	Model **Error Resolution Document** *Complete only applicable items.*	QA: QA Page 1 of 18

INITIATION

1. Originator:	2. Date:	3. ERD No.
Terry Crump/Cliff Howard	04-02-2008	MDL-MGR-GS-000005 ERD 01

4. Document Identifier:	5. Document Title:
MDL-MGR-GS-000005, Rev 02	Dike/Drift Interactions

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

The following evaluations/changes/corrections are posted to correct the conditions identified in CR-11589 and CR-6009. A justification for no impact to results or conclusions of MDL-MGR-GS-000005, Rev 02 is included. See attached for detailed responses to each CR and to the TBV resolution.

CONCURRENCE

	Printed Name	Signature	Date
7. Checker	Dwayne Kicker	[signature]	4/10/08
8. QCS/QA Reviewer	Sounia Kassabian Darnell	Sounia K. Darnell	4/10/2008

APPROVAL

9. Originator	Terry Crump/Cliff Howard	Terry R. Crump / Cliff Howard	4/10/08
10. Responsible Manager	Paul Dixon	Paul D	4-10-08

CR 11589 Evaluation

I. Background Information:

During the surveillance of three igneous activity technical products (Surveillance LQA-IS-08-008), the following data traceability and transparency, and code usage issues were associated with the analysis and modeling report (AMR) MDL-MGRGS-000005, Rev. 02, *Dike/Drift Interactions*. Generally, the issues can be separated into groups based by topic as follows: magma properties, thermal and mechanical properties of the host rock including Drift Degradation Model inputs and outputs, reference errors, and issues with use of codes FLAC3D v. 2.14, FLAC3D V. 2.1, and UDEC V. 3.1.

II. Disposition of major issues/Description of Change:

The following numbered and lettered items provide responses to each issue documented in CR 11589.

1. *The reference Detournay, E.; Mastin, L.G.; Pearson, J.R.A.; Rubin, A.M.; and Spera, F.J. 2003; Final Report of the Igneous Consequences Peer Review Panel, with Appendices [DIRS 169660] is used extensively in the AMR as direct input. The following issues associated with the use of this reference were identified:*

   (a) The Magma Density from Table-4-1 of the AMR is indicated as 751 to 2,282 kg/m^3 (Table 1-2 of the source is referenced). Magma density is not included in Table 1-2 of the source. Table 6-2 in the AMR indicates this range comes from Figure 2-1e of the source. Review of the source revealed this was correct. Table 4-1 of the AMR needs to be corrected. SCI-PRO-006, Attachment 2 requires that inputs be correctly identified and cited. Table 2-1e of the records copy of the source was mostly illegible. SCI-PRO-006, Section 6.2.1G requires that documentation be legible and in a form suitable for filing and retrieval.

   Response and AMR Changes:
   Magma density is not listed in Table 1-2 of Detournay et al (2003) [DIRS 169660]. The range of magma density is consistent with the range shown in Figure 2-1e, and the source for magma density is correctly shown in DIRS as Detournay et al 2003, Figure 2-1e. A legible copy of Figure 2-1e (Detournay et al (2003) [DIRS 169660]) has been obtained and submitted to the RPC (LLR.20080311.0099).

   Change the source for magma density in Table 4-1 to read: Detournay et al 2003 [DIRS 169660], Figure 2-1e.

   Impact Evaluation and Conclusion:
   Magma density variations might affect when the magma front arrives at the repository, but that time has no effect on the TSPA because of the assumptions that once intersection of the repository footprint occurs, all drifts are inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2).

(b) The Magma Viscosity parameter documented in Table 4-1 of the AMR shows a value range of 10 to 40 Pa-s citing Table 1-2 of the source. Table 1-2 of the source indicates a value range of 1 to 500 Pa-s with typical values of 50 Pa-s. This typical value is outside the range indicated in Table 4-1. However, Table 6-2 AMR indicates this range comes from Figure 2-1e of the source document. Review of Figure 2-1e of the source document revealed this may be correct but the figure values were mostly illegible. Table 4-1 should be corrected to reference Figure 2-1e of the source. SCI-PRO-006, Attachment 2 requires that inputs be correctly identified and cited. The referenced figure should be provided to records as a legible copy. Section 6.2.1G requires that documentation be legible and in a form suitable for filing and retrieval.

Response and AMR Changes:
A legible copy of Figure 2-1e (Detournay et al (2003) [DIRS 169660]) has been obtained and submitted to the RPC (LLR.20080311.0099).

Change the source for magma viscosity in Table 4-1 to read: Detournay et al 2003 [DIRS 169660], Figure 2-1e.

The value for magma viscosity in *Dike/Drift Interactions* (DDI) (SNL 2007 [DIRS 177430]) Table 4-1 is not the typical value provided in the *Igneous Consequences Peer Review Report* (ICPR) (Detournay et al (2003) [DIRS 169660] Table 1-2). The range in DDI Table 4-1 is consistent with the range indicated by arrows in ICPR Figure 2-1e. The values for parameters used in the analysis are explained in DDI Section 6.3.7.3 as follows: These parameters correspond to a value of the dimensionless parameter $\mathscr{D}= 6$, a width at infinity $w_\infty = 0.30$ m, and a fluid velocity at infinity $v_\infty = 1.5$ m/s. The parameter values are listed in DDI Table 6-12.

Impact Evaluation and Conclusion:
While magma viscosity variations could affect magma flow velocities into and within repository drifts, these variations have no effect on the TSPA because of the assumptions that once intersection of the repository footprint occurs, all drifts are inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2).

(c) It was unclear where the effective solidification temperature (950 C found on p. 6-143) was located in the source document. DIRS indicated this citation was from the Entire document. SCI-PRO-006, Section 6.2.1C requires that the information presented in the model documentation be traceable.

Response and AMR Changes:
The value of 950°C is described as "approximately the effective solidification temperature from Detournay et al (2003 [DIRS 169660])," but a description of "approximately the effective solidification temperature" was not found in the Detournay et al report or in Appendix 3 of the report. Based on information available in *Dike/Drift Interactions* (SNL 2007 [DIRS 177430], Section 6.4.8.2 and 6.5.1.1) the value of 950°C was developed based on information in DTN MO0411EG831811.002 and shown in Figure 6-147 and on analog information (SNL 2007 [DIRS 177430], Table 6-34). The value is in the lower part of the range of solidification

temperatures represented in Figure 6-147 and is less than the lowest solidification temperature shown in Table 6-34. The value is therefore, unlikely to underestimate the solidification temperature for a basaltic magma with a composition similar to that of Yucca Mountain region basalts.

Impact Evaluation and Conclusion:
The choice of the magma solidification temperature has no effect on the TSPA because of the assumptions that once intersection of the repository footprint occurs, all drifts are inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2). Since the assumption is that waste packages and drip shields fail when contacted by magma and not that they fail when the magma solidifies, the choice of the magma solidification temperature has no effect on TSPA. Similarly, magma solidification temperature has no effect on when seepage is re-established because seepage can only recur when temperatures are less than the boiling point of water, which is independent of the magma solidification temperature.

.

2. *DTN LA0612DK831811.001 is used as direct input to the AMR. In Appendix C of the AMR, the initial intrusive magma temperature is identified as 1150 C. Table 6-5 of the DTN shows liquidus temperatures ranging from 1169 to 1046 C, depending on water content (0 to 4 wt %) with the higher temperatures corresponding to the lower water content. 1150 C corresponds to an initial water content of between 0.5 and 1.0 wt %. The basis for choosing 1150 C as the representative value was not documented in the AMR, nor is it apparent from review of the DTN. SCI-PRO-006, Attachment 2 requires that the appropriateness of technical product inputs directly used to develop the model be documented and substantiated.*

   Response and AMR Changes:
   The 1150°C temperature is within the range of liquidus temperatures for hawaiites with 0-4 wt% H_2O (SNL 2007 [DIRS 174260], Table 7-1). The choice of the 1150°C temperature is consistent with water contents between 0.5 and 1 wt%, and therefore represents temperatures in the upper part of the range. The selected value is representative but avoids underestimating magma heating effects on EBS components and magma cooling time that might result from selecting a lower temperature for the analysis.

   Impact Evaluation and Conclusion:
   TSPA does not use the results of analyses of magma heating effects on EBS components nor is the potential for magma freezing considered as a mechanism to limit magma flow within and between emplacement drifts. Rather TSPA assumes that once intersection of the repository footprint occurs, all drifts are inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2). Magma temperatures are not needed to support the assumptions.

3. *DTN MO0408MWDDDMIO.002 is used as direct input to the AMR. The files, accessible through the DTN in the TDMS and referenced in Table 4-1 of the AMR, could not be opened due to their large sizes. This issue was identified previously in CR 11584. Refer to CR 11584 for disposition of this issue.*

4.

Response and AMR Changes:
This issue is identified in CR 11584 and has been dispositioned by the CR. CR 11584 does not impact the LA. No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
N/A

5. *DTN MO0407SPAMTSHR.000 is used as direct input to the AMR. Table 4-1 of the AMR indicates that this DTN provides data on thermal stresses induced by radioactive decay of waste as shown in Figures 6-4, 6-5, and 6-6. These figures reference output DTN SN0707ISITUTIS.001 rather than DTN MO0407SPAMTSHR.000. The data depicted in these figures were from MO0407SPAMTSHR.000. Reference citations should be corrected. SCI-PRO-006, Attachment 2 requires that inputs be correctly identified and cited.*

Response and AMR Changes:
The source for the data on thermal stresses is correctly listed in DIRS. However, the source referenced for *Dike/Drift Interactions* (DDI) (SNL 2007 [DIRS 177430]) Figures 6-4, 6-5, and 6-6 identifies output DTN SN0707ISITUTIS.001. As described in the Readme file for DTN SN0707ISITUTIS.001, the figures show plots of the output of the analysis. Input files for the regional thermo-mechanical model were extracted from DTN: MO0408MWDDDMIO.002 [DIRS 171483] and the calculations were rerun with FLAC3D V2.1 [STN 10502-2.1-00]. The stresses were extracted from the FLAC3D save files created during simulation of regional thermo-mechanical model.

Change the source for "Thermal Stresses Induced by Radioactive Decay of Waste" in Table 4-1 to read MO0408MWDDDMIO.002 [DIRS 171483], FLAC 3D Inputs & Outputs\TM model (folders Part_#1_Grid_Thermal and Part_#2_Mechanical). Remove DTN: MO0407SPAMTSHR.000 [DIRS 170679] from Section 9.4.

Impact Evaluation and Conclusion:
This was a typographical error and the corrected table completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

5. *DTN SN0307T0510902.003 is used as direct input to the AMR. Table 4-1 values range from 932 to 934 J/kg K while the values in the DTN range from 931 to 933 J/Kg K. Therefore, the values reported in the AMR are not the same values in the referenced DTN. SCI-PRO-006, Attachment 2 requires that data used as direct input to a model be correctly selected, identified in the model documentation, and incorporated.*

Response and AMR Changes:
The source for the values for Specific Heat Capacity of Solids is correctly listed in DIRS. Consistent with the source DTN, the values for Specific Heat Capacity of Solids listed in *Dike/Drift Interactions* (SNL 2007 [DIRS 177430) Table C-2) are considered to read as follows: Tptul 0.933, Tptpmn 0.931, Tptpll 0.932, and Tptpln 0.932, and the range of values for the parameter Specific Heat Capacity of Solids in Table 4-1 is read as 931 J $kg^{-1}K^{-1}$ to 933 J $kg^{-1}K^{-1}$.

Based on results in *Dike/Drift Interactions* (SNL 2007 [DIRS 177430) Table C-5, the effects on Peak Temperature and Variance of using a different range of values for specific heat capacity of solids are negligible. In fact, the analysis suggests that the principal source of uncertainty is the initial temperature (100% of the uncertainty) with none of the uncertainty attributable to the selection of values or ranges for the input parameters (SNL 2007 [DIRS 177430], Section C4). No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
The analysis shows that variations in key inputs other than initial temperature result in a shift in the time when the peak temperature occurs, but the actual peak temperature remains the same (SNL 2007 [DIRS 177430], Figure C-5). Figure C5 shows that the shift in the time when the peak temperature occurs is in the range of 1 to 3 years, which is too small a period to have an effect on the TSPA calculations for the intrusion modeling case.

6. *DTN SN0402T0503102.010 is used as direct input to the AMR. Table 4-1 and Table 6-28 of the AMR reports the heat capacity of the rock to be 985 J/kg K, referencing DTN SN0402T0503102.010 as the source. The DTN reports this value for some of the rock units, but it also reports values of 1040.1 and 1037.5 J/kg K for other rock units. The basis for establishing 985 J/kg K as the most representative value was not documented in the AMR. SCI-PRO-006, Attachment 2 requires that the appropriateness of model inputs be substantiated.*

Response and AMR Changes:
The heat capacity parameter is described in DTN SN0402T0503102.010 is for various units of the Geologic Framework Model not for magma. The analysis that uses the parameter is the flow of magma in drifts. It is possible that the choice of the value for heat capacity could affect heat loss calculations and eventually magma viscosity, which could affect magma flow distance, and possibly drift centerline and rib temperatures. *Dike/Drift Interactions* (SNL 2007 [DIRS 177430) Section 5.1 notes that the use of assumed values for various rock thermo-mechanical properties would not have a significant effect on model results. No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
Since TSPA assumes that once intersection of the repository footprint occurs, all drifts are immediately inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2), the choice of 985 J/kg K for heat capacity of the host rock has no practical effect on the analysis of repository performance.

7. *TDR-TDIP-ES-000010 [DIRS 179354] is used as a direct input to the AMR. Two issues associated with this source were identified:*

(a) Table 4-1 and Section 6.2.4 of the AMR specify a line load of 1450 W/m. Table 4-4, parameter 05-03 of the source specifies a maximum line load of 2000 W/m. Though 1450 W/m is under the maximum, it is unclear why that value was chosen based on the reference. SCI-PRO-006, Attachment 2 requires that the appropriateness of model inputs be substantiated.

Response and AMR Changes:
The analysis in Dike/Drift Interactions (SNL 2007 [DIRS 177430], Section 6.2.4 describes the thermal stresses induced in the host rock by radioactive decay of waste. While the analysis results show that thermal stresses are induced in the host rock and that such stresses could cause deflection of a rising dike (SNL 2007 [DIRS 177430], Section 6.3.7.4), no credit for the potential of heat-induced stresses to divert a dike is claimed. No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
In the analysis of dike intersection of the repository (SNL 2007 [DIRS 177432], Section 6.3.2), a rising dike that would intersect the repository in the absence of heat-induced stresses is tallied as an intersection. Since the dike intersection analysis does not consider the potential for dike diversion by thermal stress accumulation in the host rock, the value selected for the linear heat load has no effect on the dike intersection analyses. Furthermore, TSPA assumes that once intersection of the repository footprint occurs, all drifts are inundated by magma (SNL 2007 [DIRS 177432], Section 5.1) and all waste packages and drip shields fail when contacted by magma (SNL 2007 [DIRS 177430], Section 8.1.2).

(b) Table 4-1 also specifies a waste package thermal conductivity of 1.50 W/m K, referencing the same Table entry within this source. This value could not be readily traced to the source. SCI-PRO-006, Section 6.2.1C requires that direct inputs be traceable.

Response and AMR Changes:
The WP thermal conductivity value of 1.50 W/mK is listed in Table 2 of 800-IED-WIS0-00801-000-00B (BSC 2007 [DIRS 180449]). That source is identified in column 4, Parameter 05-03 of Table 4-4, Emplacement and Retrieval Requirements (SNL 2007 [DIRS 170354]). The source information is correct. No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
N/A

8. *Equations 6-1 and 6-2 in Section 6.2.3 of the AMR could not be verified against the source (Jaeger and Cook, 1979 Section 10.4 [DIRS 106219]) SCI-PRO-006 requires that equations be justified and described with regard to source and application.*

Response and AMR Changes:
The equations in question appear to be simplifications of equations in the Appendix to Aadnoy and Chenevert 1987 [DIRS 178340]. The equations are again described in Section 6.5.1.3.1 (SNL 2007 [DIRS 177430], the source for the equations is correct in Section 6.5.1.3.1. Change the reference in Section 6.2.3 for equations 6-1 and 6-2 to read as: Aadnoy and Chenevert 1987 [DIRS 178340].

The equations in question are not used in any of the calculations described in Section 6.2.3. Rather, the equations provide the analytical basis for the statements in the last paragraph: Stress changes from the drift excavation are of limited spatial extent and decay quickly into the pillars separating drifts as a function of distance from the drift wall. The stress becomes almost equal to unperturbed, far-field stress state at a distance of three drift radii from the drift wall.

Repository stresses will have an insignificant effect on dike propagation (SNL 2007 [DIRS 177430], Section 6.2.3).

Impact Evaluation and Conclusion:
The dike propagation model does not consider any focusing of dike trajectory by the altered stress field, but rather assumes that a dike rising from the mantle or deep crust continues rising along its original trajectory.

9. *DTN SN0705DRFTTEMP.001 was identified in Section 7 of the AMR as an output DTN documenting model validation results. It included DTNs LA0702PADE01EG.001 and MO0705FREEZING.000 as sources (inputs to model validation). The same DTNs, DTNs LA0702PADE01EG.001 and MO0705FREEZING.000, were output DTNs from the AMR that used Table 4-1 direct inputs (i.e., these DTNs used inputs from Table 4-1; e.g., SN0307T0510902.003). Therefore, it could not be verified that inputs used for the model were not also used for validation. SCI-PRO-006, Section 6.3.2 requires that data used for model validation shall not be used for model development.*

Response and AMR Changes:
The only references to DTN SN0705DRFTTEMP.001 found in MDL-MGR-GS-000005, Rev 02 [DIRS 177430] occurred in Sections 8.2.1 and 9.5. The description of outputs in Section 8.2.1 clearly states "In addition to the output DTNs listed in this table [8-1], the results of model validation have been submitted to the Technical Data Management System separately (DTNs: MO0408EG831811.000 and SN0705DRFTTEMP.001)."

The description in Section 7.3.2.1 (SNL 2007 [DIRS 177430] states "The magma cooling and solidification model component is corroborated by comparison with alternative analytical solutions…" The description in Section 7.3.2.1.1 (SNL 2007 [DIRS 177430] states "The model ***results*** [emphasis added] for magma cooling and solidification described in Section 6.4.6 are compared in this section with the results of two alternative models." The corroboration/validation exercise consisted of comparison of the model results (SNL 2007 [DIRS 177430], Section 6.4.6) with the results of Excel spreadsheet computations that used assumed values for thermal properties DTN: LA0307EG831811.001). Hence, the model run did not use the same inputs as the validation exercise. No changes to the AMR are necessary.

Impact Evaluation and Conclusion:
N/A

10. *The rationale for not using the alternative model (submodel) described in Section 6.4.7 was not described in the AMR. Such discussion is required by SCI-PRO-006, Attachment 2.*

Response and AMR Changes:
The rationale was provided as part of the development of the *Dike/Drift Interactions* TDIP (SNL 2007 [DIRS 180635]). The 2D analysis resulted in temperatures for the crown of the drift that are greater than, but not significantly different from, those of the 1D model, nor are any of the temperatures for the "cold" waste package case. But temperatures for the invert and

the waste package in the "hot" waste package case are 150°C to 400°C higher with the 2D model, and they stay higher for at least 30 years. No change to the model report is necessary.

Impact Evaluation and Conclusion:
The decision was to use the 1D results for TSPA to allow restoration of seepage into drifts (and resulting radionculide transport from the EBS) at the earliest possible time for the intrusion modeling case.

11. *Table 6-2 of the AMR, as well as other parts of the document, express units of density as "kg m^3". The correct units are: "kg/m^3". Other instances where this error occurs include figures on pages 6-15, 6-34, 6-38, 6-40, 6-41, 6-42, 6-43, 6-44, 6-46, 6-47, 6-48, 6-50, 6-51, 6-52, 6-81, 6-90, 6-108, 6-109, 6-117, 6-118, 6-137, 6-199, 6-202, 6-219, 6-237, 6-233, 6-244, 7-5, 7-10, 7-11, 7-12, 7-15, 8-1; Tables 1-1, 6-2, 6-3, 6-4, 6-5, 6-7, 6-9, 6-11, 6-12, 6-26, 6-33, C-2, and C-3. SCI-PRO-006, Attachment 2 requires that proper units be specified.*

Response and AMR Changes:
Replace every appearance of the density unit "kg m^3" in figures, tables, or text by "kg/m^3". Also, note that "kg/m^3" appears in text as kg m^{-3} and that is also correct.

Impact Evaluation and Conclusion:
This was a typographical error and the corrected text completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

12. *The text in Section 6.3.3.4.1 of the AMR states that when the Reynolds Number exceeds the laminar flow criterion, it is shaded and italicized in Table 6-3 (p. 6-39). However, no such identification (shading and italics) is made in the table. SCI-PRO-006, Section 6.2.1C requires that model documentation be transparent.*

Response and AMR Changes:
A replacement table with shading and font styles as described in the text of the report has been included in the ERD. This Table replaces Table 6-3 of the main model report.

Table 6-3. Independent and Derived Parameters for Base-Case Simulations

Independent Parameters					**Derived Parameters**				
$\mathcal{D}$	v_∞ (m/s)	μ (Pa·s)	κ	$\kappa\rho_r$ (kg m^3)	ρ_f (kg m^3)	$\kappa\rho_r - \rho_f$ (kg m^3)	w_∞ (m)	q_∞ (m^2/s)	Reynolds number
2.67	15	10	1.0	2,400	1,501	899	0.452	6.78	1,018
2.67	10	10	1.0	2,400	1,501	899	0.369	3.69	554
2.67	5	10	1.0	2,400	1,501	899	0.261	1.30	196
2.67	1	10	1.0	2,400	1,501	899	0.117	0.12	18
6.02	15	10	1.0	2,400	2,001	399	0.678	10.18	2,035
6.02	10	10	1.0	2,400	2,001	399	0.554	5.54	1,109
6.02	5	10	1.0	2,400	2,001	399	0.392	1.96	392
6.02	1	10	1.0	2,400	2,001	399	0.175	0.18	35

Independent Parameters					Derived Parameters				
$\mathscr{D}$	v_∞ (m/s)	μ (Pa·s)	κ	$\kappa\rho_r$ (kg m^3)	ρ_f (kg m^3)	$\kappa\rho_r - \rho_f$ (kg m^3)	w_∞ (m)	q_∞ (m^2/s)	Reynolds number
20.28	15	10	1.0	2,400	2,282	118	1.245	18.68	*4,262*
20.28	10	10	1.0	2,400	2,282	118	1.017	10.17	*2,321*
20.28	5	10	1.0	2,400	2,282	118	0.719	3.59	820
20.28	1	10	1.0	2,400	2,282	118	0.322	0.32	73
20.28	15	40	1.0	2,400	2,282	118	2.490	37.35	2,131
20.28	10	40	1.0	2,400	2,282	118	2.033	20.33	1,160
20.28	5	40	1.0	2,400	2,282	118	1.438	7.19	410
20.28	1	40	1.0	2,400	2,282	118	0.643	0.64	37
2.67	15	10	0.5	1,200	751	449	0.639	9.58	720
2.67	10	10	0.5	1,200	751	449	0.522	5.22	392
2.67	5	10	0.5	1,200	751	449	0.369	1.84	139
2.67	1	10	0.5	1,200	751	449	0.165	0.16	12
6.02	15	10	0.5	1,200	1,001	199	0.959	14.39	1,440
6.02	10	10	0.5	1,200	1,001	199	0.783	7.83	784
6.02	5	10	0.5	1,200	1,001	199	0.554	2.77	277
6.02	1	10	0.5	1,200	1,001	199	0.248	0.25	25
20.28	15	10	0.5	1,200	1,141	59	1.761	26.41	*3,014*
20.28	10	10	0.5	1,200	1,141	59	1.438	14.38	1,641
20.28	5	10	0.5	1,200	1,141	59	1.017	5.08	580
20.28	1	10	0.5	1,200	1,141	59	0.455	0.45	52
20.28	15	40	0.5	1,200	1,141	59	3.522	52.83	1,507
20.28	10	40	0.5	1,200	1,141	59	2.876	28.76	820
20.28	5	40	0.5	1,200	1,141	59	2.033	10.17	290
20.28	1	40	0.5	1,200	1,141	59	0.909	0.91	26

Source: For illustrative purposes only.

Note: Cells with shading and italics identify Reynolds number values greater than 2,200 (upper limit for laminar flow). Cells with shading only identify Reynolds number values within 10 percent of the upper limit for laminar flow.

Impact Evaluation and Conclusion:

This was a typographical error and the corrected table completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

13. *The last sentence on the page 6-61 states "One vertical layer of zones represents the dike, with magma flow into this layer simulated as explained in Section 6.4.2." No such explanation is found in Section 6.4.2. SCI-PRO-006, Section 6.2.1C requires that information in the model report be traceable.*

Response and AMR Changes:
The reference to Section 6.4.2 is clearly incorrect. The description in question occurs earlier in Section 6.3.3.5.6 in the subsection discussing Magma Flow Within the Dike.
The reference to Section 6.4.2 on page 6-61 should be Section 6.3.3.5.6.

Impact Evaluation and Conclusion:
This was a typographical error and the corrected section citation completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

14. *On page 6-70, reference is made in the third paragraph to Section 6.4.1 regarding atmospheric pressure in the drift. However, Section 6.4.1 does not make any reference to atmospheric pressure in the drift. The correct reference should have been Section 6.3.3.5.6. SCI-PRO-006, Section 6.2.1C requires that information in the model report be traceable.*

Response and AMR Changes:
As noted in the CR item, *Dike/Drift Interactions* (SNL 2007 [DIRS 177430], Section 6.3.3.5.6 discusses magma flow into drifts, and the reference to Section 6.4.1 is not correct. The reference to Section 6.4.1 on page 6-70 should be Section 6.3.3.5.6.

Impact Evaluation and Conclusion:
This was a typographical error and the corrected section citation completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

15. *On Page 6-76, the last sentence of the first paragraph of Section 6.3.3.5.7 states: "The amount going into the drift is taken to be the minimum of that calculated by the three equations described in Section 6.4.7.2." However, there are no equations in Section 6.4.7.2, neither is there any text pertaining to effusive flow. SCI-PRO-006, Section 6.2.1C requires that information in the model report be traceable.*

Response and AMR Changes:
Dike/Drift Interactions (SNL 2007 [DIRS 177430], Section 6.3.3.5.7 discusses analytical solutions for magma flow into drifts Reference is to DDI Rev 01. The reference to equations described in Section 6.4.7.2 is not correct; the descriptions of the equations occur in Section 6.4.7.1.2.

Change reference to Section 6.4.7.2 on page 6-76 to read: Section 6.3.3.5.7.

Impact Evaluation and Conclusion:
This was a typographical error and the corrected section citation completes the needed clarification. There is no impact to the results or conclusions of MDL-MGR-GS-000005 REV 02.

16. *FLAC3D V. 2.14 (STN 10502-2.14-00) was used in the AMR. This code was not on the software baseline. A software problem report (SPR012520070815) was issued to address a potential problem concerning a software validation method. This problem report was submitted and the software removed from the baseline on or about 8/15/07, prior to issuance of the AMR in September 2007. An impact assessment had not been performed at the time of the surveillance. Therefore, it appears that unqualified software was used. The AMR indicates this software was used for corroborative purposes. Use of unqualified software exclusively for corroborative purposes is permitted. However, the AMR also indicates that this version of the code was used to replace preliminary output using Version 2.1 of the code. It is unclear whether this preliminary output was also corroborative information. This should be clarified, especially since the SPR was concerned with the expanded range of validation for use of the code (i.e., the reason for V. 2.14 was to replace the preliminary output produced by V. 2.1 because V. 2.1 was used beyond its validated range, and V. 2.14 was to be qualified for this expanded range; the expanded range qualification resulted in the SPR). SCI-PRO-006, Section 6.2.1H requires that qualified software be used in model activities.*

Response and AMR Changes:
When the FLAC3D analyses were initially conducted, the software item was qualified and baselined. The software was subsequently removed from the baseline to address a potential software problem. A Software Problem Report (SPR012520070815) was completed on January 25, 2008, and the software item FLAC3D, V. 2.14 was returned back to the YMP baseline. An impact analysis showed no impacts in regards to the specified qualified software functions, performance, and intended use of the software item in support of the License Application.

FLAC3D V. 2.14 was used in analyses of vertical dike propagation, and regional stress effects, thermal effects from waste, geologic structure, and topographic effects on dike propagation, magma flow into drifts, and magma cooling analyses. Analysis results show that topographic effects are not sufficient to cause diversion of a rising dike (SNL 2007 [DIRS 177430], Section 8.1.1). Analysis results show that if magma were diverted into a high-angle fault, the effective stress-resisting fault slip would decrease, and slip could occur if the orientation of the fault relative to the regional stresses were favorable (SNL 2007 [DIRS 177430], Section 8.1.1), but geologic structures have no effects on dike propagation except for steep structures that occur at shallow depths (SNL 2007 [DIRS 177430], Section 8.1.1). Hence, no credit is claimed for effects of regional stress, geologic structure, or topography to deflect a dike. Results of similar analyses show that thermal stresses are induced in the host rock and that such stresses could cause deflection of a rising dike (SNL 2007 [DIRS 177430], Section 6.3.7.4); however, no credit for the potential of heat-induced stresses to divert a dike is claimed.

Impact Evaluation and Conclusion:
N/A

17. *Two baselined software codes were used outside their validation range to develop preliminary output from this model report: FLAC3D V. 2.1 (STN: 10502-2.1-00 [DIRS 161947]) and UDEC V. 3.1 (STN: 10173-3.1-00 [DIRS 161949]). These software codes were subsequently validated for the intended use and limitations as UDEC V. 3.14 (STN: 10173-3.14-00 [DIRS 172322]) and FLAC3D V. 2.14 (STN: 10502-2.14-00 [DIRS 172323]), as discussed in Table*

3.1 of the AMR. All products from this report were rerun, if originally *unvalidated, after validation was complete. SCI-PRO-006, Section 6.2.1L requires the following:*
"If the executable file of the baselined software has not changed from the preliminary version, then document the executable file comparison and update the status of output data from preliminary to final on the Technical Data Information Form (from TST-PRO-001) for the preliminary output DTN. If the executable file of the baselined software has changed from the preliminary version, perform the following:

1. *Repeat the work producing the preliminary output to produce final output with baselined software.*
2. *Make a comparison between the preliminary and final outputs*
3. *Document the comparison*
4. *Perform one of the following in accordance with TST-PRO-001*
   a. *Update the preliminary output to the final output and update the status from preliminary to final on the Technical Data Information Form of the preliminary output DTN.*
   b. *Supersede the DTN of the preliminary output with a new DTN containing the final.*
   c. *Initiate a new DTN for the final output, if necessary.*

It was not clear from the review of the AMR documentation that the required comparison was performed and that the required documentation was developed.

Response and AMR Changes:
The software item UDEC, V. 3.14 completed Lead Laboratory software configuration management (SCM) transfer installation and verification and validation process on February 15, 2008 with no problems. This activity confirmed the validity of the performance and functionality of the software items. The hardware key required for the testing has been returned back to the BSC SCM staff. An impact evaluation was completed for UDEC V 3.14, which showed that the Software Problem Report identified an administrative error rather than a technical problem with the code.

UDEC V 3.14 was used in the analyses of the potential for geologic structures to divert a rising dike, heat flow and magma cooling effects associated with magma flowing into and along drifts, and the potential for existence of over-pressure conditions associated with the development of secondary magma pathways. Analysis results show that if magma were diverted into a high-angle fault, the effective stress-resisting fault slip would decrease, and slip could occur if the orientation of the fault relative to the regional stresses were favorable (SNL 2007 [DIRS 177430], Section 8.1.1), but geologic structures have no effects on dike propagation except for steep structures that occur at shallow depths (SNL 2007 [DIRS 177430], Section 8.1.1). Analyses of heat flow and magma cooling produce the drift centerline and rib temperatures that are used in TSPA. The analyses include the thermal effects from emplaced waste (SNL 2007 [DIRS 177430], Section 8.2.2 and DTN: LA0702PADE01EG.001 [DIRS 179495]).

Results of the heat flow and magma cooling analysis are presented in Section 6.4.6 (SNL 2007 [DIRS 177430]), and the results of the analysis of effects of magmatic effects on waste packages and waste forms is presented in Section 6.4.8.3.5 (SNL 2007 [DIRS 177430]). Results of the analysis show that topographic and thermal stresses associated with emplaced waste would not produce diversion of a rising dike; so for purposes of subsequent analyses, a rising dike is considered to rise along the path created by the leading fracture (crack tip), and no diversion mechanisms are considered in the subsequent analyses. For TSPA, the heat flow and magma cooling analysis supports the assumption that once intersection of the repository occurs, all drifts are flooded with magma. The analysis results in a parameter named igneous EBS failure fraction (SNL 2007 [DIRS 177430], Section 8.2.3). The value of the failure fraction for drip shields and waste packages is 1, which means that these EBS components fail completely and the failure is assumed to occur upon contact by magma.

Impact Evaluation and Conclusion:
The heat flow and magma cooling analysis provides output in the form of a table of drift centerline and rib temperatures (SNL 2007 [DIRS 177430], Section 8.2.2), and the temperature table was developed in an analysis using MS EXCEL (this is exempt, commercial off-the-shelf software) (See Caveats, Limitations, Disclaimers, And Other Supporting Information section of DTN: MO0408EG831811.008 [DIRS 173078]). The table does not include output from UDEC V 3.14; so the use of the UDEC V 3.14 code has no effect on TSPA.

The analysis of the potential for development of secondary pathways concludes that even under the most favorable assumptions for growth, a subsidiary dike would not propagate effusively more than a few meters from the drift because the magma would be halted by solidification (SNL 2007 [DIRS 177430], Section 8.1.3) even if a pre-existing crack is present to serve as a potential pathway (SNL 2007 [DIRS 177430], Section 6.5.1.2). The analysis also concludes that the dike would continue to rise along the trajectory established by the crack tip. The analysis considers the potential for development of the appropriate over-pressure conditions using UDEC V 3.14, but the analysis concludes that secondary pathways to the surface could not be opened and sustained based on increases in viscosity associated with magma cooling and solidification.

Since the conclusion is based on the effects of magma cooling and solidification, the use of UDEC V 3.14 to estimate the over-pressure conditions that would be needed to open secondary pathways is moot, and that use has no effect on TSPA.

For the intrusion modeling case, TSPA assumes that

(1) once intersection of the repository occurs, all drifts are inundated with magma (SNL 2007 [DIRS 177432], Section 5.1)
(2) all waste packages and drip shields are contacted by magma fail (SNL 2008 [DIRS 178871], Section 5.3.1) and are damaged to the extent that no protection is provided for the waste from contact by percolation through the cooled basalt once seepage into drifts is restored (SNL 2007 [DIRS 177430], Section 8.1.2)
(3) waste and cladding are instantaneously degraded (SNL 2008 [DIRS 178871], Section 6.5).

Because of these assumptions, variations in parameter values associated with magma properties and thermal and mechanical properties of the host rock, reference errors, and issues with use of codes FLAC3D v. 2.14, FLAC3D V. 2.1, and UDEC V. 3.1 have no effect on the TSPA.

III. Inputs and/or Software
There is no change to the input values or to the software.

CR 6009 Evaluation

I. Background Information

CR 6009 - *During a recent review of some sections of MDL-MGR-GS-000005 Rev 01, Dike Drift Interactions, several issues related to lack of traceability to input sources and inconsistencies within the AMR were identified.*
In Dike/Drift Interactions Rev01, Section 6.4.8.2, p. 6-106 to 6-107, the diameter of a waste package is used as input to an analysis of the movement of waste packages by magma. This value (1.5 m) is not listed in Section 4 and its source is not identified.

II. Response and AMR Changes:

1) Editorial correction. Section 1.4.4, last line on page 1-10:
Change SNL 2007 [DIRS 177432], Section 8 to SNL 2007 [DIRS 177432], Section 7

2) Add the following paragraph to Section 4.1.2 of the MDL-MGR-GS-000005, REV 02:

"The development of the analysis of the potential for movement of waste packages by magma (Section 6.4.8.3.2) was completed based on preliminary design concepts for the EBS components. The assumed values are compared to the design values in Appendix I, Table I-1. Impact assessments are also provided in Table I-1."

3) Section 6.4.8.3.2, 2nd paragraph, 3rd line. Change the source for the range of waste package density from (BSC 2004 [DIRS 177432]) **to** (Assumption 5.4 and Appendix I).

4) Table I-1 "Parameter Values Used in Numerical Simulations Compared with Design Values" on page I-3, 4th and 5th rows. Change to read:

<table>
<tr><td rowspan="2">Homogenized Density of Loaded Waste Package (kg m^{-3})</td><td>6.4.7.2</td><td>3,470</td><td rowspan="2">4,546</td><td rowspan="2">Values used range from 65% to 94% of the design value. This will result in lower maximum temperature than calculated, but longer cooling times.</td></tr>
<tr><td>6.4.8.3.2</td><td>2,940 to 4,280</td></tr>
<tr><td rowspan="2">Waste Package Diameter (m)</td><td>6.4.7.2.1</td><td>1.72</td><td rowspan="2">Various</td><td>Slight variations in peak temperatures</td></tr>
<tr><td>6.4.8.3.2</td><td>1.5</td><td>Slight variations in buoyant forces and surface area</td></tr>
</table>

III. Impact Evaluation and Conclusion:

The difference in the assumed value of 1.5 m for the waste package diameter and the design value results in slight variations in buoyant forces and surface area, which do not impact the analysis of the potential movement of waste packages by magma (Section 6.4.8.3.2 of the model report MDL-MGR-GS-000005 REV 02).

IV. Inputs and/or Software

There is no change to the input values or to the software.

Note: Additional typographical errors have been found and are included in this ERD as a correction to the model report MDL-MGR-GS-000005 REV 02.

Section 6.7 is cited in a few locations. Change "Section 6.7" to read:

- p. xxiv: in the caption for Table 7-6, change "Section 6.7" to "Appendix C"
- p. 2-2: change "Section 6.7" to "Section 6.6"
- p. 7-21: change "Section 6.7.1.1.1" to "Appendix C"
- p. 7-22: at two locations, change "Section 6.7" to "Appendix C"
- p. 7-22: in the caption for Table 7-6, change "Section 6.7" to "Appendix C"
- p. 7-26: change "Section 6.7" to "Appendix C".

General Note: The resolutions described herein are for the purpose of mitigating the conditions contained in the identified Condition Reports. They are hereby conveyed by this ERD, as a means to notify all users of MDL-MGR-GS-000005 REV 02, of additional data or information that augments the report and should be considered, by way of explanation, part of the report.

List of Documents Evaluated for Impact of MDL-MGR-GS-000005 ERD 01		
Document	**Information Used**	**Impact**
ANL-WIS-MD-000024 Rev. 01 POSTCLOSURE NUCLEAR SAFETY DESIGN BASES	Section 6.7. Following an unlikely magma intrusion into the repository, it is possible that the water chemistry in the emplacement drifts will be altered by basalt-water interactions	No impact. The information describes a possible process that could occur following cooling of an intrusion into the repository not water chemistry parameter values. The basalt-water chemistry description in MDL-MGR-GS-000005 Rev 02 is based on reviews of published information. The basalt-water chemistry abstraction used in TSPA is developed in *In-Package Chemistry Abstraction* [DIRS 180506].
ANL-EBS-NU-000009 Rev. 00 COMMERCIAL SPENT NUCLEAR FUEL IGNEOUS SCENARIO CRITICALITY EVALUATION	Section 6.4.8.3. Soluble UO_2 dissolved in basalt.	No impact. ERD was completed on ANL-EBS-NU-000009 Rev. 00, which included qualifying the original source for the amount of soluble UO_2 dissolved in basalt.
ANL-WIS-MD-000027 Rev. 00 FEATURES, EVENTS, AND PROCESSES FOR THE TOTAL SYSTEM PERFORMANCE ASSESSMENT: ANALYSES	Section 8.1.2. Damage to a waste package caused by magma intrusion is extensive, compromising the durability and shape of the entire waste package. Magma intrusion also represents a corrosive environment, and rapid corrosion of the waste package occurs.	No impact. The information describes the extent of damage to waste packages caused by contact with magma. The consequences analysis for magma waste package interactions is based on an assumption that following intersection of the repository footprint occurs, all drifts are flooded by magma, and all waste packages fail as a result of contact by magma (SNL 2007 [DIRS 177432], Section 5.1).
	Section 6.4.6; Figure 6-94. The temperature of the waste package, the canister internals, and the SNF will heat up to near magma temperatures in days to weeks exceeding 700°C for one to nineteen months, depending on the temperature of the magma and the radioactive decay heat generated by the waste	No impact. The information describes the extent of damage to waste packages caused by contact with magma. The consequences analysis for magma waste package interactions is based on an assumption that following intersection of the repository footprint occurs, all drifts are flooded by magma, and all waste packages fail as a result of contact by magma (SNL 2007 [DIRS 177432], Section 5.1).

List of Documents Evaluated for Impact of MDL-MGR-GS-000005 ERD 01		
Document	**Information Used**	**Impact**
	Figures 6-98, 6-99. Simple conduction-only cooling model	No impact. Information used is a description of the cooling model.
	Section 6.4.8.3. It is expected that an igneous intrusion would sufficiently compromise the integrity of the waste packages, drip shields, and cladding in affected emplacement drifts to make them ineffective (i.e., a total loss of function in isolating waste packages and waste forms from seepage water when it returns after drifts have cooled)	No impact. The information describes the extent of damage to waste packages caused by contact with magma. The description is consistent with the WP damage abstraction (assumption) used in TSPA (SNL 2007 [DIRS 177432], Section 5.1).
	Section 6.4.8.3. The physical and chemical environment around the waste package and waste form materials in contact with active magma will include abundant steam and other potentially corrosive or reactive volatiles.	No impact. The information describes the in-drift environmental conditions that would accompany intersection of the repository by a basalt dike. The description is consistent with the WP damage abstraction (assumption) used in TSPA (SNL 2007 [DIRS 177432], Section 5.1).