Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Igneous Activity

June 21-22, 2001
Las Vegas, Nevada

Introduction and Objectives

This Technical Exchange and Management Meeting on Igneous Activity is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review and the U.S. Department of Energy (DOE) site recommendation decision. Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of aspects of igneous activity most important to repository performance. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

The objective of this meeting was to discuss and review the progress on resolving the igneous activity KTI, specifically Subissue 2 (see Attachment 1 for the description of the subissues). The quality assurance (QA) aspect of this KTI was determined to be outside the scope of the meeting and is being tracked in NRC's ongoing review of the DOE's QA program.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, the NRC staff stated that Subissue 1 remains "closed-pending" and Subissue 2 remains "open." Specific NRC/DOE agreements made at the meeting are provided as Attachment 1. Proposed NRC agreements to which DOE has not agreed are provided as Attachment 2. Modifications to existing NRC/DOE

agreements are provided as Attachment 3. The agenda and the attendance list are provided as Attachments 4 and 5, respectively. Copies of the presenters slides are provided as Attachment 6. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments and Overview

NRC opened the meeting with an overview of igneous activity (see "Overview of Igneous Activity Meeting" presentation given by Bret Leslie) and stated that this meeting would address part of DOE's performance assessment related to igneous activity. NRC discussed what performance assessment is and the terms and definitions used. NRC discussed igneous activity, the terms used, and the general areas of igneous activity which would be discussed during the meeting. NRC stated that posters and handouts which discuss performance assessment and igneous activity were available during the meeting and that NRC staff would be available to discuss specific issues during the breaks and after the meeting.

NRC then presented comments on igneous activity models with respect to performance assessment (see "Comments on Igneous Activity Models with respect to Performance Assessment" presentation given by Richard Codell). NRC stated that DOE: (1) needs to characterize igneous activity model uncertainty and propagate it through the model abstractions, and (2) is responsible to provide justification for the use of ASHPLUME and associated NRC codes in the performance assessments. NRC discussed some areas of model uncertainty and the NRC performance assessment code.

NRC then provided a general overview on the status of igneous activity issue resolution (see "NRC Introductory Comments" presentation given by John Trapp). NRC stated that although it would not discuss them in depth, a status of each existing NRC/DOE agreement and proposed path forward for each NRC concern to be discussed during the meeting are captured in its table.

2) Technical Discussions - Magma-Drift Interactions

NRC presented the scenario of a magma dike interacting with drifts (see Explosive Magmatic Eruptions into Subsurface Tunnels" presentation given by Onno Bokhove). NRC stated that during its presentation, it would be addressing two questions (1) does the pressure in the tunnels increase beyond critical pressure levels, and (2) where and when can we expect rock fracture and, hence, new pathways to the surface? NRC stated that rock hydrofracturing is assumed to occur at 5 MPa at approximately 300 meters (repository depth) below grade. NRC then discussed a magma flow model and the equations used to create the numerical model. NRC discussed the results from the model. NRC noted that this model makes the general assumptions that (1) the drift is five meters in diameter, (2) the drift does not contain waste packages, drip shields, backfill, or debris from rock collapse, (3) the end of the tunnel is an impermeable barrier, (4) there is no loss of energy into the walls, (5) the geometry of the drift-dike system is prescribed and does not change during the initial transient, and (6) standard volatile content (e.g., two percent water) and other properties of alkali basalts were used. NRC further stated that this model is a first step in exporing magma-drift interaction and that more work needs to be done to understand additional aspects (i.e., how waste packages affect

magma flow, how geometry of the dike and tunnel system affects the shock wave, the importance of rock fall, etc.). NRC stated that as the dike interacts with the drift, magma entering the drift creates a shock wave in the drift. The amplitude of the shock wave increases on reflection at the closed end of the drift and eventually the wave is propagated back down the drift into the dike. Based on the results of this first-order model, NRC stated that critical rock-fracture pressures (approximately 5 MPa) may be exceeded in magma-repository interactions, especially at the tunnel ends and to a lesser degree at the tunnel roof near the dike-drift intersection.

The next NRC presentation discussed the possible consequences of one set of scenarios for magma-drift interaction (see "Magma-Drift Interactions" presentation given by Andy Woods). Three possible scenarios were described. Case (a) involves the dike continuing its original path up to the surface after filling the drift. Case (b) involves the development of a new path from the drift where the magma moves upward to the surface (a point of weakness due to existing fractures or topography change). Case (c) involves the magma filling the drift and escaping through the access drift. NRC stated that the cross-sectional area of the drift system is of comparable magnitude to the dike indicating that magma can be diverted into the drift. NRC discussed how the volume from the eruption of the local cones is one to two orders of magnitude more than the volume of the repository, suggesting that a quasi-steady flow may develop. NRC presented the pressure and velocity profiles for magma flow as a function of depth for each case, assuming the magma-volatile mixture behaves as a pseudo-fluid using standard properties of alkali basalt. The model does not include the effects of gas-magma separation, which may complicate the flow, or the response of the engineered or geological structure to the flow. The model predicts flow rates of order 100 meters per second at the surface, typical of stromblian activity.

During these two presentations, DOE asked, and NRC answered a number of questions concerning the model, the assumptions used, and the results. These questions are discussed below.

Effects of changes in volatile content were addressed in one dimensional parametric studies. Changes in water content from 1 to 2.5 percent only had a minor effect on calculated pressures and flow rates. Questions were raised on the effects of engineered structures such as waste packages, drip shields, and naturally occurring rockfall on magma flow processes. Although those features will likely induce turbulence, they are not modeled explicitly. In addition, changes in the geometry of drift end and the presence of backfill will likely affect calculated pressures and flow rates. NRC is considering how to evaluate these effects in future models. NRC is also concerned how topography may affect the location of vertical breakout from magma-filled drifts and mechanisms for capturing an appropriate volume of ascending magma in a dike by flow into a drift.

DOE then discussed the NRC concerns expressed during an Appendix 7 meeting held on May 18, 2001 (see "Magma-Drift Interactions, Magma-Waste Package Interactions, and Magma-Waste Form Interactions" presentation given by Eric Smistad and Greg Valentine). DOE stated that during the Appendix 7 meeting, NRC presented a new igneous activity consequence model that depicts the magma-repository interactions more mechanistically. DOE stated that it has not had enough time to evaluate this new model and acknowledged that additional work to evaluate the new consequence model may be warranted and desirable to

support any potential license application, but that it needs further study of the consequence models before defining that additional work. DOE stated that its objective for this area is to continue the dialogue on the new model.

DOE then discussed each of the six NRC concerns (see Attachment 2 for description of concerns) regarding magma-drift interactions. DOE presented a synopsis of each concern and work on each concern done to date. For each concern, DOE stated that it has addressed the NRC concern in a limited or simplified manner. Following an NRC caucus on magma-drift interactions, NRC questioned whether DOE would be in a position to state whether it felt these concerns need to be addressed and if DOE could provide the NRC with any initial plans to address these concerns. DOE stated that project planning for FY2002-2004 is just beginning and has not sufficiently progressed to address these concerns, as well as the NRC concerns related to magma-waste package, magma-waste form, and miscellaneous items. NRC stated that it would document these concerns in this meeting summary (see Attachment 2) so that DOE will have the areas where NRC believes additional information is needed. In addition, NRC stated that the remaining topics (magma-waste package, magma-waste form, and miscellaneous items) did not need to be presented because the information contained in the slides did not discuss DOE plans and activities to address the concerns. Further, NRC stated that since NRC and DOE will not be able to agree on a path forward for these concerns, the consequences subissue will remain "open."

3) Technical Discussions - Magma-Waste Package Interactions, Magma-Waste Form Interactions, and Miscellaneous Items

These areas were not discussed, as noted above.

4) Technical Discussions - TSPA Supplement Sensitivity Analyses

DOE discussed several issues associated with its Total System Performance Assessment (TSPA) supplemental sensitivity analysis methodology (see Total System Performance Assessment Supplemental Sensitivity Analyses: Igneous Activity" presentation given by Peter Swift). Specifically, DOE addressed (1) sensitivity to alternative wind speed data, (2) sensitivity to uncertainty in waste particle diameter, (3) relative dose contributions from waste package damage due to igneous intrusion in Zones 1 and 2, and (4) a bounded approach to ash redistribution. DOE stated that new information developed since the Total System Performance Assessment - Site Recommendation (TSPA-SR) Revision 00, ICN 01, is being documented in the fiscal year 2001 Supplemental Science and Performance Analyses (SSPA) and will subsequently be provided to NRC in either approved calculations or analysis and model reports.

Regarding sensitivity to alternative wind speed data, DOE stated that the wind speed distribution used in supplemental analyses is based on 300 millibar data (average elevation 9400 meters above sea level). DOE concluded that calculated probability-weighted mean annual doses are moderately sensitive to wind speed uncertainty (new data increase probability-weighted dose by approximately a factor of two). NRC questioned whether the wind data was averaged for all wind directions and heights. DOE stated that all directions at 300 millibar were used in the average. NRC also questioned whether DOE had evaluated the higher wind speeds that may exist during future glacial periods. DOE stated that it felt the present data used is conservative in this respect. Following the NRC caucus on this issue, the

staff stated that the DOE approach appears reasonable and that it would review the documents noted in Attachment 3 (IA.2.09).

Regarding sensitivity to uncertainty in waste particle diameter, DOE stated that calculated probability-weighted mean annual doses are insensitive to current uncertainties in waste particle diameter within this range (0.00005 to 0.1 cm, modes between 0.0002 and 0.02 cm). Following the NRC caucus on this issue, the staff stated that the DOE approach appears reasonable and that it would review the documents noted in Attachment 3 (IA.2.02).

Regarding the relative contributions to calculated annual dose from waste package Zone 1 and Zone 2, DOE showed that Zone 1 is the major contributor to igneous groundwater dose. DOE also discussed modifications to the cumulative distribution functions (CDFs) for the number of packages damaged by intrusion. DOE stated that the new information has led to recalculation of the CDFs. NRC questioned why the upper end of the range of Zone 1 increased significantly. DOE stated that this increase is due to very infrequent intersection of a dike along the length of a drift. DOE then presented the effect of recalculating distributions for the number of waste packages damaged by igneous intrusion for both Zone 1 and 2. Following the NRC caucus on this issue, the staff stated that DOE addressed the issue as requested and that the staff would review the documents noted in Attachment 3 (IA.2.10). NRC noted that the proposed magma-drift and magma-waste package agreements need to be addressed.

Regarding the TSPA-SR, Revision 00, ICN 01 approach to the effects of ash redistribution, DOE discussed its conclusion that for the same set of input parameters, conditional dose at any time following an eruption can be no greater than the conditional dose that would result if the eruption occurred in that year (i.e., doses do not get worse than they are in the first year). DOE further stated that it considers that this approach provides a technical basis to demonstrate that the modeling assumptions in TSPA-SR, Revision 00, ICN 01 are conservative. In calculating expected annual dose, however, DOE indicated that they use a soil removal rate that is representative of all farm lands, rather than conservatively assuming no soil removal. NRC questioned how this approach provided a conservative basis to ignore potential inputs to soil from wind and water remobilization. DOE responded that other conservatisms such as directing the plume towards the critical group and using transition-phase BDCFs already achieved a level of conservatism sufficient to ignore direct modeling of remobilization effects. NRC staff disagreed that the DOE approach is a conservative basis to calculate expected annual dose, and that the long-term effects of remobilization could affect risk calculations significantly. NRC also stated that the conclusion that doses could not increase above the first year dose was only valid if the doses were mainly from inhalation. DOE stated that most of the dose in the igneous scenario is from the inhalation pathway.

Following the NRC caucus on this issue, the staff stated that DOE has not addressed the NRC concern. DOE needs to address how the process is conservative with respect to risk (i.e., expected annual dose) and that this topic should be classified as “open.” NRC further noted that as a result of the proposed NRC Agreement 11 (see Attachment 2), existing agreement IA.2.06 has been superceded. Agreement IA.2.06 can be listed as complete and should reference NRC proposed Agreement 11 as the basis for completion.

5) Technical Discussions - Biosphere Items

DOE then discussed biosphere-igneous activity interactions (see Biosphere-Igneous Activity Interactions" presentation given by A. Smith). DOE then addressed each of the NRC concerns presented at the May 18, 2001, Appendix 7 meeting.

Regarding the comparison of static versus disturbed conditions, DOE stated that scoping calculations used time-activity budgets based on the behavior of a farmer. Dust loads for post-volcanic conditions and farming activities were calculated to confirm that the static measurements were appropriate. NRC questioned what the environment was like where mass loading values for working outdoors under nominal conditions were measured. DOE indicated that these measurements were taken in a semi-arid environment.

Regarding the average annual static concentrations versus eight-hour workday disturbed conditions, DOE stated that the duration of exposure was based on assumed behaviors of farmers, that the distribution of exposure time to outdoor concentrations ranged from 8.0 to 10.8 hours per day, and that this method considers disturbed conditions.

Regarding the basis for extrapolating total suspended particulates (TSPs) concentrations, DOE stated that it is re-evaluating the ratios used to determine TSPs and is considering using measured values of TSPs in future calculations rather than estimates based on PM_{10} concentration.

Regarding the assumption that concentration of resuspended particles returns to background values within 10 years, DOE stated that the combination of the 10-year period and the assumption of no removal of material are considered to be conservative. NRC asked DOE to clarify what it meant by the "assumption of no removal of material." DOE stated that material was not removed from the system during the calculation of the BDCFs, which was a short time period compared to the time steps in TSPA.

Regarding the mass loading above a tephra deposit, DOE stated that BDCFs that include soil removal were not used in TSPA-SR. DOE further stated that more conservative BDCFs were used and that when generating BDCFs, credit was taken for stabilization (no credit was taken for removal). NRC questioned DOE's justification for the assumption that mass loading returned to nominal values within 10 years of the eruption. DOE clarified that by sampling a transition-phase mass loading value between the first year value and the value for nominal conditions and using this value to calculate dose at all later times, the time period for the return to nominal conditions does not matter.

Regarding external exposure from high level waste contaminated ash, DOE stated that an appropriate shielding factor for external exposure would be incorporated in a future update to the Input Parameter Values for External and Inhalation Radiation Exposure Analyses AMR. DOE further stated that the effect of external exposure is negligible on TSPA-SR results.

Regarding the effects of climate change on disruptive events BDCFs, DOE stated that the inhalation pathway is dominant for the volcanic eruption BDCFs. DOE further stated that climate change with increased precipitation would lead to more rapid stabilization and increased

loss from leaching and thus leads to reduced re-suspension of radionuclides. DOE stated that it was not taking credit for these processes.

As a result of additional discussions, the NRC and DOE reached six additional agreements for Subissue #2 (see Attachment 1). Since additional agreements are needed for Subissue #2, the subissue remains "open." NRC also noted as a result of these six new agreements, existing agreement IA.2.07 has been superceded. Agreement IA.2.07 can be listed as complete and should reference to these six new agreements as the basis for completion.

6) University of Nevada - Las Vegas Presentation

A presentation on new information was given by Professor Eugene Smith from the University of Nevada - Las Vegas (see " New Observations about Basaltic Volcanism near Yucca Mountain: Implications for Volcanic Hazard Studies"). The presentation was broken into three areas, patterns of volcanism, control of volcanism, and implications and recommendations.

Professor Smith presented maps showing volcanism from 9.5 to 0.02 million years ago. He concluded that volcanism is episodic and that a temporal link exists between volcanism in the Lunar Crater-Crater Flat areas. NRC questioned the distribution of volcanoes shown. Particularly, volcanoes south of Amargosa Desert were not included. Professor Smith indicated that the needed geochronological information was not available for these volcanoes. Therefore, they are not included. NRC stated that it is crucial to consider the time and spatial scales of clustering of volcanoes. NRC also questioned if the maps show individual cinder cones. Professor Smith said the maps do show individual cones. Professor Smith also concluded that volcanic fields change shape with time and new cinder cones rarely occur at sites of older events. The NRC questioned these conclusions and stated that on the scale of the maps he is showing, volcanoes occur in discrete clusters. The plots covered millions of years while the regulatory period is 10,000 years. The NRC stated that one needs to be careful with the timescales used to maintain an appropriate risk perspective.

Professor Smith then discussed the control of volcanism and the melting depth in the region from the eastern Sierra Nevada to the Colorado Plateau. Professor Smith concluded that the melting depth increases from the eastern Sierra Nevada area reaching a maximum in the central Great Basin before decreasing gradually toward the Colorado Plateau. Professor Smith also concluded that hot, deep melting exists beneath Crater Flat-Lunar Crater. DOE questioned Professor Smith's assessment. DOE suggested that the bulk of evidence supports lithosphere melting models for generation of basaltic magma, rather than melting of dry asthenosphere. DOE indicated that the evidence for large-scale mantle plumes in the Yucca Mountain Region is weak. DOE suggested that the presence of low velocity zones at great depth (200-300 km) is not relevant to melt generation in the asthenosphere and does not support a mantle plume model.

Professor Smith then summarized his conclusions and recommendations. He stated that deep melting exists beneath the central Basin and Range and that this is consistent with a mantle hot spot. Professor Smith recommended (1) that probability models that depend on steady state recurrence rates may not adequately describe the volcanic hazard, (2) that probability studies should consider the episodic nature of volcanism and the possibility that another flare-up may occur in the near future, (3) that past patterns may not be an indication of future activity, (4) that

probability models should consider the changing shape of volcanic fields and the observation that past activity may not be a key to future events, and (5) that probability models should be calibrated by going back in time. NRC noted that the probability model in use has been calibrated against patterns of basaltic volcanism in a variety of tectonic settings. NRC indicated that probability models currently in use do account for spatial clustering. NRC noted that temporal clustering, while important for understanding volcanic activity in the region, occurs on a very long time scale compared to the performance period. Therefore, uncertainty in the recurrence rate of volcanism can be treated with a temporally homogeneous model. DOE noted that there are two clusters, not a belt.

7) Existing Agreements

NRC and DOE also discussed several existing igneous activity agreements. A number of these agreements reference TSPA-SR, Revision 1, which DOE has stated will not be available in June 2001 as agreed to. After discussion on these agreements, DOE proposed changes to the wording to reference other documents. The reworded agreements are provided in Attachment 3.

In addition, as noted above, existing NRC/DOE Agreements IA.2.06 and 2.07 have been superceded and can be listed as complete. These agreements have been superceded by agreements and proposed agreements documented in this meeting summary.

8) Public Comments

None.

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