Update of Ongoing CNWRA Investigations on the Potential Consequences of Igneous Activity

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Nuclear Waste Technical Review Board

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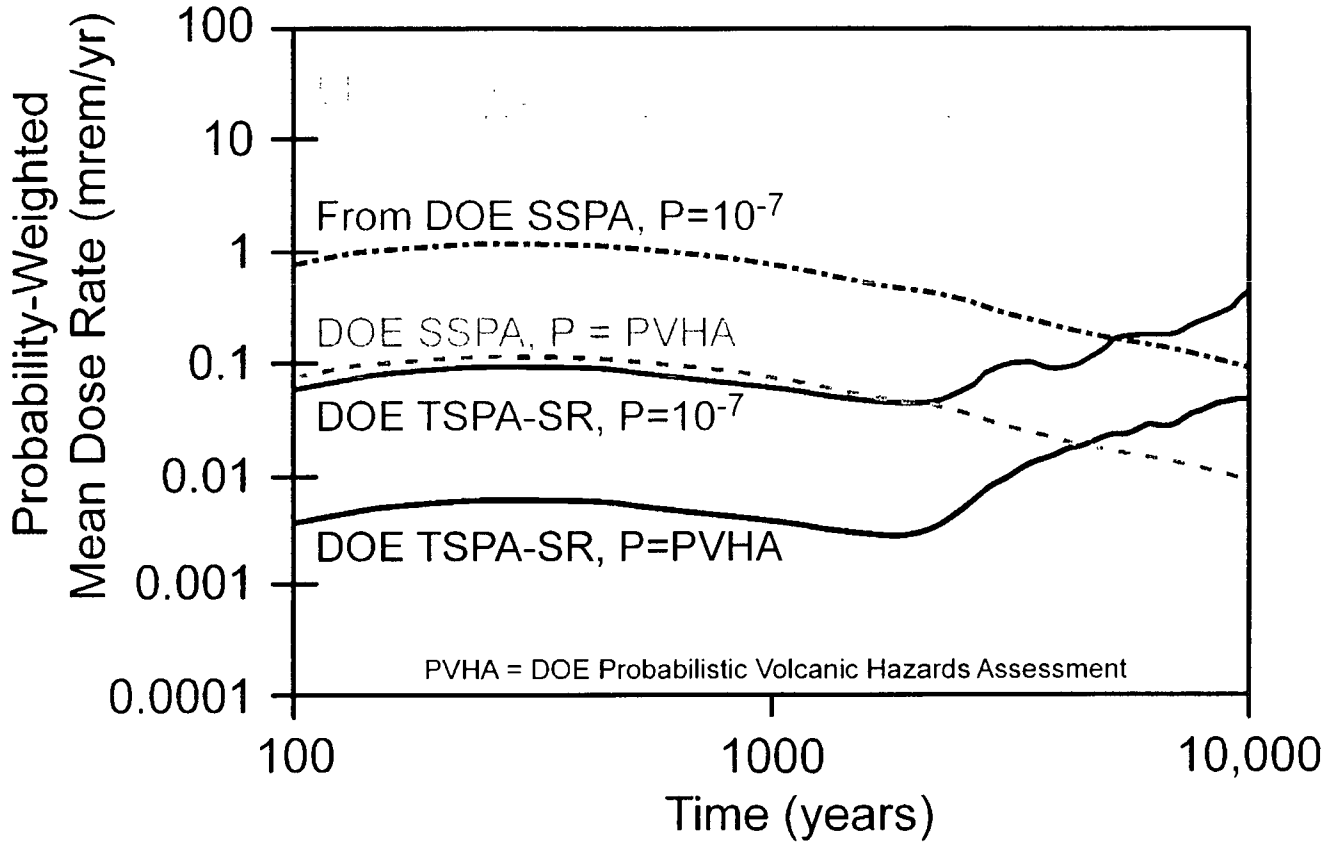
Presentation Overview

- Risk-informed basis for investigations
- Models for magma-repository interactions
- Tephra remobilization example

Risk-Informed Investigations



- Risk estimates in proposed 10,000 year compliance period are dominated by igneous activity effects

- Key technical uncertainties identified by NRC/CNWRA:
  - Number of waste packages damaged and released in extrusive events
  - Number of waste packages wholly or partially damaged in intrusive events
  - Potential long-term effects of ash remobilization

Potential Magma-Repository Interactions

- Rising basaltic magma at 300-m depth
  - Contains gas bubbles
  - Fluid overpressures of 1-10 MPa (145-1,450 psi)

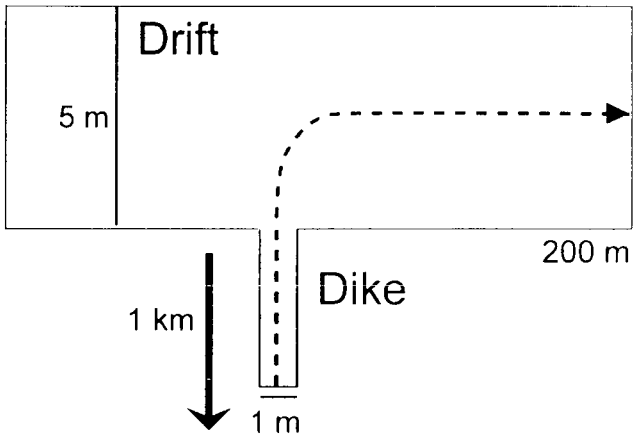
- If magma intersects a proposed drift at atmospheric pressure
  - Pressurized magma flows into drift
  - Compressed gasses expand and accelerate the flow
  - Magma fills voids, repressurizes, and continues rising to surface

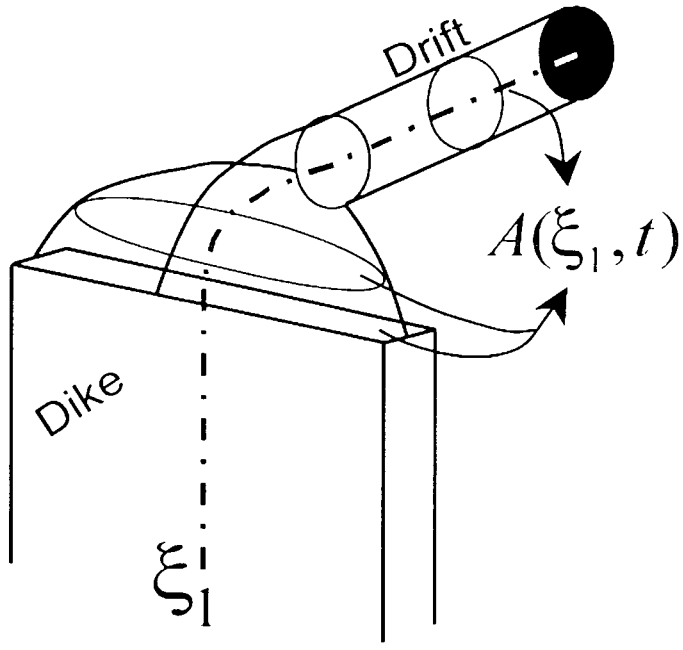
- Interaction processes that likely affect performance
  - Initial effects of magma flow contacting waste packages
  - Potential damage to drift walls from shock wave
  - Potential breakout from drifts if magmatic pressures established
  - Flow conditions in drift if pathways to surface established
  - Extent of waste package damage and waste entrainment
  - Eruption characteristics

Current CNWRA Investigations

- Develop process models from analog volcanoes and literature
- Develop numerical models for initial magma flow into closed-end drifts
  - 1D and 2D shock-tube models
- Conduct analog experimental models for initial magma flow conditions
  - Volatile-free (golden syrup) and volatile-bearing (gum resin + acetone)
  - Calibrate numerical models with experimental results
- Expand numerical models for instantaneous, steady flow
  - Alternative flow pathways to surface
  - Choked flow conditions applied

Initial Magma-Drift Interactions: Numerical Model



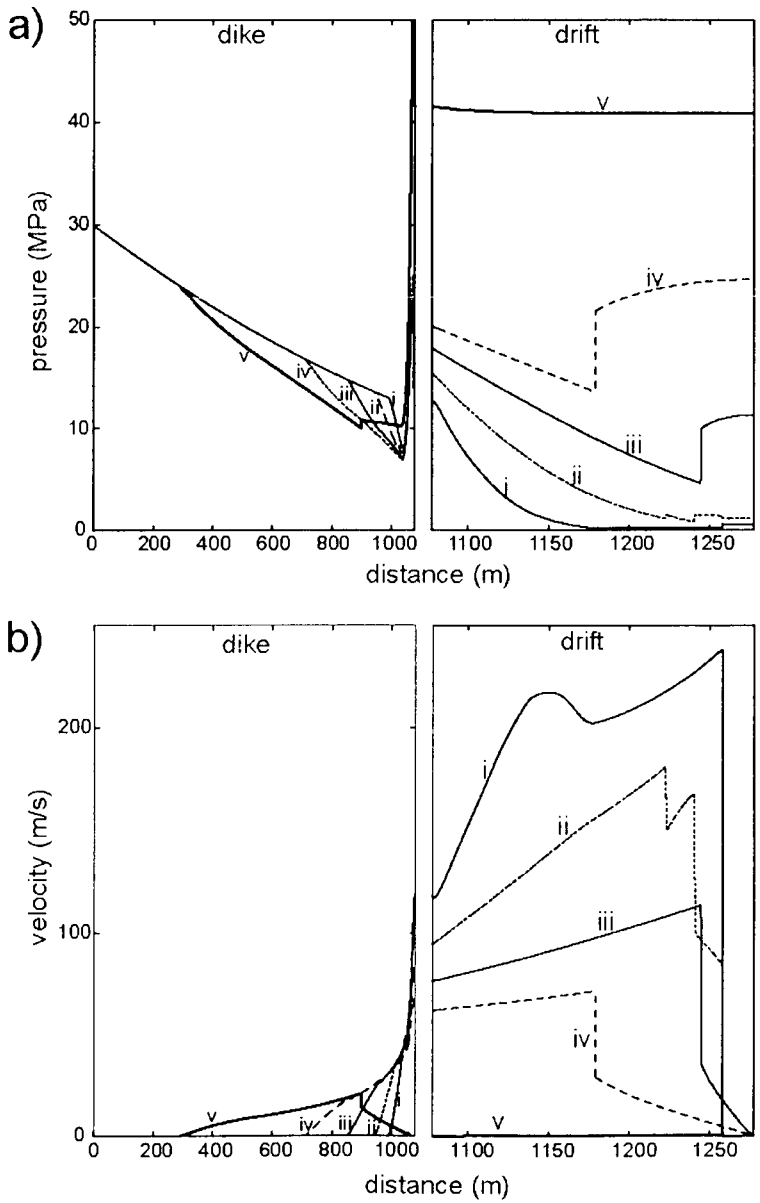


Numerical Model (Bokhove & Woods, 2001)

- Simplified 1D flow-tube model, closed end
- Instantaneous opening into drift (non-mechanistic)
- 80-m-long dike segment per drift
- Ascend @ 1 m/s:
  80 m^3/s in dike

  Flow in drift >4 m/s
  x 20 m^2 ~ 80 m^3/s
- Allow cross-sectional area to change from dike to drift

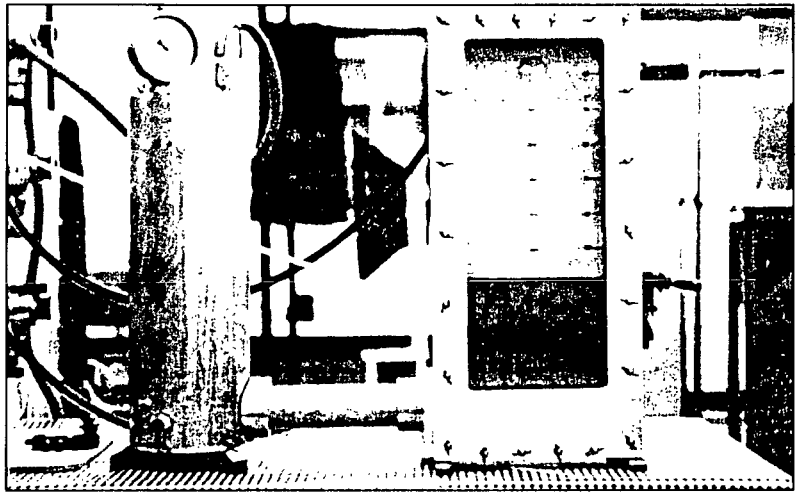
Initial Magma-Drift Interactions: Numerical Model

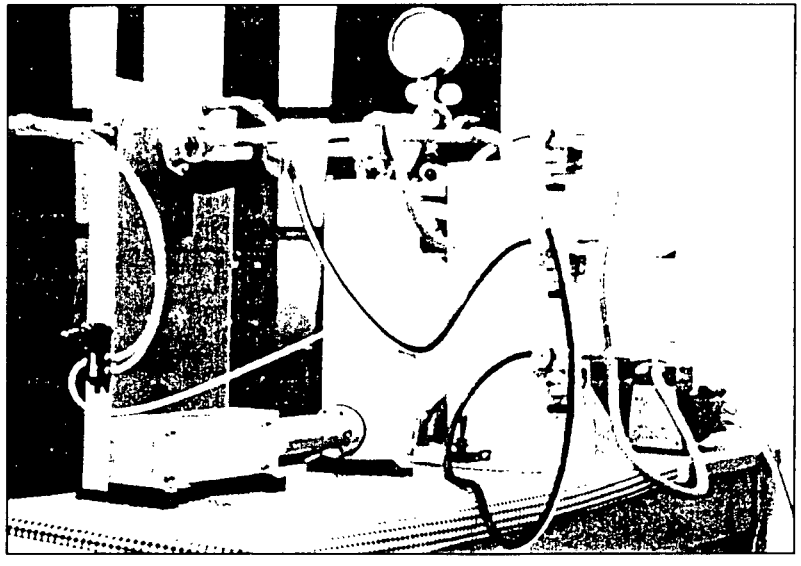


- Woods et al. (2001)[1] figure 3
- Parameterized friction, no backfill or other obstructions
- Air compresses between magma and drift end
- Decompressing magma accelerates in drift >4 m/s
- Reflected shock gives large overpressures in first several seconds
- Damage to drift walls or canisters?

[1]Woods, A.W., S. Sparks, O. Bokhove, A.-M. Lejeune, C.B. Connor, and B.E. Hill. 2001. IM 20.01402.461.115. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

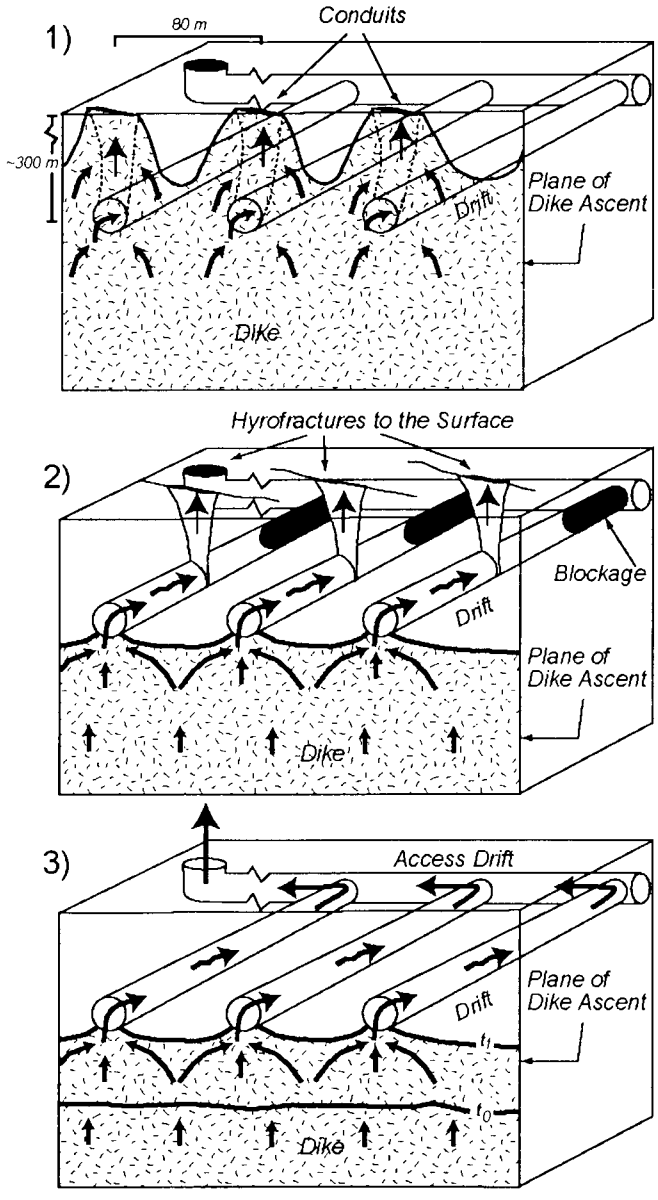
Magma-Drift Interactions: Analog Experiments





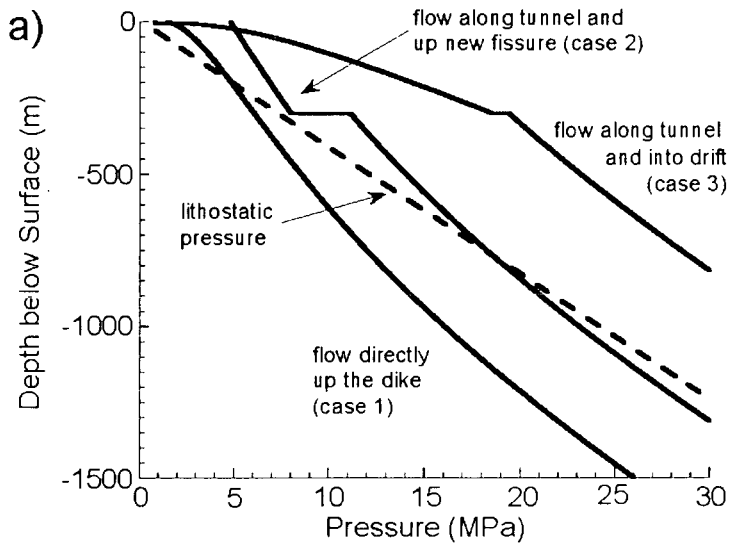
- Gum resin + acetone scales to magma + water
- Control pressure gradient in Hele-Shaw cell, open gate
- Acetone bubbles expand, little diffusion to gas phase
- Measure flow rate, pressure variations, and shock wave
- Develop pressure-density relationships
- Compare calibrated experiments with 1D and 2D numerical models

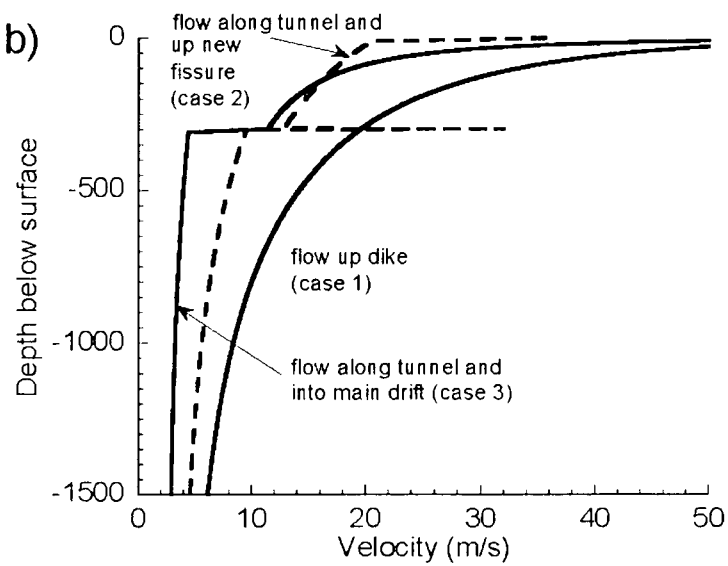
Surface Breakout and Steady Flow



- Woods et al. (2001)[1] figure 4
- Flow paths to surface depend on
  - Initial intersection point
  - Interactions in drift
  - Blockages in drift
  - Rock strength
- Topographic variations may influence location of breakout to surface
- Waste package responses
  - In flow paths to surface
  - Remaining in magma-filled drifts
  - In non-intersected drifts (e.g., degassing effects)

Surface Breakout and Steady Flow





- Woods et al. (2001)[1], figure 5
- Instantaneous conditions for the 3 alternative flow paths
- Choked flow (can not exceed speed of sound)
- High pressures (a) for case 2 & 3 likely modify flow paths (e.g., conduit widening, new conduits) as pressure exceeds local rock-fracture strength (~2-6 MPa)

Significance to Repository Performance

- Temperatures and pressures for waste package response
  - Voids in intersected drifts likely fill with magma
  - Dynamic pressure variations likely during eruption
  - Damage may be more extensive than modeled in TSPA-SR (i.e., Zone 2 = Zone 1)

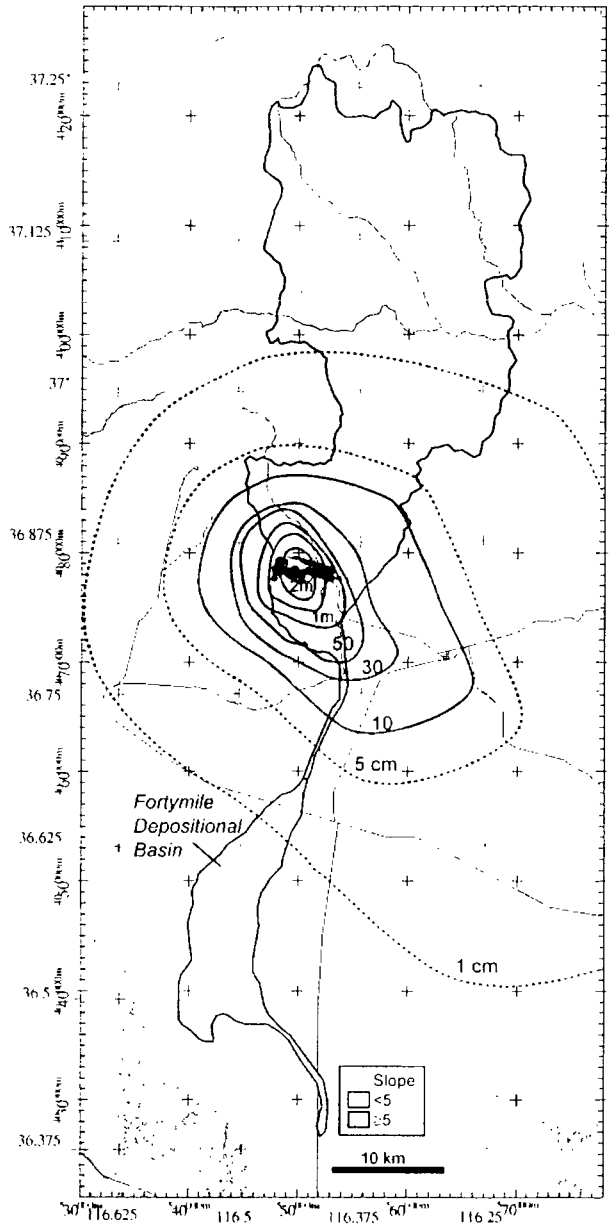
- Longer flow-paths may intersect more waste packages than modeled
  - Surface pathways may form away from plane of initial intersection
    - New or existing faults and fractures
    - Engineered shafts and ramps
  - Surface pathways may develop in each intersected drift
  - Paths could change location or shape during the eruption

- Entrainment of disrupted waste packages and possible effects on dispersal mechanics are areas of ongoing investigation

Tephra-Fall Remobilization

- Persistence of HLW-contaminated tephra affects probability-weighted annual dose calculations
  - Inhalation pathway dominates
- Tephra deposit likely distributed over areas on order of 100-1000 km^2
- 10-10,000 year characteristics of tephra deposits in YMR-type environment are poorly known
  - 80,000-year-old Lathrop Wells tephra eroded from bedrock surfaces
  - Analog volcano information: Deposits erode for 100's to 1,000's years
- Both depositional and erosional processes occur in area of reasonably maximally exposed individual (RMEI)
  - Erosion from slopes and water transport in Fortymile Wash drainage
  - Windblown particles for inhalation dose

Fluvial Remobilization: Example



- Example based on 1975 Tolbachik eruption, Kamchatka
- Deposits eroded from >5° slopes
- Uniform basin deposition gives 10x increase from original fall deposit
- Similar effects for smaller deposits
- Mobilize fines closer to RMEI area, subsequent windborne remobilization?
- Rate of remobilization important to risk

Conclusions

- Uncertainties remain in
  - Magma flow paths following potential drift intersection
  - Waste package and waste response to range of magmatic conditions
  - Eruption dispersal and long-term remobilization characteristics

- Current models have limited capacity to evaluate risk significance of
  - Alternative magma flow-paths through drifts
  - Realistic range of magmatic conditions for engineered barrier response
  - Possible changes in eruption character
  - Long-term flux of ash through RMEI area

- NRC and CNWRA staff will continue to develop technical basis to support review of DOE progress in these areas