



**Department of Energy**  
Office of Civilian Radioactive Waste Management  
Yucca Mountain Site Characterization Office  
P.O. Box 364629  
North Las Vegas, NV 89036-8629

QA: N/A

**JUL 30 2002**

**OVERNIGHT MAIL**

Janet R. Schlueter, Chief  
High-Level Waste Branch  
Division of Waste Management  
Office of Nuclear Materials Safety  
and Safeguards  
U.S. Nuclear Regulatory Commission  
Two White Flint North  
Rockville, MD 20852

**TRANSMITTAL OF REPORT ADDRESSING KEY TECHNICAL ISSUE (KTI)  
AGREEMENT ITEM IGNEOUS ACTIVITY (IA) 2.03**

**References:**

1. *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada*, ANL-MGR-GS-000001, Revision 00, ICN 01.
2. *Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, Revision 00, ICN 01.
3. *Total System Performance Assessment for the Site Recommendation*, TDR-WIS-PA-000001, Revision 00, ICN 01.
4. Ltr, Brocoum to Reamer, dtd 2/2/01.

This letter transmits a report entitled *Range of Tephra Volumes*, which satisfies the subject KTI agreement. The agreement statement is as follows:

IA 2.03 – “Document how tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos.

DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY 2002.”

For the Total System Performance Assessment - Site Recommendation (TSPA-SR), the U.S. Department of Energy (DOE) used information, described in the enclosure to this letter, as the basis to calculate tephra volumes. The enclosure is based on information on page 34 of Reference 1, and the use of the information in the ASHPLUME code, as described in Section 6.1.2.1.1 of Reference 2. Both of these references were transmitted to the U.S. Nuclear Regulatory Commission (NRC) by the referenced letter (Reference 4). The information

JUL 30 2002

in Reference 1 provides a conservative basis to represent the range of tephra volumes likely from possible future volcanoes in the Yucca Mountain Region. First, the information in Reference 1 is the total erupted volume for volcanoes in the Yucca Mountain Region. Since the volume of tephra cannot exceed the total erupted volume, use of the total volume provides a conservative upper bound on tephra volumes from basaltic volcanoes in the Yucca Mountain Region.

Second, the upper end of the range described in Reference 2 was based on information from basaltic volcanoes throughout the world. Many of these volcanoes are significantly larger than volcanoes in the Yucca Mountain Region. Hence, inclusion of volume data from basaltic volcanoes throughout the world is conservative. Finally, the sampling scheme in the ASHPLUME code considered the range of volumes as a log uniform distribution, which means that any value in the range had an equally likely chance of being sampled.

Section 5.2.9.5 of the TSPA-SR report (Reference 3) describes the results of a study of dose sensitivity to uncertainties in the volume of material erupted. The study used the 5<sup>th</sup> and 95<sup>th</sup> percentile values for the volumes, which correspond to values of 0.0026 km<sup>3</sup> and 0.336 km<sup>3</sup>, respectively. The results described in the TSPA-SR report indicate that the mean annual eruptive dose rate is insensitive to the range of values selected in the analysis for erupted volume.

While the agreement for IA 2.03 indicated that this information would be provided in an Analysis and Model Report, the information has been included in the enclosed report as discussed at the April 15-16, 2002, NRC/DOE Technical Exchange and Management Meeting on KTIs.

The DOE believes the information in the enclosure, Reference 1, Reference 2, and the sensitivity analysis referenced above, provides a basis for completion of IA 2.03.

This letter makes no new regulatory commitments. If you have any questions about this letter and its enclosure, please contact Timothy C. Gunter at (702) 794-1343 or Eric T. Smistad at (702) 794-5073.



Joseph D. Ziegler  
Acting Assistant Manager  
Office of Licensing and Regulatory Compliance

OL&RC:TCG-1325

Enclosure:  
*Range of Tephra Volumes*

JUL 30 2002

cc w/encl:

J. W. Andersen, NRC, Rockville, MD  
J. S. Trapp, NRC, Rockville, MD  
D. D. Chamberlain, NRC, Arlington, TX  
R. M. Latta, NRC, Las Vegas, NV  
S. H. Hanauer, DOE/HQ (RW-2), Las Vegas, NV  
B. J. Garrick, ACNW, Rockville, MD  
Richard Major, ACNW, Rockville, MD  
W. D. Barnard, NWTRB, Arlington, VA  
Budhi Sagar, CNWRA, San Antonio, TX  
W. C. Patrick, CNWRA, San Antonio, TX  
Steve Kraft, NEI, Washington, DC  
J. H. Kessler, EPRI, Palo Alto, CA  
J. R. Egan, Egan & Associates, McLean, VA  
R. R. Loux, State of Nevada, Carson City, NV  
Irene Navis, Clark County, Las Vegas, NV  
George McCorkell, Esmeralda County, Goldfield, NV  
Margie Paslov-Thomas, State of Nevada, Carson City, NV  
Alan Kalt, Churchill County, Fallon, NV  
Leonard Fiorenzi, Eureka County, Eureka, NV  
Andrew Remus, Inyo County, Independence, CA  
Michael King, Inyo County, Edmonds, WA  
Mickey Yarbrow, Lander County, Battle Mountain, NV  
Lola Stark, Lincoln County, Caliente, NV  
L. W. Bradshaw, Nye County, Pahrump, NV  
David Chavez, Nye County, Tonopah, NV  
Josie Larson, White Pine County, Ely, NV  
Arlo Funk, Mineral County, Hawthorne, NV  
R. I. Holden, National Congress of American Indians, Washington, DC  
Allen Ambler, Nevada Indian Environmental Coalition, Fallon, NV  
CMS Coordinator, BSC, Las Vegas, NV  
G. L. Smith, DOE/YMSCO, Las Vegas, NV  
OL&RC Library  
Records Processing Center = "17"

cc w/o encl:

C. W. Reamer, NRC, Rockville, MD  
N. K. Stablein, NRC, Rockville, MD  
L. L. Campbell, NRC, Rockville, MD  
S. L. Wastler, NRC, Rockville, MD  
Margaret Chu, DOE/HQ (RW-1), FORS  
A. B. Brownstein, DOE/HQ (RW-52), FORS

JUL 30 2002

cc w/o encl: (continued)

R. A. Milner, DOE/HQ (RW-2), FORS  
S. E. Gomberg, DOE/HQ (RW-52), FORS  
N. H. Slater-Thompson, DOE/HQ (RW-52), FORS  
R. B. Murthy, DOE/OQA (RW-3), Las Vegas, NV  
E. P. Opelski, NQS, Las Vegas, NV  
N. H. Williams, BSC, Las Vegas, NV  
S. J. Cereghino, BSC, Las Vegas, NV  
Donald Beckman, BSC, Las Vegas, NV  
R. B. Bradbury, MTS, Las Vegas, NV  
R. P. Gamble, MTS, Las Vegas, NV  
R. C. Murray, MTS, Las Vegas, NV  
R. D. Rogers, MTS, Las Vegas, NV  
Richard Goffi, BAH, Washington, DC  
J. R. Dyer, DOE/YMSCO, Las Vegas, NV  
D. G. Horton, DOE/YMSCO, Las Vegas, NV  
G. W. Hellstrom, DOE/YMSCO, Las Vegas, NV  
S. P. Mellington, DOE/YMSCO, Las Vegas, NV  
R. E. Spence, DOE/YMSCO, Las Vegas, NV  
D. C. Haught, DOE/YMSCO, Las Vegas, NV  
E. T. Smistad, DOE/YMSCO, Las Vegas, NV  
J. D. Ziegler, DOE/YMSCO, Las Vegas, NV  
W. J. Boyle, DOE/YMSCO, Las Vegas, NV  
C. M. Newbury, DOE/YMSCO, Las Vegas, NV  
T. C. Gunter, DOE/YMSCO, Las Vegas, NV  
C. L. Hanlon, DOE/YMSCO, Las Vegas, NV  
M. C. Tynan, DOE/YMSCO, Las Vegas, NV  
J. T. Sullivan, DOE/YMSCO, Las Vegas, NV  
C. A. Kouts, DOE/YMSCO (RW-2), FORS  
R. N. Wells, DOE/YMSCO (RW-60), Las Vegas, NV

## RANGE OF TEPHRA VOLUMES

July 2002

Preparation:

Terry R. Crump  
Terry R. Crump, Licensing Engineer, LAP

7/29/02  
Date

Approval:

For Paul  
Kathy N. Gaither, Manager, Disruptive Events Department

7-29-02  
Date

Reviewed by:

For Paul  
Frank Perry, Deputy Manager, Disruptive Events Department

7-29-02  
Date

ENCLOSURE

## CONTENTS

	Page
ACRONYMS AND ABBREVIATIONS .....	iii
1. BACKGROUND .....	1
1.1 NRC INITIAL COMMENTS .....	1
1.2 DOE INITIAL COMMENTS .....	1
1.3 STATEMENT OF DIFFERENCES .....	2
1.4 DEFINITION OF TECHNICAL TERMS .....	2
2. APPLICABLE NUCLEAR SAFETY STANDARDS/REQUIREMENTS/GUIDANCE .....	2
2.1 APPLICABLE REQUIREMENTS .....	2
2.2 KTI AGREEMENT .....	3
2.3 STATUS OF AGREEMENT(S) .....	3
3. BASIS FOR REGULATORY COMPLIANCE STATEMENT .....	3
3.1 BACKGROUND .....	3
3.2 SAFETY/TECHNICAL BASIS FOR THE COMPLIANCE DEMONSTRATION .....	4
4. REFERENCES .....	5
4.1 DOCUMENTS CITED .....	5
4.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES .....	6

## ACRONYMS AND ABBREVIATIONS

AMR	analysis/model report
DOE	U.S. Department of Energy
KTI	key technical issue
LA	License Application
NRC	U.S. Nuclear Regulatory Commission
SR	Site Recommendation
TSPA	Total System Performance Assessment
YMR	Yucca Mountain Region

## Range of Tephra Volumes

This report describes the basis to resolve and close an agreement item (IA 2.03) associated with the consequences subissue of the igneous activity key technical issue (KTI). The item in question is the U.S. Department of Energy (DOE)-U.S. Nuclear Regulatory Commission (NRC) agreement that DOE document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the Yucca Mountain Region in the eruptive processes analysis/model report (AMR) (ANL-MGR-GS-000002) (Crump 2001 [DIRS 156332]).

The mass/volume of ash that is erupted from a volcanic event must be defined. The mathematical model (implemented within ASHPLUME v1.4LV) uses the volume of erupted ash as an input parameter (CRWMS M&O 2000 [DIRS 151560], Section 6.1.2.1.1) to estimate the height of the ash column.

### 1. BACKGROUND

DOE originally agreed to document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the Yucca Mountain Region in the Total System Performance Assessment (TSPA)-Site Recommendation (SR), Revision 1 (Reamer and Williams 2000 [DIRS 154597]). Plans to develop Revision 1 were cancelled, and the agreement was revised during the NRC/DOE Technical Exchange and Management Meeting on Igneous Activity, June 21-22, 2001 (Crump 2001 [DIRS 156332]). Under the revised agreement, DOE would provide the information in a revision to the AMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [ANL-MGR-GS-000002].

DOE provided information about tephra volumes for volcanoes in the Yucca Mountain Region in the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000 [DIRS 151551], page 34), and described the use of the information in ASHPLUME in the AMR, *Igneous Consequence Modeling for the TSPA-SR* [ANL-WIS-MD-000017] (CRWMS M&O 2000 [DIRS 151560], Section 6.1.2.1.1). DOE considers that the information in these AMRs is adequate to resolve and close the agreement item.

#### 1.1 NRC INITIAL COMMENTS

The NRC recognized the importance of tephra volume information as input to the ASHPLUME code and requested that DOE provide the inputs that were used in TSPA-SR. The NRC defined the range of eruptive volumes as 0.004 – 0.44 km<sup>3</sup> (Reamer 1999 [DIRS 119693], page 129).

#### 1.2 DOE INITIAL COMMENTS

The AMR, *Igneous Consequence Modeling for the TSPA-SR* [ANL-WIS-MD-000017] (CRWMS M&O 2000 [DIRS 151560], Section 6.1.2.1.1), defined the range of eruptive volumes as 0.002 to 0.44 km<sup>3</sup>. Hence, the DOE range is greater than the range of volumes of analog volcanoes studied in the Yucca Mountain Region (CRWMS M&O 2000 [DIRS 151551], p. 34). DOE intends to document the range of tephra volumes and the basis for the range used to support



TSPA-License Application (LA) in an update of the AMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [ANL-MGR-GS-000002].

### 1.3 STATEMENT OF DIFFERENCES

For TSPA-SR, DOE used a range of tephra volumes that included the NRC range. The range is greater than the range of volumes of analog volcanoes studied in the Yucca Mountain Region. DOE intends to document the range of tephra volumes and the basis for the range used to support TSPA-License Application (LA) in an update of the AMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [ANL-MGR-GS-000002].

### 1.4 DEFINITION OF TECHNICAL TERMS

**aa**—A type of lava consisting of a rough surface of sharp, angular scoria (see below).

**ASHPLUME v1.4LV**—The computer code, selected from several such codes used, that the project has decided to use to simulate potential volcanic events at a repository at Yucca Mountain. The other codes are identified, and the basis for selection of the ASHPLUME code is described in the AMR, *Igneous Consequence Modeling for the TSPA-SR* [ANL-WIS-MD-000017] (CRWMS M&O 2000 [DIRS 151560], Sections 6.1 and 6.4, respectively).

**Basalt**—A dark-colored, hard, dense, fine-grained volcanic rock.

**Miocene**—A period of time between about 5 million and 23 million years before the present.

**Pliocene**—A period of time between about 1.6 million and 5 million years before the present.

**Scoria**—An irregular, rough, jagged fragment of lava that was ejected during an explosive eruption or was formed by the breaking up of the first-cooled crust of a lava flow.

**Tephra**—A collective term for all of the volcanic materials, which during an eruption, were ejected from a crater or from some other type of vent and transported through the air. Typically the term includes volcanic dust, ash, cinders, and blocks of material of varying sizes and shapes.

## 2. APPLICABLE NUCLEAR SAFETY STANDARDS/REQUIREMENTS/GUIDANCE

### 2.1 APPLICABLE REQUIREMENTS

The Yucca Mountain disposal regulations include a requirement to provide the technical basis for models used in the performance assessment (10 CFR 63.114(g)). The mathematical model (implemented within ASHPLUME v1.4LV) uses the volume of erupted ash as an input parameter (CRWMS M&O 2000 [DIRS 151560], Section 6.1.2.1.1. Agreement IA 2.03, repeated below, while not a regulatory requirement, requests DOE to provide the basis for the volume of erupted ash used as input for the ASHPLUME code.

## 2.2 KTI AGREEMENT

The following KTI agreement statement is based on the Summary Highlights of the NRC/DOE Technical Exchange and Management Meeting on Igneous Activity that occurred on August 29-31, 2000 (Reamer and Williams 2000 [DIRS 154597]) as modified in the Summary Highlights of the NRC/DOE Technical Exchange and Management Meeting on Igneous Activity that occurred on June 21-22, 2001 (Crump 2001 [DIRS 156332]).

*Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos. (Eruptive AC-1)*

*DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY2002.*

## 2.3 STATUS OF AGREEMENT(S)

DOE provided information about tephra volumes for volcanoes in the Yucca Mountain Region in the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (ANL-MGR-GS-000001, CRWMS M&O 2000 [DIRS 151551], page 34), and described the use of the information in ASHPLUME in the AMR, *Igneous Consequence Modeling for the TSPA-SR* [ANL-WIS-MD-000017], (CRWMS M&O 2000, [DIRS 151560] Section 6.1.2.1.1). DOE considers that the information in these AMRs is adequate to resolve and close the agreement item. DOE expects to document the range of tephra volumes used to support TSPA-LA calculations in an update to the AMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [ANL-MGR-GS-000002] because the documentation would be more appropriate for this AMR.

# 3. BASIS FOR REGULATORY COMPLIANCE STATEMENT

## 3.1 BACKGROUND

As described in the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000 [DIRS 151551], page 34), seven<sup>1</sup> Quaternary volcanoes occur to the south, west, and northwest of Yucca Mountain in a roughly linear zone defined as the Crater Flat Volcanic Zone. Five of the 7 volcanoes are in or near Crater Flat and are located within 20 kilometers of the Yucca Mountain site. The total eruption volume of the post-Miocene basalts is about 6 km<sup>3</sup>. The volume of individual episodes has decreased progressively through time, with the three Pliocene episodes having volumes of approximately 1 to 3 km<sup>3</sup> each and the three Quaternary episodes having a total volume of only about 0.5 km<sup>3</sup>. All of the Quaternary volcanoes are similar because they are of small volume (typically about 0.1 km<sup>3</sup> or less) and

---

<sup>1</sup> Little Cones is counted as a single volcano, but it could be counted as two volcanoes, which would change the count to eight volcanoes in the Crater Flat Volcanic Zone.

typically consist of a single main scoria cone surrounded by a small field of aa basalt flows, which commonly extend about a kilometer from the scoria cone. Estimated volumes and ages of Quaternary volcanoes in the Yucca Mountain are described in Table 4 of the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000 [DIRS 151551]). Table 4 and associated notes are reproduced below.

Estimated Volume and $^{40}\text{Ar}/^{39}\text{Ar}$ Age <sup>a</sup> of Quaternary Volcanoes in the YMR			
Volcano	Volume (km <sup>3</sup> ) <sup>b</sup>	Volume (km <sup>3</sup> ) <sup>c</sup>	Age (m.y.) <sup>d</sup>
Makani Cone	0.006	—	1.16 – 1.17
Black Cone	0.105	0.07	0.94 – 1.10
Red Cone	0.105	—	0.92 – 1.08
Little Cones	0.002	>0.01 <sup>d</sup>	0.77 – 1.02
Hidden Cone	0.03	—	0.32 – 0.56
Little Black Peak	0.03	—	0.36 – 0.39
Lathrop Wells Cone	0.14	—	0.074 – 0.084

**Notes**

Reproduced from Table 4 of ANL-MGR-GS-000001, Rev 00, ICN 01.

DTNs: LA0004FP831811.002; LAFP831811AQ97.001 (both used for reference only)

<sup>a</sup> $^{40}\text{Ar}/^{39}\text{Ar}$  dates provide the most complete and self-consistent chronology data set for Quaternary volcanoes of the YMR. A full discussion of other chronology methods used to date basaltic rocks in the YMR can be found in the Volcanism Synthesis Report (CRWMS M&O 1998, Chapter 2 [DIRS 123196]. Other chronology methods may not provide consistent or accurate estimates of the time of eruption.

<sup>b</sup>CRWMS M&O 1998, Chapter 3, Table 3.1 [DIRS 135988].

<sup>c</sup>Stamatakis et al 1997, p. 327 [DIRS 138819].

<sup>d</sup>Accounts for volume of buried flows detected by ground magnetic surveys.

<sup>e</sup>Range of ages from the Volcanism Synthesis Report (CRWMS M&O 1998, Chapter 2 [DIRS 123196], Table 2.B). Lathrop Wells ages (Heizler et al. 1999, Table 3 [DIRS 107255]) represent the range of plateau ages measured, except for sample LW157, a statistical outlier (DTN:LAFP831811AQ97.001).

### 3.2 SAFETY/TECHNICAL BASIS FOR THE COMPLIANCE DEMONSTRATION

The mathematical model (implemented within ASHPLUME v1.4LV) uses the volume of erupted ash as an input parameter to calculate the height of the eruption column. For TSPA-SR, the range for the erupted volume was provided in the AMR, *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000 [DIRS 151560], Section 6.1.2.1.1) as a log-uniform distribution ranging from 0.002 to 0.44 km<sup>3</sup>. This definition assured that the ranges of eruptive-volume for both the NRC and the DOE models were incorporated into the ASHPLUME v1.4LV calculation. For the TSPA-LA, DOE intends to use the range of eruptive volumes based on analog volcanoes from the Yucca Mountain Region (YMR). DOE expects the range based on YMR analogs to be less than the range used for TSPA-SR, which included analogs from throughout the world. DOE will document the total erupted volume and then derive the explosive fraction. DOE considers that the range of volumes based on YMR analogs will improve the technical basis for this ASHPLUME input parameter.

DOE documented the results of a study that examined the sensitivity of mean annual eruptive dose rate to volume of material erupted in the Total System Performance Assessment for Site Recommendation (TSPA-SR) (CRWMS M&O 2000; DIRS 153246, Section 5.2.9.5). In ASHPLUME version 1.4LV, the total volume of erupted material is used as the independent variable that defines the energy of eruption. The duration of eruption and the height of the erupted column are derived parameters that are calculated within each realization based on the sampled value for erupted volume.

The sensitivity study used the 5<sup>th</sup> and 95<sup>th</sup> percentile value for the volume of material erupted, which correspond to erupted volumes of 0.0026 km<sup>3</sup> and 0.336 km<sup>3</sup>, respectively. These erupted volumes correspond to calculated column heights of 2 and 5 km above the ground surface. The results of the analysis show that the total annual igneous dose rate is insensitive to the range of values selected for erupted volume in the analysis, and is therefore insensitive to uncertainty regarding the energy of the eruptive event and height of the eruptive column.

DOE considers that the information in the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000 [DIRS 151551]), the AMR, *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000 [DIRS 151560]), and the sensitivity analysis documented in the TSPA-SR (CRWMS M&O; DIRS 153246) is adequate to resolve and close the agreement item. The information in the AMR, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000 [DIRS 151551]) provides the range of tephra volumes for analog Quaternary basaltic volcanoes in the Yucca Mountain Region, and the description in the AMR, *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000 [DIRS 151560]) provides the basis for the range of volumes used in TSPA-SR. The sensitivity information in the TSPA-SR (CRWMS M&O 2000; DIRS 153246, Section 5.2.9.5) on erupted volumes indicates that dose is not sensitive to the range of erupted volumes used in the analysis. DOE intends to document the range of tephra volumes and the basis for that range used to support TSPA-LA calculations in an update to the AMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* [ANL-MGR-GS-000002].

## 4. REFERENCES

### 4.1 DOCUMENTS CITED

Crump, T. 2001. "Igneous Activity TE Meeting Summary." E-mail from T. Crump to J. McNeish, June 25, 2001, with attachment. ACC: MOL.20010723.0094; MOL.20010723.0095. DIRS 156332

CRWMS M&O 1998. "Geology and Geochronology of Basaltic Volcanism in the Yucca Mountain Region." Chapter 2 of *Synthesis of Volcanism Studies for the Yucca Mountain Site Characterization Project*. Deliverable 3781MR1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990511.0400. DIRS 123196

CRWMS M&O 1998. "Tectonic Setting of the Yucca Mountain Region: Relationship to Episodes of Cenozoic Basaltic Volcanism." Chapter 3 of *Synthesis of Volcanism Studies for the*

*Yucca Mountain Site Characterization Project*. Deliverable 3781MR1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990511.0400. DIRS 135988

CRWMS M&O 2000. *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada*. ANL-MGR-GS-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001221.0001. DIRS 151551

CRWMS M&O 2000. *Igneous Consequence Modeling for the TSPA-SR*. ANL-WIS-MD-000017 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0022. DIRS 151560

CRWMS M&O 2000. *Total System Performance Assessment for the Site Recommendation*. TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. DIRS 153246

Heizler, M.T.; Perry, F.V.; Crowe, B.M.; Peters, L.; and Appelt, R. 1999. "The Age of Lathrop Wells Volcanic Center: An 40AR/39AR Dating Investigation." *Journal of Geophysical Research*, 104, (B1), 767-804. Washington, D.C.: American Geophysical Union. TIC: 243399. DIRS 107255

Reamer, C.W. 1999. "Issue Resolution Status Report (Key Technical Issue: Igneous Activity, Revision 2)." Letter from C.W. Reamer (NRC) to Dr. S. Brocoum (DOE/YMSCO), July 16, 1999, with enclosure. ACC: MOL.19990810.0639. DIRS 119693

Reamer, C.W. and Williams, D.R. 2000. Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Igneous Activity. Meeting held August 29-31, 2000, Las Vegas, Nevada, with attachments. [Washington, D.C.]: U.S. Nuclear Regulatory Commission. ACC: MOL.20001101.0106; MOL.20001101.0107; MOL.20001101.0108; MOL.20001101.0105; MOL.20001101.0109; MOL.20001101.0110; MOL.20001101.0111; MOL.20001101.0112; MOL.20001101.0113; MOL.20001101.0114; MOL.20001101.0115; MOL.20001101.0116; MOL.20001101.0117; MOL.20001101.0118; MOL.20001101.0119; MOL.20001101.0120; MOL.20001101.0121; MOL.20001101.0122; MOL.20001101.0123; MOL.20001101.0124; MOL.20001101.0125; MOL.20001101.0126; MOL.20001101.0127; MOL.20001101.0128. DIRS 154597

Stamatakis, J.A.; Connor, C.B.; and Martin, R.H. 1997. "Quaternary Basin Evolution and Basaltic Volcanism of Crater Flat, Nevada, from Detailed Ground Magnetic Surveys of the Little Cones." *Journal of Geology*, 105, 319-330. Chicago, Illinois: University of Chicago. TIC: 245108. DIRS 138819

## **4.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES**

10 CFR 63. Energy: Disposal of High-level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.