratory tests that do not necessarily account for the rock mass discontinuities or potential creep of weakness planes and joints due to thermal loading (page 6-175, last paragraph of the draft EA).

It is suggested that the above mentioned uncertainties associated with the data and analysis procedures be described in the final EA. In addition, the conclusion (page 6-182 of the draft EA) made on the effect of thermal and mechanical stresses should be re-evaluated in light of these uncertainties.

6-79

Section 6.3.1.3.4(1), Potentially Adverse Conditions, Page 6-182 through 6-184

It is concluded in the draft EA (page 6-184, first paragraph) that, "Existing technology is adequate for constructing, operating, and closing the repository in a manner consistent with the objectives of Waste Containment." However, the technology that may be required for providing proper shaft and borehole sealing has not been adequately described in the draft EA. For example, it is stated in the draft EA (page 6-183, paragraph 3) that the exploratory boreholes will be filled with grout, slurry, or a tamped substance containing sorptive materials. However, the draft EA does not provide sufficient basis to support the adequacy of these materials to seal the boreholes. In addition, it is stated (page 4-22, paragraph 2 of the draft EA), that seals for boreholes and shafts are being developed in the laboratory. Thus, it has not been adequately substantiated in the draft EA that the sealing of the shafts and boreholes can be achieved by using reasonably available technology.

The final EA should further describe the basis for its conclusions that available technology would be sufficient to seal the necessary components of the underground facilities and exploratory shafts and boreholes, and should consider the above mentioned comments in the evaluation of its conclusions for this potentially adverse condition.

6-80

Section 6.3.1.3.4, Potentially Adverse Conditions (2), Page 6-185, Paragraph 1

With the limited amount of data available, the statement in the draft EA that more than 98 percent of the host rock within the potential repository horizon area is composed of non-hydrous minerals is inadequately supported. The amount of lateral and vertical variability in the tuff renders this a non-conservative statement (See detailed comment 6-51) in regard to the deleterious effects of dehydration. "Even where zeolite abundances (in the repository horizon) ... are very small ... The zeolites are concentrated along features and voids and therefore may be important for waste-element sorption along potential flow paths." (Vaniman et al., 1984, page 19). Dehydration or reaction that would affect the stability of these zeolites could adversely affect the performance of the repository.

6-81

Section 6.3.1.3.4, Potentially Adverse Conditions (3), Page 6-186, Paragraph 4

There is no data or information presented previously to support the statement that "...as the temperature is increased retardation caused by matrix diffusion will become more competitive with sorption processes." In addition, it indicates that matrix diffusion under normal conditions will not significantly retard radionuclides. The DOE should clarify this statement by providing data to support their findings.

6-82

Section 6.3.1.3.4, Potentially Adverse Conditions (3), Page 6-188, Paragraph 4

The statement "Permeability changes due to host rock dissolution and precipitation processes should not be significant,..." is based in part on a laboratory test that was conducted on a heated sample core of Topopah Spring Member Tuff using J-13 well water. The results may not represent in situ conditions around the proposed repository for the following reasons: (1) since the host rock is highly fractured, a sample core without fractures may not have the same response; (2) the use of J-13 water may be inappropriate since its chemistry may be different from that of the Topopah Spring Member in the unsaturated zone; and (3) the laboratory test was conducted for two weeks and the results were extrapolated over the length of time for repository performance without an assessment of the reliability of the extrapolation.

The DOE should consider re-evaluating or qualifying the conclusions for this potentially adverse condition in light of the above considerations.

6-83

Section 6.3.1.4.3, Favorable Conditions (2), Page 6-198, Paragraph 2

This section evaluates favorable condition 2 of the guideline on climatic changes (10 CFR 960.4-2-4). While the DOE's conclusion that this favorable condition is not present at Yucca Mountain is appropriate, there are statements in this section which when evaluated against previous statements and hypotheses presented in the draft EA are either inconsistent or appear to ignore the transient nature of the system.

This section discusses the potential increase in the groundwater recharge rates during pluvial periods. According to the draft EA, "The increased flux probably was not sufficient to affect the potential for developing perched-water conditions in the unsaturated zone or to modify the hydrologic system in the underlying saturated zone. Hydrologic tests and measurements of core

samples of unsaturated rock units underlying Yucca Mountain indicate that the fracture and matrix permeability is generally high enough to transmit water not only at the low modern fluxes (probably less than 1 mm/yr) but also at the postulated much higher fluxes of pluvial times (Section 6.3.1.1). Thus, the increase in recharge that is postulated for pluvial climates probably did not significantly affect the potential for developing perched-water conditions." These statements are considered relative to the following statements presented elsewhere in the draft EA:

1. It is stated on page 6-121 that "Preliminary modeling efforts using the regional hydrology model developed by Waddell (1982) predict that water table elevations at and near Yucca Mountain may have been as much as 130 m above the current position of the water table". This is restated in paragraph 3 on page 6-199. In addition, the conclusion section for this favorable condition (page 6-200) indicates that "the water table may have been as much as 25 percent shallower than at present, and flow paths to discharge areas may have been modified." This is the very basis for concluding that this favorable condition is not present at Yucca Mountain. Therefore, the statement in paragraph 2 on page 6-198 that "The increased flux probably was not sufficient to ... modify the hydrologic system in the underlying saturated zone" is inconsistent with other discussions and conclusions in the rest of the draft EA.

2. It is stated on page 6-126 that "the combined effect of the capillary and permeability barriers is to limit the downward flux through the host rock to a maximum of 1 mm/yr under unsaturated conditions". If the statement "hydrologic tests and measurements of core samples of unsaturated rock units underlying Yucca Mountain indicate that fracture and matrix permeability generally is high enough to transmit water not only at the low moderate fluxes (probably less than 1 mm/yr) but also at the postulated much higher fluxes of pluvial times" is true then the general effectiveness of the capillary and permeability barriers is in question. It appears that it would take a fortuitous combination of circumstances for the barriers to operate. Recharge events would have to be within a range of intensity, duration, and frequency such that moisture contents above the barriers increase (store water) so as to limit downward flux through the host rock to a "maximum of 1 mm/yr" under unsaturated conditions while at the same time pass "the postulated much higher fluxes of pluvial times" downward such that saturated conditions (perched water) would not develop. To assume that the capillary and permeability barriers are effective as a general condition ignores the likelihood that the range of conditions under which they would be effective is limited. In turn, this leads to increased uncertainty as to whether the estimated steady-state flux through the host rock of a maximum 1 mm/yr is conservative.

These statements reflect negatively on the appropriateness of previous interpretations and assumptions and should be re-evaluated. Previous NRC comments on the diversion of infiltration hypothesis should be reviewed.

6-84

Section 6.3.1.4.4, Potentially Adverse Conditions (2), Pages 6-201 through 6-202

This section provides the evaluation for potentially adverse condition 2 of the guideline on climatic changes (10 CFR 960.4-2-4). Evidence presented in the draft EA on effects of potential future climatic changes on the geohydrology of this site does not adequately support the DOE's conclusion that this potentially adverse condition is not present.

Evidence presented and discussed previously in the DOE's evaluations of favorable conditions 960.4-2-1(b)(2) and 960.4-2-4(b)(2) (conditions related to climate changes and resultant effects on the geohydrologic system) can be summarized as follows. First, a return to a pluvial period in 10,000 years is a plausible scenario. Second, climatic changes resulting in pluvial conditions during the Quaternary probably had the following effects on the hydrologic system: increased recharge, increased elevation and gradients of the water table, upgradient shifts in discharge points and changes in surface-water drainage systems. While quantitative estimates of the size of these effects are preliminary and thus subject to debate, the existing evidence is such that the DOE concluded that favorable conditions 9609.4-2-1(b)(2) and 960.4-2-4(b)(2) are not present at the site. Therefore, it is reasonable to conclude that future climatic changes and resultant geohydrologic effects will negatively affect the groundwater travel time to the accessible environment.

In the DOE's conclusion relative to this potentially adverse condition (paragraph 3, page 6-202) it is indicated that expected climate changes during the next 10,000 years are not likely to significantly affect the hydraulic gradient, hydraulic conductivity, effective porosity or water-table levels. Preliminary modeling results by Czarnecki (1984) suggest that water-table elevations within the Alkali-Flat Furnace Creek Basin may have increased by as much as 130 meters during maximum pluvial conditions (page 6-199, paragraph 3). The existing flow path through the unsaturated zone varies from approximately 150 to 300 meters (page 6-141). A reduction of 130 meters in this flow path would significantly reduce groundwater travel times even under a matrix flow only scenario.

Also, in the DOE's conclusion relative to this potentially adverse condition it is indicated that expected increases in precipitation may increase the flux in the matrix of the unsaturated zone at Yucca Mountain, but because the present day matrix flux is expected to be very small, any accompanying increase in the absolute rate of radionuclide transport to the accessible environment would be insignificant. Even if present day matrix flux is expected to be small it does not necessarily follow that future increases in precipitation will have an insignificant effect on absolute rate of radionuclide transport. First, there is uncertainty in the amount of present day flux (see previous comments on Section 6.3.1.1.5). Second, work by Czarnecki (1984) indicates that a two-fold increase in precipitation would result in an increase in recharge by a factor of approximately 14. Therfore, it could be interpreted that the geohydrologic

system is such that the effects of small changes are magnified in terms of absolute increases particularly if a transition from matrix to fracture flow occurs.

The DOE's conclusion that this potentially adverse condition is not present appears to be based on calculations by Sinnock et al. (1984). These calculations appear to be the only analysis of the effect of increased flux on radionuclide transport available to date. Based on this work the DOE has concluded that even for fluxes through the host rock that are many times that of the present, the proposed EPA-allowed radionuclide release limits to the accessible environment in 10,000 years would be met. However, bounding estimates of radionuclide releases provided by Sinnock et al. (1984) rely explicitly on geochemical retardation rather than travel times in order to meet the proposed EPA release rates under a scenario of increased recharge resulting in fracture flow. Review of site geochemistry indicates that this reliance on geochemical retardation under this scenario may not be warranted (refer to geochemistry comments).

It can be concluded that the evidence presented in the draft EA related to geohydrologic effects resulting from future climatic changes does not adequately support the DOE's conclusion that this potentially adverse condition is not present. This conclusion is consistent with the DOE's findings on favorable conditions 960.4-2-1(b)(2) and 960.4-2-4(b)(2). The DOE's finding implicitly relies on geochemical retardation and that reliance may not be warranted.

6-85

Section 6.3.1.5, Erosion, Page 6-204

The DOE has not completely considered the available data and alternative interpretations of Quaternary geologic processes and features (such as erosion rates) at Yucca Mountain in its evaluation of the erosion guidelines. Erosion rates at Yucca Mountain are important because in portions of the repository block the proposed repository envelope is within 30 meters of the 200 meter overburden disqualifying condition for erosion (960.4-2-5(d)).

A comprehensive analysis of Quaternary geologic processes operating in the Yucca Mountain geologic setting is required for the DOE to evaluate the following postclosure guidelines on erosion: 960.4-2-5(a), 960.4-2-5(b)(2) and (3), and 960.4-2-5(c)(1) and (2). The draft EA provides data and interpretations from only two sources from which only three measured rates of stream incision are used in the assessment of postclosure erosion rates at Yucca Mountain. Many more data and interpretations are available for the rates of geologic processes applicable to the Yucca Mountain geologic setting that have been utilized by the DOE.

Erosion rates are of significance in the Yucca Mountain geologic setting for at least three reasons: 1) the repository is sufficiently shallow as to be subject to concern for exhumation; 2) rates of erosion are highly variable in arid climates (annual precipitation is low, but often comes in pulses and results in flash flooding; and erosion is most effective on steep slopes and in washes, both of which are present at the site); and 3) the host rock for the repository (Topopah Spring Member) is exposed on both the east side of Yucca Mountain where it outcrops in Abandoned Wash above the eastern margin of the proposed repository, and on the west side, and, therefore is currently subject to erosion. The presentation of erosion rates at Yucca Mountain in the draft EA does not consider these processes which are present at Yucca Mountain (the data used were not collected from Yucca Mountain itself). Additional data from Yucca Mountain and other areas in the Southern Great Basin would provide for the evaluation of uncertainties and alternative interpretations as they are addressed under the guideline conclusions.

The DOE should consider additional and alternative interpretations of Quaternary geologic processes and features in the Yucca Mountain geologic setting and then re-evaluate the appropriate guidelines on erosion in light of these findings.

6-86

Section 6.3.1.5.2, Data Relevant to the Evaluation, Page 6-204, Paragraph 3

The overall analysis of Quaternary features and processes, including the stratigraphic units, climatic fluctuations, and erosional history, is based on the views of the authors of two references (predominately by personal communications). A comprehensive literature search could support the interpretations being suggested and would also acknowledge potential alternative hypotheses. As presented in the draft EA, the analysis is incomplete and does not aequately support the preliminary conclusions.

6-87

Section 6.3.1.5, Erosion, Page 6-210, Paragraph 3

Incision rates presented in this section are based on only three reported measurements. If more data are available they need to be presented and used in the evaluation. An erosion rate based on three measurements can, at best, be considered speculative, and not an adequate basis for decisions concerning the integrity of the proposed site.

The DOE should consider incorporating other available data in their analysis of erosion rates at Yucca Mountain and qualifying their conclusions based on the data used.

6-88

Section 6.3.1.7.3, Favorable Condition, Page 6-222

The DOE has indicated its concern for potential hydrothermal activity and its effects on the movement of groundwater. Its elimination of the Wahmonie site was because, among other reasons, "...local surface deposits from recent warm springs indicate upward seepage of groundwater, possibly from great depths," (page 2-14). The DOE has also indicated that the highest probability of basalt volcanic activity is 4.7×10^{-4} per 10,000 years (page 6-222). This exceeds the requirements for potential repository disruption. There is evidence of elevated water temperatures in boreholes surrounding Yucca Mountain within the geologic setting (page 3-22) as well as evidence of earlier hydrothermal systems below the host rock at Yucca Mountain (page 6-216). Trench work adjacent to Yucca Mountain also shows evidence of travertine and opal (potential hot spring deposits) in faults cutting alluvial sediments (NRC staff trip report, Rice, 12/28/84) suggesting that Yucca Mountain may have been more recently subjected to hydrothermal activity.

In higher temperature water, waste container integrity may decrease. The solubility of some radionuclides (as well as sorbing zeolites) increases within this higher temperature environment. This would indicate that the upward movement of hydrothermal solutions, induced by magmatic activity, may have adverse impacts on radionuclide isolation at Yucca Mountain.

It is suggested that the potential for development of hydrothermal systems be evaluated with existing data and applied to this favorable condition guideline.

6-89

Section 6.3.1.7.3, Favorable Conditions, Page 6-222, Paragraph 3

No source for the "mean" probability for basalt volcanic disruption of the repository is given. In Crowe et al. (1982), data and results indicate a wide range of probabilities, many of which appear to exceed the "1 chance in 10,000 (10^{-4}) during the first 10,000 years after closure" which is the threshold value for the favorable condition. The DOE should consider indicating how the "mean" value was derived and what the actual value is and why the mean value would be appropriate in addressing this guideline.

6-90

Section 6.3.1.7, Potentially Adverse Conditions, Page 6-224, Continuing Paragraph

The draft EA states that the lack of fault scarps on or near Yucca Mountain that are demonstrably younger than 40,000 years indicates that there have been

no repeated normal movements on faults in the vicinity. As stated in the SAIC technical report (1984), fault plane solutions for the central and western portions of the Basin and Range Province show varied distributions of pure normal, oblique normal, and strike-slip solutions. The SAIC report also states that the nature of the motion on the fault will influence the likelihood that a large scarp is generated by a large earthquake.

It is suggested that the DOE consider evidence of all fault displacements (in addition to normal displacements) when addressing the fault activity in the last 40,000 years on or near Yucca Mountain.

6-91

Section 6.3.1.7.4, Tectonics, Potentially Adverse Conditions, Page 6-226, Paragraph 2

See detailed comment 3-9.

6-92

Section 6.3.1.7.4, Potentially Adverse Conditions, Page 6-226, Paragraph 3

This paragraph states that a preliminary conclusion could be made that the north-trending faults at Yucca Mountain should be considered potentially active. This conclusion is in contrast to assumptions made elsewhere in the draft EA when addressing seismic impacts on the site.

The evidence that suggests faults at Yucca Mountain are active is based on the following: Healy et al. (1982) report a least principal horizontal stress direction of N70W ± 10 degrees based on hydraulic fracturing techniques, "...stress measurements suggest that the rocks may be extensionally stressed to near the point of failure along certain faults."; various authors have concluded that faults in the Yucca Mountain area, which have north to northeast trend, are potentially active based on the current stress regime, orientation of the faults, and type of faults (Rogers et al., 1983 and Healy et al., 1982); and "Although none of these data or arguments are conclusive, a combination of the stress data, the historical seismicity of the region, and the indication from current seismicity that fault activity depends more on fault orientation than on fault age suggests that there is a potential for significant seismicity on faults at or near Yucca Mountain (Rogers et al., 1983), despite geologic evidence of general long-term tectonic stability in the last 10 million years (personal communication from W. Carr, USGS, 1984)." (page 6-227, paragraph 1).

The DOE makes the assumption that the faults at Yucca Mountain are not active when addressing the calculation of maximum peak expected ground acceleration at the site. The consequences of doing this result in lower estimates of acceleration than if the faults were assumed to be active. The DOE states that

this maximum peak acceleration is 0.4g assuming a magnitude 6.8 earthquake were to take place on the Bare Mountain fault (located 14 kilometers west of the proposed site). The Solitario Canyon fault is located within a kilometer of the site and is approximately the same length and orientation as the Bare Mountain fault. If the faults at Yucca Mountain are considered to be active, then the Solitario Canyon fault would be potentially active. Assuming a magnitude 6.8 earthquake were to occur on the Solitario Canyon fault, the peak deterministic ground acceleration at the site could exceed 0.4g. In addition, the Ghost Dance fault, which intersects the proposed repository, would also be considered active. An earthquake on the Ghost Dance fault would most likely produce accelerations in excess of 0.4g at the repository level.

The DOE should consider re-evaluating the nature of activity of the Yucca Mountain faults when addressing the guidelines that require estimates of ground acceleration at the site. The DOE should also be consistent throughout the final EA when discussing the nature of fault activity in the geologic setting of Yucca Mountain.

6-93

Section 6.3.1.7.4, Tectonics, Potentially Adverse Conditions, Page 6-229, Table 6-33

The nature of uplift and subsidence in the Yucca Mountain region must be accurately assessed in order to determine its impacts on rates of erosion. Erosion is a potentially adverse geomorphic process affecting the isolation of waste at Yucca Mountain.

Table 6-33 shows vertical tectonic uplift rates for various locations in the Great Basin. One location is the "Sierra Nevada-Owens Valley-White-Inyo Mountains", with a 0.4m/1000 yr vertical rate. The reference listed for this vertical rate is an "average of 9 estimates from the literature". This is difficult to evaluate because it is not clear why the Sierra Nevada and the White Mountains are grouped together, and the data for the estimate are not presented. The Sierra Nevada and the White Mountains are separate blocks, and should be considered as separate entities in the tectonic analysis. Although 0.4m/1000 yr may be a good approximation for the Sierra Nevada, Huber (1981) estimates an uplift rate of 0.3m/1000 yr for the Sierra Nevada at 38 degree north latitude, while the White Mountains have been estimated to have an uplift rate of 0.8m/1000 yr (Wallace, 1978) at the northern end.

The NRC suggests that the DOE present the Sierra Nevada and White Mountains vertical tectonic rates separately and consider how this may effect erosion rate estimates at Yucca Mountain.

6-94

<u>Section 6.3.1.8.2, Data Relevant to the Evaluation, Page 6-236, Paragraph 2</u>

Natural resource exploration has been banned within the Nevada Test Site for the last 30 years. Because of this, the analysis of past and present mines and surface workings in the region may not be a good indicator of economic potential. This is particularly true since "Geophysical, geological, and geochemical data, as well as historical background, make Wahmonie (on the NTS) a prime exploration target for precious metals." (Quade and Tingley, 1983). The NRC suggests that the discussion in this section place the data used in the survey by Bell and Larson (1982) in the proper context and explain how it impacts the conclusions for each applicable guideline in this section.

6-95

<u>Section 6.3.2, Postclosure System Guideline, Pages 6-246 through 6-252</u>

It is stated in the draft EA (page 6-246, paragraph 3) that the waste-disposal system consists of a natural-barrier subsystem (the geologic setting at the site) and an engineered-barrier subsystem (the waste package and the mined repository). However, the definition of the engineered-barrier system as stated in 10 CFR 60.2 includes the waste packages and the underground facility (underground facility does not include shafts, boreholes and seals). The DOE should use the 10 CFR 60 definition of the engineered-barrier system in the final EA and base the evaluations of the environmental impacts on that definition.

6-96

<u>Section 6.3.2, Postclosure System Guidelines, Pages 6-246 through 6-252</u>

The preliminary analysis of the postclosure system guideline presented in this section states that the results may be bounding estimates because of the conservative assumptions made on page 6-249. The conclusion that Yucca Mountain will meet the requirements of the proposed EPA 40 CFR 191 and NRC 10 CFR 60, is based on these proposed conservative assumptions. The analysis and in turn the conclusion does not reflect the treatment of uncertainties affecting most of the subsystem parameters. Since the analysis is based on the main assertion that the groundwater travel time within the unsaturated rocks of Yucca Mountain is sufficiently large that almost <u>NONE</u> of the radionuclides will be released to the accessible environment within the first 93,000 years after closure (see Tables 6.44 and 6.45), an explanation and justification should consider the uncertainties of the flow of water through the unsaturated rocks and the impact on the calculations of groundwater travel time under postclosure conditions.

6-97

Section 6.3.2.2.1, Quantitative Analyses, Page 6-248, Paragraph 1

The release rates calculated here are non-conservative because at the present, there is no indication that spent fuel will be reprocessed into a borosiliciate glass waste form. As noted earlier in detailed comment 6-67, volatile radionuclides may be concentrated in the voids surrounding the UO_2 in the fuel rods. The solubility would therefore not be limited by either the UO_2, or bulk waste dissolution rate of 10^{-4} moles/l. Results based on a bulk dissolution rate would give lower values of release (curies) than those based on the solubility of the radionuclide. The DOE should re-evaluate the release rate over the range of uncertainties and present a more conservative estimate of the site's likelihood to meet the EPA release limits.

6-98

Section 6.3.3.1.2, Data Relevant to the Evaluation, Page 6-253, Paragraphs 1 and 2; Section 6.3.3.3.3, Favorable Conditions (2), Page 6-279

The DOE concludes that surface facilities will be located in areas subject to only minor and infrequent flooding and that this flooding can be mitigated during repository construction and operation. Based on this conclusion, the draft EA finds that (1) surface characteristics that could lead to the flooding of surface facilities are not present at the site (Potentially Adverse Condition 960.5-2-8) and (2) there is the absence of surface water systems that could potentially cause flooding of the repository (Favorable Condition 960.5-2-10).

Review of the draft EA and supporting flood analyses (Squires and Young, 1984) presented in the draft EA indicates that the information presented is not adequate to support the conclusions; the DOE acknowledges that a potential for site flooding exists and that engineering measures will be required for flood protection. The DOE bases its findings with respect to the guidelines on the ability to implement flood protection measures which mitigate flood effects. The guidelines, however, address the question of site flooding, rather than the feasibility of engineering measures to control flooding. Hence, it appears that consideration of potential flooding of surface facilities at this site may alter the conclusion that the favorable condition is present and that the unfavorable condition is not present. The DOE should either reconsider the findings associated with these guidelines, or support the conclusions with further documentation and analyses that clearly show that site flooding will not occur.

6-99

Section 6.3.3.1.2, Surface Characterization, Data Relevant to the Evaluation, Page 6-253

The flood analyses and data presented in the Squires and Young (1984) report do not adequately describe several characteristics which could lead to the flooding of surface facilities. Based on an examination of the location of proposed facilities (Figure 5-3) and topographic maps of the area, it appears that the surface facilities will be located in an area subject to sheet flow and located in the floodplain of Drill Hole Wash.

It is concluded in the draft EA that surface facilities will be located in areas subject to flooding and that mitigating measures can be easily implemented during repository construction and operation. Based on the information provided, it is difficult to evaluate the potential for flooding at the site and the relative ease with which mitigating designs can be employed. It appears that the conclusions are not supported by the available information and data and that the following information should have been considered in reaching conclusions:

1. Peak water levels and velocities resulting from the peak flood flows at the proposed site.

2. Size and extent of diversion channels, if necessary, that will be needed in the surface facilities area.

3. Erosion protection, if necessary, that will be used to prevent erosion to drainage channels, embankments, or other surface facilities.

4. Debris control measures that will be used to minimize the effects of stream transport of large quantities of debris expected during major floods.

5. Preliminary location of bridges, culverts, and other site features, and the potential for backwater effects caused by flow constrictions, especially when clogged by debris.

Based on the information provided regarding flood flows and velocities, it appears that it may be no simple task to design flood protection and diversion channels at the proposed location due to the high velocities produced by major floods and the large quantity of debris which would be transported. The high flow velocities could cause considerable erosion, and the debris transport could cause flooding problems due to clogging and channel cross-section reduction. These factors should be discussed in the EA along with appropriate design measures that could be implemented.

6-100

Section 6.3.3.1, Surface Characteristics, Pages 6-253 through 6-257

The use of regional maximum floods, as discussed in the Squires and Young (1984) report on flooding, does not necessarily constitute a conservative design basis for protection of surface facilities during repository operation. To protect structures and facilities and to prevent releases of radioactive materials, it is suggested that the Probable Maximum Flood (PMF) be adopted as the design flood event.

The development of regional maximum floods, which are estimated by enveloping the maximum historical discharges of regional streams, present some problems which may be difficult to account for. These problems include the following:

1. The historical flood may have been produced by a stream with basin characteristics that do not produce floods as large as those characteristics attributable to the basin in question (basin slope, time of concentration, storm orientation, etc.).

2. Rainfall-runoff relationships may be different from one stream to another.

3. Historical discharges may be underestimated due to eroded cross-sections at the time of the flood peak, or stream gauge malfunctions.

The PMF has gained widespread acceptance as a design basis flood for the protection of important structures and facilities. In fact the PMF was chosen as the design basis flood for each of the other 8 proposed repository sites. The PMF is widely used by other state and federal agencies, and methods for development of reasonable and/or conservative PMF estimates are readily available from the Corps of Engineers, Bureau of Reclamation, and Soil Conservation Service. The data required to estimate the PMF are available from US Weather Bureau rainfall estimates and from topographic maps, such that conservative PMF estimates can be easily derived for small drainage basins such as those at this site.

It should be pointed out that the regional maximum floods that were estimated for the various streams at this site may correspond very closely, or even exceed, PMF estimates. However, based on recent flood studies in the Western United States, the NRC has found that these flood estimates are generally less than PMF estimates. In order to verify the adequacy of the flood data and the degree of conservatism present, the flood peaks for each stream should be compared with PMF estimates for that stream. If the PMF exceeds the regional maximum flood, the PMF should be used for design purposes.

6-101

Section 6.3.3.2.2, Data Relevant to the Evaluation, Pages 6-258 through 6-262

The draft EA does not provide an adequate basis to conclude that the rock properties data and analyses utilized in evaluating the pre-closure siting guidelines on rock characteristics can be used with sufficient confidence.

It is stated in the draft EA (page 6-262, first sentence) that, "The degree of confidence in both the existing data for the site and the analyses made with the data is considered more than sufficient for a preliminary evaluation against the preclosure guideline on rock characteristics." However, the draft EA does not adequately support this conclusion. As stated on page 6-261, paragraph 4 of the draft EA, many of the engineering properties of the Topopah Spring welded tuff unit (host rock) have been assumed to be similar to those of the Rainier Mesa Grouse Canyon welded tuffs (G-tunnel). Although some similarities between the two units may exist (Tillerson and Nimick, 1984, page 89), a comprehensive analysis of similarities and dissimilarities for a wide range of physical properties has not been presented in the draft EA. The final EA should present detailed comparisons of the age and mineralogy of the respective formations, individual mechanical properties and rock mass characteristics (e.g. jointing, lithophysae content, etc.) to adequately support the data assumptions used for evaluating pre-closure siting guidelines on rock characteristics (10 CFR 960.5-2-9). (Also see detailed comment 6-74(2)).

6-102

Section 6.3.3.2.3(1), Favorable Conditions, Pages 6-262 through 6-264

See detailed comment 6-75.

6-103

Section 6.3.3.2.3(2), Favorable Conditions, Pages 6-264 through 267

The conclusion that the underground facility at Yucca Mountain will require minimal support is not adequately supported by the evaluation of the data and analyses presented in the draft EA. In addition, the limitations of these evaluations have not been fully described. The final EA should take into account the following comments and re-evaluate its finding on this favorable condition.

1. The estimated quality of the host rock is poor. In drill hole USW G-4, the best core index from the repository horizon is 72% (Dravo 1984, page 19) which translates into an estimated Rock Quality Designation (RQD) of

28%. This low level of Rock Quality Designation (RQD) would tend to indicate the need for more than minimal support for the underground openings.

2. The concepts for the underground-support system for repository openings described in the draft EA (page 6-266, paragraphs 2 and 3) appear to be largely based upon rock mass classifications described in Dravo (1984). Reliance on rock classification systems may not be appropriate because the classification systems are subjective and their reliability has not been adequately verified by mining experience in the United States. The CSIR (Council for Scientific and Industrial Research) and NGI (Norwegian Geotechnical Institute) empirical classifications are both based on data from single tunnels rather than intersecting grids of underground openings (e.g., mines and repositories). The application of the classification systems to evaluate the underground-support system is subject to additional uncertainties because of the following considerations.

   (i) Nearly all the joint characteristics data required to estimate rock classification ratings were obtained from only one on-site drill-hole (USW G-4) and other non site-specific data (Dravo, 1984, pages 18 and 32).

   (ii) Adequate documentation is not provided to support the magnitude of maximum and minimum stresses utilized in the classification scheme. The maximum stresses are assumed to be of the order of 6 to 8 MPa (Dravo, 1984, page 15). Based on a review of the information provided on page 10 of Healy et al. (1984), it appears that such an assumption may not be justified since reliable determination of the maximum horizontal stress at Yucca Mountain has not yet been made, and

   (iii) The effect of lithophysae was not considered.

3. The draft EA states on page 266, paragraph 3 that "The expected support requirements include 2.5 to 3.0 m long fully grouted rock bolts." However these rock bolts will be subjected to high temperatures in the repository after waste emplacement, and the differences in expansion of the bolt, rock and grout may cause the bond between the rock and the bolt to be broken (USNRC, 1984, page 56). Any necessary changes in the design of the underground support system as a result of the consideration of this possibility should be described, and the resulting effects on the evaluation of this favorable condition should be discussed in the final EA.

4. It is stated in the draft EA on page 266, paragraph 4, that ground support requirements for a repository at Yucca Mountain are considered minimal in comparison with the ground support used in similar underground construction projects. However, it appears that the draft EA has not considered the following factors in arriving at its conclusion:

(i) Rock mass physical, mechanical and thermal behavior is mainly controlled by the discontinuities (fractures, lithophysae, etc.) and not by the matrix properties (Hoek and Brown, 1980; Goodman, 1980). Since the proposed host rock is highly fractured, an extrapolation of excavation experience of the G-tunnel or the weapons testing tunnels to the highly fractured, lithophysal Topopah Spring may not be fully valid. The mechanical properties of the two horizons may be significantly different. (also see detailed comment 6-74(2)).

(ii) The excavations at the G-tunnel and the weapons testing tunnels were not subjected to heat. Moreover, the thermal effects are not fully known at present and may be a major consideration in the final repository design.

5. In paragraph 5 on page 6-266, the draft EA states that the underground support requirements for a repository are considered to be minimal in comparison with those used for civil excavations. However, it should be noted that the repository openings have to be maintained in a stable condition with minimal maintainance for up to 90 years for possible retrievability, while accommodating thermal stresses. These requirements may not apply to most civil excavations. The EA should focus on long-term stability requirements because larger support safety factors in repository design are likely to be required than those used for many other temporary excavations.

Based on the above discussion, the relevant data should be further studied and the conclusion for the presence or absence of the favorable condition should be re-evaluated.

6-104

<u>Section 6.3.3.2.4(1), Potentially Adverse Conditions, Pages 6-267 through 6-268</u>

See detailed comment 6-75.

6-105

<u>Section 6.3.3.2.4(2), Potentially Adverse Conditions, Pages 6-268 through 6-270</u>

The draft EA (page 6-268, last paragraph) states that "There are no indications that the in-situ conditions and characteristics would require engineering measures beyond reasonably available technology. The shafts and underground facility can be constructed using proven technology and standard methods. Therefore, the evidence indicates that this potentially adverse condition is not present at Yucca Mountain." This conclusion is inadequately supported in the draft EA and may not be based on a realistic assessment of the potential underground conditions and the reasonably available technology. For example:

loading of rock around waste canisters will be much greater than that used for the heater tests.

With regard to presence of minerals in the host rock that are susceptible to thermally induced dehydration/hydration, the draft EA suggests the presence of less than 2 percent of smectites and zeolites (page 6-271, paragraph 4). However, no information is provided on whether these minerals are interspersed in the rock matrix or occur within fractures and joint infillings. If indeed these minerals are found in rock joints, they may undergo contraction/expansion under the influence of heat from the waste or due to seepage of even minor quantities of fluids that may be present. This could lead to loosening of the rock blocks and ground instability. Therefore, in the absence of detailed information on the potential for hydration and dehydration of minerals, adequate allowances for their potential effect on repository operation and waste retrieval should be made.

It is recommended that the draft EA discuss some of the anticipated problems during waste retrieval operations and the mitigation alternatives. Some of the likely scenarios (USNRC, 1984) worthy of consideration include:

1. The procedure for retrieving waste canisters out of long horizontal holes.

2. Retrieval operations for breached canisters .

3. Retrieval operations, if the preclosure backfilling option is exercised.

4. Retrieval operations in the event of hole liner failure (due to faulty liner installations, corrosion, or borehole decrepitation), especially for long horizontal emplacement holes.

5. Retrieval operations near cave ins, roof falls, or floor heave.

6-108

Section 6.3.3.4.3, Favorable Condition, Page 6-286, Paragraph 2

See detailed comment 6-92.

6-109

Section 6.3.3.4.4, Potentially Adverse Conditions, Pages 6-287, Paragraph 3 and 6-288, Continuing Paragraph

See detailed comment 6-90.

6-110

Section 6.3.3.4.4, Potentially Adverse Conditions, Page 6-289, Paragraph 1

The NRC is in the process of preparing a generic technical position on seismotectonic evaluation methods. This paper will cover the types of seismotectonic investigation and evaluation methods which will need to be conducted for a repository. In addition, the NRC will need to separately review the types of structures to be constructed, their functions, and the consequences of potential accidents before the actual design requirements can be determined. At the present time, it is premature to state that the design requirements for nuclear power plants are the same as those required for a waste repository. The DOE should consider stating at this time that the design requirements of structures important to safety will comply with 10 CFR 60 and appropriate EPA regulations.

6-111

Section 6.3.3.4.5, Disqualifying Condition, Page 6-291, Paragraph 2 and Page 6-292, Paragraph 1

See detailed comment 6-92.

6-112

Section 6.4.1, Preclosure Radiological Safety Assessments for Yucca Mountain, Page 6-300

The source term presented for routine operational releases is only one of the source terms expected from the various operations indicated in the facility description, Section 6.4.1.2.2. There will be other source terms associated with cleaning and decontamination of shipping casks, with fuel disassembly and pin consolidation, with the handling of DHLW containers and TRU packages, with the processing of radioactive liquid wastes, and with the management of the low-level wastes generated on site. Spent fuel when removed from the reactor has a layer of radioactive matter on its outer surfaces that provides a source term for fuel handling operations even if no leaky fuel pins are present. Leaky fuel pins are present in most spent fuel pools and must be disposed of also. In the contamination found in spent fuel pool water the predominant radionuclides are usually Cesium-134, Cesium-137, Cobalt-58, Cobalt-60, and Ruthenium-106, depending upon the history of the spent fuel and the pool water. It is suggested that the final EA present an assessment that addresses the source terms originating in the various cleaning, handling, packaging, and processing operations that might be conducted in the Waste Handling and Packaging Facility, the expected emissions after cleanup in the HVAC, and any other gaseous waste handling systems, and the resulting radiological impacts on the environment (US NRC, 1980).

6-113

Section 6.4.2, Preliminary Analysis of Postclosure Performance, Pages 6-303 to 6-325

The preliminary performance analyses described in the draft EA used simple models of failure mechanisms (degradation of containers by uniform corrosion) and radionuclide release (congruent dissolution of the waste and solubility-limited transfer of radionuclides to the rock) in the expected failure sequence. In the performance analyses, inadequate consideration is given to the uncertainties in the models. Furthermore, available information that could bear on the evaluation of these uncertainties has been inadequately considered.

The limitations of the uniform corrosion and congruent dissolution modeling assumptions have been addressed in Comments 6-114, 6-118, and 6-119 . The performance analyses have not incorporated the uncertainties stemming from those limitations in the results. Moreover, aside from alternate corrosion failure modes, there are other failure scenarios--e.g., premature failure due to flawed containers; damage during the preclosure period--that are not considered in the performance analyses. The combined effects of expected failure scenarios and disruptive events also create uncertainties that are not addressed in the draft EA. Furthermore, the effects of uncertainties in repository conditions as a result of waste emplacement (e.g., temperature, radiation field) on corrosion and other aspects of waste package performance are not considered, nor are available studies of such effects, such as a thermal analysis reported by Lawrence Livermore Laboratory (Stein et al., 1984), mentioned in the draft EA.

It is suggested that discussion of the performance analyses include recognition of the complex uncertainties associated with such analyses, and further, that a preliminary evaluation of those uncertainties, incorporating (or at a minimum, referencing) the approaches taken in relevant studies, be provided in the final EA.

6-114

Section 6.4.2.1.1, Engineered - Barrier Subsystem, Page 6-306, Paragraph 3

The draft EA states that preliminary tests performed by the DOE for localized and stress-assisted forms of corrosion on austenitic stainless steels (the reference container materials) have not yet shown evidence of the susceptibility to these forms of attack. On this basis, the DOE states that the expected failure mode is uniform corrosion. However, the choice of uniform corrosion as the expected container failure mode, based on the limited available corrosion data, may result in significant overestimates of the waste package lifetime. Various DOE investigators have stated, "The limiting use conditions of 304L stainless steel are rarely general corrosion wastage, but

rather occur by much more rapid penetration via localized or stress-assisted forms of corrosion" (McCright et al., 1983, Juhas et al., 1984).

Experimental evidence exists to show that sensitized Type 304L stainless steel is susceptible to intergranular stress corrosion cracking when exposed to boiling deionized water in the presence of a gamma irradiation field (JAERI, 1982). Another study showed that Types 304L and 321 stainless steel, sensitized at 620°C for 24 hours, also suffer intergranular stress corrosion cracking when exposed to deionized water at 100, 150, 200, 250, and 300°C (Fujiwara et al., 1982). The maximum crack depths were observed at 200°C.

In addition to possible intergranular stress-corrosion cracking, described above, there is also a potential for transgranular stress-corrosion cracking in water/steam environments containing chloride ions. Two specific cases involve Type 304 stainless steel in which chloride in the water is concentrated due to evaporation (ASTM, 1960). Although the stainless steels contained higher levels of carbon than that expected in the reference Type 304L grade to be used for the waste container, it is unlikely that the lower carbon level will inhibit transgranular cracking, i.e., all grades of austenitic stainless steel, whether they are low-carbon or stabilized grades, could fail by transgranular stress-corrosion cracking if the stress, chloride, and oxygen levels are sufficiently high.

Based on the above discussion there appears to be a strong potential for both intergranular and transgranular stress-corrosion cracking. Techniques to minimize the sensitization of the stainless steel may minimize the likelihood of the former but would be ineffectual in preventing the latter.

The presence of crushed tuff packing material (if used) or adjacent engineered barriers may give rise to crevice-type conditions which would enhance the probability of localized corrosion failure. Since the reference waste package lifetime (3,000 years) is used as the starting time for radionuclide migration, use of an overly optimistic lifetime in this preliminary performance analysis would result in a non-conservative release rate from the engineered barrier system.

In evaluating the performance of fabricated metal components, the performance of weld metal is often variable and frequently inferior to that for base metal. The draft EA contains very few references to data on weld metal corrosion behavior. Such information should be addressed in assessing waste package performance and containment time.

In order to fully assess the impact of the uncertainties in the package lifetime, consideration should be given to a more conservative assessment of the waste package lifetime based on localized forms of corrosion failure, at least until more conclusive experimental evidence of long-term performance is obtained.

6-115

Section 6.4.2.1.2, The Natural-Barrier Subsystem, (the Geohydrologic Setting), Page 309, Continuing Paragraph

Equation 6-6 and the subsequent discussion is based on equilibrium sorption conditions and porous flow through the rock matrix. The governing equations for radionuclide retardation in the unsaturated zone and for fracture flow may differ from those presented. See detailed comment 6-58. The estimates presented here are non-conservative. The DOE should consider a more conservative estimate in this evaluation

6-116

Section 6.4.2.2, Preliminary Performance Analyses of the Major Components of the System, Page 6-310, Paragraph 1

In the first sentence of this paragraph it is stated: "In low-salinity, aerated water with a nearly neutral pH, the uniform-corrosion rate for 304L stainless steel appears to be less than 0.1 ml/yr, or about 2.54×10^{-4} cm/yr..."

A potential problem here is that the ground water that corrodes waste packages may not necessarily be "low-salinity, aerated water with a nearly neutral pH,..." Due to evaporation and/or local transient boiling, ground water near waste packages during the post-closure period may pick up significant quantities of dissolved solids. These dissolved solids, in turn, might affect the groundwater pH (e.g., increase them) so that they are no longer "nearly neutral." Ground water that contains comparatively high concentrations of dissolved solids could induce more rapid corrosion of waste canisters. Therefore, the assumption that groundwaters which contact waste canisters are "low-salinity, . . . with a nearly neutral pH, . . ." may be non-conservative.

6-117

Section 6.4.2.2, Preliminary Performance Analyses of the Major Components of the System, Page 6-311, Paragraph 2

In this paragraph it is stated: "Wilson and Oversby (1984) report the initial results from tests of spent fuel cladding containment. Solution concentrations indicate a uranium-release rate of 5×10^{-6} per year from bare fuel (pellets from a 13 cm (5-in.) long rod segment) submerged in 250 ml of deionized water and a release rate of 2×10^{-5} per year for plutonium."

These statements refer to tests performed with deionized water, but no mention is made of the temperature(s) at which the tests were conducted. Also, using results from tests with deionized water may be inappropriate, because it is

6-115

<u>Section 6.4.2.1.2, The Natural-Barrier Subsystem, (the Geohydrologic Setting), Page 309, Continuing Paragraph</u>

Equation 6-6 and the subsequent discussion is based on equilibrium sorption conditions and porous flow through the rock matrix. The governing equations for radionuclide retardation in the unsaturated zone and for fracture flow may differ from those presented. See detailed comment 6-58. The estimates presented here are non-conservative. The DOE should consider a more conservative estimate in this evaluation

6-116

<u>Section 6.4.2.2, Preliminary Performance Analyses of the Major Components of the System, Page 6-310, Paragraph 1</u>

In the first sentence of this paragraph it is stated: "In low-salinity, aerated water with a nearly neutral pH, the uniform-corrosion rate for 304L stainless steel appears to be less than 0.1 ml/yr, or about 2.54 x 10^{-4} cm/yr..."

A potential problem here is that the ground water that corrodes waste packages may not necessarily be "low-salinity, aerated water with a nearly neutral pH,..." Due to evaporation and/or <u>local</u> transient boiling, ground water near waste packages during the post-closure period may pick up significant quantities of dissolved solids. These dissolved solids, in turn, might affect the groundwater pH (e.g., increase them) so that they are no longer "nearly neutral." Ground water that contains comparatively high concentrations of dissolved solids could induce more rapid corrosion of waste canisters. Therefore, the assumption that groundwaters which contact waste canisters are "low-salinity, . . . with a nearly neutral pH, . . ." may be non-conservative.

6-117

<u>Section 6.4.2.2, Preliminary Performance Analyses of the Major Components of the System, Page 6-311, Paragraph 2</u>

In this paragraph it is stated: "Wilson and Oversby (1984) report the initial results from tests of spent fuel cladding containment. Solution concentrations indicate a uranium-release rate of 5 x 10^{-6} per year from bare fuel (pellets from a 13 cm (5-in.) long rod segment) submerged in 250 ml of deionized water and a release rate of 2 x 10^{-5} per year for plutonium."

These statements refer to tests performed with deionized water, but no mention is made of the temperature(s) at which the tests were conducted. Also, using results from tests with deionized water may be inappropriate, because it is

possible that the per-year uranium-release rate would be significantly different (either faster or slower) if significant amounts of dissolved silica were present in the ground water. Ground waters at Yucca Mountain are saturated with silica, and the presence of dissolved silica may tend to diminish the rate of release of uranium by promoting the precipitation of $USiO_4$. On the other hand, some uranium might become attached to (sorbed by) easily transportable silica-rich colloids, and this might tend to increase the release rate of uranium.

6-118

Section 6.4.2.2.2, Release Rate From the Engineered-Barrier Subsystem, Pages 6-311 and 6-312

The draft EA estimates of radionuclide release are based on the assumption of congruent leaching of the spent fuel UO_2 matrix, although it is acknowledged that some radionuclides may be released at rates larger than those based on simple UO_2 matrix dissolution (Woodley, 1983; Davies and Ewart, 1971). A more realistic calculation could be based on prototypic spent fuel leaching tests.

The equation M = FAS, where M is the rate of mass loss, F is the water flux, A is the area of the container normal to the flux, and S is the solubility limit for uranium, is used in the draft EA to calculate the uranium fractional release rate. In performing the calculation of the mass loss in flowing ground water, the DOE does not select the worst case values for F, A, and S, so there is considerable uncertainty in the calculated fractional release values. Recently, the value of F was cited to be about 8×10^{-3} m/yr (Sass and Lachenbruch, 1982), versus the 5×10^{-4} m/yr value cited in the draft EA.

The value of A in these calculations is assumed to be the vertical projection of the container. This is unlikely to be conservative because water will wet all surfaces. For the case of spent fuel disposal, a single canister may contain upwards of 1000 individual fuel rods. This would increase the total available surface area by a factor of 20 over that calculated for the assumed solid monolith.

Radionuclide solubilities are also subject to considerable uncertainty. The solubility of an individual element will be affected by the character of the solid phase, the presence of common ions and complexing ions, the pH, the Eh, the temperature, the presence of concentrated electrolytes, and radiolysis, which may increase the oxidizing nature of the environment.

Strickert and Rai (1982) measured the solubilities of two solid forms of Pu over a pH range from 4 to 8 and under oxidizing conditions. $Pu(OH)_4$ was found to have a higher solubility than crystalline PuO_2, and both forms exhibit a change in solubility of approximately 3 orders of magnitude in the pH range investigated. Solubilities for americium are ambiguous (Pigford et al., 1983) Measured solubilities of Am vary over eight orders of magnitude as the pH

changes from approximately 9 to 6 (Rai et al., 1983). Ogard et al. (1981) estimate that at pH 4 the solubility of uranium in deionized water may vary 10 orders of magnitude depending on whether conditions are oxidizing or reducing. Neptunium, like uranium, exhibits a wide range in solubilities depending on Eh and the crystallinity of solid NpO_2 (Pigford et al., 1983). Also, phases may exist that exhibit retrograde solubilities and the presence of colloidal species (Olofsson et al., 1982; Kim et al., 1984) may increase releases from the engineered barrier system (EBS).

Furthermore, the solubilities from thermodynamic data are subject to large uncertainties and are often inconsistent with experimentally determined solubilities. For example, it has been noted (Ogard et al., 1984) that it is not possible to predict with great confidence the solubilities of Pu or Am in ground water characteristic of Yucca Mountain.

The calculation of nuclide transport based on retardation factors that may not be accurately known also leads to uncertainties in the predicted transport times. The retardation factor depends strongly on the distribution coefficient, the ratio of the amount sorbed on the solid to the solution concentration; and the distribution coefficient depends strongly on the environment, i.e., temperature, groundwater composition, solution concentration, and pH. It is acknowledged in the draft EA (Section 6.4.2.2.2, p. 314) that there are uncertainties of up to two orders of magnitude in the experimentally measured distribution coefficients. Because the distribution coefficient is multiplied by the ratio of the bulk density to the porosity (which is roughly 10) in obtaining the retardation factor, a two order of magnitude difference in distribution coefficient becomes a three order of magnitude difference in retardation factors. For this reason, use of average distribution coefficients obtained under experimental conditions that may not represent the repository environment may lead to non-conservative prediction of transport times.

In summary, the selection of radionuclides, an estimate -- including uncertainties -- of the concentration of radionuclides in the EBS, and their release rates, are important in demonstrating the performance of the EBS. Particular consideration should be given to the impact of these uncertainties before arriving at a finding for the Post Closure Guideline 960.4-1.

6-119

<u>Section 6.4.2.2.2, Release Rates from the Engineered-Barrier Subsystem, Page 6-311, Paragraph 2</u>

The draft EA cites work by Wilson and Oversby (1984) on spent fuel leaching to show that fuel covered with partially breached Zircaloy cladding will meet the one part in 10^5 per year controlled release criterion. The analysis is preliminary and does not consider several problems. These include:

(a) Only releases of uranium and plutonium were addressed. Important radionuclides not addressed include technetium, iodine, and americium, and gaseous or volatile radionuclides which would be rapidly released upon failure of the cladding. This latter group of radionuclides includes ^{3}H, ^{36}Cl, ^{85}Kr, ^{222}Rn and ^{14}C.

(b) The Wilson and Oversby data were obtained at room temperature in deionized water. Solubilities of radionuclides may be much higher at elevated repository temperatures. Radiocolloid transport is also not considered.

(c) No consideration is given to the effects of pH on solubility and spent fuel leach rates. This is important in a tuff repository since the gamma radiolysis of air/water mixtures may produce nitric acid and significantly lower the pH of the repository water. A change in the spent fuel leaching mechanism is predicted if the pH falls below about four (Wang, 1981).

The discussion in the draft EA clearly shows the uncertainty associated with the likelihood of long-term congruent dissolution of spent fuel. The 180-day tests by Wilson and Oversby do not resolve this issue. It seems that longer term leaching data are required under prototypic conditions to determine whether congruent leaching is, in fact, probable. If it is, then estimation of long-term radionuclide release is simplified.

The problems and uncertainties mentioned here in relation to the analysis of long-term radionuclide release should receive particular consideration before a finding is made with respect to the Post-Closure Guideline (960.4-1).

6-120

Section 6.4.2.2, Preliminary Performance Analyses of the Major Components of the System, Page 6-312, Continuing Paragraph

In this text it is stated: "Available evidence suggests that the flux is less than 1 mm/yr and could be as low as 0.003 mm/yr (see detailed comments on Section 6.3.1.1). Taking the approximate midpoint value of this range, $F = 5 \times 10^{-4}$ m/yr, ..."

Assuming a flux of 5×10^{-4} m/yr may be non-conservative (see detailed comments 6-44 through 6-49).

6-121

Section 6.4.2.3.2, System Analysis Release Rate from the Engineered Barrier Subsystem, Page 6-312, Paragraph 1

The uncertainties in radionuclide solubilities are not discussed in the draft EA, Section 6.3.1.2. The large range of uncertainty in solubilities will affect these results, and should be considered in this section.

6-122

Section 6.4.2.2.2, Release Rate from the Engineered-Barrier Subsystem (Ground Water Travel Times), Pages 6-313 and 6-314

When the travel time through the Topopah Spring unit is calculated the flux is 0.5 mm/yr, which is one half of the 1 mm/yr flux used in the rest of the EA. A consistent value of flux should be used throughout the final EA to determine the travel time.

6-123

Section 6.4.2.2.2, Release Rate from the Engineered-Barrier Subsystem (Ground Water Travel Times), Page 6-313, Paragraph 1

This section discusses the method used to obtain estimates of groundwater travel times in the unsaturated zone for use in determining radionuclide release rates. According to the draft EA, "the moisture content is...the product of the effective porosity and the saturation; it is often taken as the analogue of effective porosity in partially saturated media because--when saturation is 100%--the two quantities, moisture content and effective porosity, are numerically equal."

This statement suggests that there has been inadequate consideration of alternative interpretations in the draft EA. According to Freeze and Cherry (1979), moisture content is equal to porosity for saturated flow. According to Corey (1977, page 42), effective porosity (n_e) is equal to one minus the residual saturation multiplied by the porosity, whereas moisture content is equal to saturation multiplied by porosity. Effective porosity for unsaturated flow generally is considered to be less than the total porosity due to water held on the surfaces of the particles by molecular forces. This water (residual saturation) generally does not take part in the movement of water through the unsaturated zone. The meaning used in the draft EA is not consistent with sources of information on unsaturated flow. Correct definition of parameters is critical to the travel time estimates presented in the draft EA because those estimates are based on specific values for these terms.

6-124

Section 6.4.2.2.2, Release Rate from the Engineered-Barrier Subsystem (Reference Travel Times), Page 6-314, Paragraph 1

This section presents a range of travel times for flow to the accessible environment. According to the draft EA, "a 0.5 mm/year flux at the repository level implies an expected water travel time between the disturbed zone (assumed to be approximately 25 m of host rock) and the accessible environment of about 93,000 years. In a similar fashion--since travel time in each unit is roughly proportional to the flux as long as matrix flow prevails--a 0.01 mm/year flux implies a travel time of about 4.7 million years, and the upper limit of the flux range, 1 mm/year, implies a travel time of 47,000 years." The implied travel time of 47,000 years based on a flux rate of 1 mm/year is inconsistent with the travel time presented on page 6-121. According to page 6-121 of the draft EA, "the estimated groundwater travel time to the base of the host rock is 5,000 years or more" for a flux through the repository of less than 1 mm/year. The reported estimated travel time between the base of the host rock and the water table is 20,000 years or more, and the travel time within the saturated zone from the outer boundary of the primary repository area to the accessible environment is estimated to be at least 500 years."

This estimate of travel time amounts to 25,500 years. The reason for the differences in the travel time estimates is not stated. Consistent interpretations or assumptions are critical to reviewing travel time estimates. Without further information it is not possible to evaluate the reasons for presenting two different travel time estimates for the 1 mm/yr flux.

6-125

Section 6.4.2.3.2, System Analysis, Page 6-318, Paragraph 2

This section discusses estimated radioactivity releases to the accessible environment. According to the draft EA, "the estimated radioactivity releases to the accessible environment by the model system in two configurations are listed in table 6-45. Because of the estimated long ground water travel times (47,000 to 4.7 million years), no releases occur by 10,000 years and only the radionuclide species whose migration is not retarded are released in the 10,000 to 100,000 year period." This statement is inconsistent with earlier statements (page 6-121) that the minimum travel time to the accessible environment is estimated to be about 25,500 years. The estimated travel time of 47,000 years first appears on page 6-314. A complete discussion of travel time calculations is presented with the NRC comments concerning Table 6-17 and page 6-139.

6-126

Section 6.4.2.4, Comparisons with Regulatory Performance Objectives, Page 6-321, Paragraph 1

This section discusses potential radioactivity releases from the repository. According to the draft EA, "if flux conditions change drastically, in time the rock could become saturated, and fracture flow could become dominant. In such an event, travel time to the accessible environment could be decreased; if any radionuclides could be released from the waste package as soon as it was emplaced, they might reach an an aquifer in 300 years." If the Topopah Spring Member became saturated it would become an aquifer. Hydraulic property data for well J-13, completed in the saturated section of the Topopah Spring Member, indicate that where saturated the Topopah Spring Member forms a significant aquifer. Therefore, the statement, "if any radionuclides could be released from the waste package as soon as it was emplaced, they might reach an aquifer within 300 years" does not recognize the fact that the release of radionuclides into the saturated Topopah Spring Member would mean that radionuclides would reach an aquifer immediately. This recognition should be factored into the DOE's discussion of potential radioactivity releases from the repository.

Chapter 6 References

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CHAPTER 7 COMMENTS

7-1

Section 7.2.1.2, Geochemistry, Favorable Conditions on Geochemistry, Page 7-20, Paragraph 1

The statement that no heat-induced alteration of the tuff is expected at Yucca Mountain is more optimistic than statements made in the draft EA on page 6-161. There, the statement is made that heulandite and smectite might be (adversely) affected by increased temperatures. The DOE states, however, that this effect is of no significance at Yucca Mountain based on inadequate consideration of available data (detailed comment 6-67). The statement on page 7-20 accurately reflects the draft EA finding for the favorable condition 960.4-2-2(b)(3); however, the statement is not entirely correct as written nor is it supported by the discussion on page 6-161.