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BSC	**Model Administrative Change Notice** *Complete only applicable items.*	QA: QA Page 1 of 2

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7. Affected Pages	**8. Description of Change:**
6-15	Citation error: Last paragraph, 2nd sentence - Corrected erroneous DIRS citation from DIRS 169681 to DIRS 169861 This error was identified in CR 4434.
6-16	Citation error: 2nd paragraph, last sentence - Corrected erroneous DIRS citation from DIRS 169681 to DIRS 169861 This error was identified in CR 4434.
6-3	Citation Error In Section 6.1.2, 3rd paragraph, 3rd sentence: Change: "… documented in BSC (2004 [DIRS 170038], Tables 7 and 8)." To: "… documented in BSC (2004 [DIRS 170038], Tables 6-5 and 6-6)." This change is associated with TBV 6348.

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6-9	Text Clarification Section 6.1.5, 4th paragraph, first sentence currently states: *"In summary, because lateral flow is hypothesized to be insignificant above the repository and significant focusing infiltration near faults may not occur (Section 6.1.7), faults conduct only a small amount of water and are not considered to contribute significantly to the large-scale percolation pattern from the surface to the repository level."* This is being clarified to read: *"In summary, because significant focusing of infiltration near faults is assumed not to occur (Section 6.1.7), faults are not considered to contribute significantly to the large-scale percolation pattern from the surface to the repository level."* This is a self-identified change

Significant precipitation (and infiltration) occurs only every few years (Flint et al. 1996 [DIRS 100147], pp. 46–50). In these years, the amount of infiltration still varies greatly, depending on storm amplitudes, durations, or frequencies. In very wet years, infiltration pulses may infiltrate into Yucca Mountain during a relatively short time period. A more detailed discussion of infiltration at Yucca Mountain is documented in a report describing simulation of net infiltration for modern and potential future climates (BSC 2004 [DIRS 170007]).

6.1.2. Fracture and Matrix Flow Component

This subsection describes fracture and matrix flow component in various geologic layers (including the TCw, PTn, TSw and CHn) in the UZ.

As a result of the relatively high density of interconnected fractures and low matrix permeabilities in the TCw, infiltration pulses are expected to move rapidly through the fracture system with little attenuation (Bodvarsson et al. 1999 [DIRS 120055], p. 10). This is partially supported by pneumatic sensors in the TCw showing little attenuation of the barometric signal in monitoring boreholes compared with the barometric signal observed at the land surface (Rousseau et al. 1999 [DIRS 102097], p. 89). In this unit, the gas flow paths are considered to be similar to those of liquid water.

Once the unsaturated flow leaves the TCw and enters the PTn, totally different processes are evident. Because the PTn has relatively high matrix permeabilities and porosities, and low fracture densities, the predominant fracture flow in the TCw is expected to convert to dominant matrix flow within the PTn. The measured properties for the PTn and other units are documented in BSC (2004 [DIRS 170038], Tables 6-5 and 6-6). Pneumatic data are consistent with the notion that fracturing within the PTn is limited; the pneumatic signal is propagated predominantly through the high-storage matrix, leading to significant attenuation (Ahlers et al. 1999 [DIRS 109715], p. 49). Similarly, much of the water flow occurs in the relatively high-porosity matrix in this unit. As a result, the PTn greatly attenuates infiltration pulses such that liquid-water flow below the PTn is approximately in steady state. This interpretation is consistent with the results of a modeling study by Wang and Narasimhan (1993 [DIRS 106793], pp. 354–361).

The dominance of matrix flow in the PTn unit and the attenuation effects are supported by field tests conducted in the same unit. Salve et al. (2003 [DIRS 164470]) performed water release tests along a fault within the PTn unit. Water was released under constant-head conditions from a 0.3-m interval within a borehole that crosses the fault. A total of 193 L of water during seven distinct events was released over two weeks between October 21, 1998, and November 5, 1998. Between November 30, 1999, and December 2, 1999, an additional 136 L of water were introduced into the same interval during three distinct events lasting 4 to 7 hours (Salve et al. 2003 [DIRS 164470]). It was observed that during the first release test, the wetting front advanced slowly as a result of significant matrix imbibition. It was also found that water that imbibed into the matrix was retained for periods extending to at least a few months for the given test conditions. Based on these observations and considering that water release rates used in the tests were much larger than water percolation rates under ambient conditions, it is concluded that the dry porous PTn matrix is capable of attenuating episodic percolation fluxes in localized areas

6.1.5 Effects of Major Faults

Numerous strike-slip and normal faults with varying amounts of displacement exist at Yucca Mountain. It is important to understand how major faults affect the flow processes in the UZ at Yucca Mountain.

A fault can act as a fast-flow conduit for vertical liquid-water flow. In this case, transient liquid-water flow may occur within the fault as a result of temporally variable infiltration. Note that major faults cut through the PTn, and the damping effect of the PTn is significantly reduced. However, if occurring, this transient flow along the major faults is expected to carry only a small amount of water and may not be a significant liquid-flow mechanism for the UZ at Yucca Mountain, as will be discussed in Section 6.1.7. It is reasonable to assume that recharge through alluvial channels and the associated faults and other potential fast pathways above the repository is minimal compared to the overall recharge flux. Note that faults intercepting the perched water bodies below the repository, however, can correspond to significant vertical liquid-water flow (see Figure 6-4).

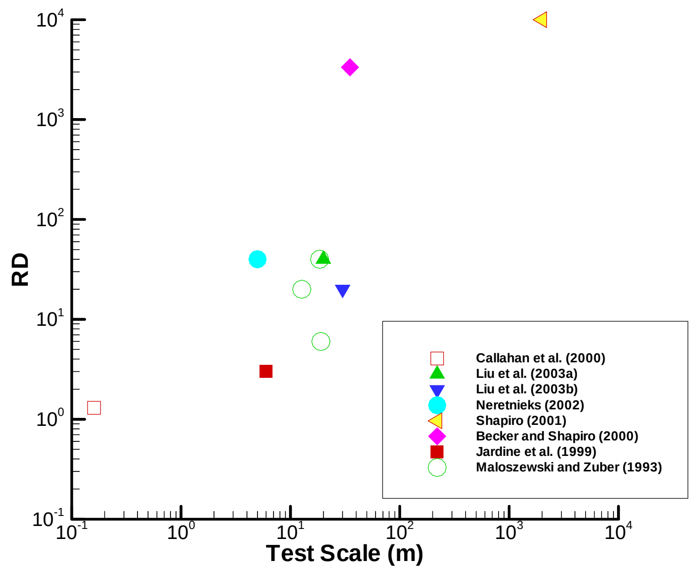
A fault can also act as a barrier for lateral liquid-water flow. Where a fault zone is highly fractured, the corresponding coarse openings will create a capillary barrier for lateral flow. Alternatively, a fault can displace the surrounding geologic units, such that a unit with low permeability faces one with relatively high permeability in a fault zone. In this case, the fault will act as a permeability barrier to the lateral flow within the units with relatively high permeability. Montazer and Wilson (1984 [DIRS 100161], p. 20) conceptualized that permeability would vary along faults, with higher permeability in the brittle, welded units and lower permeability in the nonwelded units where gouge or sealing material may be produced. Whereas a fault sealed with gouge or other fine-grained material would have much higher capillary suction, it will also have low permeability, retarding the movement of liquid water.

In summary, because significant focusing of infiltration near faults is assumed not to occur (Section 6.1.7), faults are not considered to contribute significantly to the large-scale percolation pattern from the surface to the repository level. Below the repository, low-permeability layers in the CHn channel some flow to faults acting as conduits to the water table.

6.1.6 Transient Flow

Flow in the UZ is time dependent or transient, mainly resulting from the temporal variation in the infiltration flux at the surface. The temporal variation of the infiltration may be approximated as occurring over short intervals characterized by changes in weather, resulting in episodic transient flows, or over much longer time periods corresponding to climate change.

However, as discussed in Section 6.1.2, the PTn greatly attenuates episodic infiltration pulses such that liquid-water flow below the PTn is considered to be approximately in steady state. This is supported by the modeling study of Wang and Narasimhan (1993 [DIRS 106793], pp. 354–361). The attenuation is a result of matrix flow in the PTn and the relatively large storage that mainly results from the relatively low matrix saturation in this unit. On the other hand, longer-term climate change has a more pronounced influence on flow pattern within the larger effective matrix-diffusion-coefficient value seems to be needed to match the data from the latter well, an indication of a possible increase in the coefficient with scale. Therefore, in Figure 6-6, the fitted effective matrix diffusion is considered to correspond to a test scale of 6 m only. Note that, as indicated by Jardine et al. (1999 [DIRS 169950]), their intentions were not to rigorously model all of the processes contributing to solute transport in the system, but, rather, to test the importance of matrix diffusion.



Source: Liu et al. 2004 [DIRS 169948], Figure 1.

Figure 6-6. Effective Matrix Diffusion Coefficient as a Function of Test Scale. RD Refers to the Effective Coefficient Value (Estimated from Field Data) Divided by the Corresponding Local Value

Neretnieks (2002 [DIRS 162140]) reported matches to tracer test data collected from the Äspö site with a test scale of 5 m and found a need for a factor 30 times larger for the fracture-matrix interface area (or effective matrix-diffusion coefficient) than expected. The increase in fracture-matrix interface area is equivalent to the increase in effective diffusion coefficient (for a given interface area in a model). He also indicated that nine other research groups had also independently evaluated the tracer test data from the site using different modeling approaches. Nearly all the groups found the need for a factor 30-50 times larger effective fracture-matrix interface area (or effective matrix-diffusion coefficient) than expected. In Figure 6-6, a representative RD value of 40 is used for the Äspö test site.

Liu et al. (2003 [DIRS 162470]) and BSC (2004 [DIRS 169861], Section 7.6) presented model analyses of two different field test data, collected in the UZ of Yucca Mountain. Unlike studies reported by other researchers mentioned in this subsection, Liu et al. (2003 [DIRS 162470]) and BSC (2004 [DIRS 169861], Section 7.6) matched both the flow field (characterized by water travel time and/or seepage into subsurface openings) and tracer breakthrough curves. They reported that increased fracture-matrix interface areas (or effective matrix diffusion coefficients) were needed for both tests. The data of Callahan et al. (2000 [DIRS 156648]) were also collected for the rock matrix in the UZ of Yucca Mountain.

Becker and Shapiro (2000 [DIRS 169947]) and Shapiro (2001 [DIRS 162132]) reported analyses of tracer test data from fractured crystalline rock at the Mirror Lake site. Becker and Shapiro (2000 [DIRS 169947]) showed that laboratory measurement of the effective diffusion coefficient should be replaced by the coefficient in free water (corresponding to RD = 3,333) to match the bromide data in their Test C with a test scale of about 36 m. However, they were not able to match all the breakthrough curves for different tracers, and argued that advective transport processes contribute to this discrepancy. An alternative explanation may be that a simple model used by those authors cannot capture all the importance processes (such as effects of subsurface heterogeneity), even when matrix diffusion is a dominant process. Nevertheless, the value of RD = 3,333 is included in Figure 6-6. Shapiro (2001 [DIRS 162132]) found that 3-5 orders of magnitude greater than the estimates of the matrix-diffusion coefficient from laboratory experiments were needed to match the tracer data observed at a kilometer scale. His analysis probably provides the first estimate for kilometer-scale effective diffusion coefficient. A representative value of Shapiro (2001 [DIRS 162132]) for RD (1.0E+4) is used in Figure 6-6. Figure 6-6 also includes analyses results of Maloszewski and Zuber (1993 [DIRS 101460]) for three different sites.

Although some uncertainties exist, the data shown in Figure 6-6 seem to strongly suggest that the effective matrix diffusion coefficient, like permeability and dispersivity, increases with test scale. A number of researchers have attempted to explain why the effective coefficient determined from field data is larger than the corresponding laboratory value (Shapiro 2001 [DIRS 162132]; Neretnieks 2002 [DIRS 162140]; Liu et al. 2003 [DIRS 162470]; BSC 2004 [DIRS 169861], Section 7.6).

Shapiro (2001 [DIRS 162132]) suggested that kilometer-scale "effective matrix diffusion" is not a diffusive process, but actually an advective process between high and low permeability zones, resulting in a significantly large "effective diffusion coefficient." While this may be a plausible explanation, further confirmation is still needed. For example, Liu et al. (2003 [DIRS 162470]; BSC 2004 [DIRS 169861], Section 7.6) used a dual-permeability model involving both fast flow in fractures and slow flow in the matrix (as well as the advective transport between the two) and still found the need to use increased effective diffusion coefficients for matching the tracer test data. Neretnieks (2002 [DIRS 162140]) argued that existence of fracture in-filling creates relatively large areas for solute to diffuse into rock matrix, which, together with the process of diffusion into stagnant water, contributes to the need for increasing the effective diffusion coefficient to match the data. Wu et al. (2001 [DIRS 156399]) and Liu et al. (2003 [DIRS 162470]) indicated that the existence of many small-scale fractures (which considerably increase the fracture-matrix interface area, but are not considered in numerical models) may be the major reason for the relatively large effective diffusion coefficient calculated from field data. While these suggested mechanisms seem to be reasonable for field-scale solute transport in fractured rock, they cannot be directly used to explain why the effective diffusion coefficient increases with test scale because they are not able to relate the effective matrix diffusion coefficient to the corresponding test scale.