OCT 27 1993

Mr. Ray Wassel, Project Officer
Committee on Technical Bases
for Yucca Mountain Standards
National Academy of Sciences
Room 456
2001 Wisconsin Avenue, N.W.
Washington, D.C. 20007

Dear Mr. Wassel:

SUBJECT: NRC COMMENTS ON THE DOE TSPA-91

Several of the presentations made, to the Committee on the Technical Bases for Yucca Mountain Standards, at the August 1993, meeting relied upon elements of the U.S. Department of Energy's (DOE) TSPA-91 modeling. I have enclosed a copy of NRC staff comments on the TSPA-91, which were transmitted to DOE on October 21, 1993. The Committee may find these comments useful in reviewing information, pertaining to the TSPA-91 analysis, that was presented at the August 26-27 meeting.

Sincerely,

/S/

Margaret V. Federline, Chief
Hydrology and Systems Performance Branch
Division of High-Level Waste Management, NMSS

Enclosure: As stated

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Central File	BJYoungblood, HLWM	JJLinehan, HLWM	HLHP r/f
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OFC	HLHP	C	HLHP	C	HLHP		HLWM	N
NAME	JRFirth/wd	SRF	NAEisenberg		MVFederline		JJLinehan	
DATE	10/26/93		10/26/93		10/27/93		10/27/93	

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Enclosure

OCT 21 1993

Mr. Dwight E. Shelor, Associate Director
for Systems and Compliance
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Shelor:

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF SAND91-2795, "TSPA 1991: AN INITIAL TOTAL-SYSTEM PERFORMANCE ASSESSMENT FOR YUCCA MOUNTAIN"

On August 31, 1992, the U.S. Department of Energy (DOE) transmitted the subject Sandia National Laboratories report, SAND91-2795, "TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain" (TSPA), to the U.S. Nuclear Regulatory Commission for information and comment. On December 17, 1992, the NRC staff met with DOE representatives to discuss preliminary NRC staff comments on the report. At that interaction, the NRC staff committed to provide written comments to DOE at a later date. This letter is in response to that commitment.

The NRC staff's review was a preliminary audit of the subject report. The staff believes that SAND91-2795 provides the first step in demonstrating progress toward resolution of concerns stated in Comment 1 of the NRC staff's Site Characterization Analysis (SCA). The report was reasonably comprehensive with regard to the issues addressed and, for most areas, there was generally enough technical detail and discussion provided to understand methodologies and conceptual models. Objectives of the staff's review of the TSPA were to identify issues that: 1) should be addressed in future DOE TSPAs or may require further discussions between DOE and NRC; 2) may be resolved (or insights gained) by a more detailed review; and 3) because of their complexity or overall importance, the staff may choose to evaluate by analysis as part of Phase 3 or later phases of NRC's Iterative Performance Assessment (IPA). Those concerns that the staff may review in more detail as a part of its ongoing IPA effort will be further discussed in reports following completion of each IPA phase as well as in future technical exchanges.

Because the TSPA represents DOE's initial attempt at an assessment of repository performance, the staff has elected to provide its concerns as observations rather than in the standard open item format previously used for SCA objections, comments, and questions. These concerns will not be included in the NRC Open Item Tracking System, but are considered by the staff to be significant enough for DOE to address in future iterations of the TSPA. Enclosure 1 identifies general and specific concerns in the above three categories (Enclosure 1). The staff is not soliciting written responses to its observations. It should be noted that many of these observations could easily have been placed in more than one of the three categories.

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Enclosure 2 is a list of "not-readily-obtainable" references that the staff will need to support its efforts to evaluate concerns identified in category 3 above. In addition, the NRC staff may also wish to acquire some or all of the computer codes used to generate the TSPA results, and the input and output files. Early discussions may be needed to arrange for the transfer of desired information in electronic format, as well as software documentation, from DOE to NRC and other program participants.

The NRC staff continues to be interested in how the results of the total system performance assessments are used in the repository program, especially to guide site characterization activities, to assist design, and to prioritize program activities.

If you have any questions concerning this letter or the enclosures, please contact Charlotte Abrams of my staff at (301) 504-3403.

Sincerely,

Original Signed by Kenneth R. Hooker

for Joseph J. Holonich, Director
Repository Licensing and Quality
Assurance Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

cc: R. Loux, State of Nevada
T. Hickey, Nevada Legislative Committee
J. Meader, State of Nevada
C. Gertz, DOE/NV
M. Murphy, Nye County, NV
M. Baughman, Lincoln County, NV
D. Bechtel, Clark County, NV
D. Weigel, GAO
P. Niedzielski-Eichner, Nye County, NV
B. Mettam, Inyo County, CA
V. Poe, Mineral County, NV
F. Sperry, White Pine County, NV
R. Williams, Lander County, NV
L. Fiorenzi, Eureka County, NV
J. Hoffman, Esmeralda County, NV
C. Shank, Churchill County, NV
L. Bradshaw, Nye County, NV

U.S. NUCLEAR REGULATORY COMMISSION STAFF OBSERVATIONS ON SAND91-2795

ISSUES FOR FUTURE DISCUSSION OR TO BE ADDRESSED IN FUTURE TOTAL SYSTEM PERFORMANCE ASSESSMENTS (TSPAs)

GENERAL COMMENT

1) Only ad hoc sensitivity studies were performed for TSPA 1991. The staff notes that Chapter 11 describes plans to perform a formal sensitivity study. Sensitivity analyses are important because they provide insight on those processes and parameters most significant to waste isolation and therefore highlight additional data collection or analyses needed to reduce uncertainty. The uncertainties involved in the estimates of the probabilities of scenarios are also key in this regard. Therefore, the staff recommends that the U.S. Department of Energy implement its plans discussed in Chapter 11 to perform a formal sensitivity study and include the results of that study in future TSPA iterations.

SPECIFIC COMMENTS

Section 3.2.2: Stratigraphy (Problem Setup)

2) The cross section of site stratigraphy shown for the Ghost Dance Fault in Figure 3-2 may not fully reflect current knowledge about the site, as shown by the recent work of R. Spengler (U.S. Geological Survey). Based on mapping at Yucca Mountain, the main trace of the Ghost Dance has been shown to be about 1-2 m in width with a displacement of about 50 m at the mapping locale. It appears that the schematic cross-section presented in the TSPA does not include additional work by Spengler that shows the Ghost Dance fault is "bordered" by a zone of faulting about 700 feet in width, wherein the subsidiary faults comprising the zone are characterized by offsets of 3-4 m on individual faults. Future iterations of the TSPA should consider the full extent of the brecciated zone.

Section 3.3: Development of Parameter Distributions (Problem Setup)

3) The hydrologic properties of the fractures were simulated using the hydrologic properties of sand from Carsel and Parrish (1988). Fracture properties are available from Klavetter and Peters (1986) using actual Yucca Mountain fractured tuff cores. The reason for choosing the sand properties as opposed to the published fracture properties should be explained in future TSPA iterations.

4) Page 3-33. An estimate of the expected value of the residual degree of saturation is made by taking the quotient of the expected value of residual volumetric water content and the expected value of porosity.

ENCLOSURE 1

Although, this may be an acceptable estimate, DOE should provide its rationale for estimating expected values on the basis of other expected values when a precise formulation would consider the functional relationship among the variables and the exact nature of their distributions.

Section 3.4: Geochemistry Data (Problem Setup)

5) The K_d approach may be insufficient to accurately represent aqueous transport in geologic media. The assessment necessarily makes use of numerous simplifying assumptions and a limited data base. Given these limitations, it is difficult to determine the degree of conservatism in the analysis of radionuclide release. Since this assessment is not intended to demonstrate compliance, strict adherence to demonstrable conservatism is not needed. However, as future iterations of the performance assessment are produced, more of the assumptions and data need to be shown to be conservative, or DOE needs to provide its basis for not including the degree of conservatism needed. The following are some facets of the current analyses that may make it not demonstrably conservative and for which additional information, either analytical or experimental, may be warranted:

- Species such as colloids and organic complexants that may greatly augment transport do not appear to be considered.

- The range of conditions under which K_d experiments have been conducted is limited.

- Anomalously rapid transport of radionuclides as anionic species has been observed at contaminated sites for species that exhibit large K_d's in laboratory experiments.

- Anion exclusion can lead to negative retardation, such as, transport rates that exceed flow rates, or transport rates that exceed those calculated using a static system distribution coefficient (K_d). This is a clear possibility for iodide or other anionic species.

- The ambient temperature at the repository is about 30°C; and, for example, after 4000 years the temperature will be above 60°C from the water table to about half way between the repository and the ground surface. The effects on K_d's of temperature different from the laboratory conditions under which K_d's were measured may need to be considered. The effects of varying temperatures on the K_d approximation may also require consideration.

- The empirical data base for K_d's presented is sparse, and probability distributions are based on admittedly subjective interpretations of sparse data. The manner in which conservatism is assured in these exercises of expert judgement eventually needs to be addressed and documented.

Section 4.2: Method (Groundwater Flow and Transport)

6) Page 4-10 states: "Using the Monte Carlo method, predictions to a probability of one part in 1000 (a criterion from 40 CFR Part 191) require at least 1000 deterministic calculations." The staff does not believe this is the correct interpretation of the U.S. Environmental Protection Agency's (EPA) standard (40 CFR Part 191). The standard requires estimation of the probabilities of releases of various magnitudes. This probability can be decomposed into the probability of the events causing the release (the scenario probability) and the probability of the set of parameter values that produce that release, given the initiating events. The Monte Carlo simulation discussed in this part of the report only considers the parameter set probability. Thus, fewer samples may suffice, if the scenario probabilities are considered.

Section 4.3: Radionuclide Source Term For Aqueous Releases (Groundwater Flow and Transport)

7) Burnup figures cited on page 4-14 (line 1) are low. Although they may represent the figures previously considered for the Site Characterization Plan (SCP), currently, reactor fuels routinely achieve greater burnups. Current trends are toward even higher burnups. Furthermore, higher burnups are likely to change the spent fuel materials characteristics including isotopic and fractional distribution of radionuclides within the matrix, grain boundaries, and the fuel-cladding gap.

   Realizing that current inventory of spent fuel in the country represents less than one-third of all the spent-fuel assemblies that are being considered for eventual emplacement in the Yucca Mountain repository, future iterations of the TSPA should consider higher burnups, which more realistically represent the bulk of spent fuel.

8) The glass wasteform was not treated in TSPA 1991. Packages for glassified waste will be relatively cooler at the time of emplacement, and will generate much less heat, as a result of the radioactive decay of its contents, than the spent fuel containers. If the glass wasteform containers are not placed with spent fuel containers so as to maintain a uniform areal power density, then the areas where the glass wasteform containers are placed will be cooler than the rest of the repository and likely to become wet sooner. Assuming that wet containers will fail earlier than dry containers, the glass containers may fail prior to the spent fuel containers. There may be possible consequences of early failure of glass wasteform containers on the performance of spent fuel containers which may need consideration. Therefore, DOE should consider the glass waste form in future TSPAs or provide rationale for the exclusion of this topic.

9) If the radioactivity in the structural parts of the spent fuel is significant (as the authors state it), and if it is transportable, such as by spalling of the surface oxide, etc., then radioactivity in the

structural parts should eventually be addressed, explicitly or as a side analysis, in the TSPA. Also, the TSPA models take account of fuel rods of different characteristics, (e.g., fission gas release). Among the existing inventory of spent fuel there is an order of magnitude difference between rods with low fission gas release as compared to those with high fission gas release. The quantity of fission gas produced is a function of a number of fabrication and operational parameters, and is not correlatable in a simple way with the total burnup. Consideration of these differences could be reflected in the modeling or taken into account in the abstraction process.

10) No container failure model is incorporated in this iteration of the TSPA model. Instead the failure time is arbitrarily assumed to be 300 years for early failures and 1,300 years for longer-time failures. Many investigators assume or believe that the container closure may be the weakest part of the waste package, as such it may fail before the container fails as a result of general or localized corrosion (pitting, etc.). Consideration of a container failure distribution based on closure failure or container localized failure would be desirable for future iterations of the TSPA.

11) Table 4-2 tabulates distribution values and mean values for parameters as input for the source term model. However, dependencies exist between some of these factors [e.g., container failure time (t_c) is affected by container environment and vice versa]. The source term model should consider these dependencies in future iterations of the TSPA.

<u>Section 4.4: Unsaturated Zone Flow Models (Groundwater Flow and Transport)</u>

12) Although the connectivity factor has been considered by the authors, it may be desirable to see that an additional statistical property of the fractures, such as correlation between fracture length and aperture, be considered in their future investigations.

ISSUES WHICH MAY BE FURTHER EVALUATED IN MORE DETAIL

Section 3.1.1: Construction of Relational Diagrams and Scenarios (Problem Setup)

13) The TSPA methodology adopted by the authors [i.e., Features, Events and Processes (FEP)] which is based on the six-step process proposed by Barnard (1992) provides an alternative to the one based on "event trees" proposed earlier by Sandia National Laboratories (SNL) (Barr and others, 1991). The authors base the use of this alternative methodology on the grounds that the amount of information available from the site is still limited. The four scenarios investigated in this report appear to have been developed independently of each other and the staff is uncertain as to how the authors plan to integrate some of the events and processes common to these scenarios, in order to develop a unified logic diagram which will meet the objective of the TSPA methodology and assure a mutually exclusive and complete set of scenarios. Furthermore, the methodology stated in the TSPA appears not to have resolved methodological differences between NRC and DOE or addressed open items related to the Site Characterization Plan.

Section 3.3: Development of Parameter Distributions (Problem Setup)

14) In some places TSPA 1991 uses loguniform and lognormal distributions where the order of magnitude of the parameter is what the expert is able to estimate. The section describing Shannon's informational entropy discusses the use of the uniform, exponential, normal, and truncated normal distributions and why beta distributions of similar shape were frequently used in their place. It appears that maximizing Shannon's informational entropy is not necessarily the same as making assumptions which reflect the information which is known and making reasonable conservative assumptions regarding the information which is unknown. The exponential distribution, which is identified as the maximum entropy probability density function (PDF) when only the mean is known, has the property that 63% of the values sampled will be less than the mean and 37% of the values sampled will be greater than the mean. This may be inappropriate for a parameter for which only the mean can be estimated and larger values of the parameter are associated with larger releases. Therefore, the utility of using the informational entropy approach in a regulatory context may be a worthwhile topic for further evaluation.

Section 4.2: Method (Groundwater Flow and Transport)

15) The level of confidence inherent in the predictions of these one-dimensional (1D) models will remain questionable as long as these are not evaluated against results obtained from more sophisticated two-dimensional (2D) or three-dimensional (3D) models and experimental data that is being acquired in the site characterization process.

Section 4.3: Radionuclide Source Term for Aqueous Releases (Groundwater Flow and Transport)

16) It is not clear in source term calculations whether the amount of water contacting wastes is independently sampled or is correlated with the flux used to model hydrogeologic transport.

Section 4.4: Unsaturated Zone Flow Models (Groundwater Flow and Transport)

17) For steady-state flow, the authors claim that the composite-porosity model yields identical results as "other classical models". However, these other models are not identified (page 4-35, paragraph 2).

18) The authors report a relation for the fracture conductivity K_f (see Eq. 4.45) based on the assumption of laminar flow and, subsequently, derive an expression of the flux in the fracture using the same K_f for a turbulent flow system with a correction for turbulence. The adequacy of of this correction should be more thoroughly discussed if used in a future TSPA.

Section 4.7: Results (Groundwater Flow and Transport)

19) Results yielded by a deterministic method based on an average value of the system parameters are known to be less reliable than a stochastic based one, particularly in the case of highly nonlinear problems. It would be desirable to see an investigation of the average case carried out using a first order second moment method (Benjamin and Cornell, 1970) which would have resulted in a more balanced set of results. This approach will provide an estimate of the relative importance of the parameters of the system to the selected performance measure (i.e., cumulative mass release at some observation points of the accessible environment) obtained through a first order sensitivity analysis, and also an overall variance of the performance measure resulting from the various uncertainties incumbent to the various random variables.

Chapter 8.0: Combination of Conditional Complementary Cumulative Distribution Functions (CCDF's)

20) The manner in which the performance models are run independently within the same realization (vector) and then combined into the CCDF may lead to unnecessary complications in interpretation of the results. For example, the assumption that each rock column is independent and not correlated with the other five, violates the conceptual model which states that one sixth of the radionuclide release occurs from each column. Although the "probabilistic sum" method, which combines highest releases with highest releases and lowest releases with lowest releases in generating the CCDF, maximizes the releases at the high end of the spectrum, this combination scheme may not be conservative across the full range of (lower) probabilities to be considered.

21) TSPA 1991 uses a methodology which assumes that both the consequences and probability of one event or process (such as human intrusion) are unaffected by the occurrence or non-occurrence of another event or process (such as volcanism). This method combines the conditional CCDFs for each process or event using a "probabilistic sum" (pp 8-9 - 8-13) of the two CCDFs. It is unclear whether this methodology is to be reexamined in future work towards developing "an exhaustive set of scenario categories" (p 11-1). This methodology, if continued in future phases of TSPA, will limit the types of consequences of scenarios which can be considered. If a given adverse consequence requires the presence of two or more conditions and one event or process produces one of them and the other event or process produces another, this methodology will not detect the presence of the adverse consequence, because each event or process is unable to produce it by itself. However, a methodology which models combinations of events and processes, if sufficiently complete, could detect such an effect. As the models used in TSPA become more refined, the limitations of this methodology may become more apparent. This methodology may not adequately address questions such as: What effect would a pluvial period (which increases the amount of water available for fracture flow) following a period of human intrusion (which increases the number of fractures) have on repository performance?

22) TSPA 1991 considers two conceptual models of unsaturated flow, one in which water transfer between the fracture and matrix is completely free and one in which such water transfer is impossible. TSPA 1991 states that the results of these two models bound the actual unsaturated flow, and that unsaturated flow under partial matrix-fracture coupling can be computed as a weighted mean of the results of these two models. If partial matrix-fracture coupling occurs fast pathways through the fractures could exist under transient conditions and damp rock could contact the canisters. The results of partial matrix-fracture coupling could therefore be larger than either of the two "bounding" cases considered in TSPA 1991. The repository system is probably sufficiently complex that a more robust analysis may be needed to substantiate the assertion that the two flow conditions bound performance.

23) The linear summation of CCDFs of two events such as gas and aqueous releases was used in the TSPA. This linear combination method may be a good pragmatic choice for the two independent events; however, investigation of the nonlinear dependency of natural events should be considered in future TSPAs. The TSPA states that coupling effect of gas flow on thermal loading will be conducted in the future. DOE should consider investigating other coupling effects such as thermal loading change, climate change, and seismic events for future TSPAs.

24) The EPA Standard requires that all releases which occur during a 10,000 year period of performance be summed to determine compliance. The consequences calculated according to the procedures presented in Chapter 8 only include the releases that occur during the period of active volcanic activity. They do not include the releases which could

occur prior to, and after, the period of volcanic activity, and, therefore, do not include the complete 10,000 year period of performance. Consequences calculated in this way should not be combined with such things as the consequences from the weeps model for aqueous transport as the weeps model covers a complete 10,000 year period of performance. Such combinations may not be adjusted properly for probability or reflect changes in repository processes due to external events.

Chapter 10.0: Conclusions and Summary

25) TSPA 1991 states "...given the uncertainties and sparseness of the data, the exact shape of a PDF may not be too important. As long as the PDF includes the entire range of significant probability, the results will be roughly similar" (p. 10-4). The basis for this statement does not appear to be present in the body of the report. If this reasoning were used as a part of the rationale for a demonstration of compliance, the substantiation, theoretical or otherwise, would be needed. Was the statement intended to apply to changes in the form of the PDF (truncated normal versus uniform, for instance) or only to truncation of the tail of the PDF? The plans for future research in Chapter 11 do not mention plans to explore the effect of distribution shape or differences in distribution parameters.

ISSUES THAT MAY BE FURTHER EVALUATED BY INDEPENDENT ANALYSIS

[NOTE: The NRC has not yet initiated planning for the next Iterative Performance Assessment (IPA) iteration; whether or not the staff will explore the issues identified below in the next or future IPA iterations is uncertain and will depend on staff resources. It is hoped that identification of these issues, listed below, will encourage, the DOE to evaluate these issues by further analysis of their own.]

GENERAL COMMENT

26) The TSPA explicitly describes and uses the process of model "abstraction," whereby complex, detailed models are used to formulate simpler models used in Monte Carlo simulations to propagate uncertainties. The NRC staff is interested in the abstraction process and may choose one or more examples in the TSPA to explore the formulation of general principles for the use of the abstraction process in a regulatory context. The abstraction process is an essential element in distilling the large and complex amount of information generated by site characterization, laboratory studies, detailed analyses, and design activities into a performance measure that will be used, in part, to determine regulatory compliance.

SPECIFIC COMMENTS

<u>Section 3.1.1: Construction of Relational Diagrams and Scenarios (Problem Setup)</u>

27) The TSPA uses FEP (Features-Events-Processes) relational diagrams as a fundamental input to the performance assessment. This is a departure from the approaches used previously and articulated in the SCP. It may be worthwhile to explore the implications of the use of FEP diagrams on the form, results, and regulatory use of the performance assessment.

<u>Section 3.3: Development of Parameter Distributions (Problem Setup)</u>

28) The elicitation process was not documented in enough detail to determine whether or not the process used good practices (e.g., see Bonano and others, 1990). The procedure followed for the entire elicitation, including selection of experts, training of experts, and the expert's rationale for the results, should be documented if used in future TSPAs. The NRC staff will evaluate the expert elicitation process as part of its ongoing IPA activities.

29) The bases for choosing several PDFs (e.g., PDFs in Table 3-6) for physical parameters are not stated clearly. It is recommended that future TSPAs explain the mathematical or physical bases for the choices. The effects of various assumptions regarding PDFs may be evaluated in future iterations of the NRC IPA effort.

Section 3.4: Geochemistry Data (Problem Setup)

30) The K_d for elements varies with pH because the aqueous speciation of the elements changes. More work on the controls on speciation and solubility is needed to sort out what is sorption and what is not. Sorption models are being refined as part of the ongoing NRC IPA activity.

31) For the stated future work on the source term model (Section 11.2.2) regarding formation and migration of colloids, it is suggested that more realistic values of concentrations of species (ions or polynuclei) and colloids be used. The transport of colloids and species may have varied values of K_d depending on environmental factors such as pH or rock fracture properties, which can alter the calculated results significantly. The concentrations are also strongly dependent on temperatures. For instance, for Pu or Am, the values of solubility limits could increase when the temperature is decreased from 90°C to 60°C. Colloidal transport is planned to be evaluated in future phases of the NRC IPA activity.

Section 4.1: Problem Development and Scenario Screening (Groundwater Flow and Transport)

32) Page 4.4 states: "The TSPA composite-porosity calculations are based on the premise that water flow is steady-state...The weeps model, on the other hand, assumes episodic water flow down fractures, because significant matrix imbibition is not allowed by the model." The staff agrees that whether or not the groundwater flow is steady or time-varying is an important aspect of choosing the appropriate conceptual model for estimating radionuclide migration and repository performance. In addition, consideration should be given to the interaction of the liquid groundwater flow with the movement of air, water vapor, and other gases in the flow system. These gas flows are known to be transient, with significant diurnal and annual periodicities. Evaluation of the interactions of the liquid and gas flows is planned for future phases of the NRC IPA activity and is expected to provide a basis for future technical interactions on conceptual models for evaluating repository performance.

Section 4.3: Radionuclide Source Term for Aqueous Releases (Groundwater Flow and Transport)

33) The analysis was simplified to largely eliminate chain decay and the presence of multiple isotopes of the same radionuclide. Justification of the simplifications will require more detailed auxiliary analyses not present or referenced in this report. These simplifications could be more difficult with any potential dose-based standards. The effects of radionuclides with complex decay chains is planned for further evaluation in future NRC IPA calculations.

34) The TSPA describes a highly abstracted model for the source term. The NRC staff would be interested in exploring how this model compares to

NRC models and to less abstracted models (NRC's, DOE's, and other's). Of primary interest are the various assumptions made in different models and their effects on performance. Comparison of results other than to explore differences in approach is not intended at this time by the NRC staff.

Section 4.4: Unsaturated Zone Flow Models (Groundwater Flow and Transport)

35) The TSPA postulates two conceptual models of groundwater flow through partially saturated, fractured rock: (1) the composite-porosity model and (2) the "weeps" model considering significant fracture flow. These models are posited as extremes of fracture matrix interaction. The NRC staff is interested in exploring the implications of the two conceptual models on total system performance and on the performance of components of the repository system (e.g., source term, far-field migration). The staff is also interested in investigating whether and under what conditions these two conceptual models may represent extremes of system performance.

Section 4.5: Saturated Zone Flow Models (Groundwater Flow and Transport)

36) Czarnecki's 2D model (Czarnecki and Wadell, 1984) treats the geologic strata in the third dimension (depth) as a single composite medium. The fluid flow properties associated with this medium consist of a combination of the tuffaceous and carbonate aquifer, and are based on an assumed saturated thickness of 1000 meters. It is likely that the saturated thickness through the region varies and that the flow patterns and velocities within the tuffaceous and carbonate aquifers are distinctly different. There also may be areas where the two aquifers are connected. Consequently, this is one area of possible controversy in assessing the accuracy of results obtained from the horizontal flow tube analysis used in TSPA calculations to model transport in the saturated zone. Various regional groundwater flow models are presently being evaluated as part of the NRC IPA activity.

37) As mentioned above (observation 36), a single set of properties was used to simulate the third dimension (depth). These properties are taken to be some average of the tuffaceous and carbonate materials used in Czarnecki's model. In addition, these material property values are assumed to be a composite of the matrix and fracture properties of the medium. An auxiliary analysis on the use of only one equivalent "lumped" material property in the flow and transport calculations within the saturated zone could explore the appropriateness of this assumption.

Section 4.6: Transport Analysis (Groundwater Flow and Transport)

38) The adoption of a single fixed migration length of 5,000 m for the modelled region to delineate the accessible boundary limit from the repository location may be too restrictive in light of the discussions presented in Section 4.5. In addition, the impact of the variation in thickness of the saturated zone which plays a role in the computation of the cumulative mass release of a typical radionuclide has been overlooked. This is a departure from the assumptions used in modeling

the saturated zone, where the vertically integrated model accounts for the areal variation of the saturated thickness of the aquifer. The inclusion of thickness in Eqs. (4.55) through (4.57) should be considered in future TSPAs and may be evaluated in future NRC IPA activities.

Chapter 5.0: Gas Flow and Transport

39) In future iterations of TSPA models for gas flow and C-14 transport DOE may wish to consider the following phenomena:

- Changes in gas permeability with changes in temperature and saturation.

- Changes in retardation with changes in temperature and liquid saturation.

- Inaccessibility of water in pores to interact with CO_2 in the gas stream.

These phenomena are currently being evaluated in NRC IPA activities and the NRC High-Level Waste Research program.

40) The release rate of most carbon-14 is assumed to be controlled by the same spent fuel alteration rate used for the liquid release. At high temperatures, it is possible that the release is limited by dry oxidation of the spent fuel pellets which can occur at a faster rate. This could occur with initially defective containers. Future iterations of the TSPA should consider alternative mechanisms for C-14 release as will future iterations of the NRC IPA activity.

41) The TSPA describes a complex calculation of gas flow and transport. The NRC staff has also developed models of C-14 release and transport to the accessible environment. It may be useful to explore the differences in approaches between the DOE and NRC models to better identify which assumptions need further site data or analytical study.

Chapter 7.0: Basaltic Igneous Activity

42) Estimates of the probability of igneous activity may be conservative. However, these models do not take into account basic geological information, such as the episodic nature of volcanism in the Great Basin and the relationship between tectonic deformation and magmatism. Critical parameters in the consequence analysis, such as erosion depth, conduit shape, speed of entrainment, and total lithic fraction, may be underestimated by this performance assessment model. Altering the values of these parameters may increase the predicted volume of waste material involved in disruptive magmatic activity and the amount of radionuclides released as a result of this activity. Furthermore, the consequence models do not account for activity of long duration (decades to centuries) within or near the repository. The authors' conclusion that EPA limits will not be exceeded by igneous activity is based on assumptions which may not be conservative.

43) Probability models for the frequency of eruption in the Great Basin are based on estimates of the number of eruptions which have occurred in the Crater Flat Volcanic Zone and elsewhere in the Great Basin in the Quaternary. The recurrence rate table given in Crowe and others (1992) gives predicted recurrence rates of between 1.2e-6 and 2.8e-5, where events are averaged over the Quaternary. The figures used in the performance assessment model agree well with these figures. However, elsewhere in the Great Basin, volcanism has been highly episodic on the scale of 10^5 years; therefore, averaging the number of events over the Quaternary may be inappropriate.

Present models for the probability of eruption at the repository are Gaussian and Bayesian (Ho, 1992). None of these models have yet attempted to incorporate geological information into the model, such as attempting to quantify the likelihood of an igneous event should substantial slip occur along the Ghost-dance fault. Also, these models do not address numerous studies that show episodic behavior in volcanic eruption rates. At this time, this simplification is appropriate because the geologic studies are still underway. It has been estimated that the likelihood of a repository disrupting event to be 2.4e-4. However, Ho (1992) has recalculated the likelihood of site disruption during a 10,000 year period and placed that event between 1e-3 and 6.7e-3 with 90 percent confidence. These conflicting probability estimates are indicative of the need for additional geologic constraints on the problem. The staff plans to evaluate its probability model for magmatic activity used in Phase 2 of the IPA.

44) The TSPA describes models for human intrusion and volcanism. The NRC staff has also developed models for these disruptive events. The staff considers some comparison of these models useful to evaluate the impact of different assumptions and conceptual models. Currently, the staff is evaluating models related to the consequences of volcanism.

Chapter 8.0: Combination of Conditional CCDF's

45) The TSPA describes and employs three approaches to constructing CCDF's. Although these approaches appear to be correct and suitable mathematical methods, the staff is sensitive to the use of the CCDF to evaluate compliance with the EPA standards for high-level waste disposal. Thus, the staff may explore the regulatory implications of various constructs for the CCDF.

REFERENCES FOR NRC OBSERVATIONS

Barnard, R.W. 1992. A six-step method for systematic performance assessment. *Proceedings of the 1992 Annual Meeting*. La Grange Park, IL: American Nuclear Society (ANS): 55-57.

Barr, G.E., R.W. Barnard, H.A. Dockery, E. Dunn, and A.T. MacIntyre. 1991. Scenario evolution: Interaction between event tree construction and numerical analyses. *High Level Radioactive Waste Management: Proceedings of the Second Annual International Conference*. La Grange Park, IL: ANS: 1480-1486.

Benjamin, J.R., and C.A. Cornell. 1970. *Probability, Statistics, and Decisions for Civil Engineers*. New York, NY: McGraw-Hill.

Bonano, E.J., S.C. Hora, R.L. Keeney, and D. von Winterfeldt. 1990. *Elicitation and Use of Expert Judgment in Performance Assessment for High-level Radioactive Waste Repositories*. NUREG/CR 5411, SAND89-1821. Washington, D.C.: Nuclear Regulatory Commission (NRC).

Crowe, B.M., R. Picard, G. Valentine, and F. Perry. 1992. Recurrence models for volcanic events: Applications to volcanic risk assessment. *Third Conference on Radioactive Waste Management April 14-16, Las Vegas, Nevada*: 2344-2355.

Czarnecki, J.B., and R.K. Wadell, 1984, "*Finite-Element Simulation of Ground-Water Flow in the Vicinity of Yucca Mountain, Nevada-California*," USGS/WRI-84-4349, U.S. Geological Survey, Denver, CO. (NNA.870407.0173)

Ho, C.H. 1992. Risk assessment for the Yucca Mountain high-level nuclear waste repository site: Estimation of volcanic disruption. Las Vegas, Nevada: Panel on structural geology and geoengineering meeting on volcanism. *U.S. Nuclear Waste Technical Review Board, Sept. 14-16, 1992*.

Klaveter, E.A., and R.R. Peters, *Fluid Flow in a Fractured Rock Mass*, SAND85-0855, Sandia National Laboratories, Albuquerque, New Mexico, 1986.

NOT-READILY-OBTAINABLE
TSPA REFERENCES REQUESTED

Dudley, A.L., R.R. Peters, J.H. Gauthier, M.L. Wilson, M.S. Tierney, and E.A. Klavetter, 1988, "Total System Performance Assessment Code (TOSPAC), Volume 1: Physical and Mathematical Bases," SAND85-0002, Sandia National Laboratories, Albuquerque, NM. (NNA.881202.0211).

Fewell, M.E., S.R. Sobolik, and J.H. Gauthier, 1992, "Estimation of the Limitations for Surficial Water Addition above a Potential High Level Radioactive Waste Repository of Yucca Mountain, Nevada," SAND91-0790, Sandia National Laboratories, Albuquerque, NM. (NNA.911217.0002)

Gainer, G.,p.g. Kaplan, A.S. Schenker, and H.A. Dockery, 1992, "Model Domains and Hydrogeologic Data Base To Support Early Site Suitability and Total-System Performance Assessment Models," SAND92-0799, Sandia National Laboratories, Albuquerque, NM. (NNA.920630.0035)

Gauthier, J.H., M.L. Wilson, R.R. Peters, A.L. Dudley, and L.H. Skinner, 1992b, "Total System Performance Assessment Code (TOSPAC) Volume 2: User's Guide, " SAND85-0004, Sandia National Laboratories, Albuquerque, NM. (NNA.920623.0013)

O'Connell, W.J., 1990, "Status of Integrated Performance Assessment of the Waste Packages and Engineering Barrier System," UCRL-10214, Lawrence Livermore National Laboratory, Livermore, CA. (NNA.900607.0215)

O'Connell, W.J., 1992, "Simplified Source Term Model for Total System Performance Assessment," UCRL-110511, Lawrence Livermore National Laboratory, Livermore, CA. (NNA.920505.0309)

Wilson, C.N., and C.J. Bruton, 1989, "Studies on Spent Fuel Dissolution Behavior Under Yucca Mountain Repository Conditions," PNL-SA-16832, Pacific Northwest Laboratory, Rickland, WA. (NNA.890905-0053)

Wilson, M.L., 1991, "A Simplified Radionuclide Source Term for Total-System Performance Assessment," SAND91-0155, Sandia National Laboratories, Albuquerque, NM. (NNA911118.0079)

ENCLOSURE 2