DOC.20081001.0001

YMP	**Model** **Error Resolution Document** *Complete only applicable items.*	QA: QA Page 1 of 49

1. Document Number:	ANL-MGR-GS-000002	2. Revision/Addendum:	Rev 03	3. ERD:	ERD 02
4. Title:	Characterize Eruptive Processes at Yucca Mountain, Nevada				
5. No. of Pages Attached:	48				

6. Description of and Justification for Change (Identify affected pages, applicable CRs and TBVs):

The following evaluations, changes, and corrections (attached) are posted to address the recommendations and associated issues identified in CR 11939 and CR 11940. Responses that include ERD revisions to the document provide corrections to specified reference citations, clarifications to descriptions, or provide editorial corrections to typographical errors. None of the responses to the items identified in the two CRs adversely affects the results of the TSPA that supports the license application. Detailed responses to each recommendation and the associated issues are attached. Table ERD-1 provides an evaluation of the impacts of the ERD revisions on documents that referenced the report, *Characterize Eruptive Processes at Yucca Mountain, Nevada* Rev 03.

7. CONCURRENCE			
	Printed Name	Signature	Date
Checker	Gordon Keating	Gordon Keating	9/30/08
QCS/QA Reviewer	Sounia Kassabian Darnell	Sounia K. Darnell	9/30/2008
8. APPROVAL			
Originator	Terry Crump/Cliff Howard	Terry R. Crump / J McNeish for C Howard.	9/30/2008
Responsible Manager	Jerry McNeish	Jerry A McNeish	9.30.08

SCI-PRO-006.3-R1

CR 11939 Evaluation

I. Background Information:

The audit of three igneous activity technical products (Lead Lab Internal Audit LQA-IA-08-001), described information in ANL-MGR-GS-000002, Rev. 03, that was presented without identifying the information source, or the wrong information source as referenced (CAQ #1). Furthermore, it was determined that technical errors in report details were identified in the Analysis Report ANL-MGR-GS-000002, Rev. 03 (CAQ #2) and that the Analysis Report ANL-MGR-GS-000002, Rev. 03, "Purpose" does not adequately reflect the document contents (CAQ #3).

II. Disposition of Major Issues/Descriptions of Changes

The following numbered and lettered items provide responses to each issue documented in CR 11939.

CAQ #1

Requirement: SCI-PRO-005, Revision 9, Section 6.2.1, Paragraph C, states: "[Originator] Document the Analysis/Calculation in accordance with Attachment 2, Outline for Analysis/Calculation Reports. Ensure information presented in the scientific Analysis/Calculation documentation is transparent, traceable, and reproducible to other qualified individuals."

Condition: Contrary to the requirement stated above, during Lead Lab Internal Audit LQA-IA-08-001, it was discovered that information was presented in ANL-MGR-GS-000002, Rev. 03, without identifying the information source, or the wrong information source as referenced. See examples documented below:

(Issue 2a)
The source for the information on dike width provided on page 6-19 is not identified.

Response: The information in question is in the following paragraph taken from the report:

“Because the dike widths in the regional analogues range over only one order of magnitude, a normal distribution for dike widths is appropriate for description. The normal distribution of dike widths can be described as having a mean of 8 m, a minimum of 1 m and 95th percentile of 12 m.”

For the ERD, the paragraph is revised to read as follows:

"Based on field observations (Appendix F; Table F-1), the dike widths at analogues in the region range over only one order of magnitude, and the dikes measured indicate that a normal distribution for dike widths is considered appropriate. The normal distribution of dike widths can be described as having a mean of 8 m, a minimum of 1 m and 95th percentile of 12 m."

Impact Evaluation and Conclusion: The ERD revision clarifies that the source for the dike width information is field observations but does not alter the distribution of dike widths in the technical product output. There is no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

(Issue 51)
Figures C-7, C-8, C-9, C-11, C-12, C-15, C-16, E-3, E-4, E-5, E-6, E-7, E-8, E-9 and Tables E-1 have no source document cited. All figures and tables in the document require correct sources.

Response: The ERD revision adds the following source information or caveats, as appropriate, as notes to figures or tables:

Fig. C-7: [to the note for (a):] "For illustration purposes only."
[to the note for (b):] "Figure developed from data in DTN: LA0302GH831811.002."

Fig. C-8: "Figure developed from data in DTN LA0305DK831811.001."

Fig. C-9: [below note for (b), pertaining to both (a) and (b):] "Figures developed from data in DTN: LA0302GH831811.002 and DTN LA0305DK831811.001."

Fig. C-11: "For illustration purposes only."

Fig. C-12: [pertaining to all photos:] "For illustration purposes only."

Fig. C-15: "Figures developed from information discussed in Perry et al. 1998 [DIRS 144335], pp. 2-66 to 2-67."

Fig. C-16: "For illustration purposes only."

Fig. E-3: "For illustration purposes only. Map developed from field studies described in accompanying text."

Fig. E-4: [pertaining to (a), (b), (c):] "For illustration purposes only."

Fig. E-5: "For illustration purposes only. Map developed from field studies described in accompanying text."

Fig. E-6: "For illustration purposes only."

Fig. E-7: "For illustration purposes only."

Fig. E-8: "For illustration purposes only. Map developed from field studies described in accompanying text."

Fig. E-9: "Figure developed from data in DTN: LA0411AC831142.001."

Fig. E10: "For illustration purposes only. Map developed from field studies described in accompanying text."

Fig E-11: "For illustration purposes only."

Fig. E-12: "For illustration purposes only."

Fig. E-13: "For illustration purposes only."

Table E-1: "Note: For comparative use only. Source: LA0710DK150308.001."

Impact Evaluation: The ERD adds source information for the figures and tables or adds clarification that the figures and tables are for illustration or comparative purposes only. The added notes do not alter the distribution of dike widths in the technical product output. There is no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

(Issue 55)
The information for dike orientation, number of dikes, and azimuth can be found in the text and the peer review documents. However this information is not sourced in the tables including Table 6—6, table 6-7, and Figure 6-3. All figures and tables in the document require correct sources.

Response: Tables 6-6 and 6-7 and Figure 6-3 present information that is developed in the surrounding text.

For the ERD, the following note is added to the captions of Tables 6-6, 6-7, and Figure 6-3: "Note: the information on which this [table / figure] is based is developed in the text of Section 6.3.3.1.

Impact Evaluation: The ERD adds source information for the figures and tables. The added notes do not alter the distribution of dike widths in the technical product output. There is no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

(Issue 57)
There are many lower tiered discussions found in the document that make subtitle assumptions and they are not always documented or discussed. Some examples include 1) page 6-20 where a random uniform distribution is used for dike spacing between 0.5

and 1,500 m. There has been an assumption about the kind of distribution. An uncertainty has not been captured because there is no discussion of the distribution. 2) The information used for dike width is on page 6-19. This includes that it is a normal distribution with a mean of 8m, a minimum of 1 m, and a 95th percentile of 12 m. There is no basis presented of why this should be a normal distribution, and 3) conduit diameter is assumed to have a normal distribution. These distributions need to be discussed and justification or rational for their use is required.

Response: See responses by page number indicated in the issue description.

Item 1, Page 6-20: For the ERD, text on page 6-20 is revised as follows:
"Based on the variability observed in the field and lack of a recognizable distribution of spacings between dikes, the recommended dike spacing (measured edge-to-edge) for the Yucca Mountain region is a random uniform distribution ranging from 0.5 m to 1,500 m."

Item 2, Page 6-19: For the ERD, the text on page 6-19 is revised to read as follows:
"Based on field observations (Appendix F, Table F-1), the dike widths at analogues in the region range over only one order of magnitude, and the dikes measured indicate that a normal distribution for dike widths is appropriate. The normal distribution of dike widths can be described as having a mean of 8 m, a minimum of 1 m and 95th percentile of 12 m."

Impact Evaluation: The ERD revision clarifies the basis for the distribution of dike widths but does not change the distribution. Therefore, the ERD item has no impact on results or conclusions of ANL-MGR-GS-000002 REV 03

Item 3, Source not identified in comment, but apparently Section 6.3.3.3: Conduit diameter is assumed to have a normal distribution.

Response: The last sentence of paragraph 1 of the Summary (P. 6-28) is the basis for the comment: "Therefore, the range of conduit diameters sampled for eruptive modeling in TSPA should be a normal distribution with a minimum value that is determined by the dike width of a given realization, a 95th percentile value of 21 m, and a mean of 15 m."

The basis for the conduit geometry is described in the first paragraph of the Summary:
"Based upon the eroded analogues, roughly circular conduits do not reach down to repository depths of 300 m, implying that the effective "conduit diameter" at that depth would be the dike width; therefore, it is recommended that the dike width (chosen from a distribution, Section 6.3.3.1) be used as a minimum conduit diameter for TSPA."

For the ERD, the description of dike widths is revised as shown in Item 2 (above). No additional source is needed.

Impact Evaluation: The ERD adds source information for the page number items identified in the issue statement. The added notes do not alter the distribution of dike spacings or conduit diameters in the technical product output. The ERD revision has no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03

(Issue 81a)
Page 6-25, Paragraph 2. The discussion that dike intrusion could trigger a relatively large earthquake on a preexisting fault is controversial; a reference is required.

Response: The description in question is:
"By triggering slip on a preexisting tectonic fault, dike intrusion could generate an earthquake with a magnitude that is larger than that caused directly by dike formation (i.e., larger than earthquakes observed within active volcanic rift zones; Figure 6-4). Such a process could affect the timing of a specific earthquake on a pre-existing fault, but should not affect the long-term average rate of movement, which would be driven by the larger-scale tectonic state of stress."

The text clearly states appropriate qualifications "(i.e., larger than earthquakes observed within active volcanic rift zones; Figure 6-4)." The range of instrumentally observed seismicity at active volcanic rift zones (3 to ~ 4.7) is clearly identified in Figure 6-4 and described in the Note below the figure, and Figure 6-4 is clearly referenced in the parenthetical description. Since some of the earthquake magnitudes shown in Figure 6-4 are greater than the magnitudes typical of range of instrumentally observed seismicity at active volcanic rift zones, a sufficient basis exists within the discussion to support the hypothesis.

The discussion of dike induced earthquakes (Section 6.3.3.2) is well-referenced, including references on reactivation of pre-existing faults and the potential for earthquakes generated in the process. The analysis report text cites appropriate references, and the methods used to determine potential dike induced earthquake magnitudes follow published methodologies. No additional source information is needed.

Impact Evaluation: None
CAQ #2

Requirement: In SCI-PRO-005, Rev. 09, the originator has assigned responsibility for performing a scientific analysis/calculation, for preparing scientific analysis/calculation documentation (e.g., analyst, investigator, preparer), and for ensuring the adequacy, accuracy, and completeness of the scientific analysis/calculation documentation.

Condition: Contrary to the requirement stated above, during Lead Lab Internal Audit LQA-IA-08-001, technical errors in report details were identified in the Analysis Report ANL-MGR-GS-000002, Rev. 03. See below for details:

Issue 16:
Page 5-2, Assumption 3. Pressure in dikes and conduits during eruption is equal to lithostatic pressure. This is not possible; the magma will not rise. The discussion on P. 6-

33 (first bullet) states that "vertical pressure profile" (magma pressure)… is very close to the lithostatic pressure. This is correct - the difference can be only several MPa (~200 bars, Wilson & Head, 1981, P.2973) This assumption should be consistent with the statement on P. 6-33. The concept of lithostatic pressure should be reviewed, as deviations from lithostatic pressure would not result in "partial failure" of the dike walls.

Response: Page 6-33, bullet at top of page says: "Vertical pressure profile in the dike/conduit below the fragmentation depth is very close to the lithostatic pressure profile (Section 5, Assumption 3)."

Assumption 3 says: "Pressure in dikes and conduits during eruption is equal to lithostatic pressure. This assumption is discussed in Section 6.3.4.2."

For the ERD, Assumption 3 is revised as follows:
"The vertical pressure profile in the dike/conduit below the fragmentation depth is very close to the lithostatic pressure profile. This assumption is discussed in Section 6.3.4.2."

The Rationale supporting Assumption 3 says: "Actual pressure is a complex function of the velocity, density, and composition of the magma as it rises, and of the strength of wall rocks. Because a general model for these effects (including the uncertainty associated with wall rock properties at depth) does not exist, lithostatic pressure is used as a first-order approximation. In addition, significant deviations from lithostatic pressure might result in partial failure of the dike walls or conduit walls such that the size of these features might adjust to maintain a fluid pressure that is near to lithostatic pressure."

For the ERD, the Rationale is revised as follows:
"Actual pressure is a complex function of the velocity, density, and composition of the magma as it rises, and of the strength of wall rocks. Because a general model for these effects (including the uncertainty associated with wall rock properties at depth) does not exist, lithostatic pressure is used as a first-order approximation. In addition, significant deviations in dike/conduit pressures might result in partial failure of the dike walls or conduit walls as the sizes of these features adjust to maintain the fluid pressure."

Impact Evaluation: The ERD revision clarifies that deviations in dike/conduit pressures could result in partial failure of walls of dikes or conduits. Failure of dike or conduit walls produces blockage of a dike or conduit, but the cause is correctly described as deviations in dike/conduit pressures rather than deviations in lithostatic pressure. Since the presence of a blockage and not its cause is the element needed for the analysis, the ERD revision has no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

Issue 48:
Page E-26 describes the volume of eruptive material for Lathrop Wells and is 0.05 km3 and 0.04 km3 for a total of 0.09 km3, yet stands in contrast to other tables that list a value of 0.12 km3. It was agreed that the 0.04 km3 was in error and likely should have been and 0.07 km3. The report needs to reflect the correct number in the text as well as checking of source documentation.

Response: The text in question reads as follows: "However, because other features of the three volcanoes are very similar, it seems reasonable to postulate that Red and Black Cone volcanoes may have originally had laterally extensive fallout deposits similar to those associated with Lathrop Wells (~0.04 km^3; Valentine et al 2005 [DIRS 177782], p. 629)."

For the ERD, the text is revised as follows:
"However, because other features of the three volcanoes are very similar, it seems reasonable to postulate that Red and Black Cone volcanoes may have originally had laterally extensive fallout deposits similar to those associated with Lathrop Wells (~0.07 km^3; recalculated based on information in Valentine et al 2005 [DIRS 177782], p. 629)."

Impact Analysis: The ERD corrects the volume estimate for Lathrop Wells volcano. The volume estimate is used only as part of the description of the Lathrop Wells volcano and not in subsequent analyses. The ERD revision has no impact on the technical product outputs. The volume of Lathrop Wells is correctly described in SAR 2.3.11.

(Issue 79)
Page 6-31. Sec. 6.3.4.2, Paragraph 1. "volatiles to exsolve" is incorrect. The responsible organization agreed to delete "may".

Response: For the ERD, the word "may" is deleted from the text on p. 6-31. Sec. 6.3.4.2, Paragraph 1, first sentence.

Impact Evaluation: The ERD revision clarifies the description but has no impact on the technical product output. Exsolution of volatiles from magma is correctly described in SAR 2.3.11.

Issue 90:
Page C-34, first paragraph. Not clear how "varying degrees of separation in the two-phase eruptive mixture to produce simultaneous violent Strombolian columns and lava effusion" can lead to these incompatible eruptive processes. A major difference in professional opinion developed. No documentation is provided on this point. A review of the literature should be undertaken, and when resolved the conclusion should be referenced.

Response: The text in question says: "The complexity of the Lathrop Wells eruption, given that the major element composition changed very little throughout, indicates that fluid dynamic processes such as vesiculation and bubble coalescence, gas loss to country rocks, and varying degrees of separation in the two-phase eruptive mixture to produce simultaneous violent Strombolian columns and lava effusion, are of fundamental importance in determining eruption processes at scoria cone volcanoes."

Violent Strombolian and effusive eruption styles are not "incompatible eruptive processes" as demonstrated by descriptions at historic eruptions that are cited elsewhere in the report (e.g., Paricutin – Luhr and Simkin 1993 [DIRS 144310], Figures 33 and 94; Tolbachik –

Maleyev et al. 1983 [DIRS 144325], p. 57). This type of activity is also discussed in Section 6.3.4. The text in question poses several possible mechanisms for this duality of eruptive styles. No change is needed.

Impact Evaluation: None

Issue 95:
Page C-21, paragraph 3. The statement"…lava effusion during the violent Strombolian cone-building phase" implies that these are simultaneous processes. Answer is that violent Strombolian eruption can be a small part of the total eruption duration and that lava effusion and explosive activity can alternate over short periods. Recommend clarification by adding "periods of" before the words "lava effusion".

Response: For the ERD, the text is revised as follows:
"In contrast, the mounds are interpreted here to be material that was rafted from the cone during periods of lava effusion that occurred during the violent Strombolian cone-building phase."

Impact Analysis: The ERD revision clarifies the description, but the revision has no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

CAQ #3

Requirement: SCI-PRO-005, Revision 9, Section 6.2.1, Paragraph C, states: "[Originator] Document the Analysis/Calculation in accordance with Attachment 2, Outline for Analysis/Calculation Reports. Ensure information presented in the scientific Analysis/Calculation documentation is transparent, traceable, and reproducible to other qualified individuals."

Condition: Contrary to the requirement stated above, during Lead Lab Internal Audit LQA-IA-08-001, it was determined that the Analysis Report ANL-MGR-GS-000002, Rev. 03, "Purpose" does not adequately reflect the document contents. See below for details:

Issue 88:
The evaluator (technical specialist) believes the reader should receive a balanced presentation based on the scientific data and the scenarios developed. The scientific reader would expect to have been presented (following data presentation and development) a nominal or expected case for any key variable, as well as, for eruptive scenario. The "tail ends" of the ranges (e.g., 10% and 90%) should be identified/discussed for either a parameter or the scenarios.

Characterize Eruptive Processes at Yucca Mountain, Nevada, ANL-MGR-GS-000002, Rev 3, 2007 presents a mixture of data and scenarios where extreme conditions and scenarios *are not adequately identified. The nominal case is not adequately identified and discussed. The scientific reader upon reading this document a few times would likely have the impression that violent Strombolian eruption or hydrovolcanic events, or large intrusion-induced earthquakes are a part of the nominal case.*

For example, throughout the text hydrovolcanic activity and violent Strombolian activity are frequently discussed as part of the eruptive scenario. However, there is little or no evidence that these eruptive features are typical or even likely in the historical/local-analog record. The supporting documents should present a balanced approach and presentation of the nominal case and a presentation of the "tail ends" of the parameter distributions or scenarios developed. If a balanced presentation is not the intent of the analysis report, then the analysis report should be modified by detailed discussion to reflect exactly what the intent of the analysis report is.

Response: The title of Section 6.4 POTENTIAL ERUPTION SCENARIO AT THE YUCCA MOUNTAIN REPOSITORY indicates that one of the purposes of the report that one of the purposes of the report is to present one scenario of a surface eruption at Yucca Mountain. In addition the paragraph clearly states "This scenario is proposed as a guide to a likely sequence of eruption phenomena at the surface and is not proposed as a conservative event sequence; it is based upon investigations of Yucca Mountain region volcanoes with emphasis on recent (≤1 my) geological history" (Section 6.4, paragraph 1). If "conservative" is equated with the reviewer's description "presentation of the 'tail ends' of the parameter distributions," it is clear that the reviewer's concerns are not well founded because presentation of a "conservative event sequence" is not included as one of the purposes of the report.

For the ERD, part of the description in Section 1 is revised as follows:
"Section 6, the scientific analysis, lists the parameters and values used to anticipate and model processes of shallow subsurface (less than about 350 m) and surface volcanic activity relevant to a repository at Yucca Mountain. Section 6.1 discusses the scientific approach, background, and data sources. The scientific approach includes the principle that the basaltic eruptive history of the Yucca Mountain region, in terms of analogue volcanoes, provides the best data to establish future volcanic scenarios. Section 6.2 lists the features, events, and processes (FEPs) supported by the analyses. Section 6.3 discusses the analyses of the eruption characteristics, which include:

- Geometry of volcanic feeder systems (conduits and dikes) of small-volume basaltic volcanoes, which are of primary importance in modeling how much area and volume of the repository might be affected by an intrusion of a feeder system
- Description of the physical and chemical properties of the basaltic magma, which influence both eruptive styles and mechanisms for interaction with waste packages containing radioactive waste
- Characteristics of shallow intrusive features, including dikes and conduits
- Estimates of the maximum magnitude of dike-induced earthquakes

- Ascent velocity of magma at depth, onset of bubble nucleation and growth in the rising magmas, magma fragmentation, and velocity of the resulting gas-particle mixture
- Eruption volume, duration of eruptions, power output, and mass discharge rates.

Section 6.4 describes a potential representation of future basaltic magma intrusion into the subsurface of Yucca Mountain followed by a surface eruption of scoria, lava, and ash. Based on the properties of basaltic magma and the eruption processes discussed in Sections 6.1 through 6.3, Section 6.4 presents one scenario of a surface eruption. This scenario is proposed as a guide to a likely sequence of eruption phenomena at the surface and is not proposed as a conservative event sequence. The scenario is based upon investigations of Yucca Mountain region volcanoes with emphasis on recent (≤1 my) geological history."

Impact Evaluation: The ERD revision clarifies the description, but the revision has no impact on the results or conclusions of ANL-MGR-GS-000002 REV 03.

Hydrovolcanism. Hydrovolcanism is typically mentioned in descriptions of tephra fall deposits associated with various eruptions from Lathrop Wells volcano or other Crater Flat volcanoes. The reviewer's concern with the potential for a scientific reader to conclude that hydrovolcanic events are included in some "nominal" disruption scenario is not warranted based on the following statement in Section 6.4 POTENTIAL ERUPTION SCENARIO AT THE YUCCA MOUNTAIN REPOSITORY:
"Although hydrovolcanism is included as part of this scenario, it was discounted as a significant phenomenon by the PVHA since the depth to the saturated zone is ~600 m and there is negligible perched water present within the unsaturated zone at Yucca Mountain (Section 6.4, Item D)." No change needed for the ERD.

Impact Evaluation: None

Violent Strombolian activity: Item C of Section 6.4 describes changes in the character of the eruption with duration of the event. The description specifically notes "Individual pulses (or violent Strombolian eruptive phases) may last between about half an hour to many days." The eruption model certainly includes violent Strombolian phases as parts of the eruption sequence that develops during the duration of the event. In fact, the conceptual model for aerial dispersal of contaminated tephra requires a violent Strombolian eruption as the atmospheric dispersal mechanism. In the TSPA, the ASHPLUME code models only the violent Strombolian eruption phase. But, given the description, the reviewer's apparent concern with undue emphasis on the occurrence of violent Strombolian eruption phases is not warranted. No change needed for the ERD.

Intrusion-induced earthquakes: (See also CAQ #1, Issue 81a). Section 1 of the report clearly states that one of the purposes of the report is to document analyses that estimate the maximum magnitude earthquake associated with an intrusion (Bullet 4, p. 1-2). Table 7-1 lists the maximum moment magnitude for dike induced earthquakes as 6.1, and notes that the magnitudes are calculated from the recommended distribution of dike lengths in the Yucca Mountain region. Assuming that the calculation method is sound, the magnitudes are based on observed features in the region and hence should represent a reasonable bound for earthquake magnitudes that might occur with intrusion into the repository. Earthquakes with magnitudes up to 6.1 are possible with an intrusion, but that magnitude represents the maximum magnitude not the magnitudes that would be more likely to occur. No change needed for the ERD.

Impact Evaluation: None

CR 11940 Evaluation

Recommendation #1

Issue 1:
The purpose of the AMR (Characterize Eruptive Processes at Yucca Mountain, Nevada, ANL-MGR-GS-000002, Rev 3, 2007) includes use of analogue volcanoes and volcanic features to model future volcanic behavior. In doing so there is a range in uncertainty reflected by the variety of analogues used. Analogs used capture some information about physical parameters (e.g., dike width), processes (e.g., eruptive styles), and chemistry (e.g., water contents and volatile contents). Not every analog is appropriate or germane when considering an individual parameter or process one wishes to examine. The criteria for analog selection should consider if the analog is appropriate and can be justified, what disclaimers should be applied and discussed, and whether the analog aids in the definition of an expected versus an extreme (unlikely) case. Finally, the lack of a "good" analog does not justify the use of a "bad" analog.

Some examples of the appropriate use of analogues with adequate discussion in the text of the AMR include the use of the Lathrop Wells Volcanic Center (LWC) as representative of future expected chemical composition (pages 6-10 and 6-11) and eruptive style (page 5-1). The discussion on magmatic temperatures, viscosities, and densities are based on the LWC (page 6-13 to-16). In addition, the LWC is also an appropriate analogue for eruptive activity (page 6-19) and grain size distributions (page 6-41) and all of the parameters found in Table 6-12. Other Quaternary volcanoes near Yucca Mountain are appropriate analogs as they reflect the youngest events and are the very features that lead to the concern for future volcanic events. In addition Quaternary volcanoes are found in a similar structural/tectonic framework, intrude and erupt in similar country rocks, and rock mechanical property settings.

Use of the 3.7 Ma volcanic center in Crater Flat and the ~8.5 Ma Paiute Ridge dike complex requires very careful qualification because of the great differences in age, magma volumes and structural settings. An estimate of volcanic gases is derived from igneous rocks from all over the world. This includes, for example, tholeiitic basalt from Kilauea, nephelenite from Nyiragongo, and Hawaiite from Mt Etna. These rocks differ compositionally from those of the Yucca Mountain region, and they occur in tectonic *settings that are not similar to the extensional setting of the Yucca Mountain area. Clearly, these examples must be carefully justified for applicability as analogs, as in certain important ways they are not analogous. Estimated dike-induced earthquakes at Yucca Mountain are very high. Again, radically different analogues from a variety of tectonic settings were used to compare to the Yucca Mountain area. This included volcanic rift zones and the Snake River Plain, areas having a very high magma production rate compared to the Yucca Mountain region.*

It is recommended that all of the analogues used in the AMR be reviewed, and modified, as appropriate. Careful justification for every analog used should be provided in the text.

Response: The analogs described in the report were evaluated prior to inclusion in the report. Identification of appropriate analogs is a product of the information each analog provides. For example, tholeiitic basalt from Kilauea, nephelenite from Nyiragongo, and Hawaiite from Mt Etna were selected because of their magmatic gas information that would have been used in consequences analyses. The consequences analyses now assume that once intersection of the repository occurs, all drifts are inundated with magma and all waste packages and drip shields are damaged and fail (SNL 2007 [DIRS 177432], Section 5.1). The analysis no longer evaluates damage effects from exposure to magmatic gases; so the analog gas information is not used in an analysis and has no effect on the Total System Performance Assessment (TSPA) and the Safety Analysis Report (SAR).

However, for the ERD, the following clarification is added to the end of Section 6.2.3.2, paragraph 3:

"Tholeiitic basalt from Kilauea and a nephelenite from Nyiragongo were included as analogs for gaseous components of magma to ensure that a reasonable range of magmatic gas compositions were considered."

The basis for the selection of Lathrop Wells volcano as an analog for an unlikely future eruption at Yucca Mountain is well described in the report (Appendix C and Section 6.4) and needs no further elaboration.

The 3.7 Ma volcanic centers in Crater Flat and the ~8.5 Ma Paiute Ridge dike complex are relevant analogs because of their use in the estimation of the number of waste packages damaged in the volcanic eruption modeling case and as information provided to the PVHA-Update experts. These analogues were chosen because of their exposure resulting from extended periods of erosion that the Pleistocene volcanoes have not experienced. Conduit geometry used in the waste packages damaged analysis is based, in part, on characteristics observed at the 3.7 Ma centers in Crater Flat and at the Miocene Paiute Ridge complex. In the context of the evolution of eruptive activity in the YMR, the conduit sizes resulting from studies of the Plio-Pleistocene complexes represent an upper bound and have been evaluated in this context by the PVHA-U panel. In addition, in developing their respective event definitions and resulting hazard models, the experts gave more weight to events younger than 5 Ma and specifically used information about volcanic features and processes demonstrated by the Crater Flat centers and Paiute Ridge.

Since the analogs described in the report were evaluated for appropriateness prior to inclusion in the report, no modifications of the descriptions are needed. No changes to the AMR are necessary.

The DIRS report has been changed to add as indirect input SNL 2007 [DIRS 177432], Section 5.1 assumption about waste package damage following contact by magma.

Impact Evaluation: None

Issue 6:
Page 1-2, paragraph 3 describes quarrying operations at Lathrop Wells Cone that "expose some of the cone interiors" which supports emphasis on LWC as a volcanic analog. A discussion of what these interiors consist of and why they are important was not provided. These exposures reveal eruptive style and historical features unavailable at other sites. This statement should be added for clarity.

Response: The text specified in the comment is as follows:
"Appendix C provides results of field work and laboratory analyses and the interpretation of the eruptive history for Lathrop Wells volcano, which is a young cinder cone/tephra sheet/lava flow complex 18 km south of the repository site. Emphasis on the Lathrop Wells volcano is engendered by its young age and the cone's excellent state of preservation, combined with active quarrying operations that expose some of the cone interiors."

For the ERD, the text is revised as follows:
"Appendix C provides results of field work and laboratory analyses and the interpretation of the eruptive history for Lathrop Wells volcano, which is a young cinder cone/tephra sheet/lava flow complex 18 km south of the repository site. Emphasis on the Lathrop Wells volcano is engendered by its young age (~80,000 years; Heizler et al. 1999 [DIRS 107255], p. 803) and the cone's excellent state of preservation, combined with active quarrying operations that expose some of the cone interiors. The quarry exposures reveal deposits from which details of eruptive style and sequence can be interpreted in greater detail than at other sites."

Impact Analysis: The ERD revision clarifies the value provided by quarry exposures at Lathrop Wells volcano but has no impact on the technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 10:
Page, F.-31, second paragraph discusses "transition to supersonic conditions." It is unclear that this is applicable to the eruption scenario? Evidence is entirely theoretical (Mitchell, 2005) or rests on appeal to dubious "catastrophic processes" of vent widening that include annular flow, pulsing, brecciation, or slumping, none of which are indicative

of supersonic velocities but are well explained by subsonic hydraulic mechanisms exerted by magma/lava. The personnel interviewed did not know of any observed eruptions, world-wide, that had evidence of supersonic flow. It is recommended that much of the paragraph be rewritten and that the applicability of supersonic conditions to the scenario eruption be reviewed.

Response: The paragraph specified in the comment is as follows:
"Third, the conduit flow models themselves represent simplified systems based on certain assumptions (lithostatic-pressure balance, parallel pipe, etc.) that do not capture the complexities of natural systems. Complexities in shallow conduit shape are implied in the work of Mitchell (2005 [DIRS 178154], pp. 198 to 200), who describes the downward migration of the choke point, above which the transition to supersonic conditions near the vent may continue to widen the conduit. Complex eruptive dynamics may include a mixture of magmatic and hydromagmatic mechanisms that will contribute to additional disruption of the near-surface country rock. Although some models account for the evolution of the conduit via uniform erosion processes that are slow compared to the sound speed in the conduit (Macedonio et al. 1994 [DIRS 178155], p. 140; Mitchell 2005 [DIRS 178154], p. 189), the complex or catastrophic processes of vent widening (annular flow, multiple intrusion, pulsing, brecciation, slumping) are not explicitly considered (Mitchell 2005 [DIRS 178154], pp. 195 to 197). Likewise most modeling studies have assumed time-invariant boundary conditions: either the parallel plate (with or without atmospheric vent pressure) or the lithostatic-pressure balanced, flaring conduit conditions (or more complex variants of the two) that do not evolve during the modeled eruption (Wilson and Head 1981 [DIRS 101034], p. 2,973; Macedonio et al. 1994 [DIRS 178155], pp. 139 and 140; Morrissey and Chouet 1997 [DIRS 178166], p. 7,969). In spite of these limitations, the models are useful in interpreting the observed flaring shape and the depth scale as consistent with conduit widening processes due to expansion, fragmentation, and acceleration of gas-rich magma."

For the ERD, the following text is added: "This discussion of possible supersonic conditions in the conduit has been peer-reviewed as part of a related journal article (Keating et al. 2008, Bulletin of Volcanology 70: 563-582). The analysis and approach are consistent with the literature cited in the text."

The DIRS report has been changed to add DIRS 185741 Keating et al. 2008 p 563-382 for the description of supersonic conditions in conduit as indirect input used in ERD.

Impact Evaluation: The ERD revision provides an additional reference for supersonic flow conditions in a conduit but has no impact on the technical product output.

Issue 23:
Page 6-16, Sec 6.3.3.1, first paragraph. Is the 3.7 Ma volcanic center in Crater Flat an appropriate analogue for Yucca Mountain region volcanism? In fact, it is not an analogue for anything because it is not compared with the other centers or to a future event. The

answer is that is a suitable analogue for dike swarm prediction or dike swarm characterization but the analogy fails with respect to magma volume. Answer was accepted but it was recommended that a qualification statement concerning volume be added.

Response: The text specified in the comment is as follows:
In addition, the 3.7-Ma basalts of southeastern Crater Flat provide a younger (Pliocene) analogue for Yucca Mountain region volcanism. Although these Pliocene eruptive products have not been sufficiently eroded to expose plumbing below the paleosurface, dikes are exposed where they intrude into the lower parts of their own pyroclastic deposits.

For the ERD, the text is revised as follows:
"In addition, the 3.7-Ma basalts of southeastern Crater Flat provide a younger (Pliocene) analogue for dike swarm geometry but not eruption volume. Although these Pliocene eruptive products have not been sufficiently eroded to expose plumbing below the paleosurface, dike widths and strikes are exposed where they intrude into the lower parts of their own pyroclastic deposits, and the outcrop patterns form part of the basis for descriptions of dike characteristics in the region."

Impact Evaluation: The ERD revision clarifies that the analogy provided by the Pliocene Crater Flat basalts is appropriate for dike swarm geometry but not eruption volume. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.
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Issue 24:
Page 6-12, Sec. 6.3.2.3, third paragraph: Clarify how a tholeiitic basalt from Kilauea and a nephelenite from Nyiragongo are credible analogs for Crater Flat basalts. Hawaiite from Mt. Etna and alkali basalt from Surtsey are more reasonable choices because of the common basalt kindred. Choice of analogues should be reviewed and justified.

Response: Tholeiitic basalt from Kilauea and a nephelenite from Nyiragongo were included as analogs for gaseous components of magma that would be used in consequences analyses. The consequences analyses now assume that once intersection of the repository occurs, all drifts are inundated with magma and all waste packages and drip shields are damaged and fail (SNL 2007 [DIRS 177432], Section 5.1). The analysis no longer evaluates damage effects from exposure to magmatic gases; so the analog gas information is not used in an analysis and has no effect on TSPA or SAR

For the ERD, the following clarification is added to the end of Section 6.2.3.2, paragraph 3:

"Tholeiitic basalt from Kilauea and a nephelenite from Nyiragongo were included as analogs for gaseous components of magma to ensure that a reasonable range of magmatic gas compositions were considered."

Impact Evaluation: The ERD revision clarifies the basis for including tholeiitic basalts from Kilauea and a nephelenite from Nyiragongo. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 25:
Page 6-12, second paragraph. The analogues for water content are challenged: are submarine lavas from the Pacific credible analogues for basalts in Crater Flat? Muenow et al. (1979) and Byers et al (1985) cite possible contamination and variability problems. In addition, basalts and basaltic andesites, boninites are questionable analogues. A review of these sources and applicability is recommended.

Response: The paragraph specified in the comment is as follows:
"Direct measurements of water in mafic (low silica) magmas or magmatic products from a range of tectonic settings indirectly support the recommended parameter values and cover the range of values that can be reasonably expected for future basaltic igneous activity. Garcia et al. (1989 [DIRS 122542], Table 1, p. 10,527), Byers et al. (1985 [DIRS 122532], Figure 4, p. 1,891), and Muenow et al. (1979 [DIRS 125093], Table 1, p. 74) found total water contents in Hawaiian tholeiites and transitional alkalic basalts that range from near 0% to nearly 1%. These melts probably represent higher degrees of partial melting than Yucca Mountain region basalts, so their low water contents are expected. On the other hand, Gaetani et al. (1993 [DIRS 144274], pp. 332 to 334) and Sisson and Grove (1993 [DIRS 144351], p. 163) present experimental evidence that high-alumina basalt and basaltic andesite magmas commonly contain up to several wt % water. Sisson and Layne (1993 [DIRS 122549], Table 1, p. 622) measured water contents in glass inclusions from arc basalts and basaltic andesites that range from 1% to 6%. True magmatic values could be somewhat lower because of concentration of water in the inclusions, which is caused by partial crystallization of the melt after entrapment. Water contents of 0.2% to 2% have been reported for back arc basin lavas and 1.2% to 3% for island arc tholeiites and boninites (Danyushevsky et al. 1993 [DIRS 149303], Tables 1 and 4, pp. 349 and 358)."

The values are included to provide a reference framework for the range of water contents that is subsequently developed. The first sentence of the paragraph clearly states "Direct measurements of water in mafic (low silica) magmas or magmatic products from a range of tectonic settings **INDIRECTLY** [emphasis added] support the recommended parameter values and cover the range of values that can be reasonably expected for future basaltic igneous activity." No change to the description is needed. No changes to the AMR are necessary.

Impact Evaluation: None

Issue 32:
Page 6-23, fourth paragraph. Estimated dike-induced earthquakes for Yucca Mountain are compared with those of worldwide volcanic rift zones and the Snake River Plain. These

analogs are misleading, and there is not basis given for promoting the comparison. Recommend removing this discussion since no Basin and Range analog exists for control or, alternatively, provide qualifying statements regarding the Snake River Plain data.

Response: The paragraph specified in the comment is as follows:
"The estimated maximum magnitudes of dike-induced earthquakes for the Yucca Mountain region are compared to maximum magnitude ranges:

- Estimated for normal faults, fissures, and graben widths in volcanic rift zones worldwide and in the eastern Snake River Plain (Smith et al. 1996 [DIRS 101020], Tables 1 and 2)
- Estimated for fault width using a volcanic crust 4-km thick (referred to as depth to the level of neutral buoyancy shown by Smith et al. (1996 [DIRS 101020], Table 2)
- Calculated for instrumentally observed earthquakes at active volcanic rift zones (Smith et al. 1996 [DIRS 101020], Figure 5)."

The text makes no statement about earthquakes in the Snake River Plain or volcanic rift zones as suitable analogs for earthquakes at Yucca Mountain. The statement before the bullets clearly states that comparison is for maximum magnitude ranges. The first sentence following the bullets also clearly states "The maximum magnitudes estimated for the Yucca Mountain region overlap maximum magnitude estimates derived from surface lengths in volcanic rift zones worldwide and the eastern Snake River Plain." Based on the description, the only comparison made is showing that maximum magnitudes for earthquakes in the Yucca Mountain region overlap maximum magnitudes of earthquakes in the SRP and in volcanic rift zones. The basis for determining the range of earthquake magnitudes for the YMR follows the approach used by Smith et al. (1996 [DIRS 101020], pp. 6,287 and 6,288). The description is, therefore, not misleading as stated in the comment. No changes to the AMR are necessary.

Impact Evaluation: None

Issue 47:
The documents defend ability and transparency could be greatly improved by a substantial review and edit. This could be accomplished by any number of procedures including for example SCI-PRO-005. The reviewer should have a strong background in igneous petrology and/or volcanology.

The following is a list that serves as examples of a pervasive concern about the document. The document has numerous areas where data or low level assumptions are not sourced (Issues 51 & 54), the definitions are not clear (Issue 27). There confusing and poorly worded sentences (Issue 81, the justification for what analogue is appropriate (or if it is appropriate) is not clearly presented (Issues 23 & 24). Issue 31 and discussions pointed out that a more complete discussion of igneous activity that leads to large earthquakes or displacements needs to be more thoroughly discussed and justified, numerous sections of *the text needed to be rephrased for clarity and defensibility (for example, Issues 20, 22, 23, 25, 27, 48, 74, 77, 89, 90). Numerous figures and tables that lack source documentation and in some cases adequate discussions in the text (e.g., Issue 51).*

Response: Responses to numbered issues are provided for those issues and are not repeated here. The report was developed according to procedures, which include document review, as specified in SCI-PRO-005. No additional review or editing is required.

Impact Evaluation: None

Issue 54:
The information used for dike width is not sourced on page 6-19. It was discussed that some of this information was developed from the 3.7 my basalts found on the NTS. It is not clear that this is an appropriate analogue for the younger Miocene and Pleistocene basalts where, the latter, dike parameters including dike width are likely much smaller. In addition the 3.7 my old basalts are much more voluminous, have a greater number of contemporary volcanic centers, etc. than the younger basalts that are of concern. This analogue is also a large driver on the assumed dike width distribution. In the opinion of the technical specialist this is an inappropriate analog. This topic should be reviewed, further discussions and justifications added, and a revision of the parameters discussed would be appropriate.

Response: The text specified in the comment is as follows:
"Because the dike widths in the regional analogues range over only one order of magnitude, a normal distribution for dike widths is appropriate for description. The normal distribution of dike widths can be described as having a mean of 8 m, a minimum of 1 m and 95th percentile of 12 m."

This issue is the same as that described in CR 11939, CAQ #1, Issue 2a and this CR, Issue 1. See Issue 1 and CR 11939, CAQ #1, Issue 2a for resolution.

Recommendation #2

Issue 2b:
On page 6-19, the basis for the normal distribution specified for the dike width information is not discussed.

Response: The issue is associated with Recommendation #1, Issue 54 and with CR 11939, CAQ #1, Issue 2a. See CR 11939, CAQ #1, Issue 2a for resolution.

Issue 3:

On page 6-20, a random uniform distribution is used for dike spacing between 0.5 and 1,500 m. The basis for assuming this distribution is not discussed

Response: The issue is associated with CR 11939, CAQ #1, Issue 57. See CR 11939, CAQ #1, Issue 57 for resolution.

Issue 5:
Page 1-2, paragraph 3 contains a discussion of the Lathrop Wells Cone. Its significance arises from its "young age" and it being the "youngest" example of volcanism in the region. It is recommended that the actual known age and a reference to the source be provided in this paragraph.

Response: This issue is associated with CR 11940, Recommendation #1, Issue 6. See Recommendation #1, Issue 6 for resolution.

Issue 15:
Page 5-2, Assumption 4. "Rising magma composed of melt liquid and volatile gases is …characterized by equilibrium between melt and exsolved phases " is incorrect. Clarify the meaning of equilibrium here, as phase equilibrium is certainly not correct The statement on P. 6-32 that bubble nucleation and growth kinetics can be ignored does not support Assumption 4. It is recommended the assumption be rewritten to correspond with the statement on p. 6-32. It is recommended that the text change to mechanical equilibrium.

Response: The text specified in the comment is as follows:
"Assumption: Rising magma, composed of melt liquid and volatile gases and not undergoing fragmentation, can be considered homogeneous and characterized by equilibrium between melt and exsolved volatiles. This assumption is discussed in Section 6.3.4.2."

For the ERD, the text is revised as follows:
"*Assumption*: Rising magma, composed of melt liquid and volatile gases and not undergoing fragmentation, can be considered homogeneous and characterized by mechanical equilibrium between melt and exsolved volatiles. This assumption is discussed in Section 6.3.4.2."

Impact Evaluation: The ERD revision clarifies that the equilibrium condition of interest is mechanical equilibrium between the melt and exsolved volatiles, not chemical equilibrium. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 17:
Page 6-20, second paragraph, Dike azimuth probability is based on a regional stress study by Zobak & Zoback (1980). The scale of this study and its precision is inappropriate for

this AMR. There was agreement that the basis for azimuth probabiltiy could be improved. A report by Morris et. al. (1996) is recommended.

Response: The statement specified in the comment is as follows:
"The probability is considered higher for the 010° ± 15° range because those directions are roughly perpendicular to the WNW-direction of least principal stress (Zoback and Zoback 1980 [DIRS 108658], Table 2)."

For the ERD, the text will be revised as follows:
"The probability is considered higher for the 010° ± 15° range because those directions are roughly perpendicular to the WNW-direction of least principal stress (Zoback and Zoback 1980 [DIRS 108658], Table 2) and is consistent with the description of effective principal stresses in Morris et al., 1996 [DIRS 106394], p. 277)."

The DIRS report has been changed to add [DIRS 106394] as indirect input:

Used from: p. 277
Used in *Characterize Eruptive Processes at Yucca Mountain, Nevada* [DIRS 174260], Section 6.3.3.1
Description: Direction and magnitude of effective principal stresses at Yucca Mountain

Impact Evaluation: The ERD revision enhances the description and provides an additional reference but does not impact the technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 18:
Page 6-20, first paragraph. The variability of dike spacing is a function of local faulting and structural state of the host rock. Each analogue site is different. No work was done to consider/analyze and evaluate these local factors; instead, the different populations are considered to be expressions of a single, random uniform distribution. No justification or background for this decision is available. It is recommended that this paragraph be rewritten for clarity.

Response: The paragraph specified in the comment is as follows:
"In addition to the number of possible dikes, the spacing between dikes is another important variable. For the Paiute Ridge intrusion, mean dike spacing for dikes greater than 1-km long is ~995 m (maximum 1,440 m; minimum 250 m) (Byers and Barnes 1967 [DIRS 101859]). For the 3.7-Ma-old Crater Flat basalts, dike spacing is ~385 m (Perry et al. 1998 [DIRS 144335], Appendix 2-M1). In each example, some dike splitting or en echelon geometry may occur that provides less than one meter spacing. In order to capture the variability observed in the field, the recommended dike spacing (measured edge-to-edge) for the Yucca Mountain region can be judged as a random uniform distribution ranging from 0.5 m to 1,500 m."

For the ERD, the paragraph is revised as follows:

"In addition to the number of possible dikes, the spacing between dikes is another important variable. For the Paiute Ridge intrusion, mean dike spacing for dikes greater than 1-km long is ~995 m (maximum 1,440 m; minimum 250 m) (Byers and Barnes 1967 [DIRS 101859]). For the 3.7-Ma-old Crater Flat basalts, dike spacing is ~385 m (Perry et al. 1998 [DIRS 144335], Appendix 2-M1). In each example, some dike splitting or en echelon geometry may occur that provides less than one meter spacing. Based on the variability observed in the field, the recommended dike spacing (measured edge-to-edge) for the Yucca Mountain region is a random uniform distribution ranging from 0.5 m to 1,500 m."

Impact Evaluation: The ERD revision describes the basis for the recommended dike spacing and distribution but has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 27:
Page 6-1, Sec 6.1.3.1 Definition of Dike: while technically correct in a very narrow sense, the definition should be restated to emphasize that bedding (esp in the study area) is typically assumed to be horizontal/sub-horizontal. The entire technical discussion of dike intrusion is predicated on vertical dikes.

Response: The text specified in the comment is as follows:
"Dike–A tabular, subplanar, magma-filled crack that cuts across the bedding of older rock. Length and width (or thickness) describe the size of a dike, although minor variations in width and strike direction can be expected along the length of any one dike."

For the ERD, the text is revised as follows:
"Dike–A tabular, subplanar, magma-filled crack that cuts across the bedding of older rock. Given that bedding of the country rock at Yucca Mountain is generally subhorizontal, the implied orientation of dikes in this analysis is subvertical. Length and width (or thickness) describe the size of a dike, although minor variations in width and strike direction can be expected along the length of any one dike."

Impact Evaluation: The ERD revision clarifies the description of the geometry of a dike but has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 49:
It could not be determined that the sources in the paragraphs were correct for the described preserved volume of 0.03 km3 at Hidden Cone on page D-2 or the volumes (0.014 km3) reported for Little Black Peak on page D-5? It is recommended that the sources be checked and, if inappropriate, the correct sources added.

Response: The statements specified in the comment are as follows:

Page D-2, Section D.2, 1st sentence "Hidden Cone (Figure D-2a) is a scoria cone with two or three small lava fields, and an estimated total preserved volume of about 0.03 km^3."

Page D-5, Section D.3, 1st paragraph "The total volume of preserved eruptive material at Little Black Peak is 0.014 km^3."

For the ERD, the statements are revised as follows:
"Hidden Cone (Figure D-2a) is a scoria cone with two or three small lava fields, and an estimated total preserved volume of about 0.03 km^3 (Table 6-2)."

"The total volume of preserved eruptive material at Little Black Peak is 0.014 km^3 (Table 6-2)."

Impact Evaluation: The ERD revision adds source information for the volumes of Hidden Cone and Little Black Peak but has no impact on technical product output. Volumes are correctly described in SAR 2.3.11.

Issue 73:
Page 6-36, ¶3. When the evaluator asked the responsible organization why duration is important (it is not transparent in the document), the answer provided was that duration factors into risk assessment and for calculations related to effects of repository intersection. When asked why lava flow length is a parameter the responsible organization answered that its utility is discussed by Walker (1973). Recommend a statement of this utility, its justification, with citation of Walker (1973) be added for clarity.

Response: The text specified in the comment is as follows:
"In addition to constraining volumes of volcanic eruptions for the purposes of predicting the effects of an igneous event on the repository, it is important to constrain the duration of various processes. Wood (1980 [DIRS 116536], p. 402) states that over 90% of historical basaltic eruptions last less than 12 months, although notable exceptions exist. Appendices C and E discuss potential time scales for the entire eruptive duration for some of the Quaternary volcanoes in the Yucca Mountain region based upon lava flow lengths and cone dimensions and comparison with historical analogues."

Regarding the utility of the lava flow length, the text makes direct reference to discussions in Appendices C and E, where the use of specific methods of Walker 1973 is discussed. No further text changes are required.

For the ERD, the text is revised as follows:
"In addition to constraining volumes of volcanic eruptions for the purposes of predicting the effects of an igneous event on the repository, it is important to constrain the duration of various processes to inform the process model of atmospheric dispersal of tephra."
[Remainder of text unchanged.]

Impact Evaluation: The ERD clarifies the use of duration in tephra transport modeling. The ERD revision has no impact on technical product output or the conclusions of ANL-MGR-GS-000002, Rev 03.

Issue 78:
Page 6-36, ¶2. When the evaluator asked the responsible organization why Northern Cone was not used for the minimum potential volume, the answer provided was that the pyroclastic/tephra volume is important in this consideration, and Northern Cone has no tephra. It is recommended that qualifying language be added, or support the statement that NE Little Cone can be considered an entirely separate event from SW Little Cone, otherwise the volume calculations are in error.

Response: The text in the comment is as follows:
"The minimum potential volume can be accounted for using a similar tephra/cone ratio for NE Little Cone (the smallest volcanic cone in the Yucca Mountain region), whose dimensions are provided by Stamatakos et al. (1997 [DIRS 138819], pp. 322 and 328)."

For the ERD, the text is revised as follows:
"The minimum potential volume can be accounted for using a similar tephra/cone ratio for NE Little Cone (the smallest volcanic cone in the Yucca Mountain region), whose dimensions are provided by Stamatakos et al. (1997 [DIRS 138819], pp. 322 and 328). [Note: Northern (Makani) Cone is not considered because it has no associated tephra volume.] "

Impact Evaluation: The ERD revision provides the basis for not including Northern Cones in the group of cones with associated tephra deposits. The ERD has no impact on technical product output.

The part of the comment about NE Little Cone and SW Little Cone is as follows:
Assuming that the estimated volume of tephra originally associated with NE Little Cone, which is about 5% that of Lathrop Wells, represents the smallest potential pyroclastic event in the Yucca Mountain region, it is reasonable to assume that the total duration of NE Little Cone explosive activity would be about 5% of the duration of the pyroclastic activity at Lathrop Wells, or between about one hour and five days.

It is clear that the description is only for NE Little Cone and not SW Little Cone; so contrary to the comment, no qualifying language is needed.

Impact Evaluation: None

Issue 82:
Page 6-29, Sec. 6.3.4, ¶1. The possibility of gas loss through conduit walls during an eruption is controversial; it should be referenced. In any event, it would be insignificant during an eruption. Recommend it be downplayed (perhaps placed in parentheses). Response was that a reference could be added. The comment on loss of volatiles had been added by the authors for completeness.

Response: The text specified in the comment is as follows:
"A further complication in this sequence of events is the possibility of loss of volatiles through the walls of the conduit or dike as magma ascends. This action can reduce the effective volatile content for the eruption."

For the ERD, the text is deleted.

Impact Evaluation: The ERD revision deletes the controversial text but has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Recommendation #3

Issue 4:
Page 1-1, paragraph 4 contains a list defined as "eruptive processes." Only of these five items could be considered a process. The other items define some physical parameter or characteristic (e.g., eruption volume). The description is misleading. It is recommended that the items be redefined.

Response: The text specified in the comment is as follows:
"Section 6.2 lists the features, events, and processes (FEPs) supported by the analyses. Section 6.3 discusses the analyses of the eruptive processes, which include:

- Geometry of volcanic feeder systems (conduits and dikes) of small-volume basaltic volcanoes, which are of primary importance in modeling how much area and volume of the repository might be affected by an intrusion of a feeder system
- Description of the physical and chemical properties of the basaltic magma, which influence both eruptive styles and mechanisms for interaction with waste packages containing radioactive waste
- Characteristics of shallow intrusive features, including dikes and conduits
- Estimates of the maximum magnitude of dike-induced earthquakes
- Ascent velocity of magma at depth, onset of bubble nucleation and growth in the rising magmas, magma fragmentation, and velocity of the resulting gas-particle mixture
- Eruption volume, duration of eruptions, power output, and mass discharge rates."

For the ERD, the text is revised as follows:
"Section 6.2 lists the features, events, and processes (FEPs) supported by the analyses. Section 6.3 discusses the analyses of eruption characteristics, which include: ..."

Impact Evaluation: The ERD revision clarifies the scope of Section 6.3 of the report but has no impact on technical product output conclusion of ANL-MGR-GS-000002 REV 03.

Issue 12:

Page 4-1, first paragraph. The topic sentence states that "investigations of analogue volcanoes are reviewed". Also, "Brief descriptions of the data used as direct input are listed in Table 1. Since Lathrop Wells volcano is not mentioned, the implication is that "Data used" in Table 4-1 is a summary of data from analogue volcanoes, as stated above. But Table 4-1 lists only data from Lathrop Wells volcano. It is recommended that this be clarified in the report.

Response: The text specified in the comment is as follows:
"In this scientific analysis report, relevant scientific literature and investigations of analogue volcanoes in the Yucca Mountain region are reviewed, and theoretical concepts, parameter values, and distributions are developed. This information is used to recommend parameter distributions for other models and analyses that inform the YMP total system performance assessment (TSPA) calculations. Parameter distributions are based on field-acquired data and data available in published sources. Brief descriptions of the data used as direct input are listed in Table 4-1."

For the ERD, the text is revised as follows:
"In this scientific analysis report, relevant scientific literature and investigations of analogue volcanoes in the Yucca Mountain region are reviewed, and theoretical concepts, parameter values, and distributions are developed. This information is used to recommend parameter distributions for other models and analyses that inform the YMP total system performance assessment (TSPA) calculations. One focus of the report is the suitability and appropriateness of the Lathrop Wells volcano as an analog for unlikely future volcanic activity at the repository. Parameter distributions are based on field-acquired data, many at Lathrop Wells volcano, and on data available in published sources. Brief descriptions of the data used as direct input are listed in Table 4-1."

Impact Evaluation: The ERD revision clarifies part of the purpose of the report but has no impact on technical product output conclusion of ANL-MGR-GS-000002 REV 03.

Issue 20:
Page 6-18, third paragraph determines that the N-S trending magnetic anomalies represent faults rather than dikes? Answer is that these anomalies project north to bedrock where on-strike faults are exposed. Answer is satisfactory. A discussion on whether anomalies could also reflect local dikes occupying these faults was deemed unimportant, although this issue is the gist of the following text. Therefore, it is recommended that dikes be added to the fault statement.

Response: The text specified in the comment is as follows:
"Observations of anomalies in high-resolution aeromagnetic data collected from the Crater Flat area show that there is close association between locations of these volcanoes and underlying faults (Perry et al. 2005 [DIRS 177379], p. 485, Figure 1). In the case of Black Cone and Makani volcano, inferred structural control by separate north–south trending faults implies that individual feeder dikes fed these separate volcanic events; Makani

volcano also exhibits a ~north-south-trending dike within its pyroclast deposit (Appendix D)."

For the ERD, the text is revised as follows:
"Observations of anomalies in high-resolution aeromagnetic data collected from the Crater Flat area show that there is close association between locations of these volcanoes and underlying faults (Perry et al. 2005 [DIRS 177379], p. 485, Figure 1) and any small dikes associated with the faults." [Remainder of text unchanged.]

Impact Evaluation: The ERD revision clarifies that the nearly north-striking fault geometry also applies to dikes associated with the faults. The ERD revision has no impact on technical product output conclusion of ANL-MGR-GS-000002 REV 03.

Issue 21:
Page 6-17, second paragraph, five or more dikes are exposed at Paiute Ridge. This statement is imprecise given Figure F-5. It is recommended that Fig F-5 in appendix F be referenced so the reader can see the number of mapped dikes.

Response: The text specified in the comment is as follows:
"At Paiute Ridge, Nevada, exposures of five or more alkali-basalt dikes, small sills, and at least one conduit, extend downward from shallow levels to >250 m below the paleosurface (Appendix F)."

For the ERD, the text is revised as follows:
"At Paiute Ridge, Nevada, exposures of five or more alkali-basalt dikes, small sills, and at least one conduit, extend downward from shallow levels to >250 m below the paleosurface (Section F.2.2)."

Impact Evaluation: The ERD revision corrects the reference for the discussion of conduit extent at Paiute Ridge, Nevada. The ERD revision has no impact on technical product output or conclusion of ANL-MGR-GS-000002 REV 03.

Issue 22:
Page 6-17, first paragraph. When the evaluator asked whether the dike zone widen or the dike, the responsible organization responded "the dike zone." When asked if the conduit extends to >250m depth, the responsible organization replied "probably." It is recommended that the insertion of "dike zone" to clarify the term "flaring".

Response: The text specified in the comment is as follows:
"At depths of 250 m to 150 m below the paleosurface, feeder dikes from these examples are single tabular masses 10-m to 12-m wide with occasional swelling to 15 m. They often follow preexisting, vertical cooling joints where developed in the host ignimbrites. At shallower levels, the feeder dikes can bifurcate into closely spaced, multiple (5 to 6) dikes with overall widening of the intruded zone to ~25 m. Basalt Ridge includes exposure of a

~3-m-thick sill extending ~30 m into a nonwelded pumiceous tuff about 35 m below the paleosurface. Within the vertical dike, incorporation of pebble-size pieces of host rock xenoliths along the margins is common, while boulder-size pieces are far less common. Rotation and fusing of blocks of the silicic tuff is common. At east Basalt Ridge, further widening of the dike zone (up to 40-m thick at 35-m depth) occurred toward the paleosurface as overburden stresses became reduced during ascent, and flaring into an 80-m- to 100-m-wide, funnel-shaped vent within 25 m of the surface marks the eruptive source vent. In summary, the two small-volume eruptive centers at Basalt Ridge expose single-feeder dikes at depths slightly shallower than the proposed Yucca Mountain repository, which bifurcate into multiple closely spaced, small dikes with up to 100% widening of the intruded zone as they approach the surface, and which flare into a wide vent only at very shallow depths (Figure F-9)."

Response: The existing text includes the information suggested in the comment. No additional changes are needed.

Impact Evaluation: None

Issue 28:
Page 6-1, Section 6.1.1, first paragraph states in part: "…whereas the basaltic composition that might define the potential future volcanic event is derived from multiple chemical analyses from the nearby Lathrop Wells volcano. It is recommended that this statement be deleted or re-written to represent some realistic consequence on effect of basaltic composition.

Response: The text specified in the comment is as follows:

"Magma properties (e.g., water content, viscosity) and characteristics of buoyant rise (e.g., velocity, volatile exsolution) that best reflect the basaltic magma characteristics of the Yucca Mountain region are taken from the literature, whereas the basaltic composition that might define the potential future volcanic event is derived from multiple chemical analyses from the nearby Lathrop Wells volcano."

For the ERD, the text is revised as follows:
"Magma properties (e.g., water content, viscosity) and characteristics of buoyant rise (e.g., velocity, fluid density) that best reflect the basaltic magma characteristics of the Yucca Mountain region are taken from the literature and are developed from multiple chemical analyses from the nearby Lathrop Wells volcano."

Impact Evaluation: The ERD revision clarifies that chemical analyses of basalts from Lathrop Wells volcano are used in describing the characteristics of buoyant rise. The ERD revision has no impact on technical product output or conclusion of ANL-MGR-GS-000002 REV 03.

Issue 29:

Page 6-1, Sec. 6.1.1, first paragraph, states in part, "Magma properties (e.g., water content, viscosity) and characteristics of buoyant rise (e.g., velocity, volatile exsolution)...." It is recommended that "volatile exsolution" be deleted and substituted with hydrostatic pressure, viscosity, or fluid density.

Response: See previous ERD item for issue # 28.

Impact Evaluation: None

Issue 52:
Sec 7.1, 1st paragraph refers to old AMRs and DIRs numbers for "Number of Waste Packages hit by Igneous Intrusions, 2005", "Dike/Drift Interactions, 2005", and "ATMOSPHERIC DISPERSAL AND DEPOSITION OF TEPHRA FROM A POTENTIAL VOLCANIC ERUPTION AT YUCCA MOUNTAIN, NEVADA, 2005 (should be 2007). The same is true in the reference list. Documents were appropriately cited at the time the document was issued. It is recommended that if an opportunity is presented, these references be updated to the latest revisions.

Response: At the time the report was approved (February 26, 2007), the current versions of the documents specified in the comment were the versions cited. No change to text is needed.

Impact Evaluation: None

Issue 75:
Page 6-44, Sec. 6.3.5.3. It is recommended, that the author consider adding a conditional clause to the beginning of "There are two reasonable ways…." "Because Blong (1984) gives no additional data," since these data seem incomplete as documented and these are empirical data – this is all that is available, there is no information on range and mean, etc.

Response: The text specified in the comment is as follows:
"Blong (1984 [DIRS 144263], p. 208) has measured a range of fallout deposits that have a density of approximately 1,000 kg/m^3. There are two reasonable ways of treating deposit density in TSPA calculations: 1) simply use 1,000 kg/m^3, or 2) use a sample from a normal distribution of deposit densities ranging from 300 kg/m^3 to 1,500 kg/m^3 with a mean of 1,000 kg/m^3."

For the ERD, the text is revised as follows:
"Blong (1984 [DIRS 144263], p. 208) has measured a range of fallout deposits that have a density of approximately 1,000 kg/m^3. Lacking information in Blong (1984) about the distribution of deposit densities, there are two reasonable alternatives available to treat deposit density in TSPA-related calculations: 1) simply use 1,000 kg/m^3, or 2) use a sample from a distribution of deposit densities ranging from 300 kg/m^3 to 1,500 kg/m^3 with a mean of 1,000 kg/m^3."

Impact Evaluation: The ERD revision clarifies that Blong (1984) did not include information about the distribution of deposit densities and supports the identification of reasonable alternatives for treating deposit density in subsequent analyses. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 77:
Page 6-39. Paragraph 4. When asked to clarify the meaning of "in humid environments without air," the responsible organization responded that it meant water vapor in presence of argon, reflecting experiments or calculations done during an early phase of waste pellets. Recommend deleting the text and begin the paragraph with the sentence on the last line: "During a volcanic eruption…" as this is the only relevant part of this discussion.

Response: The text specified in the comment is as follows:
"Oxidation of waste pellets is common and well-studied, though most such studies have been conducted at temperatures well below magmatic (BSC 2004 [DIRS 169987], Section 6.2.2.2). In warm (~100°C to 400°C), humid environments, oxidation of spent fuel in the presence of air occurs rapidly; in dry air it takes place more slowly, and in humid environments without air very slowly or not at all (BSC 2004 [DIRS 169987], Section 6.2.2.2). At temperatures greater than 500°C, however, waste can be oxidized by pure steam (BSC 2004 [DIRS 169987], Section 6.2.2.2) to form thin coatings on preexisting UO_2 grains or, under moisture-saturated conditions, dehydrated schoepite crystals tens to hundreds of microns in length (BSC 2004 [DIRS 169987], Section 6.2.2.2). Oxidation of grain surfaces partially disaggregates the waste and increases specific surface area, making it more easily soluble in water (BSC 2004 [DIRS 169987], Section 6.2.2.2)."

For the ERD, the text is revised as follows:
"Oxidation of waste pellets is common and well-studied, though most such studies have been conducted at temperatures well below magmatic (BSC 2004 [DIRS 169987], Section 6.2.2.2). At temperatures greater than 500°C, waste can be oxidized by pure steam (BSC 2004 [DIRS 169987], Section 6.2.2.2) to form thin coatings on preexisting UO_2 grains or, under moisture-saturated conditions, dehydrated schoepite crystals tens to hundreds of microns in length (BSC 2004 [DIRS 169987], Section 6.2.2.2). Oxidation of grain surfaces partially disaggregates the waste and increases specific surface area, making it more easily soluble in water (BSC 2004 [DIRS 169987], Section 6.2.2.2)."

Impact Evaluation: The ERD revision clarifies the description of test conditions for the oxidation of waste pellets by deleting the ambiguous description of testing in humid conditions. The ERD revision has no impact on technical product output or the conclustion of ANL-MGR-GS-000002 REV 03.

Issue 79:

Page 6-31. Sec. 6.3.4.2, Paragraph 1. "volatiles may begin to exsolve" is incorrect. The responsible organization agreed to delete "may".

Response: The issue is the same as that described in CR 11939, CAQ #2, Issue 79. See CR 11939, CAQ #2, Issue 79 for resolution. Exsolution of volatiles from magma is correctly described in SAR 2.3.11.

Impact Evaluation: None

Issue 80:
Page 1-2, Paragraph 4. When asked to clarify the meaning of the word "principles" and what it refers to, the responsible organization responded that refers to methods and strategy for developing a model. It is recommended that usage be made explicit: e.g. replace "principles" with "applying the information to models", etc.

Response: The text specified in the comment is as follows:
"The investigations described in Appendix D lay groundwork for interpreting eruptive history, and feeder dike number and geometry, and for applying the principles to potential eruptions in the Yucca Mountain region."

For the ERD, the text is revised as follows:
"The investigations described in Appendix D lay groundwork for interpreting eruptive history, and feeder dike number and geometry, and for applying the information to models of potential eruptions in the Yucca Mountain region."

Impact Evaluation: The ERD revision eliminates the potential ambiguity associated with use of the word "principles." The ERD revision has no impact on technical product output or the conclusion of the analysis report.

Issue 81b:
Page *6-25, Paragraph 2, the phrase "long-term average rate of movement" (next to last line) should be replaced with "seismic recurrence interval".*

Response: The text specified in the comment is as follows:
"Such a process could affect the timing of a specific earthquake on a pre-existing fault, but should not affect the long-term average rate of movement, which would be driven by the larger-scale tectonic state of stress."

For the ERD, the text is revised as follows:
"Such a process could affect the timing of a specific earthquake on a pre-existing fault, but should not affect the seismic recurrence interval, which would be driven by the larger-scale tectonic state of stress. "

Impact Evaluation: The ERD revision clarifies the description of a parameter that is used to describe seismic features and events. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 91:
Page B-7, paragraph 2, item #1. It is recommended that the words "modeling of" should be inserted after the word "influence" in item 1.

Response: The text specified in the comment is as follows:
"This analysis report develops parameter values and distributions that directly or indirectly influence the airborne transport of radionuclide particles via surface volcanic eruption of basaltic magma after intersection with the waste-packages-filled drifts."
For the ERD, the text is revised as follows:
"This analysis report develops parameter values and distributions that directly or indirectly influence modeling of the airborne transport of radionuclide particles via surface volcanic eruption of basaltic magma after intersection with the waste-packages in emplacement drifts."

Impact Evaluation: The ERD revision clarifies the description of the use of volcanic processes in the analysis of the volcanic eruption modeling case. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 93:
Page *7-6, Paragraph 2. The statement "Reasoned arguments, especially those that rely on the expected future eruptive event, support the basis that the phenomena inferred from old eruptive centers in the Yucca Mountain region adequately sample future eruptive processes" seems circular and unfounded. Clarify why confidence in the measured distributions is supported by a trend of decreasing activity that leads to "simpler geometries." When asked if this is a conclusion based on data ("old eruptive centers") or reasoning, the responsible organization replied that confidence is based less on reliance on the established trend than on the expected distributions. Recommend a rewrite of the 3rd and 4th sentences for clarity, and a clarification of the usage of "simpler", which is in quotes, suggesting a special meaning.*

Response: The text specified in the comment is as follows:
"The qualitative descriptions of uncertainties in Table 7-1 are due to limited relevant published data on many parameters and to the small number of analogue volcanoes where relevant data were obtained. The recommended distributions indeed capture most of the spread of data provided in Section 6 and the appendices. Reasoned arguments, especially those that rely on the expected future eruptive event, support the basis that the phenomena inferred from old eruptive centers in the Yucca Mountain region adequately sample future eruptive processes. Confidence in the distributions is supported by the established trend of decreasing volcanic activity in the Yucca Mountain region (leading to "simpler" geometries of individual events), and the consistency of parameters that accompany that volcanism (e.g., the number of dikes associated with the Quaternary events)."

For the ERD, the text is revised as follows:
"The qualitative descriptions of uncertainties in Table 7-1 are due to limited relevant published data on many parameters and to the small number of analogue volcanoes where

relevant data were obtained. The recommended distributions indeed capture most of the spread of data provided in Section 6 and the appendices. The distributions are supported by the established trend of decreasing volcanic activity in the Yucca Mountain region (leading to simpler geometries of individual events), and the consistency of parameters that accompany that volcanism (e.g., the number of dikes associated with the Quaternary events)."

Impact Evaluation: The ERD revision clarifies the description of the technical bases for parameter distributions. There is no impact to the results or conclusions of ANL-MGR-GS-000002 REV 03.

Issue 96:
Page C-16, paragraph 1, states: "Plastically deformed bedding that surrounds a 4-cm-diameter clast suggests the beds were moist during deposition." It is recommended that a parenthetical statement, about where the moisture came from (rainfall?), be provided for optimum clarification.

Response: The text specified in the comment is as follows:
"Plastically deformed bedding that surrounds a 4-cm-diameter clast suggests the beds were moist during deposition."

Speculation about the source of moisture in the deformed beds adds no value to the discussion. No change to text is needed.

Impact Evaluation: None

Issue 97:
Page C-6, Sec. C.2, paragraph 1. Because these centers have no bearing on post-5 Ma basaltic volcanism and they are not shown in Fig. C-1, it is recommended that the author delete mention of "silicic volcanic centers" on p. C-6 and the figure caption.

Response: The text specified in the comment is as follows:
"Volcanism in the Southwestern Nevada Volcanic Field began in the mid-Miocene with eruptions at several large calderas and silicic volcanic centers (Figure C-1; Sawyer et al. 1994 [DIRS 100075], p. 1,305)."

For the ERD, the text is revised as follows:
"Volcanism in the Southwestern Nevada Volcanic Field began in the mid-Miocene with silicic eruptions at several large calderas (Figure C-1; Sawyer et al. 1994 [DIRS 100075], p. 1,305)."

Impact Evaluation: The ERD revision clarifies the description of the onset of volcanic activity in the Southwestern Nevada Volcanic Field consistent with the description in the cited reference. The ERD revision has no impact on technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Recommendation #4

Issue 7*:*
Page C-35, first paragraph. The statement ". . . Vesiculation and bubble coalescence … and varying degrees of separation in the two-phase eruptive mixture (i.e., melt and volatile or gas phase)…produce simultaneous violent Strombolian columns and lava effusion" is challenged. The mechanism of fragmentation and tephra (ash) comminution, beginning at depths below the volcano and requiring a volatile volume fraction greater than or equal to 0.75, is irreversible. Effusion of low-viscosity, quasi-Newtonian liquid lava is incompatible with violent Strombolian ash generation. When asked if these different volcanic products could be produced "simultaneously" from the same conduit, the line organization responded that abrupt alternation of activity could simulate "simultaneity" in the eruption products. It is recommended that this be clarified by adding a statement regarding alternation of activity in the text and appropriately supported by a reference.

Response: The text specified in the comment is found on page C-34 as follows:
"The complexity of the Lathrop Wells eruption, given that the major element composition changed very little throughout, indicates that fluid dynamic processes such as vesiculation and bubble coalescence, gas loss to country rocks, and varying degrees of separation in the two-phase eruptive mixture to produce simultaneous violent strombolian columns and lava effusion, are of fundamental importance in determining eruption processes at scoria cone volcanoes."

Contrary to the issue statement, the "line organization" did not "respond that abrupt alternation of activity could simulate 'simultaneity' in the eruption products." Rather LANL staff said that, while the specific mechanism was unknown, simultaneous eruptions of finely comminuted ash by violent Strombolian eruption and effusion of lava have been observed at more than one historic eruption (e.g., Paricutin and Tolbachik). Several processes are listed that may explain this behavior as discussed by other researchers, although the precise mechanism is unimportant to the discussion of the potential eruptive activity at Yucca Mountain presented in this section. The reviewer was provided with these examples and the key references. These references are cited in the report at the appropriate points where this kind of activity is discussed. It is unnecessary to insert these reference citations again in this particular summary section. No revision of the text is necessary.

Impact Evaluation: None

Issue 8:
Page C-21, Section C.6.3, second paragraph. The test states, "Mounds of pyroclasts… are interpreted… to be material rafted from the cone by lava effusion driving the violent Strombolian cone-building phase." An approximate 45-day duration of flow implies that

the violent Strombolian phase was at least this long. When asked, by the evaluator, if these processes can be simultaneous, effusion of lava should relieve volatile pressure to a point where fragmentation and gas volatilization may not support violent Strombolian eruption, the response was that eruption/effusion can be simultaneous. The technical correctness of this assertion should be reviewed, and if confirmed, appropriate source references should be provided.

Response: The text specified in the comment is as follows:
"Mounds of pyroclasts within the northeast lava field are apparently more aligned along flow direction of associated lava than those on the south lava field. Perry et al. (1998 [DIRS 144335], p. 2-41) considered the alignment of mounds, along with observations from trenching their margins, to indicate the trend of fissures and vents for surrounding lava flows. In contrast, the mounds are interpreted here to be material that was rafted from the cone by lava effusion during the violent Strombolian cone-building phase. This is consistent with the grain size and lack of agglutination in the mounds of the northeast lava field (compare with mounds on the south lava field that commonly are agglutinated or welded and retain some original bedding, having been scavenged from the early, Strombolian cone). The alignment of mounds simply reflects flow direction of proximal lavas that carried the rafts."

This issue is essentially a repetition of Issue 7 above. See response to Issue 7 above for resolution.

Impact Evaluation: None

Issue 9:
Page E.-18, Sec.E.3.3, first paragraph "The lapilli-and-bomb facies may have resulted from eruptions with sustained, high-standing columns approaching a violent Strombolian mechanism" . The statement is unsupported. At a minimum it should be referenced. The statement was defended by auditees. However, it is contradicted in the text by the assertion that lapilli-and-bomb facies are results of ballister[sic] Strombolian activity, and review of observational data from Red and Black Cones (pp E-6 and E-12) show no evidence of violent Strombolian activity, either early or late. The expression "may have" is an inadequate qualification, as the inference of violent Strombolian activity still stands. It is recommended that this topic be reviewed by literature search and reappraisal of all the analogue sites.

Response: The text specified in the comment is as follows:
"The overall eruptive sequence of Black Cone volcano is similar to that of Red Cone volcano. Pyroclastic facies in the cone remnant preserve an evolution from eruption of relatively well-fragmented material that was cool and brittle (except for large bombs) upon deposition even very near to the vent, forming the lapilli-and-bomb facies, to eruption of coarse spatter. The lapilli-and-bomb facies may have resulted from eruptions with sustained, high-standing columns approaching a violent Strombolian mechanism, although recycling and breaking-up of large clasts by avalanching in the vent area probably had an

important role in producing this facies as well. The spatter facies represents a later phase of weak, asymmetric bursts or short-lived fountains of lava. The cone may have had an open horseshoe shape during part of its eruptive history that was filled in or healed by later pyroclastic activity that terminated with a bowl-shaped crater where the cone remnant's summit is now."

For the ERD, the following text is added to the description:
"The key aspect here for the interpretation of these vent-proximal lapilli-and-bomb deposits from a sustained, high-standing column is the overall lack of well-developed welding textures, as described on p. E-12. Had these deposits formed from Strombolian or weak-column eruption, the clasts (especially the relatively fine-grained lapilli) would have spent very little time in the air and would have therefore retained sufficient heat to weld into a spatter deposit, as is described at the Pliocene (3.7 Ma) fissure eruptions and at East Basalt Ridge (Sections F2.5, F2.6)."

Impact Evaluation: The ERD revision augments the description and provides additional references but does not change technical product outputs or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 31:
Page 6-22, second paragraph. Surface faults are known to be magma-induced in areas of high magma production (e.g. East Africia, Iceland, Hawaii), but not Crater Flat. Perhaps surface faulting could be magma-related (e.g. LWC and Solitario Canyon Fault), but this is very uncertain. The first part of this paragraph is difficult to support for Yucca Mountain (no evidence). It is recommended that a rewrite and review of literature be conducted for a more balanced application.

Response: The text specified in the comment is as follows:

"Worldwide, geodetic measurements, cointrusive seismicity, and field observations indicate a propagating dike incrementally forms small normal faults, fissures, tensile cracks, and grabens at the surface above the dike. The magma-induced surface faults with cointrusive displacements of up to several meters can form aseismically or be accompanied by shallow depth, low-magnitude earthquake swarms (Hackett et al. 1996 [DIRS 169781], pp. 147 and 158). The volcanic earthquake swarms can include high frequency earthquakes that can generate ground motions similar to those generated by tectonic induced earthquakes."

For the ERD, the text in Section 6.3.3.2, paragraphs 1 and 2 is combined into an introductory paragraph that summarizes worldwide occurrences of seismicity associated with intrusion as follows:

"Worldwide, geodetic measurements, cointrusive seismicity, and field observations indicate a propagating dike incrementally forms small normal faults, fissures, tensile cracks, and grabens at the surface above the dike (Hackett et al. 1996 [DIRS 169781], pp.

147 and 158). If the ambient state of stress is such that existing faults are near failure, then the stress perturbation due to dike intrusion can induce failure along these faults (Rubin 1995 [DIRS 164118], p. 321; Rubin and Gillard 1998 [DIRS 169786], p. 10,017 and 10,026; Rubin et al. 1998 [DIRS 169787], p. 10,011). Dike-induced rupturing of fractures and faults near the dike tip, the subject of this discussion, form in the shallow crust at depths less than 4 km to 5 km, where differential stress and rigidity are lower than at depth (Smith et al. 1996 [DIRS 101020], p. 6,284). Numerical and scaled empirical experiments on dike intrusion provide information on the relationships between dike geometry, stress and strain distribution, and surface deformation (Mastin and Pollard 1988 [DIRS 169783], p. 13,228 and Figure 12; Rubin 1992 [DIRS 169784], Figure 6), and results indicate that rupture areas and the maximum magnitudes of strain release associated with dike intrusion are small, in comparison with regional faults that extend to the brittle-ductile transition."

The main description begins with paragraph 3 of the current text.

Impact Evaluation: The ERD revision adds introductory text to the section but does not change the technical product output or the conclusion of the analysis report.

Issue 33:
Page 6-23, third paragraph. "Surface fault length is equated to the dike-length distribution at repository depth." The audit team disagreed with using fault length as a proxy for dike length and thereby deriving earthquake magnitudes on the basis of surface-rupture lengths. This results in unusually large, surface-breaking earthquakes indistinguished from tectonic recurrence earthquakes. The audit team recommends a review of Smith et. al. (1996, p. 6,284) and that this paragraph be clarified.

Response: See responses to CR 11939, CAQ #1, Issue 81a and CAQ #2 Issue 88, Intrusion-induced earthquakes.

The text clearly states appropriate qualifications "(i.e., larger than earthquakes observed within active volcanic rift zones; Figure 6-4)." The range of range of instrumentally observed seismicity at active volcanic rift zones (3 to ~ 4.7) is clearly identified in Figure 6-4 and described in the Note below the figure, and Figure 6-4 is clearly referenced in the parenthetical. Since some of the earthquake magnitudes shown in Figure 6-4 are greater than the magnitudes typical of range of instrumentally observed seismicity at active volcanic rift zones, a sufficient basis exists within the discussion to support the hypothesis.

In addition, Section 1 of the report clearly states that one of the purposes of the report is to document analyses that estimate the maximum magnitude earthquake associated with an intrusion (Bullet 4, p. 1-2). Table 7-1 lists the maximum moment magnitude for dike induced earthquakes as 6.1, and notes that the magnitudes are calculated from the recommended distribution of dike lengths in the Yucca Mountain region. Assuming that the calculation method is sound, the magnitudes are based on observed features in the region and hence should represent a reasonable bound for earthquake magnitudes that might occur with intrusion into the repository. Earthquakes with magnitudes up to 6.1 are possible with an intrusion, but that magnitude represents the maximum magnitude not the magnitudes that would be more likely to occur.

No additional revisions to text or additional references are needed.
Impact Evaluation: None

Issue 50: *The conclusions on page C-34 are not sourced or back referenced to the section that justifies these conclusions (Items 1-3). It is recommended that the text be revised; Item 3 of the list in particular should be revised. Specifically, the term "significant volatiles", "hydrovolcanic activity", and "shallow groundwater" (rare perched water?) should be re-evaluated and the text revised as appropriate.*

Response: The item 3 text specified in the comment is as follows:
"Based upon the violent Strombolian nature of much of the eruption, explosivity of the initial interaction with repository drifts and subsequent eruptive dispersal could be high if the basaltic magmas have significant volatiles (see Woods et al. 2002 [DIRS 163662] p. 19-3; Dartevelle and Valentine 2005 [DIRS 178142], Figures 2 and 3). Hydrovolcanic explosions might occur if shallow groundwater is available, but this would be relatively minor based upon the small fraction of products at Lathrop Wells that might be of hydrovolcanic origin and the near absence of evidence for such activity in other volcanoes of Crater Flat (Section E.6.1)."

The references for the description of "significant volatiles" are included in the text. For the ERD, no revisions to the existing text are needed and no change to the analysis report is required.

The term "shallow groundwater" occurs in a description of conditions that are necessary for a hydrovolcanic eruption to occur. For the ERD no additional reference is needed.

Hydrovolcanic deposits have been observed at Lathrop Wells and correlated with periods of violent Strombolian activity. Similar deposits attributed to similar processes have been reported at Red Cone and Black Cone. An appropriate reference for the Red Cone and Black Cone deposits is in the existing text.

For the ERD, the text is revised as follows to include references for hydrovolcanic deposits observed at Lathrop Wells:

"Based upon the violent Strombolian nature of much of the eruption, explosivity of the initial interaction with repository drifts and subsequent eruptive dispersal could be high if the basaltic magmas have significant volatiles (see Woods et al. 2002 [DIRS 163662] p. 19-3; Dartevelle and Valentine 2005 [DIRS 178142], Figures 2 and 3). Hydrovolcanic explosions might occur if shallow groundwater is available, but this would be relatively minor based upon the small fraction of products at Lathrop Wells that might be of hydrovolcanic origin (Sections C.6.1 and C.6.2) and the near absence of evidence for such activity in other volcanoes of Crater Flat (Section E.6.1)."

Impact Evaluation: The ERD revision adds references for hydrovolcanic deposits observed at Lathrop Wells volcano. Adding a reference does not affect the technical product output or the conclusion of ANL-MGR-GS-000002 REV 03.

Issue 56:
The viscosities and temperatures recommended in the text are too high. Viscosity is affected by the amount of phenocrysts and microlites, the degree of visiculation, the number of xenoliths or xenocrysts, the water content, etc. In addition, textures in the lava flows (aa vs ropey) and other features indicate some evidence of the viscosities involved. Clearly the magmas in the Crater Flat area were subliquidus. This does not strongly support the range of temperatures, viscosities, or high water contents (i.e., greater than 2 wt %) presented in table 6-5. While water contents are discussed in the text, a better discussion of the water contents used could be improved (e.g., discussions of olivine and plagioclase).

It is recommended that a clearer discussion be presented, that the range of values presented (and later used in other AMRs) be "lowered" or justified (temperature, viscosity, and water contents).

Response: Table 6-5 provides calculated saturation pressures, liquidus temperatures, viscosities, and densities as a function of water content for Lathrop Wells magmas. The values are from the Lathrop Wells lavas are based on analytical results, and as currently presented, the ranges calculated are appropriate and justified in the text. An extensive note follows the table and explains how the table values were calculated. In addition, paragraphs 3 and 5 following the table describe the method used to calculate liquidus temperatures associated with water contents varying between 0.5 wt% and 4.0 wt % for the Lathrop Wells lavas. Paragraph 6 following Table 6-5 describes how viscosity effects were considered. No changes to the existing text are needed.

Impact Evaluation: None

Issue 74:
Page 6-44, Sec 6.4, Paragraph 1. "one scenario" is proposed as a "likely" scenario, and is not proposed as a conservative event sequence. This implies that there are more scenarios available, some more or less likely than others. When asked how liklihood is determined, the response was that liklihood is about 87%. It is recommended that the author provide a statement about where and how this liklihood is determined and supported, as scenario selection is not transparent.

Response: Issue 74 is the same as CR 11939, CAQ #3, Issue 88. See CR 11939, CAQ #3, Issue 88 for resolution.

Impact Evaluation: None

Issue 76:
Page 6-40, Paragraph 2. The Doubik and Hill (1999) reference is problematic; only one sample is reported from an unspecified location and an undefended assertion is made that xenolith abundance is a function of eruption violence. The discussion should include an appraisal of the validity of a report that presents only one undocumented sample, and the relevance of a comparison of Lathrop Wells Cone with Tolbachik. It is recommended that a review of Doubik and Hill be performed to verify it is credible for scenario development.

Response: The text specified in the comment is an argument that Doubik and Hill (1999) were incorrect in their estimate of the xenolith content at Lathrop Wells. The argument is fully developed in Appendix C, as described in the text. No change to text is needed.

Impact Evaluation: None

Issue 94:
Page 6-46, paragraph D. Hydrovolcanism is included as part of the eruptive scenario and paragraph D mentions the evidence for it: "… a small fraction of deposits at Lathrop Wells volcano; Appendix C" Appendix C describes a single deposit 120 cm thick of finely laminated and cross laminated ash. The discussion here is speculative; the ash grains shown in Fig. C-10 are conspicuously rounded, and the terms wind, stong wind, eolian and abraded are used repeatedly. The evidence implies eolian deposition rather than fallout from a hydrovolcanic explosion. The response was that cross-referencing between paragraph D and Appendix C would help. At least a reference for the second sentence in paragraph D is recommended. It is also recommended that specific examples from the literature be given to support the inference of hydrovolcanic eruption (e.g. Ubehebe Crater) or that paragraph D be rewritten to minimize the confidence in the assumption, as it is very weakly supported by Appendix C.

Response: Paragraph D clearly indicates that an eruption at Yucca Mountain "might" include "brief periods of explosive magma-groundwater interaction." Deposits and changes to the structure of the volcano that "might" result from a hydrovolcanic phase are then described. The paragraph concludes with a statement that acknowledges that while hydrovolcanism in included in the eruption scenario for Yucca Mountain, hydrovolcanism is discounted as a significant phenomenon because the depth to the saturated zone is ~600 m and there is negligible perched water present within the unsaturated zone at Yucca Mountain.

The items suggested in the comment, including the suggested reference for the second sentence, add little value to the discussion in paragraph D. No change to text is needed.

Impact Evaluation: None

Issue 98: *p. E-18, Sec. E.3.3, paragraph 1. "The lapilli-and-bomb facies may have resulted from eruption with sustained, high-standing columns approaching a violent Strombolian mechanism…although avalanching probably had an important role…as well". The statement is contradictory as the report clearly defines the contrasting effects of Strombolian versus violent Strombolian. In fact, according to criteria presented in the report there is absolutely no evidence at all for any violent Strombolian activity having occurred at Black, Red and Little Cones. It is recommended that this statement be deleted as it is misleading and misrepresents the data available from the analogues.*

Response: The text specified in the comment is as follows:
"The lapilli-and-bomb facies may have resulted from eruptions with sustained, high-standing columns approaching a violent Strombolian mechanism, although recycling and breaking-up of large clasts by avalanching in the vent area probably had an important role in producing this facies as well."

The statement is not contradictory, as both of these processes occur simultaneously near the vent. Issue 98 is substantially equivalent to Issue 9. See response to Issue 9 for resolution.

Impact Evaluation: None

Recommendation #5

Issue 53:
Page 6-36, Table 6-9. It was agreed that very short eruption durations are found with the higher eruptive rates. The calculations could be made and perhaps a distribution created with what would be expected vs what the tail-end limits (e.g., 10% and 90%) might be. In addition, more discussion could be added to the text to describe how these potential analogues come into play in the calculations. Reporting duration times for an example will be instructive to include in the report. It is recommended that these concepts be considered during any modification of the document.

Response: Analogue durations are appropriately documented in Table 6-9 and used as a basis for developing the eruption duration range. No changes to text are required.

Impact Evaluation: None

Issue 89:
Page C-34, item (3). The anticipated eruption begins with violent Strombolian activity (an extreme case: "could be high") whereas elsewhere in the report the scenario calls for dike effusion gathering into conduits that proceed from fire fountains to relatively low-energy Strombolian activity. The condition for violent Strombolian eruption is that the magmas have "significant volatiles". "Significant volatiles" needs to be clarified. The team recommends rewording to clarify this point and emphasize that "significant " is based

entirely on volatile values reported for LWC as the text makes clear that LWC IS THE BASIS for the future volcanic event.

Response: See Recommendation #4, Issue 50. See CR 11939, CAQ #2 Issue 88, Hydrovolcanism for resolution.

III. Conclusion:

The changes contained in the ERD that addresses CR 11939 and CR 11940 provide specified reference citations, clarifications to descriptions, or provide editorial corrections to typographical errors. The changes in the ERD have no effects on the conclusions of, or technical product outputs from, the analysis documented in the report, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [DIRS 174260]. According to the procedural requirements (MGT-PRO-004) for an evaluation of potential impacts of the ERD on the Safety Analysis Report, as described in Table ERD-1, the changes described in the ERD do not impact the TSPA or the SAR.

IV. Inputs and/or Software

Additional indirect inputs have been added for clarification, but there are no changes to input values or software used in the analysis resulted from the responses to CR 11939 and CR 11940.

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
100-IED-WHS0-00201-000-00D	IED SURFACE FACILITY AND ENVIRONMENT	Estimated volumes of Quaternary volcanoes in the Yucca Mountain Region from Table 6-2. ERD 02 adds a reference to Table-6-2; no impact.
ANL-DS0-NU-000001 Rev. 00	SCREENING ANALYSIS OF CRITICALITY FEATURES, EVENTS, AND PROCESSES FOR LICENSE APPLICATION	Extent of vitrophyre formation following intrusion from Section F.2.2. No changes made to the description of the extent of vitrophyres. No impact.
ANL-MGR-GS-000003 Rev. 03	NUMBER OF WASTE PACKAGES HIT BY IGNEOUS EVENTS	Igneous parameters include dike swarm features and conduit features supporting assumptions about conduit spacing, formation of conduits along the principal dike, and descriptions of dike length and orientation, general description of eruptive processes. Since none of the parameters listed has been changed by the ERD, the ERD has no impact on the analysis presented in ANL-MGR-GS-000003, Rev 03.
ANL-WIS-MD-000024 Rev. 01	POSTCLOSURE NUCLEAR SAFETY DESIGN BASES	ANL-WIS-MD-000024 Table 6-1 lists ANL-MGR-GS-000002 as a source for indirect inputs. Table 6-4 associates ANL-MGR-GS-000002 with the Volcanic Eruption Submodel. No specific volcanic processes are identified. The ERD has no impact on the analysis presented in ANL-MGR-GS-000003, Rev 03.
ANL-WIS-MD-000027 Rev. 00	FEATURES, EVENTS, AND PROCESSES FOR THE TOTAL SYSTEM PERFORMANCE ASSESSMENT: ANALYSES	FEP 1.2.03.03.0A, Direct Inputs: Range of dike widths. Indirect inputs: Description of calculation of maximum magnitudes of dike-induced earthquakes in ANL-MGR-GS-000002. FEP 1.2.04.02.0A Direct Inputs: Range of dike widths. Extents of altered zones around dikes. Indirect inputs: Characteristics of Paiute Ridge volcanic center. Description that the presence of faults that may locally

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
		control alignment of dikes in the shallow crust. Sill characteristics. Dike orientations and thicknesses. FEP 1.2.04.03.0A indirect inputs: characteristics and properties of magma, magma chemistry. FEP 1.2.04.05.0A: Direct inputs: ANL-MGR-GS-000002, Table 6-2: volumes of volcanoes near YM and extents of lava flows. Pyroclastic eruption characteristics. Lateral extent of base surge deposit and extent of ash deposits from Lathrop Wells. Indirect inputs: Conditions needed for hydrovolcanic eruption and distributions of hydrovolcanic deposits. FEP 1.2.04.06.0A: Indirect: General description of volcanic characteristics. Water contents of hawaiites. FEP 1.2.04.07.0A: Indirect Inputs: Description of volcanic characteristics and parameters needed for the ASHPLUME code. FEP 1.2.04.07.0B Indirect input general description of volcanic processes. FEP 1.2.05.00.0A: Indirect Inputs: Typical widths of dikes near YM. Dikes near YM often occupy faults. FEP: 1.2.09.01.0A Direct input: estimated size distributions for any potential future dikes at Yucca Mountain. FEP: 1.2.10.02.0A Direct input: estimated size distributions for any

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
		potential future dikes at Yucca Mountain. Indirect Input: limited extent of effusive flow from small-scale volcanoes such as Lathrop Wells; blockage of drainage by lava near Lathrop Wells. FEP: 1.2.10.02.0A Direct Input: Describes the range of mean particle size erupted during violent Strombolian eruptions. Indirect Inputs: general description of characteristics for eruption near YM. FEP: 1.4.01.03.0A Direct input: short duration and small volume of eruption near YM. FEP: 2.1.14.26.0A Indirect Input: Expected thickness of vitrophyre in intrusion modeling case. Impact Evaluation: The ERD revisions do not change the product outputs listed in ANL-MGR-GS-000002, Table 7-1; therefore, the ERD has no impacts on the FEPs analyses that reference ANL-MGR-GS-000002.
MDL-MGR-GS-000002 Rev. 03	ATMOSPHERIC DISPERSAL AND DEPOSITION OF TEPHRA FROM A POTENTIAL VOLCANIC ERUPTION AT YUCCA MOUNTAIN, NEVADA	Indirect: Violent Strombolian eruption characteristics; Strombolian-type eruption eruption characteristics; self-consistent relationships among eruptive duration, eruptive volume, and vent radius; Cerro Negro 1995 erupted volume; eruptive history and volumes from Lathrop Wells; ascent velocity is related to magma volatile content. Direct: Ash physical characteristics required as inputs to the

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
		Ashplume model; description of the turbulent and unsteady flow environment that creates and evolves in the volcanic conduit; ash settled density; Maximum particle diameter for transport; eruptive power; eruption duration; mean ash particle diameter; ash particle standard deviation; range of conduit diameters; ash particle density. Impact Evaluation: The ERD revisions do not change the product outputs listed in ANL-MGR-GS-000002, Table 7-1; therefore, the ERD has no impacts on the development of parameters needed for the ASHPLUME code, as described in MDL-MGR-GS-000002.
MDL-MGR-GS-000005 Rev. 02	DIKE/DRIFT INTERACTIONS	Indirect Inputs: Magma bouyancy related to exsolution of water vapor in the lower pressure environment of the upper several kilometers of the crust; conceptual model for igneous processes; chemical characteristics of alkali basalts in western US; typical dike dimensions and orientations near YM; limitation of dike propagation model based on magma chemical characteristics; relation between water content and magma pressure; drift cross-sectional flow area; height of Lathrop Wells volcano; lava flow thickness; density of degassed magma; exsolution depth. Impact Evaluation: The ERD revisions do not change the product outputs listed in ANL-MGR-GS-000002, Table 7-1; therefore, the ERD has no impacts on the development of parameters needed for the models or analyses described in MDL-MGR-GS-000005.

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
MDL-WIS-PA-000005 Rev. 00, MiscId 01	TOTAL SYSTEM PERFORMANCE ASSESSMENT MODEL/ANALYSIS FOR THE LICENSE APPLICATION - Volume I	Indirect: Description of source for information about natural volcanic systems and parameters used to model their behavior; volume of Lathrop Wells volcano; source for ash settled density. Impact Evaluation: The ERD revisions do not change the product outputs listed in ANL-MGR-GS-000002, Table 7-1, and ANL-MGR-GS-000002 provides no direct inputs to TSPA. Therefore, the ERD has no impacts on the TSPA.
MDL-WIS-PA-000005 Rev. 00, MiscId 02	TOTAL SYSTEM PERFORMANCE ASSESSMENT MODEL/ANALYSIS FOR THE LICENSE APPLICATION - Volume II	
MDL-WIS-PA-000005 Rev. 00, MiscId 03	TOTAL SYSTEM PERFORMANCE ASSESSMENT MODEL/ANALYSIS FOR THE LICENSE APPLICATION - Volume III	
TDR-WIS-PA-000014 Rev. 00	TSPA INFORMATION PACKAGE FOR THE DRAFT SEIS	Indirect inputs: Descriptions of umber of dikes; dike widths; conduit diameters. Impact Evaluation: The ERD revisions do not change the product outputs listed in ANL-MGR-GS-000002, Table 7-1, and ANL-MGR-GS-000002 provides no direct inputs to TSPA. Therefore, the ERD has no impacts on the TSPA or on the information package for the draft SEIS.
LAGI-5	LA GENERAL INFORMATION SECTION 5	Indirect: identification of studies of regional analogs; Table 6-2 listed as a data source (basalt ages) for LA Figure 5-29. Impact Evaluation: The ERD does not revise the description of the analog studies. The ERD revises a volume estimates for Little Black Peak and Hidden Cone, but the ages are not revised. Since the ages are not revised, the ERD has no effect on the

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
		basalt age information supporting LA Figure 5-29.
LASAR-2.02	LA SAFETY ANALYSIS REPORT SECTION 2.2	Indirect: identification of studies of regional analogs; identification of information needed to estimate the probability of eruption within the repository footprint and the associated uncertainties; Table 6-2 listed as a data source (basalt ages) for SAR Figure 2.2-24. Impact Evaluation: The ERD does not revise the description of the analog studies. The ERD revises a volume estimates for Little Black Peak and Hidden Cone, but the ages are not revised. Since the ages are not revised, the ERD has no effect on the basalt age information supporting SAR Figure 2.2-24.
LASAR-2.03.11	LA SAFETY ANALYSIS REPORT SECTION 2.3.11	Indirect: identification of studies of regional analogs; identification of information needed to estimate the probability of eruption within the repository footprint and the associated uncertainties; range of water contents in basalts; ranges of dike widths and lengths in YMR; dikes typically occupy pre-existing faults; characteristics of volcanic centers; distribution of conduit locations along dikes; extent of typical tephra deposit in YMR; volumes of Quaternary volcanic centers in YMR; magma characteristics and controls on basaltic intrusions and eruptions; ash particle characteristics; ash settled density. The indirect inputs identified above are not changed by the ERD. Table 2.3.11-2 and Figure 2.3.11-3 list DIRS 174260, Table 6-2 as a data source. The ERD revises volume estimates in Table 6-2 for Little Black

Table ERD-1. ANL-MGR-GS-000002 ERD 2 IMPACT EVALUATION		
Document ID	Document Title	Data Used and Impact
		Peak and Hidden Cone, but SAR Table 2.3.11-2 lists the correct volumes for Little Black Peak and Hidden Cone. Therefore, the ERD has no impact on SAR Table 2.3.11-2 or on SAR Figure 2.3.11-3.
LASAR-2.04	LA SAFETY ANALYSIS REPORT SECTION 2.4	Indirect: volume of Lathrop Wells cone in a description of a corroborative study. The ERD does not change the source for the volume of Lathrop Wells cone cited in SAR 2.4.2.3.2.3.3.2.