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Hydrology and Earth System Sciences Discussions

Interactive comment on "Simple estimation of fastest preferential contaminant travel times in the unsaturated zone: application to Rainier Mesa and Shoshone Mountain, Nevada" *by* B. A. Ebel and J. R. Nimmo

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Please find below a 3rd anonymous referee report:

The authors utilize a very simple model termed the Source Responsive Preferential Flow (SRPF) model, originally proposed by Nimmo (2007), and apply this model for fastest travel time predictions for unsaturated zone transport of conservative radionuclides at Rainier and Shoshone Mountain, Nevada Test Site. The SRPF model is re-

liant on the presence of preferential flow and transport mechanisms, and assumes a constant maximum transport velocity over a defined infiltration duration, irrespective of medium type or transport distance. To apply the SRPF model to Shoshone Mountain and Rainier Mesa, underground tests were grouped according to infiltration source types: continuous or intermittent. Fastest transport times to the water table are then estimated from their simple model. The work contained in the manuscript does not provide further development nor validation for the SRPF model, and little if any information from the site – despite the length of the paper – are utilized in the fastest travel time predictions.

The authors mention multiple times in the manuscript that the value of the SRPF model lies in its simplicity, and that only minimal site characterization is needed. While I personally feel that simple models (with simple inputs) that have the ability of capturing relevant features of hydrological systems is a worthwhile pursuit in hydrology, as noted by *Sivapalan et al.* (2003); the SRPF method falls far short of this goal by heavily relying on layers of assumptions that are inconsistent with the known hydrological conditions at Rainier Mesa, particularly the assumption of unsaturated flow conditions. Thus, it is my assessment that the transport predictions presented in the manuscript, especially for the continuously ponded sources at Rainer Mesa, are not scientifically defensible.

A further detraction from the manuscript is the SRPF model only provides the time for a single molecule (or particle) to reach a designated location. I strongly argue that this metric provides little or no information to a regulatory agency, and in reality may be counterproductive, as alarmingly fast and unjustifiable radionuclide transport rates to the water table will most likely lead agency personnel and their public constituents to overreact. I should mention here that transport distances from the test cavities to the water table at Rainier Mesa often exceed 400 vertical meters, and the authors predict this to occur in just a one month!

It is well known that the transport of contaminants in geologic media will produce a broad distribution of arrival times, yet the SRPF model only addresses the arrival or breakthrough of a single molecule which in most cases, would not only be undetectable, but would not exceed the maximum contaminant level (MCL) for any contaminant that I am aware of. This leads me to ask the question: "Who is the intended audience of this manuscript?"

The most major violations of the SRPF conceptual model as applied to Rainier Mesa are discussed in detail below. I focus on radionuclide transport under ponded source conditions as these conditions produced the shortest maximum travel times in the manuscript.

1. **The volcanic tuffs below the test cavities for E-, N- and T-tunnel complexes are saturated.** Rainier Mesa has two distinct flow systems: a laterally extensive upper zone of saturation in the Tertiary volcanics at an elevation of approximately 1800 m amsl (ER-12-3 and ER-12-4 piezometers; wells: U-12M1 UG, U-12e.03-1, Hagestad #1, and many others) and a second zone of saturation mostly in the Paleozoic carbonates at an elevation of 1300 m amsl (ER-12-3 and ER-12-4 main completions) (*Thordarson*, 1965; *Fenelon et al.*, 2006). The test cavities at E-, N-, and T-tunnel are all located well below the upper zone of saturation at $\sim$1800 m. There have not been any dry wells drilled in the Tertiary volcanics below the upper zone of saturation. This is despite the fact that the average fracture spacing in these units is quite large, which is strong evidence that the water levels are independent on intercepting water-bearing fractures. Moreover, water level measurements collected from U-12M1 UG, U-12e.03-1, and Hagestad #1 during drilling indicate that the entire thickness of the volcanic sequence (over 300 meters), starting at Tn4 down to Tl is saturated. The only known evidence of unsaturated flow conditions below the E-, N- and T-tunnel complexes is a narrow unsaturated zone located at the contact of the base of the Tertiary volcanics and top of the Paleozoic carbonates detected during well drilling and hydrologic testing at ER-12-3 and ER-12-4 (SNJV, 2006a,b). The tunnel ponds associated with the E-, N- and T-tunnel complexes are unsaturated directly below, but this

zone of unsaturation is expected to be of limited extent given the evidence above.

These observations violate the number one assumption of the SRPF model – unsaturated flow.

(2) **Application of a non-site specific universal maximum velocity.** A single value for maximum velocity of 13 m/d, obtained using the geometric mean of the continuous source cases in presented *Nimmo* (2007), was deemed in the manuscript to provide a “universal” maximum velocity for all media types and transport scales. I strongly reject this premise as this maximum velocity was deterministically obtained from a limited number of tracer tests at other field sites in different media, and the order of magnitude of error about this mean value precludes any reasonable level of predictive certainty. The application of a constant maximum velocity is also dependent on the presence of continuous preferential flow pathways over very large transport distances (discussed below).

(3) **Lack of a proven, direct route for unsaturated preferential flow to water table.** The authors explain the SRPF model in a perspective that unsaturated preferential flow is expected to occur, perhaps through different mechanisms (persistent finger flow over large distances does seem very unlikely, so unsaturated fracture flow would be the dominant choice), but key details on the actual pathways from the test cavities down to the water table are neglected in the manuscript. For example, the zeolitized tuffs below E-, N- and T-tunnel complexes are sparsely fractured (nearly all fractures are small normal faults with relatively small or nonexistent damage zones) and poorly connected (*Thordarson*, 1965). So, unlike other large-scale tracer tests in *Nimmo* (2007) in fractured media consisting of intermediate or well connected fracture networks, Rainier Mesa is a very different site. The authors ignore this and maintain that there are interred pathways through the Mesa that yield a sustainable, maximum velocity of 13 m/d.

Rainier Mesa is a minimally extended terrain, and as such, many of the faults are not only closed to flow, but most likely do not persist from the tunnel cavities down to the water table and terminate at the argillic paleocolluvium at the base of the Tertiary sequence (*Thordarson*, 1965; NSTec Geologists, unpublished white paper on fault persistence). Only the largest faults are thought to extend down to the water table (NSTec Geologists, unpublished white paper on fault persistence), and the "conductiveness" of any fault planes passing through the argillic paleocolluvium remains an open question, rather than a known fact. *Thordarson* (1965) hypothesized that water-filled faults are closed at depth in the argillic paleocolluvium unit, and this is what enables these faults to remain saturated and not drain. *Thordarson* (1965) further states that the closure of faults at depths leads to an impedance (or retardation) of flow at depth, not a fast transport pathway as the authors suggest when try to justify their SRPF model. There have not been any fractures detected in cores collected from the argillic paleocolluvium unit. And, given the high clay content, any other forms of preferential flow through this unit appear unlikely.

My concern here is that only the largest faults *may* be open at depth but this is not known with any degree of certainty, and further questions the 1 month fastest travel time predictions based on the 13 m/d constant maximum velocity.

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