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Evaluation of Principal SDU Design Features to Inform Future Optimization

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ACRONYMS/ABBREVIATIONS

HDPE	High Density Polyethylene
MOP	Member of the Public
PA	Performance Assessment
SA	Special Analysis
SDF	Saltstone Disposal Facility
SDU	Saltstone Disposal Unit
TAR	Technical Assistance Request

1.0 INTRODUCTION

This document provides a model-based evaluation of variations to principal design features to Saltstone Disposal Units (SDUs) at the Saltstone Disposal Facility (SDF). The objective of these activities is to characterize the dose performance-significance of the various engineered barriers. All modeling performed in support of this evaluation is based on the model from the *FY2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site* (hereafter referred to as the FY2014 SDF SA). [SRR-CWDA-2014-00006] The FY2014 SDF SA incorporated modeling approaches and inputs that since the issuance of the *Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site*. [SRR-CWDA-2009-00017]

Changes to design features affect projected SDU flow. As such, this evaluation relies on PORFLOW modeling to evaluate the modified flow fields. This document provides the results and a high-level evaluation of each modeling activity. Direction for the modeling activities was described in a Technical Assistance Request (TAR). [SRR-CWDA-2015-00120] Specific modeling inputs were provided via an interoffice memorandum. [SRR-CWDA-2015-00133]

Note that these models do not reflect "Base Case" modeling and should not be interpreted as support for regulatory compliance decisions. These models were explicitly developed to inform future design decisions. For computational efficiency, these models used relatively coarse time stepping (10-year steps rather than 1-year steps) and only six initial radionuclides (and their decay products) were evaluated: Cs-135, I-129, Ra-226, Tc-99, Th-230, and U-234. If SDU design changes are adopted based on the results of these models (or for any other reason), a Special Analysis (SA) or revised Performance Assessment (PA) will be developed to support regulatory compliance decisions.

1.1 Summary of Modeling Activities

Seventeen modeling cases were developed for this activity. Table 1.1-1 provides a high-level summary of each modeling case. Additional details for each of these runs are available within the TAR, the input memo, and the PORFLOW model report (*PORFLOW Simulations Supporting Saltstone Disposal Unit Design Optimization*). [SRR-CWDA-2015-00120; SRR-CWDA-2015-00133; and SRNL-STI-2015-00671] PORFLOW design checking for the modeling cases is documented in the *Design Review of PORFLOW Simulations Supporting Saltstone Disposal Unit Design Optimization*. [SRNL-L3200-2015-00146]

All changes to the model were limited to the future 375-foot diameter SDUs. SDUs 1, 2A, 2B, 3A, 3B, 4, 5A, 5B, and 6 were all left unchanged when modeling the full facility results.

The conclusions about SDU design alternatives presented within this report are only from the perspective of transport modeling and dose results. Any SDU design alternatives that may be investigated must include other performance considerations including structural, environmental, radiation shielding, or construction impacts.

Table 1.1-1: Summary of Modeling Cases

Case	Title	Description
1	Comparison Basis Case	Same inputs as the FY2014 SDF SA Evaluation Case, except with the 10-year time steps and limited radionuclides. Developed as a basis for comparisons.
2	Soil Wall Case	The walls of 375-foot diameter SDUs were modeled as having soil properties, including backfill K_ds.
3	Nominal Shotcrete Wall Case	The walls of 375-foot diameter SDUs were modeled as having nominal shotcrete properties.
4	Conservative Shotcrete Wall Case	The walls of 375-foot diameter SDUs were modeled as having conservative shotcrete properties.
5	Half Wall Thickness Case	The walls of 375-foot diameter SDUs were modeled as being half as thick as in the FY2014 SDF SA.
6	Double Wall Thickness Case	The walls of 375-foot diameter SDUs were modeled as being twice as thick as in the FY2014 SDF SA.
7 [a]	Half Roof Thickness Case	The roof of 375-foot diameter SDUs was modeled as being half as thick as in the FY2014 SDF SA.
8	Half Floor Thickness Case	The floor of 375-foot diameter SDUs was modeled as being half as thick as in the FY2014 SDF SA.
9	Smaller SDU Case	The 375-foot diameter SDUs were replaced with an alternative 250-foot diameter SDU.
10	Over Extension Case	The roof of 375-foot diameter SDUs was modeled as extending five feet past the outer edge of the walls.
11	Over Extension with Capillary Barrier Case	The roof of 375-foot diameter SDUs was modeled as extending five feet past the outer edge of the walls and the walls were surrounded by a two-foot thick capillary (gravel) barrier.
12	Umbrella Case	The High Density Polyethylene (HDPE) layer above the roof of the 375-foot diameter SDU is modeled as being an impervious stainless steel “umbrella” which degrades as a step function at about 7,700 years after closure.
13	Umbrella with Capillary Barrier Case	Same as Case 12, but also includes the two-foot thick capillary (gravel) barrier surrounding the walls (from Case 11).
14	Alternative Layout Case 1	The layout of the SDF was modified to reduce peak doses. See Figure 1.1-1. No change was made to the 375-foot diameter SDUs (i.e., Case 1 designs were applied).
15	Alternative Layout Case 2	The layout of the SDF was modified to reduce peak doses and to use the alternative (smaller) SDU design (from Case 9). See Figure 1.1-2.
16	Degraded Column Case	The roof support columns of 375-foot diameter SDUs were modeled as being initially hydraulically degraded.
17	Optimization Case	Combines Cases 4, 5, 8, and 14.

Note: (a) Case 7 showed unexpected results (discussed in Section 2.2). To further evaluate the roof as a barrier to flow, this case was renamed to Case 7A and a new case, Case 7B, was added, which increases the hydraulic conductivity of the roof. This is a deviation from the input memo.

Figure 1.1-1: Alternative SDF Layout for Case 14

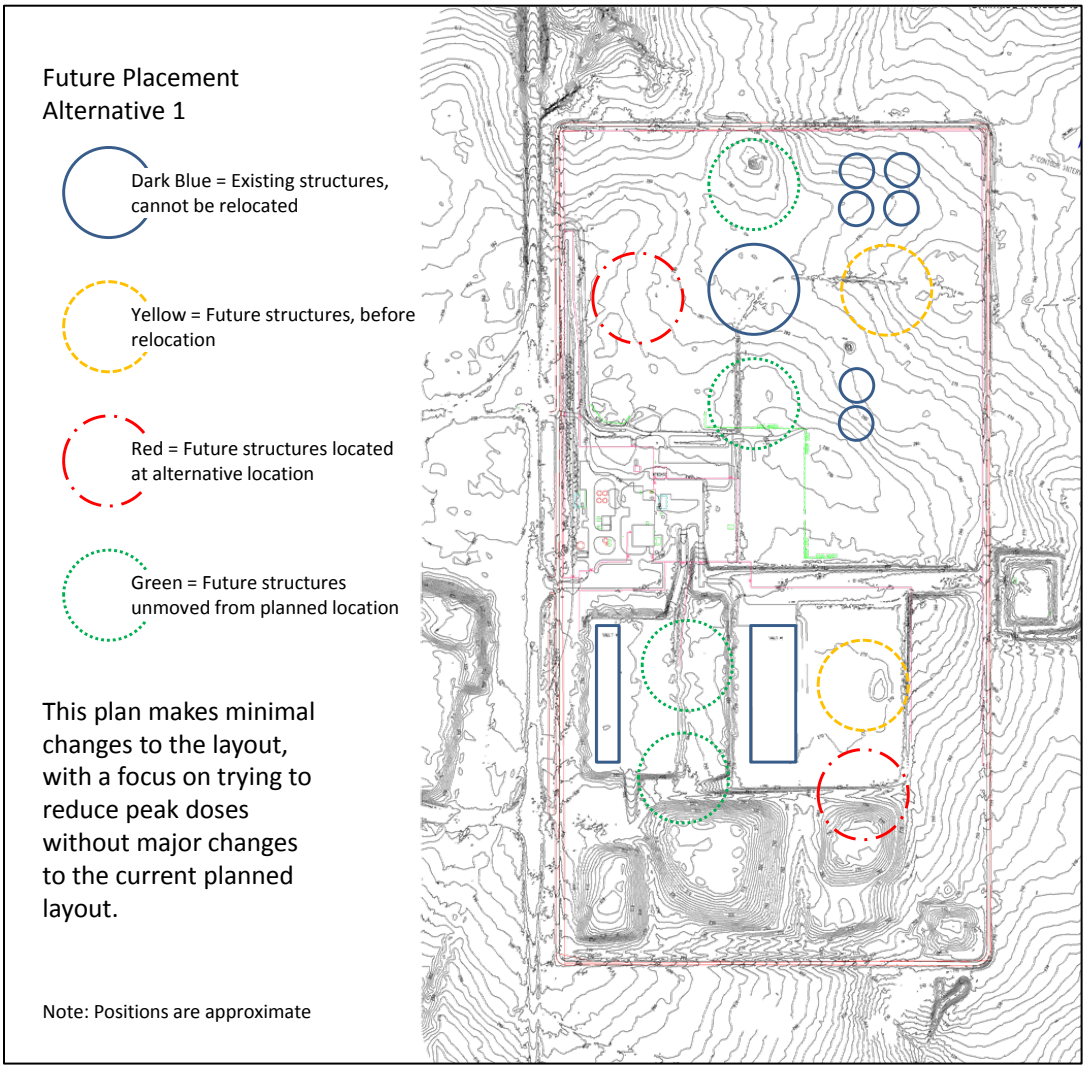
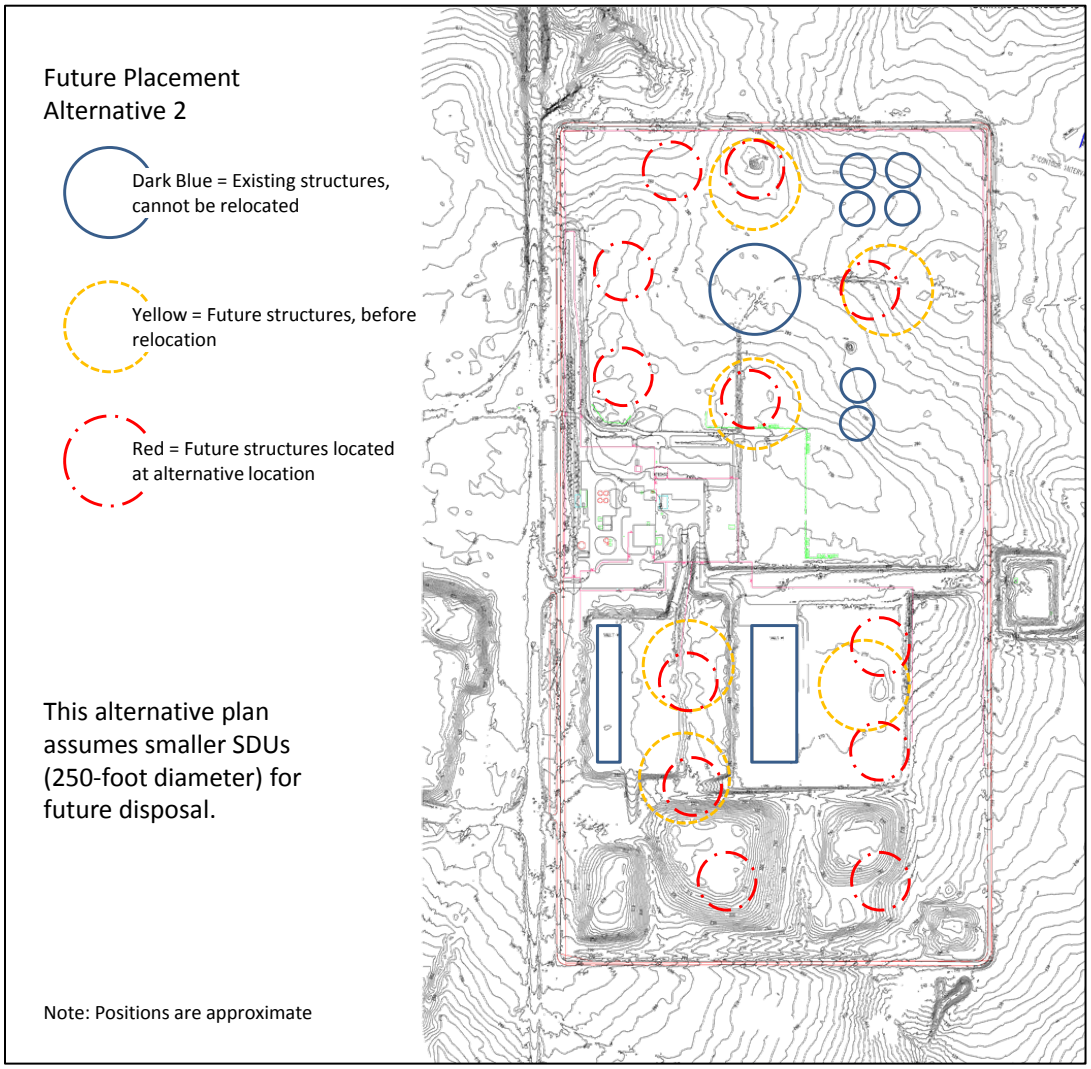


Figure 1.1-2: Alternative SDF Layout for Case 15

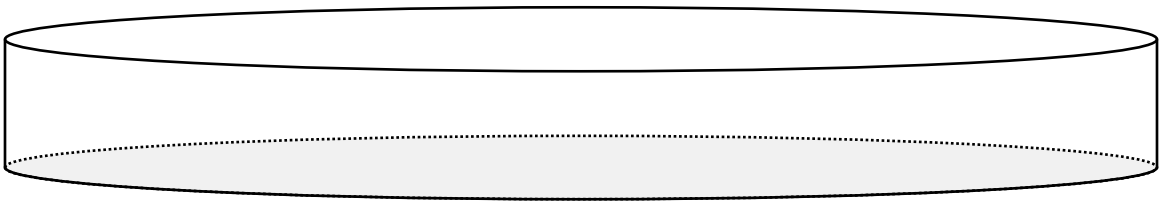


1.2 Interpreting Cross-Section Figures

Throughout this document, there are a number of vertical cross-section figures. The following provides a brief primer for interpreting these types of figures.

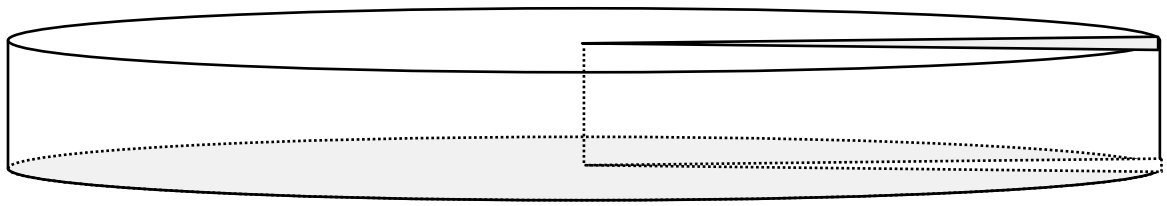
First, each SDU may be thought of as a single cylinder (Figure 1.2-1).

Figure 1.2-1: Conceptual SDU Cylinder



Next, imagine that a "wedge" is cut from this SDU cylinder (Figure 1.2-2). This wedge would start at the center of the SDU, then span right, towards the outer edge.

Figure 1.2-2: Wedge Sliced into Conceptual SDU Cylinder



Presenting only the face of the wedge, along with coordinate axes, provides a complete vertical cross-section (Figure 1.2-3).

Figure 1.2-3: Example of the Vertical Cross-Section of an SDU

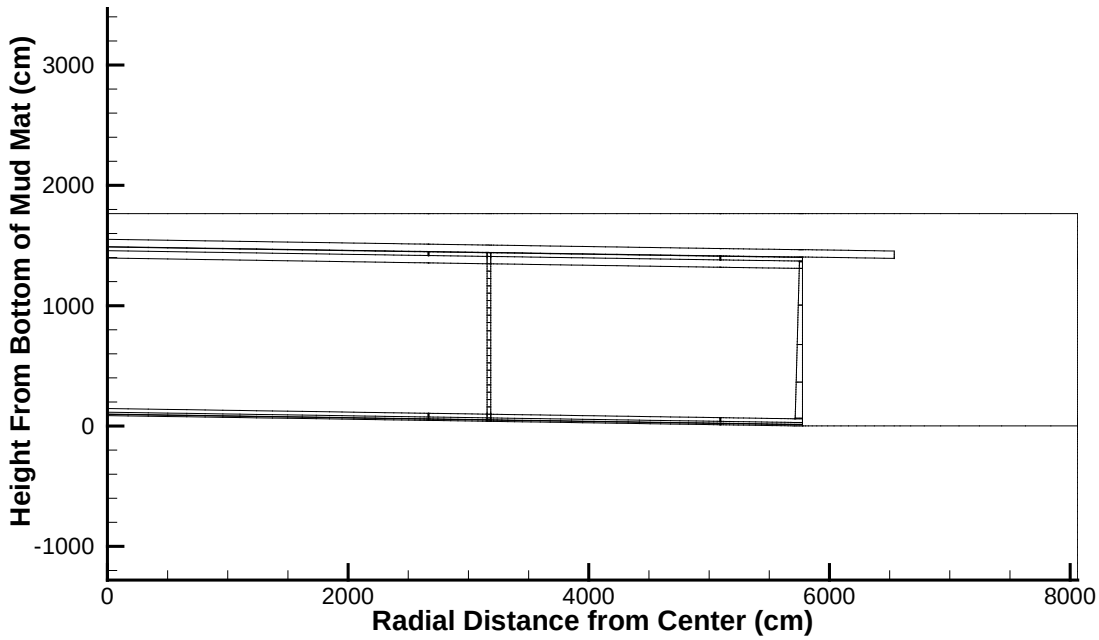


Figure 1.2-4 identifies a number of the larger features that appear within these vertical cross-sections. Similarly, Figure 1.2-5 provides a more detailed view of the outer edge of the SDU and identifies more of the modeled features.

Figure 1.2-4: Vertical Cross-Section of an SDU, Identifying Larger Features

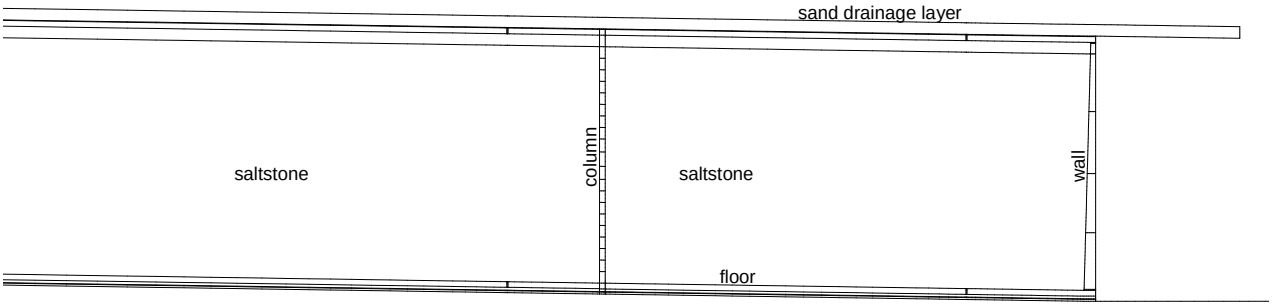
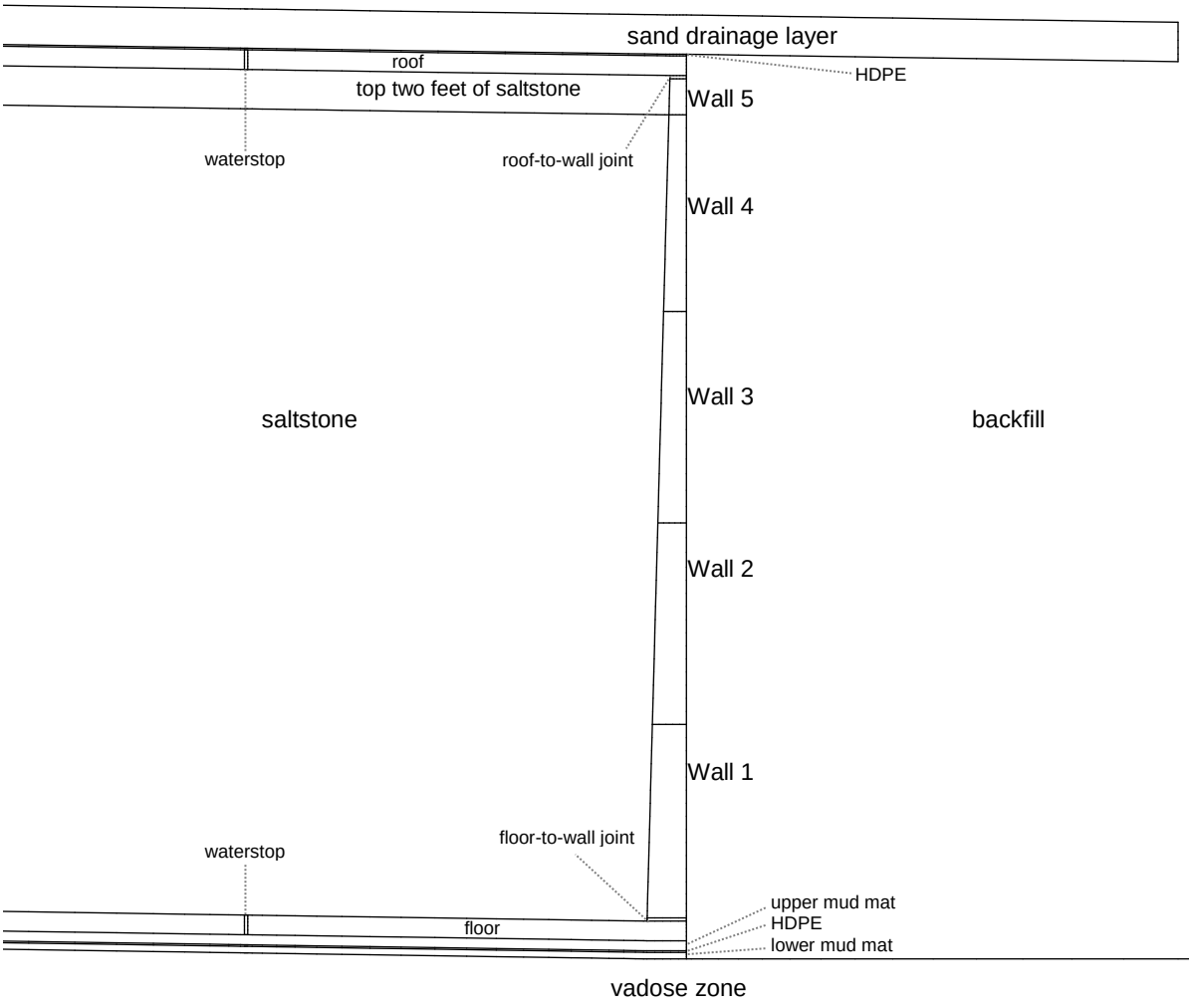


Figure 1.2-5: Vertical Cross-Section of the Outer Edge of an SDU, Identifying Features



2.0 FLOW MODEL RESULTS

All of the cases developed for this evaluation use 10-year time stepping; whereas the Evaluation Case of the FY2014 SDF SA (Case_sa) used 1-year time stepping. Therefore, prior to using these cases for various evaluations, the validity of the longer time-stepping must be verified. Figure 2.0-1 shows the volumetric flow through saltstone from the Evaluation Case of the FY2014 SDF SA (Case_sa) and from Case 1. Case 1 is intended to provide the basis for comparisons throughout these evaluations. It was designed to reflect the Evaluation Case, only with the longer time steps and (for dose evaluations) fewer radionuclides. Figure 2.0-2 shows the same curves along a shorter time scale. The two curves are identical; therefore, Case 1 is an acceptable basis for comparisons.

Figure 2.0-1: Comparison of Case 1 to FY2014 SDF SA Flow Results (0 to 100,000 Years)

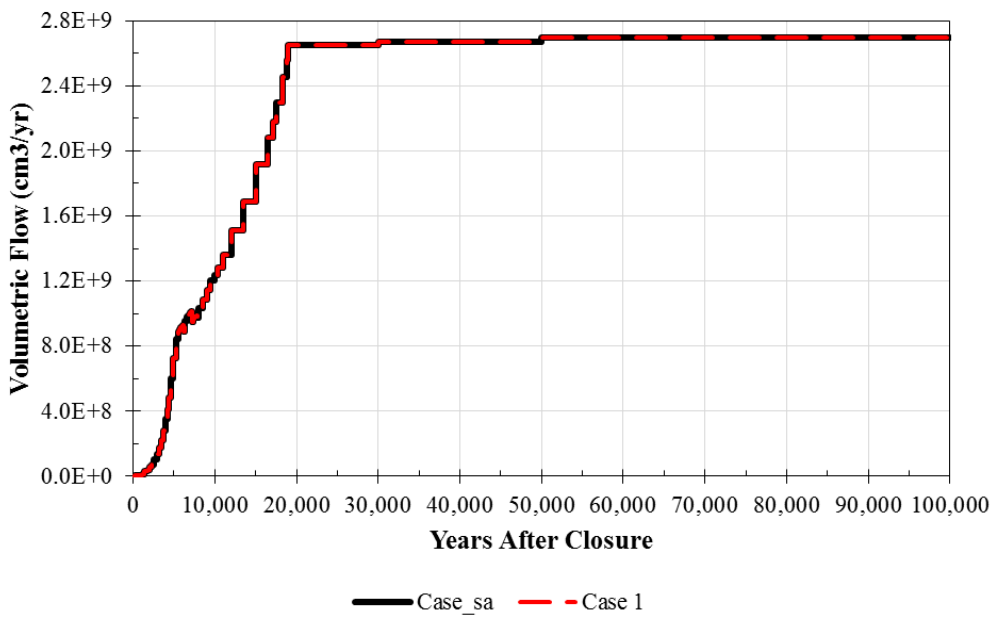
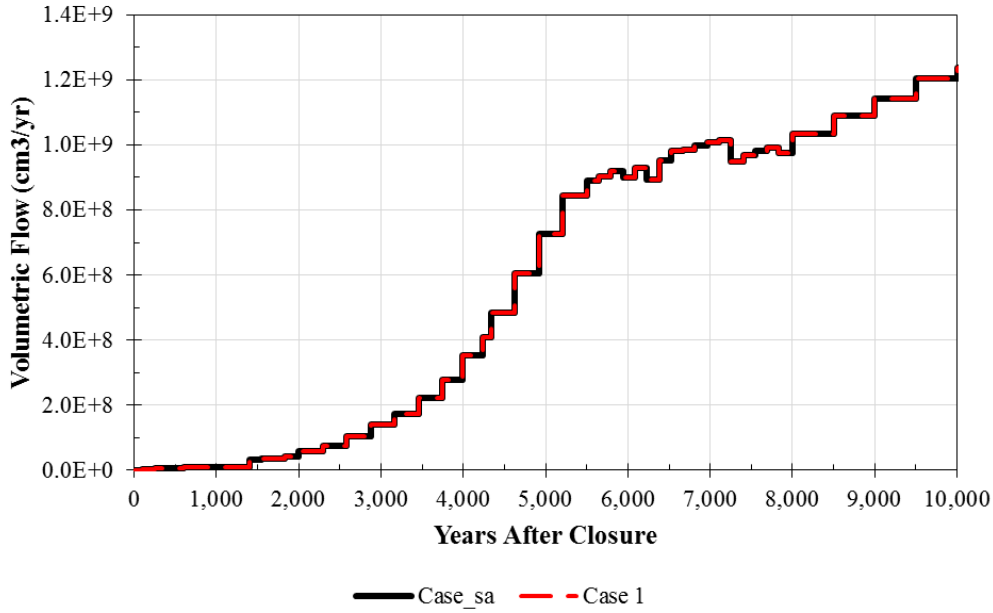


Figure 2.0-2: Comparison of Case 1 to FY2014 SDF SA Flow Results (0 to 10,000 Years)



2.1 Flow Evaluation of Wall Modifications

Model Cases 2, 3, 4, 5, and 6 all involve modifications to the walls. Cases 2 through 4 use the same geometry as Case 1 (presented in Figure 2.1-1), but vary the properties of the wall. Case 2 models the walls as being made of soil. Cases 3 and 4 model the walls as being made of "nominal" shotcrete and "conservative" shotcrete, respectively (see Table 2.1-1).

Figure 2.1-1: Vertical Cross-Section of the SDU Wall: Cases 1 through 4

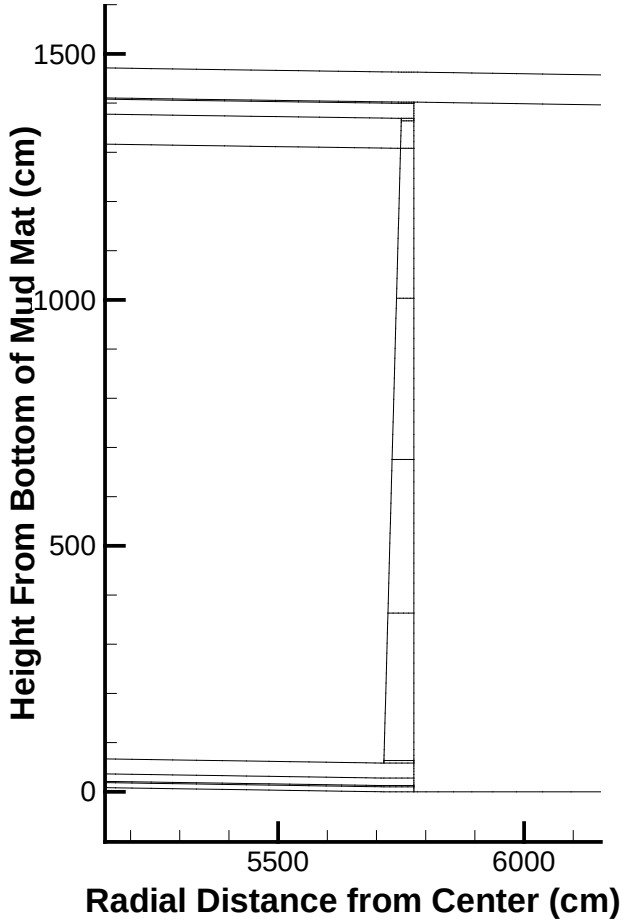


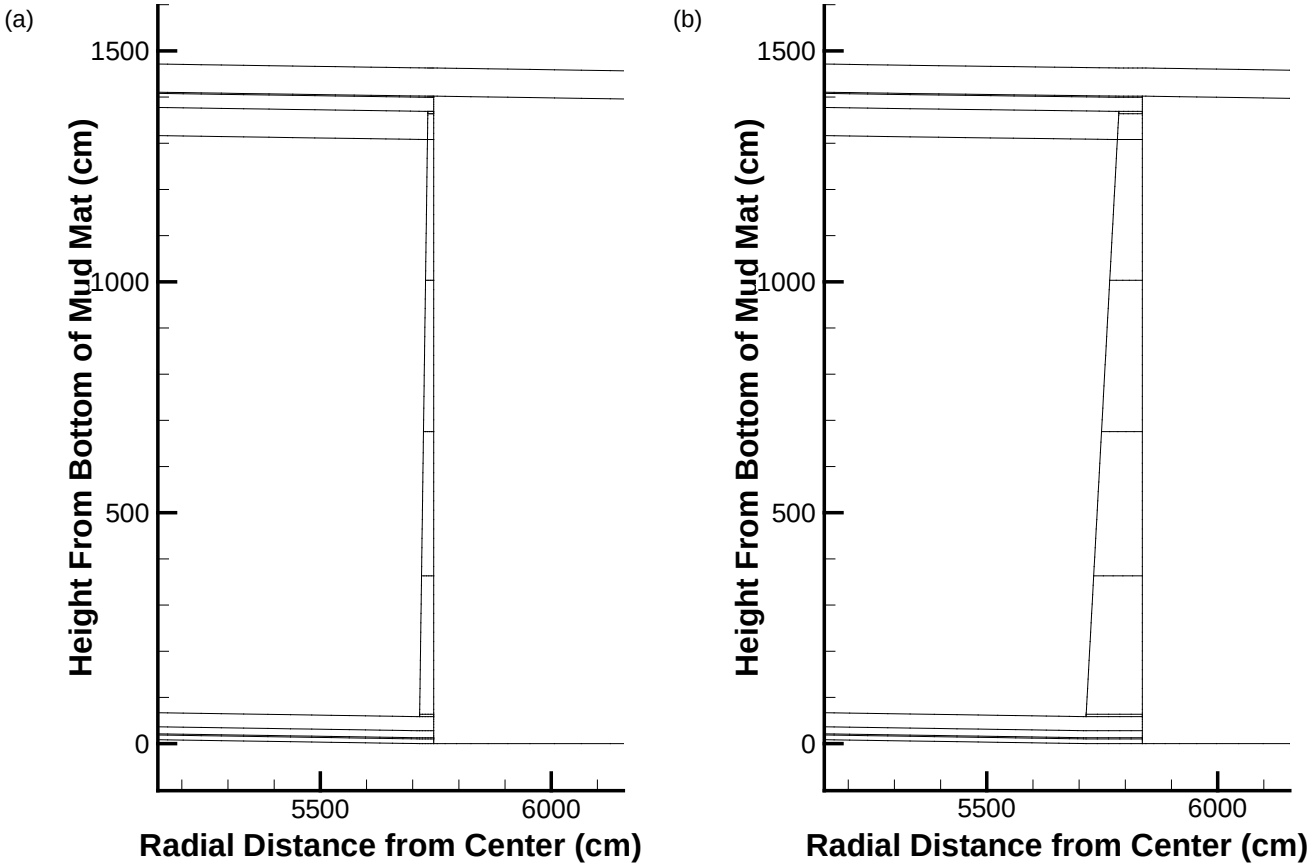
Table 2.1-1: Modeled Wall Properties

Case	Material	Saturated Hydraulic Conductivity (cm/sec)		Diffusion Coefficient (cm^2/s)		Porosity (%)	Bulk Density (g/cm^3)
		Intact	Degraded	Intact	Degraded		
Case 1	Concrete (As-Designed)	9.3E-11	4.1E-05	5.0E-08	5.3E-06	11%	2.21
Case 2	Backfill Soil	4.1E-05		5.3E-06		35%	1.71
Case 3	Nominal Shotcrete	1.0E-08	4.1E-05	1.0E-07	5.3E-06	14%	2.08
Case 4	Conservative Shotcrete	1.0E-07	4.1E-05	1.0E-07	5.3E-06	14%	2.07

Note: The saturated hydraulic conductivity value for nominal shotcrete is consistent with test results reported in SRR-SDU-012-00027. The conservative shotcrete value is assumed by increasing the nominal shotcrete value by an order of magnitude.

Cases 5 and 6 model the walls with half thickness and double thickness, respectively (see Figure 2.1-2), but use the same material properties as Case 1.

Figure 2.1-2: Vertical Cross-Section of the SDU Wall: Cases 5 and 6



(a) Case 5 (Half Wall Thickness)
(b) Case 6 (Double Wall Thickness)

Figure 2.1-3 shows the volumetric flow rates through the wall (i.e., the sum of each of the five wall segments) for Cases 1 through 6. Cases 5 and 6 show the lowest and highest volumetric flow rates, respectively. These results are expected because Case 5 has walls that are half as thick (i.e., a smaller wall volume means less pore volume, therefore less volumetric flow); whereas Case 6 has walls that are twice as thick (i.e., a larger wall volume means more pore volume, therefore more volumetric flow).

Case 2 shows the second highest volumetric flow. Because Case 2 simulates the walls as having the same properties as backfill soil, increased flow is expected.

Cases 3 and 4 are very similar to Case 1. The only differences are observed at very early times, while flow rates are still extremely low and when the initial hydraulic conductivity of the shotcrete (1.0E-08 cm/sec for nominal shotcrete and 1.0E-07 cm/sec for conservative shotcrete) is mostly undegraded. However, because the walls are assumed to degrade very quickly, the initial condition is not significant after about 500 years. These changes are not observable in Figure 2.1-3, so Figure 2.1-4 shows the results during the first 500 years.

Figure 2.1-3: Comparison of Flow Results Through the Wall: Cases 1 through 6

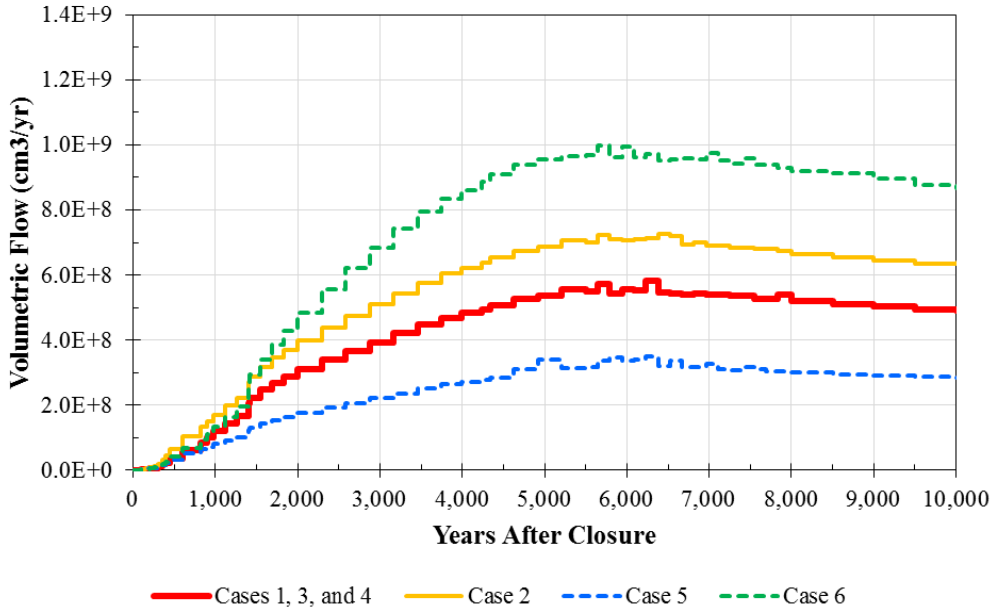
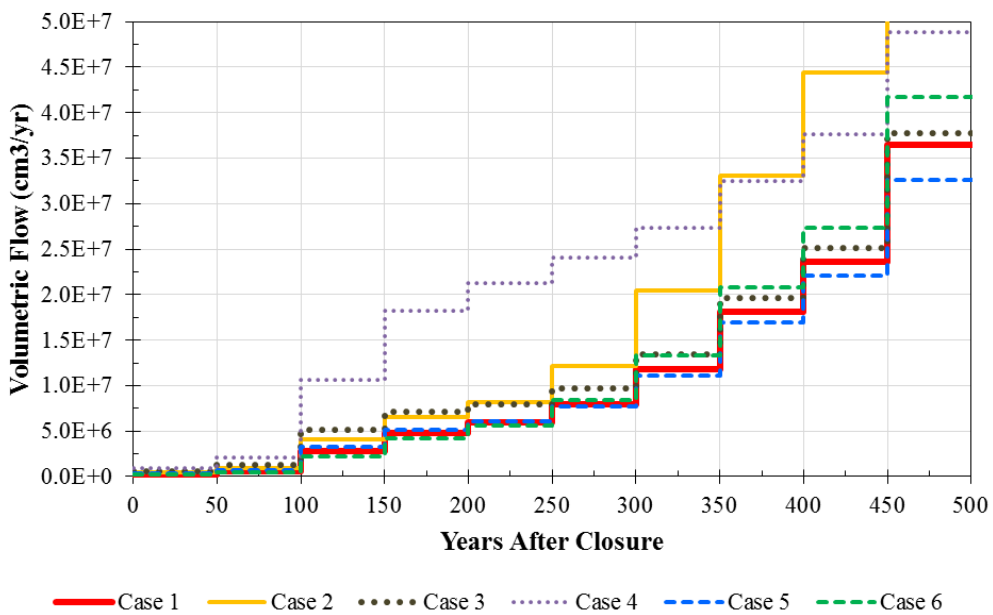


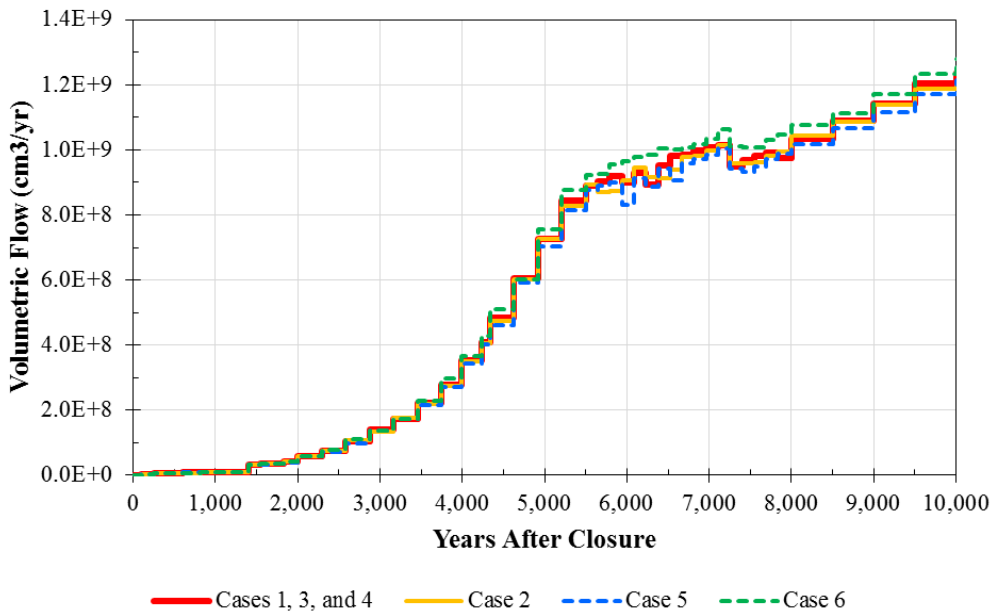
Figure 2.1-4: Comparison of Flow Results Through the Wall: Cases 1 through 6 (0 to 500 Years)



Although the differences in the flow though the walls are noticeable, the impact on flow through the saltstone is relatively minimal as seen in Figure 2.1-5. After the roof degrades (by 1,400 years), the dominant direction of water penetration is downward, such that water flowing inward from the walls has a smaller impact on the overall volumetric flow through saltstone. The

impacts from the modifications within each of these cases, with respect to dose, will be evaluated in Section 3.

Figure 2.1-5: Comparison of Flow Results Through Saltstone: Cases 1 through 6

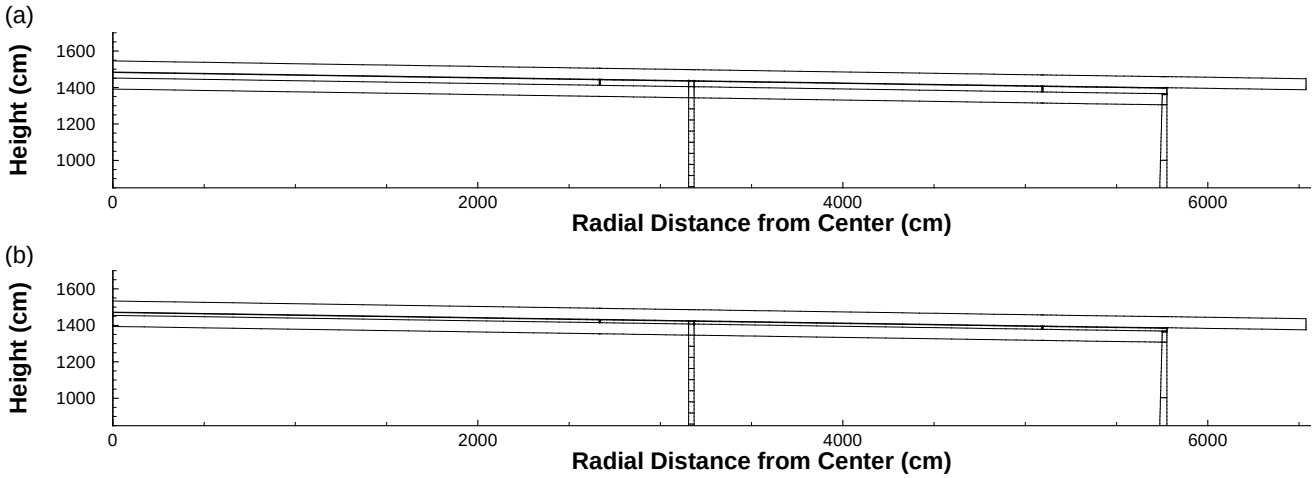


2.2 Flow Evaluation of Roof Modifications

Cases 7, 10, and 11 look at variations on the roof of the 375-foot diameter SDUs.

In Case 7, the thickness of the roof was reduced by half (from 12 inches to 6 inches), as specified in the input document (SRR-CWDA-2015-00133). Figure 2.2-1 provides a cross-section of the roof for Cases 1 and 7.

Figure 2.2-1: Vertical Cross-Section of the SDU Roof: Cases 1 and 7



(a) Case 1 (Comparison Basis Case)
(b) Case 7 (Half Roof Thickness)

When comparing the modeled flow results from Case 7 to those from Case 1, the impact on the volumetric flow due to the reduced roof thickness revealed unexpected behavior: despite the thinner roof, the volumetric flow through the roof and through the saltstone was reduced by more than 50%. This is likely caused by the extreme differences in the hydraulic conductivities between the sand drainage layer (5.0E-02 cm/s) and the saltstone (which varies between 6.4E-07 cm/s and 8.1E-07 cm/s within 10,000 years). In Case 1 the 12-inch roof (with an intermediate hydraulic conductivity of 4.1E-05 cm/s after 1,400 years) provided an effective "buffering zone" which allowed water to penetrate downward. By reducing the thickness of the roof, this buffering zone was less effective, such that a greater percentage of flow followed a path of less resistance (i.e., flow was diverted horizontally).

Although this may be a real phenomenon, it is nonconservative and counter to expectations (i.e., a thinner roof was expected to increase flow). Therefore, Case 7 was renamed to Case 7A and an alternative Case 7 was developed, identified as Case 7B. For Case 7B, instead of reducing the thickness of the roof by half, the hydraulic conductivity was doubled. This resulted in a flow field that more closely resembled the expected flow conditions (shown in Figures 2.2-2 and 2.2-3).

Figure 2.2-2: Comparison of Flow Results Through the Roof: Cases 1, 7A, and 7B

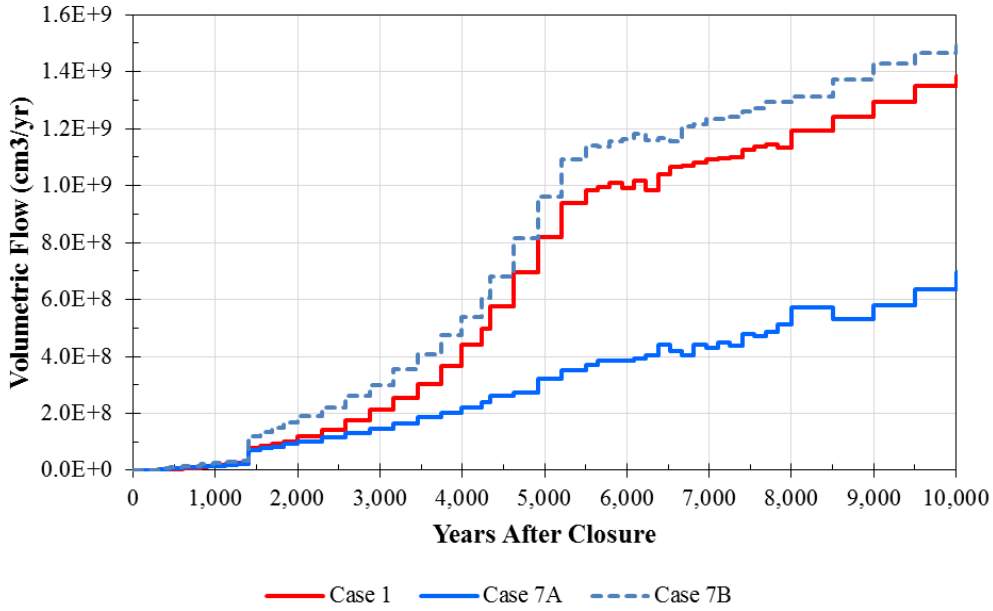
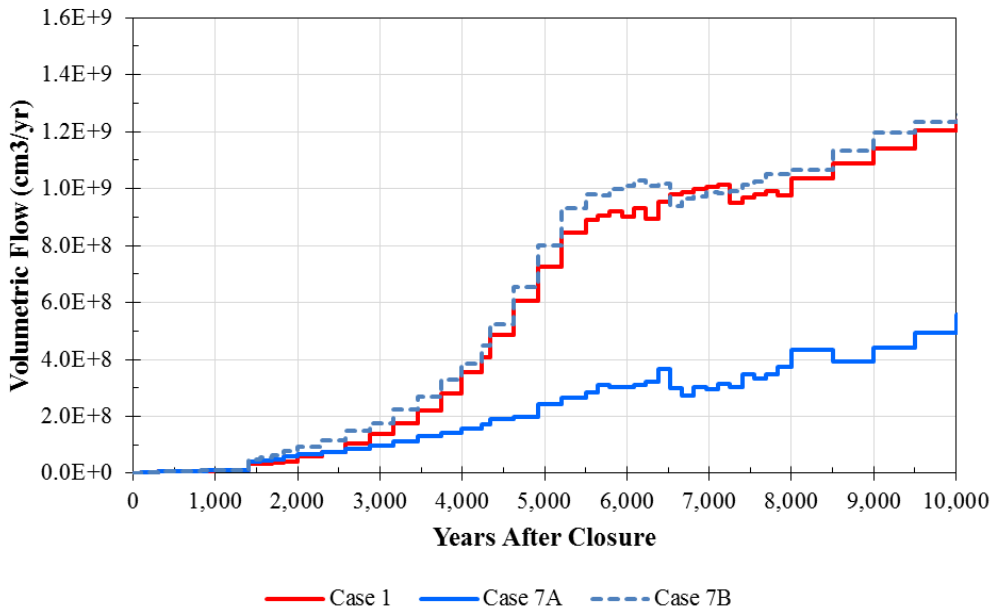


Figure 2.2-3: Comparison of Flow Results Through the Saltstone: Cases 1, 7A, and 7B



Cases 10 and 11 both model the roof as extending five feet beyond the edge of the walls. Case 11 also includes a two-foot thick capillary barrier (gravel) that surrounds the outside of the SDU walls. The purpose of this barrier is to provide a path of lower resistance to divert water away from the outer edge of the SDU. Figures 2.2-4 and 2.2-5 show the configurations for these two modeling cases.

Figure 2.2-4: Vertical Cross-Section of an SDU: Case 10

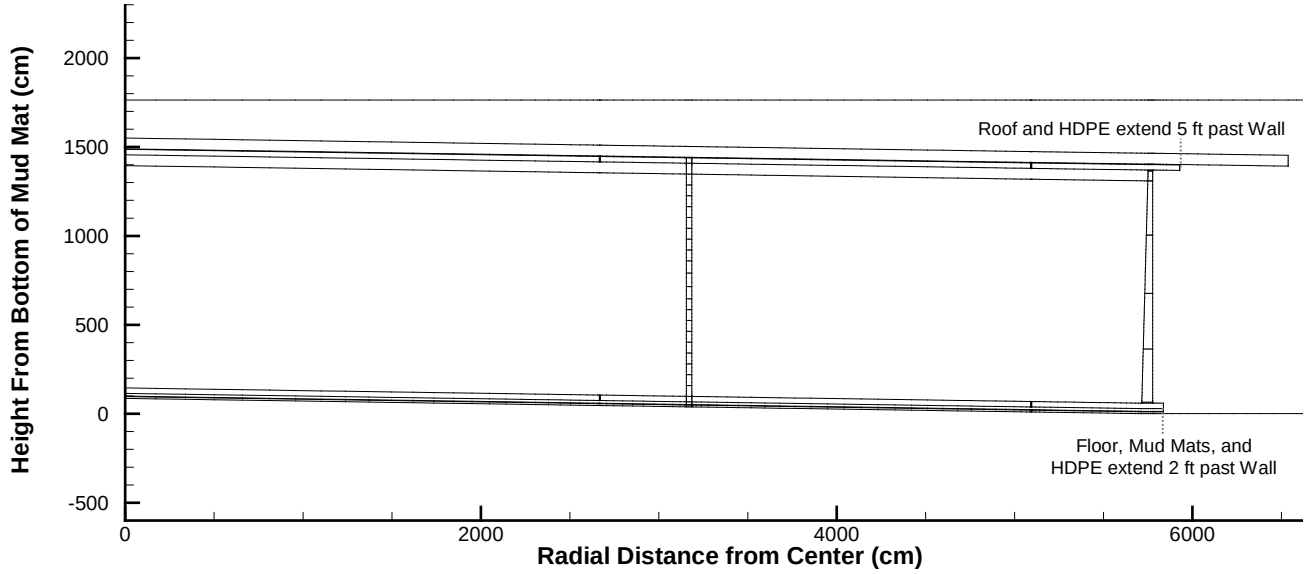
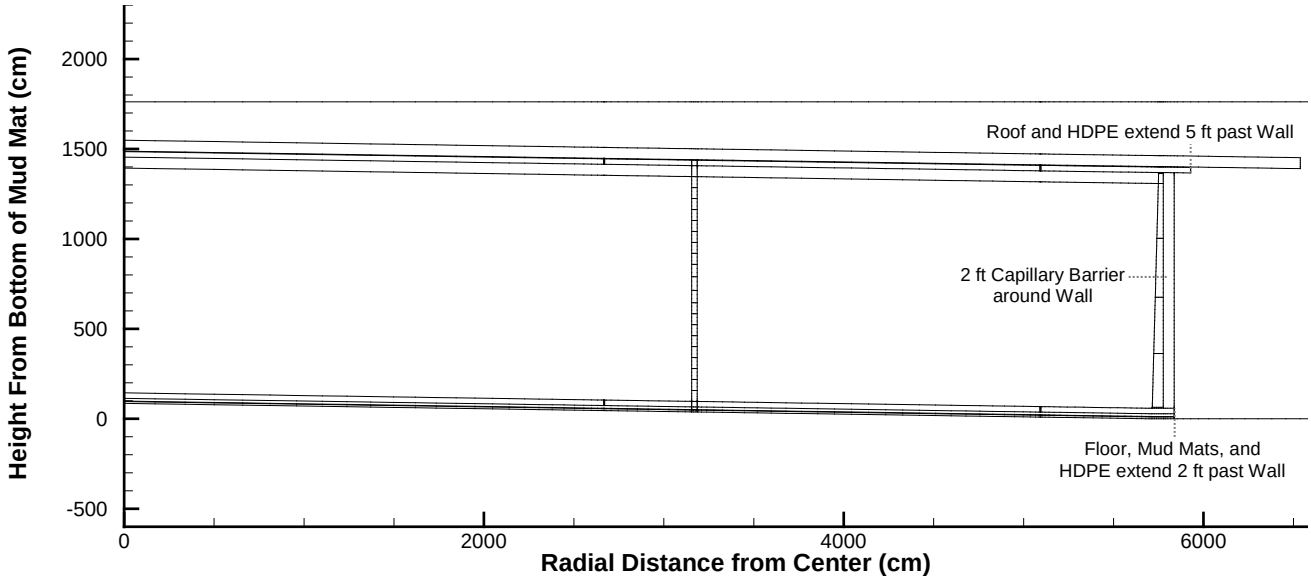


Figure 2.2-5: Vertical Cross-Section of an SDU: Case 11



An initial comparison of the volumetric flow through the roof (Figure 2.2-6) is somewhat misleading for these cases, because the roof in Case 1 has a different volume from the roof in Cases 10 and 11. Therefore, the volumetric flow through the saltstone provides a better basis for comparison (Figure 2.2-7).

Figure 2.2-6: Comparison of Flow Results Through the Roof: Cases 1, 10, and 11

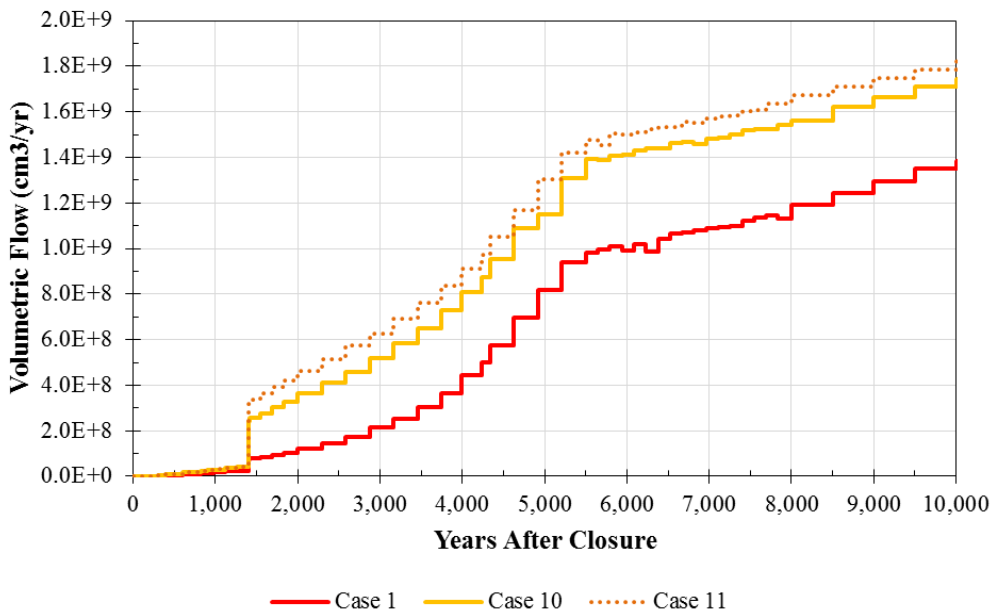


Figure 2.2-7: Comparison of Flow Results Through the Saltstone: Cases 1, 10, and 11

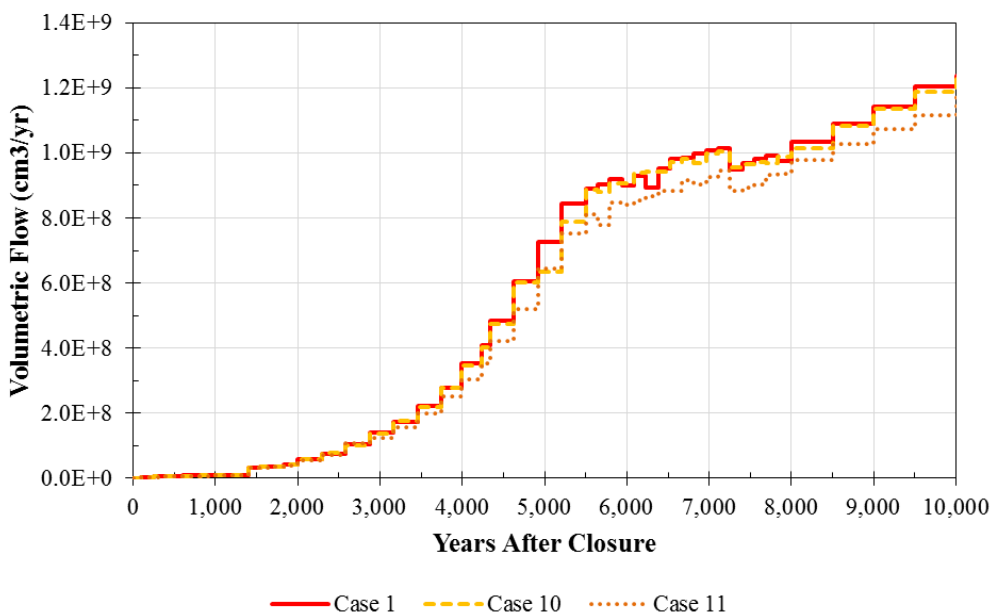
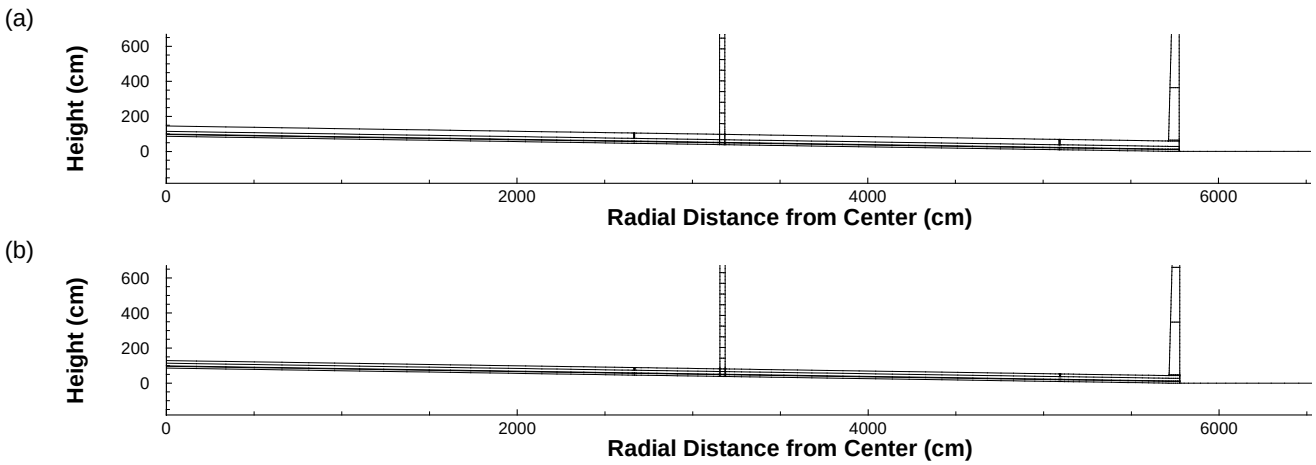


Figure 2.2-7 shows that Case 10 is not significantly different from Case 1, except between about 4,900 years and 5,500 years, when it shows slightly lower flow. This timing corresponds to the timing of the peak doses from I-129 releases (per the FY2014 SDF SA); therefore, Case 10 might show lower peak doses than Case 1 (as will be evaluated in Section 3). For Case 11, the volumetric flow rate is typically approximately 8% less than Case 1 due to flow being diverted via the capillary barrier.

2.3 Flow Evaluation of Floor Modifications

In Case 8, the thickness of the floor for the 375-foot diameter SDU is reduced by half (from 12 inches to 6 inches). Figure 2.3-1 provides a cross-section of the floor for Cases 1 and 8.

Figure 2.3-1: Vertical Cross-Section of the SDU Floor: Cases 1 and 8



(a) Case 1 (Comparison Basis Case)
(b) Case 8 (Half Floor Thickness)

A comparison of the volumetric flow through the floor (Figure 2.3-2) and through the saltstone (Figure 2.3-3) shows a negligible impact within 10,000 years. Case 8 does show slightly higher volumetric flow through the saltstone between 1,400 years and about 4,500 years. This slight increase in early flow could result in depressing peak doses by "bleeding" off the available inventory of I-129; this will be evaluated in Section 3.

Figure 2.3-2: Comparison of Flow Results Through the Floor: Cases 1 and 8

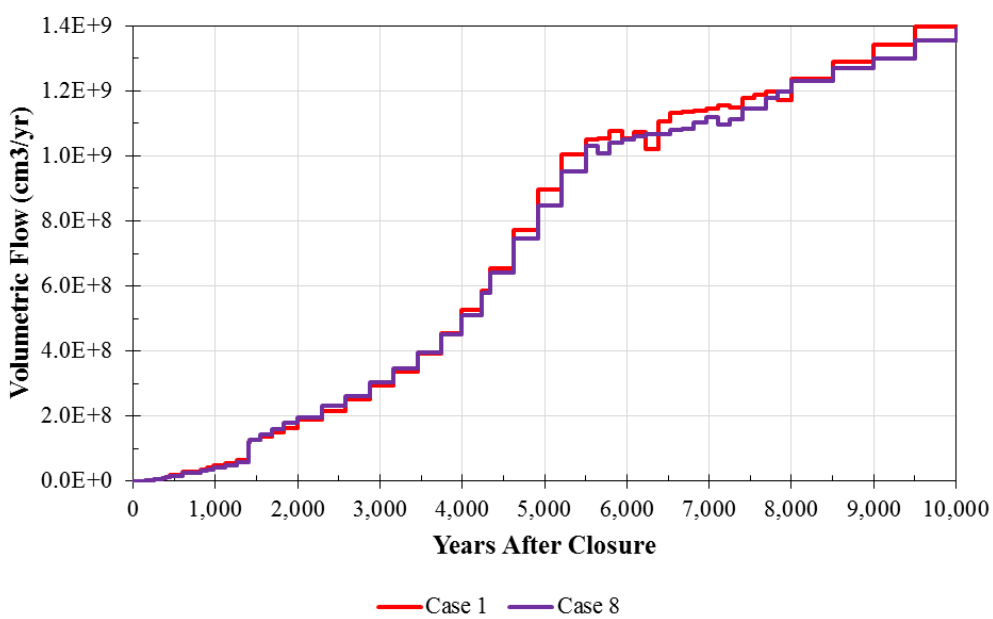
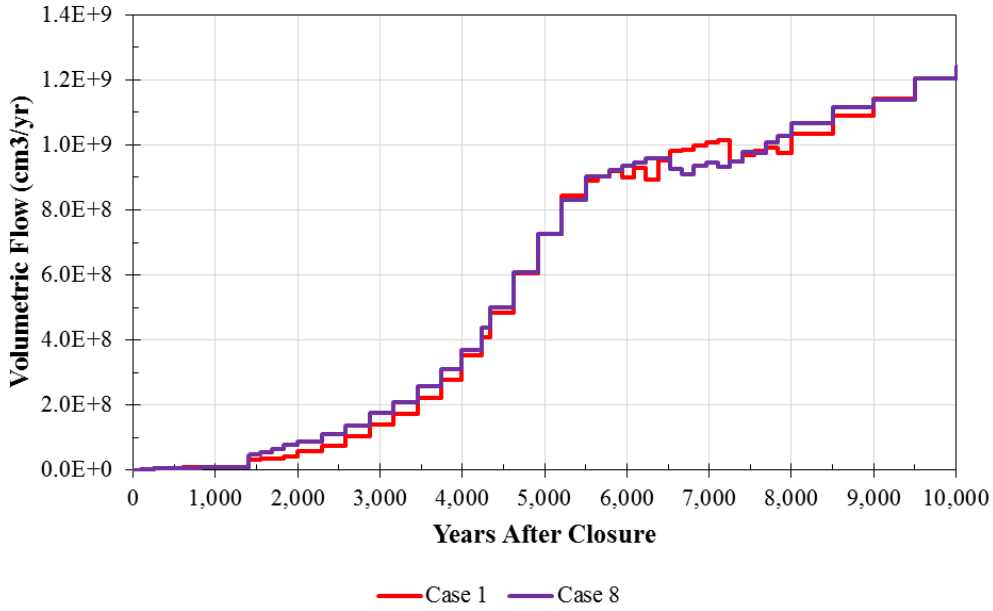


Figure 2.3-3: Comparison of Flow Results Through the Saltstone: Cases 1 and 8



2.4 Flow Evaluation Due to Stainless Steel Umbrella

Cases 12 and 13 both include a stainless steel umbrella in the place of the HDPE layer above the roof (see Figure 1.2-5). This stainless steel umbrella is assumed to fail as a step function. The timing of this failure is estimated to occur at approximately 7,700 years after closure based on an analysis of steel degradation from the *Life Estimation of High Level Waste Tank Steel for H-Tank Farm Closure Performance Assessment* (SRNL-STI-2010-00047) and the following assumptions:

(1) an assumed stainless steel umbrella thickness of 0.5 inches,

(2) an assumed general corrosion rate of 0.04 mil per year (mpy),

(3) an assumed pitting depth based on the function $d = 7.255t^{0.1434}$, and

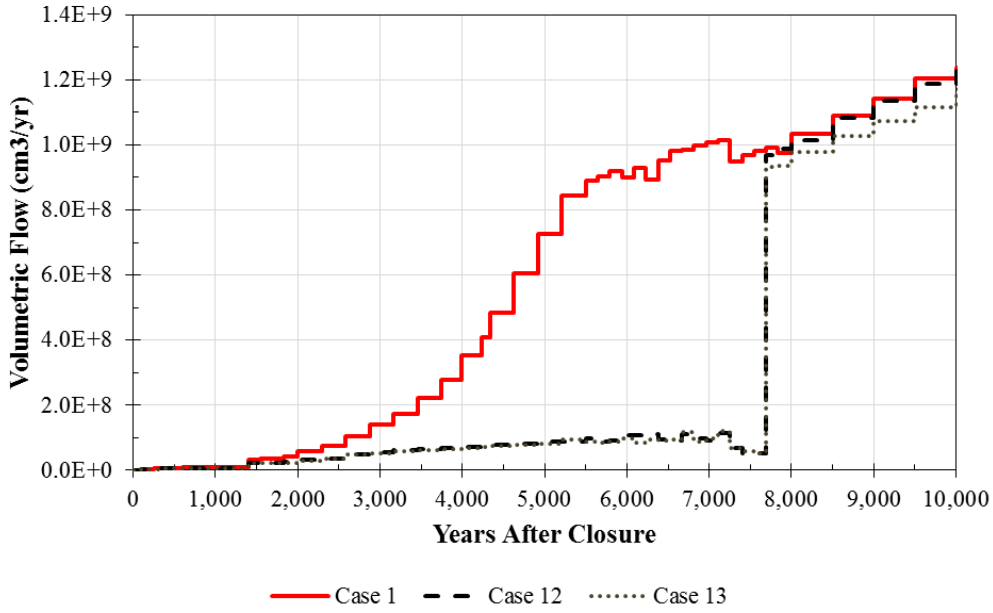
(4) an assumption that complete failure occurs once the combined effects of general corrosion and pitting depths reaches 2/3rd the thickness of the material.

These assumptions may be overly conservative, but given that 7,000 year-old steel does not exist, there is uncertainty in how it may degrade over time.

Case 13 also includes a two-foot thick capillary barrier (gravel) that surrounds the outside of the SDU walls (similar to the equivalent barrier in Case 11).

Figure 2.4-1 shows the volumetric flow rates through the saltstone for Cases 12 and 13. Case 1 is also included for comparison purposes.

Figure 2.4-1: Comparison of Flow Results Through Saltstone: Cases 1, 12, and 13



As expected, the stainless steel umbrella provides a barrier to flow prior to the assumed failure time. After the umbrella is instantly degraded, the flows for Cases 12 and 13 very closely resemble the flows from Case 10 and 11, respectively. Section 3 will evaluate how these flow changes will impact dose results.

2.5 Flow Evaluation of Degraded Roof Support Columns

In Case 16, the roof support columns were modeled as being fully degraded at the start of the simulation. The hydraulic properties of the representative column is modeled in 2-foot segments; Figures 2.5-1 and 2.5-2 show the volumetric flow through the segments for the comparison case (Case 1) and the column degradation case (Case 16), respectively.

As shown in Figures 2.5-1 and 2.5-2, during the first 1,400 years (i.e., prior to the roof degradation) flow through the column is negligible for both Case 1 and Case 16. Once the roof is degraded, Case 1 shows significant variability in the flow as the column segments gradually degrade over time. For Case 16, there is relatively little variability as the entire column effectively acts as a fast flow path that reflects the rate of incoming flow from above. By 7,500 years, both flow profiles are identical.

Figure 2.5-1: Volumetric Flow Results Through Column Segments: Case 1

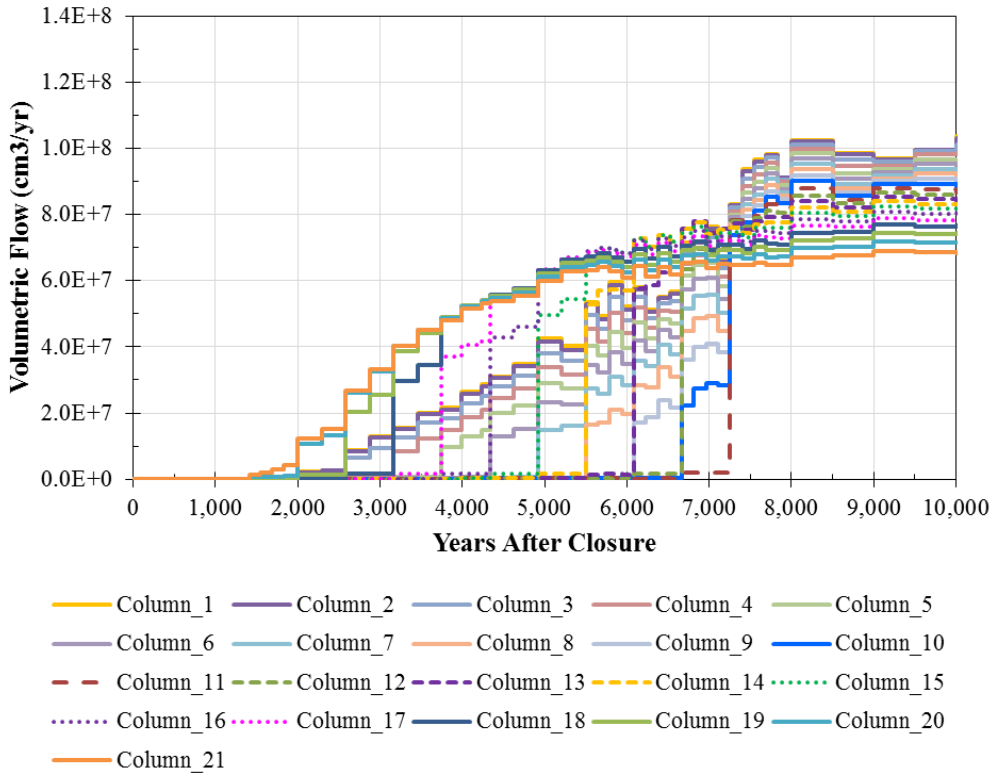
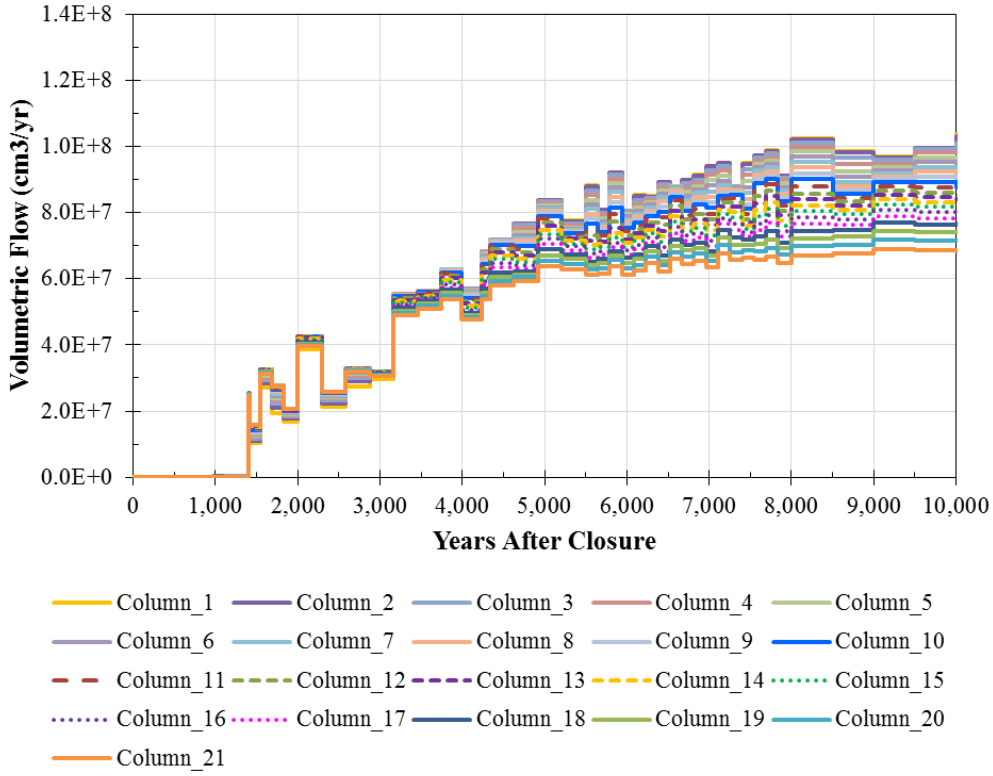
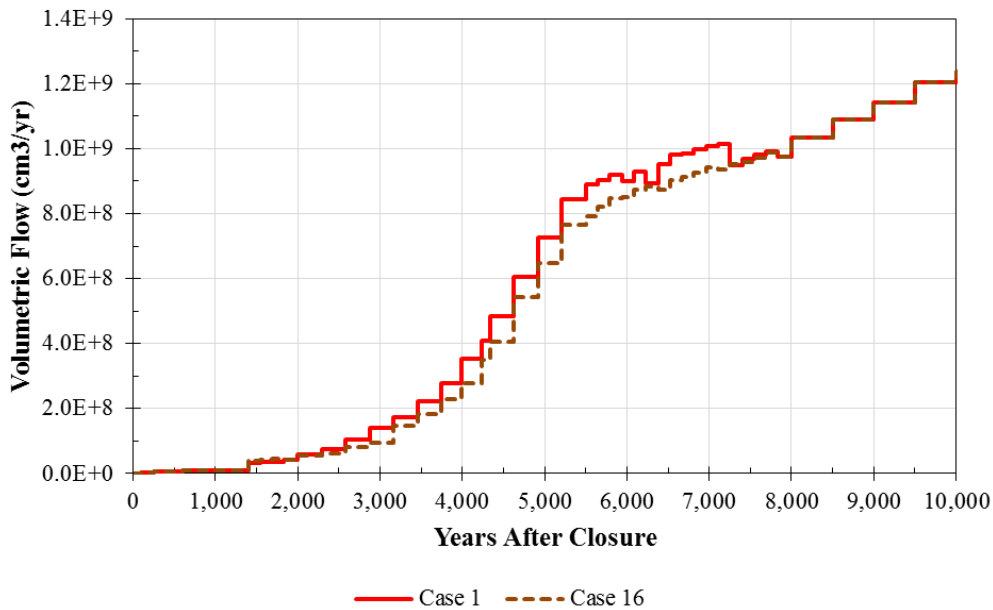


Figure 2.5-2: Volumetric Flow Results Through Column Segments: Case 16



However, the roof support columns make up a relatively small fraction of the total volume of the system. As such, the net effect on the volumetric flow through the saltstone is relatively small (Figure 2.5-3). The initially degraded columns provide a preferential flow path, channeling some water away from the saltstone. As such, modeling degraded columns is expected to be non-conservative for periods greater than 1,400 years; however, these results also indicate that the SDU design may be optimized if the columns can be designed in such a way as to facilitate greater flow (e.g., hollow roof support columns), thereby diverting water away from the source term.

Figure 2.5-3: Comparison of Flow Results Through Saltstone: Cases 1 and 16



2.6 Flow Evaluation of 250-Foot Diameter SDU

In Case 9, the geometry of the SDU was revised. Instead of the diameter of 375 feet, this alternative SDU design had a diameter of 250-feet. The height of the SDU was set to 40 feet. The 1.5% slope was retained from the 375-foot diameter SDU design, as were the thicknesses of the roof, floor, and walls. Figure 2.6-1 provides a vertical cross-section of 375-foot diameter SDU (black) overlaying the 250-foot diameter SDU (red).

The 375-foot diameter SDU has an estimated maximum capacity between 30 and 35 million gallons; whereas the 250-foot diameter SDU has maximum capacity of about 15 million gallons. As such, this design would require at least twice as many disposal units to be constructed in order to accommodate an equivalent disposal volume for the facility.

Due to the significant difference in the volume of saltstone, the volumetric flow rates between Cases 1 and 9 do not provide an adequate basis for comparison; therefore, the spatially-averaged Darcy velocities shall be used. The Darcy velocity through saltstone (Figure 2.6-2) shows that this alternative design (Case 9) results in much slower rates of flow through the SDU saltstone during the first 10,000 years. This is attributed to the shorter distance from the center of the SDU

to the edge, thereby providing less opportunity for the water to penetrate into the roof before shedding off the edge of the SDU. Given a longer timeline, both SDUs reach the same flow rate (Figure 2.6-3).

Figure 2.6-1: Vertical Cross-Section of the 375-Foot Diameter SDU Overlaying a Vertical Cross-Section of the 250-Foot Diameter SDU: Cases 1 and 9

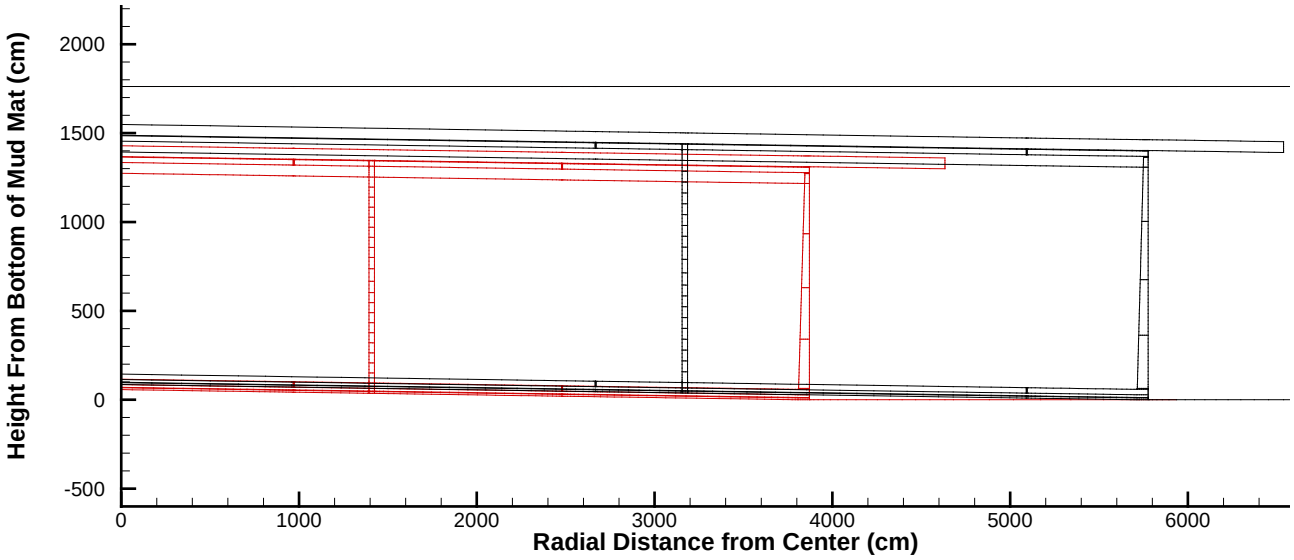


Figure 2.6-2: Comparison of Flow Results Through the Saltstone Within 10,000 Years: Cases 1 and 9

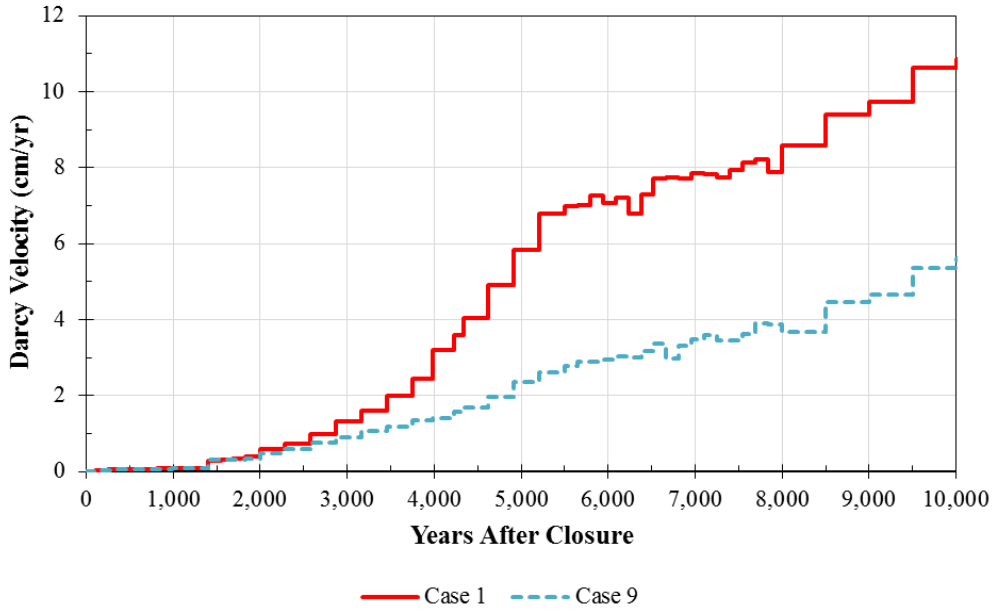
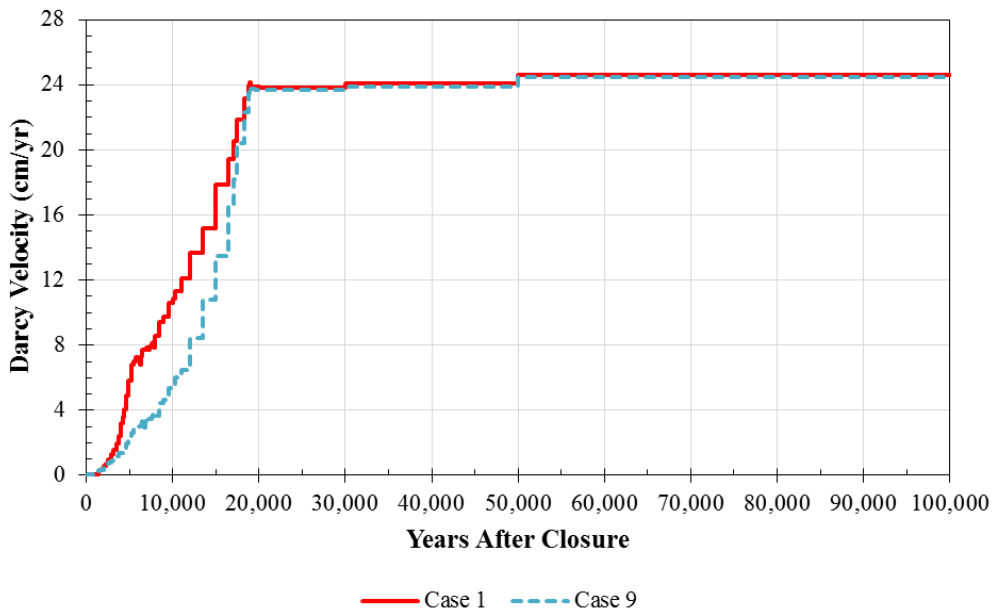


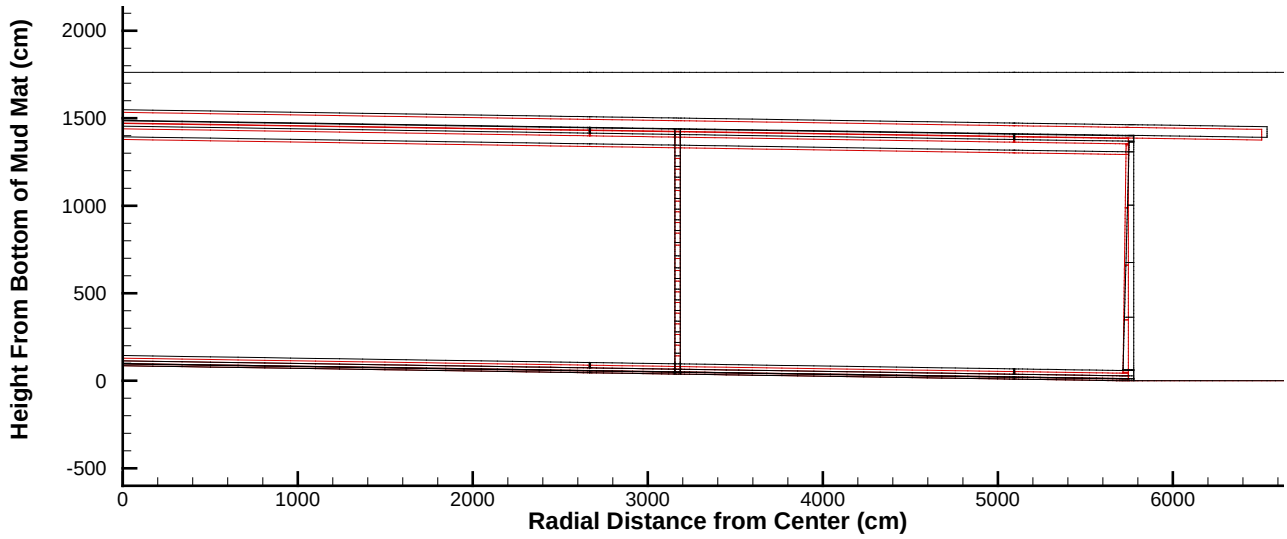
Figure 2.6-3: Comparison of Flow Results Through the Saltstone Within 100,000 Years: Cases 1 and 9



2.7 Flow Evaluation of Optimization Case

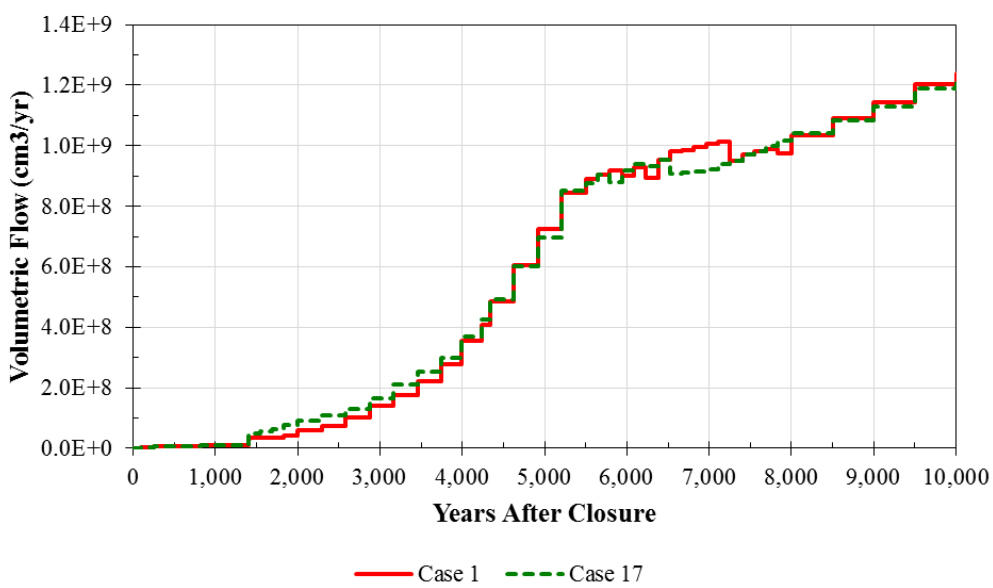
Case 17 was developed after review of the results from the previous cases. This case combines a number of the cases to determine the combined impact. Specifically, the flow modifications from Cases 4, 5, and 8 were combined (i.e., the walls were assumed to be made of conservative shotcrete, the walls were half as thick, and the floor was half as thick). Due to the uncertainty associated with the significant differences in the flow results from Cases 7A and 7B, no changes were applied to the roof. The resulting SDU shall hereafter be referred to an "optimized 375-foot diameter SDU". Figure 2.7-1 provides a vertical cross-section of a 375-foot diameter SDU (black) overlaying the optimized 375-foot diameter SDU (red).

Figure 2.7-1: Vertical Cross-Section of the 375-Foot Diameter SDU Overlaying a Vertical Cross-Section of the Optimized 375-Foot Diameter SDU: Cases 1 and 17



Despite these design differences, the flow through saltstone is not significantly different (see Figure 2.7-2). In general, the optimized SDU has slightly higher flow at early times (i.e., during the first 5,000 years) and slightly lower flow at later times (i.e., after the first 5,000 years). These changes are expected to have a negligible impact on dose results, which shall be evaluated in Section 3.

Figure 2.7-2: Comparison of Flow Results Through Saltstone within 10,000 Years: Cases 1 and 17



3.0 DOSE EVALUATIONS BASED ON FLOW AND TRANSPORT RESULTS

The following provides dose comparisons based on the transport results from the various design modifications. All doses presented reflect doses to the member of the public (MOP) based on well water drawn from the 100-meter facility boundary. The same dose methodologies were applied as used in the FY2014 SDF SA (SRR-CWDA-2014-00006) and as described in the report *Dose Calculation Methodology for Liquid Waste Performance Assessments at the Savannah River Site*. [SRR-CWDA-2013-00058]

Every dose figure includes Case 1 dose results as the basis for comparison. Also, note that figures showing doses out to 50,000 years include a significant Tc-99 dose contribution at approximately 31,000 years. This peak does not change in magnitude or timing because it is due to releases from the 150-foot diameter SDUs (i.e., SDUs 2A, 2B, 3A, 3B, 5A, and 5B). These SDUs were not modified for any of the modeling considered in this evaluation. Therefore, only impacts to the secondary dose peak (near 38,500 years) are considered.

Table 3.0-1 provides a summary of the peak dose results from each of the transport cases considered.

Table 3.0-1: Summary of Dose Results from Transport Modeling

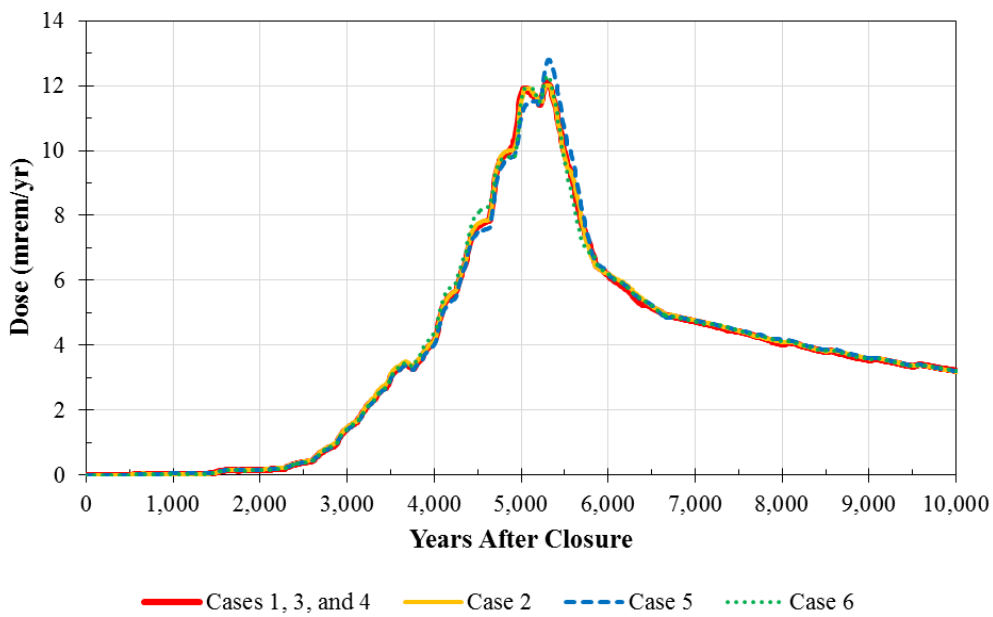
Case	Title	Peak MOP Dose (mrem/yr)[a]		
		Within 1,000 Years	Within 10,000 Years	Between 35,000 Years and 50,000 Years[b]
1	Comparison Basis Case	0.035	12.1	170
2	Soil Wall Case	0.046	12.0	170
3	Nominal Shotcrete Wall Case	0.036	12.1	170
4	Conservative Shotcrete Wall Case	0.036	12.1	170
5	Half Wall Thickness Case	0.047	12.8	183
6	Double Wall Thickness Case	0.032	12.3	169
7A	Half Roof Thickness Case	0.035	6.8	240
7B	Double Roof Conductivity	0.036	12.1	159
8	Half Floor Thickness Case	0.038	11.4	217
9	Smaller SDU Case	See Case 15		
10	Over Extension Case	0.034	11.9	164
11	Over Extension with Capillary Barrier Case	0.033	11.9	171
12	Umbrella Case	0.033	14.8	203
13	Umbrella with Capillary Barrier Case	0.033	14.2	210
14	Alternative Layout Case 1	0.031	10.8	154
15	Alternative Layout Case 2	0.031	6.8	156
16	Degraded Column Case	0.034	11.5	86
17	Optimization Case	0.045	10.6	276

Notes: (a) Doses do not include all radionuclide contributors.
(b) Because all changes considered within this evaluation impact the 375-foot diameter SDUs, the peak dose near 31,000 years (i.e., from the 150-foot diameter SDUs) is not considered. Also, doses beyond 20,000 years only consider contributions from Tc-99.

3.1 Dose Evaluation of Wall Modifications

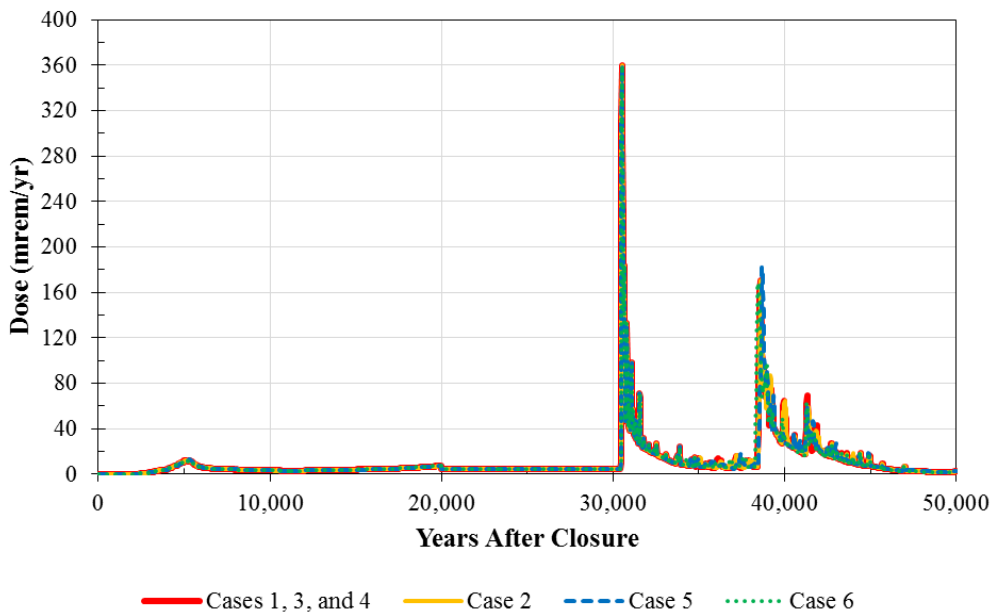
Figures 3.1-1 and 3.1-2 show the total dose results for Cases 1 through 6. As shown, modifying the walls has a minimal impact on the dose results. The greatest difference came from Case 5 (i.e., the case with walls set to half thickness). Case 5 had a peak dose of about 13 mrem/yr near 5,300 years, while the other cases with wall modifications were closer to 12 mrem/yr. Similarly, the peak near 38,500 years was about 183 mrem/yr from Case 5, while the other cases with wall modifications were closer to 170 mrem/yr. Based on these results, the walls of the 375-foot diameter SDUs are not significant barriers with respect to performance. Lower quality material (e.g., Type II concrete instead of the Type V concrete in the current design) may be used and different thicknesses may be used, both with a minimal impact to future performance.

Figure 3.1-1: Total MOP Dose Comparison Within 10,000 Years, Wall Variations (Cases 1 through 6)



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.1-2: Total MOP Dose Comparison Within 50,000 Years, Wall Variations (Cases 1 through 6)



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

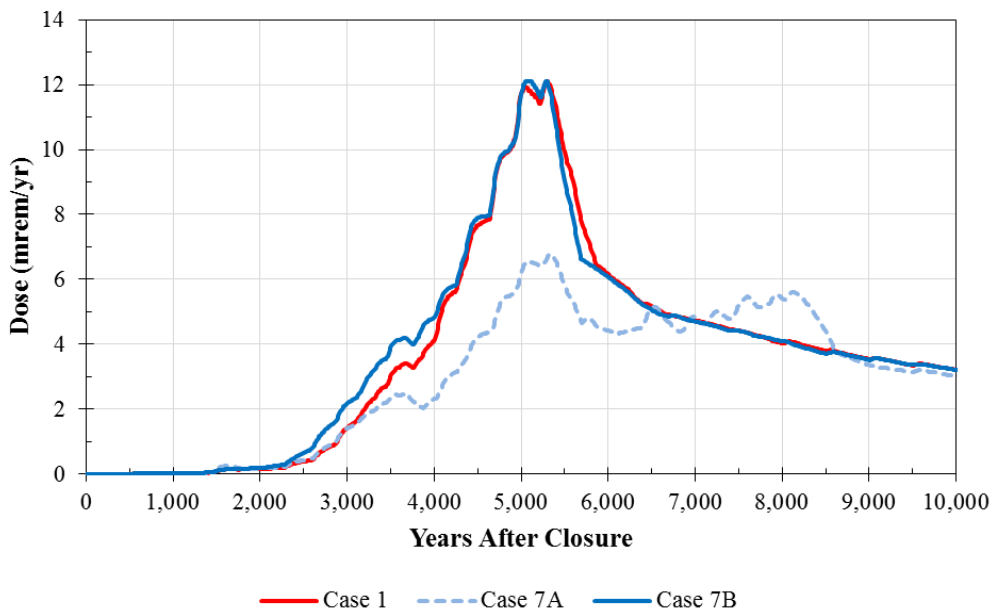
3.2 Dose Evaluation of Roof Modifications

Cases 7A, 7B, 10, and 11 each reflect various modifications to the roof.

Cases 7A and 7B are shown in Figures 3.2-1 and 3.2-2. Case 7A assumed the roof was only half as thick as the current SDU design (i.e., 6 inches versus 12 inches) and shows the most significant difference. As described in Section 2.2, the thin roof significantly altered the flow pattern, diverting a larger amount of water to shed off the edge of the roof rather than allowing water to penetrate into the SDU. As expected, the decreased flow through the SDU saltstone significantly depressed the release of I-129, thus resulting in a significantly lower peak dose (about 7 mrem/yr near 5,300 years).

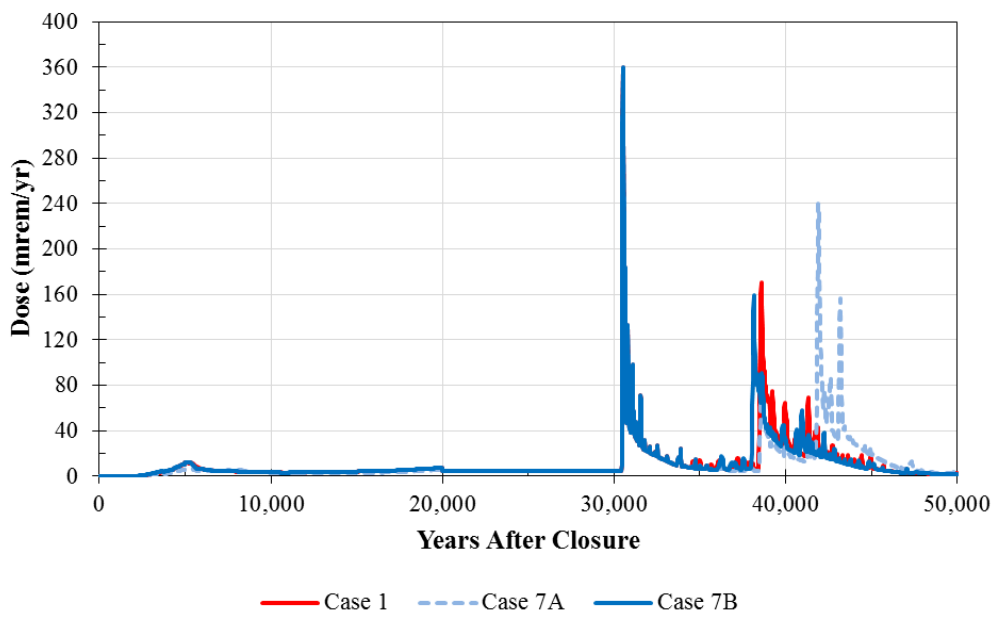
However, there is not full confidence that this flow-diverting phenomenon reflects realistic system behavior because the thinner roof was expected to result in increased flow through the saltstone. Therefore, Case 7B was developed in which the roof thickness was unchanged (i.e., 12 inches), but the hydraulic conductivity was increased to allow greater flow. Here, the change to the dose was minimal (see Figures 3.2-1 and 3.2-2). Accordingly, a thinner roof or a roof made with lower quality concrete would not significantly impact system performance.

Figure 3.2-1: Total MOP Dose Comparison Within 10,000 Years, Roof Variations: Cases 1, 7A, and 7B)



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

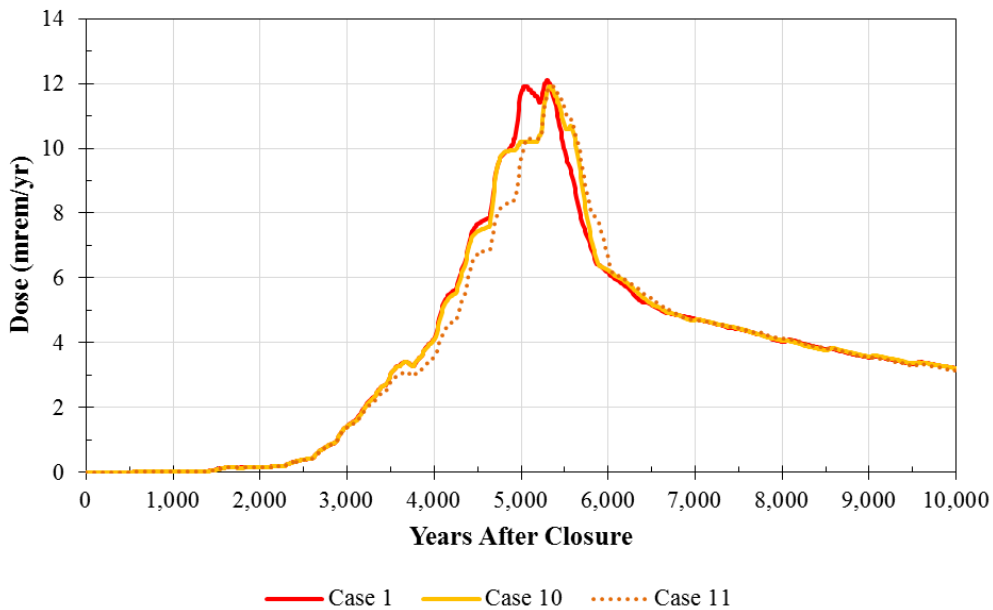
Figure 3.2-2: Total MOP Dose Comparison Within 50,000 Years, Roof Variations: Cases 1, 7A, and 7B)



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

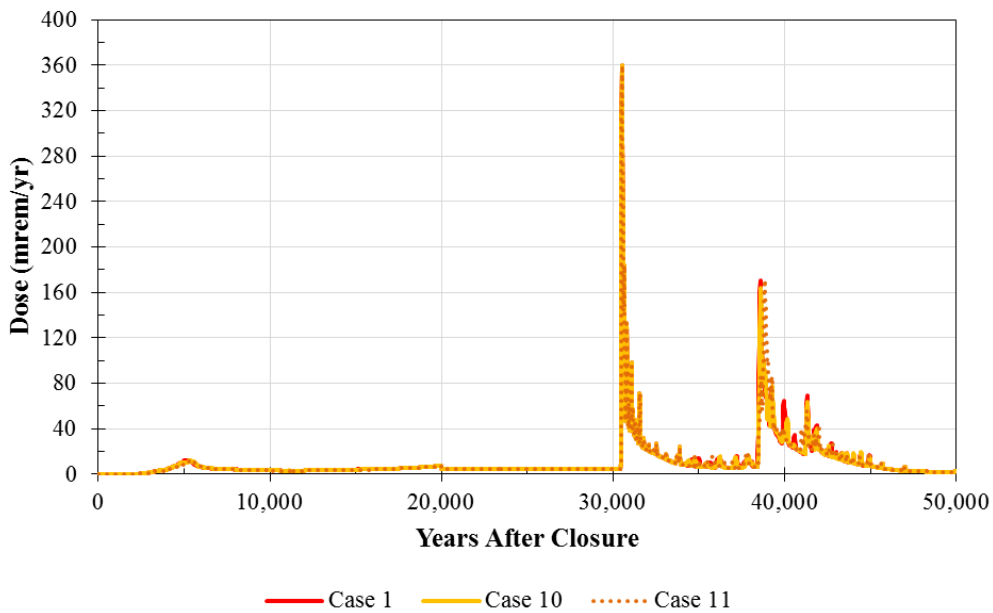
Cases 10 and 11 are shown in Figures 3.2-3 and 3.2-4. Cases 10 and 11 both modeled the roof as extending five feet past the wall. Case 11 also includes a capillary boundary around the wall of the SDU. Cases 10 and 11 both show peak doses that are negligibly less than Case 1, thus indicating that a roof overhang has a minimal impact on flow. The differences between Cases 10 and 11 are negligible with respect to the magnitude and timing of the dose peaks. Therefore, there appears to be little benefit from including a capillary boundary (gravel) beneath the roof overhang and surrounding the SDU walls.

Figure 3.2-3: Total MOP Dose Comparison Within 10,000 Years, Roof Variations: Cases 1, 10, and 11)



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.2-4: Total MOP Dose Comparison Within 50,000 Years, Roof Variations: Cases 1, 10, and 11)



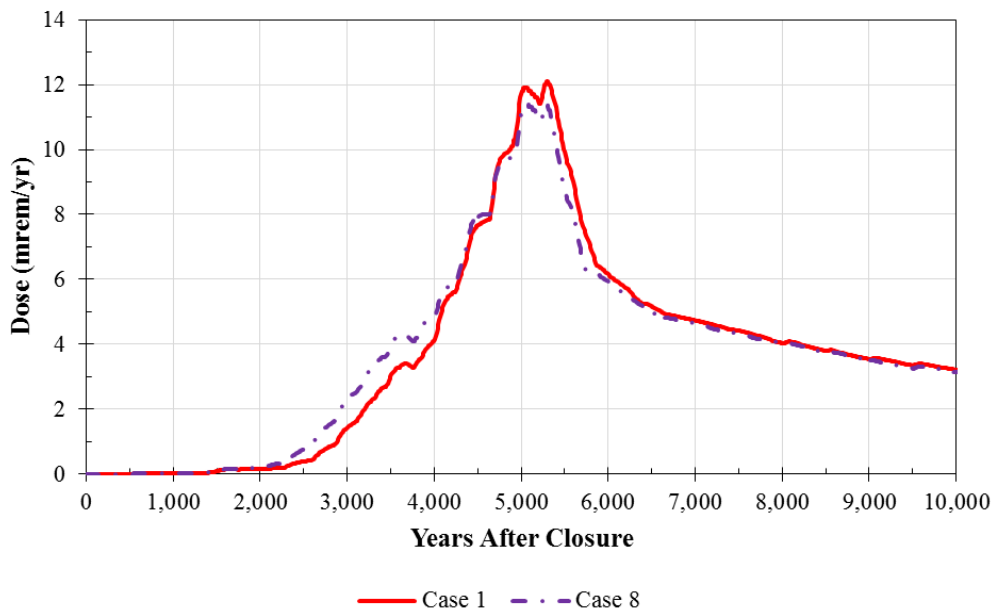
Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

3.3 Dose Evaluation of Floor Modifications

Figures 3.3-1 and 3.3-2 show the total dose results for Cases 1 and 8. Case 8 assumes that the floor of the 375-foot diameter SDU is half as thick as designed (6 inches instead of 12). Note that both cases have two dose peaks within 10,000 years. The earlier dose peak occurs near 5,000 years while the second peak occurs near 5,300 years. In Case 8, the earlier peak (at around 5,000 years) is slightly higher than the later peak. Regardless, both peaks are near 11 mrem/yr. This compares to Case 1 in which the later peak (near 5,300 years) is slightly higher with a magnitude near 12 mrem/yr.

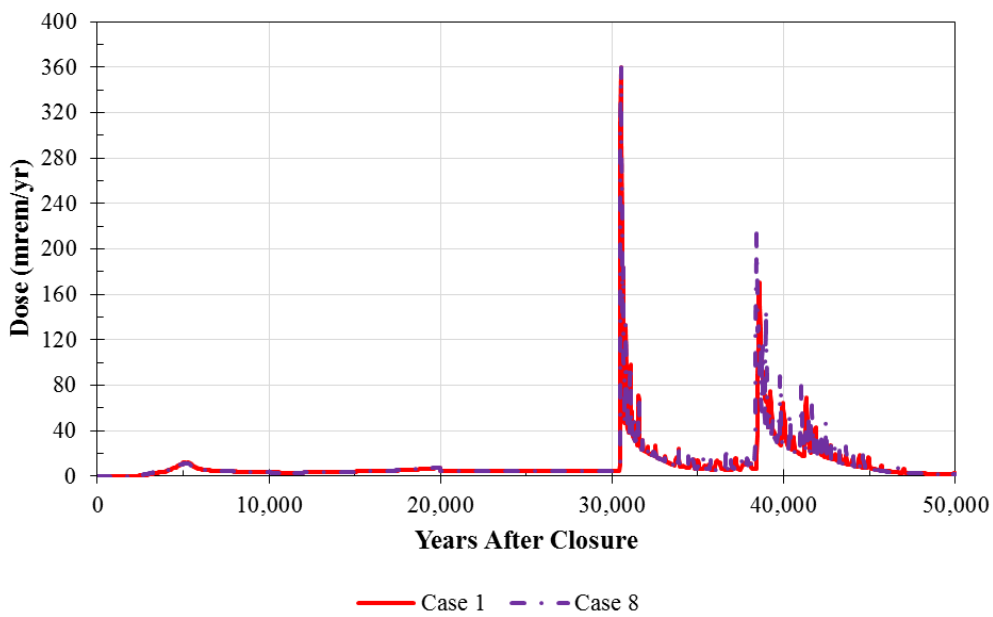
Alternatively, as seen in Figure 3.3-2, Case 8 shows a dose peak near 38,500 years that is considerably higher (217 mrem/yr) than the peak from Case 1 (170 mrem/yr). However, because the overall peak within 50,000 years is still driven by releases from the 150-foot SDUs (peak near 30,500 years), this increase in dose does not affect the overall peak. Therefore, decreasing the thickness of the floor does not have an adverse impact on the magnitude of the dose peaks for the facility, even though it does result in slightly earlier rise in the dose within 10,000 years.

Figure 3.3-1: Total MOP Dose Comparison Within 10,000 Years, Floor Variation: Cases 1 and 8



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.3-2: Total MOP Dose Comparison Within 50,000 Years, Floor Variation: Cases 1 and 8

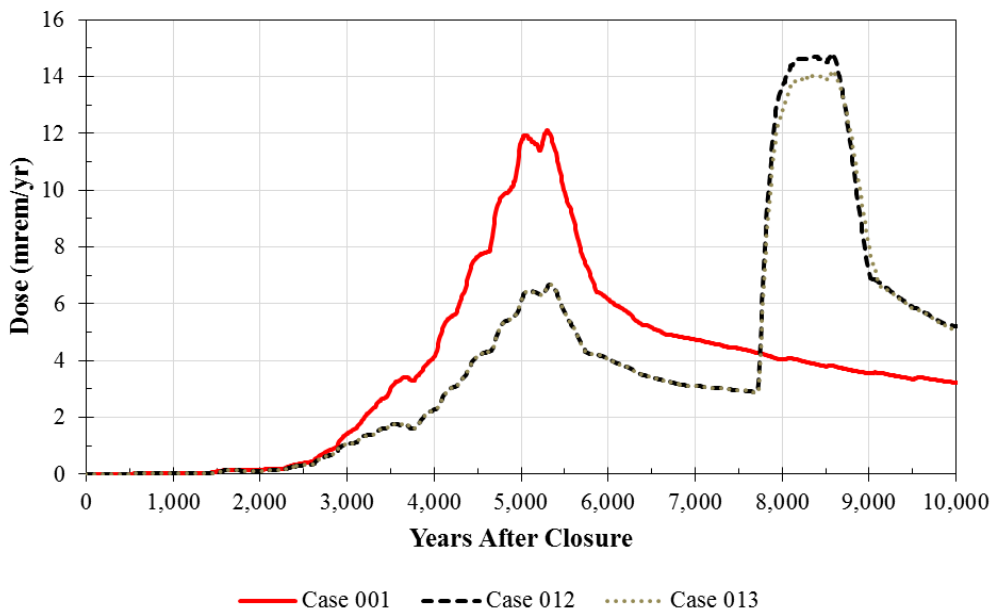


Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

3.4 Dose Evaluation of Stainless Steel Umbrella

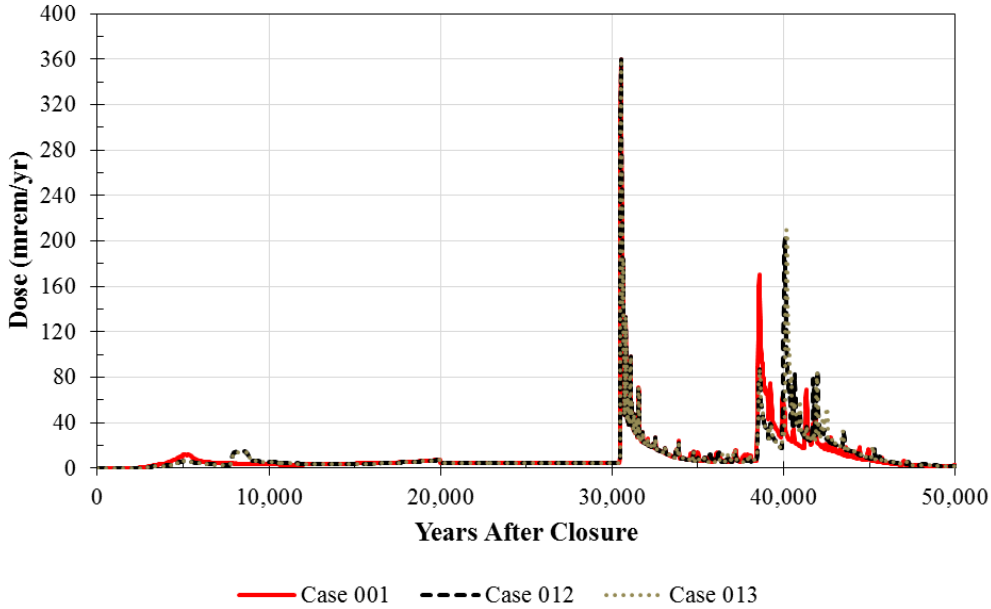
Cases 12 and 13 both include a stainless steel umbrella in place of the HDPE layer. Case 13 also includes a two-foot thick capillary barrier (gravel) that surrounds the outside of the SDU walls. As expected, assuming that such an impervious layer is intact over the SDU significantly alters the dose profile (Figures 3.4-1 and 3.4-2). Those SDUs which have already been constructed (i.e., SDUs 1, 4, 2A, 2B, 3A, 3B, 5A, 5B, and 6) were not modeled as having the umbrellas installed over them. Therefore, prior to the umbrella degradation, doses are driven by releases from these SDUs. For the SDUs which were modeled with the umbrella (i.e., SDUs 7, 8, 9, 10, 11, and 12), a minimal amount of inflow does occur prior to umbrella degradation but only through horizontal flow paths (i.e., via walls and joints) seen in Figure 2.4-1. This minimal inflow results in dose contributions which account for only 1 to 2 mrem/yr of the total doses in Figure 3.4-1. Even with the already-constructed SDUs, the doses are significantly lower until the time that the umbrella is assumed to fail (at about 7,700 years); then the I-129 release generates a significant "pulse" of about 14 or 15 mrem/yr.

Figure 3.4-1: Total MOP Dose Comparison Within 10,000 Years, Umbrella Variations: Cases 1, 12 and 13



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.4-2: Total MOP Dose Comparison Within 50,000 Years, Umbrella Variations: Cases 1, 12 and 13

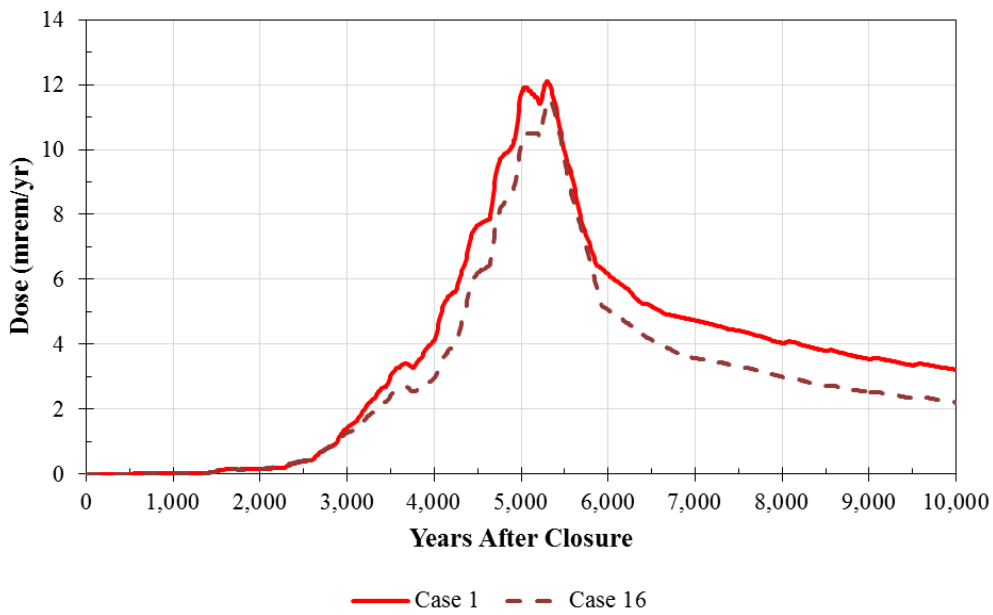


Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

3.5 Dose Evaluation of Degraded Roof Support Column

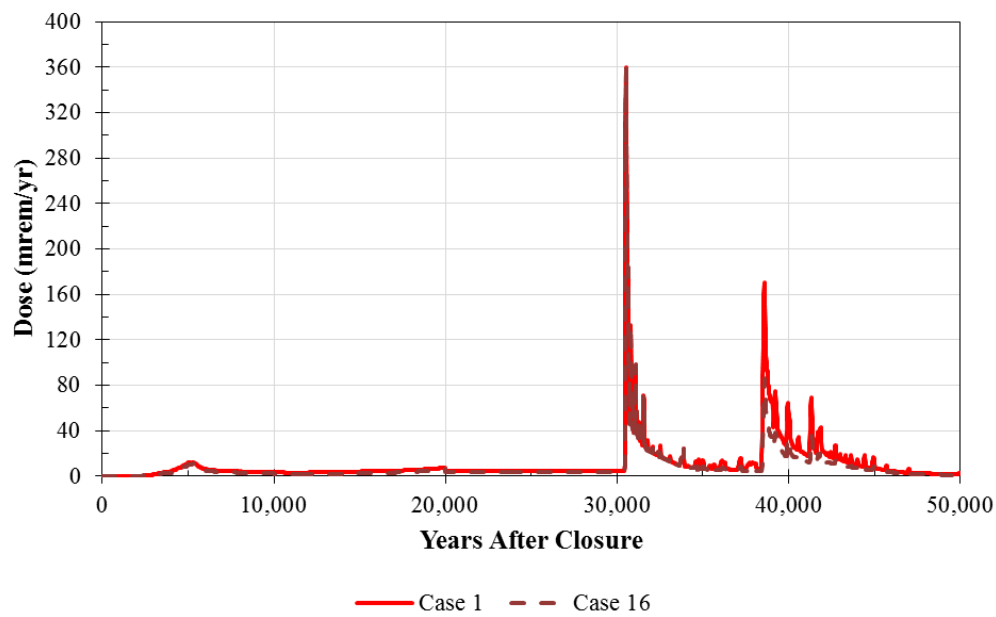
In Case 16, the roof support columns were modeled as being initially degraded. This provided a fast flow path that diverted a fraction of the water influx, such that more water flowed through the column, relative to the comparison case, while less water flowed through the saltstone (as described in Section 2.5). This diversion of flow resulted in slightly lower peak doses (Figures 3.5-1 and 3.5-2). As such, assuming degraded columns would be a non-conservative assumption; however, these results also indicate that the SDU design may be optimized if the columns can be designed in such a way as to facilitate greater flow (e.g., using lower quality concrete such as Type II concrete or shotcrete), thereby diverting water from the source term.

Figure 3.5-1: Total MOP Dose Comparison Within 10,000 Years, Column Variation: Cases 1 and 16



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.5-2: Total MOP Dose Comparison Within 50,000 Years, Column Variations: Cases 1 and 16



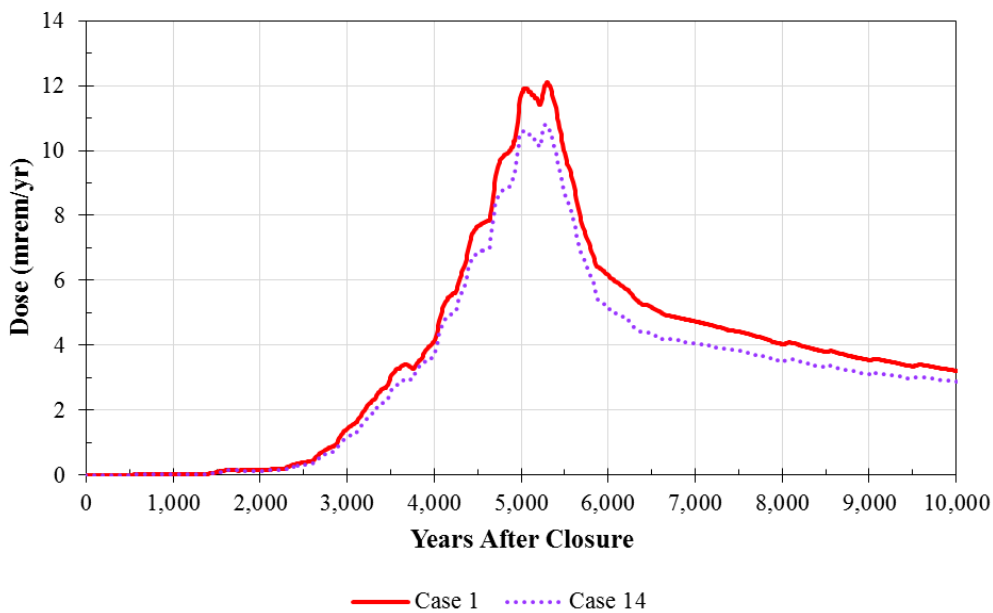
Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

3.6 Dose Evaluation of Alternative Layout 1

For Case 14, Alternative SDF Layout 1 was applied (see Figure 1.1-1). The 375-foot diameter SDUs used for this transport case were unmodified relative to the FY2014 SDF SA. Figures 3.6-1 and 3.6-2 show that the alternative layout had a positive influence on the dose results. Within 10,000 years, the peak dose was reduced from about 12 mrem/yr to a little less than 11 mrem/yr. Similarly, for the peak dose near 38,500 years, the peak was reduced from 170 mrem/yr to about 155 mrem/yr.

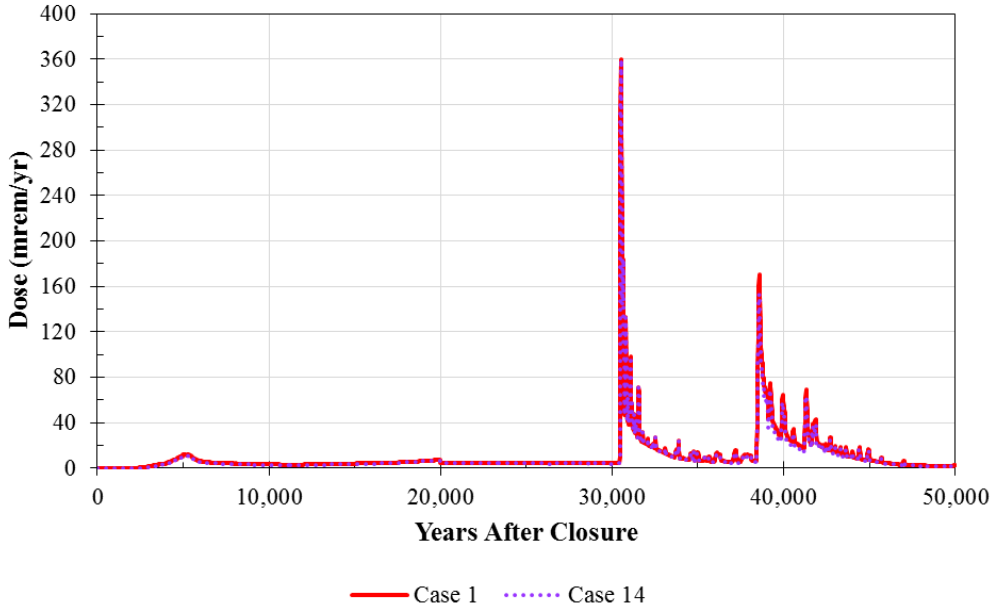
Not immediately apparent from Figures 3.6-1 and 3.6-2 is the influence these layout changes had on specific modeling sectors. The peak doses from each sector are summarized in Table 3.6-1 and show that the revised layout reduces the potential dose risks to the MOP. Although these layout changes increased the doses in some sectors, the overall dose risk was reduced. Figure 3.6-3 indicates the location of each of the modeled sectors relative to the SDUs and the 100-meter boundary. Figures 3.6-4 and 3.6-5 show the sector-specific dose results from Cases 1 and 14, respectively, within 10,000 years.

Figure 3.6-1: Total MOP Dose Comparison Within 10,000 Years, Alternative SDF Layout: Cases 1 and 14



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.6-2: Total MOP Dose Comparison Within 50,000 Years, Alternative SDF Layout: Cases 1 and 14



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

Table 3.6-1: Comparison of Peak Doses to MOP (Case 1 versus Case 14) within 10,000 Years, Sectors A through L

Sector	Case 1 Peak Dose (mrem/yr)	Case 14 Peak Dose (mrem/yr)
Sector A	7.6	4.4
Sector B	10.1	5.3
Sector C	7.6	9.9
Sector D	4.6	8.4
Sector E	7.1	4.6
Sector F	4.5	1.3
Sector G	7.6	9.6
Sector H	9.4	10.8
Sector I	7.1	7.2
Sector J	10.0	5.7
Sector K	12.1	6.7
Sector L	7.1	6.6
Mean of All Sectors	**7.9**	**6.7**
Peak at Maximum Sector	**12.1 (Sector K)**	**10.8 (Sector H)**

Figure 3.6-3: SDF 100-Meter Modeled Cells and Sectors for Alternative Layout 1: Case 14

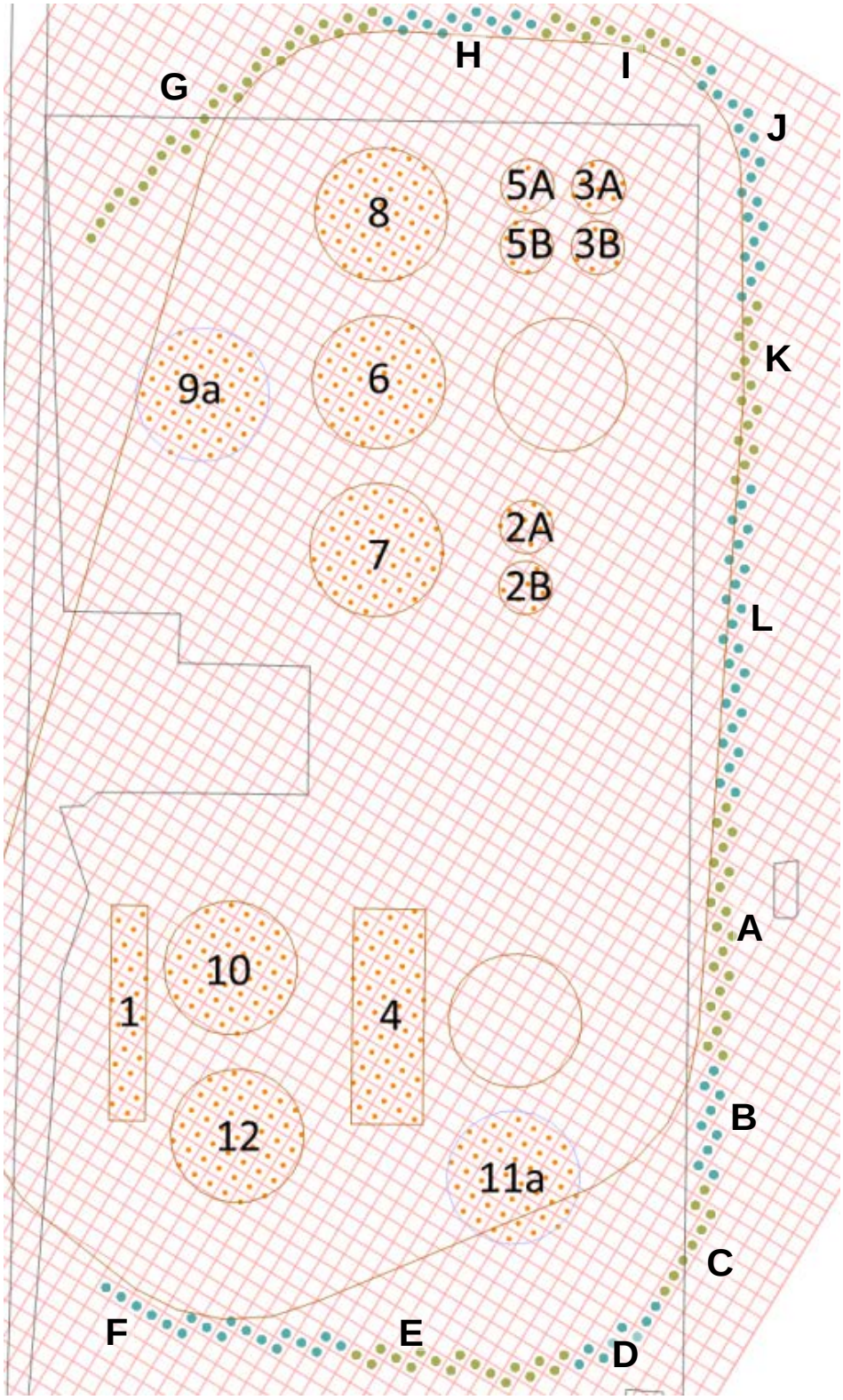
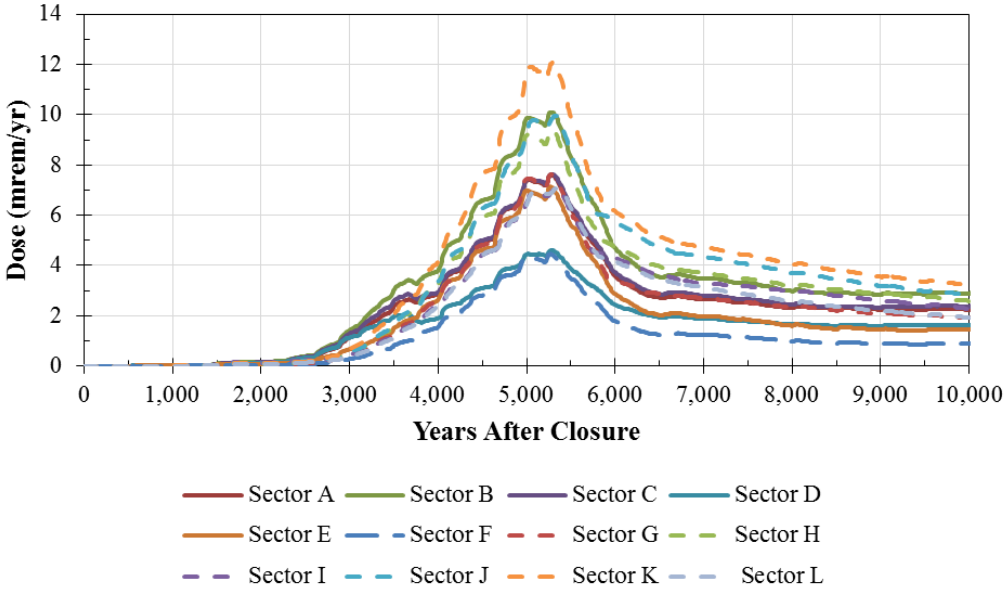
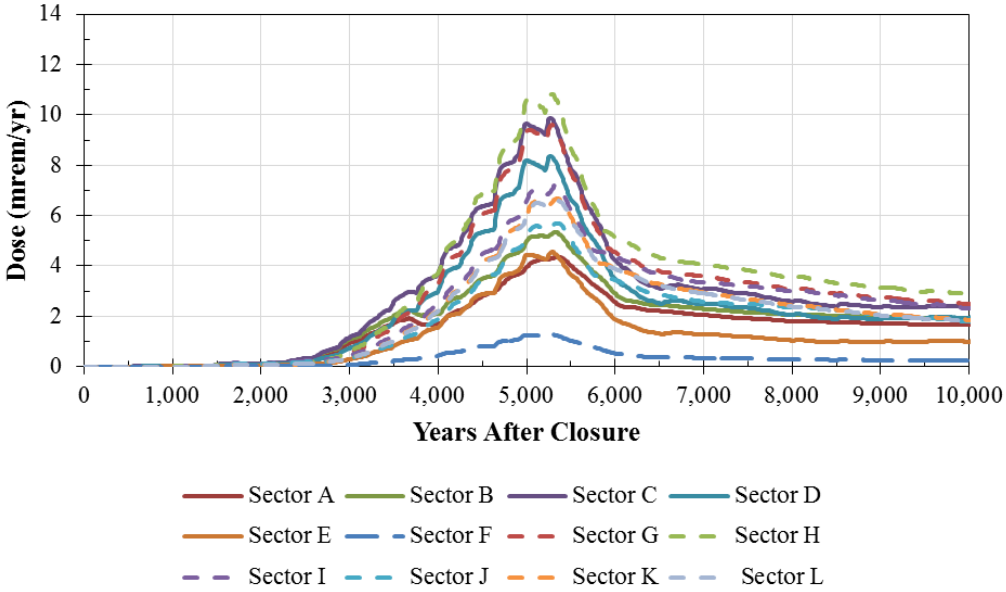


Figure 3.6-4: 100-Meter MOP Peak Groundwater Pathways Dose within 10,000 Years, Sectors A through L: Case 1



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.6-5: 100-Meter MOP Peak Groundwater Pathways Dose within 10,000 Years, Sectors A through L: Case 14

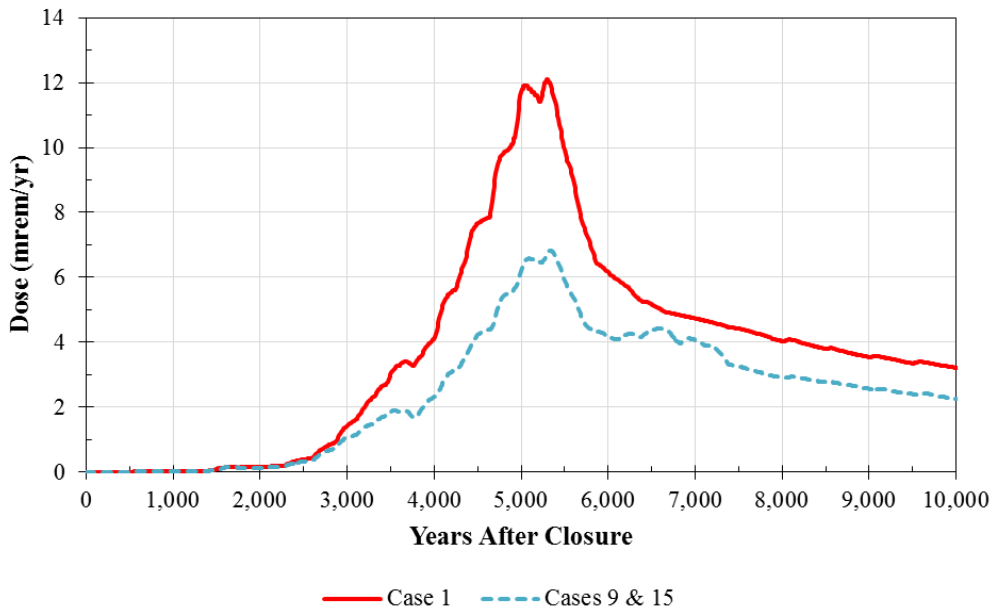


Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

3.7 Dose Evaluation of 250-Foot Diameter SDU with Alternative Layout 2

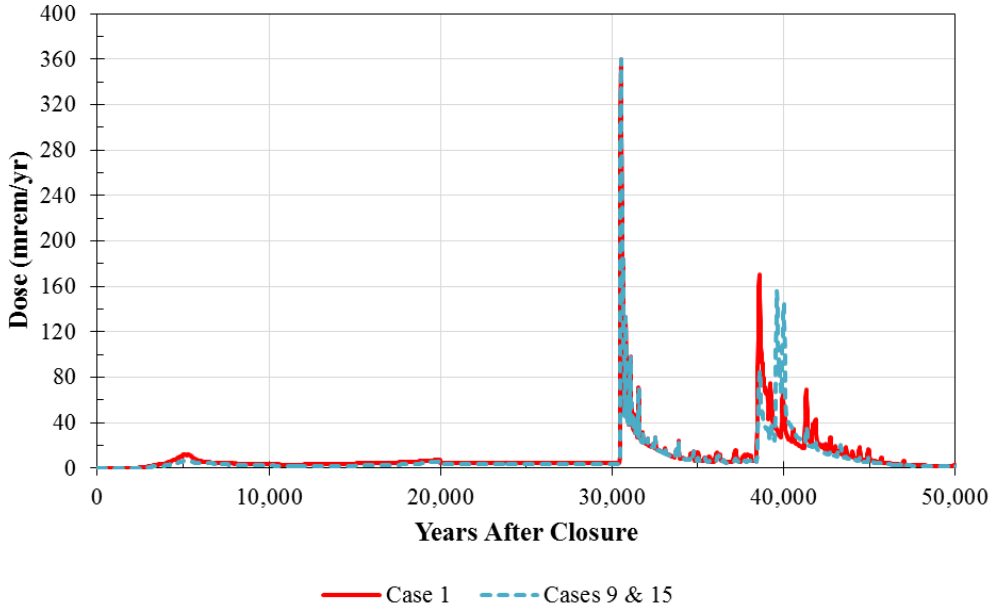
In Case 15, the geometry of the SDU was altered, using an SDU with a 250-foot diameter (as defined for Case 9 flow). Within PORFLOW, the SDF layout was modified to replace each 375-foot diameter SDU with two separate 250-foot diameter SDUs (as shown in Figure 1.1-2). Figures 3.7-1 and 3.7-2 provide the resulting doses. Here, the peak dose near 5,300 years is lower (about 7 mrem/yr versus 12 mrem/yr). The peak dose near 38,500 years is delayed to about 40,000 years and is lower (156 mrem/yr versus 170 mrem/yr). This indicates that if two 250-foot diameter SDUs can be constructed for a lower price than a single 375-foot diameter SDU, then the 250-foot diameter SDUs may be a preferable option to pursue.

Figure 3.7-1: Total MOP Dose Comparison Within 10,000 Years, 250-Foot Diameter Variation: Cases 1 and 9 With Alternative SDF Layout 2: Case 15



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.7-2: Total MOP Dose Comparison Within 50,000 Years, 250-Foot Diameter Variation: Cases 1 and 9 With Alternative SDF Layout 2: Case 15



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

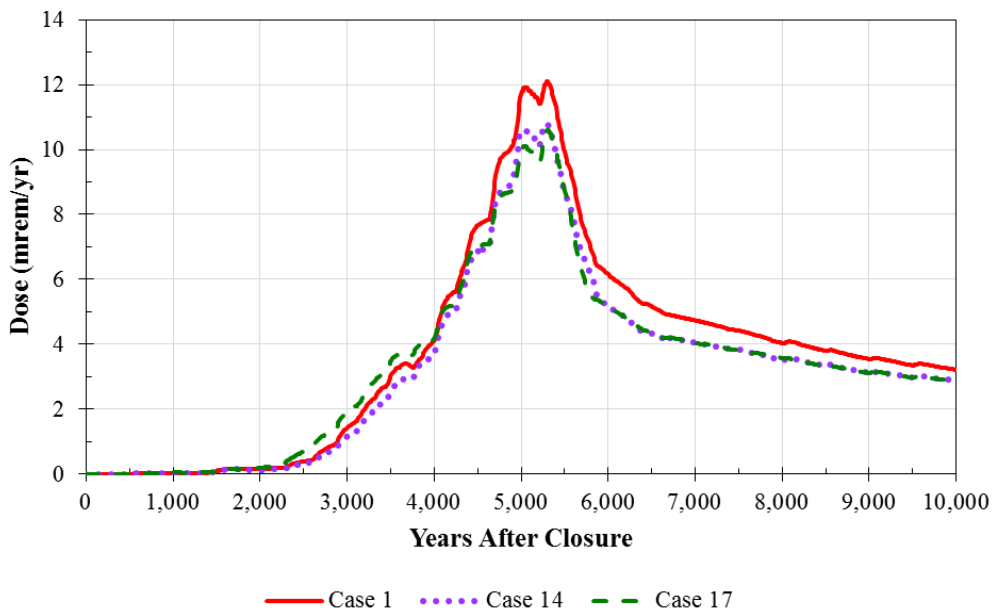
3.8 Dose Evaluation of Optimization Case

Case 17 combines the flow modifications from Cases 4, 5, and 8 (i.e., the walls were assumed to be made of conservative shotcrete, the walls were half as thick, and the floor was half as thick). Due to the uncertainty associated with the significant differences in the flow results from Cases 7A and 7B, no changes were applied to the roof. Modeling the roof-support columns as fully degraded (Case 16) was shown to be non-conservative and was, therefore, not included in this Optimization Case. Additionally, this case also assumes Alternative SDF Layout 1 (see Figure 1.1-1 and Section 3.6). The results from Case 14 (i.e., the Alternative SDF Layout) are also included in these figures to provide an additional point of reference for comparisons.

As can be seen in Figure 3.8-1, the Optimization Case shows slightly higher doses within the first 4,000 years due to earlier releases through the less robust barriers. However, these earlier releases actually result in less inventory being available during the 4,500-year to 6,000-year, effectively lowering the peak doses during the performance period.

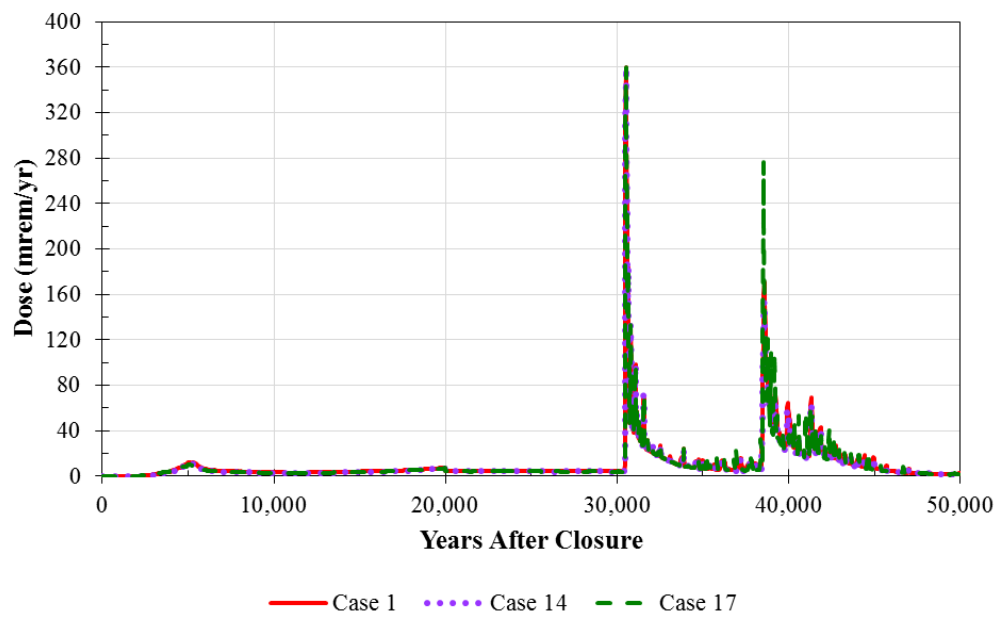
Alternatively, Figure 3.8-2 shows a significantly higher peak near 38,500 years as the Tc-99 release is less inhibited at the time of the oxidation breakthrough. However, this peak is still lower than the peak from the 150-foot diameter SDUs, and therefore has no adverse impact on the demonstration of performance.

Figure 3.8-1: Total MOP Dose Comparison Within 10,000 Years, Combined Optimization: Cases 1, 14, and 17



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only.

Figure 3.8-2: Total MOP Dose Comparison Within 50,000 Years, Combined Optimization: Cases 1, 14, and 17



Note: Doses do not include all radionuclide contributors. Intended for scoping purposes only. Beyond 20,000 years, doses only include Tc-99.

4.0 CONCLUSIONS

Based on this evaluation, system performance is strongly influenced by the condition of the saltstone material. Changes to the floor and the walls of the SDU that do not directly change the properties of the saltstone (e.g., structural stability), show relatively little change to future dose results. The influence of thickness of the roof is not as definitive (see Figures 3.2-1 and 3.2-2). The roof overhang (i.e., extension of the roof past the wall) has no significant impact on dose.

The changes which made the most significant impact on the dose results were (1) the inclusion of the stainless steel umbrella, (2) the alternative facility layout, and (3) the use of the 250-foot diameter SDU. The umbrella provided a significant delay to the timing of the peak dose within 10,000 years, but once the peak did occur, it was higher than the comparison case. The alternative facility layout (see Figure 1.1-1) provided an approximate 10% reduction to the dose results (compare Figure 3.6-3 to Figure 3.6-4). This approach made no changes to the current SDU designs. The 250-foot diameter SDU provides improved performance (see Figures 3.7-1 and 3.7-2). Note, however, that the improved performance was based on a 40-foot tall, 250-foot diameter SDU. Other potential SDU designs will provide different results and would require further evaluation, should this course be pursued.

The conclusions about SDU design alternatives presented within this report are only from the perspective of transport modeling and dose results. Any SDU design alternatives that may be investigated must include other performance considerations including structural, environmental, radiation shielding, or construction impacts.

5.0 REFERENCES

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