**SRR-CWDA-2014-00095**
**Revision 1**

# Saltstone Disposal Facility Sensitivity Modeling to Address Concerns Related to Saturated Zone Transport

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# ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| DOE | U.S. Department of Energy |
| EPA | U.S. Environmental Protection Agency |
| FY | Fiscal Year |
| MOP | Member of the Public |
| N/A | Not Applicable |
| NRC | U.S. Nuclear Regulatory Commission |
| PA | Performance Assessment |
| RAI | Request for Additional Information |
| SA | Special Analysis |
| SDF | Saltstone Disposal Facility |
| SDU | Saltstone Disposal Unit |
| SZ | Saturated Zone |

# 1.0 INTRODUCTION

The purpose of this report is to present results from sensitivity models that were developed to address concerns related to the transport of contaminants released from the Saltstone Disposal Facility (SDF) to the saturated zone (SZ).

## 1.1 History

Initial modeling of the SDF releases and transport were presented in the 2009 *Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site* (hereafter identified as the 2009 SDF PA). [SRR-CWDA-2009-00017] This modeling work was improved based upon new information in the *FY2013 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site* in October 2013 (hereafter identified as the FY2013 SDF SA). [SRR-CWDA-2013-00062] The U.S. Nuclear Regulatory Commission (NRC) reviewed the FY2013 SDF SA and provided the U.S. Department of Energy (DOE) with Requests for Additional Information (RAIs) in July 2014. [ML14148A153] Meanwhile, DOE initiated a second SA, the *FY2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site* (hereafter identified as the FY2014 SDF SA). [SRR-CWDA-2014-00006] The FY2014 SDF SA was developed to reflect a revised SDF layout that incorporates newly-designed 375-foot diameter Saltstone Disposal Units (SDUs). The FY2014 SDF SA was completed in September 2014.

## 1.2 Purpose

This report specifically addresses concerns raised by the NRC in two of the RAIs for the FY2013 SDF SA: FFT-1 and FFT-4. [ML14148A153] FFT-1 recommends that sensitivity analyses be developed to improve the understanding of affects for the assumed SZ thickness and the associated resulting dilution. FFT-4 requests that DOE provide a basis for the assumption that the vadose zone will be impacted by leachate from the cementitious materials for the duration of the assessment. The full text for these RAIs has been reproduced and is provided as Appendix A for convenience.

This report provides a series of sensitivity model results and analyses designed with the intent of addressing the concerns raised through these RAIs. The latest available SDF GoldSim Model, as described in the FY2014 SDF SA, was used as the basis for comparison. The FY2014 SDF SA provides a benchmarking analysis that demonstrates that the SDF GoldSim Model is an appropriate modeling abstraction for use in sensitivity modeling. [SRR-CWDA-2014-00006]

Section 2.0 provides an analysis to address FFT-1. Section 3.0 provides a discussion to address FFT-4.

# 2.0 RAI FFT-1 SENSITIVITY MODELING

The SDF GoldSim Model for the FY2014 SDF SA includes two parameters that are relevant to the concerns raised by the NRC via RAI FFT-1 (see Appendix A). The two relevant parameters are both used within GoldSim "plume functions" to model SZ transport from the footprint of the SDUs to a hypothetical 100-meter boundary. These parameters are: (1) SZ thickness, and (2) dispersivity.

The sensitivity modeling to address RAI FFT-1 shall be performed in two phases. In the first phase, the SZ thicknesses shall be modified. For the second phase, the dispersivity values will be modified and the SZ thickness will be reset to match the Evaluation Case value from the FY2014 SDF SA. All other parameters will be held at the same values as used in the Evaluation Case of the FY2014 SDF SA.

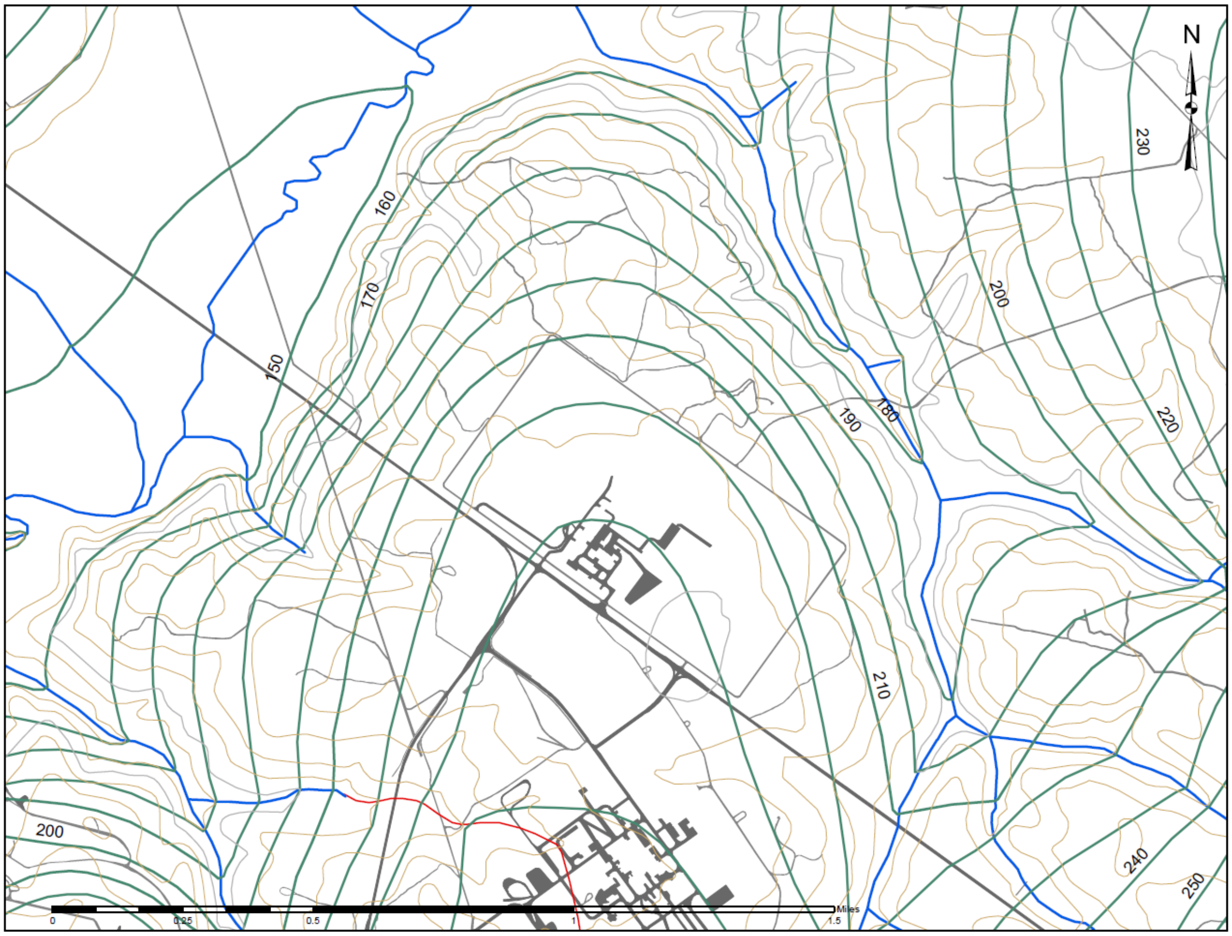
For each sensitivity study performed, the results shall be compared to the total dose to a hypothetical member of the public (MOP) at the 100-meter boundary of the SDF. For these comparisons, the Evaluation Case results shall be used, as determined by the SDF GoldSim Model from the FY2014 SDF SA. [SRR-CWDA-2014-00006]

## 2.1 Saturated Zone Thickness Variability Modeling

Values used for sensitivity modeling of SZ thickness variability were developed based on careful analysis of the data that informed the values used for Base Case (2009 SDF PA) and Evaluation Case (FY2014 SDF SA) modeling. The 2009 SDF PA assumed a conservative SZ thickness of 12 m for the Base Case model. [SRR-CWDA-2009-00017] This value was conservatively selected based on a review of information provided in *Saltstone Disposal Facility: Determination of the Probable Maximum Water Table Elevation*. [SRR-CWDA-2009-00017; WSRC-TR-2005-00131] Alternatively, the FY2014 SDF SA applied a less conservative (but more realistic) value of 65.5 feet (20 m) based upon observation of PORFLOW-generated plume data. The SDF PORFLOW Model for the FY2014 SDF SA was developed using data reported in the *Integrated Hydrogeological Modeling of the General Separations Area, Volume 1: Hydrogeologic Framework*. [WSRC-TR-96-0399-Vol-1] The change in the SZ thickness used in the SDF GoldSim Model (from 12 m to 20 m) was part of an effort to improve the physical realism of the calculations applied within the SDF GoldSim Model from the 2009 SDF PA to the FY2014 SDF SA. The modeling improvements were first described in the *Saltstone Disposal Facility Stochastic Fate and Transport Model* report. [SRR-CWDA-2011-00178]

Physically, the thickness of the SZ near the SDF is defined as the vertical distance from the water table (i.e., the top of the SZ aquifer) to the top of the Gordon Aquifer (i.e., the "green clay" confining unit that represents the bottom of the SZ aquifer). The 2005 water table report used to inform the value used in the SDF GoldSim model used for the 2009 SDF PA provided a figure of the long-term average water table elevation near the SDF, shown here as Figure 2.1-1. [WSRC-TR-2005-00131] Based upon this figure, the elevation of the water table varies between approximately 210 feet (64.0 m) at the lower edges and 235 feet (71.6 m) near the apex of the SDF.

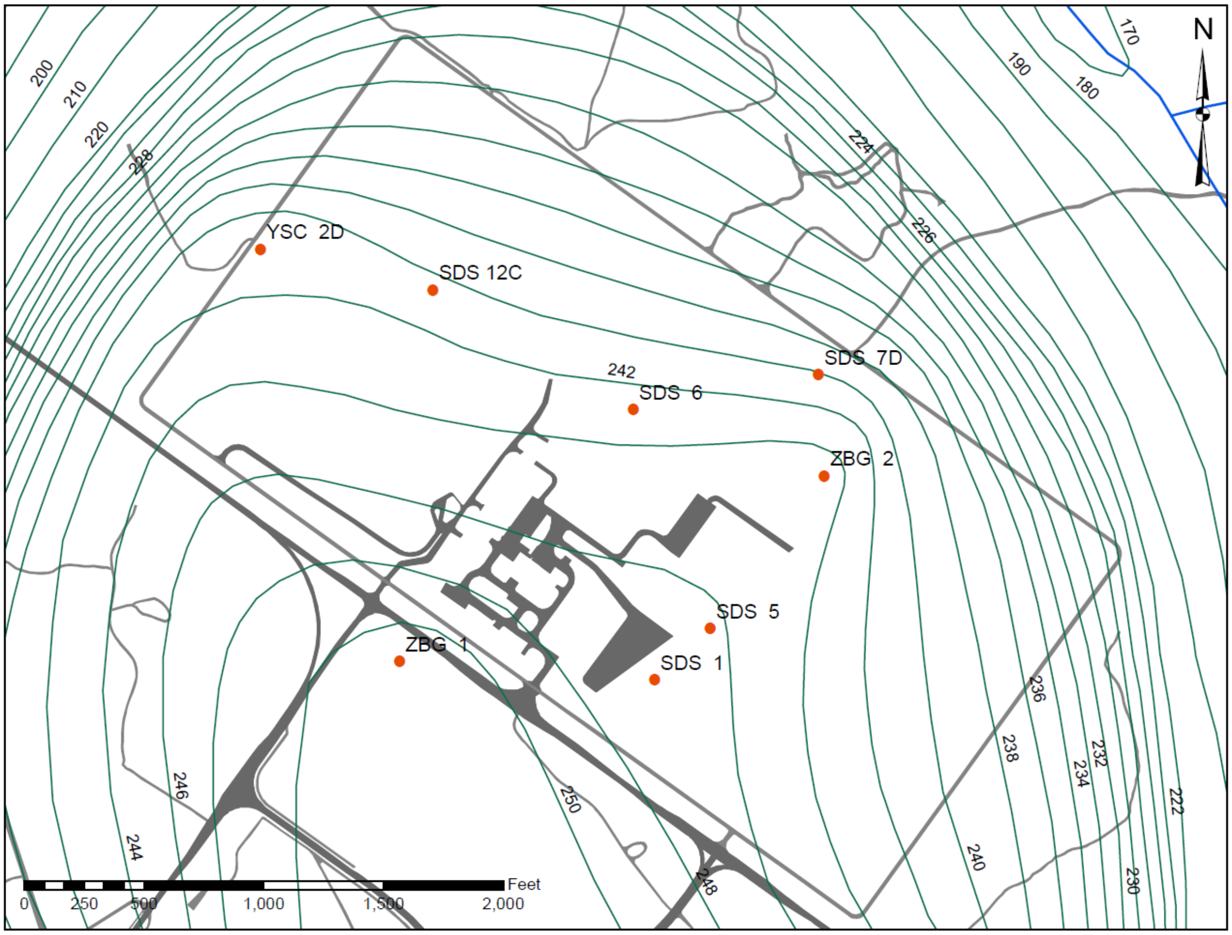
**Figure 2.1-1: Average Water Table Elevations (in Feet Above Sea Level) Near the SDF**




[Source: Figure 2 from WSRC-TR-2005-00131]

The report also indicates that the water table levels fluctuate an average of 12.5 feet (3.8 m) between high and low levels. Figure 2.1-2 provides probable maximum water table elevations. Based upon this figure the maximum elevation of the water table in the vicinity of the SDF varies between approximately 230 feet (70.1 m) at the lower edges and 250 feet (76.2 m) near the apex of the SDF.

**Figure 2.1-2: Probable Maximum Water Table Elevations (in Feet Above Sea Level) Near the SDF**




[Source: Figure 8 from WSRC-TR-2005-00131]

According to *Integrated Hydrogeological Modeling of the General Separations Area, Volume 1: Hydrogeologic Framework*, the top of the green clay confining unit (within the vicinity of the SDF) varies in elevation between approximately 125 feet (38.1 m) at the southern edge of the facility and 150 feet (45.7 m) at the northern edge of the facility. [WSRC-TR-96-0399-Vol-1] Alternatively, *Reconnaissance Hydrogeological Investigation of the Defense Waste Processing Facility and Vicinity* indicates that top of the green clay confining unit varies between approximately 135 feet (41.1 m) and 160 feet (48.8 m). [ML113320350]

Table 2.1-1 summarizes this information and provides a range of estimated SZ thicknesses. Based upon these values, five SZ thickness sensitivity models were developed using the following thicknesses: 19 m, 22 m, 24.4 m, 28 m, and 32 m. These values generally capture the minimum, average, and maximum values as well as two intermediate values. Further, the values in Table 2.1-1 provide additional confidence that the 12 m SZ thickness assumed for the 2009 SDF PA was overly conservative and the 20 m value assumed for the FY2014 SDF SA is both reasonable and appropriate.

**Table 2.1-1: SZ Thickness Variability Summary**

| | Elevation Above Sea Level | | | |
|---|---|---|---|---|
| **Water Table Elevation (Top of the SZ)** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
| Maximum (from WSRC-TR-2005-00131) | 230 | 250 | 70.1 | 76.2 |
| Average (from WSRC-TR-2005-00131) | 210 | 235 | 64.0 | 71.6 |
| Minimum (assumes average value minus 12.5 feet) | 197.5 | 222.5 | 60.2 | 67.8 |
| **Elevation of Green Clay (Bottom of the SZ)** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
| 1989 Estimate (from ML113320350) | 135 | 160 | 41.1 | 48.8 |
| 1996 Estimate (from WSRC-TR-96-0399-Vol-1) | 125 | 150 | 38.1 | 45.7 |
| **Estimated SZ Thickness** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
| Maximum[a] | 105 | 100 | 32.0 | 30.5 |
| Average[b] | 80 | 80 | 24.4 | 24.4 |
| Minimum[c] | 62.5 | 62.5 | 19.1 | 19.1 |

Notes:
(a) Maximum SZ thickness is estimated using the maximum value for the top of the SZ (230 ft), minus the minimum value from the two values available for the bottom of the SZ (125 ft).
(b) Average SZ thickness is estimated using the average value for the top of the SZ (210 ft), minus the average of the two values available for the bottom of the SZ (130 ft).
(c) Minimum SZ thickness is estimated using the minimum value for the top of the SZ (197.5 ft), minus the maximum value from the two values available for the bottom of the SZ (135 ft).

The variability between the lower and upper bound values in Table 2.1-1 is driven by variation in the local topography (e.g., higher surface topography generally results in higher water table levels) and not by fluctuations in water levels or uncertainty in measured data. The three sets of water table values (i.e., Maximum, Average, and Minimum) are used to capture the fluctuations in water table levels over time. The two sets of values used for the "Bottom of the SZ" are used to capture uncertainty in measured values.

Figure 2.1-3 provides a conceptualization of these SZ thickness sensitivity models.

**Figure 2.1-3: Conceptual Approach for Modeling Variable SZ Thicknesses**

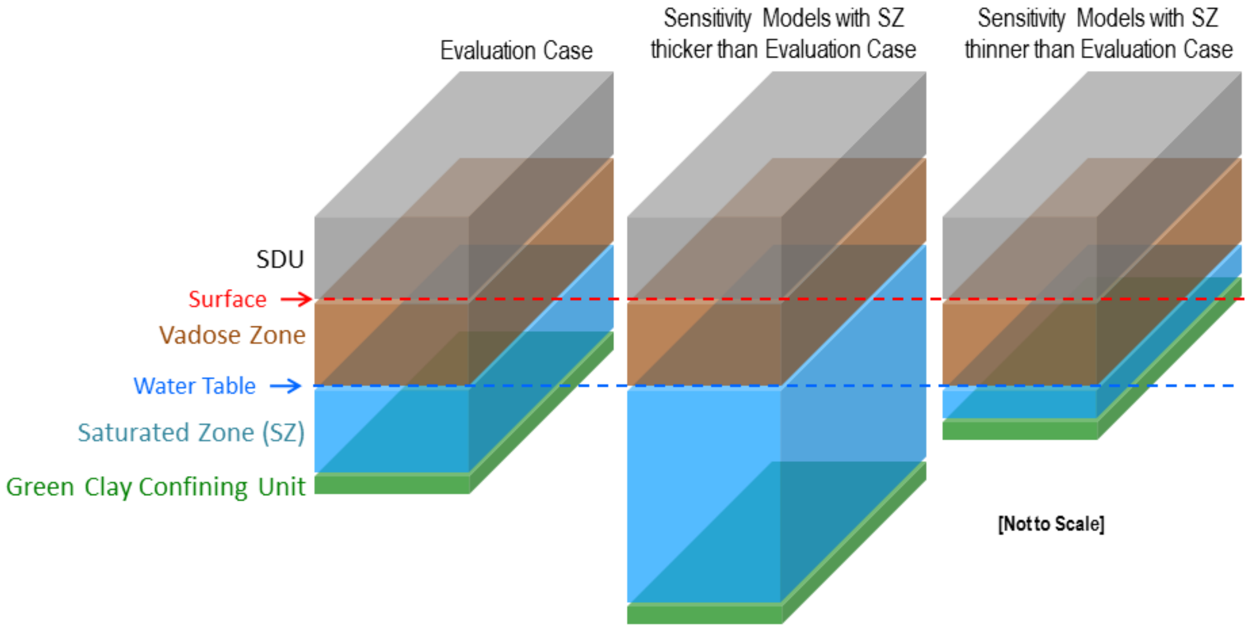



Figure 2.1-4 shows the total doses to the MOP over time from each of the SZ sensitivity models. This figure shows that the dose results from each of the sensitivity models are essentially the same. Table 2.1-2 summarizes the peak doses within select time periods from each of these sensitivity models. Given the analytic solution applied within the plume function of the SDF GoldSim Model, when the SZ is thicker than 20 m the contaminant plume fails to reach the bottom of the SZ, as such SZ thicknesses greater than 20 m do not result in significantly different dose results. Therefore, for time periods greater than 1,000 years the magnitudes of the sensitivity model dose results not significantly different. Regardless, the smaller SZ thicknesses dose show higher the peak doses.

Figure 2.1-5 shows dose ratios, comparing each sensitivity model to the model where the SZ thickness = 19 m. The peak doses within the 0 to 10,000-year period and the 0 to 50,000-year period show very little difference. The early doses (in the 0 to 1,000-year period) are more sensitive to the thickness of the saturated zone. These early doses are attributed to I-129 releases from SDUs 1 and 4. Despite the relatively low soil $K_d$s for iodine, these SDUs are located toward the southwest side of the SDF while the dominant direction of flow is from west to east, thus the contaminant plumes from these SDUs have relatively longer travel distances. Further, SDUs 1 and 4 are conservatively assumed to have initially degraded walls. With these initially degraded walls, these SDUs release more contaminants at early times while the flow rates are undergoing continuous increases. As such, the releases from these SDUs are more sensitive to the thickness of the saturated zone.

**Figure 2.1-4: Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using Various SZ Thicknesses**

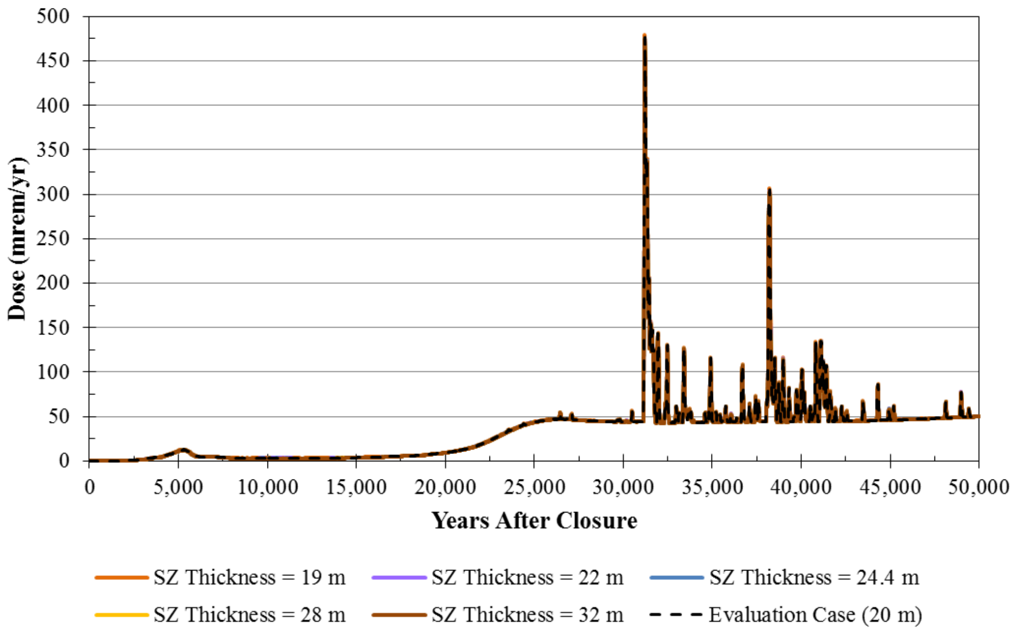



**Table 2.1-2: Peak Doses to the MOP Using the Range of Expected SZ Thicknesses**

| SZ Thickness (m) | Description | Time (Years) when MOP Dose = 25 mrem/yr | Total Peak Dose to MOP (mrem/yr) | | |
|---|---|---|---|---|---|
| | | | 0 to 1,000 Years | 0 to 10,000 Years | 0 to 50,000 Years |
| **19** | Minimum | 22,660 | 8.40E-02 | 12.8 | 479 |
| **20** | Evaluation Case (FY2014 SDF SA) | 22,680 | 8.14E-02 | 12.7 | 477 |
| **22** | Mid-Low | 22,700 | 7.74E-02 | 12.6 | 475 |
| **24.4** | Average | 22,700 | 7.46E-02 | 12.6 | 474 |
| **28** | Mid-High | 22,720 | 7.25E-02 | 12.6 | 474 |
| **32** | Maximum | 22,720 | 7.17E-02 | 12.6 | 474 |

Although the values from Table 2.1-2 represent the range of expected future conditions, an additional set of sensitivity models was developed to provide additional insight. These additional sensitivities apply values that are beyond the expected conditions, but provide more information by exaggerating the impact from varying the SZ thickness. The low-end assumes half the estimated average value (24.4 m × 0.5 = 12.2 m), and the high-end assumes twice the estimated average value (24.4 m × 2 = 48.8 m). The results of this analysis are provided in Figure 2.1-6 and the peak doses are summarized in Table 2.1-3.

**Figure 2.1-5: Ratio to the Peak MOP Dose at SZ Thickness = 19 Meters**

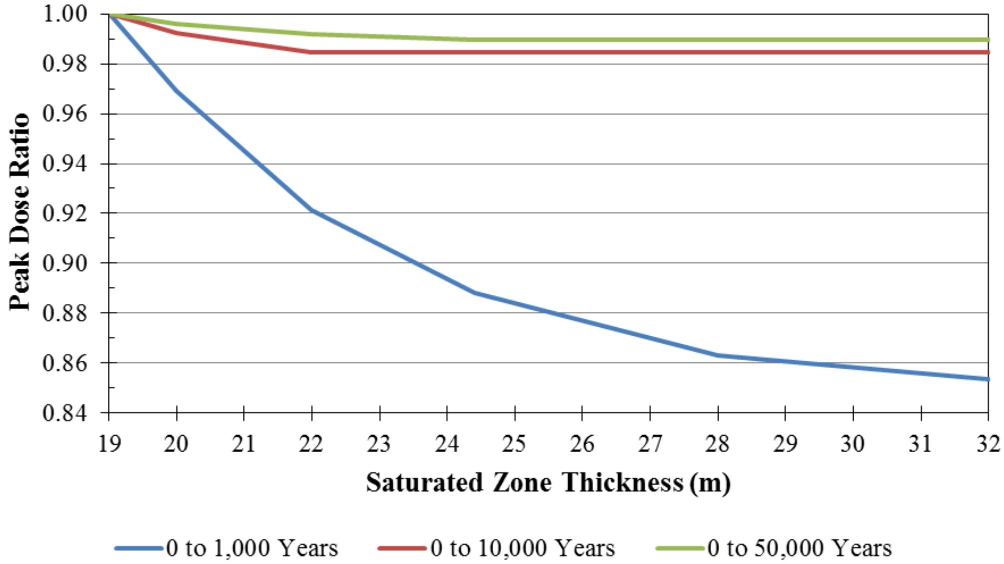



**Figure 2.1-6: Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using SZ Thicknesses Beyond Expected Values**

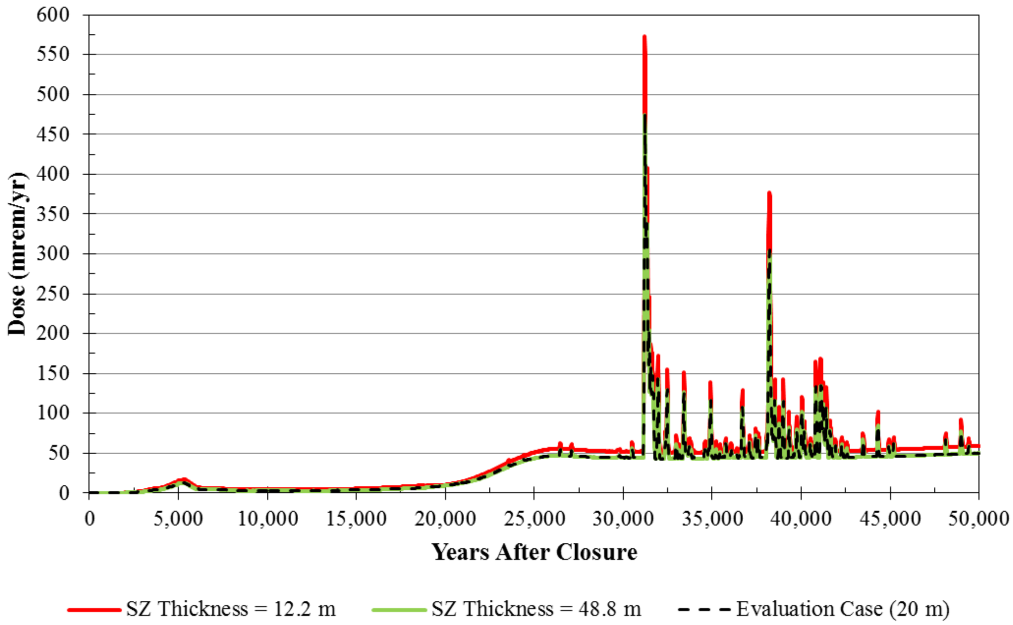


**Table 2.1-3: Peak Doses to the MOP Using a Range Beyond Expected SZ Thicknesses**

| SZ Thickness (m) | Description | Time (Years) when MOP Dose = 25 mrem/yr | Total Peak Dose to MOP (mrem/yr) | | |
|---|---|---|---|---|---|
| | | | 0 to 1,000 Years | 0 to 10,000 Years | 0 to 50,000 Years |
| **12.2** | Average × 0.5 | 22,300 | 1.24E-01 | 17.1 | 573 |
| **20** | Evaluation Case (FY2014 SDF SA) | 22,680 | 8.14E-02 | 12.7 | 477 |
| **24.4** | Average | 22,700 | 7.46E-02 | 12.6 | 474 |
| **48.8** | Average × 2.0 | 22,720 | 7.14E-02 | 12.6 | 474 |

Analysis of the results presented in Tables 2.1-2 and 2.1-3 indicates that, for time periods greater than 1,000 years, there is very little variability in the peak dose results whenever the SZ thickness is modeled as equal to or greater than 19 m. The values provided in Table 2.1-1 indicate that 19 m value is the minimum expected SZ thickness (i.e., values below 19 m are not supported by current field data). Therefore, the value assumed in the FY2014 SDF SA (20 m) is appropriate because it is within the range of expected values and relatively close to the conservative minimum value.

Note that while reducing the thickness of the SZ leads to higher doses, the simplified modeling approach described above is physically unrealistic. As shown in Figure 2.1-3, increasing the SZ thicknesses conceptually moved the green clay confining layer to a greater depth. Physically, the elevation used to define the depth of the green clay confining layer should not change. When modeling less thickness in the SZ, the thickness of the vadose zone should be also be adjusted (increased) to ensure that the physical distance between the bottom of the SDUs and the top of the green clay confining unit remain constant.

Table 2.1-4 provides a summary of physical parameters that are relevant to establishing appropriate values for adjusting the thickness of the vadose zone. These values indicate that the vertical distance from the bottom of the SDUs to the top of the green clay confining unit should be between 121.5 and 135 feet. Review of modeling parameters used in the FY2014 SDF SA (for both PORFLOW and GoldSim) indicate that the assumed travel distances were reflect similar ranges. Appendix B shows that the PORFLOW model generally simulated the distance from the bottom of the SDUs down to the green clay as ranging from approximately 121 to 137 feet. As an abstraction of the SDF PORFLOW Model, the SDF GoldSim Model applied vertical distances that were based on some conservative assumptions, resulting in values that are generally 15 to 20 feet shorter than the physical distances.

Given the scale of the models and the uncertainty associated with future transport, the difference between the modeled values and the physical distances is both reasonable and appropriate. However, reducing the thickness of the SZ, without also increasing the thickness of the vadose zone, increases conservatism.

**Table 2.1-4: Physical Parameter Values**

| **Elevations of SDU Bottoms** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
|---|---|---|---|---|
| From 2009 SDF PA, Figure 3.1-5 | 260 | 281.5 | 79.2 | 85.8 |
| **Elevation of Green Clay** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
| 1989 Estimate (ML113320350) | 135 | 160 | 41.1 | 48.8 |
| 1996 Estimate (from WSRC-TR-96-0399-Vol-1) | 125 | 150 | 38.1 | 45.7 |
| **Estimated Depth to Green Clay (Elevation of SDU Bottoms – Elevation of Green Clay)** | **Lower Bound (ft)** | **Upper Bound (ft)** | **Lower Bound (m)** | **Upper Bound (m)** |
| Based on 1989 Estimate | 125 | 121.5 | 38.1 | 37.0 |
| Based on 1996 Estimate | 135 | 131.5 | 41.1 | 40.1 |

To better assess the impact from varying the SZ thickness a final sensitivity model was developed to better reflect the physical conditions of the SDF. This final sensitivity model uses the conservative 12.2 m SZ thickness, but also modifies the thickness of the modeled vadose zone to correct for the change in depth, as conceptualized by Figure 2.1-7. In this case, the vadose zone thickness was increased by 7.8 m to account for the difference in depth from the 20 m used in the Evaluation Case to the 12.2 m used in the sensitivity model (20 m – 12.2 m = 7.8 m). Figure 2.1-8 presents the dose results over time. Table 2.1-5 summarizes the resulting peak doses. As expected, this correction has little impact to the faster moving radionuclides with relatively low soil $K_d$s (e.g., Tc-99 and I-129), but a significant impact on the slower moving radionuclides with relatively high soil $K_d$s (e.g., Ra-226).

**Figure 2.1-7: Conceptual Approach for Modeling Variable SZ Thicknesses with Adjusted Vadose Zone Thicknesses**

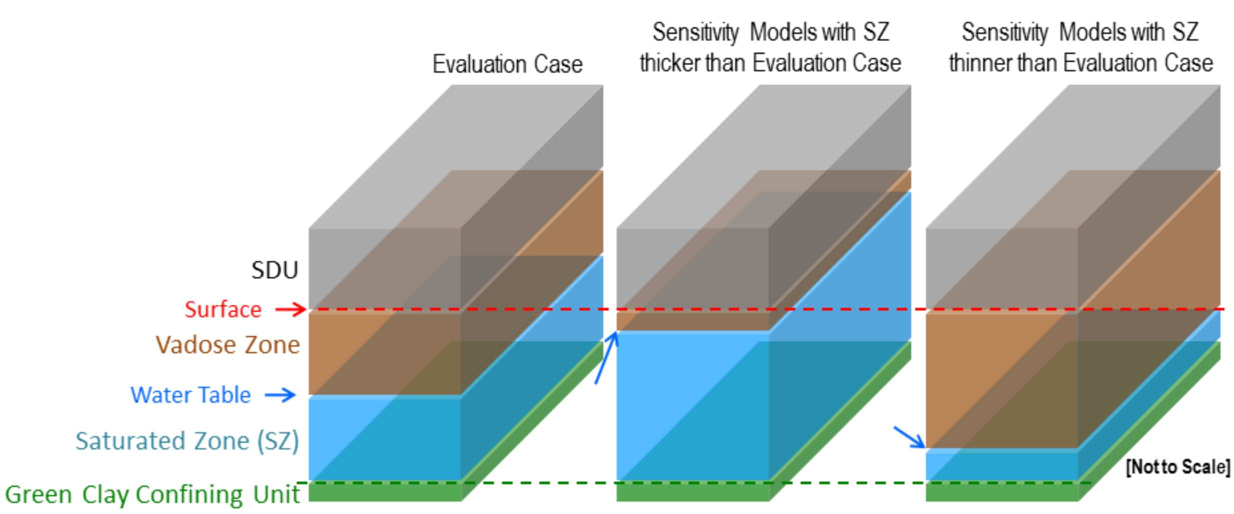


**Figure 2.1-8: Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using a Less-than-Expected SZ Thickness and Correcting for Vertical Distance**

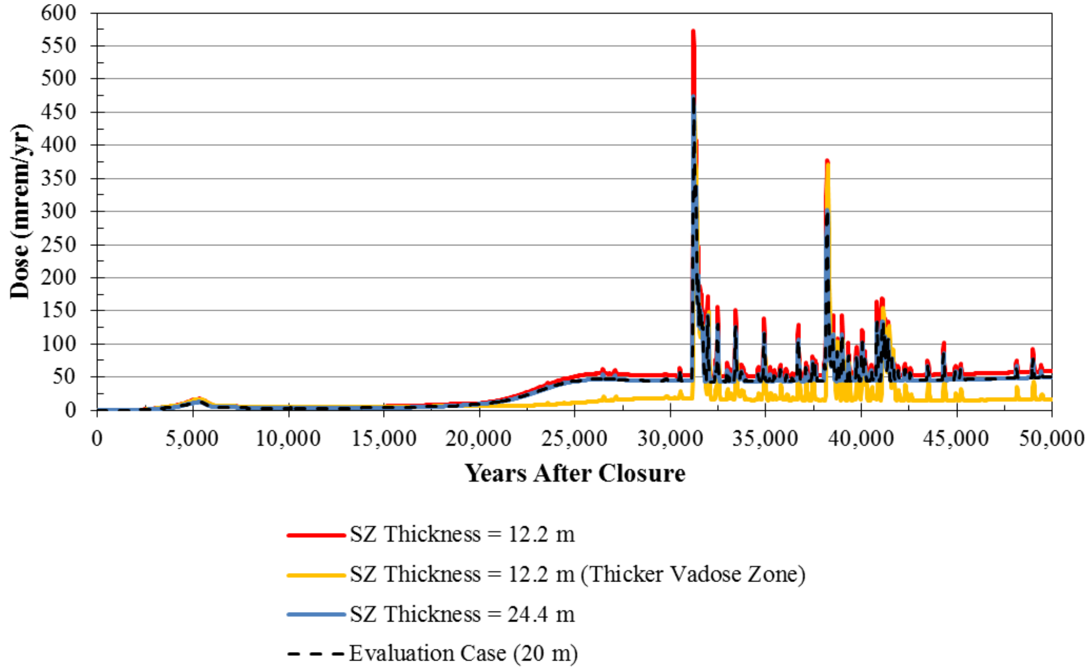



**Table 2.1-5: Peak Doses to the MOP Using a Less-than-Expected SZ Thicknesses and Correcting for Vertical Distance**

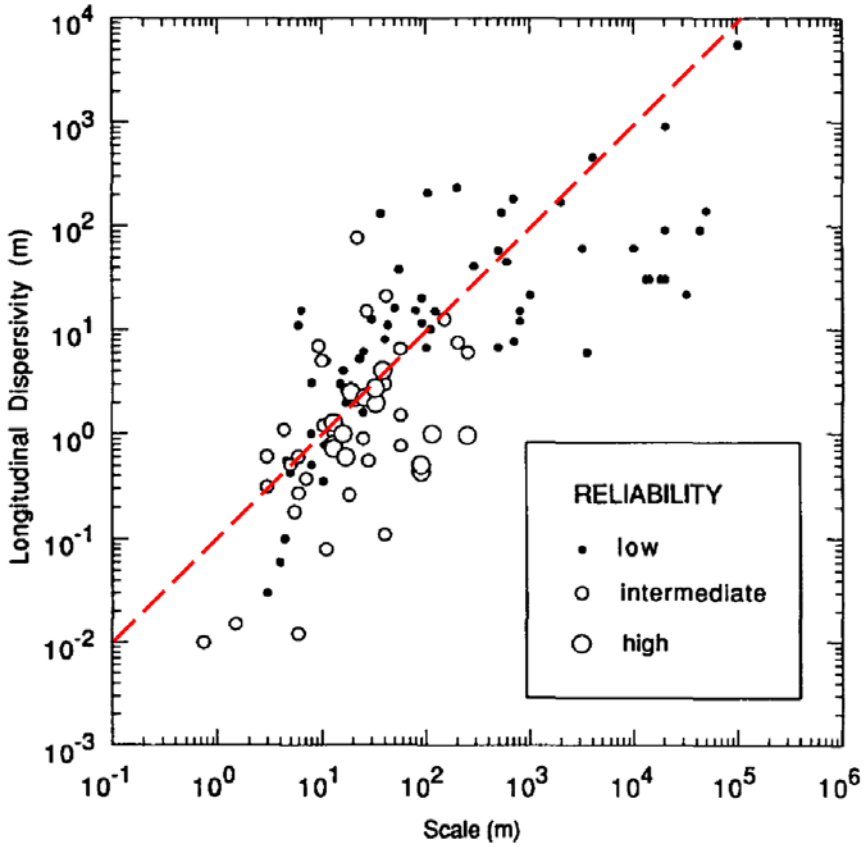
| SZ Thickness (m) | Description | Total Peak Dose to MOP (mrem/yr) | | |
|---|---|---|---|---|
| | | 0 to 1,000 Years | 0 to 10,000 Years | 0 to 50,000 Years |
| **12.2** | Average × 0.5 | 1.24E-01 | 17.1 | 573 |
| **12.2 + Increased Vadose Zone** | Average × 0.5 with Vadose Zone thickness increased by 7.8 m | 6.55E-02 | 16.9 | 458 |
| **20** | Evaluation Case (FY2014 SDF SA) | 7.46E-02 | 12.6 | 477 |
| **24.4** | Average | 7.14E-02 | 12.6 | 474 |

## 2.2 Saturated Zone Dispersivity Variability Modeling

The 2009 SDF PA states that "hydrodynamic dispersion is represented by longitudinal and transverse dispersivities of 10 m and 1 m, respectively, which are 10% and 1% of a nominal 100m plume travel distance." [SRR-CWDA-2009-00017] The *Saltstone Disposal Facility Stochastic Fate and Transport Model* report explains that the SDF GoldSim Model uses the same dispersivity values as the SDF PORFLOW Model. [SRR-CWDA-2011-00178] The assumed value for the longitudinal dispersivity (10 m) is consistent with the so-called "Rule of Thumb" based on Gelhar's (1992) analysis of field-scale dispersion in various aquifers, which showed a

correlation between longitudinal dispersivity and the travel distances considered (see Figure 2.2-1). [DOI: 10.1029/92WR00607]

**Figure 2.2-1: Longitudinal Dispersivity Versus Travel Distance**




[Source: Modified from Gelhar *et al*, 1992 (DOI: 10.1029/92WR00607)]

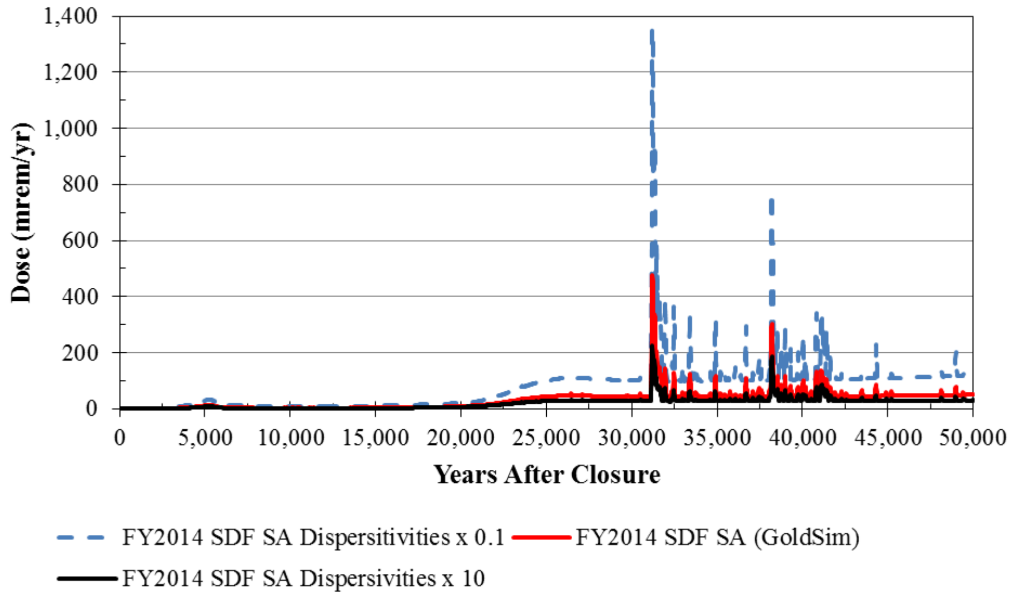
Note that while preparing the sensitivity models documented within this report, it was determined that the SDF GoldSim Model for the FY2014 SDF SA actually applied a vertical dispersivity value of 0.1 m. Although this is consistent with the values applied within the SDF PORFLOW Model, and although this value better reflects those found in literature data, the change from 1.0 m to 0.1 m for the vertical dispersivity was not previously documented.

Three approaches were used to evaluate dose sensitivity relative to potential SZ dispersivity values. The first approach simply increases and decreases the SZ dispersivities by an order of magnitude. The second approach applies a methodology described within the *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Parameters/Data Background Document* to develop alternative dispersivity values. [EPA-530-R-03-003] The third approach applies a different methodology for developing dispersivity values, as described in the *Guidelines to Determine Site-Specific Parameters for Modeling the Fate and Transport of Monoaromatic Hydrocarbons in Groundwater* (Lovanh *et al.*, 2000). The results from each approach are compared to the dose results from the FY2014 SDF SA.

### 2.2.1 Order of Magnitude Variation of SZ Dispersivities

Increasing the dispersivities by an order of magnitude gives (on the upper bound) longitudinal, horizontal, and vertical dispersivities of 100 m, 10 m, and 1 m, respectively. Decreasing the dispersivities by an order of magnitude gives (on the lower bound) longitudinal, horizontal, and vertical dispersivities of 1.0 m, 0.1 m, and 0.01 m, respectively. Figure 2.2-2 provides the dose results with these varying dispersivities. (Note that peak values are summarized in Section 2.2.4.)

**Figure 2.2-2: Comparison of Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using Dispersivities Increased / Decreased by an Order of Magnitude**




### 2.2.2 SZ Dispersivity Variation Based on EPA Methodology

The *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Parameters/Data Background Document* provides a complex mathematical approach for estimating dispersivities when such data is not available. [EPA-530-R-03-003] This approach is defined by the following equations:

$$\alpha_L = \alpha_{Ref} \times \left[\frac{(0.5 \times D_{SDU} + D_{100m})}{152.4}\right]^{0.5} \quad \text{(Eq. 2.2-1)}$$

$$\alpha_H = \frac{\alpha_L}{8} \quad \text{(Eq. 2.2-2)}$$

$$\alpha_V = \frac{\alpha_L}{160} \quad \text{(Eq. 2.2-3)}$$

Where:

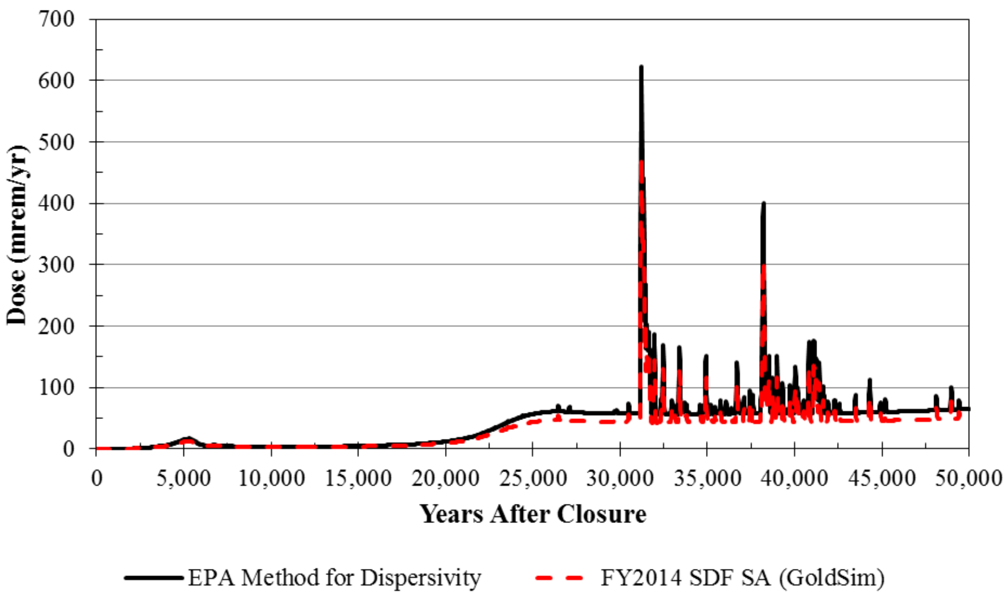
| | | |
|---|---|---|
| $\alpha_L$ | = | longitudinal dispersivity (m) |
| $\alpha_{Ref}$ | = | reference dispersivity multiplier based on Table 5.24 from the EPA's reference (see the following discussion) |

| | | |
|---|---|---|
| $D_{SDU}$ | = | diameter or transverse distance of each SDU (m) |
| $D_{100m}$ | = | travel distance from the SDU to the 100 m boundary (m) |
| $\alpha_H$ | = | horizontal transverse dispersivity (m) |
| $\alpha_V$ | = | vertical transverse dispersivity (m) |

In the absence of measured values, the EPA recommends applying a probabilistic approach for the reference dispersivity multiplier ($\alpha_{Ref}$), using a defined cumulative probability distribution (see Table 5.24 in EPA-530-R-03-003). For simplicity, the 50$^{th}$ percentile of the recommended distribution is assumed for this deterministic approach (i.e., a value of 7.0).

Due to the layout of the SDF and the direction of flow, each SDU has a different travel distance to the 100-meter boundary; therefore, each SDU yields a different longitudinal dispersivity value (e.g., the estimated longitudinal dispersivity from SDU 3B is 4.23 m while the estimated longitudinal dispersivity for SDU 10 is 12.71 m). For this approach, the average value for all SDUs is assumed (i.e., 8.82 m). Therefore, the horizontal and vertical dispersivities are 1.10 m and 0.0552 m, respectively. Figure 2.2-4 provides the resulting dose comparison from the application of the EPA method.

**Figure 2.2-4: Comparison of Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using Dispersivities Based on EPA Method**




### 2.2.3 SZ Dispersivity Variation Based on Lovanh *et al.* Methodology

Similar to the EPA approach, the *Guidelines to Determine Site-Specific Parameters for Modeling the Fate and Transport of Monoaromatic Hydrocarbons in Groundwater* also provides a mathematical approach for estimating dispersivity values. [Lovanh *et al.*, 2000] This approach is defined as follows:

$$\alpha_L = 0.0175 \times {D_{100m}}^{1.46} \qquad \text{(Eq. 2.2-4)}$$

$$\alpha_H = \alpha_L \times 0.3 \qquad \text{(Eq. 2.2-5)}$$

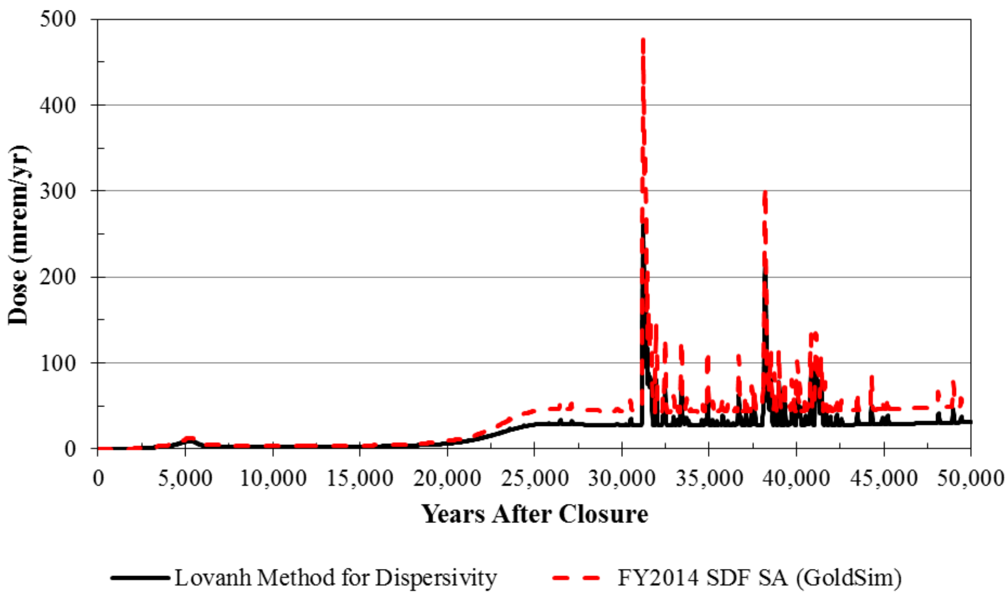
$$\alpha_V = \alpha_L \times 0.05 \qquad \text{(Eq. 2.2-6)}$$

Where:

| | | |
|---|---|---|
| $\alpha_L$ | = | longitudinal dispersivity (m) |
| $D_{100m}$ | = | travel distance from the SDU to the 100 m boundary (m) |
| $\alpha_H$ | = | horizontal transverse dispersivity (m) |
| $\alpha_V$ | = | vertical transverse dispersivity (m) |

Assuming a travel distance of 100 m, the resulting longitudinal dispersivity is 14.6 m. Therefore, the horizontal and vertical dispersivities are 4.37 m and 0.728 m, respectively. Figure 2.2-5 provides the resulting dose comparison from the application of the Lovanh method.

**Figure 2.2-5: Comparison of Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using Dispersivities Based on Lovanh Method**




### 2.2.4 Summary of SZ Dispersivity Variation

Table 2.2-1 summarizes the peak dose results from the various dispersivity sensitivities studies considered. In general, lower dispersivities result in higher doses because less spreading increases the concentrations along the centerline of the contaminant plumes. The sensitivity modeling that increased and decreased the dispersivities by an order of magnitude are considered to be bounding conditions (although it should be noted that there is no evidence that would support decreasing the dispersivities by an order of magnitude). These bounding studies showed that the peak 50,000-year doses to the MOP can vary between 227 mrem/yr and 1,358 mrem/yr based upon uncertainty in SZ dispersivities.

The SZ dispersivity values determined by the EPA method and the Lovanh method are expected to more closely resemble actual field conditions because these approaches were developed based upon comparisons of actual field-measured dispersivities. These two cases showed that the peak 50,000-year doses to the MOP would more realistically fall between 261 mrem/yr and 623 mrem/yr. The 477 mrem/yr peak dose described in the FY2014 SDF SA is within these bounds, demonstrating that the approach assumed for the Evaluation Case was reasonable. [SRR-CWDA-2014-00006]

Finally, it should be noted that while lower dispersivity increases the magnitude of peak doses, it also reduces the probability that a future water well would actually intersect the contaminant plume. Although DOE conservatively assumes that the MOP draws water from a well that intersects the plume at a point along the 100-meter boundary that shows the highest contaminant concentrations, a plume that shows less spreading would make DOE's assumed scenario less likely.

**Table 2.2-1: Peak Doses to the MOP Using Varying SZ Dispersivities**

| | **SZ Dispersivities Applied (m)** | | | **Time (Years) when MOP Dose = 25 mrem/yr** | **Peak Doses (mrem/yr)** | | |
|---|---|---|---|---|---|---|---|
| **Modeling Case** | **Longitu-dinal** | **Horizontal, Transverse** | **Vertical, Transverse** | | **From 0 to 1,000 Years** | **From 0 to 10,000 Years** | **From 0 to 50,000 Years** |
| FY2014 SDF SA (GoldSim) | 10 | 1.0 | 0.1 | 22,680 | 0.081 | 12.7 | 477 |
| Dispersivities Increased by an Order of Magnitude | 100 | 10 | 1.0 | 24,220 | 0.050 | 8.3 | 227 |
| EPA Method (see Section 2.2.2) | 8.82 | 1.10 | 0.052 | 22,060 | 0.097 | 16.6 | 623 |
| Lovanh Method (see Section 2.2.3) | 14.6 | 4.37 | 0.728 | 24,160 | 0.063 | 9.3 | 261 |
| Dispersivities Decreased by an Order of Magnitude | 1.0 | 0.1 | 0.01 | 4,760 | 0.21 | 32.8 | 1,358 |

# 3.0 RAI FFT-4 SENSITIVITY MODELING

The concerns raised by the NRC via RAI FFT-4 (see Appendix A) are related to the use of "Leachate Impacted" distribution coefficients ($K_d$s) for soils that are impacted by concrete and saltstone leachates. In the 2009 SDF PA, the $K_d$ values that were used assumed no chemical interactions from pore water and the cementitious materials (i.e., all soils were assumed to be non-impacted by chemistry changes from water that has passed through the cementitious SDU materials). [SRR-CWDA-2009-00017] As a modeling improvement, the FY2013 and FY2014 SDF SAs modified the soil $K_d$s in the vadose zone beneath the SDUs to account for expected changes to pore water chemistry. Table 3.0-1 provides the soil $K_d$ values, as used within the FY2014 SDF SA. [SRR-CWDA-2014-00006]

**Table 3.0-1: Distribution Coefficients ($K_d$ Values) for Elements in Soils**

| Element | Clayey Soil (Backfill) (mL/g) | | Sandy Soil (Vadose) (mL/g) | |
|---|---|---|---|---|
| | Without Leachate | Leachate Impacted | Without Leachate | Leachate Impacted |
| Ac | 8,500 | 12,750 | 1,100 | 1650 |
| Ag | 30 | 96 | 10 | 32 |
| Al | 1,300 | 1,950 | 1,300 | 1,950 |
| Am | 8,500 | 12,750 | 1,100 | 1,650 |
| As | 200 | 280 | 100 | 140 |
| At | 0.9 | 0.1 | 0.3 | 0 |
| Ba | 101 | 303 | 15 | 45 |
| Bk | 8,500 | 12,750 | 1,100 | 1,650 |
| C | 400 | 2,000 | 10 | 50 |
| Cd | 30 | 90 | 15 | 45 |
| Ce | 8,500 | 12,750 | 1,100 | 1,650 |
| Cf | 8,500 | 12,750 | 1,100 | 1,650 |
| Cl | 8 | 0.8 | 1 | 0.1 |
| Cm | 8,500 | 12,750 | 1,100 | 1,650 |
| Co | 100 | 320 | 40 | 128 |
| Cr | 400 | 560 | 1,000 | 1,400 |
| Cs | 50 | 50 | 10 | 10 |
| Cu | 70 | 224 | 50 | 160 |
| Eu | 8,500 | 12,750 | 1,100 | 1,650 |
| Fe | 400 | 600 | 200 | 300 |
| Fr | 50 | 50 | 10 | 10 |
| Gd | 8,500 | 12,750 | 1,100 | 1,650 |
| H | 0 | 0 | 0 | 0 |
| Hg | 1,000 | 3,200 | 800 | 2,560 |
| I | 3 | 0.3 | 1 | 0.1 |
| K | 25 | 25 | 5 | 5 |
| Mn | 200 | 280 | 15 | 21 |
| N | 0 | 0 | 0 | 0 |

**Table 3.0-1: Distribution Coefficients ($K_d$ Values) for Elements in Soils (Cont.)**

| Element | Clayey Soil (Backfill) (mL/g) | | Sandy Soil (Vadose) (mL/g) | |
|---|---|---|---|---|
| | Without Leachate | Leachate Impacted | Without Leachate | Leachate Impacted |
| Na | 25 | 25 | 5 | 5 |
| Nb | 900 | 1260 | 160 | 224 |
| Ni | 30 | 96 | 7 | 22 |
| Np | 9 | 180 | 3 | 60 |
| Pa | 9 | 180 | 3 | 60 |
| Pb | 5,000 | 16,000 | 2,000 | 6,400 |
| Pd | 30 | 96 | 7 | 22 |
| Pm | 0 | 0 | 0 | 0 |
| Po | 5,000 | 10,000 | 2,000 | 4,000 |
| Pr | 0 | 0 | 0 | 0 |
| Pt | 30 | 96 | 7 | 22 |
| Pu | 5,950 | 11,900 | 650 | 1,300 |
| Ra | 185 | 555 | 25 | 75 |
| Rb | 50 | 50 | 10 | 10 |
| Re | 1.8 | 0.2 | 0.6 | 0.1 |
| Rh | 0 | 0 | 0 | 0 |
| Rn | 0 | 0 | 0 | 0 |
| Ru | 0 | 0 | 0 | 0 |
| Sb | 2,500 | 3,500 | 2,500 | 3,500 |
| Se | 1,000 | 1,400 | 1,000 | 1,400 |
| Sm | 8,500 | 12,750 | 1,100 | 1,650 |
| Sn | 5,000 | 15,000 | 2,000 | 6,000 |
| Sr | 17 | 51 | 5 | 15 |
| Tc | 1.8 | 0.2 | 0.6 | 0.1 |
| Te | 1,000 | 1,400 | 1,000 | 1,400 |
| Th | 2,000 | 4,000 | 900 | 1,800 |
| U | 400 | 1,200 | 300 | 900 |
| V | 0 | 0 | 0 | 0 |
| Y | 8,500 | 12,750 | 1,100 | 1,650 |
| Zn | 30 | 90 | 15 | 45 |
| Zr | 2,000 | 4,000 | 900 | 1,800 |

[Source: SRR-CWDA-2014-00006]

The NRC's concern, as expressed in RAI FFT-4, is with respect to the simplified modeling approach that was applied. Specifically, it is assumed that leachate impacts remain constant for the full duration of the simulations. However, the NRC indicates that "the impact of the leachate on the vadose zone is expected to decrease over time."

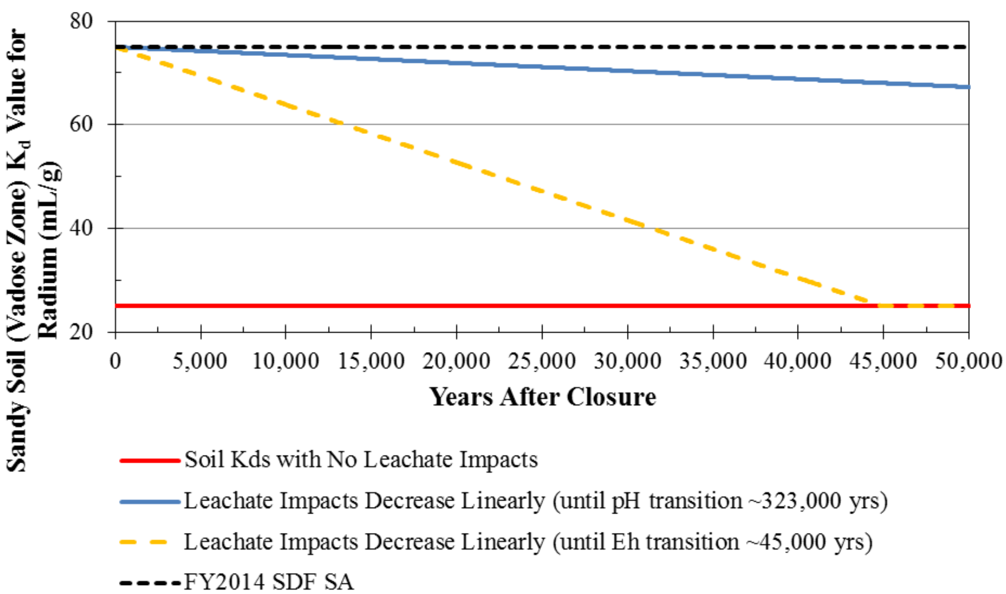
The rationale for assuming that the leachate impacts to soils do not change over time was driven by the large mass of the saltstone within the SDUs. Due to the size of the SDUs, the degradation analysis from Section 4.2 of the FY2014 SDF SA estimated that it would take hundreds of thousands of years for the saltstone to chemically transition. For the Eh transitions (from

reduced to oxidized), Table 4.1-2 of the FY2014 SDF SA indicates that the 150-foot diameter SDUs transition around 32,500 years and the 375-foot diameter SDUs transition around 45,000 years. The pH transitions do not occur until more than 100,000 years after closure. [SRR-CWDA-2014-00006] Given that the period of performance is 10,000 years and estimates beyond this period increase uncertainty, this simplifying assumption was considered reasonable and appropriate.

Regardless of the rationale, DOE agrees that leachate impacts would likely decrease over time, but it is unlikely that such decreases would be significant within the evaluation period. To assess the potential impact from decreasing leachate affects, three sensitivity models were developed. The first sensitivity model ignores all cementitious leachate impacts, applying the non-impacted soil $K_d$s to contaminants in all soils. This approach is unrealistic but provides an extreme upper bound to inform decision making. The second sensitivity model assumes a linear rate of change for the soil $K_d$s (from leachate-impacted to non-impacted). For this approach, the change in the soil $K_d$s was set to start at the beginning of the simulation (time = 0 years) and ends when saltstone undergoes the pH transition (approximately 323,000 years after closure). This approach reflects the best approximation of expected future transport. Finally, the third sensitivity model also applies a linear rate of change that starts at the time of the conservatively, but this time assumes that the leachate is only a function of Eh, thus the end time is set to the time of the Eh transition (approximately 45,000 years after closure).

To illustrate these various approaches, Figure 3.0-1 shows the applied sandy soil (vadose zone) $K_d$ values for radium for each sensitivity model.

**Figure 3.0-1: Alternative Leachate-Impacted Soil $K_d$s for Radium**




Figures 3.0-2 and 3.0-3 show the resulting doses within 10,000 years and within 50,000 years, respectively. Figure 3.0-2 illustrates that the effects of applying the leachate-impacted soil Kds are not significant within the 10,000-year performance period. The total peak doses to the MOP increased by less than 1.0 mrem/yr.

**Figure 3.0-2: Total Dose to the MOP at the SDF 100-Meter Boundary within 10,000 Years, Using Various Leachate-Impacted Soil $K_d$s**

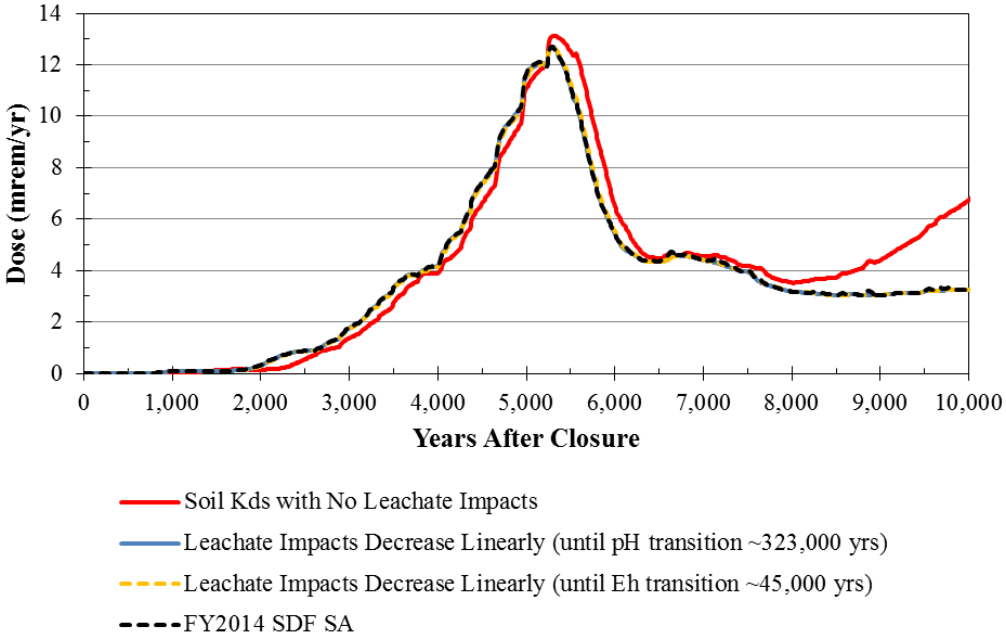
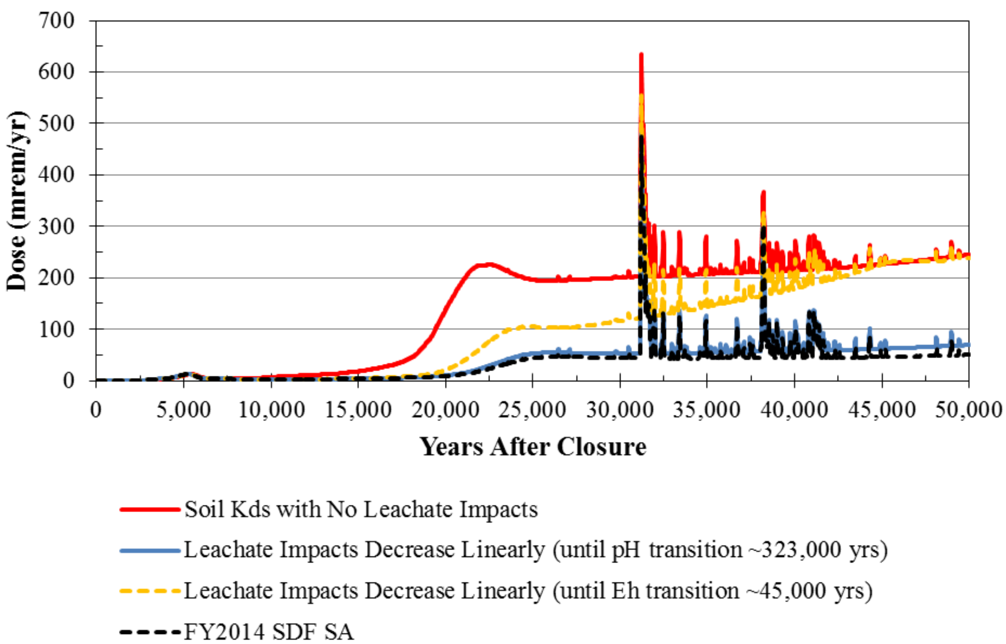



**Figure 3.0-3: Total Dose to the MOP at the SDF 100-Meter Boundary within 50,000 Years, Using Various Leachate-Impacted Soil $K_d$s**




Over 50,000 years, the change is significant for two of the sensitivity studies (depicted by the red and yellow curves). These studies resulted in doses to the MOP that are approximately 75 mrem/yr to150 mrem/yr higher than those from the FY2014 SDF SA Evaluation Case. It is

important to note that these two sensitivity studies do not reflect the expected future conditions but are intended to reflect extreme or bounding conditions. Further, the increase in dose is driven by the change to the transport of Ra-226. This specific radionuclide was modeled with a conservative inventory (as described in the FY2014 SDF SA). [SRR-CWDA-2014-00006] Applying a more realistic inventory for Ra-226 and its parent radionuclides would significantly reduce the influence of this effect.

The expected future conditions, reflected by the blue curve, also shows a slight increase to the doses (approximately 10 mrem/yr to 20 mrem/yr) at times beyond 20,000 years after closure. This increase is also driven by the change to the transport of Ra-226, which was modeled with a conservative inventory (as described in the FY2014 SDF SA). Because this impact doesn’t occur until well beyond the 10,000-year period of performance and is driven by a radionuclide that was modeled with a conservative inventory, the simplified approach applied within the FY2014 SDF SA is reasonable and appropriate.

# 4.0 CONCLUSIONS

Based upon the sensitivity modeling described herein, the following conclusions can be made with respect to SZ transport in the FY2014 SDF SA:

- The current SDF models (PORFLOW and SDF GoldSim) both apply conservative modeling assumptions for the depth from the bottom of the SDUs to the green clay confining layer, as used to define the lower bound of the SZ.
- Changes to the SZ thickness, within the range of expected values, have no significant impact to total dose results.
- Applying alternative approaches for estimating the applicable SZ dispersivity values showed that the values assumed in the SDF modeling were reasonable, with long-term (i.e., > 20,000 years) peak doses to the MOP varying between 261 mrem/yr (with the Lovanh Method) and 623 mrem/yr (with the EPA Method). The FY2014 SDF SA Evaluation Case had a peak dose of 477 mrem/yr, demonstrating that the Evaluation Case is reasonable.
- The assumed values for dispersivities (longitudinal, vertical, and horizontal) are consistent with values determined via alternative analytical methods.
- Assuming that leachate impacts to soil $K_d$s remain constant for the full duration of the simulations is a reasonable modeling simplification.

In addition to these conclusions, the following recommendation should be applied as improvements to future SDF GoldSim modeling:

- The vadose zone thicknesses beneath the SDUs should be linked to the sampled SZ thickness parameter in order to maintain the physically constant distance from the bottom of the SDUs to the top of the green clay confining layer.

# 5.0 REFERENCES

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ML14148A153, *U.S. Nuclear Regulatory Commission Staff Comments and Requests for Additional Information on the Fiscal Year 2013 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site, SRR-CWDA-2013-00062, Revision 2*, U.S. Nuclear Regulatory Commission, Washington, DC, June 13, 2014.

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WSRC-TR-96-0399-Vol. 1, Flach, G. P., et al., *Integrated Hydrogeological Model of the General Separations Area, Vol. 1*, Savannah River Site, Aiken, SC, Rev. 0, August 1997.

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# APPENDIX A. REQUESTS FOR ADDITIONAL INFORMATION

The following provides the RAIs addressed within this report. These RAIs were prepared by the NRC and provided to DOE in reference to the FY2013 SDF SA (SRR-CWDA-2013-00062). The full set of RAIs are available in the *U.S. Nuclear Regulatory Commission Staff Comments and Requests for Additional Information on the Fiscal Year 2013 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site, SRR-CWDA-2013-00062, Revision 2*. [ML14148A153]

| | |
|---|---|
| **FFT-1** | **Comment:** Additional information is needed to support the assumed saturated zone thickness. |
| | **Basis:** Section 5.6.3 indicated that the sampled saturated zone thickness was increased based on the observation of cross sections of Far-Field PORFLOW-generated plumes, as described in Section 4.4.2.1 in SRR-CWDA-2011-00178. In the 2012 SDF NRC TER (see ML121020140), NRC staff indicated that far-field performance results include potentially overly optimistic levels of dilution and dispersion of SDF source plumes and limited cumulative impacts from the SDF. The TER also stated:<br>(a) “Changes to key parameters (e.g., hydraulic conductivities, recharge rates reflective of capped conditions) and improved model calibration in the area of interest could lead to: (i) variability in the location of the groundwater divide, (ii) changes to the hydraulic gradient, or (iii) changes to Darcy velocities that could result in significantly lower levels of modeled dilution and dispersion, which could result in larger predicted doses.”<br>In addition, Section 5.6.2.6 indicated that the dose rate from a well can differ significantly depending on the methodology of the numerical code used. For example, the GoldSim concentrations are taken at the centerline of the source, as opposed to PORFLOW, which uses the above mentioned element thicknesses. GoldSim had the generally higher dose results. |
| | **Path Forward:** Provide basis for additional information beyond the PORFLOW-generated plume cross-sections, such as Figure 4-4 in SRR-CWDA-2011-00178, to support the assumed saturated zone thickness and the associated resulting dilution. Sensitivity analyses would be helpful to determine the significance of different modeling methods and different parameter values (e.g., vertical hydraulic conductivity, dispersion). |

| | |
|---|---|
| **FFT-4** | **Comment:** A basis is needed for the assumption that the vadose zone will be impacted by leachate from the cementitious materials for the duration of the assessment. The uncertainty due to that assumption was not considered in the Special Analysis. |
| | **Basis:** As cementitious materials age and leaching occurs, it is expected that the pH value and ionic strength will decrease. Therefore, the impact of the leachate on the vadose zone is expected to decrease over time. |
| | **Path Forward:** Provide a basis for the assumption that the vadose zone will be impacted by leachate from the cementitious materials for the duration of the assessment and provide an evaluation of the sensitivity of the projected dose to this assumption. |

# APPENDIX B. CROSS-SECTIONS OF SELECT PORFLOW PLUMES

The following figures (Figure B-1 through B-5) show vertical cross sections from the SDF PORFLOW transport model. Each cross section depicts a hypothetical "tracer" plume from a specific SDU. The top of the depiction represents the ground surface. The tops of the tracer plumes coincide with the tops of the water table. Table 45 from *Numerical Flow and Transport Simulations Supporting the Saltstone Facility Performance Assessment* provides the modeled depths from the bottom of the SDUs to the water table, as used in the 2009 SDF PA. [SRNL-STI-2009-00115] Based on this information, the vadose zone has an average thickness of 42 feet (12.8 m).

Two rows of cells across the middle of each image indicate where the green clay confining unit is modeled. The "Z" Axis on the left-hand side provides elevation (in feet above mean sea level) where the green clay confining unit is typically around an elevation of 140 feet. (Note that these images show vertical exaggeration.) Table B-1, following these figures provides a summary of the elevations depicted. These elevations were used to estimate the modeled depth to the green clay confining unit, as discussed in Section 2.1. Given the average vadose zone thickness of 42 feet, an approximate water table elevation, and the depth to the green clay confining unit, the thickness of the SZ beneath each SDU can be estimated.

Alternatively, the SDF GoldSim Model applies values for the vadose zone under each SDU type, which can then be combined to the 20 m thickness of the saturated zone to determine the modeled depth to the green clay. Table B-2 provides the GoldSim element identifiers and the respective values.

**Figure B-1: Vertical Cross-Section of a PORFLOW-Generated Plume for SDU 1**

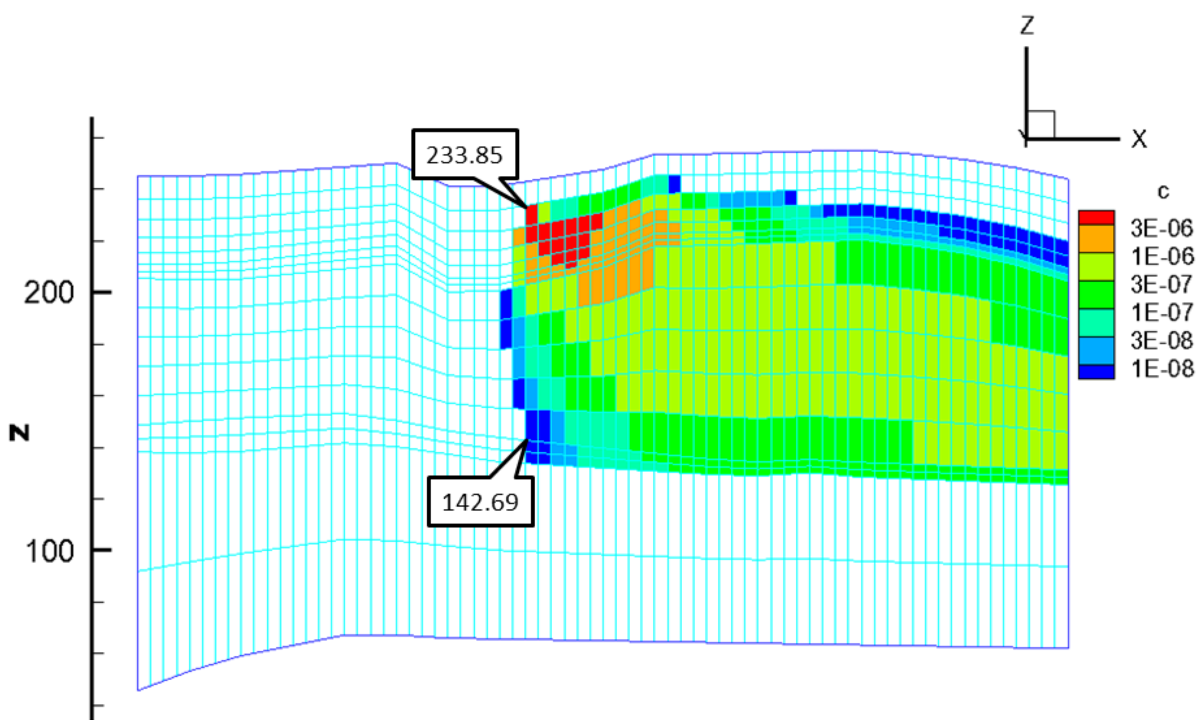

**Figure B-2: Vertical Cross-Section of a PORFLOW-Generated Plume for SDUs 3A**

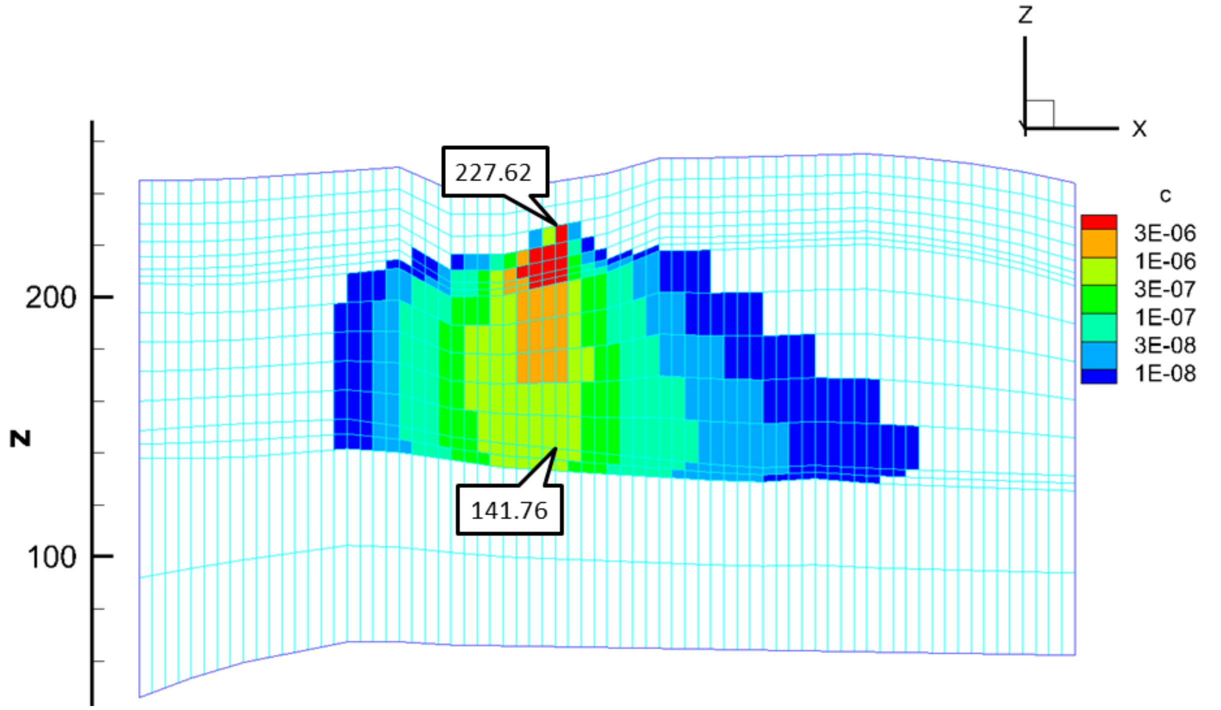


**Figure B-3: Vertical Cross-Section of a PORFLOW-Generated Plume for SDU 4**

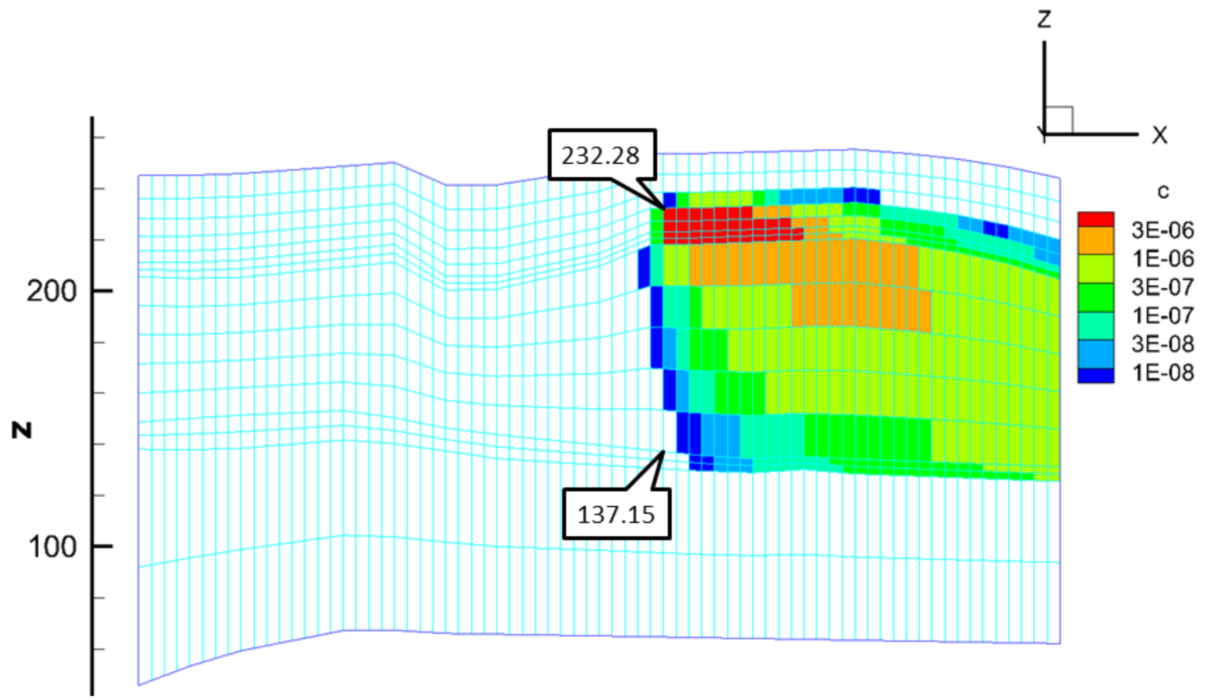

**Figure B-4: Vertical Cross-Section of a PORFLOW-Generated Plume for SDU 9**

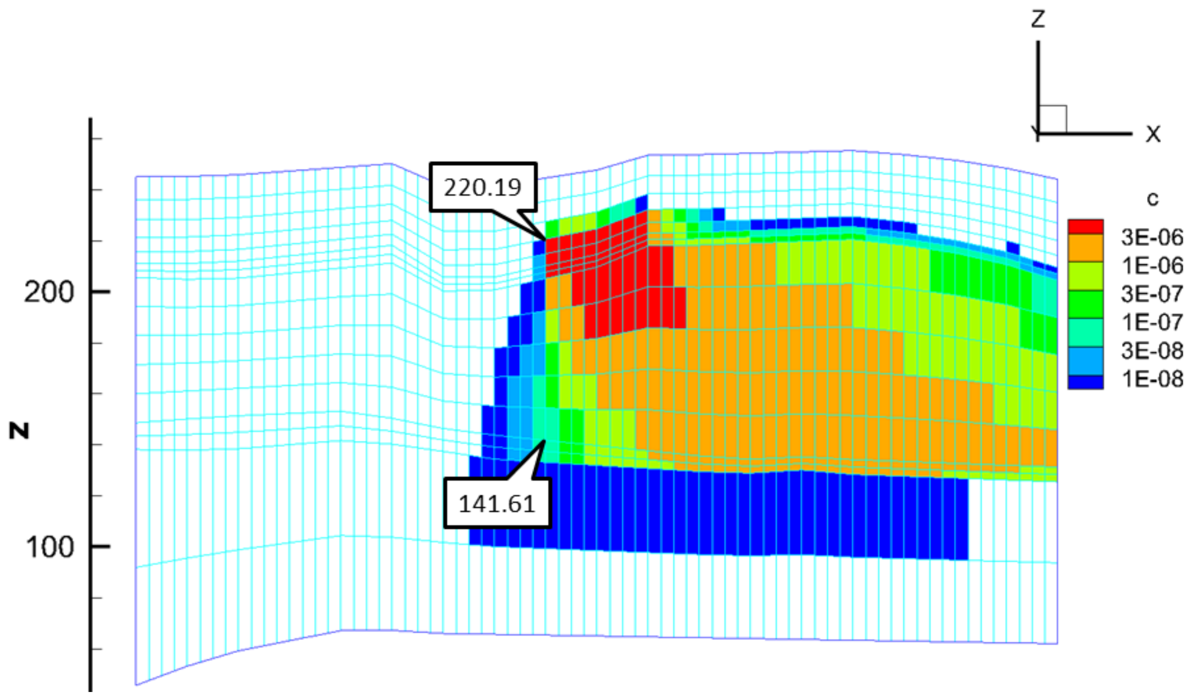


**Figure B-5: Vertical Cross-Section of a PORFLOW-Generated Plume for SDU 11**

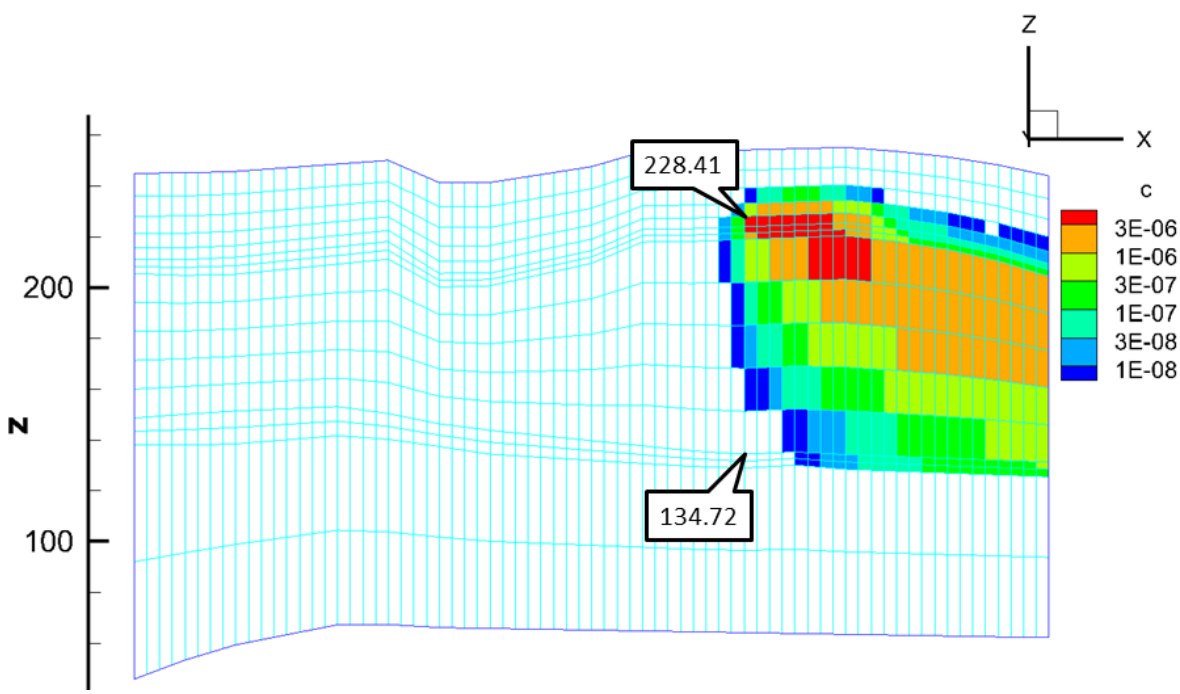

**Table B-1: Summary of Modeled PORFLOW Elevations (Mean Sea Level in Feet)**

| SDU | Figure | Water Table Elevation | Green Clay Elevation | SZ Thickness (ft) | SZ Thickness + Vadose Zone Thickness[a] (ft) |
|---|---|---|---|---|---|
| 1 | B-1 | 233.85 | 142.69 | 91.16 | 133.2 |
| 3A | B-2 | 227.62 | 141.76 | 85.86 | 127.9 |
| 4 | B-3 | 232.28 | 137.15 | 95.13 | 137.1 |
| 9 | B-4 | 220.19 | 141.61 | 78.58 | 120.6 |
| 11 | B-5 | 228.41 | 134.72 | 93.69 | 135.7 |

a) Assumes the average vadose zone thickness of 42 feet, as provided in Table 45 of SRNL-STI-2009-00115.

**Table B-2: Select Parameter Data from the SDF GoldSim Model**

| GoldSim Model Location | Element Name | Vector | Value | Unit |
|---|---|---|---|---|
| \DisposalUnits\VaultData | UZThickness_table | SDU 1 | 1524 | cm |
| | | SDU 4 | 1219 | cm |
| | | 150-Foot Diameter SDUs | 1280 | cm |
| | | 375-Foot Diameter SDUs | 1280 | cm |
| \Transport\WaterTransport | SatThickness_determ | N/A (applied to all SDUs) | 20 | m |

Given the values in Table B-5, the depth to the green clay confining unit (as modeled in GoldSim) is as follows:

SDU 1: 1524 cm = 15.24 m + 20 m = 35.24 m = 115.6 ft

SDU 4: 1219 cm = 12.19 m + 20 m = 32.19 m = 105.6 ft

150-foot diameter SDUs: 1280 cm = 12.8 m + 20 m = 32.8 m = 107.6 ft

375-foot diameter SDUs: 1280 cm = 12.8 m + 20 m = 32.8 m = 107.6 ft