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U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Igneous Activity

Presented to:
**NRC/DOE Technical Exchange
on Yucca Mountain Pre-Licensing Issues**

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**YUCCA
MOUNTAIN
PROJECT**

2/m-70

Current Status

(Issue Resolution Status Report Revision 2)

- **Subissue 1 - Probability**

- Three technical acceptance criteria are closed; staff have no further questions at this time
- Five technical acceptance criteria remain open pending additional demonstrations

- **Subissue 2 - Consequences**

- Two technical acceptance criteria are closed; staff have no further questions at this time
- Four technical acceptance criteria remain open pending additional demonstrations

Key Activities

- **Fiscal Year (FY) 1996:**
 - **Completed PVHA, culminating more than a decade of volcanic hazard investigations in the Yucca Mountain area**
- **FY 1998:**
 - **Used PVHA results (annual probabilities for intersection of dike with repository) as input to igneous effects scenarios in Total System Performance Assessment - Viability Assessment (TSPA-VA)**
 - **Calculated conditional probabilities of 1 or more eruptive centers through the proposed repository**

Key Activities

(Continued)

- **FY 1998**

- **Completed volcanic synthesis report that provided integrated description of igneous activity site characterization studies**

- **FY 2000**

- **Brocoum to Reamer letter (3/00) provided comments on Revision 2 of the Issue Resolution Status Report for this Key Technical Issue (KTI)**
- **Developed 6 Analysis and Model Reports (AMRs) to document the igneous characteristics of the site and surrounding region, and provide inputs for TSPA - Site Recommendation (SR) analyses**

Key Activities

(Continued)

- **FY 2000**
 - **Described conceptual framework for igneous activity consistent with volcanic and tectonic history of the Yucca Mountain Region**
 - **Recalculated probability of igneous intersection of the repository based on reconfigured repository design**
 - ◆ **Probability distributions for dike lengths and azimuths within repository footprint**
 - ◆ **Number of eruptive centers within repository footprint conditional on dike intersecting repository**

Key Activities

(Continued)

- **FY 2000**
 - **Features, events, and processes (FEPs) screening used as basis to identify igneous consequences to be included in TSPA-SR. Documentation provided in *Disruptive Events Features, Events, and Processes* AMR**
 - **Work in progress to**
 - ◆ **Evaluate volcanism effects on postclosure performance**
 - ◆ **Identify safety case factors associated with igneous activity subissues of Probability and Consequences**

KTI Subissues and Associated Factors of the Safety Case

KTI Subissues	Associated Factors of the Safety Case	Importance to Repository Performance
1 Probability	Not yet identified	Disruptive events will be evaluated as part of the Repository Safety Strategy process.
2 Consequences	Not yet identified	



Subissue 1, Probability

- **Estimates of volcanic hazard were determined based on expert elicitation results as described in PVHA report**
 - Results expressed as mean annual probability and 5th and 95th percentiles
 - Mean annual probability of igneous intrusion is about 1.6×10^{-8}
 - Frequency distribution includes NRC's annual probability of 10^{-7} (~0.995) *→ intrusive probability treated as intrusive probability*
- **Probability is specifically included in TSPA-SR**
- **For 3 technical criteria, staff have no further questions**

Subissue 1, Probability

(Continued)

- **Five technical criteria remain open pending results that show**
 - Sufficient information has been included in DOE analyses
 - Consideration of post-PVHA information
 - DOE estimates of future volcanic activity are consistent with tectonic models proposed for the Yucca Mountain Region
- ***Disruptive Events Process Model Report (PMR) and Supporting AMRs address these open technical criteria***
- **The following slides provide examples of methods DOE has used to address Acceptance Criteria 2 and 6 associated with the Probability subissue**

Subissue 1, Probability, Criterion 2

Estimates of the probability of future igneous activity in the Yucca Mountain Region will be acceptable provided that the definitions of igneous events are used consistently. Intrusive and extrusive events should be distinguished and their probabilities separately estimated.

- **DOE's View:**

- **The definitions of igneous events are used consistently. Intrusive and extrusive events should be distinguished and their probabilities estimated separately. Basis for probabilities is documented in *Disruptive Events* PMR**

- **NRC Issues**

- **Staff consider there is not enough information to rigorously define the probability of igneous activity, or the related probability of intrusive activity affecting repository**

Criterion 2, DOE Approach

- **Intrusive and extrusive events are defined and analyzed separately**
- **Probability of igneous intrusion intersecting the repository derived from PVHA**
 - **Uncertainty included as a distribution of probabilities**
- **Probability of eruption at repository**
 - **Based on PVHA interpretation for dike intersection of repository**
 - **Eruption probability is conditional on dike intrusion probability**
- **Documentation will be presented in the *Disruptive Events* PMR. The documentation and upcoming interactions should resolve open acceptance criteria**

Summary - DOE Position on Probability, Criterion 2

- **DOE meets acceptance criterion**
- ***AMR, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada***
 - **Develops separate probabilities for intrusive and eruptive events at repository location**
 - **Documents that probability of intrusion into repository is greater than probability of eruption**

Subissue 1, Probability, Criterion 6

Estimates of the probability of future igneous activity in the Yucca Mountain Region will be acceptable provided that the probability values used by DOE in performance assessments reflect the uncertainty in DOE's probabilistic volcanic hazard estimates

- **DOE's View**

- **DOE's value is the mean of the probability distribution for annual frequency and is about 1.6×10^{-8} for the igneous intrusion**
- **10^{-7} is high percentile (~0.995) in DOE distribution range for intrusive events and will be included in the range of values used**

- **NRC Issues**

- **DOE conditional probability of one or more eruptive centers forming within repository footprint is too low**

Summary - DOE Position on Probability, Criterion 6

- DOE meets acceptance criterion
- DOE will continue to use full probability distributions derived from PVHA model as recalculated for current repository footprint
- Basis for probability is documented in AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada*

Subissue 1, DOE Position on Probability, Criterion 6

(Continued)

- **DOE will evaluate significance of uncertainty in probability estimates in sensitivity analyses performed for TSPA-SR**
 - **Sensitivity analysis will be run for 10^{-7} value**

Subissue 2, Consequences

- **FEPs screening used to identify consequences included in TSPA**
- **Staff have no further questions for 2 technical criteria**
- **Analyses in AMRs are believed to be responsive to NRC's concerns in remaining open criterion**
- **Additional analyses are in progress**
 - **Analyses of no-backfill case**

Summary

- **Current analyses indicate that:**
 - Mean annual frequency of igneous intrusion is about 1.6×10^{-8}
 - Probability of eruption is conditional and is less than probability of intrusion
 - Uncertainty in probability is included in TSPA
 - FEPs screening used to identify consequences that are included in TSPA
 - Volcanism effects on postclosure performance are being evaluated

Summary

(Continued)

- **Areas of Agreement**

- **NRC and DOE estimates of probability of future igneous activity are based on the same information**
- **DOE work will include consideration of the NRC's annual probability and associated uncertainty**

Summary

(Continued)

- **Areas of Disagreement (Brocoum letter to Reamer, 3/00)**
 - **DOE will use the full range of annual frequencies of igneous intersection rather than a single value preferred by the NRC**
 - **DOE believes that the NRC approach, emphasizing a single value, is based on overly conservative interpretations and does not represent the appropriate range of interpretations and uncertainties**

Backup



Key Technical Issue: Igneous Activity		
Acceptance Criterion	IA IRSR Rev 2 Status	DOE Comment
Subissue: Probability		
1 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the estimates are based on past patterns of igneous activity in the YMR.	Staff have no questions with material presented in TSPA-VA.	Agree
2 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the definitions of igneous events are used consistently. Intrusive and extrusive events should be distinguished and their probabilities estimated separately.	Staff considers that there is not enough information to rigorously define the probability of igneous activity, or the related probability of intrusive activity affecting the repository.	DOE definition of volcanic event allows for calculation of probabilities for both intrusive and extrusive events (see AMR "Characterize Igneous Framework for Igneous Activity at Yucca Mountain, Nevada").
3 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the models are consistent with observed patterns of volcanic vents and related igneous features in the YMR?	Staff have no questions with material presented in TSPA-VA.	Agree
4 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that parameters used in probabilistic volcanic hazard assessments, related to recurrence rate of igneous activity in the YMR, spatial variation in frequency of igneous events, and area affected by igneous	Open; effects of post-PVHA data on PVHA results need to be evaluated.	Disruptive Events PMR and supporting AMRs will provide technical justification and documentation.

Key Technical Issue: Igneous Activity

Acceptance Criterion	IA IRSR Rev 2 Status	DOE Comment
events, are technically justified and documented by DOE.		
5 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the models are consistent with tectonic models proposed by NRC and DOE for the YMR.	Open; staff questions ability of DOE to reconcile volcanological models with the tectonic models and geophysical data.	PVHA models are consistent with conceptual model of volcanism in Yucca Mountain Region (AMR "Characterize Igneous Framework for Igneous Activity at Yucca Mountain, Nevada").
6 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the probability values used by DOE in performance assessments reflect the uncertainty in DOE's probabilistic volcanic hazard estimates.	Open; staff analyses indicate that low values (mean 6×10^{-9}) do not accurately account for the long history of recurring basaltic volcanism around Yucca Mountain and better represent the annual probability of a volcano erupting randomly within the western Great Basin.	For TSPA, DOE will continue to use the full probability distribution for a dike intersecting the repository (intrusive) and eruptive center forming in repository (extrusive) based on PVHA and the Disruptive Events PMR. DOE will include 10^{-7} in range of values used.
7 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the values used (single values, distributions, or bounds on probabilities) are technically justified and account for uncertainties in probability estimates.	Staff has no further questions but will monitor implementation of analyses that include 10^{-7} annual probability.	See information for criterion 6.
8 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that if used, expert elicitations were conducted and documented using the	Open; pending reconciliation of post-PVHA information with PVHA results.	Treatment of new information is included in the Disruptive Events PMR and supporting AMRs.



Key Technical Issue: Igneous Activity		
Acceptance Criterion	IA IRSR Rev 2 Status	DOE Comment
guidance in the Branch Technical Position on Expert Elicitation, or other acceptable approaches.		
9 - Estimates of the probability of future igneous activity in the YMR will be acceptable provided that the collection, documentation, and development of data and models has been performed under acceptable QA procedures, or if data was not collected under an established QA program, it has been qualified under appropriate QA procedures.	Open; TBD.	Process Validation and Reengineering (PVAR) and other key initiatives provide procedural QA framework guiding development of DE PMR and the supporting AMRs and calculations
Subissue: Consequences		
1 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that the models are consistent with the geologic record of basaltic igneous activity within the YMR.	Open; use of physical conditions representative of violent strombolian activity would resolve NRC questions under this criterion.	The TSPA model is not final at this time.
2 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste	Staff have no questions regarding the implementation of the modified Suzuki model in TSPA-VA.	The TSPA model is not final at this time.

Key Technical Issue: Igneous Activity

Acceptance Criterion	IA IRSR Rev 2 Status	DOE Comment
repository will be acceptable provided that the models are verified against igneous processes observed at active or recently-active analog igneous systems and reflect the fundamentals of ash-plume dynamics.		
3 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that the models adequately account for changes in magma ascent characteristics and magma/rock interactions brought about by repository construction.	Open; pending DOE demonstrating adequate consideration of the effects of developing and operating a repository on magma ascent characteristics.	The TSPA model is not final at this time.
4 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that the models account for the interactions of basaltic magma with engineered barriers and waste forms.	Open; pending analyses to support waste package resiliency and waste particle fragmentation.	The TSPA model is not final at this time.
5 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that the	Open; pending DOE developing a reasonably conservative technical basis supporting analyses of radiological dose during and following a volcanic eruption.	The TSPA model is not final at this time.



Key Technical Issue: Igneous Activity		
Acceptance Criterion	IA IRSR Rev 2 Status	DOE Comment
parameters are constrained by data from YMR igneous features and from appropriate analog systems such that the effects of igneous activity on waste containment and isolation are not underestimated.		
6 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that if used, expert elicitations were conducted and documented using the guidance in the Branch Technical Position on Expert Elicitation, or other acceptable approaches.	Resolved, but also pending demonstration that staff questions associated with Probability criterion 7 have been satisfactorily addressed.	Agree
7 - Estimates of the dose consequences of igneous activity on the proposed Yucca Mountain high-level radioactive waste repository will be acceptable provided that the collection, documentation, and development of data and models has been performed under acceptable QA procedures, or if data was not collected under an established QA program, it has been qualified under appropriate QA procedures.	Open; TBD	Process Validation and Reengineering (PVAR) and other key initiatives provide procedural framework guiding development of DE PMR and the supporting AMRs and calculations