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

TSPA-SR Models: Disruptive Events

Presented to:
DOE/NRC Technical Exchange on Total System Performance Assessment (TSPA) for Yucca Mountain
San Antonio, TX

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YUCCA MOUNTAIN PROJECT

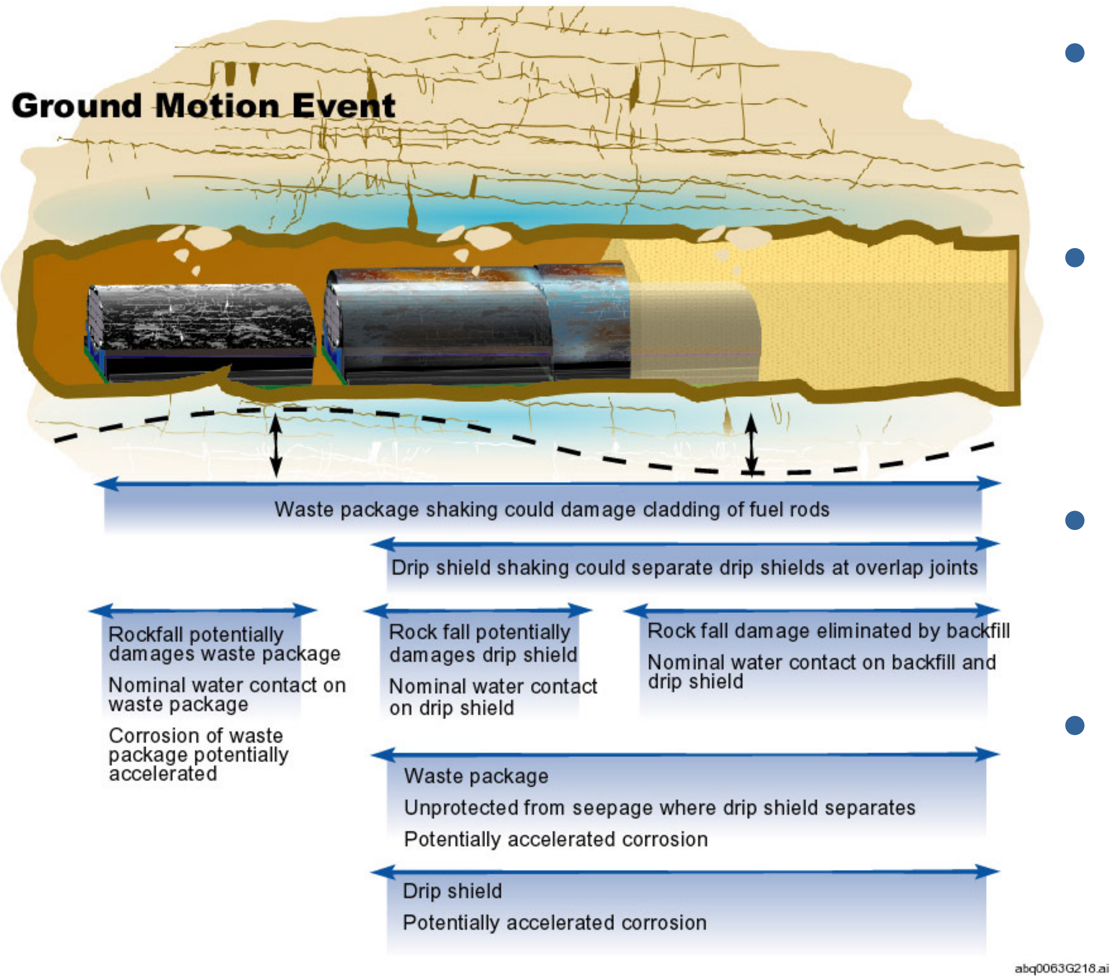
KTI Subissues

- From TSPAI IRSR
  - Mechanical Disruption of Engineered Barriers
  - Volcanic Disruption of Waste Packages
  - Airborne Transport of Radionuclides
- Other IRSR
  - Structural Deformation and Seismicity
  - Igneous Activity
- Other meetings
  - July 18 - Disruptive Events - Seismic
  - August 30/31 - Disruptive Events - Igneous

Feature, Event, and Process (FEP) Screening of Disruptive Events

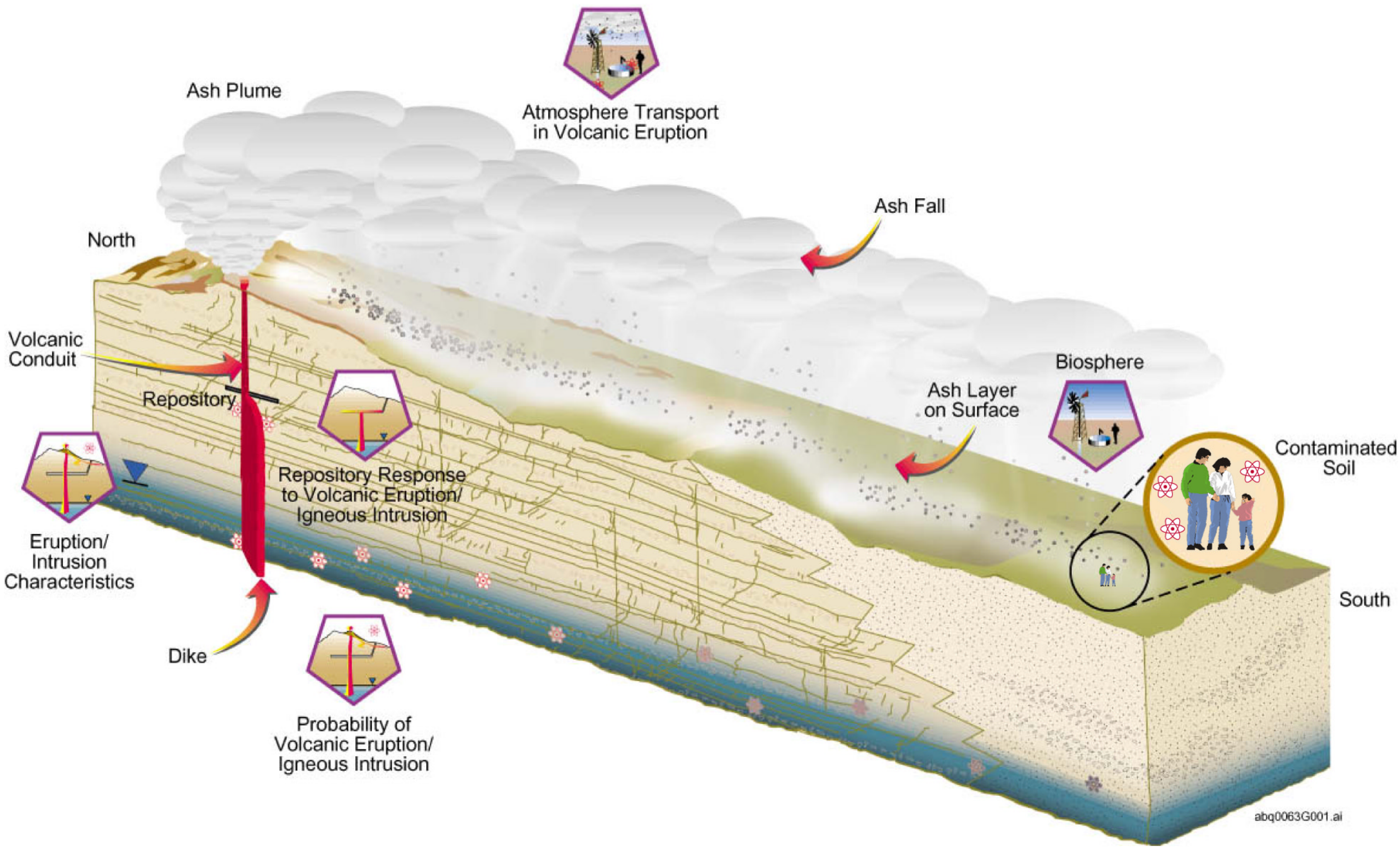
- **Igneous Activity is screened in**
- **Seismic damage to cladding is screened in (and treated in the nominal scenario)**
- **All other potentially disruptive events are screened out by project subject-matter experts**
  - **e.g., faulting, ground motion damage to engineered barrier system, rockfall, seismically-induced water-table rise, criticality**
  - **screening arguments documented through Process Model Reports (PMRs) and FEPs Analysis/Model Reports (AMRs)**
- **Human Intrusion is prescribed by regulation, and is not treated as a disruptive event**

Seismic Activity

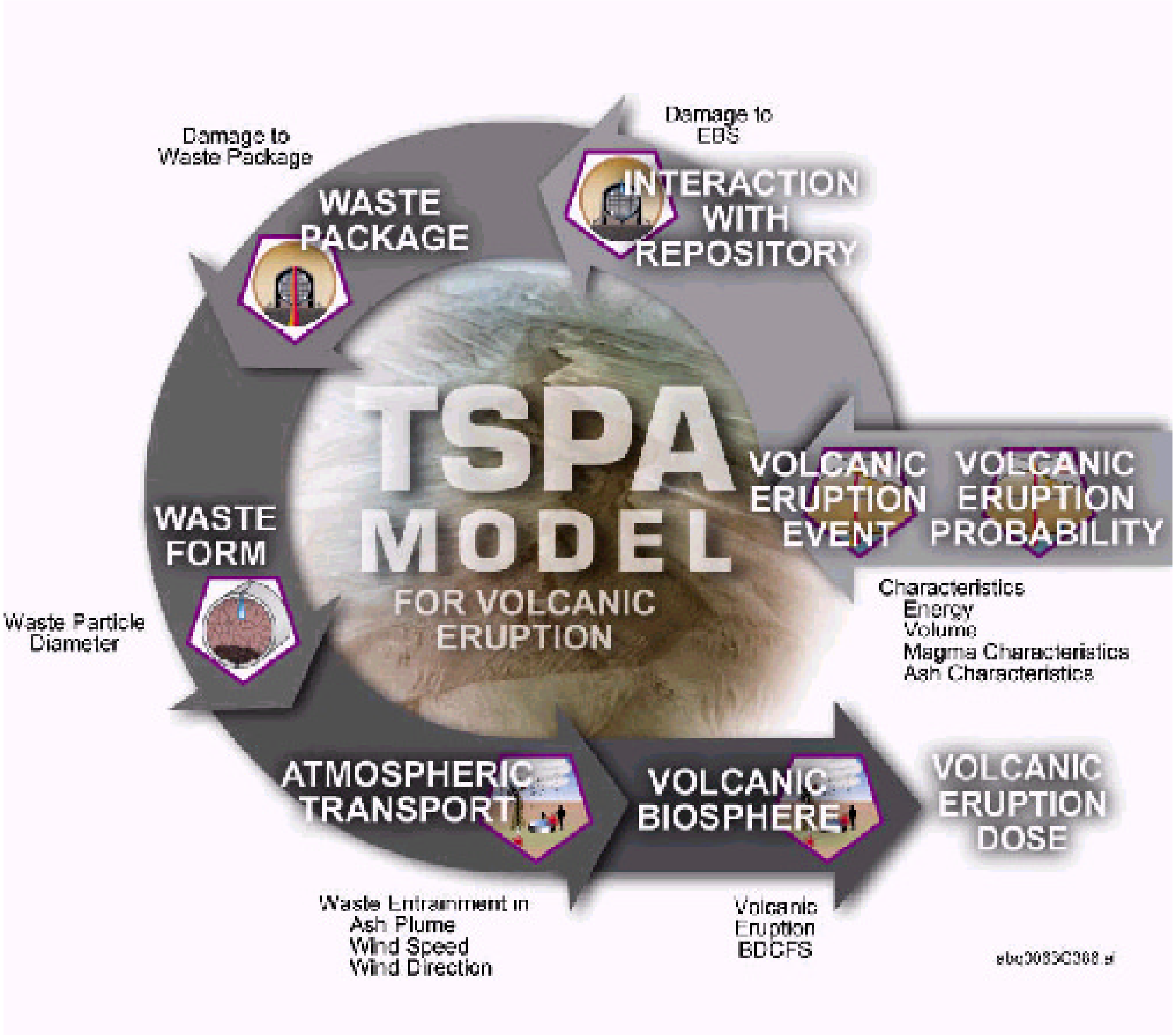


- **Screening analyses by project subject-matter experts**
- **Seismic-induced degradation of engineered barriers screened out**
- **Indirect effects of seismic activity (including seismic induced water table changes) screened out**
- **Seismic effects on cladding included in nominal performance**
- **Screening arguments address seismic aspects of mechanical degradation ISI (igneous degradation included in TSPA)**

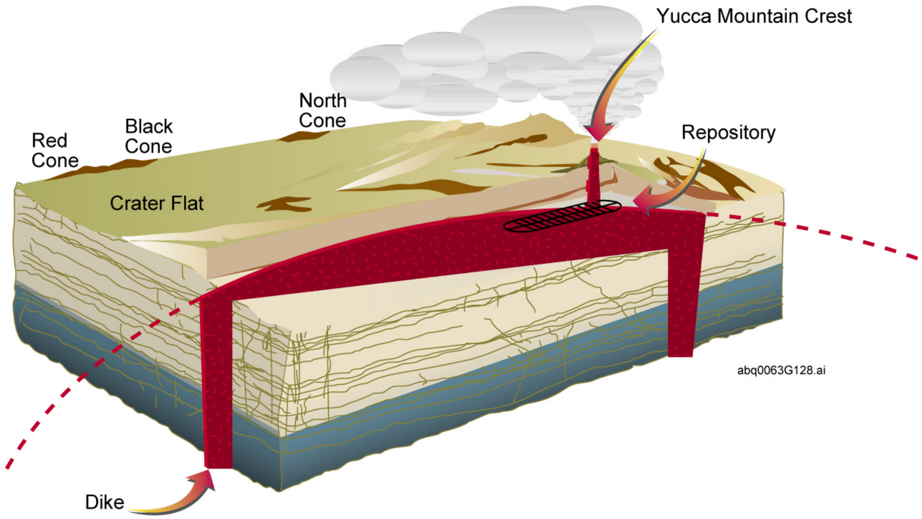
Igneous Disruption Scenario

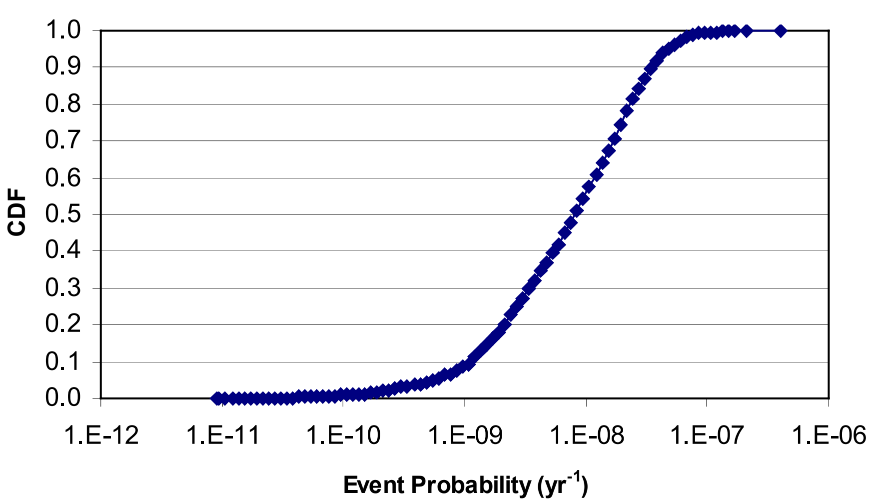


TSPA-SR Disruptive Events Scenario



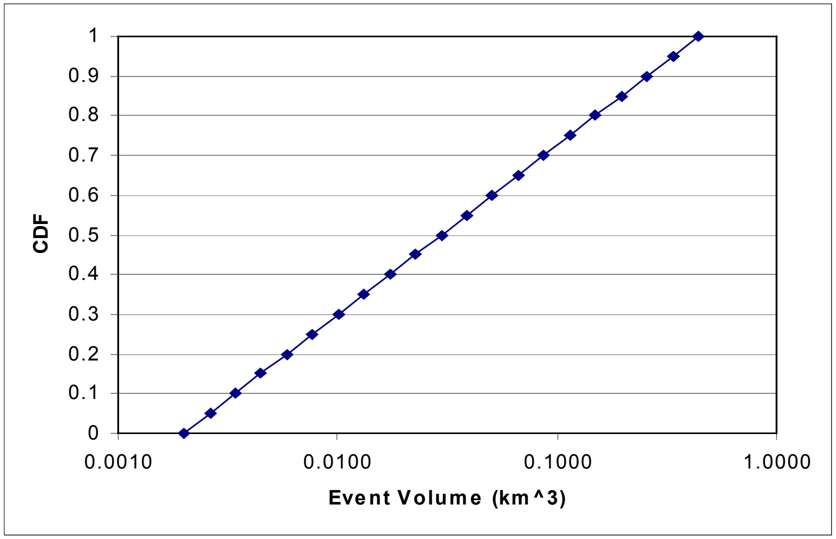
Probability of Volcanic Event

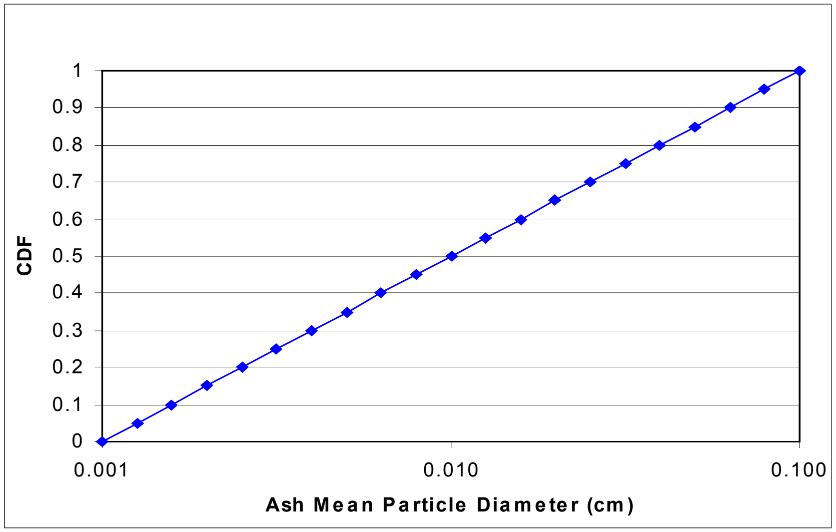




- **Annual probability of dike intersecting repository footprint based on PVHA expert elicitation (modified by current design)**
- **Mean intrusion event probability is 1.6×10^{-8} year^{-1}**
- **Probability of a dike generating an eruption at the repository is 0.36 times probability of dike intersecting repository (mean eruptive 5.8×10^{-9})**
- **NRC considers probability of 1.0×10^{-7} year^{-1}**

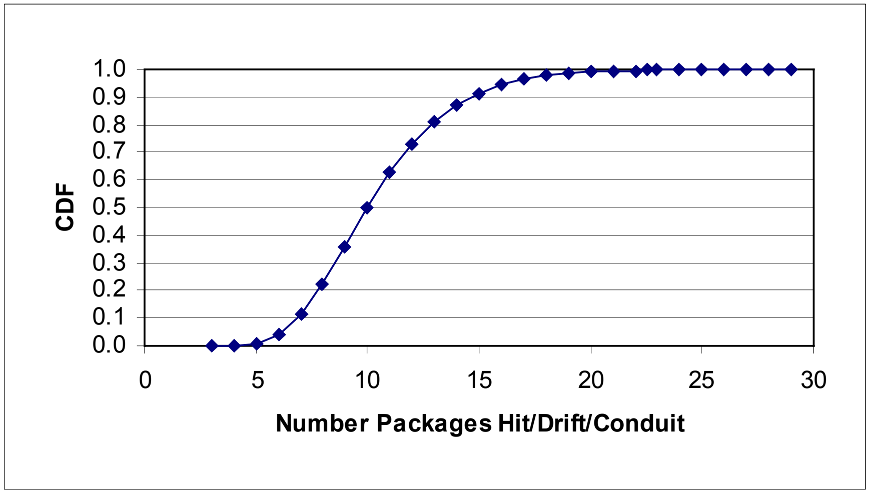
Characteristics of Volcanic Eruption Event

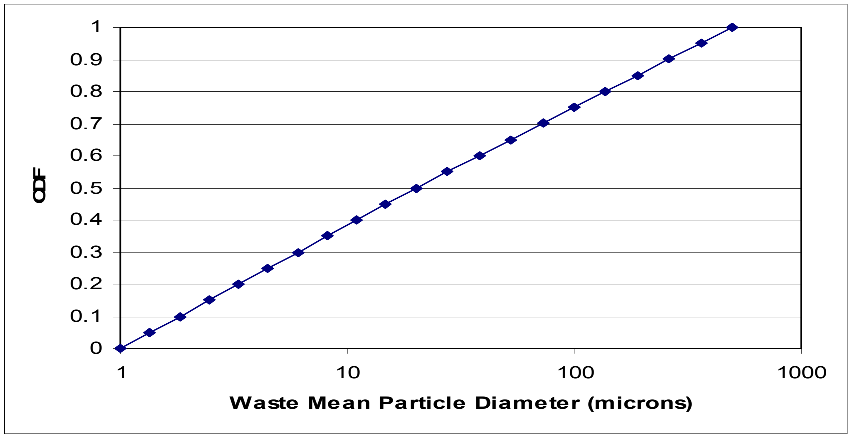




- **Characteristics derived from site-specific data and literature based analogs**
- **Effects similar to those in the NRC consequence model**
- **Median particle diameter of eruptive material ~100x less than in Viability Assessment (VA)**

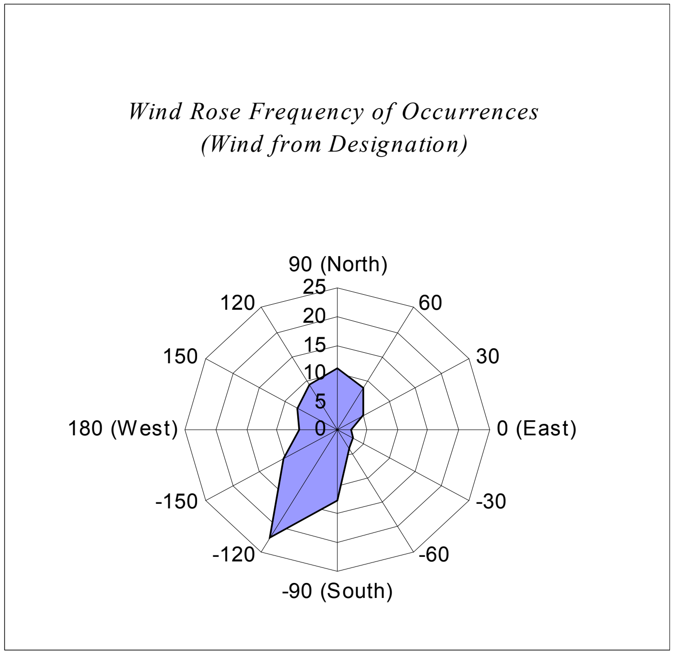
Effects of Volcanic Eruption Event

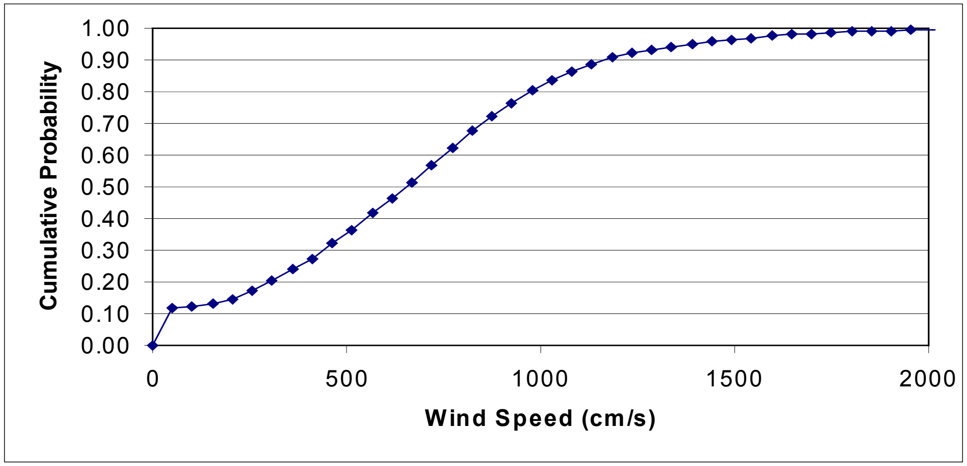




- Number of packages intersected by an eruption is a function of conduit diameter and number of conduits (1-5)
- Packages intersected by eruptive conduits are assumed fully damaged and all waste is available to be erupted (unlike VA)
- Waste degrades to small grains (tens of microns, mode is 50x smaller than VA)

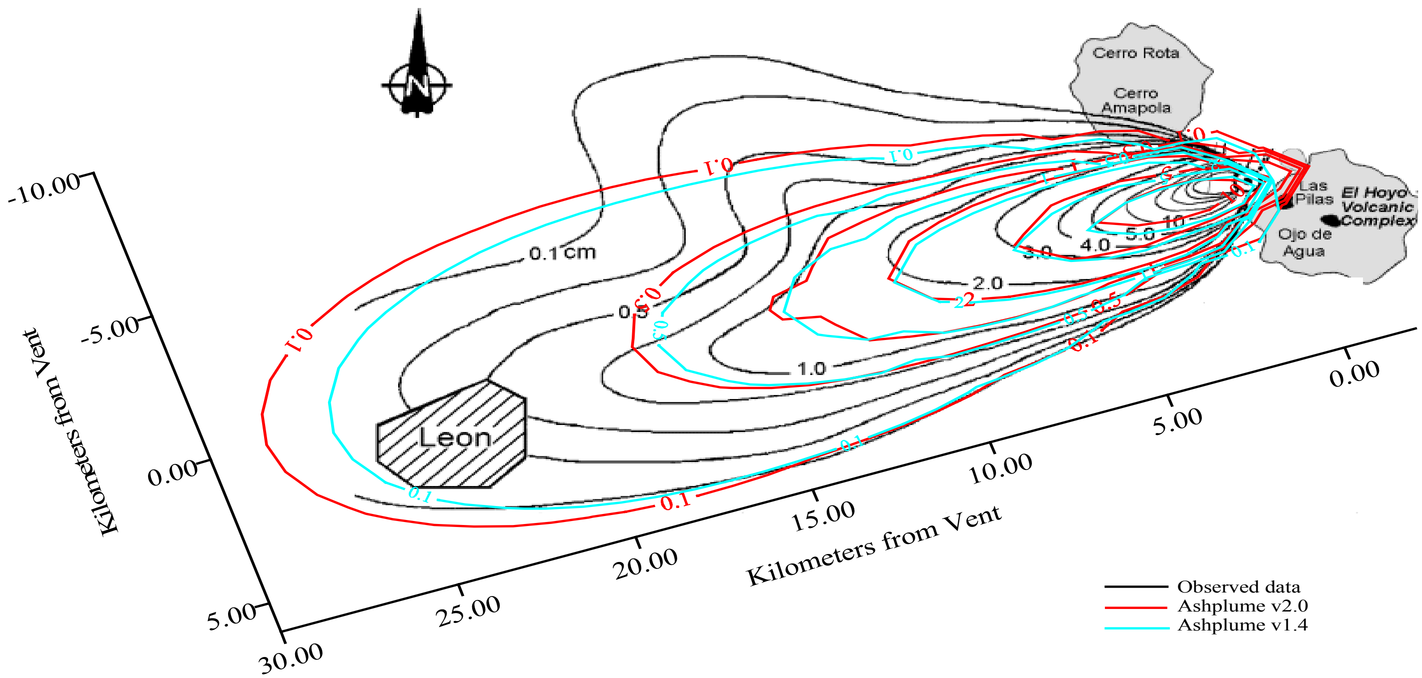
Atmospheric Transport of Volcanic Eruption Material



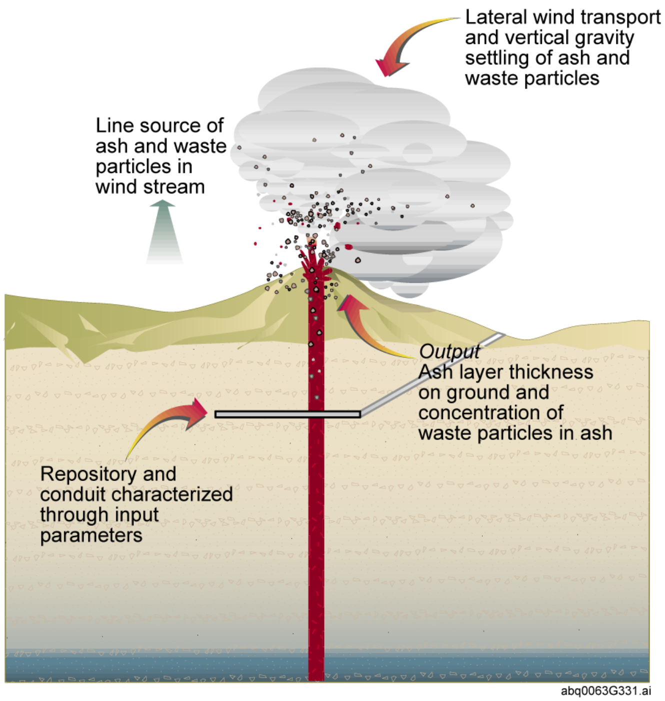


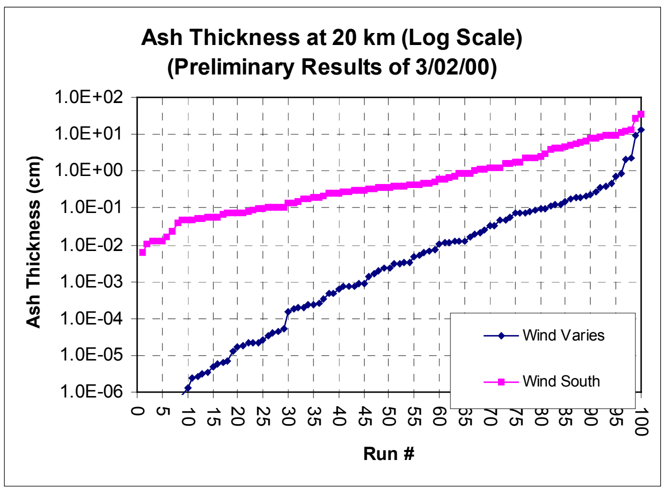
- **Wind direction and velocity based on NTS information (up to ~5km altitude above mean sea level)**
- **Eruption magnitude based on volumes of past Yucca Mountain (YM) region eruptions and modern analogs**
- **Waste entrainment determined by ratio of waste particle size to ash particle size**
- **Transport modeled using ASHPLUME code, version 1.4LV**

ASHPLUME Comparison with 1995 Cerro Negro Eruption (Preliminary Non-Q Results)



Volcanic Eruption Biosphere

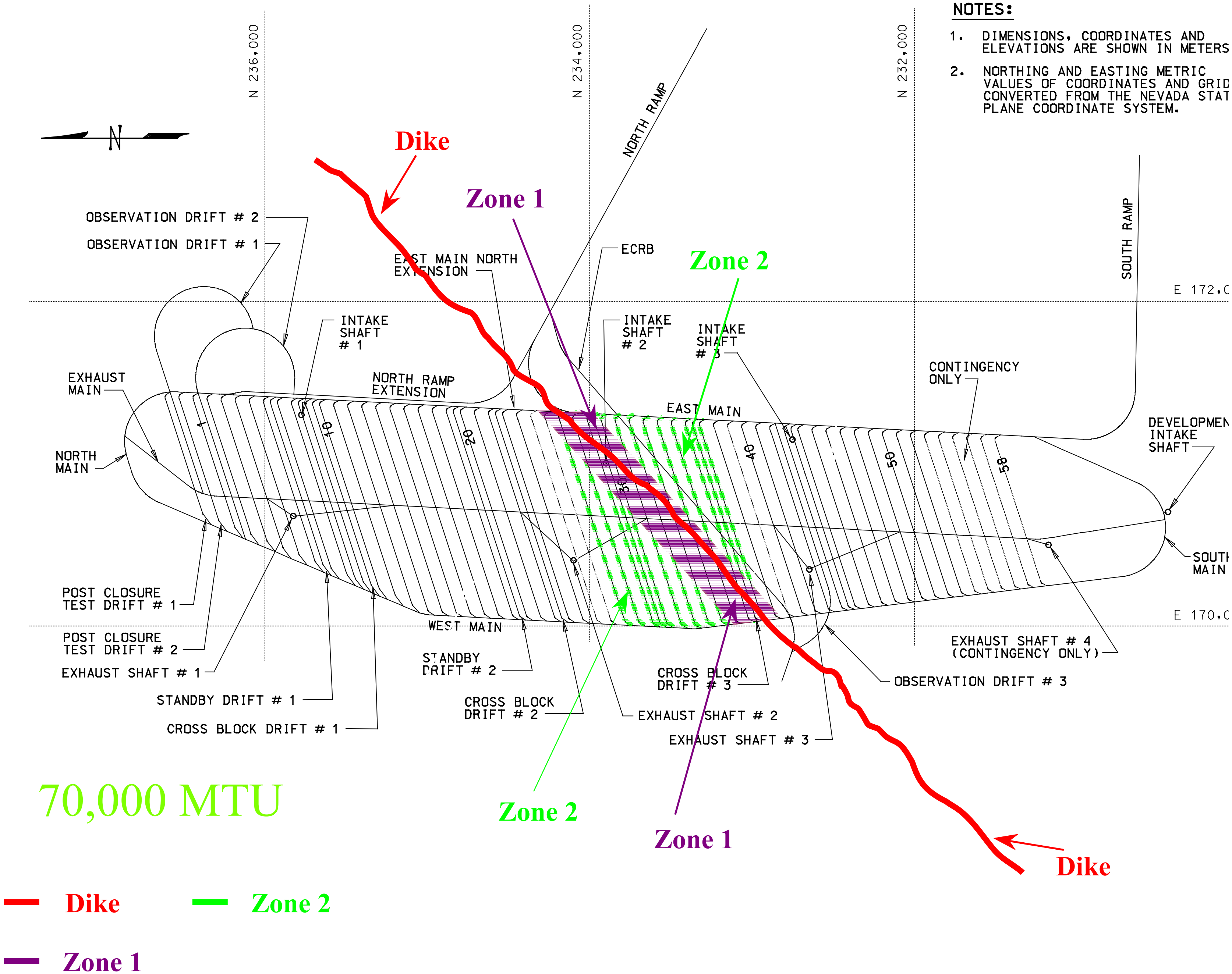




- Thickness of ash deposit is variable and depends on eruption and transport characteristics
- Conservative Biosphere Dose Conversion Factors (BDCFs) assume air mass loading does not decrease with time
- Soil erosion is used, consistent with high air mass loading
- Inhalation and ingestion of suspended particles evaluated separately (TSP 3000 ug/m^3: PM_{10} = 1/3; 10-100um = 2/3)
- Soil Redistribution ISI is addressed by assuming southerly wind direction (maximizes ash thickness)

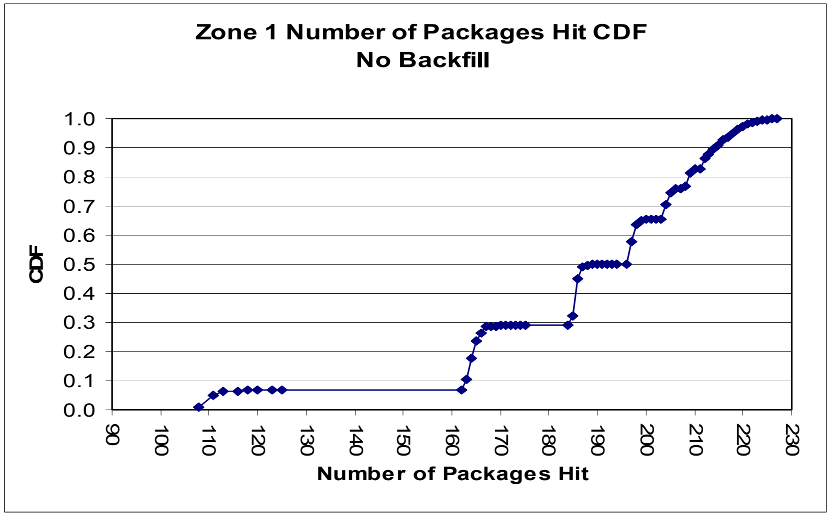
Volcanic Eruption Biosphere
(continued)

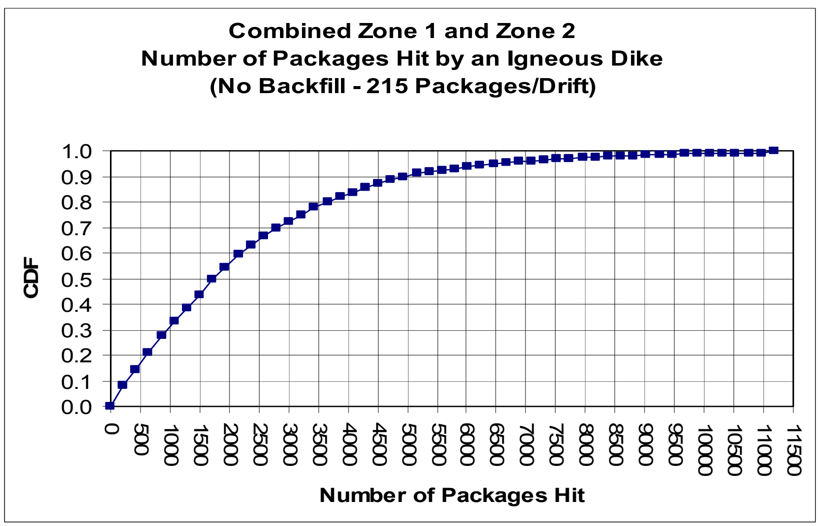
- **Recalculated BDCFs**
  - **Eruption Phase (during eruption)**
    - **Dominant pathway is inhalation of airborne ash**
    - **PM_{10} fraction of airborne particulates is 1/3**
  - **Transition Phase (~10 years after eruption)**
    - **Resuspension of volcanic ash is main driving process**
    - **Mass loading loguniform distribution from (PM_{10}) 1000 ug/m^3 (Mt St Helens analog) to 30 ug/m^3 (Nevada current annual average)**
    - **Radionuclides in ash thickness 1cm or 15cm**
  - **Steady State (after transition phase ends)**
    - **Mass loading has reached a constant 30 ug/m^3**
    - **Radionuclides mixed in 15cm of soil**
- **TSPA-SR Uses 1cm Transition Phase BDCFs for 10,000 years (conservative: high mass loading for 10,000 years)**



NOTES:
1. DIMENSIONS, COORDINATES AND ELEVATIONS ARE SHOWN IN METERS
2. NORTHING AND EASTING METRIC VALUES OF COORDINATES AND GRID CONVERTED FROM THE NEVADA STAT PLANE COORDINATE SYSTEM.
N 236,000
N 234,000
N 232,000
E 172,0
E 170,0
N
NORTH RAMP
SOUTH RAMP
Dike
Zone 1
Zone 2
OBSERVATION DRIFT # 2
OBSERVATION DRIFT # 1
EAST MAIN NORTH EXTENSION
ECRB
INTAKE SHAFT # 1
INTAKE SHAFT # 2
INTAKE SHAFT # 3
NORTH RAMP EXTENSION
EXHAUST MAIN
NORTH MAIN
EAST MAIN
CONTINGENCY ONLY
DEVELOPMEN INTAKE SHAFT
SOUTH MAIN
WEST MAIN
POST CLOSURE TEST DRIFT # 1
POST CLOSURE TEST DRIFT # 2
EXHAUST SHAFT # 1
STANDBY DRIFT # 1
CROSS BLOCK DRIFT # 1
STANDBY DRIFT # 2
CROSS BLOCK DRIFT # 2
CROSS BLOCK DRIFT # 3
EXHAUST SHAFT # 2
EXHAUST SHAFT # 3
EXHAUST SHAFT # 4 (CONTINGENCY ONLY)
OBSERVATION DRIFT # 3
1
10
20
30
40
50
58
70,000 MTU
Zone 2
Zone 1
Dike
Dike
Zone 2
Zone 1

Igneous Intrusion Effects and Consequences





- **Number of packages damaged depends on igneous event characteristics and presence of backfill**
- **Portion of waste packages (~200) lose containment function (as do drip shields and cladding) due to temperature, pressure, and chemical effects of the igneous intrusion**
- **Remaining portion of affected waste packages (~1500) have end caps degraded and are partially breached by high temperatures and pressures**
- **Other process-model factors treated in same fashion as nominal performance scenario**

Summary of TSPA-SR Disruptive Events

- Igneous Disruption is the only Disruptive Scenario
  - Modeled in two components
    - Groundwater release pathway following intrusion
    - Atmospheric release pathway following eruption
  - Consequence models revised from VA, approach now similar to that used in NRC Igneous Activity Issue Resolution Status Reports (IRSR) Rev. 2
- Other potentially disruptive events screened out by project subject matter experts
  - structural deformation, seismicity, criticality
  - (seismic ground motion damage to cladding included in nominal scenario modeling)

BACKUP

Comparison of SR, VA, and NRC Igneous Models

Model Information	TSPA-SR	TSPA-VA	NRC IA IRSR Rev. 2
Code	ASHPLUME 1.4LV	ASHPLUME 1.3	ASHPLUME 1.0
Sample size and time	100 plus, every time step	17, random times (all late)	Variable, uncertain
Annual Probability	Variable, mean for intrusion $1.6x10^{-8}$, Mean for eruption $5.8x10^{-9}$	$1.5x10^{-8}$	10^{-7}
Wind Direction	Variable or fixed to S	Variable	Fixed to south
Mean Ash Particle Diameter	0.001-0.1 cm, 0.01 cm mode	0.01-10 cm, 1 cm mode	Unspecified, probably 0.01-10 cm, 0.1 cm mode
Waste Particle Diameter	0.0001 cm - 0.05 cm, 0.002 cm mode (1-500 microns)	0.01 cm – 1 cm, 0.1 cm mode (100-10,000 microns)	0.0001-0.01 cm (1-100 microns)
Ash Layer Thickness at 20 km	Variable 5-10% > 5 cm, median < 1 cm	~ 0.05 cm (max)	Unspecified, possibly 10 cm
Waste Mass concentration at 20 km	Variable Up to 10^{-5} gm/cm^2	Peak of $4.9x10^{-11}$ gm/cm^2	unknown

Comparison of SR, VA, and NRC Igneous Models (continued)

Model Information	TSPA-SR	TSPA-VA	NRC IA IRSR Rev. 2
Soil removal	Soil half-live of ~ 250 yr	Not used	Varied, insensitive if soil half-life is 400yr+
Main exposure pathway	uncertain	ingestion	"about 90% inhalation"
Waste package performance in eruption	No protection in eruption	Some credit taken	No protection in eruption
Waste package performance following intrusion	No protection following intrusion	No protection following intrusion	Not analyzed
Number of waste packages in eruption conduit	3-58, 10 median (possibility of up to 5 conduits)	0-13 (possibility of up to 2 conduits)	10 (single conduit)
Number of waste packages damaged by intrusion (with backfill)	98-227 (3 on either side of dike in each drift, mean of 3 dikes/swarm)	not analyzed	Not analyzed
Number of waste packages damaged by intrusion (without backfill)	Some damage to all packages in all drifts intersected by the dike	0-170	Not analyzed

ASHPLUME Comparison with 1995 Cerro Negro Eruption

- **Version 1.4LV**
  - **Input: Volume (Adjusted So Tephra Mass Matches)**
  - **** Volume (Dense Rock Equiv.-DRE) = Tephra Mass/Magma Density**
  - **Calc: Duration = 15.29 + 0.527*log(volume)**
  - **Calc: Column Height = exp[7.83 + 0.394*log(volume/duration)]**
- **Version 2.0**
  - **Input: Duration**
  - **Input: Power (Adjusted So Column Height is 2.4 km)**
  - **** Power = $(\text{Column Height}/0.0082)^4$**
  - **Calc: Tephra Mass = Duration*$(\text{Column Height}/0.24)^4$**
- **Same Tephra Mass Modeled for All 3 Cases**

ASHPLUME Comparison with 1995 Cerro Negro Eruption (continued)

Eruption Parameters	1995 Cerro Negro [d]	ASHPLUME v1.4LV	ASHPLUME v2.0
Wind Speed (m/s)	**9**	**9**	**9**
Column Height (km)	**2.4**	4.4[a]	**2.4**
Tephra Column Duration (s)	**$3.46x10^5$**	$1.15x10^6$ [a]	**$3.46x10^5$**
Tephra Mass-DRE/Volume (m^3)	**$1.32x10^6$**	$2.88x10^6$[b]	**-----**
Average Clast Diameter (mm)	**0.7**	**0.7**	**0.7**
Average Clast Sorting	**0.9**	0.8	0.8
Average Clast Density (kg/m^3)	**1200**	**1200**	**1200**
Clast Shape Factor	**0.5**	**0.5**	**0.5**
Constant Beta	**10**	**10**	**10**
Constant C ($cm^2/s^{5/2}$)	**400**	**400**	**400**
Wind Direction	**Towards Leon**	**Towards Leon**	**Towards Leon**
Power (W)	**-----**	**-----**	$7.3382x10^9$[c]
Tephra Mass (kg)	**$3.5x10^9$**	**$3.5x10^9$**	$3.5x10^9$[a]

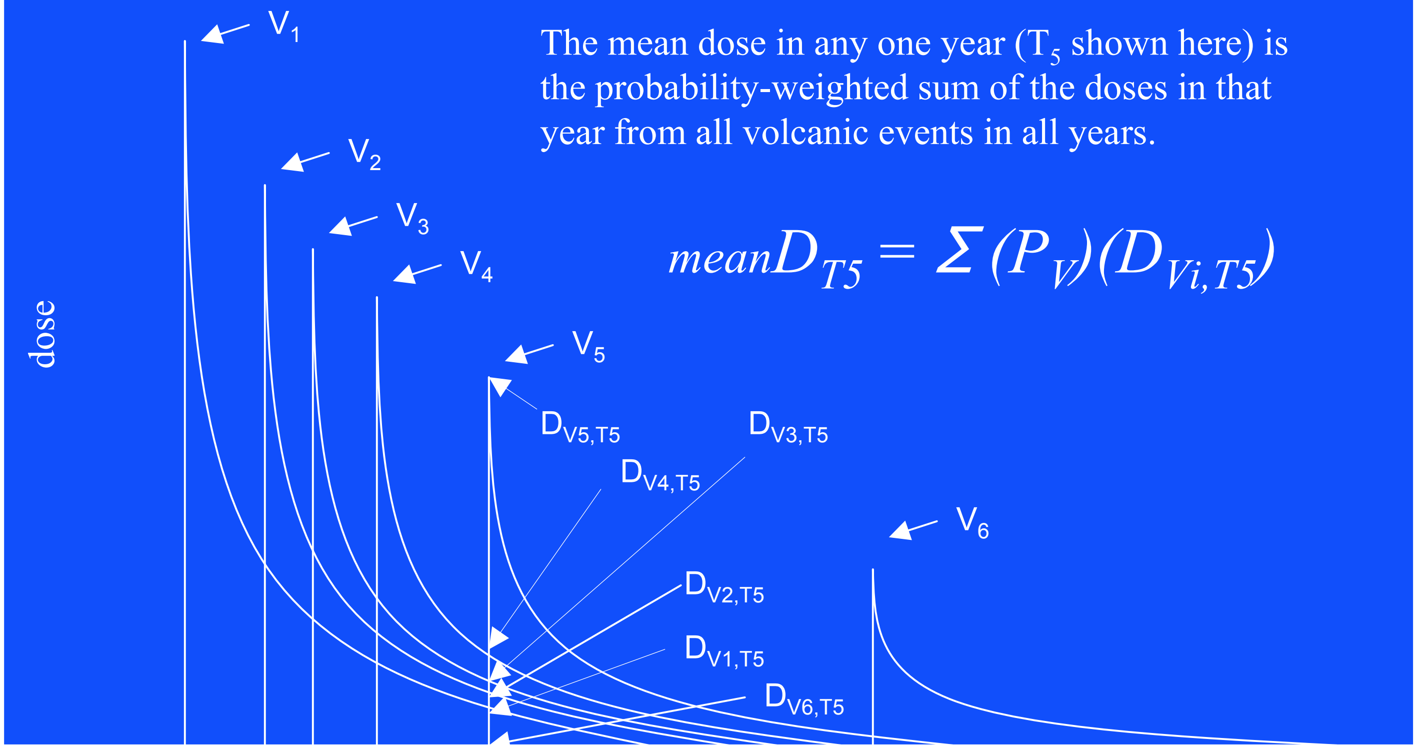
[a] Calculated in Code

[b] Adjusted to Match Total Tephra Mass

[c] Adjusted to Match Column Height

[d] From Hill et al. 1998

The Mean Eruptive Volcanic Dose in One Year



The mean dose in any one year (T_5 shown here) is the probability-weighted sum of the doses in that year from all volcanic events in all years.

$$meanD_{T5} = \Sigma (P_V)(D_{Vi,T5})$$