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JUL 10 1992

Mr. John P. Roberts, Acting Associate Director
for Systems and Compliance
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Mr. Roberts:

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF STUDY PLAN FOR PROBABILITY OF MAGMATIC DISRUPTION OF THE REPOSITORY

In a letter to the U.S. Department of Energy (DOE) dated October 5, 1991, the Nuclear Regulatory Commission informed DOE that the NRC staff's Phase I Review had identified no objections with any of the activities proposed in the "Study Plan for Probability of Magmatic Disruption of the Repository" (Study Plan 8.3.1.8.1.1). At that same time, NRC also indicated that it had decided to proceed with a Detailed Technical Review of that study plan. The purpose of this letter is to transmit the results of the NRC staff's Detailed Technical Review.

This study plan is one of more than 20 study plans describing the program of investigations for magmatic/volcanic phenomena. The primary purpose of this plan is to provide information and direction on methods by which the probability of magmatic disruption of the repository can be determined. Although this study plan does not describe data collection methods, it is important as it describes how information gathered under other study plans will be assimilated to develop probabilities which will be used in other studies designed to directly address the performance objectives.

The staff is concerned that this study plan, as presently written, may not provide the analyses necessary to demonstrate compliance with 10 CFR Part 60. Specifically, based on the activities described in this study plan, it is unclear that a sufficient understanding of the magmatic processes will exist so as to minimize uncertainties in the projections of the probabilities and consequences. For example, the staff considers that the program of geophysics alluded to in this study plan may not provide data necessary to make judgements about the presence or absence of magma bodies in the vicinity of Yucca Mountain. In its Site Characterization Analysis (SCA), the staff provided comments related to the sufficiency of the program to gather data for the

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understanding of volcanic processes (SCA comments 45, 51, and 52). DOE provided responses to those comments; however, neither those responses, nor this study plan, has resolved the staff's concerns.

In addition to concerns related to the sufficiency of data and geophysical tests, the NRC staff has identified thirteen comments and one question (Enclosure 1) related to the material presented in the study plan. The staff also noted that three, yet to be developed, procedures identified in the study plan may resolve some of the staff's technical concerns. Those procedures are "Methods for Magma Volume Determinations for Calculating the Probability of Magmatic Disruption of the Repository and Controlled Area," "Methods for Weighting Volcanic Probability Calculations Through Use of Expert Opinion," and "Methods for Calculating the disruptive Parameter for Calculation of the Probability of disruption of the Repository by Magmatic Activity." We request that those procedures be made available as soon as possible.

The concern of having sufficient data on which to make a regulatory decision is reflected in Comments 12 and 13 (Enclosure 1) on expert judgement. The staff recognizes that procedures for the application of expert judgement for weighting the probability sets have not been developed and only an overview of the proposed use of expert judgement is provided in the study plan. Because DOE plans to rely on expert judgement to rank the suitability of models of volcanic recurrence rates and models of the disruption parameter, such weighting of the models will have a crucial impact on calculation of the probability distribution function. In the SCA, NRC commented that weighting alternative conceptual models according to the judgement that they are likely to be correct is inappropriate and may overestimate the quality of repository performance. The staff believes that a detailed technical review of the use of expert judgement as applied to this study should be undertaken when the appropriate procedures are developed and incorporated into the study plan.

The staff knows of no NRC precedent on handling the formalized use of expert judgement during a licensing hearing. Traditionally, the licensing board has reviewed the testimony of each expert and determined the "weight" to be placed on each expert's review and testimony. On the basis of statements in this study plan, it appears that DOE plans to "weigh" the input of each expert. Because there can be no assurance that the process planned by DOE will be acceptable to the licensing board, or to the Commission, DOE should articulate its basis for such weighting in the procedures for this study plan.

The Detailed Technical Review comments and questions on this study plan will be tracked by the NRC staff as open items similar to SCA

objections, comments, and questions. NRC recommends timely resolution of these open items. The comments and question raised by this review are of sufficient depth that they should be addressed in the revision to this study plan noted in the Roberts to Holonich letter of April 21, 1992. The staff also recommends that a technical exchange be held to discuss the comments and question related to this study plan, prior to completing the revision.

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

Sincerely,

/s/

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

Enclosure: As stated

cc: R. Loux, State of Nevada
T. J. Hickey, Nevada Legislative Committee
C. Gertz, DOE/NV
S. Bradhurst, 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
P. Goicoechea, Eureka County, NV
L. Vaughan II, Esmeralda County, NV
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KMcConnell, HLGE			

*See previous concurrence

OFC	:HLPD	:HLGE*	:HLGE*	:HLHP*	:HLGE	:HLPD
NAME	:CAbrams	:JTrapp	:KMcConnell	:MFederline	:RBallard	:JHolonich
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Enclosure only

QUESTION 1

In which document will the program for evaluation of silicic volcanism be described?

BASIS

In Section 1.1, DOE states that final resolution of the question of silicic volcanism is dependent on the results of drilling of volcanic drill holes and evaluation of young silicic volcanism at Mt Jackson.

While some of the investigations appear to be tied into Study Plan 8.3.1.8.5.1, the process of evaluation of silicic volcanism does not appear to be described in any existing study plan.

While the NRC would agree that present data suggest that the potential for silicic volcanism is low, this has yet to be established.

RECOMMENDATION

Provide a reference for the document in which the program or methodology for resolving concerns related to silicic volcanism will be described.

ENCLOSURE

COMMENT 1

The use of the term "event" in this study plan appears to be limited to cone formation, and therefore provides an incomplete description of magmatic processes and events, and the requirement to determine consequence of the resultant activity.

BASIS

The objective of this study plan, as is stated in such places as the end of the first paragraph on page 9, is to evaluate the probability of magmatic activity penetrating the repository or controlled area during the next 10 ka. The activities described within this plan, however, appear to be of insufficient scope to accomplish this objective.

Each magmatic event consists of release of magma from a magma source with the released material being emplaced in the lithosphere and in some cases being released to the surface.

As a result of the magmatic event such features as dikes, sills, plugs, lava flows, and cones may be formed, or such things as hydrothermal fluids may be introduced.

The resultant features from an event (the release of magma from the magma source) could be any grouping of features such as a series of dikes, a series of dikes and cones, or a series of dikes, cones, plugs, and sills. The resultant effects on a repository could range from no effect, to alteration of the host rock, modification of the groundwater system, disruption of the canisters, or breaching of the repository.

In parts of the study plan, such as Section 3.4.2.2, the term event, and the associated analysis which is described, appears to be restricted to events which resulted in the formation of volcanic cones while neglecting all other types of events. Not only is there the possibility of undercounting episodes of magmatic activity due to buried vents, but methods that only count a selected group of features that represent a narrow group of events could seriously undercount the total number of events which have occurred. While such data and analyses may provide an approximation of the probability for the formation of a certain feature, it can not provide a reasonable and conservative approximation of the probability that the repository will be affected by magmatic processes.

RECOMMENDATION

DOE should demonstrate that the program integration of exploration and analysis will be sufficient to account for the various types and sizes of magmatic events, differentiate between the various events, and provide a reasonable description of the complete magmatic process.

COMMENT 2

Use of surface extrusion rates to approximate magma production rates could underestimate the effects of the magmatic process on repository performance.

BASIS

Most Quaternary cones in the area of Yucca Mountain have a volume on the order of 10E+6 to 10E+8 cubic meters.

If, as an example, it is assumed that a cone was emplaced from a feeder dike 1000 meters long by one meter in width, or a pipe with a diameter of approximately 50 meters, either of which emanated from a magma chamber at a depth of 20 kilometers, the feeder system would contain approximately 10E+7 cubic meters of material. The feeder system could, therefore, contain approximately as much material as is present at the surface.

In addition to the feeder system itself, offshoots from the system such as radial dikes and sills could account for a significant volume of volcanic material.

In studies in the Hawaiian Islands, a 3-to-1 proportionality between total magma supply and extrusive volume has been suggested (Shaw, 1987). While such a proportionality may also be applicable to Basin and Range systems, the Division of High-Level Waste Management (DHLWM) staff knows of no data which could support such a relationship.

Neglecting the material within the subsurface while attempting to approximate a magma production rate could result in probability and consequence models which are in error.

The DHLWM staff knows of no available information which could be used to evaluate the effect of neglected subsurface material on the probability and consequence analysis.

The DHLWM staff questions the geologic significance of magma effusion rates calculated in accordance with procedures presented in Study Plan 8.3.1.8.1.1. For example, if volcanic activity follows some type of power law relationship, substituting the volume of surface material for the production rate could produce a totally misleading recurrence curve.

The staff notes that a technical procedure "Methods for Magma Volume Determinations for Calculating the probability of Magmatic Disruption of the Repository and Controlled Area" is to be developed. It is possible that some of the staff concerns could be resolved if this procedure was available.

RECOMMENDATION

DOE should demonstrate that magma effusion rates calculated in accordance with the procedures described in Study Plan 8.3.1.8.1.1 can be used as an approximation of magma production rates, at least to the extent of demonstrating that such an approximation does not underestimate possible effects on the repository; or provide some alternative mechanism to calculate production rates. As some of the concerns raised in this comment may be addressed in the procedure "Methods for Magma Volume Determinations for Calculating the Probability of Magmatic Disruption of the Repository and Controlled Area," DOE should provide this document for NRC review.

REFERENCES

Crowe B.M., Vaniman, D.T., and Carr, W.J., 1983, Status of volcanic hazard studies for the Nevada Nuclear Waste Storage Investigations: Los Alamos National Laboratory, LA-9325-MS.

Shaw, H., 1987, Uniqueness of volcanic systems, in Decker, R.W., Wright, T.L., and Stauufer, eds., Volcanism in Hawaii: U.S. Geological Survey Professional Paper 1350.

COMMENT 3

The evaluation of the presence of crustal magma bodies in the vicinity of Yucca Mountain must consider the requirements of 10 CFR Part 60.122(a)(2).

BASIS

Section 3.3.1, 1st paragraph states, "If evidence is obtained that indicates or is permissive (using multiple geophysical methods) with the presence of magma beneath Yucca Mountain, the second approach will be followed. This second approach involves focused geophysical studies to obtain detailed data to test the location, nature, and geologic credibility of anomalies that may represent magma."

Section 3.3.1, 3rd paragraph states, "These geophysical data will be analyzed as part of the individual activities. We will evaluate the results of data reduction and interpretations from these activities to make two decisions. First, are the data obtained sufficient to resolve questions of the possible existence of crustal magma bodies? Second, is evidence present from the geophysical studies that is indicative of the presence of crustal magma bodies? If the answer to either question is positive, we will develop a document describing the additional geophysical and noble gas studies that are required to resolve the issue of the possible presence of subcrustal magma in the Yucca Mountain Region."

10 CFR 60.122(a)(2)(i) requires that, "The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations;"

10 CFR 60.122(a)(2)(ii) requires that, "The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect;"

According to Brocher and others (1989), Line AV-1 from the seismic reflection feasibility study indicates a bright spot similar to the bright spots imaged by COCORP in Death Valley and near Socorro, New Mexico, both of which have been interpreted as reflections from discontinuous molten magma chambers.

According to Evans and Smith (1992) teleseismic tomography of the Yucca Mountain region suggests that a large volume of small-fraction partial melt may underlay the site location.

With the present data, and within the requirements of the rule, the NRC staff considers that focused, detailed studies may be required to evaluate the presence of (and effect of) magma bodies in the vicinity of Yucca Mountain.

RECOMMENDATION

DOE should consider beginning the development of the document describing the additional activities considered in section 3.3.1, as it appears these will be necessary to resolve, within the requirements of 10 CFR Part 60, the presence or absence of a magma body in the Yucca Mountain Region; or, demonstrate, with analyses that will not underestimate the effects of possible magmatic activity, that the presence of a magma body has been considered in accordance with the requirements of 10 CFR Part 60.

REFERENCES

Brocher, T.M., Hart P.E., and Carle S.F., 1990, Feasibility study of the seismic reflection method in Amargosa Desert, Nye County, Nevada: United States Geological Survey, USGS-OFR-89-133.

Evans, J.R., and Smith, M. III, 1992, Teleseismic tomography of the Yucca Mountain region: volcanism and tectonism, in Proceedings of the Third Annual High-Level Radioactive Waste Management Conference.

COMMENT 4

One of the main activities within this study plan, as stated on page 8, is to estimate the probability of future magmatic disruption of the Yucca Mountain site, however, the probability calculations that this study plan is intended to produce appear too limited to resolve the geologic and regulatory concerns.

BASIS

40 CFR 191 requires that all significant processes and events be considered in the evaluation of compliance.

Section 3.4.2.1, last paragraph, states that potential secondary effects will be considered in Study Plan 8.3.1.8.1.2, but will not be considered in the probability calculations.

Section 4.0 lists 5 required probability estimates which will come from this study plan, but does not include any probability estimates related to disruption of the engineered barrier system.

Formula 2, page 30, defines the disruption parameter as the probability that the repository is disrupted by the formation of a new volcanic center, given occurrence of a new volcanic center during the containment period of the repository.

The methodology description in section 3.2.2.2 refers to previous studies in which only surface cones, or potential buried cones or groups of cones, have been considered in the calculations. The methods described have not considered the possibility of such things as dikes, sills, hydrothermal fluids, or other non-surface-breaching disruptive effects.

The methods used to previously calculate disruption parameters, such as those presented on page 21, only attempted to calculate disruption through the formation of cones. They did not consider disruption due to formation of dike systems, sills, or the like, and did not consider the resultant effect on groundwater flow system.

The procedures, as presented in this study plan, can not provide the information required for the other investigation listed in Table 4.

RECOMMENDATION

The methods of analysis used to calculate the probability of disruption of a repository must include all significant processes and events that may effect the ability of the repository to meet the performance objectives.

COMMENT 5

It is unclear how a volcanic recurrence model can be constructed without knowledge of magmatic events of a size less than that needed to produce a cone.

BASIS

The DHLWM staff is in agreement that an analog for magmatic recurrence models may possibly be obtained by examination of seismic recurrence rates as is suggested in such places as page 37 of the study plan.

The staff is also in agreement that there may be some power law relationship between time and magma volume as has been suggested by Shaw (1987).

The staff notes, however, that in order to develop an earthquake recurrence curve it is necessary to have information which provides a size relationship for the different earthquakes which have occurred during a specified time period. (For example, how many earthquakes in the various magnitude or intensity ranges have occurred during a specific period.)

Calculation of the surface volume of the cones within the Yucca Mountain region indicates the surface volume varies within a very restricted range (Crowe, Vanamin and Carr, 1983). This, in turn, provides a very limited range of magmatic events for consideration in the calculations, even if the uncertainty with the amount of material present in the subsurface is ignored (See Comment 2).

If a volcanic recurrence relationship exists which is similar to the earthquake-magnitude relationship, for each magmatic event which is of sufficient size to produce a cone there must be some quantity of magmatic events which are of a different size. Without some information on the number of these different size events there appears no way to constrain the slope or intercept of the curve which expresses this relationship.

The staff does not consider that the present volcanic program will be able to provide the information necessary to develop a volcanic recurrence model, or that this study plan provides a means of analysis to develop volcanic recurrence models, which can be defended in a licensing hearing.

RECOMMENDATION

The DOE should consider including in its program of investigations and analyses some means of characterizing magmatic features and events of a size smaller than those needed to produce cones, such that a valid recurrence model can be developed.

REFERENCES

Shaw, H., 1987, Uniqueness of volcanic systems, in Decker, R.W., Wright, T.L., and Stauufer, P.H., eds., Volcanism in Hawaii: U.S. Geological Survey Professional Paper 1350.

Crowe, B.M., Vaniman, D.T., and Carr, W.J., 1983, Status of volcanic hazard studies for the Nevada Nuclear Waste Storage Investigations: Los Alamos National Laboratory, LA-9325-MS.

COMMENT 6

This study plan does not appear to be calculating a "recurrence rate", but rather the average recurrence rate for the sampled population.

BASIS

In places such as page 34, 3rd paragraph, it is stated that the recurrence rate is established by dividing the average number of events by a specified period of time. Such a calculation can be very much a function of the specific period of time selected and may not be a function of the actual recurrence of events. If, for example, there is clustering of events in time, selection of a time period which does not reflect this clustering would provide incorrect results.

While a limited sample population is available, statistical tools are available for pattern recognition, and should be used. Ho and others (1991), for example, suggest some techniques which may provide further insight into the data.

RECOMMENDATION

DOE should consider making full use of available data and analytical techniques to establish the range of models that are permissible by the data in order to reflect the limitations/uncertainties in the resultant rates.

REFERENCE

Ho, C., Smith, E., Feuerbach, D., and Naumann, T., 1991, Eruptive probability calculations for the Yucca Mountain Site, USA: statistical estimation of recurrence rates: Bulletin of Volcanology, V. 54, p. 50-56.

COMMENT 7

The study plan does not appear to adequately consider models that assume volcanism is a non-poissonian process.

BASIS

A poisson distribution function is often used to describe events which are random in time and space.

As is stated on page 42 of the study plan, "The occurrence of volcanic activity in the geologic record is not random."

On Page 43 of the study plan the DOE states "All studies are not yet completed, but the decreasing volume of erupted basalt in the Pliocene and Quaternary in the region suggests that volcanism is waning (Vanamin and Crowe, 1981; Crowe, 1986). If this proves to be the case, then probability calculations based on an assumed steady-state model of volcanic activity can be demonstrated to be conservative."

If volcanism is non-poissonian, the process displays a "Memory", and future activity is dependent on both when and where previous activity has occurred.

The ability to provide a probability for volcanic activity under these conditions is therefore dependent on knowing and understanding where the region is within the volcanic cycle. Assumption of a non-poissonian distribution requires knowledge of the stage in the cycle to determine the probability of volcanism during some specific 10,000 year period. Without this knowledge it can not be demonstrated that an assumed steady state model is conservative for any specific 10,000 year period, even if it can be proven that volcanism is in a stage of waning activity.

The study plan does discuss non-poissonian recurrence models on page 37, however, the plan only appears to consider renewal models. If such models are to be developed they are dependent on knowledge of such things as magma production rates. However, the staff is unsure how the data for such models are to be obtained (See comment 5). The study plan does not appear to provide adequate consideration of such things as Markov models or "trigger" models.

RECOMMENDATION

DOE should consider developing alternative models of volcanic recurrence which incorporate non-poissonian assumptions to demonstrate that the analysis does "not underestimate the effects," in accordance with the requirements of 10 CFR 60.122(a)(2). For those models which are dependent on magma production rates, DOE will need to demonstrate that such rates also do not underestimate the effects.

REFERENCES

Vaniman, D.T., and Crowe, B.M., 1981, Geology and petrology of the basalt of Crater Flat: applications to volcanic risk assessment for the Nevada Nuclear Waste Storage Investigations: Los Alamos National Laboratory, LA-8845-MS.

Crowe, B.M., 1986, Volcanic hazard assessment for disposal Of high-level radioactive waste, in Active Tectonics: Impact on Society: Nation Science Academy Press, Washington D.C., p. 247-260.

COMMENT 8

The conditional probability of disqualification, Formula 2, Page 30, does not appear to be formulated such that the probabilities that will be necessary to demonstrate compliance with the overall performance objective can be obtained.

BASIS

On page 30 DOE states that "The volcanic event of significance for the Yucca Mountain site is the formation of a new volcanic center."

E1 (the recurrence rate of future volcanic events) and E2 (the disruption parameter) from formula 2 are only related to formation of a new volcanic center.

The EPA standard, however, requires an evaluation of the releases from "all significant processes and events". This could include such things as both direct and indirect releases from volcanic events at "old" volcanic centers.

The EPA standard requires that cumulative releases be determined for all significant processes and events which may occur during the period of performance, not just those releases from single events which occur during the period of performance.

Release of radioactive materials to the accessible environment must be evaluated for more than "release from ascending magma" as is stated under E3 (the release probability), to determine compliance with the performance objectives.

The study plan proposes the use of a formula equal to the product of the probability of a single event times the consequences resulting from that event to evaluate site suitability. Because the EPA standard requires comparison of cumulative releases from all significant processes and events against release limits, this approach is inconsistent with the EPA containment requirement.

To determine compliance with the EPA standard it will be necessary to determine the cumulative releases for all significant proceses and events which will occur during the period of performance given a specific set of circumstances. It would include the summation of releases prior to a volcanic event, releases from the volcanic event and releases which occur after the volcanic event given the new set of boundary conditions. This is a larger group of processes and events than is incorporated in E3.

The staff notes that a detailed technical procedure on "Methods for Calculating the Disruption Parameter for Calculation of the Probability of Disruption of a Repository by Magmatic Activity" is to be developed. It is possible that some of the staff concerns could be resolved if this procedure was available for review.

RECOMMENDATION

DOE should consider modifying Formula 2 to reflect the requirements for demonstrating compliance with the overall performance objective.

COMMENT 9

The geophysical program described in the SCP and referenced in this study plan appears too limited to provide the information necessary to develop reasonable probability models.

BASIS

The study plan states on page 8 that an integrated evaluation of geophysical data from the preclosure tectonics program would provide information on the subsurface structures of Yucca Mountain. The NRC staff in 1989 (NUREG-1347, Comment 32), requested such integration be performed. At present such an integrated geophysical program does not exist.

The study plan indicates that geophysical data from the preclosure tectonics program will be evaluated for the existence of magmatic anomalies, although these data may not be of high resolution and adequate to identify buried magmatic material.

This study plan will not provide any direct measurements or experimental tests, as all geophysical data to be used in this study plan will be based on information collected from other study plans. However, these other study plans are carried out to accomplish certain objectives which may not coincide with magmatic body identification.

The proposed study plans do not state alternative programs to be used for characterizing deep crustal and shallow geologic features if the prototype, feasibility testing mentioned in these study plans does not provide positive results.

The staff considers that the published geophysical data do not have the resolution required to adequately identify the distribution of magmatic material in the Yucca Mountain region such that realistic probability calculations and consequence models can be developed.

The White Paper, "Status of data, major results and plans for geophysical activities", DOE (1990), is not a complete integration of geophysical data, but as DOE stated, serves as a basis for implementing an integrated program during site characterization.

The study plan indicates that under Study Number 8.3.1.17.4.3 a single deep geophysical survey in an east-west transect crossing the Furnace Creek Fault zone, Yucca Mountain, and Walker Lane, will be conducted to evaluate deep structures.

The staff considers that a single east-west transect will not be sufficient to provide the necessary information for characterizing the nature of magmatic features in the Yucca Mountain region.

2-D geophysical surveys may not be adequate to characterize the volume and distribution of magmatic features in the Yucca Mountain region.

SCP Comment 52 (NUREG-1347) summarized the NRC staff's concern regarding the approach used to identify the distribution of igneous features and their extent in the site region.

RECOMMENDATION

In order to develop the probability models for evaluating future volcanic activity, DOE needs to demonstrate that sufficient data will be present to evaluate the presence, distribution and characteristics of magmatic features in the Yucca Mountain Region.

REFERENCES

DOE, 1990, Status of data, major results, and plans for geophysical activities, Yucca Mountain Project: YMP/90-38.

NRC, 1989, NRC staff site characterization analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada, NUREG-1347.

COMMENT 10

The MODEL 1 methodology for calculating the probability for repository disruption presented in section 3.2.2.2 appears to be incorrect.

BASIS

The regression plots in Figure 3 and their associated confidence bands cannot be used to calculate the probability of repository disruption, P_{rd}. Assuming that the mean longitude of volcanic centers is a linear function of latitude, each regression line in Figure 3 is an estimate of this relation. Given that a volcanic center is located at latitude X, a confidence interval for the longitude Y of the volcanic center is given by the intersection of a vertical line through X and the confidence band in Figure 3. If a confidence band with confidence level C_i intersects Yucca Mountain, all that is known is that Y lies inside the confidence interval with probability C_i and outside it with probability $1-C_i$. This does not mean that $P_{rd} = 1 - C_i$.

RECOMMENDATION

The DOE should consider developing a model for the spatial distribution of volcanic centers in the vicinity of Yucca Mountain and a model for the probability of repository disruption as a function of the location of a volcanic center, and combining these two models to calculate P_{rd}.

COMMENT 11

The equation for the disruption probability in Section 3.4.2.1 should be revised.

BASIS

The study plan notation appears to confuse events and their probabilities. A better formulation is to define the events E1, E2, and E3 as follows:

E1 = {a volcanic center is formed in the Yucca Mountain region during the repository isolation period of 10,000 years}

E2 = {the repository is disrupted}

E3 = {a release of radioactive waste to the accessible environment exceeds the regulatory requirements}

Then Equation 2 should be written as

$$\begin{aligned} Pr_{dq} &= Pr(E1 \text{ and } E2 \text{ and } E3) \\ &= Pr(E1).Pr(E2|E1).Pr(E3|E2) \end{aligned}$$

where the probability of E1 = $1-e^{-\lambda t}$, where λ = annual rate of volcanic center formation and t is the repository isolation period.

While the equation for Pr_{dq} above is correct, it is not very useful for calculating Pr_{dq} since it does not allow for the possibility that several volcanic centers might be formed during the period of performance. The correct approach is given in the referenced paper by Crowe, Johnson, and Beckman (1982), where Pr_{dq} is written as 1-Pr (no disqualification in time t). This complementary probability is then evaluated by summing over the number of eruptions.

RECOMMENDATION

DOE should consider defining the events E1, E2, and E3 as above, and replacing Equation 2 by its complementary form.

REFERENCE

Crowe, B.M., Johnson, M.E., and Beckman, R.J., 1982, Calculation of the probability of volcanic disruption of a high-level radioactive waste repository within southern Nevada, USA: Radioactive Waste Management and the Nuclear Fuel Cycle, V. 3, p.167-190.

COMMENT 12

Bias is not necessarily reduced or limited by weighting alternative models as is implied on page 40. Use of weighted models may obscure information essential for regulatory decision.

BASIS

If alternative models yield different results and the correct result was somewhere in the middle, then weighting models would tend to reduce bias. However, there is no assurance that the correct result is in the middle - it might be at one of the extremes or even beyond. If this were the case, then weighting could give a false assurance that bias had been reduced.

Identifying alternative models is an essential first step in reducing bias. Emphasis should be placed on identifying as wide a range as possible of alternatives which are consistent with existing data and knowledge. These alternatives should be subject to rigorous peer review. When existing data is insufficient to accurately estimate model parameters and expert opinion must be used, experienced practitioners should be used to train the experts and elicit their judgement. Care should be taken to assure that the results reflect the full extent of scientific uncertainty as expressed by the experts and should not artificially reduce it.

Suppose that Model A leads to a release which exceeds the regulatory requirements while Model B leads to a release which does not exceed the requirements. Suppose further that half of an expert panel prefers Model A while the other half prefers Model B, so that each is given equal weight. If the weighted release does not exceed the regulatory requirements, then the NRC may be led to believe that the repository design is acceptable. However, since only one of Model A or Model B can be correct, this conclusion is justified only if there is reasonable assurance that Model B is the correct model. However, since half of the experts prefer Model A, it would be necessary to determine whether such assurance exists. In this situation, the NRC's conclusion would be based on the realization that neither Model A nor Model B can be ruled out. The results of the various models should be presented separately, together with their accompanying justifications. This will allow the regulatory decision to reflect the full range of scientific uncertainty.

The staff notes that a procedure titled "Methods for Weighting Volcanic Probability Calculations Through the Use of Expert Opinion" is to be developed. It is possible that some of the staff concerns could be resolved if this procedure was available for review.

RECOMMENDATION

The proposed procedure should be developed and submitted to the NRC for review. In developing this procedure the DOE should factor in the considerations in the above comment.

COMMENT 13

The study plan proposes to use expert judgement to weight alternative models. This is inconsistent with previous NRC comments on the Site Characterization Plan, does not necessarily reduce bias, and may reduce information essential for a regulatory decision.

BASIS

In Objection 1 of the CDSCP, the staff recommended that "a full range of alternative conceptual models and associated boundary conditions suggested by available preliminary evidence should be systematically and clearly identified..." The hypotheses testing tables that were included in the Site Characterization Plan were prepared in response to the objection. They were intended to provide a systematic basis for identifying models and studies to accept or reject them.

The study plan does indeed place the emphasis on identifying as many alternative models as possible. This, if implemented properly, is consistent with the intent of Objection 1. The systematic identification of a full range of alternative models is a necessary first step in planning site characterization studies. However, properly implemented field studies and analysis of the resultant data while attempting to eliminate or verify the proposed models is the necessary second step. The study plan does not describe a data collection and analysis program to evaluate alternative models.

Expert judgment should be undertaken only after all reasonable means of obtaining data and doing analyses have been exhausted. The staff has stated this in its Site Characterization Analysis (SCA) Comment 3.

In its SCA, the staff has commented that weighting alternative conceptual models according to the judgment that they are likely to be correct is inappropriate and may overestimate the quality of repository performance (Comments 3, 93 and 98). The proposed approach in the study plan is not consistent with these open comments.

Although it is not the purpose of this study plan to collect data, the plan should provide some mechanism to assure that sufficient data will be available to allow the regulatory decisions to be made.

RECOMMENDATION

DOE should consider revising the study plan to demonstrate how the data to eliminate models and to support the remaining models will be obtained.

REFERENCES

NRC, 1989, NRC staff site characterization analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada: NUREG-1347.

NRC, 1988, R. E. Browning Letter to Mr. Ralph Stein of DOE transmitting NRC staff Draft Point Papers on the DOE Consultation Draft Site Characterization Plan (CDSCP).