Fluvial Redistribution of Contaminated Tephra: Description of an Abstracted Model

Roland Benke\textsuperscript{1}
Brittain Hill\textsuperscript{2}
Donald Hooper\textsuperscript{1}

International High-Level Radioactive Waste Management Conference
April 30 – May 4, 2006
Las Vegas, Nevada

\textsuperscript{1} Center for Nuclear Waste Regulatory Analyses, San Antonio, Texas
\textsuperscript{2} U.S. Nuclear Regulatory Commission, Washington, DC
Outline

- Introduction
- Significance to Waste Isolation
- Disruptive Scenario
- Consequence Modeling
  - HLW Concentration Factor in Tephra
  - Fluvial Dilution Factor
  - Duration of Fluvial Redistribution
- Summary of Modeling Assumptions
- Conclusion
- Companion Paper
- Acknowledgment
Introduction

- U.S. Department of Energy (DOE) — Repository Developer
- U.S. Nuclear Regulatory Commission (NRC) — Regulator
- Center for Nuclear Waste Regulatory Analyses (CNWRA) — Federally Funded Research and Development Center
Introduction (cont’d)

- DOE Total System Performance Assessment (TSPA) Model
- NRC Total-system Performance Assessment (TPA) Code
Risk = Probability x Consequence

Current Risk Insights on Key Factors

- Inhalation of Resuspended Volcanic Ash
- Remobilization of Ash Deposits
- Wind Vectors During an Eruption
- Volume of Ash Produced by an Eruption
Disruptive Scenario

- Volcanic Conduit Intersection with Potential Repository
- Waste Package Disruption by Magma
- High-Level Waste (HLW) Incorporation into Erupting Tephra
- Direct Release into Biosphere
Disruptive Scenario (cont’d)

- Atmospheric Transport of Tephra
- Tephra Deposition within Yucca Mountain Region
- Redistribution of Deposited Tephra by Water (Fluvial) and Wind (Eolian)
- Resuspension of Contaminated Ash (Tephra < 2 mm [0.08 in])
- Inhalation of Airborne Ash
Consequence Modeling

- NRC TPA Code
- New Abstracted Model
  - Improve Realism
  - Reduce Uncertainty
- Fluvial Redistribution Modeling Component
  - HLW Concentration Factor in Tephra
  - Fluvial Dilution Factor
  - Duration of Fluvial Redistribution
HLW Concentration Factor

- Uniform Mixing of High-Level Waste in Tephra

\[ C_f = \frac{m_{\text{HLW}, f}}{m_{\text{ash}, f}} \]

- \( m_{\text{HLW}, f} \): Mass of high-level waste deposited in the Fortymile Wash catchment basin from the eruption [g]
- \( m_{\text{ash}, f} \): Mass of ash deposited in the Fortymile Wash catchment basin from the eruption [g]
Fluvial Dilution Factor

Uniform Mixing of Contaminated and Clean Sediments

\[ d_f = \frac{1}{1 + \frac{Y_{\text{sediment,f}}}{Y_{\text{ash,f}}} \left( \frac{A_{\text{basin,f}}}{a_{\text{ash,f}}} - 1 \right)} \]

- \( Y_{\text{sediment,f}} \): Preeruption sediment volume from the drainage basin that discharges through Fortymile Wash per unit area per discharge event [m/event]
- \( Y_{\text{ash,f}} \): Posteruption volume of fluvial redistributed ash at the Fortymile Wash depositional region per unit area per discharge event [m/event]
- \( A_{\text{basin,f}} \): Area of the drainage basin that discharges through Fortymile Wash [m²]
- \( a_{\text{ash,f}} \): Area of the Fortymile Wash catchment basin with an ash deposit from the eruption [m²]
Duration of Fluvial Redistribution

- Time to Deplete Fortymile Wash of Contaminated Tephra

\[
t_{\text{duration},f} = \frac{m_{\text{ash},f} T_f}{Y_{\text{ash},f} a_{\text{ash},f} \rho_{\text{ash},f}}
\]

- \( T_f \): Average time between significant flow events [yr/event]
- \( \rho_{\text{ash},f} \): Density of proximal ash deposit [g/m³]
Summary of Modeling Assumptions

- Uniform Mixing of High-Level Waste in Tephra
- Frequent Flooding Events
- Surface of Depositional Area Regularly Renewed with Fresh Fluvial Tephra Deposits
- Uniform Mixing of Contaminated and Clean Sediments
- Airborne Concentration of High-Level Waste Persists Until Fortymile Wash is Depleted of Contaminated Tephra
Conclusion

- New Abstracted Model
  - Improve Realism
  - Reduce Uncertainty
- Independent Capability to Evaluate Risk-Significant Processes
- Fluvial Redistribution Component
- Companion Paper on Process-Level Modeling
Process-Level Modeling Determines Input Values for Abstracted Model Parameters

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_{\text{sediment},f}$</td>
<td>Preeruption sediment volume from the drainage basin that discharges through Fortymile Wash per unit area per discharge event [m/event]</td>
</tr>
<tr>
<td>$Y_{\text{ash},f}$</td>
<td>Posteruption volume of fluvial redistributed ash at the Fortymile Wash depositional region per unit area per discharge event [m/event]</td>
</tr>
<tr>
<td>$A_{\text{basin},f}$</td>
<td>Area of the drainage basin that discharges through Fortymile Wash [m²]</td>
</tr>
<tr>
<td>$\rho_{\text{ash},f}$</td>
<td>Density of proximal ash deposit [g/m³]</td>
</tr>
<tr>
<td>$T_f$</td>
<td>Average time between significant flow events [yr/event]</td>
</tr>
</tbody>
</table>
Acknowledgment

- This presentation describes work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the Nuclear Regulatory Commission (NRC) under Contract No. NRC–02–02–012.

- The activities reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of High-Level Waste Repository Safety.

- This presentation is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the NRC.

- The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or acceptability of a license application for a geologic repository at Yucca Mountain.