U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Disruptive Events PMR Volcanism, Seismicity and Structural Deformation

Presented to:
Nuclear Waste Technical Review Board
Carson City, NV

Presented by:
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YUCCA MOUNTAIN PROJECT

Goals of Presentation

- **Describe Disruptive Events for TSPA-SR**
- **Describe seismicity and structural deformation FEPs analyzed**
- **Describe intrusive and eruptive volcanic event consequence models developed by AMRs**
- **Describe TSPA-SR treatment of volcanic events**
- **Present TSPA-SR dose results for volcanic events**
- **Present dose results sensitivity analyses related to volcanism**

Process Model Factors for Disruptive Events Scenario

Key Attributes of Performance	Process Model Factor	TSPA-SR Input Parameters
Effects of Potentially Disruptive Processes and Events	Seismic Activity	• Probability of seismicity/structural deformation
	Volcanic Direct Release	• Annual probability of igneous intrusion • Atmospheric transport parameters • Probability that an intrusion will result in one or more eruptive vents • Number of vents through the waste • Wind direction factor • Wind speed • Biosphere dose conversion factors - f (radionuclide) • Factor to account for radionuclide removal from soil
	Intrusive Indirect Release	• Annual probability of igneous intrusion • Number of Waste Packages damaged by intrusion (for groundwater transport source term)

Seismicity and Structural Deformation Analysis

- **Examined 13 primary Features, Events, Processes (FEPs):**
  - **Topics: Tectonics; Seismicity; Fractures; Faulting; Hydrologic Effects**
  - **Ground motion/seismic vibration effects:**
    - **Include, nominal case, seismic vibration effects on cladding and drip shield**
    - **Exclude others**
  - **Faulting, Fracturing:**
    - **Include as existing properties in UZ/SZ**
    - **Exclude effects of potential changes on properties, low consequence**
  - **Hydrologic response to seismicity/faulting: Exclude, low consequence**
- **Used expert elicitation: Probabilistic Seismic Hazard Analysis**
  - **Developed hazard curves for fault displacement and ground motion**
- **Two Disruptive Events AMRs support FEPs analysis of fracture change and fault displacement effects**

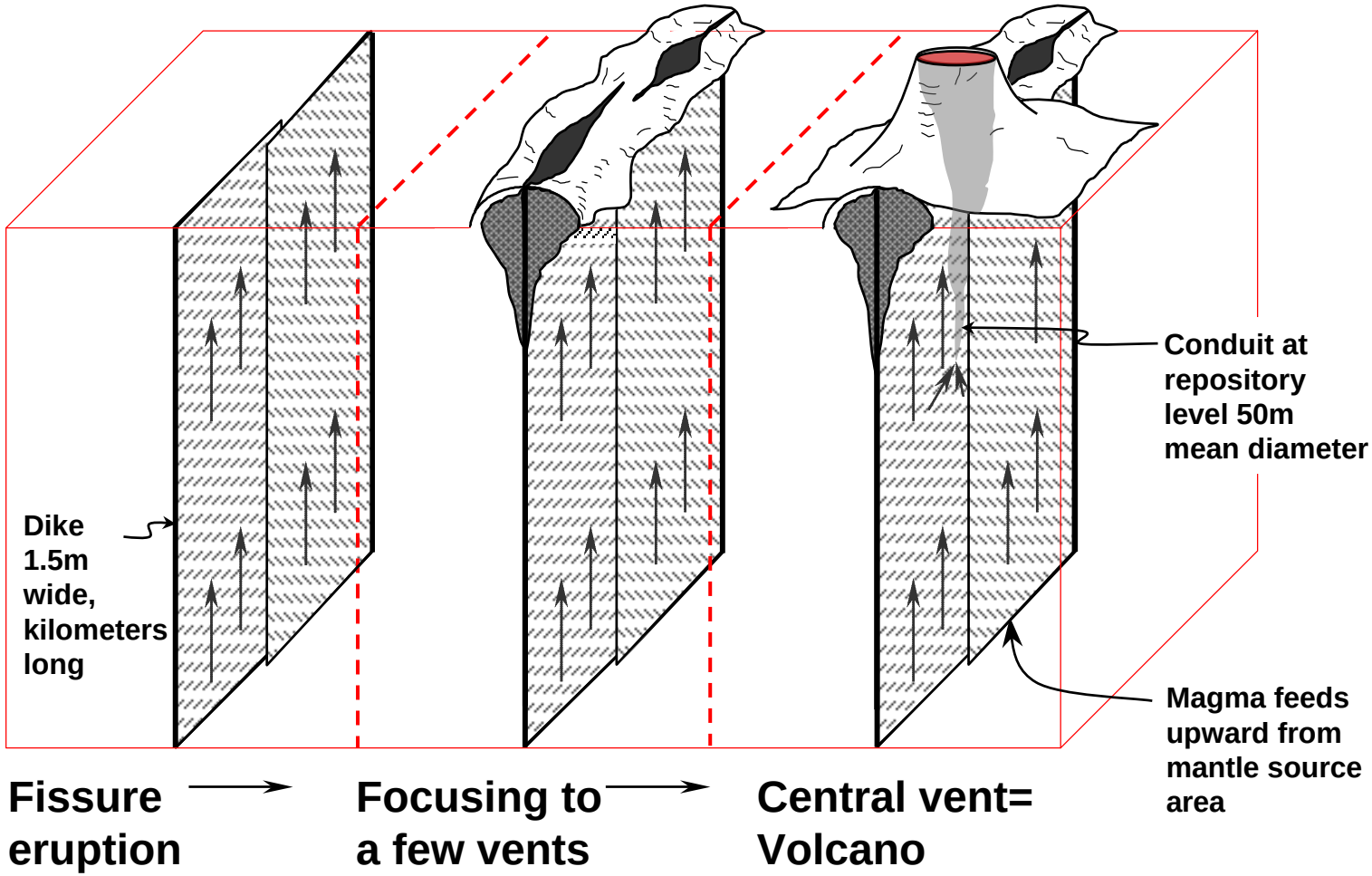
Primary Seismicity and Structural Deformation FEPs

YMP FEP Database Number	FEP Name	Screening Decision	Screening Basis
1.2.01.01.00	Tectonic activity—large scale	"Exclude"	Low Consequence
1.2.02.01.00	Fractures	"Include": existing characteristics "Exclude": changes to characteristics.	Low Consequence
1.2.02.02.00	Faulting	"Include": existing characteristics "Exclude": changes in fault properties.	"Excluded" based on low consequence, and low probability
1.2.02.03.00	Fault movement shears waste container	"Exclude"	Low Probability
1.2.03.01.00	Seismic activity (Note: Includes faulting, hydraulic heads, recharge-discharge zones, rock stresses, drift integrity)	"Exclude" for indirect effects "Include" for drip shield and fuel-rod cladding damage	Low Consequence
1.2.03.02.00	Seismic vibration causes container failure	"Exclude" TBV for waste package "Include" for drip shield and fuel-rod cladding.	Low Consequence
1.2.03.03.00	Seismicity associated with igneous activity	"Exclude" for indirect effects "Include" for drip shield and fuel-rod cladding damage	Low Consequence
1.2.10.01.00 *	Hydrologic response to seismic activity	"Exclude"	Low Consequence

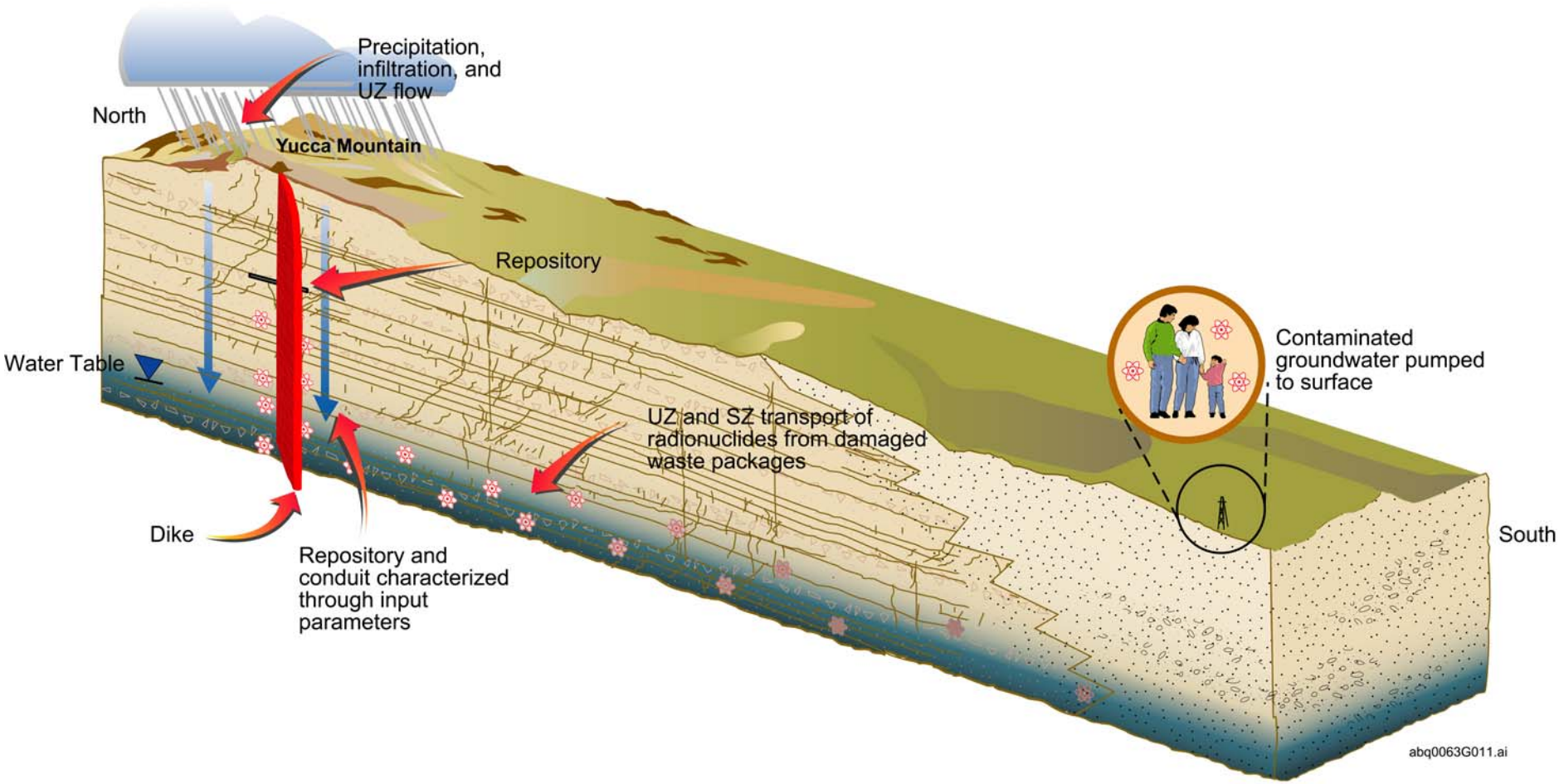
Disruptive Events Analysis
Volcanism

- **Examined 8 primary volcanism FEPs**
  - **3 excluded, low consequence/ 5 included TSPA-SR**
- **Used expert elicitation results, probability**
  - **Summarized key concepts from expert elicitation**
  - **Added new consequence data**
  - **Updated probability values for current repository layout**
  - **Examined potential impact of recent studies (Wernicke, Magsino)**
- **Produced parameters for probability/consequence**
  - **Dike intersecting repository, conduit within repository, eruptive process/ash plume, interaction of magma with repository**
- **Consequence AMR recommended to PA conceptual model/parameters for intrusive and extrusive events**

Intrusive Dike and Extrusive/Eruptive Volcano Formation



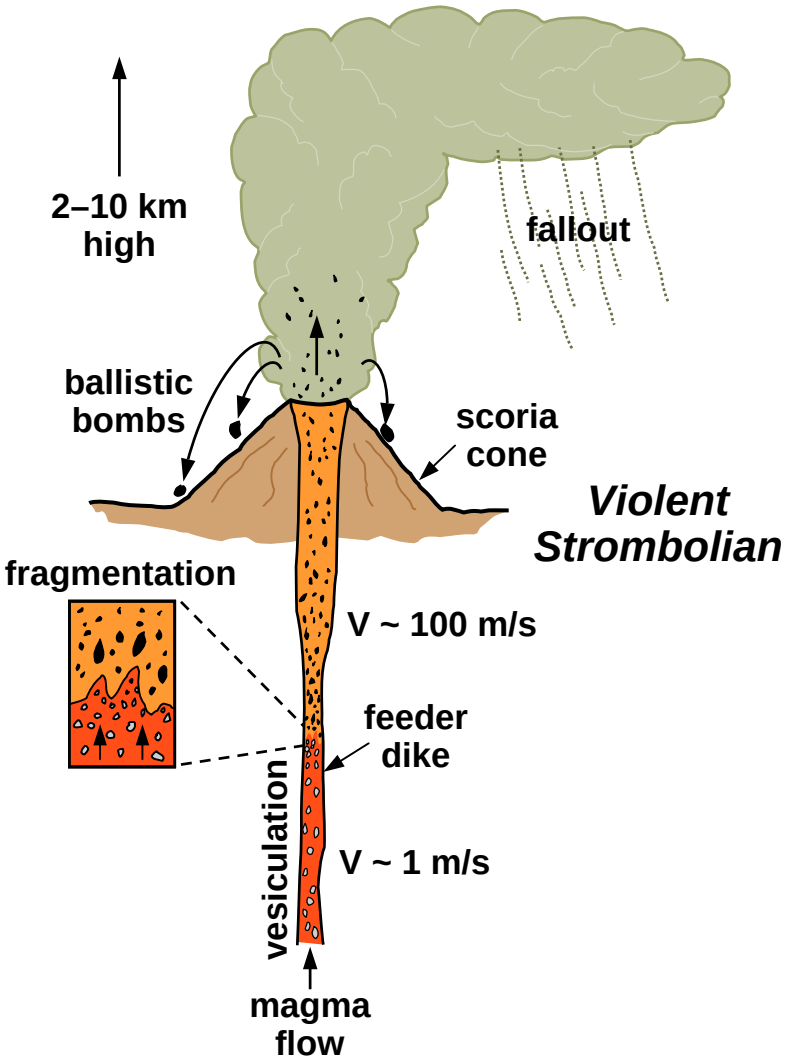
Igneous Intrusion Groundwater Release

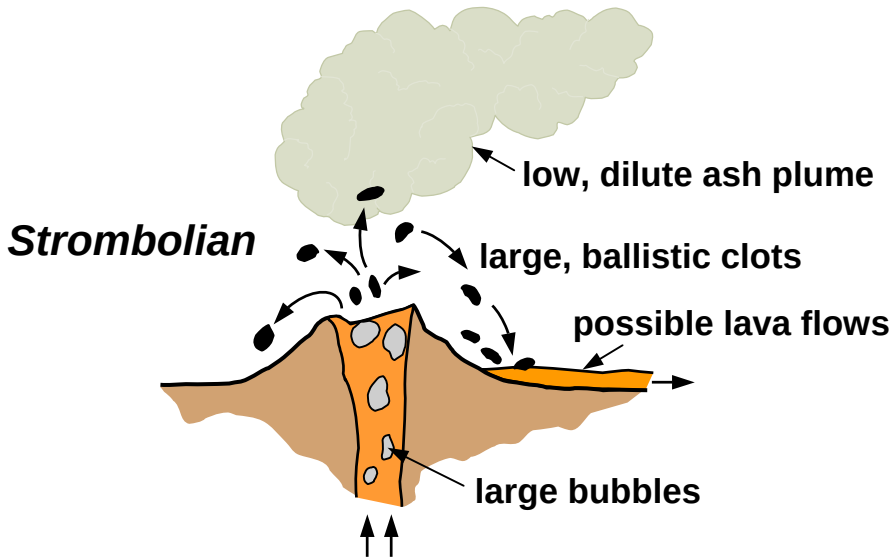


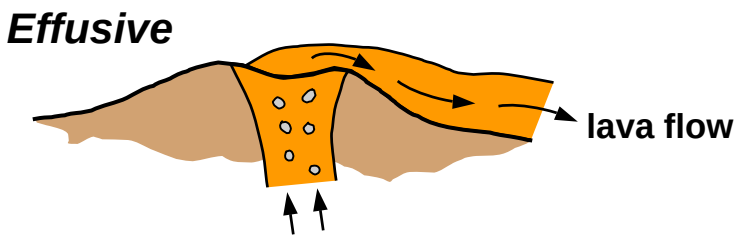
Igneous Intrusion Groundwater Model

- **Probability of dike intersection with repository**
  - **PVHA 1.5 X10^{-8} AMR updated value 1.6 X10^{-8}**
- **Consequence parameters:**
  - **More comprehensive literature review/analysis**
  - **Magma characteristics: Temperature, Pressure, Chemistry**
  - **Dike properties: Width, length, number of dikes**
  - **Conceptualization of magma-drift and magma-waste package interaction, number packages hit**
- **Conceptual model TSPA-SR:**
  - **Waste packages compromised by magmatic environment**
  - **Magma cools, fractures**
  - **Groundwater infiltrates, contacts exposed waste**
  - **Increased source term in groundwater, modeled same as nominal case in UZ/SZ transport**

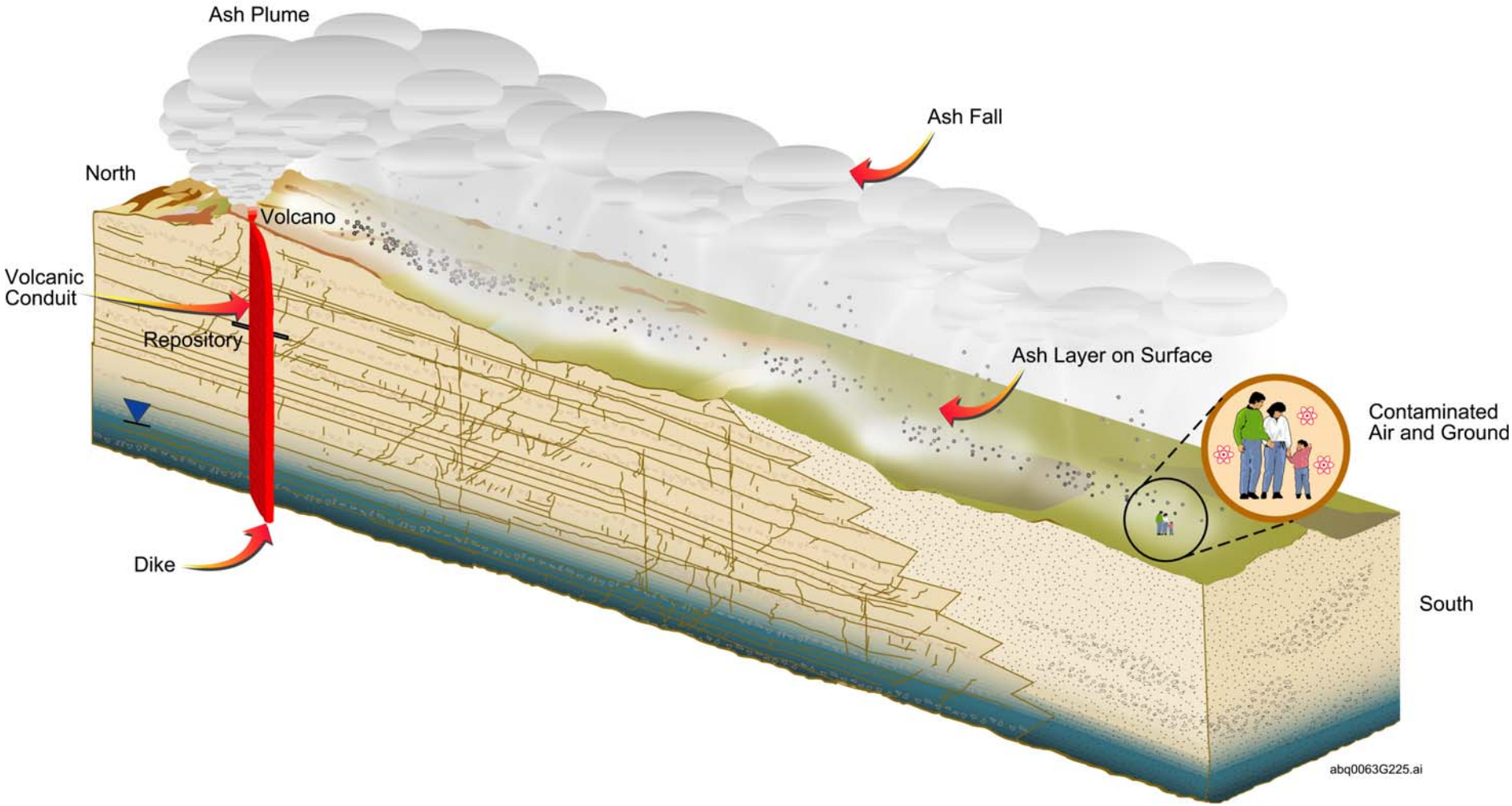
Magma Ascent and Eruptive Processes in YMR







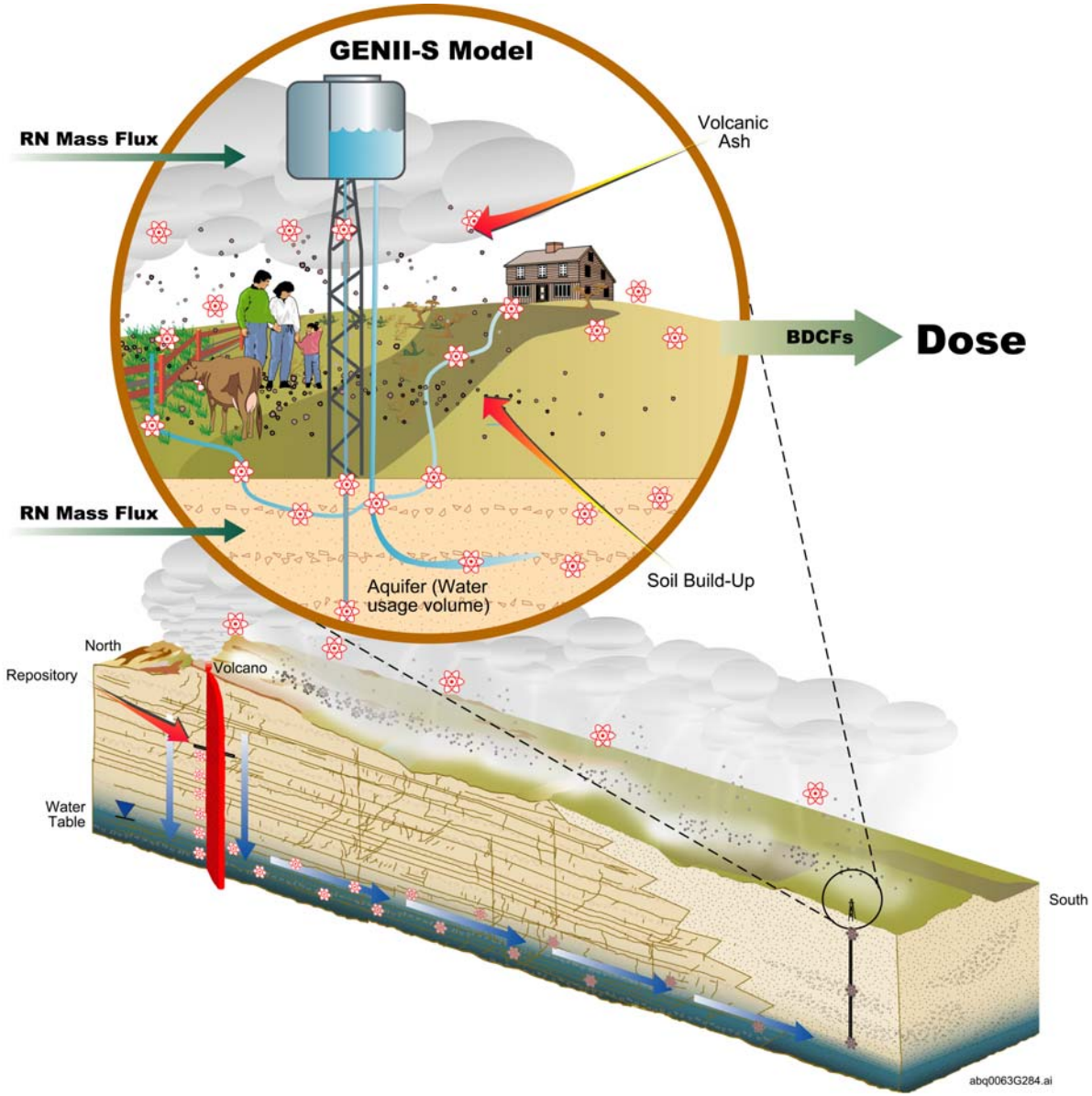
Volcanic Eruption Release



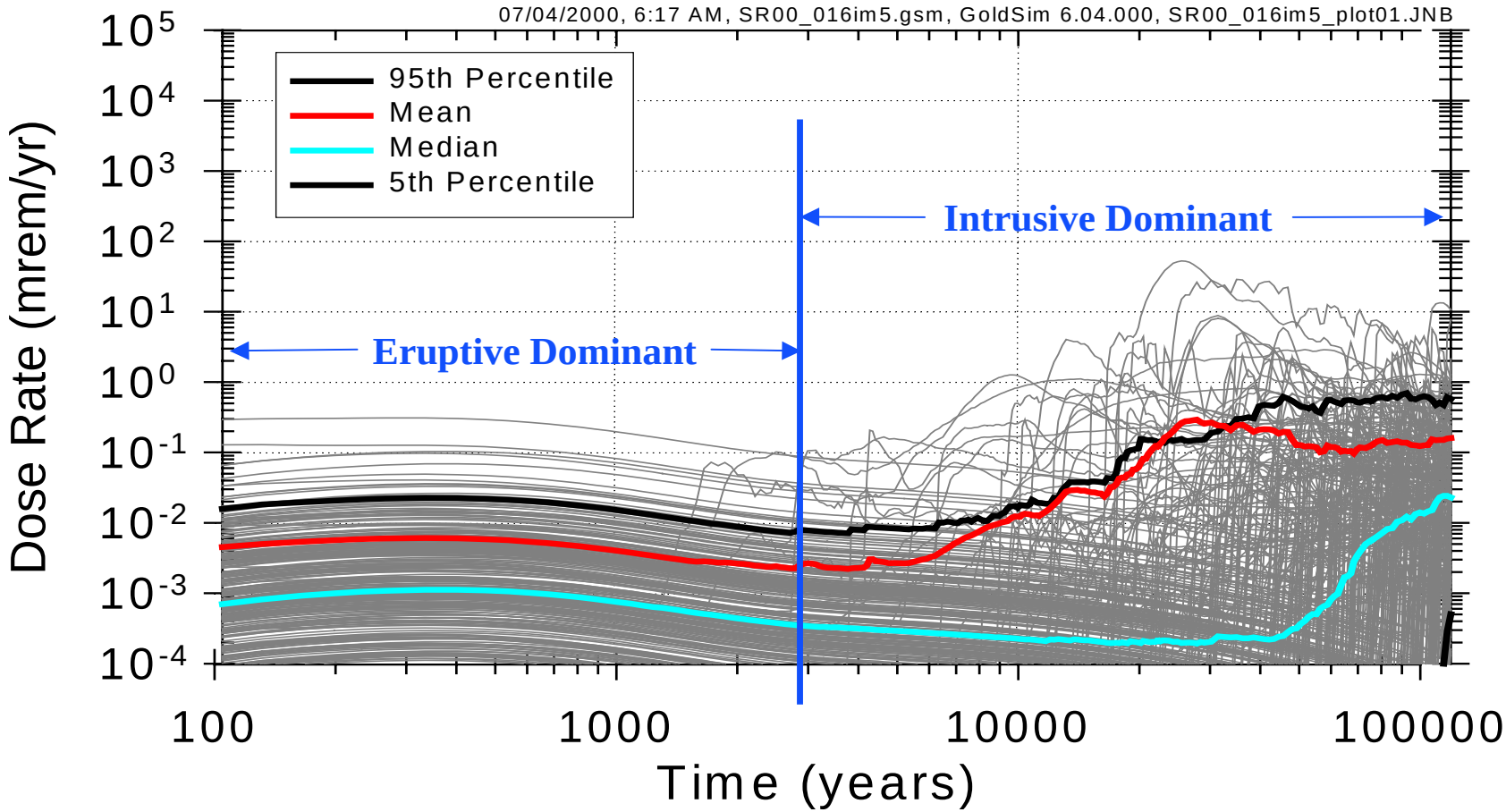
Volcanic Eruption Release

- **Probability of eruption through repository**
  - **Probability of dike intersection $1.6X10^{-8}$**
  - **Conditional probability of one or more eruptive centers within repository $5.8X10^{-9}$**
- **For all packages within conduit all waste available for transport in eruptive column**
- **Disruptive Events Consequence AMR presents parameters that characterize processes:**
  - **Eruptive characteristics: Conduit diameter; magma characteristics; eruption duration and volume; bulk grain size/shape**
  - **Atmospheric transport: Wind direction and speed; waste particle size**

Biosphere Inputs to Volcanism Dose



TSPA-SR Dose
Volcanism, Eruptive and Intrusive



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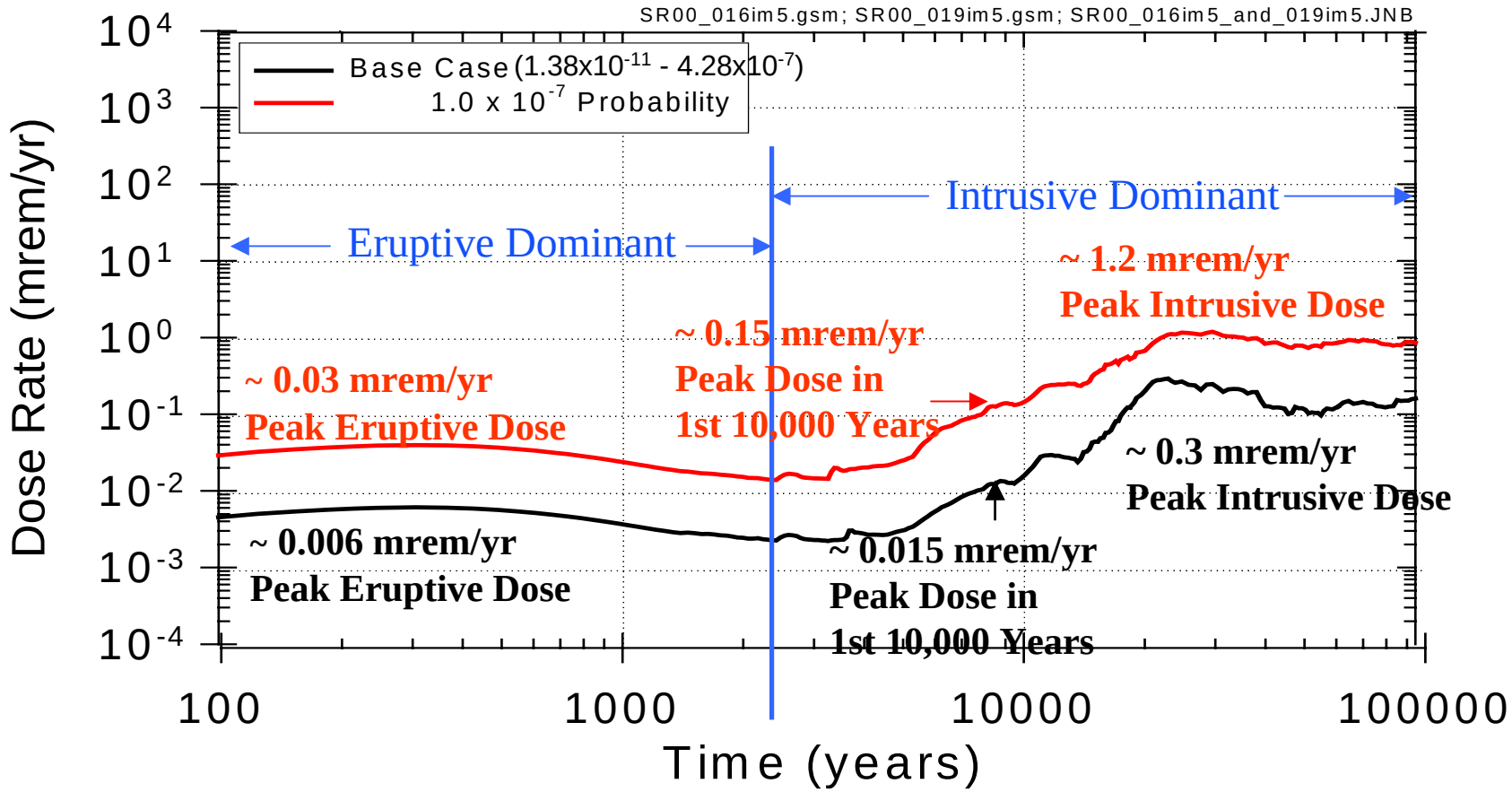
TSPA-SR Dose Sensitivity Analysis Event Probability



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Conclusions

- **Disruptive Events are included as Process Model Factors for TSPA-SR**
  - **Sensitivity analyses have been performed on Factors**
- **TSPA-SR modeling of seismicity/faulting**
  - **Seismicity (ground motion), include, nominal case, seismic vibration effects on cladding and drip shield**
  - **FEPs analysis shows remaining FEPs, excluded, low consequence or low probability**
  - **Currently re-examining FEPs, no backfill design**
- **TSPA-SR includes volcanism, only contributor to dose within regulatory period**

Backup Slides

Primary Volcanism FEPs

YMP FEP Database Number	FEP Name	Screening Decision	Screening Basis
1.2.04.01.00	Igneous activity (Note: Also effects on faults, topography, rock stresses, groundwater temperatures & drift integrity)	"Include": for direct effects "Exclude": for indirect effects	Low Consequence of Indirect Effects
1.2.04.02.00 *	Igneous activity causes changes to rock properties	"Exclude"	Low Consequence
1.2.04.03.00	Igneous intrusion into repository	"Include"	
1.2.04.04.00	Magma interacts with waste	"Include"	
1.2.04.05.00	Magmatic transport of waste	"Exclude" for transport in liquid magma and other types of transport. "Include" for transport through eruptive events	Low Consequence
1.2.04.06.00	Basaltic cinder cone erupts through the repository (Note: Also entraining waste)	"Include"	
1.2.04.07.00	Ashfall	"Include"	
1.2.10.02.00	Hydrologic response to igneous activity (Note: Includes groundwater flow directions; water level, chemistry, temperature; change in rock properties)	"Exclude"	Low Consequence
2.1.07.01.00	Rockfall (large block)	"Exclude"	Low Consequence
2.1.07.02.00	Mechanical degradation or collapse of drift	"Exclude"	Low Consequence
2.2.06.01.00 *	Changes in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock	"Exclude"	Low Consequence
2.2.06.02.00 *	Changes in stress (due to thermal, seismic, or tectonic effects) produces change in permeability of faults	"Exclude"	Low Consequence
2.2.06.03.00 *	Changes in stress (due to seismic or tectonic effects) alter perched water zones)	"Exclude"	Low Consequence

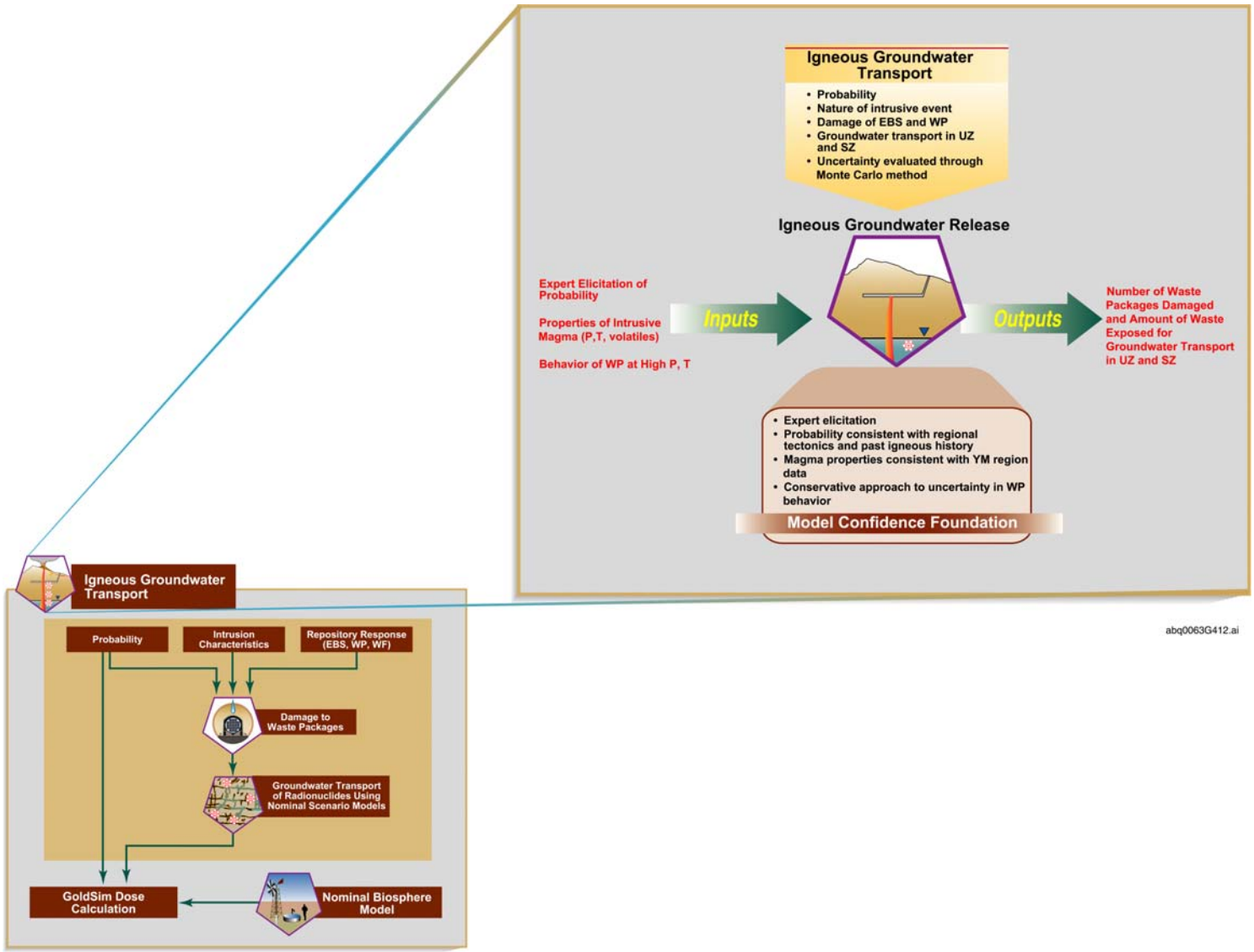
Methodology: Annual Frequency of Volcanic Event Producing One or More Eruptive Centers Within Repository from Disruptive Events AMR

Calculate the frequency of intersection of the repository footprint by a dike
PVHA formulation
Recalculated using the current (EDA II) repository footprint
Calculate the conditional probability that an intersecting dike will produce a specific value of length and azimuth within the repository
Break down (disaggregate) the total frequency of intersection into frequencies for specific values of intersecting dike length, dike azimuth , and intersection length increments
The sum of the numbers in all length-azimuth bins equals the frequency of intersection
The values in each bin divided by the frequency of intersection provide a conditional distribution for length and azimuth given an intersection
Calculate the conditional distribution for the number of eruptive centers that occur within the repository footprint given that there is an intersection by a dike associated with a volcanic event
Based on the PVHA experts' assessments of the number of volcanic events represented by the observed eruptive centers in the Yucca Mountain Region and characteristics of Quaternary volcanoes in the PMR (and assumptions described above), derive empirical distributions for the number of eruptive centers per volcanic event
Assess the possible correlation between the number of eruptive centers and dike length
Assess the spatial distribution of eruptive centers along the length of the dike
Use a range of possible assessments to incorporate uncertainties in these parameters into the analysis. Five alternative approaches developed to implement assumptions in order to span the range of available approaches

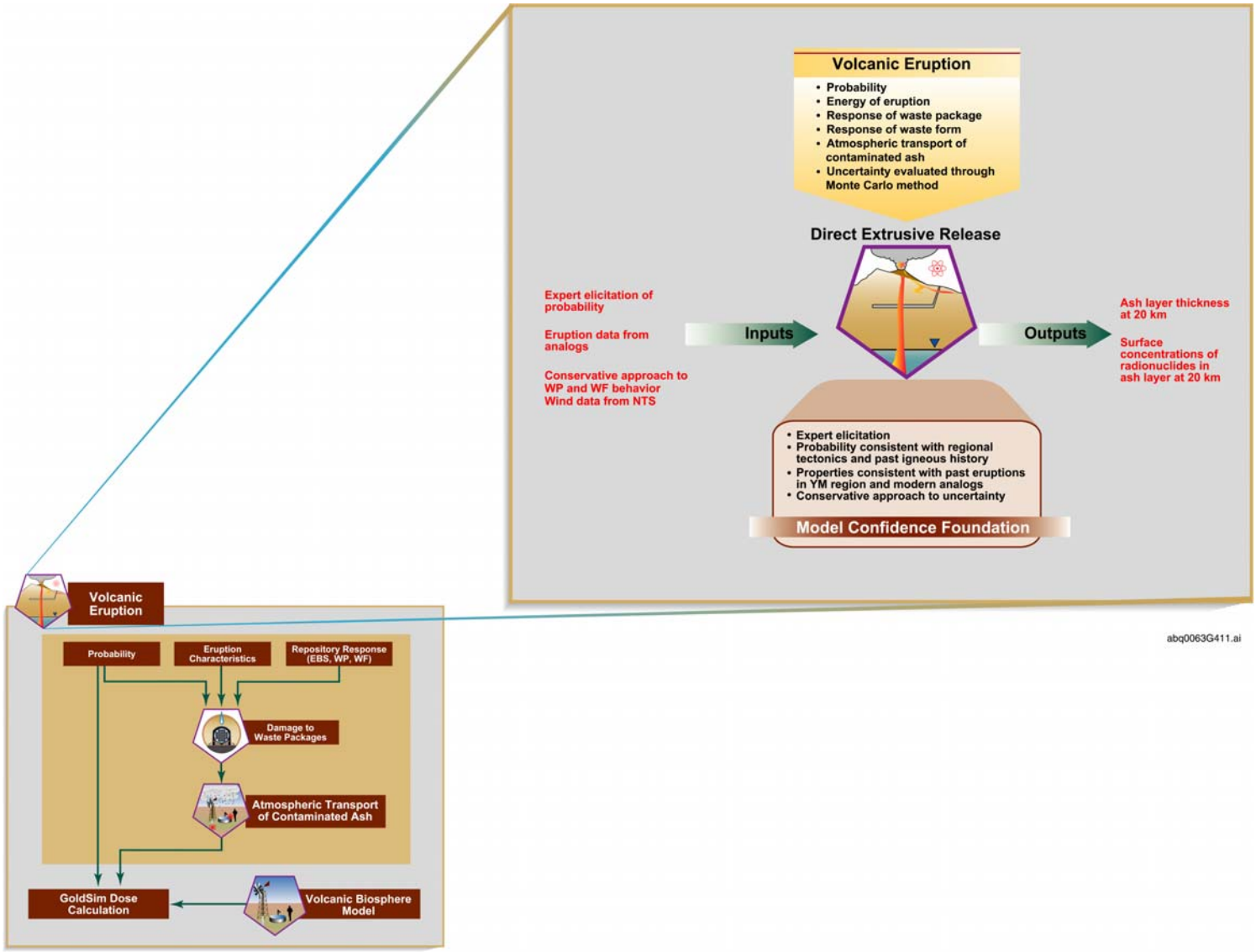
Summary: Frequencies of Volcanic Events TSPA-SR

Repository Footprint (EDA II)	Hazard Level	Annual Frequency of Intersection of Repository by a Dike	Annual Frequency of Occurrence of One or More Eruptive Centers within Repository
Primary+Contingency Blocks	5^{th} percentile	5.8×10^{-10}	2.7×10^{-10}
	Mean	**1.6×10^{-8}**	**5.8×10^{-9}**
	95^{th} percentile	4.9×10^{-8}	1.8×10^{-8}

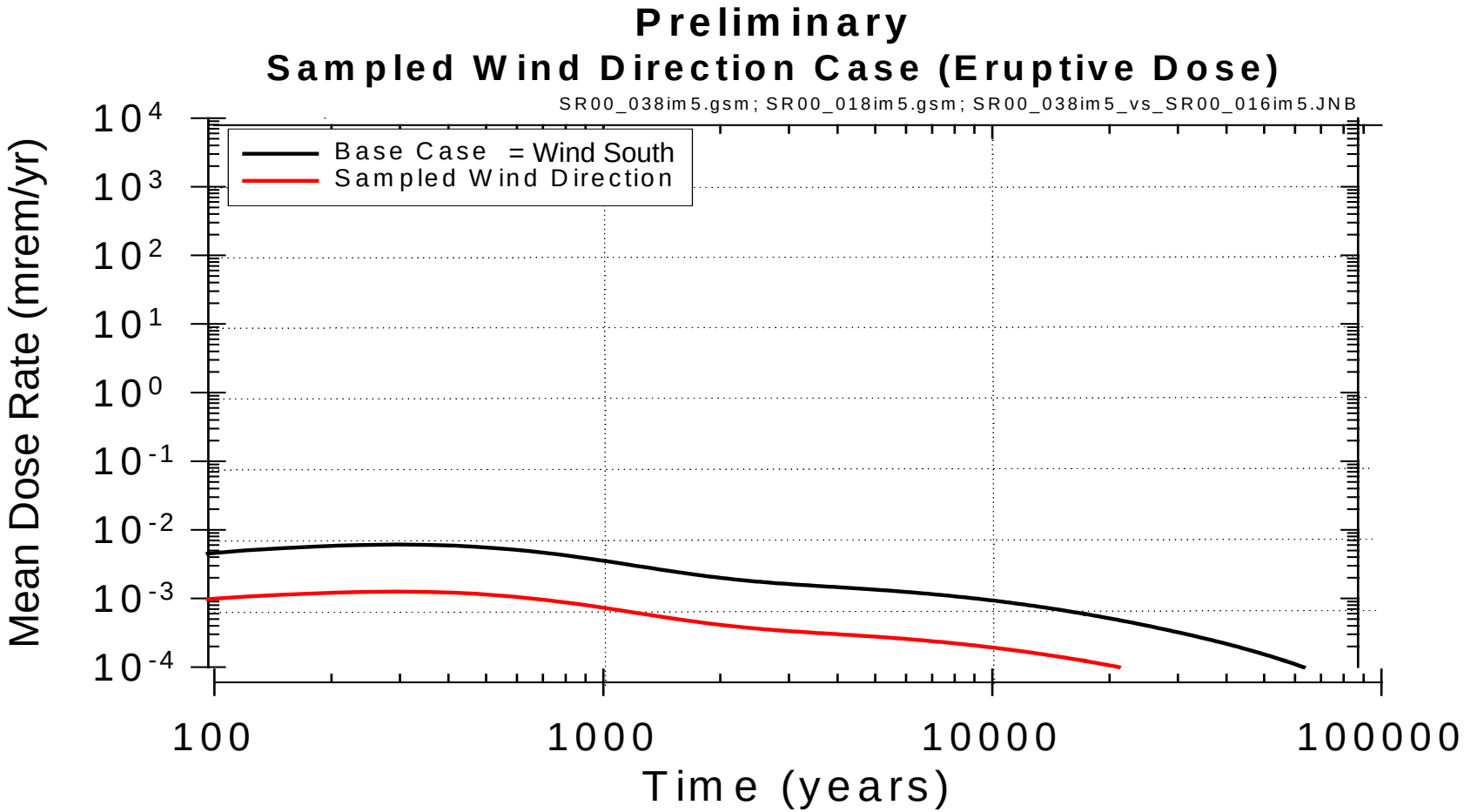
Igneous Groundwater TSPA-SR Model



Volcanic Eruption TSPA-SR Model



TSPA-SR Sensitivity Analysis
Wind Direction (Eruption Dose)



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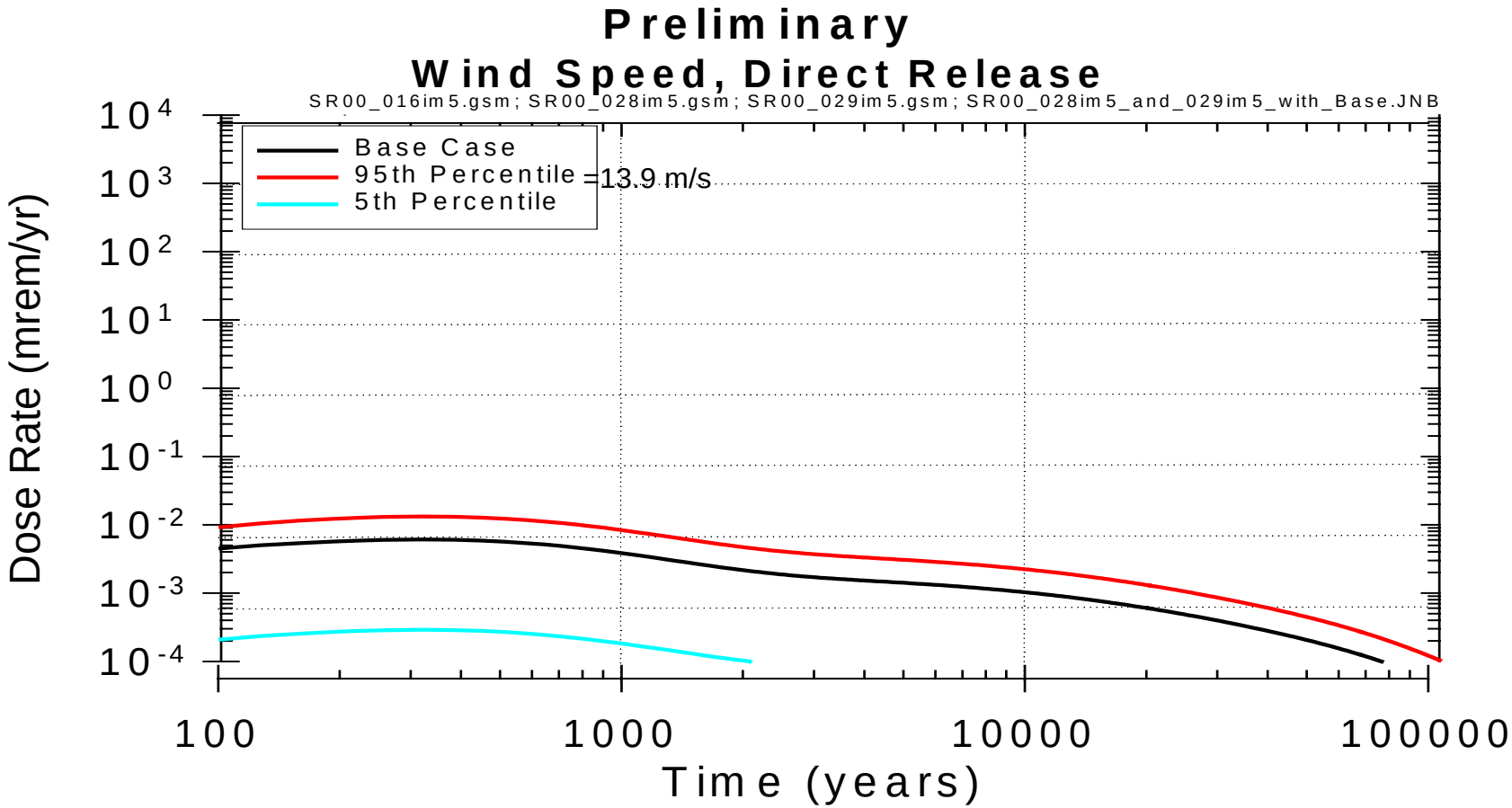
TSPA-SR Sensitivity Analysis
Wind Speed (Eruption Dose)



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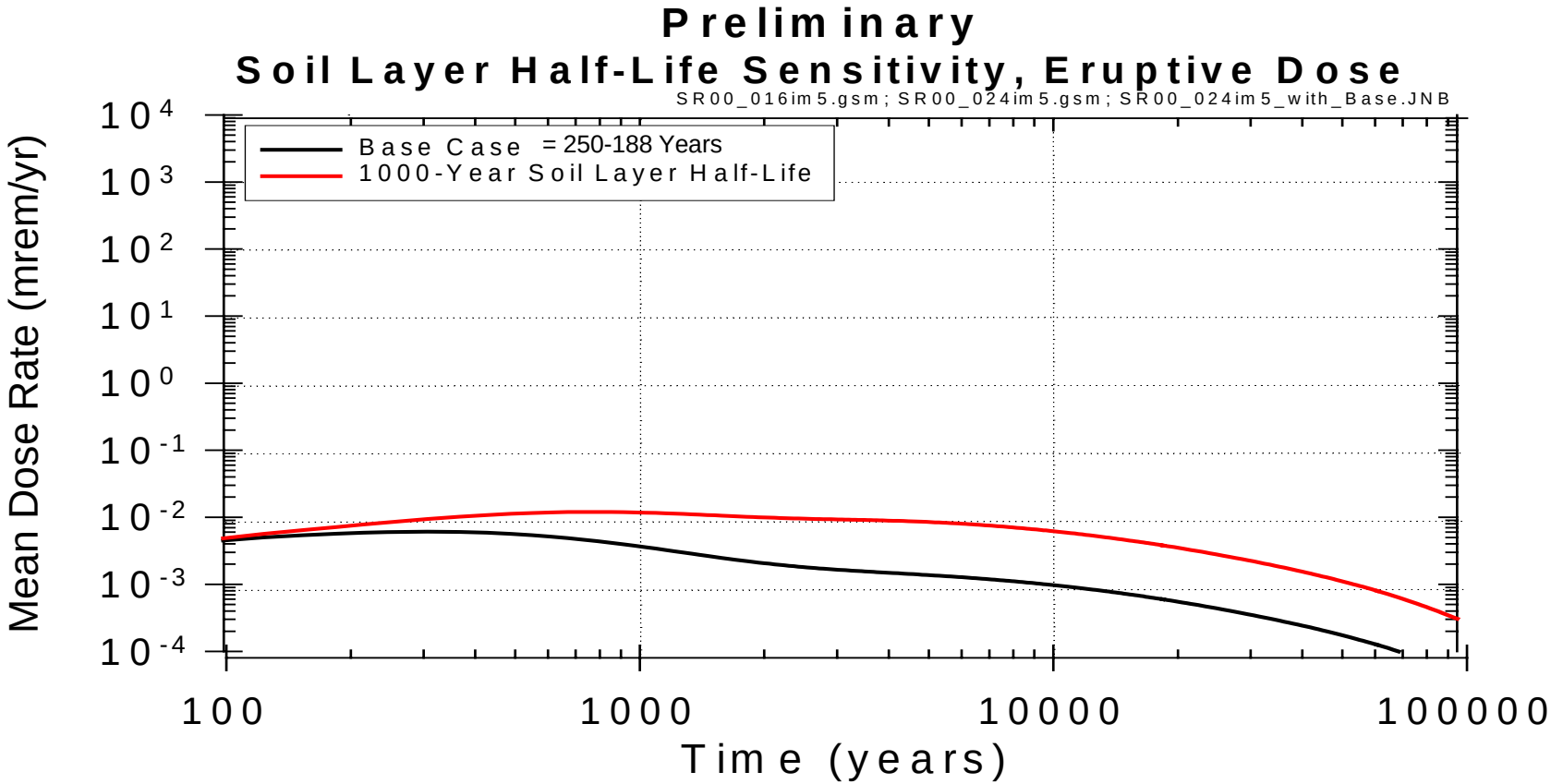
TSPA-SR Sensitivity Analysis
Soil Removal Rate,Eruptive Dose
(Rate to remove 15 cm of topsoil)



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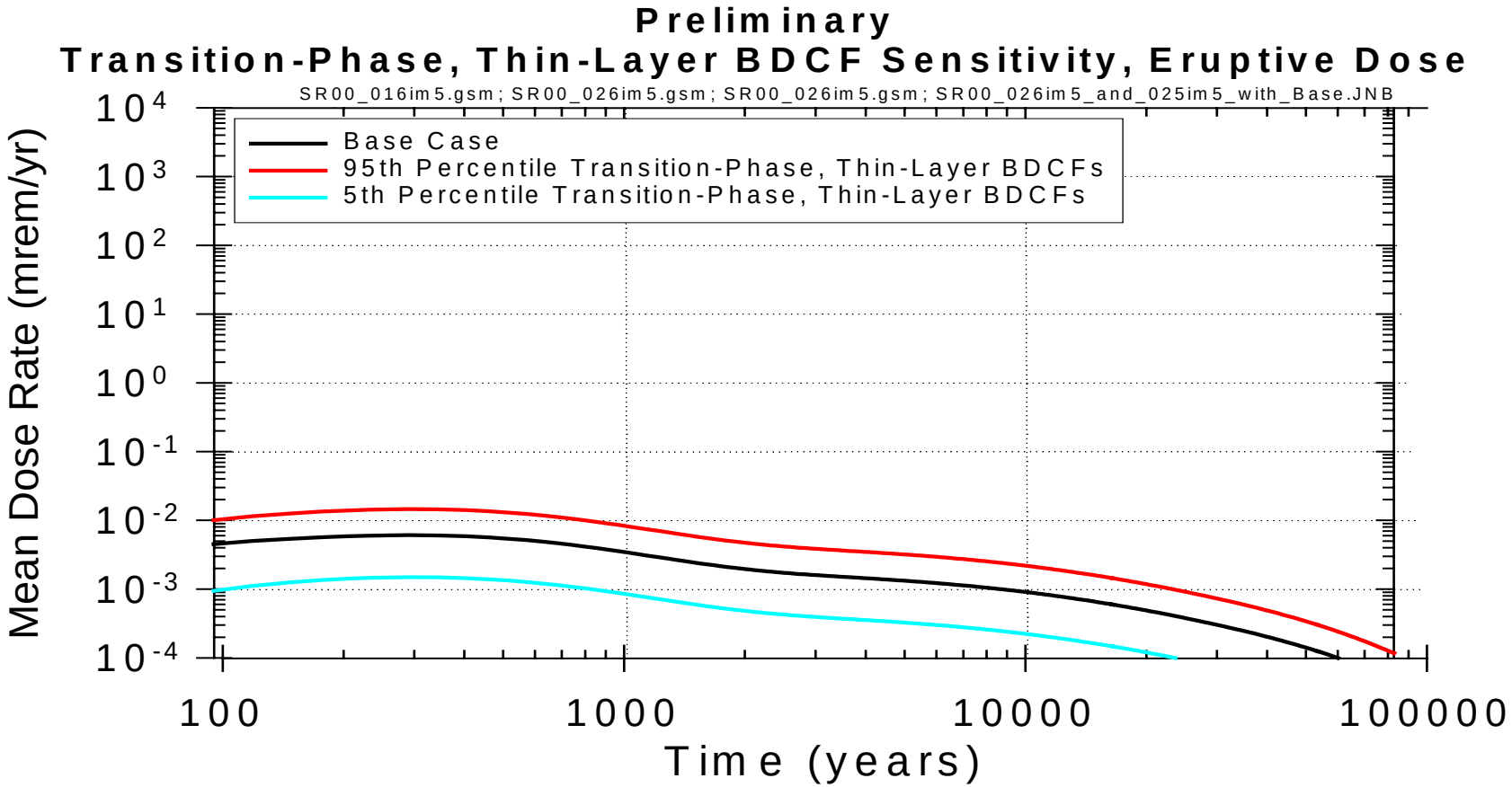
TSPA-SR Sensitivity Analysis BDCFs, Eruptive Dose



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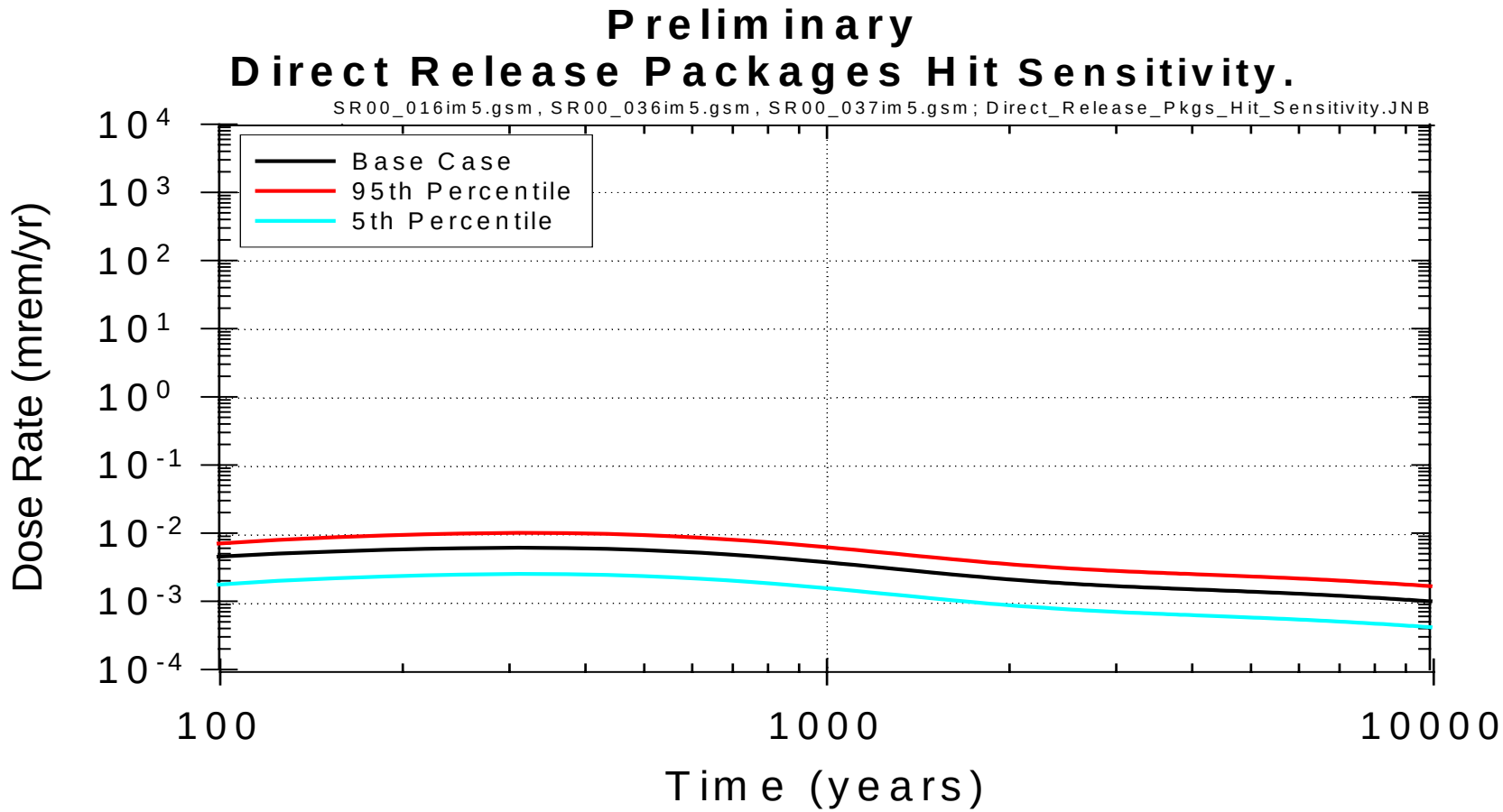
5th/95th Sensitivity Runs on Number of Packages Damaged

- **Eruptive Event: Packages in conduit destroyed**
  - **5th percentile: 6 Packages Destroyed**
  - **95th percentile: 16 Packages Destroyed**
- **Intrusive Event: 2 Zones of magmatic environment**
  - **Zone 1: High energy pyroclasts, pressure, heat**
    - **Packages Destroyed**
    - **5th: 108 Packages Destroyed**
    - **95th: 218 Packages Destroyed**
  - **Zone 2: Lower energy pyroclasts, pressure, heat**
    - **Package end cap welds develop apertures: Min.=1cm^2; Median=10cm^2; Max.=One end Cap Removed**
    - **5th percentile: 24 Packages Damaged**
    - **95th percentile: 6298 Packages Damaged**

TSPA-SR Sensitivity Analysis
Volcanic Eruption Packages Damaged



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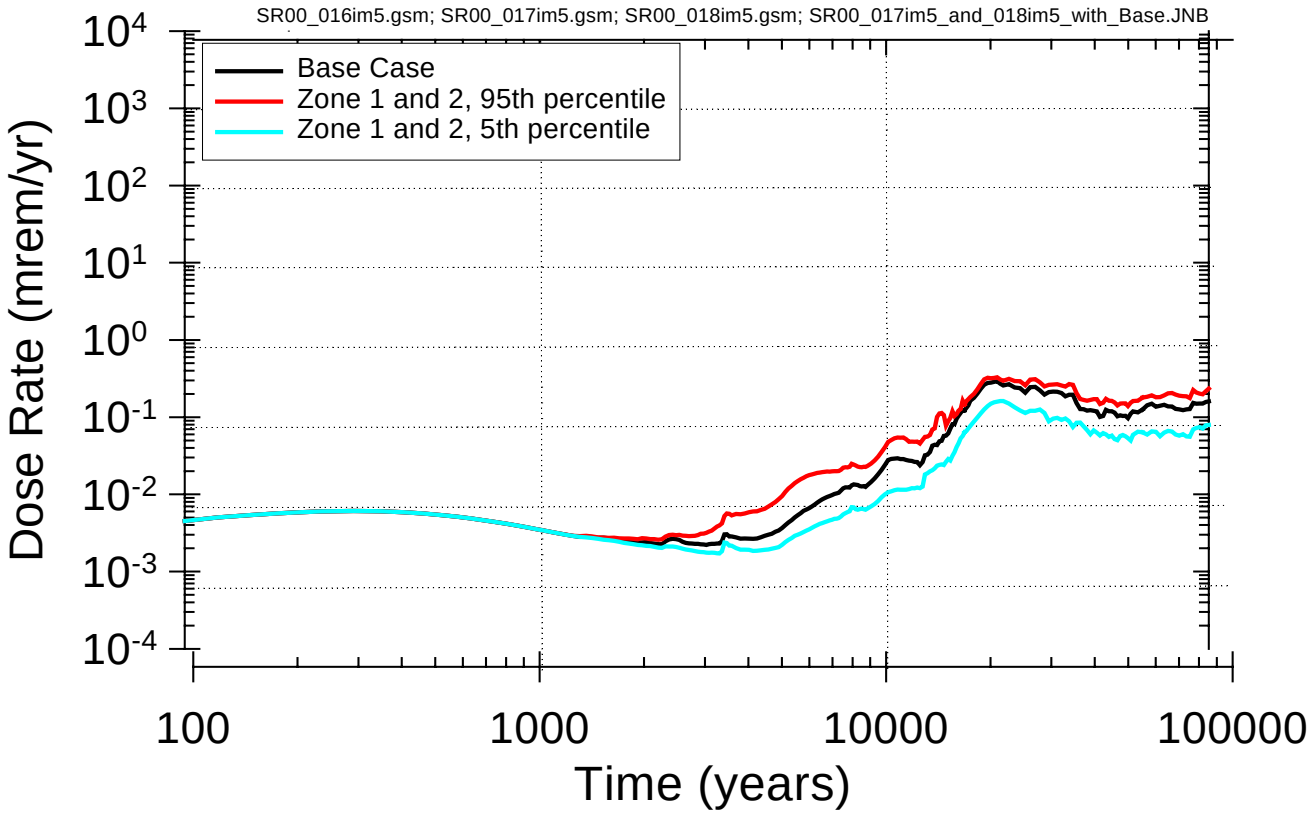
TSPA-SR Plot
Groundwater + Volcanic Eruption for Packages Damaged Sensitivity Analysis

Preliminary

Igneous Base Case versus Zone 1 and 2 combined



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