Fluvial Redistribution of Contaminated Tephra: Description of an Abstracted Model

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Abstract—A total-system performance assessment code has been developed to allow for independent evaluations of uncertainties in risk-significant features, events, and processes related to a potential geologic repository for high-level waste. An abstracted model was developed for the code to gain fundamental insights into tephra redistribution processes and risk to the reasonably maximally exposed individual. An abstracted sediment yield approach was used to model the long-term fluvial redistribution of potential tephra deposits in Fortymile Wash, in southern Nevada. Results of this model for fluvial redistribution are used with other inputs to estimate airborne particle concentrations, which are important factors for calculating inhalation dose to the reasonably maximally exposed individual. A companion paper presents how process-level modeling supports the fluvial redistribution modeling in the performance assessment code through the determination of values for the five local input parameters presented in this paper.

I. INTRODUCTION

The U.S. Department of Energy (DOE) is preparing a license application for a potential geologic repository for high-level waste disposal. A performance assessment would be submitted as part of the license application for review by the U.S. Nuclear Regulatory Commission (NRC). NRC would conduct a risk-informed performance-based review, in which in-depth technical evaluations are focused on technical areas that are significant with respect to waste isolation. In preparation for a regulatory review of a potential DOE license application and an associated performance assessment, the Center for Nuclear Waste Regulatory Analyses (CNWRA) and NRC staffs developed the Total-system Performance Assessment (TPA) code to provide the capability to independently evaluate uncertainties in risk-significant features, events, and processes.

Although considered an unlikely event, extrusive volcanism could occur if a subsurface volcanic conduit directly intersects the potential repository at Yucca Mountain. Waste packages entrained by this potential conduit could release high-level waste (HLW) as trace contamination of the erupting tephra, with subsequent atmospheric transport and deposition from a volcanic eruption plume. Following initial deposition from the plume, the long-term transport of tephra by wind and surficial water drainage in Fortymile Wash is referred to as eolian and fluvial redistribution, respectively. Figure 1 illustrates that the direction of fluvial remobilization of contaminated tephra is toward the hypothetical receptor location. Resuspension of ash particles (i.e., tephra < 2 mm [0.08 in]) produces airborne concentrations of ash and associated HLW, referred to as the airborne mass load. The estimated total dose for extrusive volcanism, which is dominated by the inhalation of resuspended volcanic ash, is significantly influenced by the amount of ash particles in the air [1]. Ash redistribution processes may significantly affect the thickness of the ash deposit near the receptor location and the extent of potential mixing of the ash with the underlying soil, which both factor into the proportion of ash in the airborne mass load.

With the intention of gaining fundamental insights into tephra redistribution processes and risk to the reasonably maximally exposed individual, the CNWRA developed and implemented a model abstraction [2] for the TPA code. Additional

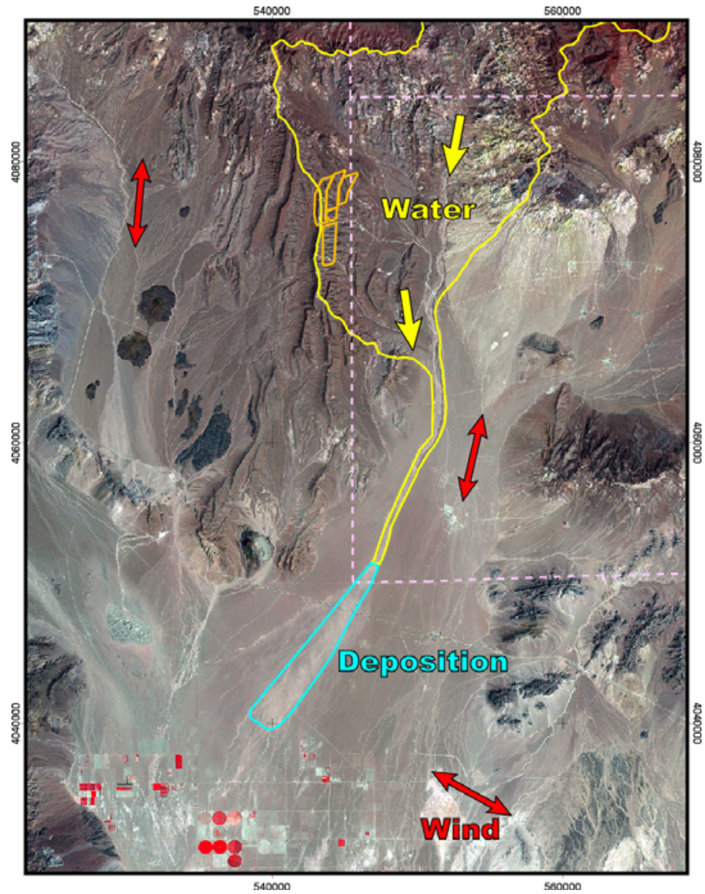

Figure 1. Satellite image showing the Fortymile Wash catchment basin (light line), depositional fan (light region at the end of catchment basin), potential repository site (set of adjacent shapes in the upper center), and Nevada Test Site boundary (dashed line). General trends of near-surface winds are shown by dark arrows.

capabilities were developed that may be included in the TPA code to provide more realistic estimates of volcanic eruption consequences. Primary capabilities of the new abstraction are (i) modeling of wind-field variations along the height of the eruption column, which affect the initial deposition of tephra, and (ii) modeling of the first-order processes affecting fluvial and eolian redistribution of tephra. Although this paper provides a general description of the modeling components for estimating volcanic eruption consequences that may be used in TPA computations, the objective of this paper is to describe the abstracted model component for fluvial redistribution. Additional capabilities that may be built into the TPA code for calculating volcanic eruption consequences are beyond the scope of this paper. Implementation in the TPA code is only at the proof-of-concept level.

II. WORK DESCRIPTION AND RESULTS

For TPA calculations, the amount and distribution of potential tephra deposits are calculated using the TEPHRA code, which is based on the modeling approach in [3], using stochastic sampling of Yucca Mountain-specific volcanic parameters. For each TPA code realization, the calculated tephra deposit is partitioned into three parts to represent (i) initial deposits (if any) at the receptor location, (ii) potential deposits in the Fortymile Wash drainage system subject to fluvial redistribution, and (iii) potential deposits in areas subject to eolian redistribution. This paper focuses on the fluvial redistribution of potential deposits in the Fortymile Wash catchment basin.

Figure 2 shows the flow of information in the TPA code when the new abstracted model is selected by the user for the volcanic eruption scenario. The passing of information from one TPA code module/component to the next is denoted with arrows. In addition to information transferred from other models/components (called global input or output), each module component may have specific local inputs. Arrows into a box represent global input, and arrows out of box represent global output. Local inputs in the TPA code can be input parameters, specified in a master input file for particular modules, or auxiliary files of input data. Table I presents the inputs used in the fluvial redistribution calculations.

The fluvial redistribution component calculates three quantities for use in the down-stream calculations pertaining to airborne mass loading:

c_f — concentration factor for high-level waste in the sediment [$g_{HLW}/g_{sediment}$],

d_f — dilution factor for mixing noncontaminated and contaminated sediments during fluvial redistribution [unitless], and

$t_{duration,f}$ — duration that Fortymile Wash yields contaminated sediment [yr].

The concentration factor, c_f, is calculated in the following manner

$$c_f = \frac{m_{HLW,f}}{m_{ash,f}} \quad . \qquad (1)$$

Areas of Fortymile Wash that lack tephra deposits are assumed to contribute noncontaminated sediment with the preeruption ambient sediment yield. The dilution factor, d_f, is calculated as the ratio of contaminated sediment volume to the total sediment volume (noncontaminated + contaminated) assuming uniform mixing of contaminated and noncontaminated sediment

$$d_f = \frac{1}{1 + \frac{Y_{sediment,f}}{Y_{ash,f}}\left(\frac{A_{basin,f}}{a_{ash,f}} - 1\right)} \quad . \qquad (2)$$

The duration that Fortymile Wash yields contaminated sediment, $t_{duration,f}$, is calculated as the time period for significant flow events to completely deplete Fortymile Wash of ash

$$t_{duration,f} = \frac{m_{ash,f} T_f}{Y_{ash,f} a_{ash,f} \rho_{ash,f}} \quad . \qquad (3)$$

The reader is referred to other descriptions [2] for how the outputs of the fluvial redistribution model component are used by other components in the consequence calculation.

III. CONCLUSION AND DISCUSSIONS

The long-term fluvial redistribution of potential tephra deposits can be modeled for Fortymile Wash, Nevada, using an abstracted sediment yield approach. Past rates of sedimentation in Fortymile Wash would likely increase following deposition of a potential tephra deposit, resulting in the redistribution of potentially contaminated tephra near the receptor location. The fluvial redistribution model for the TPA code accounts for gradual erosion of potential tephra deposits, mixing with noncontaminated sediments, and episodic depositional events. Results of this model for fluvial redistribution are used with other inputs to

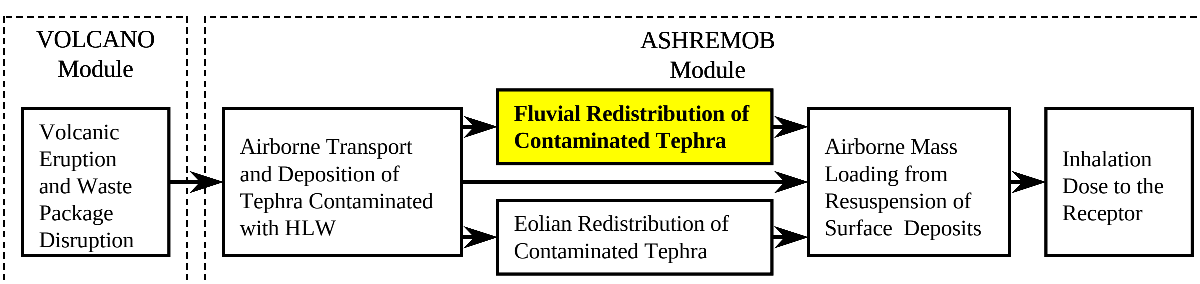

Figure 2. Flow chart of individual modeling components for estimating consequences from a volcanic eruption

Table I. Inputs for Fluvial Redistribution		
Symbol	**Description**	**Input Type / Source**
$m_{\text{HLW},f}$	Mass of high-level waste deposited in the Fortymile Wash catchment basin from the eruption [g]	Global input from the component for airborne transport and deposition
$m_{\text{ash},f}$	Mass of ash deposited in the Fortymile Wash catchment basin from the eruption [g]	Global input from the component for airborne transport and deposition
$a_{\text{ash},f}$	Area of the Fortymile Wash catchment basin with an ash deposit from the eruption [m^2]	Global input from the component for airborne transport and deposition
$Y_{\text{sediment},f}$	Preeruption sediment volume from the drainage basin that discharges through Fortymile Wash per unit area per discharge event [m/event]	Local input parameter from the TPA code input file
$Y_{\text{ash},f}$	Posteruption volume of fluvial redistributed ash at the Fortymile Wash depositional region per unit area per discharge event [m/event]	Local input parameter from the TPA code input file
$A_{\text{basin},f}$	Total area of the drainage basin that discharges through Fortymile Wash [m^2]	Local input parameter from the TPA code input file
$\rho_{\text{ash},f}$	Density of proximal ash deposit [g/m^3]	Local input parameter from the TPA code input file
T_f	Average time between significant flow events [yr/event]	Local input parameter from the TPA code input file

estimate airborne particle concentrations, which are important factors for calculating inhalation dose in the TPA code. A companion paper highlights how process-level modeling supports the fluvial redistribution modeling for the TPA code through the determination of values for the five local input parameters presented in this paper.

DISCLAIMER

This paper was prepared to document 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 paper 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 the acceptability of a license application for a geologic repository at Yucca Mountain.

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REFERENCES

1. U.S. NUCLEAR REGULATORY COMMISSION. “Risk Insights Baseline Report.” ML040560162. Washington, DC: U.S. Nuclear Regulatory Commission. April 2004. <www.nrc.gov/waste/hlw-disposal/reg-initiatives/resolve-key-tech-issues.html>

2. S. MOHANTY, R. BENKE, R. CODELL, K. COMPTON, D. ESH, D. GUTE, L. HOWARD, T. MCCARTIN, O. PENSADO, M. SMITH, G. ADAMS, T. AHN, P. BERTETTI, L. BROWNING, G. CRAGNOLINO, D. DUNN, R. FEDORS, B. HILL, D. HOOPER, P. LAPLANTE, B. LESLIE, R. NES, G. OFOEGBU, R. PABALAN, R. RICE, J. RUBENSTONE, J. TRAPP, B. WINFREY and L. YANG. "Risk Analysis for Risk Insights Progress Report." San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 2005.

3. C.B. CONNOR, B.E. HILL, B. WINFREY, N. FRANKLIN, and P.C. LA FEMINA. "Estimation of Volcanic Hazards from Tephra Fallout." *Natural Hazards Review*. Vol. 2, No. 1. pp. 33–42. 2001.