

# **Use of Barrier Analysis in NRC Staff's Performance Assessment Reviews**

**Performance and Risk Assessment Community of Practice  
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United States Nuclear Regulatory Commission**

# Outline

- What is a barrier analysis?
- How does NRC use barrier analysis in our reviews?
- Barrier analysis review examples
- Final thoughts

# What is a Barrier Analysis?

- Identification and description of barriers in a performance assessment
- Function of barriers in limiting or delaying timing of releases or exposures; or reducing likelihood of releases or exposures
- Can be qualitative or quantitative
- Natural and engineered barriers are considered

# What is a Barrier Analysis

- Examples of types of quantitative barrier analyses
  - One-off analyses
  - One-on analyses
  - Factorial designs
- Qualitative description of barrier functions and capabilities

# What is a Barrier Analysis

## Example of a Factorial Analysis

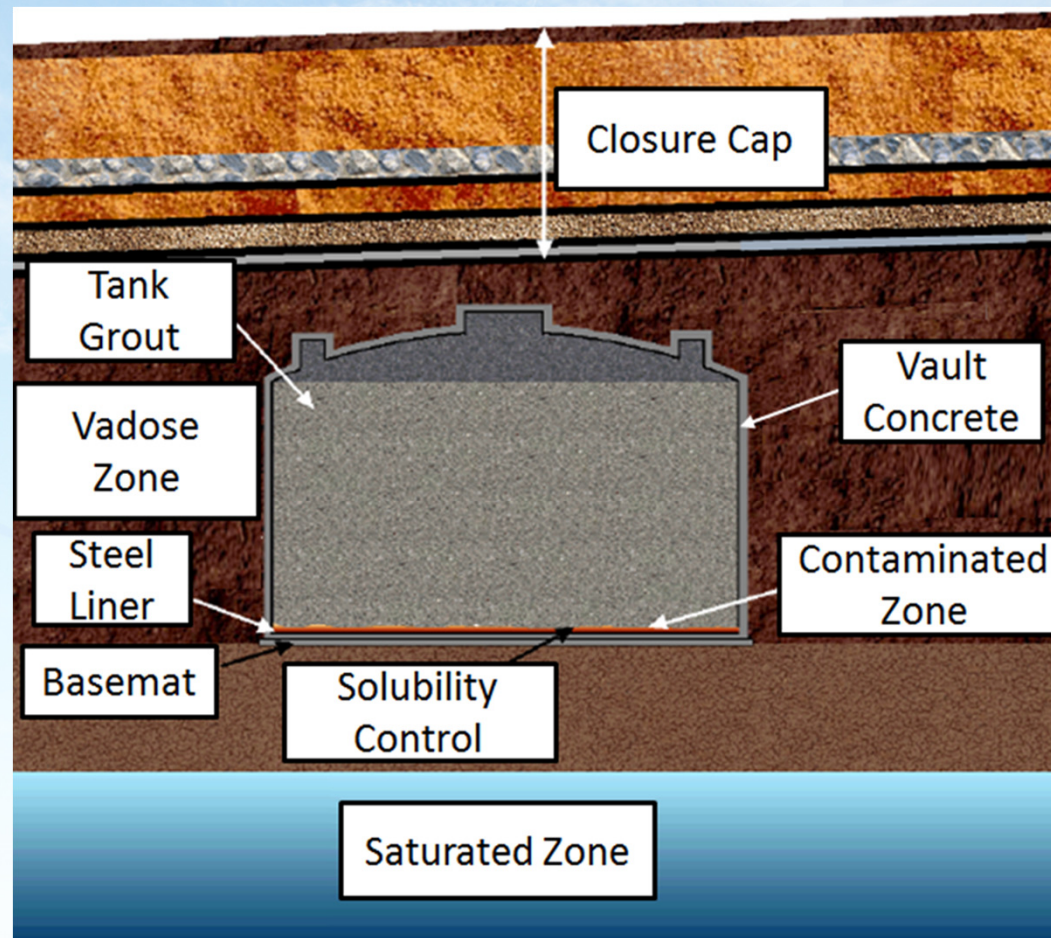
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on	off	on	on	on
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on	on	on	on	off
off	off	on	on	on
off	on	off	on	on
		....		
off	off	off	on	on
			....	
off	off	off	off	on
				....

# How Does NRC Use Barrier Analysis?

- To focus reviews and monitoring activities on areas most important to risk
  - To ask better questions
  - To make better decisions
- To better understand system behavior
- To evaluate impact of challenges to disposal facility performance
- To evaluate impact of uncertainty with respect to barrier performance
- To focus data collection and research efforts

# Barrier Analysis Examples: Savannah River Site (SRS)

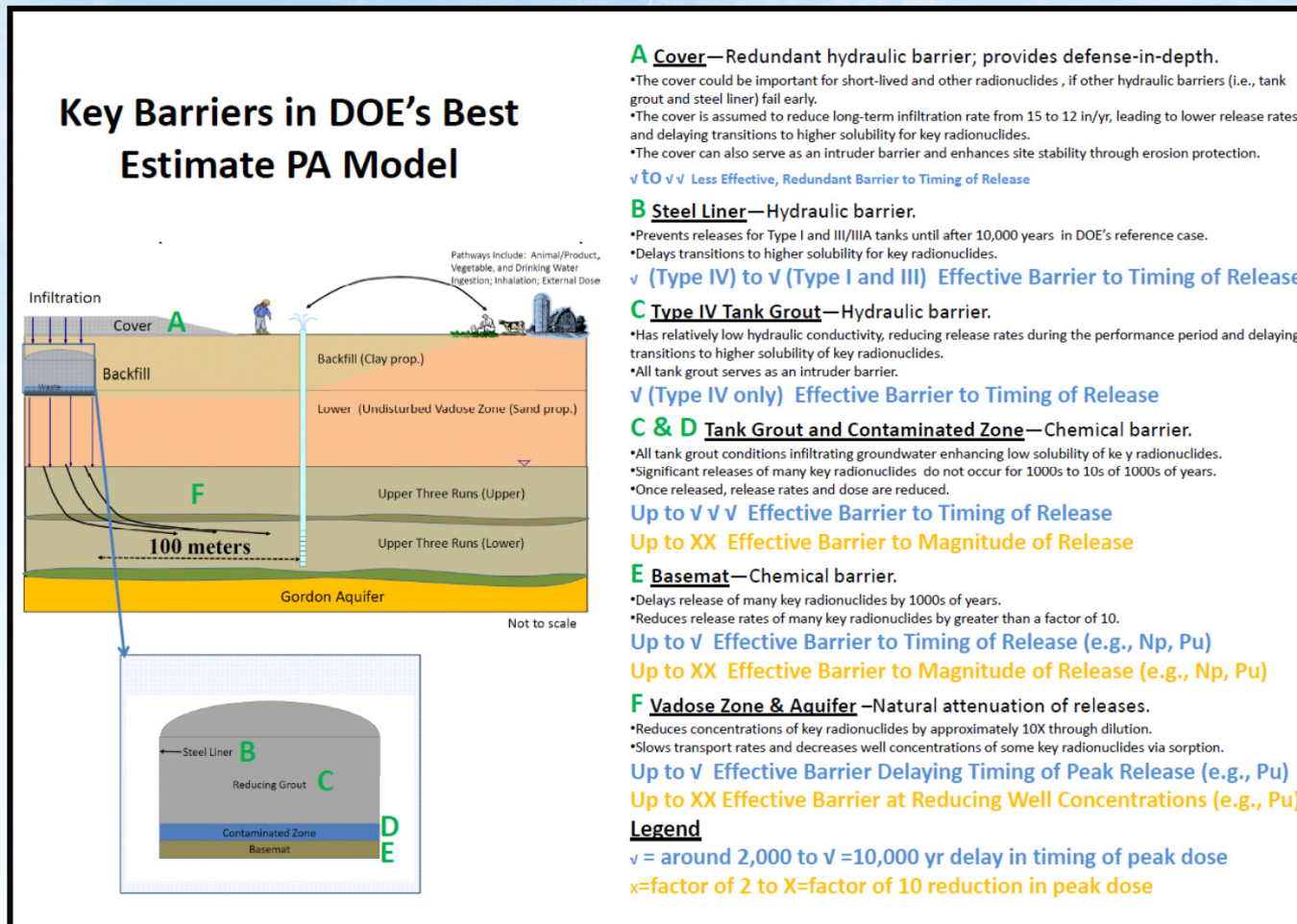
## F-Tank Farm Facility (FTF) Barriers



Adapted from SRR-REG-2007-00002, Rev. 1

# Barrier Analysis Examples: SRS FTF

## Qualitative Barrier Analysis Example





# Barrier Analysis Examples: SRS FTF

## Quantitative Barrier Analysis Example

		<b>Tc</b>	<b>Pu</b>	<b>Np</b>
1	Total Barrier Performance Needed (Function of Inventory)	6 (Type 1)	9 (Type IV, Tank 18)	6 (Type I)
2a	Final Solubility Control	0	2	1 to 2
2b	(Initial Solubility Control)	(9 to 11)	(9 to 11 )	(5 to 6)
3	Basemat Attenuation (Sorption)	<1	2	2
4	Near-Field Diffusion or Dispersion	2	1	1
5	Aquifer Dilution	1	1	1
6	Sorption	<<1	1	<<1
7	Additional Dispersion to POC	1-2	1	1
8	Total Barrier Performance	5	8	6 to 7
9	Calculated Safety Margin (calculated to peak dose)	<b>-1</b>	<b>-1</b>	<b>0 to 1</b>

# Barrier Analysis Examples: SRS FTF

## Partial Factorial Barrier Analysis Example

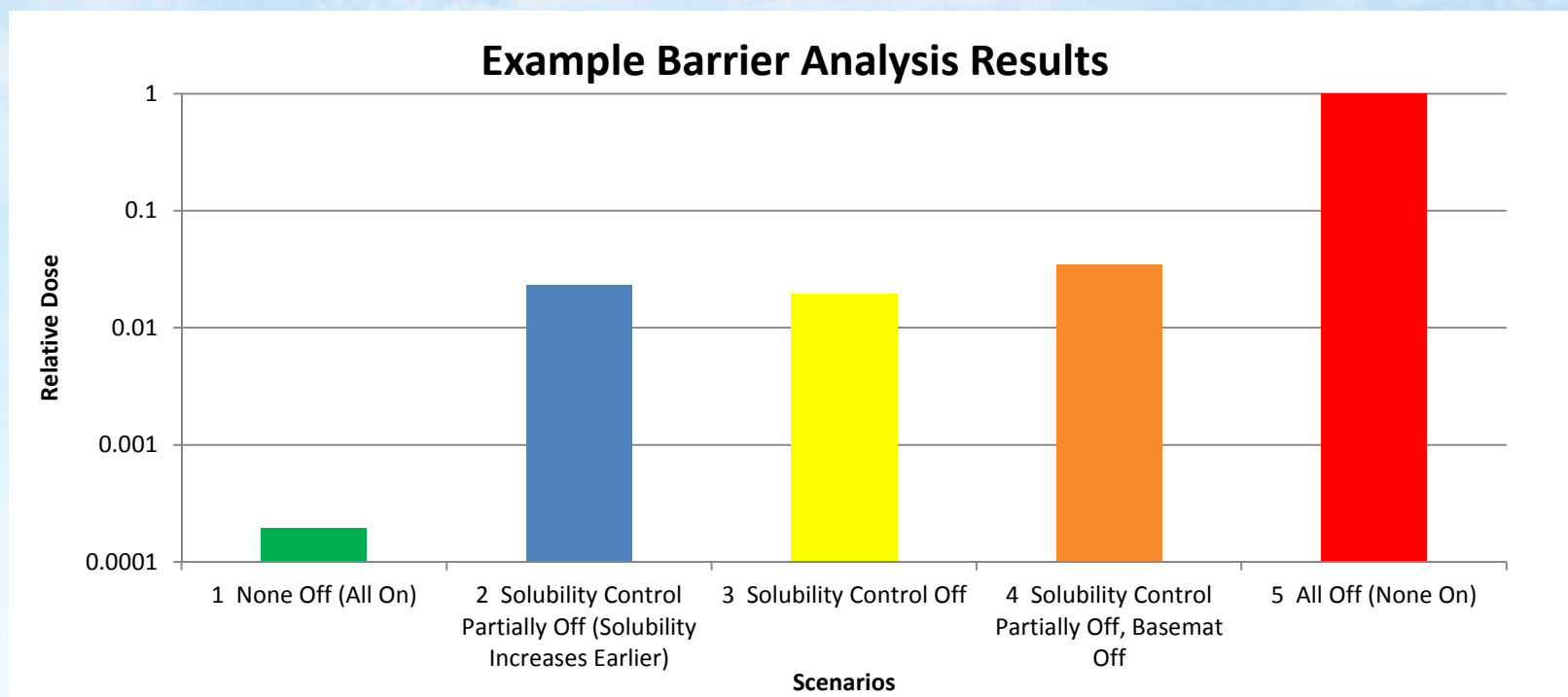
Barriers	States (Worst to Best)		
Solubility Control	Low Solubility Control (Very High Solubility Limit)	Moderate Solubility Control (Moderate Solubility Limit)	High Solubility Control (Low Solubility Limit)
Basemat Sorption	None (No sorption or by-Pass)	Moderate to High Sorption (High $K_d$ )	
Natural System Sorption	Low Sorption (Low $K_d$ )	Moderate Sorption	High Sorption (High $K_d$ )

	Solubility Control	Basemat Sorption	Natural System Sorption
Case 1 None Off (All On)	High	Moderate to High	High
Case 2 Solubility Partially Off **Solubility Increases Earlier	Moderate	Moderate to High	Moderate
Case 3 Solubility Control Off	Low	Moderate to High	Moderate
Case 4 Solubility Control Partially Off, Basemat Off (By-Pass)	Moderate	None	Moderate
Case 5 All Off (None On)	Low	None	Low

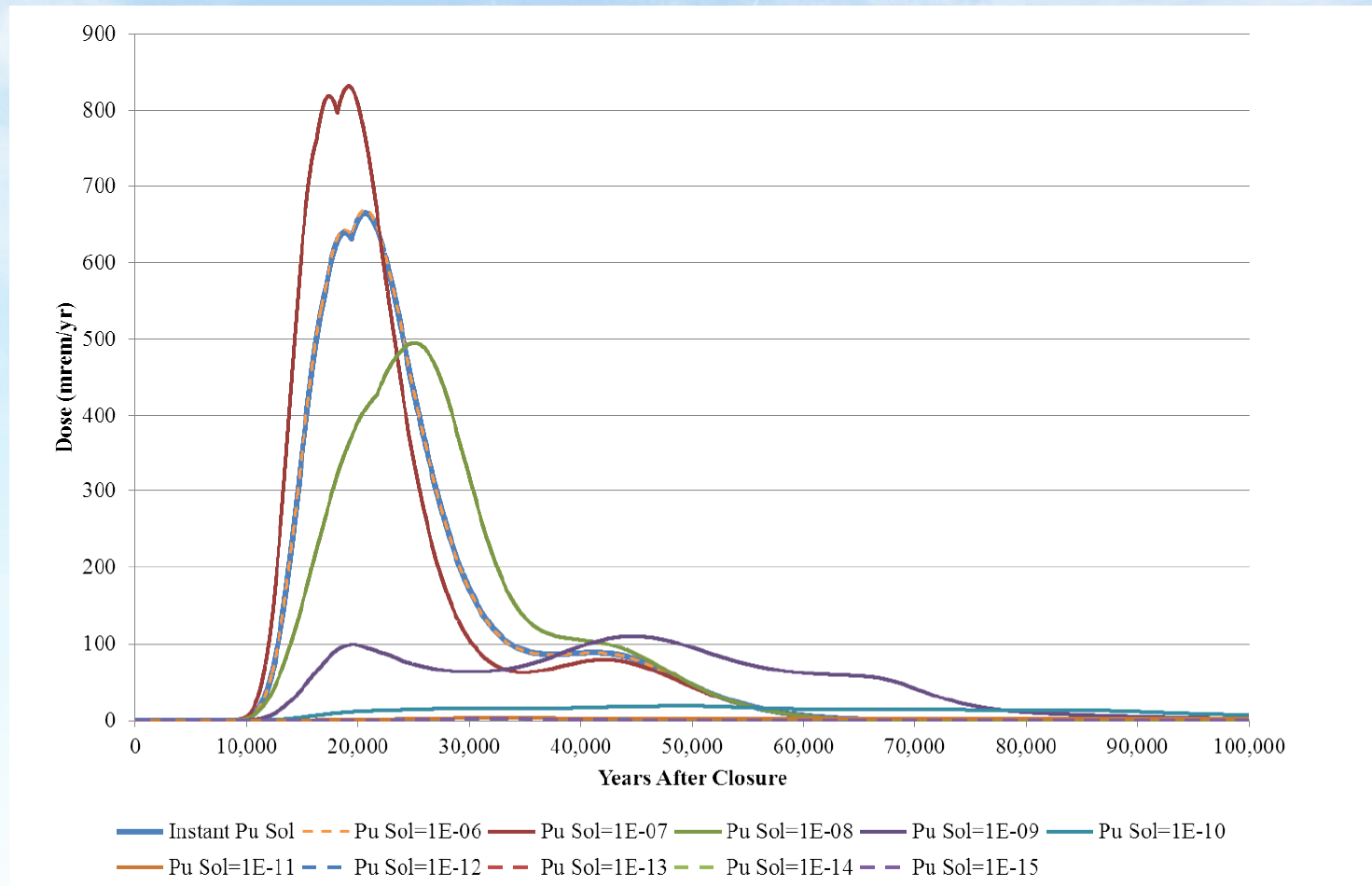
# Barrier Analysis Examples: SRS FTF

## Partial Factorial Barrier Analysis Example



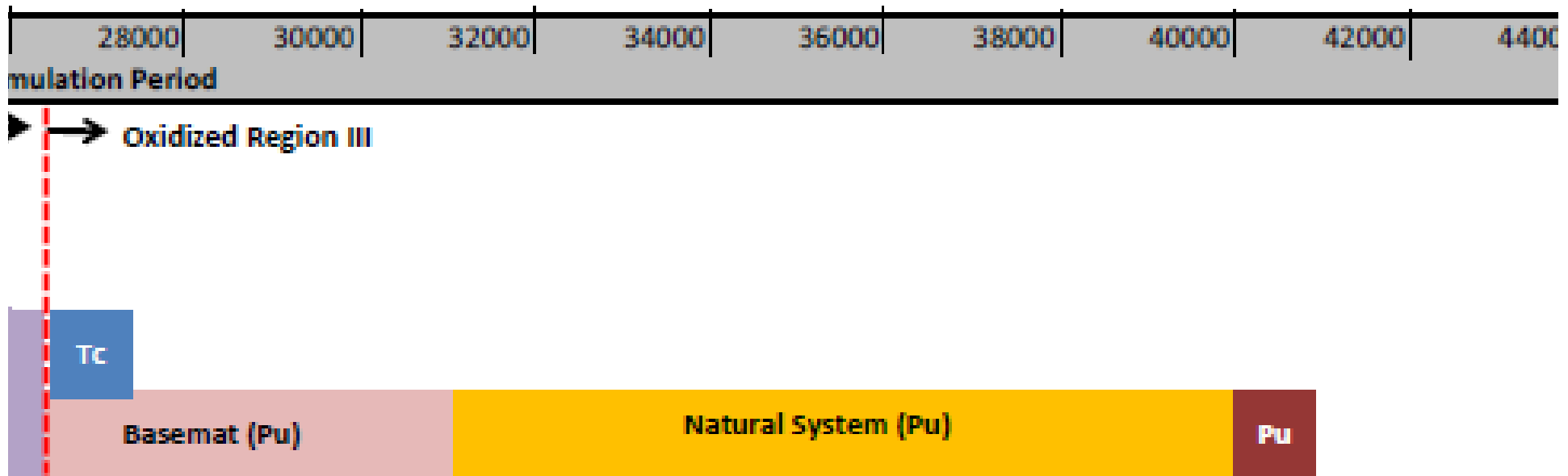
# Barrier Analysis Examples: SRS FTF

## Sensitivity/Barrier Analysis Example



# Barrier Analysis Examples: SRS FTF

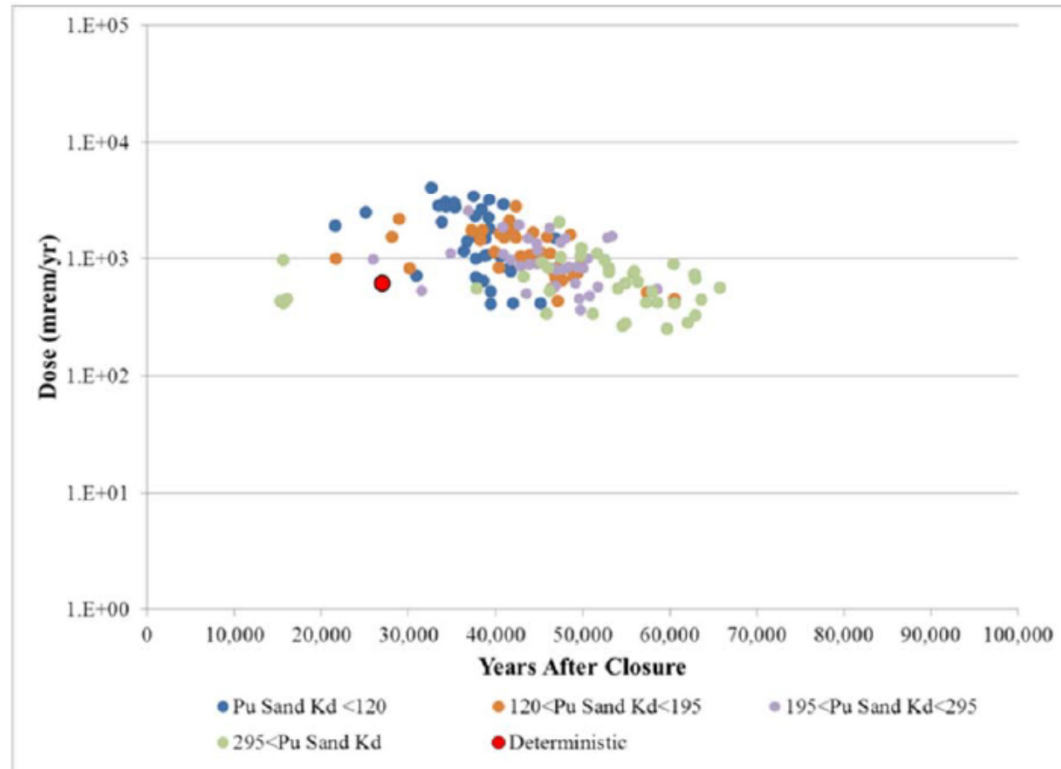
## Barriers to Timing Example



# Barrier Analysis Examples: SRS FTF

## Binning Results to Identify Important Barriers

Figure 1: Indicating .  
Figure 2: Indicatin Aquifer `.  
Figure 3: Indicatin Aquifer \.  
Figure 4: 100,000-Year Peak MOP Doses at the Well of Maximum Concentration, Indicating Plutonium  $K_d$  Values for Sandy Soil (Less Gordon Aquifer Well Depths, Tc OxII Sol. Limits =  $3.0E-13$ , and Pu OxII Sol. Limits  $\neq 4.0E-14$ )

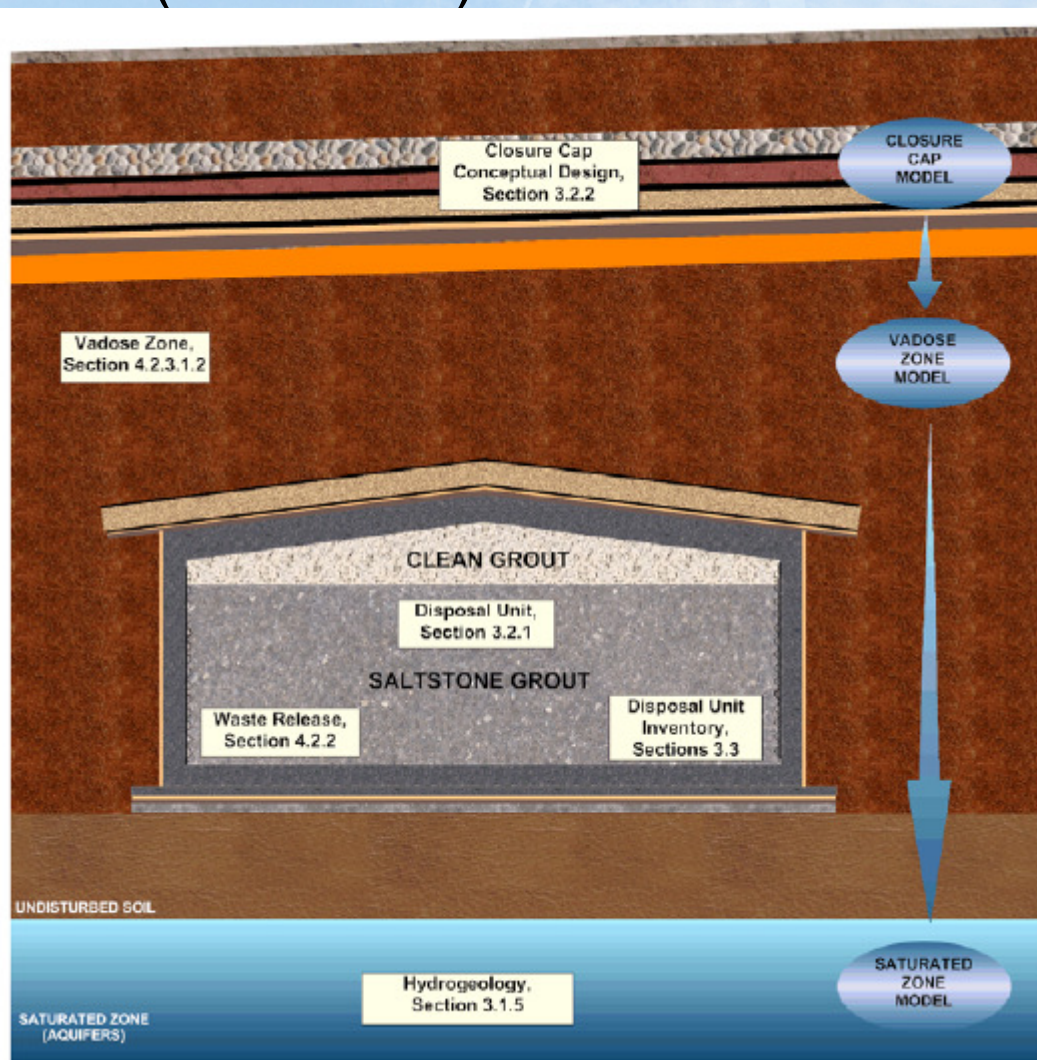


A) All Cases Configuration (286 - 138 = 148 realizations)

A) All Cases Configuration (370 - 204 = 200 realizations)

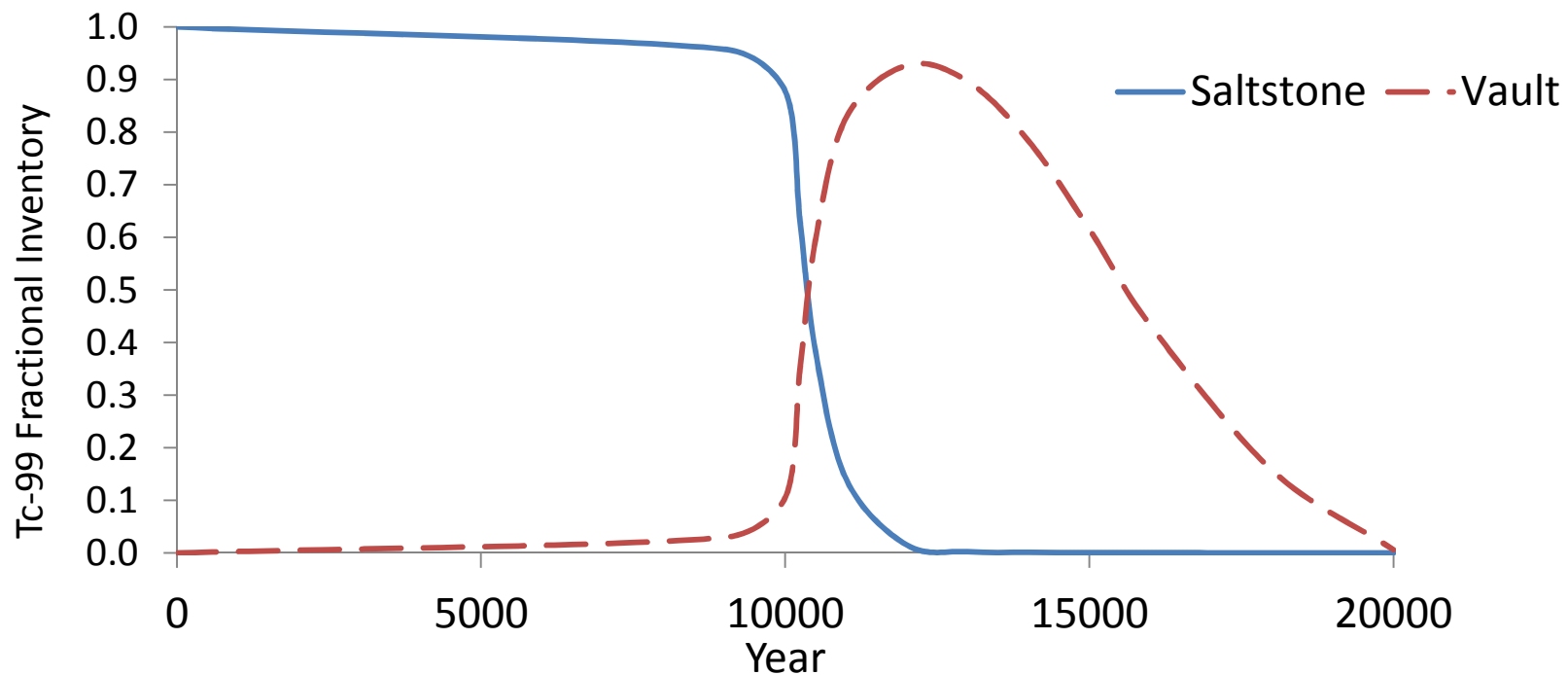
# Barrier Analysis Examples: SRS Saltstone Disposal Facility (SDF)

## SDF Barriers (2009 PA)



# Barrier Analysis Examples: SRS SDF

## Analysis of PORFLOW Output (Related to 2009 PA Review)





# Barrier Analysis Examples: SRS SDF

Re-ran PORFLOW Model to Consider Alternative Barrier Performance (related to 2009 PA review)

(Highlighted values indicate values changed since the previous test.)

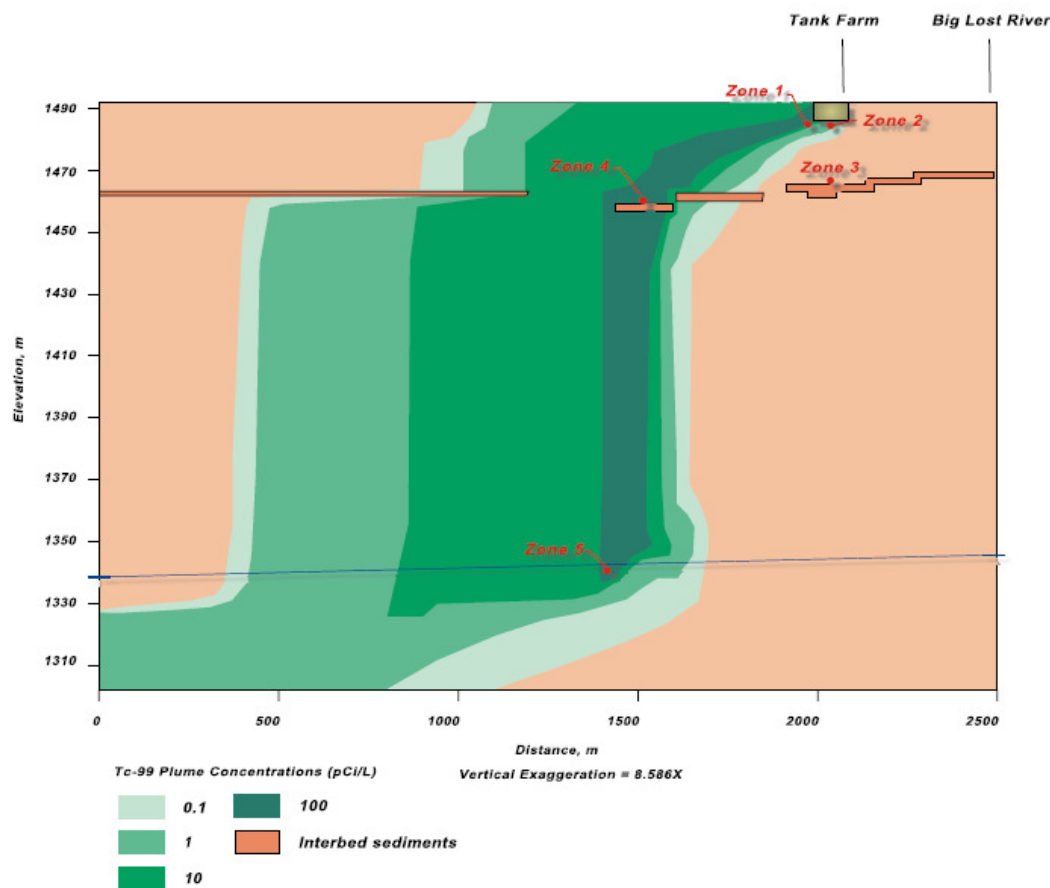
	Saltstone $K_d$ (mL/g)		Disposal Unit $K_d$ (mL/g)	Fracturing Scheme	Final Fracture Spacing (m)	Time of Peak Release Rate (yr)	Dose Estimate <sup>1</sup> (mrem/yr)
	Reduced	Oxidized					
DOE Case K1	500	0.8	500 to 217	Log	0.1	12,800	90
Test 1	500	0.8	500 to 217	<b>Quadratic</b>	0.1	12,100	86
Test 2	500	0.8	<b>0.8</b>	Quadratic	0.1	8730	680 <sup>2</sup>
Test 3	500	0.8	0.8	<b>Log</b>	0.1	10,300	930 <sup>2</sup>
Test 4	500	0.8	0.8	Quadratic	<b>1</b>	19,100	25
Test 5	<b>139</b>	0.8	0.8	Quadratic	1	10,100	35





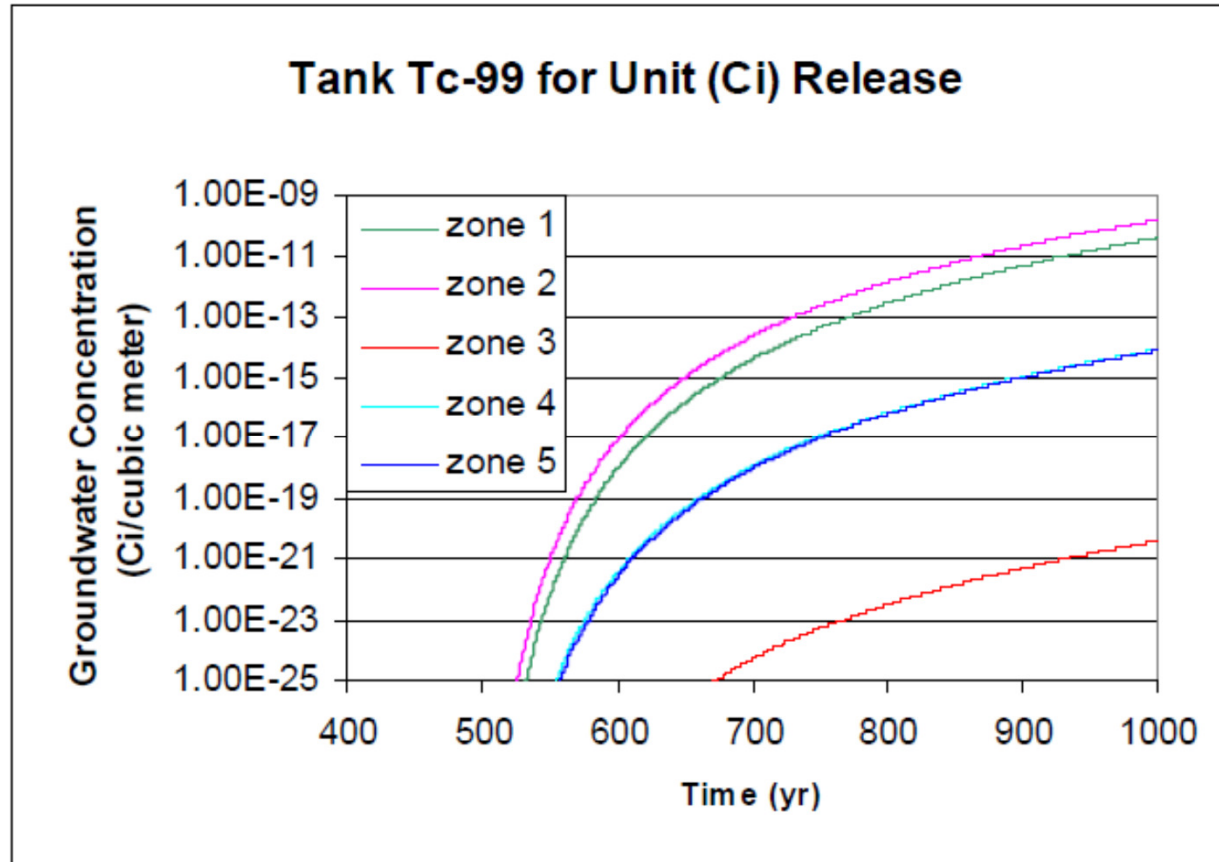
# Barrier Analysis Examples: Idaho National Laboratory

## Tracking of Peak Plume Concentrations Through Barriers



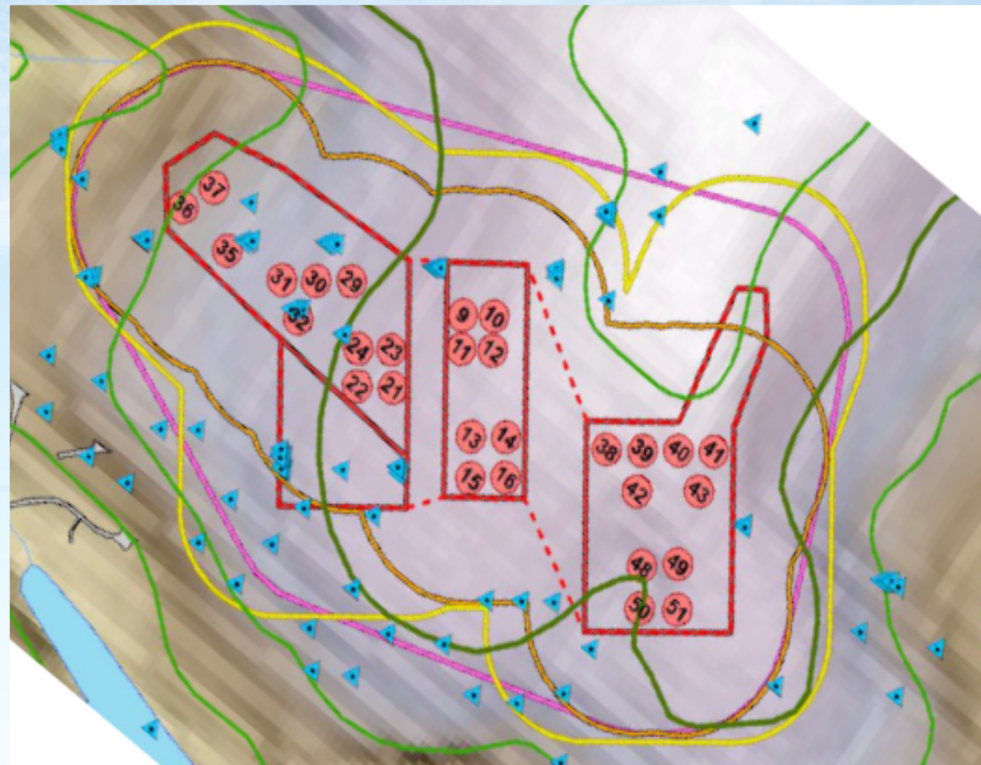
# Barrier Analysis Examples: Idaho National Laboratory

## Tracking of Peak Plume Concentrations Through Barriers



# Barrier Analysis Examples: SRS HTF

## Impact of Assessment Endpoint on Barrier Contributions



# Final Thoughts

- Barrier analyses can contribute substantially to better understanding model performance and potential modeling issues
- Barrier analysis can help reviewers ask better questions and focus on areas that are most important to risk
- Barrier analyses are important to understanding the impact of challenges to the disposal system
- Barrier analyses facilitates communication between stakeholders
- Barrier analysis contributions are a function of assessment endpoints including point of compliance and period of performance

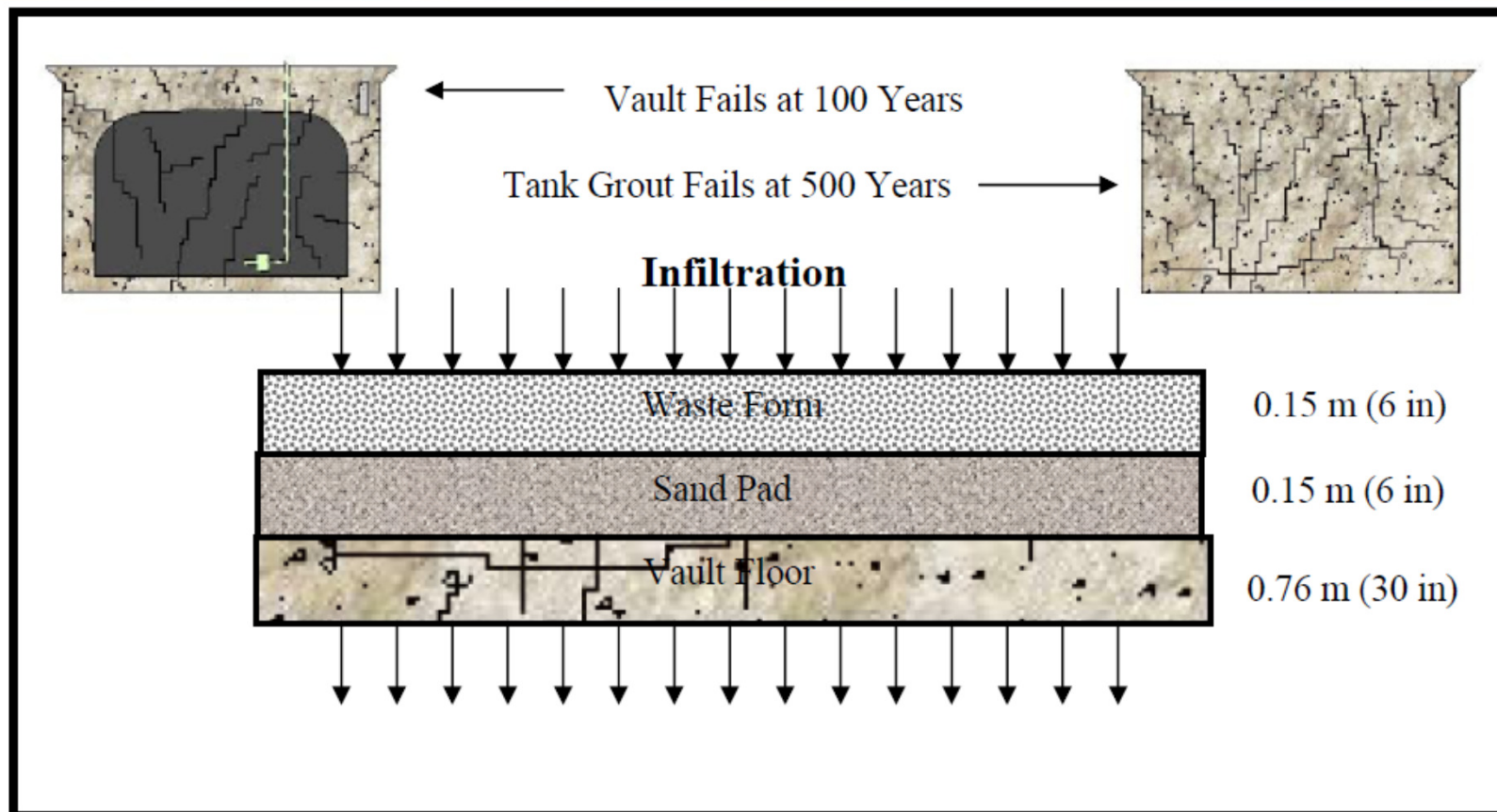
# Additional slides if needed





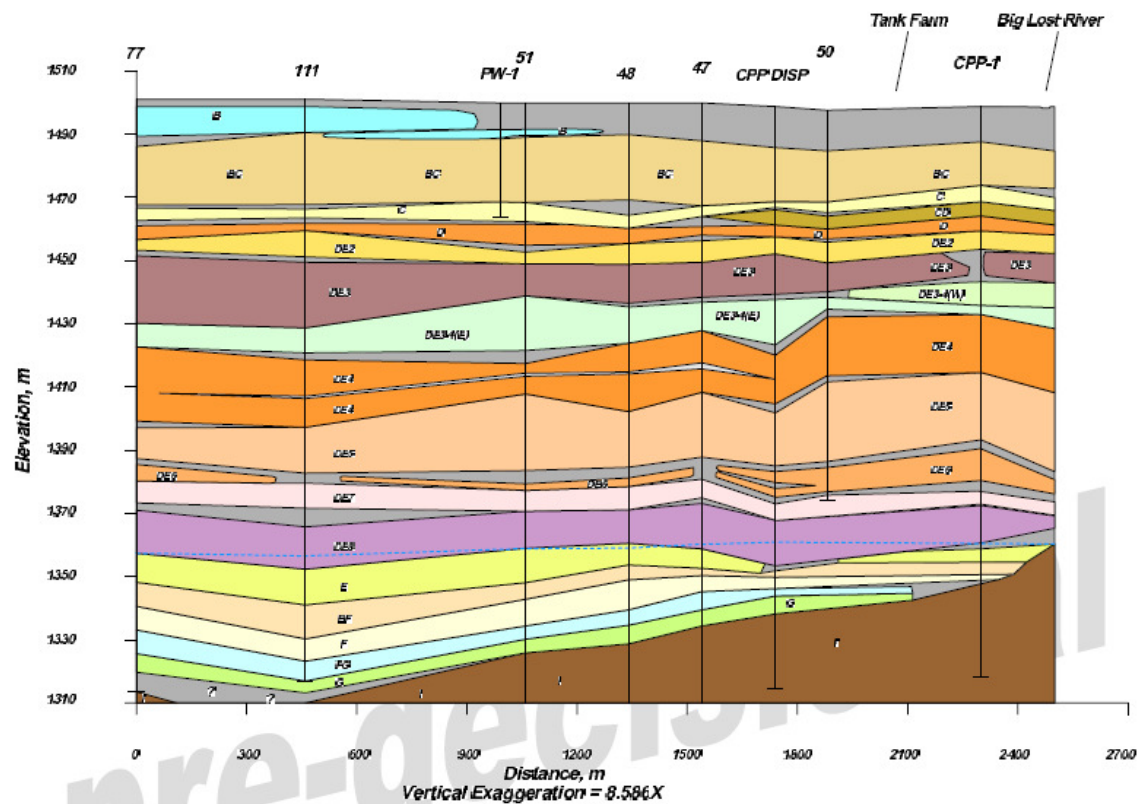
# Barrier Analysis Examples: Idaho National Laboratory

## Idaho Nuclear Technology and Engineering Center Tank Farm Facility (INTEC TFF) Barriers



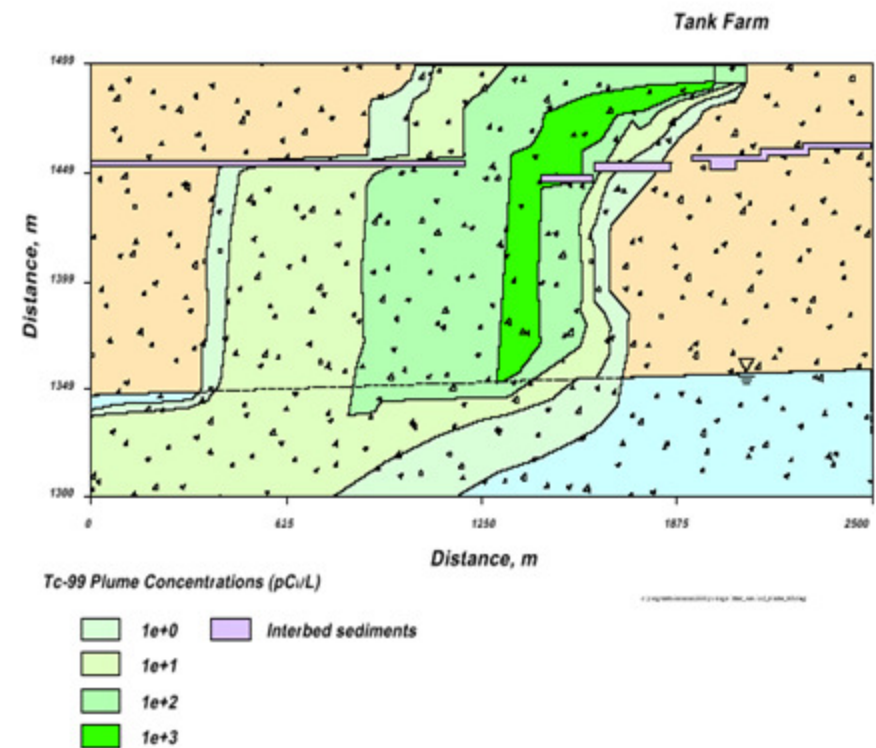
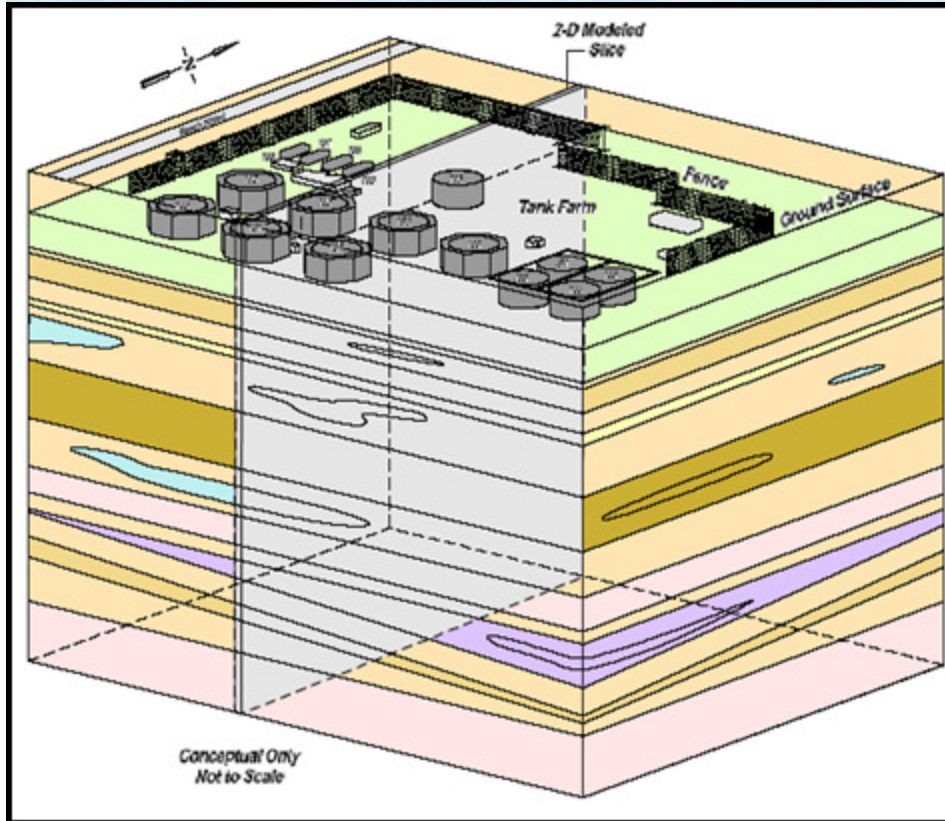
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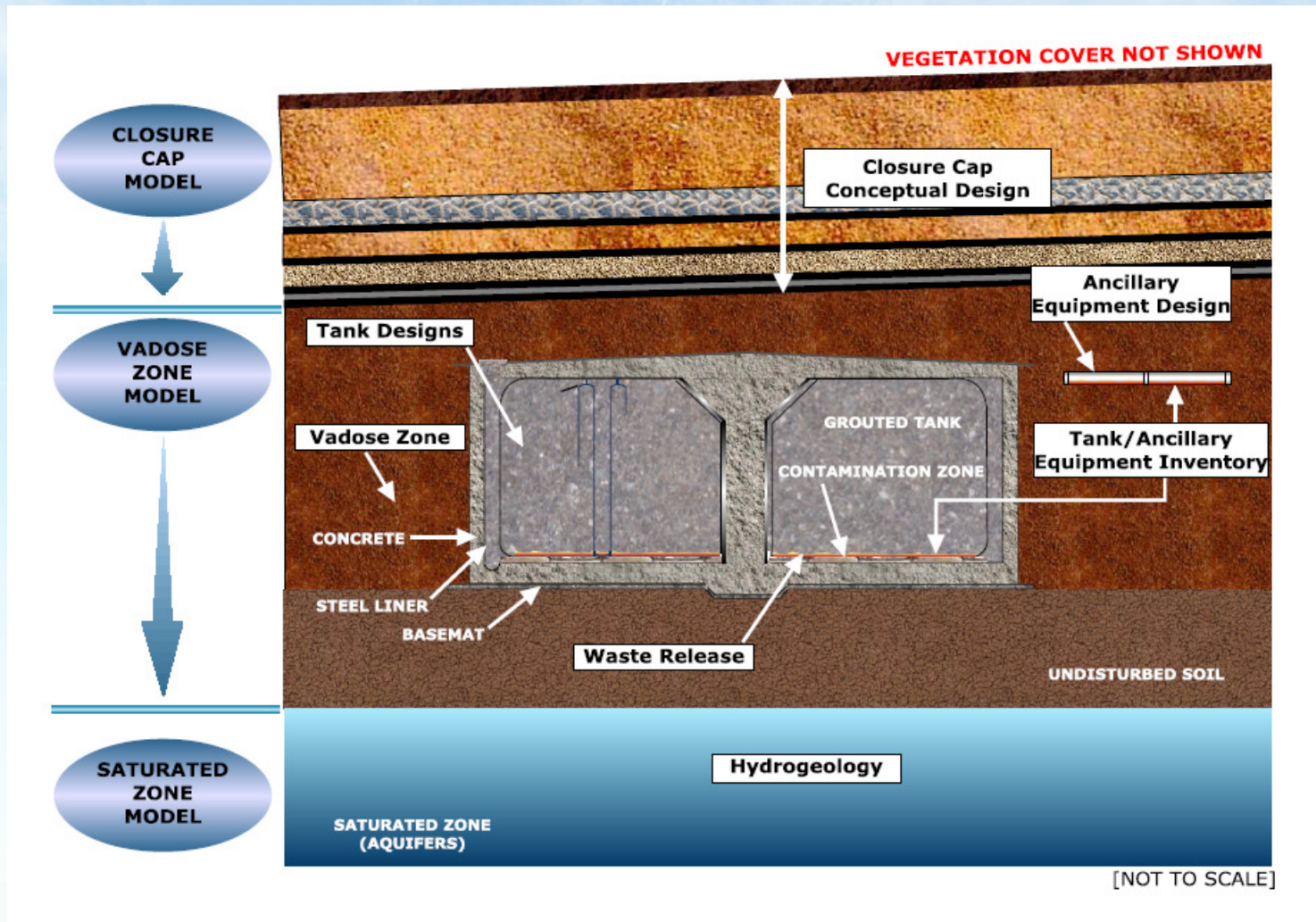
# Barrier Analysis Examples: Idaho National Laboratory

## Idaho Nuclear Technology and Engineering Center Tank Farm Facility (INTEC TFF) Barriers



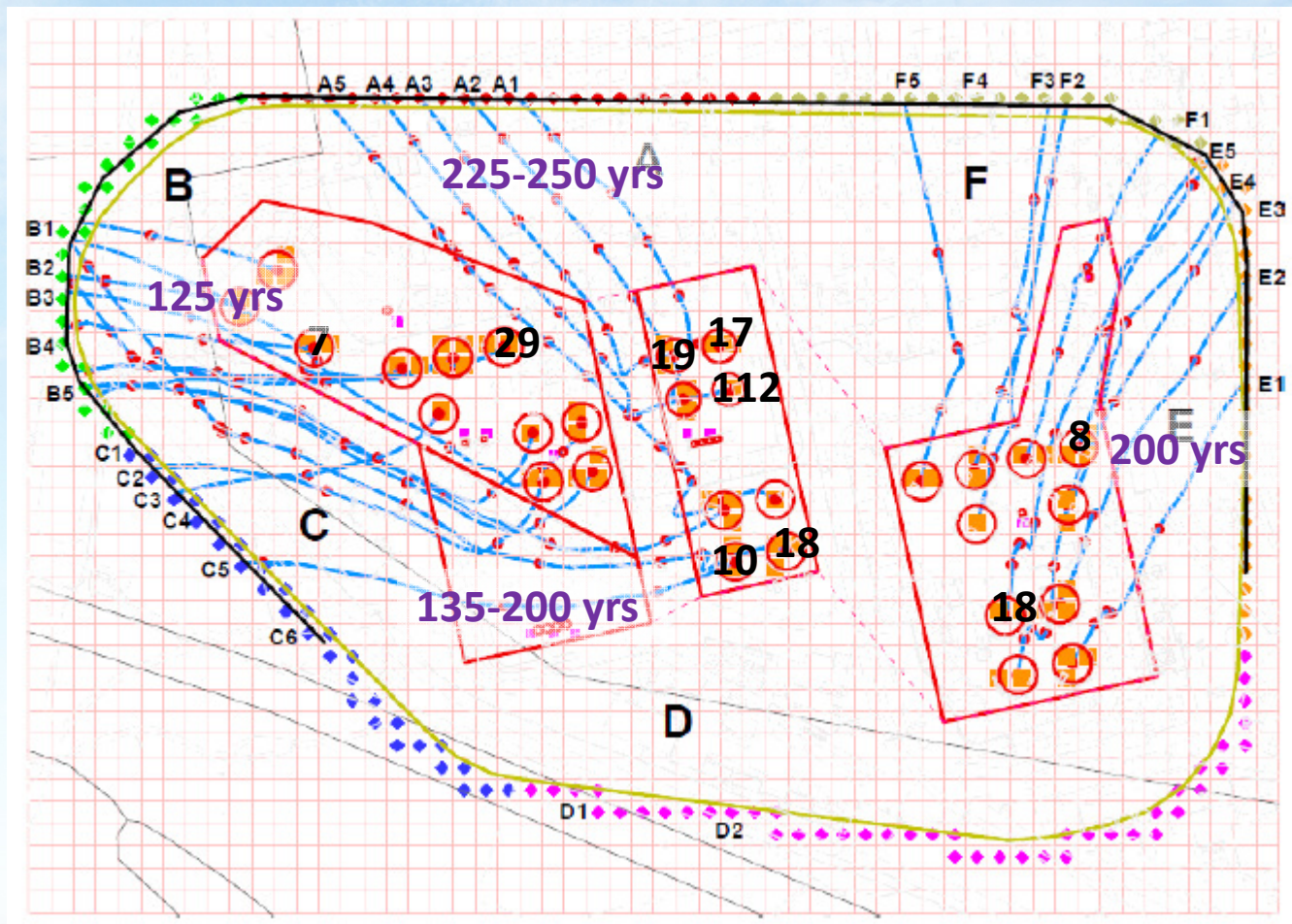
# Barrier Analysis Examples: SRS

## H-Tank Farm Facility (HTF) Barriers



# Barrier Analysis Examples: SRS HTF

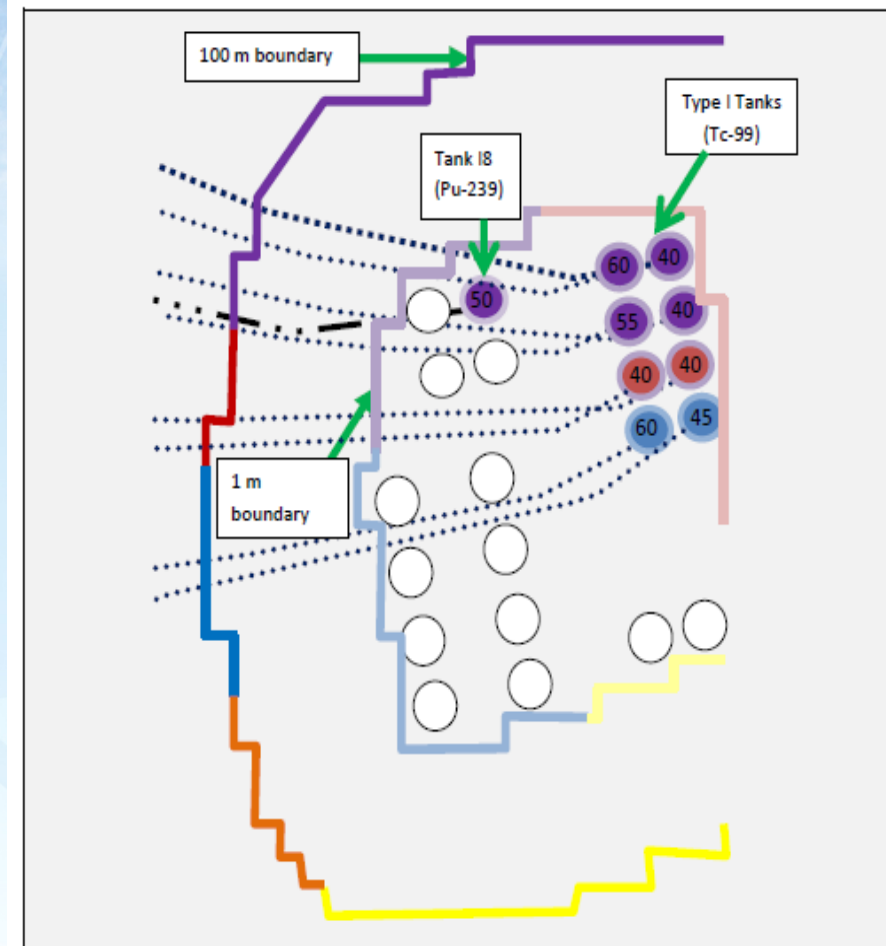
## Dilution/Attenuation Factor Example



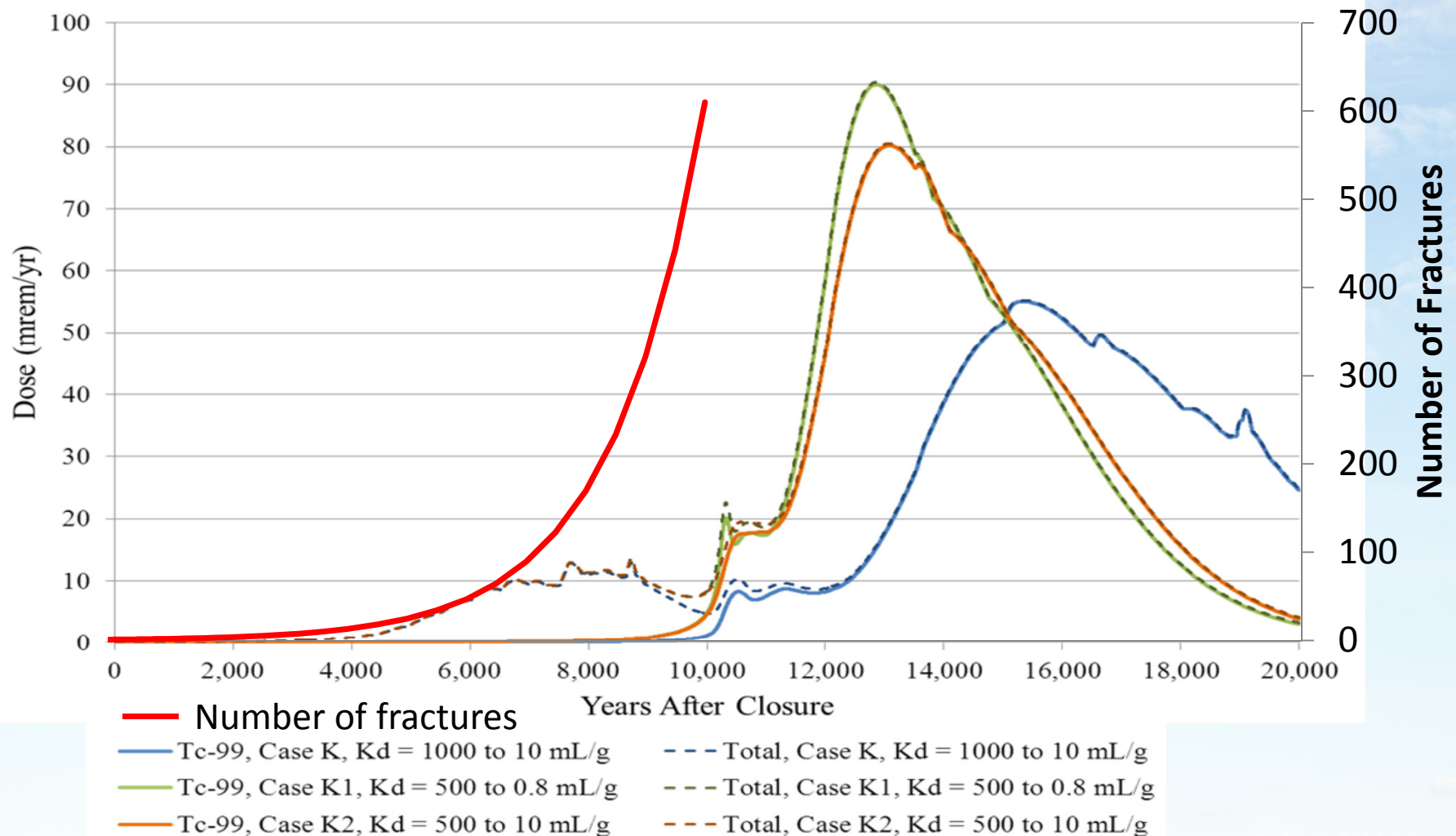
# Barrier Analysis Examples: SRS FTF

## Single Natural System Barrier Example

- Type I Tanks--Attenuation factors are 15-40 from the source to the 1-m boundary and 1.3 to 3 from the 1-m to the 100-m boundary for Tc-99. Dispersion, cumulative impacts relatively significant (trade-off).
- Tank 18--Attenuation factor is 5 from the source to the 1-m boundary and 10 from the 1-m to the 100-m boundary for Pu-239. Dispersion, cumulative impacts less significant.



# Barrier Analysis Examples: SRS SDF



Adapted from DOE Response to NRC's Second Request for Additional Information, Fig. SP-19