BSC

Model Administrative Change Notice

Complete only applicable items.

QA: QA

1. Document Number:	MDL-NBS-HS-000015	2. Revision:	02	3. ACN:	01
4. Title:	DRIFT-SCALE COUPLED PROCESSES (DST AND TH SEEPAGE) MODELS				
5. No. of Pages Attached	10				

6. Approvals:

Preparer:	Sumit Mukhopadhyay [signature] Print name and sign	10/17/2005 Date
Checker:	Bruce Kirstein [signature] Print name and sign	10/18/2005 Date
QER:	Darrell Svalstad [signature] Print name and sign	10/18/2005 Date
Independent Technical Reviewer:	Rob Howard [signature] Print name and sign	19Oct05 Date
Responsible Manager:	Ernest Hardin [signature] Print name and sign	11/16/05 Date

7. Affected Pages	8. Description of Change:
2-1	Citation update (Correct DIRS as appropriate) Replace citation, change: (BSC 2004 [DIRS 168361]) to (BSC 2005 [DIRS 175539]) This was identified in CR 6024 (item 4).
4-18	Corrected typographical error in section number Table 4.1-2, footnote b, replace section number in citation, change: Section 6.2.1.1.3. to Section 5 (Assumption 4). This error was identified in CR 6024 (item 2).
5-2	Added clarification Section 5, Assumption 4, 3rd paragraph, change: matrix thermal conductivity with the fracture to matrix thermal conductivity (not bulk thermal conductivity) with the fracture This was identified in CR 6024 (item 1).

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5-2	Corrected typographical errors in values Section 5, Assumption 4, replace values of the yield, change: yield 0.0018 W/m/K (=1.89 x 9.6 x 10^{-3} x 0.1) to yield 0.00199 W/m/K (=2.0701 x 9.6 x 10^{-3} x 0.1) This error was identified in CR 6024 (item 1).
5-2	Added clarification (Correct DIRS as appropriate) Section 5, Assumption 4, add source for value of 2.0701, change: yield 0.00199 W/m/K (=2.0701 x 9.6 x 10^{-3} x 0.1; see Table 4.1-2 to yield 0.00199 W/m/K (=2.0701 x 9.6 x 10^{-3} x 0.1; see DTN: LB0210THRMLPRP.001 [DIRS 160799] for the wet matrix thermal conductivity and Table 4.1-2 This error was identified in CR 6024 (item 1).
5-2	Corrected typographical error in a value Section 5, Assumption 4, replace value of the thermal conductivity, change: 1.891 W/m/K to 1.889 W/m/K This error was identified in CR 6024 (item 1).
5-2	Corrected typographical error Section 5, Assumption 4, "matrix" thermal conductivity, change: matrix thermal conductivity, to bulk thermal conductivity, This error was identified in CR 6024 (item 1).
5-3	Corrected typographical error in section number Section 5, Assumption 4, last paragraph, change: Section 6.2.4.3 to Section 6.2.4.2.4 This error was identified in CR 6024 (item 3).

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5-3	Added clarification Section 5, Assumption 4, last paragraph, change: various to two different This was identified in CR 6024 (item 3).
6-102	Corrected typographical errors in value Section 6.2.4.2.4 values of the thermal conductivity, change (note this occurs twice in section 6.2.4.2.4): 0.0018 W/m/K to 0.00199 W/m/K This error was identified in CR 6024 (item 1).
6-102	Added clarification Section 6.2.4.2.4 added section number for clarification: (see Assumption 4) to (see Section 5, Assumption 4)
9-4 & 9-5	Citation update (Correct DIRS as appropriate) Replace citation, change: DIRS 168361 BSC 2004. *Q-List.* 000-30R-MGR0-00500-000-000 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040721.0007. (on page 9-4) to DIRS 175539 BSC (Bechtel SAIC Company) 2005. *Q-List.* 000-30R-MGR0-00500-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050929.0008. (on page 9-5) This was identified in CR 6024 (item 4).

2. QUALITY ASSURANCE

Development of this report on drift-scale TH processes and the supporting modeling activities have been determined to be subject to the Yucca Mountain Project's quality assurance (QA) program as documented in the technical work plan (TWP) (BSC 2004 [DIRS 170236], Section 8.1, Work Package ARTM02). Approved QA procedures identified in Section 4 of the TWP (BSC 2004 [DIRS 170236]) have been used to conduct and document the activities described in this report. Electronic management of information was evaluated in accordance with AP-SV.1Q, *Control of the Electronic Management of Information*, and controlled under YMP-LBNL-QIP-SV.0, *Management of YMP-LBNL Electronic Data*, as planned in the TWP (BSC 2004 [DIRS 170236], Section 8.4).

This report examines the properties of natural barriers that are classified in the *Q-List* (BSC 2005 [DIRS 175539]) as "Safety Category" because they are important to waste isolation, as defined in AP-2.22Q, *Classification Analyses and Maintenance of the Q-List*. The report contributes to the analysis and modeling data used to support performance assessment (PA). The conclusions of this report do not affect the repository design or engineered features important to safety, as defined in AP-2.22Q.

Table 4.1-2. Summary of Hydrological and Thermal Properties of Geologic Units Tptpul, Tptpmn, and Tptpll (Continued)

		DS/AFM-UZ02-Mean				DKM-TT99 (Sensitivity Case)			
	Geol. Unit >	***Tptpul (tsw33)***	***Tptpmn (tsw34)***	***Tptpll (tsw35)***	**Source**	***Tptpul (tsw33)***	***Tptpmn (tsw34)***	***Tptpll (tsw35)***	**Source**
FRACTURE DATA[b]									
Permeability	k_f (m^2)	7.8E-13	3.3E-13	9.1E-13	LB0208UZDSCPMI.002 [DIRS 161243][c]	6.353E-13	1.00E-13	1.87E-12	BSC 2001 [DIRS 157330], Table 5
Porosity	f_f (-)	5.8E-3	8.5E-3	9.6E-3	LB0205REVUZPRP.001 [DIRS 159525]	0.171E-3	0.263E-3	0.329E-3	BSC 2001 [DIRS 157330], Table 5
van Genuchten α	α_f (1/Pa)	1.59E-3	1.04E-4	1.02E-4	LB0208UZDSCPMI.002 [DIRS 161243][c]	1.57E-4	9.73E-5	1.66E-5	BSC 2001 [DIRS 157330], Table 5
van Genuchten m (or λ)	m_f (-)	0.633	0.633	0.633	LB0208UZDSCPMI.002 [DIRS 161243][c]	0.492	0.492	0.492	BSC 2001 [DIRS 157330], Table 5
Residual saturation	S_{lrf} (-)	0.01	0.01	0.01	LB0208UZDSCPMI.002 [DIRS 161243][c]	0.01	0.01	0.01	BSC 2001 [DIRS 157330], Table 5
Effective Tortuosity	τ (-)	0.0041[d]	0.0060[d]	0.0067[d]	de Marsily 1986 [DIRS 100439], p. 233	0.2[e]	0.2[e]	0.2[e]	de Marsily 1986 [DIRS 100439], p. 233
AFM coefficient	γ (-)	0.60	0.57	0.57	LB0208UZDSCPMI.002 [DIRS 161243][c]	N/A	N/A	N/A	(AFM not applied)

[a] The tsw33, tsw34, and tsw35 units are referred to in the source document (DTN: LB0208UZDSCPMI.002 [DIRS 161243]) as tswM3, tswM4, and tswM5, respectively.
[b] Fracture thermal properties are calculated from matrix thermal properties as discussed in Section 5 (Assumption 4).
[c] The tsw33, tsw34, and tsw35 units are referred to in the source document (DTN: LB0208UZDSCPMI.002 [DIRS 161243]) as tswF3, tswF4, and tswF5, respectively.
[d] Fracture tortuosity of 0.7 is multiplied by fracture porosity to arrive at effective tortuosity factor for the fracture continuum.
[e] In the DKM-99 sensitivity case, effective tortuosity is set to 0.2 in order to be consistent with previous simulations.

3. The TH seepage model does not account for specific emplacement sequencing of waste forms with different decay heat characteristics. Rather, it is assumed that emplacement occurs all at once, followed by a preclosure period of 50 years, during which a large fraction of the decay heat is removed by ventilation (Section 6.2).

   Basis:
   Waste sequencing effects and generated heat differences between individual waste packages will give rise to heterogeneity in the drift-scale temperatures. The sensitivity studies (see Sections 6.2.2, 6.2.3, and 6.2.4.2) presented in this report give rise to both boiling and nonboiling TH conditions that more than adequately cover the range resulting from the temperature heterogeneity. This assumption is considered adequate and requires no further confirmation.

4. Since the volume of the fracture continuum is a small fraction of the matrix continuum, heat conduction occurs primarily through the matrix and, as a result, the model is not sensitive to the amount of heat conduction in fractures. Thermal conductivity of the fracture continuum is therefore assumed to be small compared to the thermal conductivity of the matrix continuum. This is done for both the TH seepage model and the DST TH model (Sections 6.2 and 7).

   Basis:
   Since the fractures are open channels, they do not have a grain thermal conductivity (as would be the case for the rock matrix) associated with them. The thermal conductivity of the fractures is therefore determined by the thermal conductivity of the fluid (either air or water) filling their open space. In the fractured tuff of Yucca Mountain, fractures are mostly air-filled. Air has negligible thermal conductivity compared to the rock matrix, and thus heat conduction through the fractures can be safely ignored. However, for numerical simulation of TH processes with the TOUGH2 simulator (Pruess 1991 [DIRS 100413]), a thermal conductivity value for the fracture continuum is needed.

   In most simulation cases, the thermal conductivity of the fracture continuum is calculated by multiplying the matrix thermal conductivity (not bulk thermal conductivity) with the fracture porosity and then by reducing the product further by 0.1. The reduction by the factor 0.1 is to account for the limited spatial continuity and connectivity between fracture grid-blocks. The choice provides a reasonably small value for the thermal conductivity of the fracture continuum. For example, for the Tptpll (lower lithophysal) geological layer, this choice will yield 0.00199 W/m/K ($= 2.0701 \times 9.6 \times 10^{-3} \times 0.1$; see DTN: LB0210THRMLPRP.001 [DIRS 160799] for the wet matrix thermal conductivity and Table 4.1-2 for the fracture porosity of Tptpll or tsw35) as the thermal conductivity of the fracture continuum. This fracture thermal conductivity is about three orders of magnitude smaller than the bulk thermal conductivity (= 1.889 W/m/K; see Table 4.1-2) of the Tptpll geological layer.

   While most simulations were conducted with the above fracture continuum thermal conductivity, the TH simulations for the Tptpll submodel with heterogeneous permeability fields (LL-HET-01 and LL-HET-02; see Section 6.2.3) were performed with a slightly different method. For those simulations, fracture thermal conductivity was calculated by multiplying the thermal conductivity of air with the porosity of the fracture continuum. The adopted value of thermal conductivity of air is 0.03 W/m/K at 350K temperature (Perry et al. 1984 [DIRS 125806], p. 3-254, Table 3-314). For the Tptpll geological layer, this approach gives the fracture continuum thermal conductivity as 0.000288 W/m/K (= $0.03 \times 9.6 \times 10^{-3}$). This thermal conductivity value is about one-sixth the value of the Tptpll fracture thermal conductivity if the first approach was adopted. However, both values are small enough to have any significant impact on the TH results.

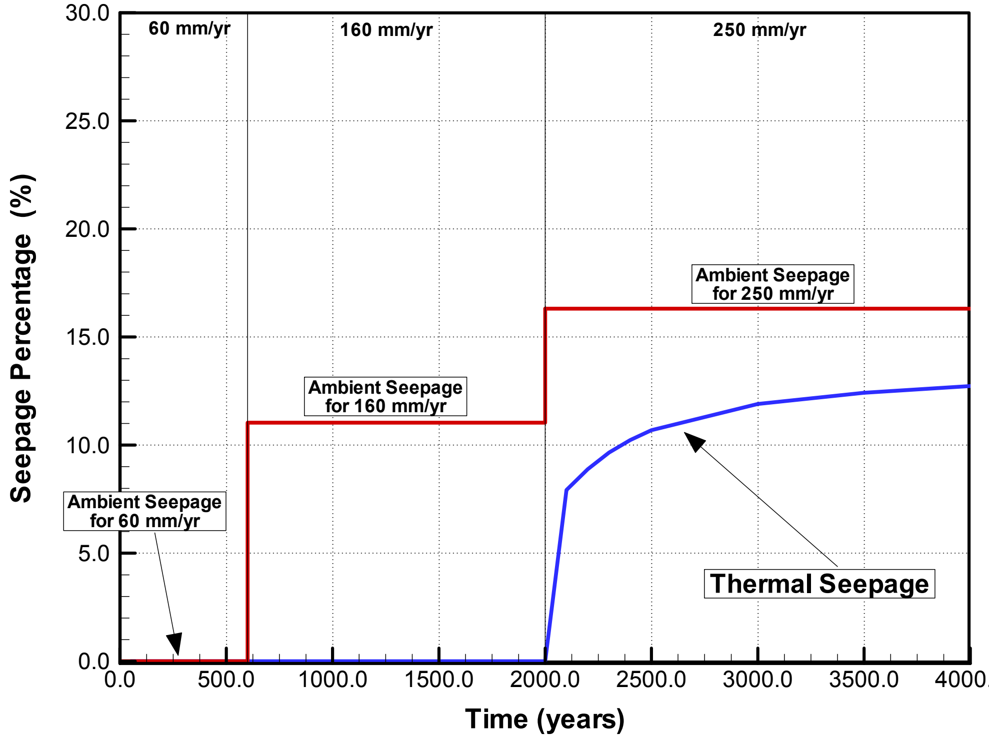
The thermal conductivity values for the fracture continuum selected in this model report are reasonable choices. In Section 6.2.4.2.4, sensitivity analyses with two different fracture continuum thermal conductivity values are presented. It will be established in Section 6.2.4.3 that the choice of fracture thermal conductivity has almost no impact on thermal seepage results presented in this model report. This assumption is considered adequate and requires no further confirmation.

5. Measured data from flow visualization experiments of Su et al. (1999 [DIRS 107846]) are used as input for the alternative conceptual model in Section 6.3. These experiments were conducted with transparent replicas of natural granite fractures from the Stripa Mine in Sweden. It is assumed that the flow characteristics observed in these experiments can serve as reasonable estimates for episodic preferential flow in unsaturated fractures at Yucca Mountain.

   Basis:
   Differences between fractures from Yucca Mountain and the Stripa Mine—with respect to aperture distributions, surface roughness, and contact angle—will bring out differences in flow behavior and distribution. However, this approach is valid for a qualitative analysis intended to demonstrate the impact of an alternative flow conceptualization on thermal seepage. The main phenomenological aspects of episodic preferential flow observed by Su et al. (1999 [DIRS 107846], Sections 2 and 3) should hold true for fractures of similar geometric characteristics, since local aperture variation is the main driver inducing episodic finger flow (see details in Section 6.3.1.2). This assumption is considered adequate and requires no further confirmation.

6. In collapsed drifts that are filled with rubble rock material, capillary diversion depends upon the difference in capillary strength ($1/\alpha$) between the interior of the drift and the rock surrounding the drift. The rubble material is assumed to have a capillary strength of rubble material about 100 Pa. This assumption is used in the thermal seepage predictions for collapsed drifts in Section 6.2.5. The chosen value is identical to the value used in the ambient seepage studies for collapsed drifts presented in *Seepage Model for PA Including Drift Collapse* (BSC 2004 [DIRS 167652], Section 5).

   Basis:
   The bulk porosity of the rubble material in the drift is much greater than the porosity of intact rock, because it includes large voids between chunks of fragmented rock. The chunks of fragmented rock are expected to have sizes on the order of centimeters



Output DTN: LB0301DSCPTHSM.002.

NOTE: The simulation case is MN-HET-10.

Figure 6.2.4.2-12. Seepage Percentage Tptpmn Submodel Using a Standard Dual-Permeability Method, Showing Results from Thermal Run and from Long-Term Ambient Runs

6.2.4.2.4 Sensitivity to Fracture Continuum Thermal Conductivity

It has been stated in Section 5 (Assumption 4) that the fracture continuum thermal conductivity for most of the thermal seepage simulations are assumed to be the product of thermal conductivity of the matrix continuum and the fracture continuum porosity, which is further reduced by the factor of 0.1. For example, this resulted in fracture thermal conductivity of 0.00199 W/m/K (see Section 5, Assumption 4). However, the heterogenous simulation runs for the Tptpll submodel (LL-HET-01 and LL-HET-02) have been performed with a different conceptual model for calculating fracture thermal conductivity. For these cases, fracture thermal conductivity is calculated as the product of thermal conductivity of air and the porosity of the fracture continuum. This resulted in, as an example, a fracture thermal conductivity of 0.000288 W/m/K for the tsw35 model layer. A sensitivity analysis (LL-HET-03; see Table 6.2.1.6-1) is carried out to demonstrate that this difference in fracture thermal conductivity does not impact the TH simulations at all. All aspects of the LL-HET-03 sensitivity simulation are identical to the LL-HET-01 run except for the changed fracture thermal conductivity (for example, the fracture thermal conductivity for tsw35 is 0.000288 W/m/K in LL-HET-01 and 0.00199 W/m/K in LL-HET-03). The flow multiplication factor applied for the sensitivity simulation is 5. Figure 6.2.4.2-13 shows a comparison of temperature at the drift crown with the two approaches adopted for calculating the fracture thermal conductivity. Figure 6.2.4.2-14 compares the fracture saturation for the two approaches. From Figures 6.2.4.2-13 and 6.2.4.2-14, it can be concluded

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