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

YUCCA MOUNTAIN PROJECT

Uncertainty Analyses and Strategy Report

Presented to:
Nuclear Waste Technical Review Board

Presented by:
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Overview

- **Uncertainty Analyses and Strategy Report**
- **Implementation of a consistent treatment of uncertainty in the Total System Performance Assessment (TSPA) for License Application**

Section 1 - Introduction

- **The three main goals of the report are**
  - **Summarize and discuss what has been done to evaluate, clarify, and improve the representation of uncertainty in TSPA**
  - **Develop a strategy for how to handle uncertainties, and propose some improvements for the future**
  - **Discuss issues related to communication of uncertainties, and propose some improvements for the future**

Section 2 - Evaluation of Uncertainty Treatment in TSPA-SR and the Significance of Uncertainties

Components of TSPA	Uncertainties	Perceived Significance of Risk	Possible Analysis Treatment	Summary of Impacts of Remaining Uncertainties
Seepage	Effect of infiltration, heterogeneity, drift degradation and coupled thermal-hydrologic-mechanical-chemical (THMC) processes on seepage distribution and amount	Low	Consider range of seepage fluxes including bound that 100% of drift area receives 100% of percolation flux.	Infiltration updates are not expected to produce significant changes because a wide range of infiltration rates has already been incorporated in unsaturated zone models. The non-welded units tend to redistribute or smear out the effects of heterogeneity, thus limiting the impact on uncertainty. The effects of coupled process uncertainties on seepage are insignificant because thermally induced changes in rock or hydrologic properties are too small to impact TSPA results. A wide range of flow focusing factors was previously analyzed, and Site Recommendation (SR) results are not sensitive to this process.
In-Drift Thermal-Hydrologic-Chemical (THC)	Effect of local heterogeneity and coupled THC processes on in-drift chemistry. This includes the likelihood of forming near neutral pH brines or high pH brines.	Medium	Develop probability and weighting functions for the likelihood of forming different brines based on potential starting water compositions / Consider range of in-drift chemistries and bounding salt content on drip shield and waste package surfaces.	Additional analyses, and short term testing were conducted to evaluate in-drift THC effects over the expected range of temperature and chemistry (pH), and found no significant effect; pH values used in the SR model bounded the potential pH range.

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				Anions (nitrates, sulfates) are likely to be present and will mitigate formation of corrosive salt solutions such as $MgCl_2$ and $CaCl_2$.
Drift Degradation	Effect of seismically - induced and thermal-hydrologic-mechanical (THM) processes on rock degradation and rock fall	Medium	Develop site-specific ground motion time histories appropriate for the post-closure period. Develop appropriate thermal and mechanical properties of rock blocks and joints. Consider range of rock fall sizes including bounding sizes.	Case histories show repository horizon does not have characteristics typical of regions that experience severe seismic effects on underground openings. Key block analysis is conservative regarding joint strength and other factors.
Waste Package Degradation	Local chemistry on waste package and drip shield surface (NaF, $CaCl_2$, or $MgCl_2$)	High	Characterize scale and deposits likely to form on metal surfaces. Consider likely range of chemical environments for range of dust/hygroscopic salt contents.	Formation and quantity of $CaCl_2$, or $MgCl_2$ solutions is expected to be limited, and is bounded by existing analyses which contains large uncertainty. Quantity of NaF solutions is expected to be insignificant, so overall uncertainty due to these conditions is expected to be low.
Waste Package Degradation (continued)	Stability and degradation of passive films on waste package surface, including effects of defect/debris accumulation	High	Continue to characterize passive film under repository relevant conditions. Consider low probability of instability and combine with performance of drip shield barrier and more realistic water ingress models.	Passive film growth appears to level off to steady-state thickness, so cracking or spalling is not likely to disrupt films. As long as changes in environmental conditions do not cause susceptibility to localized

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				corrosion, evidence to date suggests passive films would remain passive over long time periods. Peer Review panel stated that a passive film could, in principle, survive over a geologic time scale.
Waste Package Degradation (continued)	Possibility of concentrated trace ionic species on waste package (lead, mercury, arsenic) and corrosion consequences	Medium	Consider low probability of such aggressive species and combine with more realistic water ingress models.	Literature review of these trace ionic species determined that they are not expected to have a significant effect on corrosion, either because of limited solubility, or because they do not significantly enhance corrosion processes.
Waste Package Degradation (continued)	Post-welding residual stress distribution of closure welds and manufacturing flaws in waste package	Medium	Consider low probability of improper heat treatment and develop reasonable representation of the consequences.	Additional analyses evaluated the effect of residual stress on the closure-lid welds, and found that the SR analyses conservatively bounded the effect. Number, size and distribution of manufacturing flaws are uncertain, but were conservatively analyzed for the SR.
Waste Form Degradation	Initial cladding state	Low	Consider taking no credit for cladding or increase the uncertainty distribution on the initial cladding perforation.	Taking no credit for cladding would be more conservative, but is not realistic. The SR conservatively models the fraction of cladding that is initially failed at 9.7% compared to the

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				best estimate of 0.05% from literature sources.
Radionuclide Concentration	Radionuclide solubility and colloid formation/stability	Low	Consider range of solubilities and colloid formation/stability.	Assumptions used for SR over - predict dissolved plutonium levels (assumes the most soluble plutonium phases and oxic conditions in waste package). In-package sorption was neglected, leading to dissolved neptunium and plutonium levels that are substantially larger than would occur. Neptunium thermodynamic modeling is consistent with lab results and also conservatively modeled. Colloid model maximizes releases and minimizes retardation/filtration. Natural analog information suggests only minor transport of radionuclides in many situations, so colloid model is believed to be highly conservative and appropriate to support SR decision process.
Unsaturated Zone Transport	Presence and distribution of low advective transport times (Paintbrush nonwelded unit lateral flow,	Low	Consider distribution of advective transport times.	The key uncertainties relate to processes that would improve performance, so the current analyses are conservative (i.e.,

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	active fracture model, drift shadow zone)			inclusion of the uncertainties would increase travel time and improve performance of the unsaturated zone).
Saturated Zone Transport	Saturated zone specific discharge	Low	Constrain rock permeability estimates with data collected from the Nye County Drilling Program.	Numerous modeling studies have been conducted to bound the effect of a wide range of specific discharges. Current model bounds the potential travel times, and reduction in uncertainty would only serve to lengthen the travel time (i.e., improve saturated zone performance)
Igneous Consequences	Interaction between magmas and repository structures; response of waste packages and waste forms to igneous conditions; eolian and fluvial remobilization of contaminated volcanic ash	Medium	Consider range that includes the Nuclear Regulatory Commission bound as low probability consequence.	The low probability of an igneous event is not expected to significantly affect doses relative to the regulatory limits. New analyses may lead to reduction of the probability of explosive eruptive phenomena. New analysis of remobilization of contaminated volcanic ash is being conducted; however, this is not expected to significantly affect doses relative to the regulatory limits. Improved magma-repository interaction analysis (e.g.,

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				potentially more packages affected directly or indirectly from igneous activity) may lead to an increase in quantity of waste being erupted. However, this is not expected to significantly decrease the performance of the system.
Notes: NaF = sodium fluoride, $CaCl_2$ = calcium chloride, $MgCl_2$ = magnesium chloride				

Section 3 - Strategy for the Future Treatment of Uncertainties

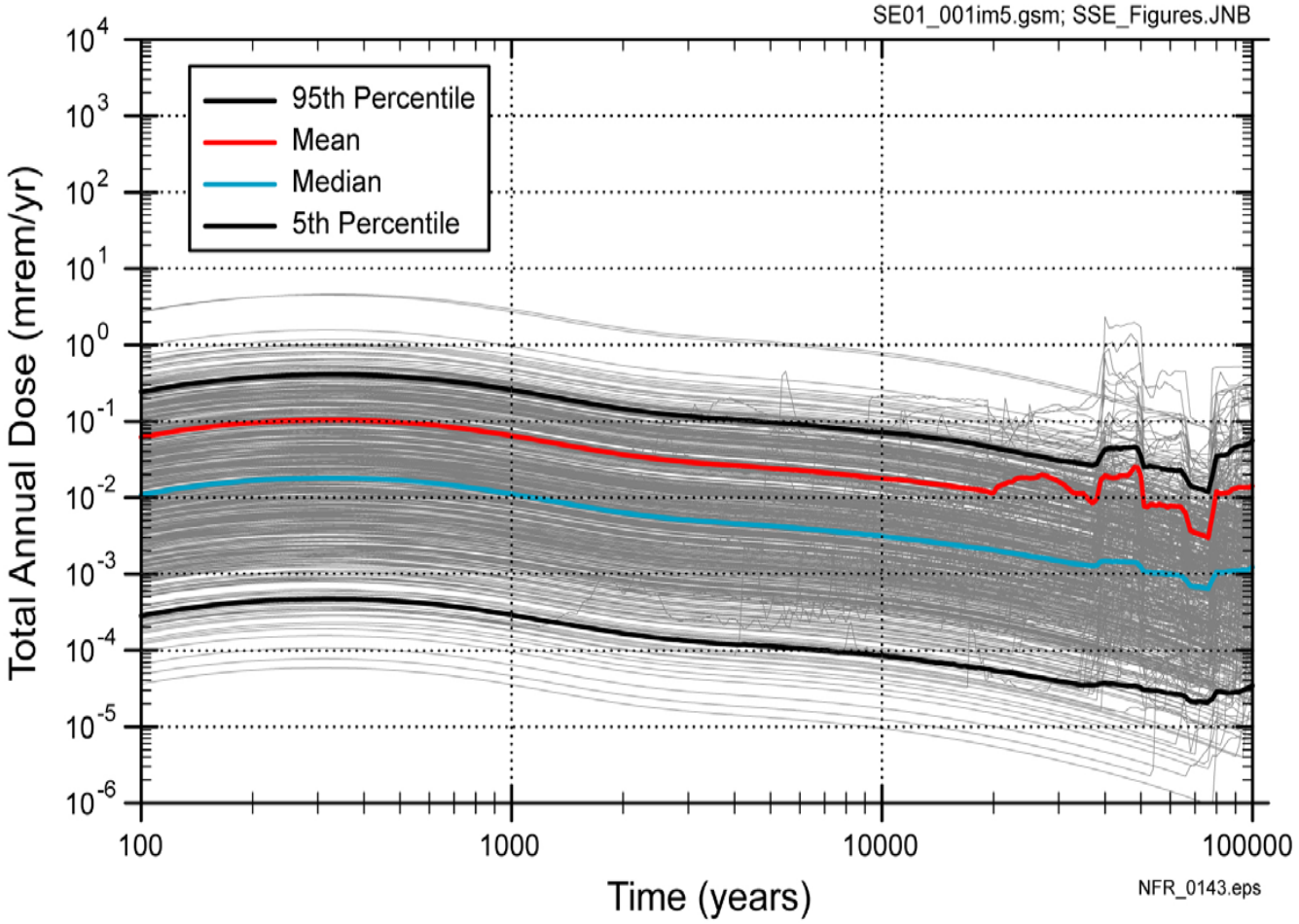
- **General framework for uncertainty treatment: develop a TSPA that meets the intent of "reasonable expectation"**
- **Quantify uncertainties in inputs to the performance assessment**
- **Identify processes that encourage the quantification of uncertainties and gain concurrence on approaches with the Nuclear Regulatory Commission**
- **Provide the technical basis for all uncertainty treatment**

Section 3 - Strategy for the Future Treatment of Uncertainties

(Continued)

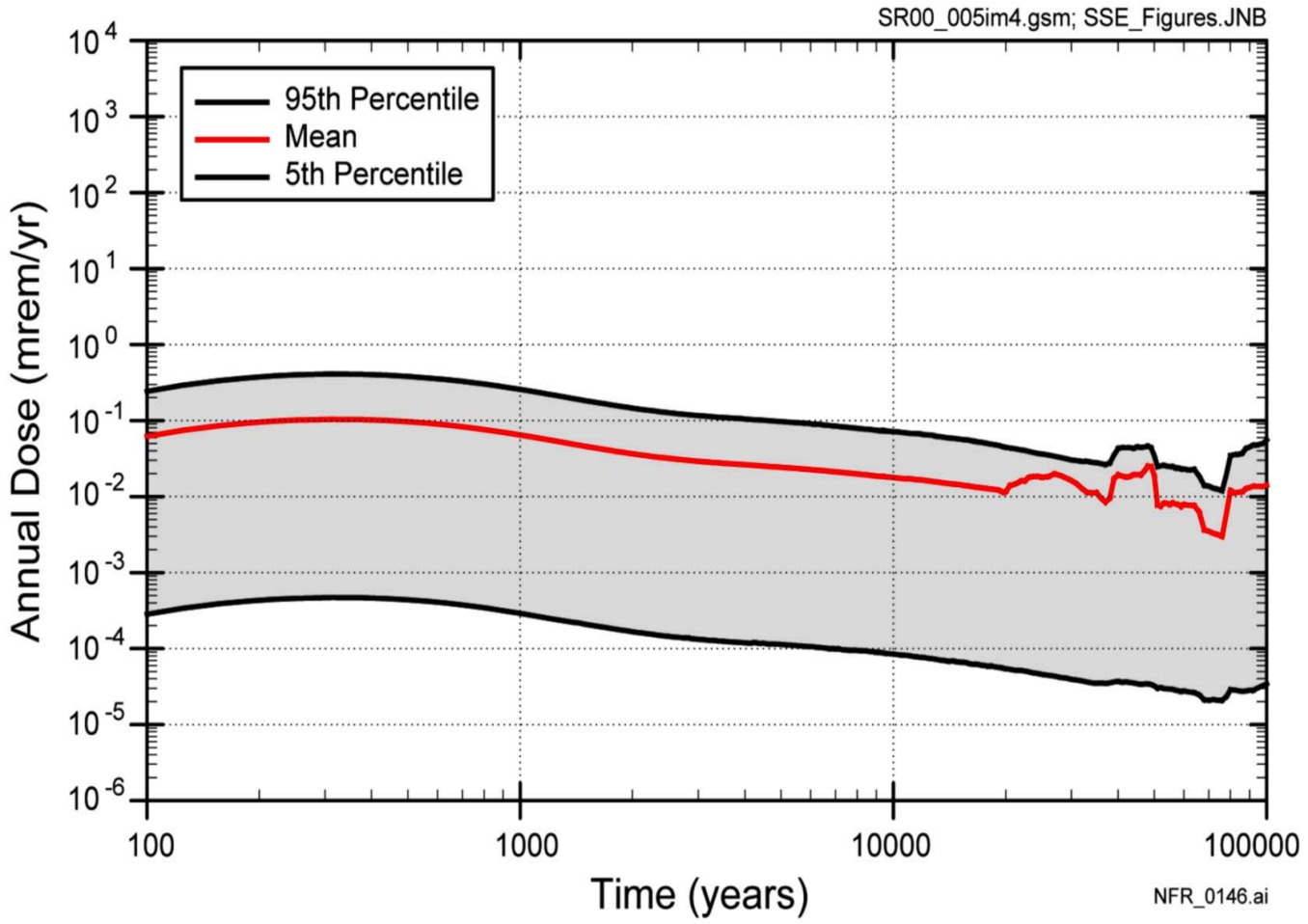
- **Address conceptual model uncertainty**
- **Develop a consistent set of definitions and methods for “bounds” and “conservative” estimates**
- **Develop and communicate information that can be used by decision-makers**
- **Develop detailed guidance and provide for its implementation**

Section 4 - Communication of Uncertainties



Revised Supplemental TSPA Model Results of Annual Dose to a Receptor for Disruptive (Igneous Activity) Scenario

Section 4 - Communication of Uncertainties



Modified Horsetail Diagram with Individual Realizations Removed and Statistical Measures—Mean and 5th and 95th Percentiles—Displayed Separately

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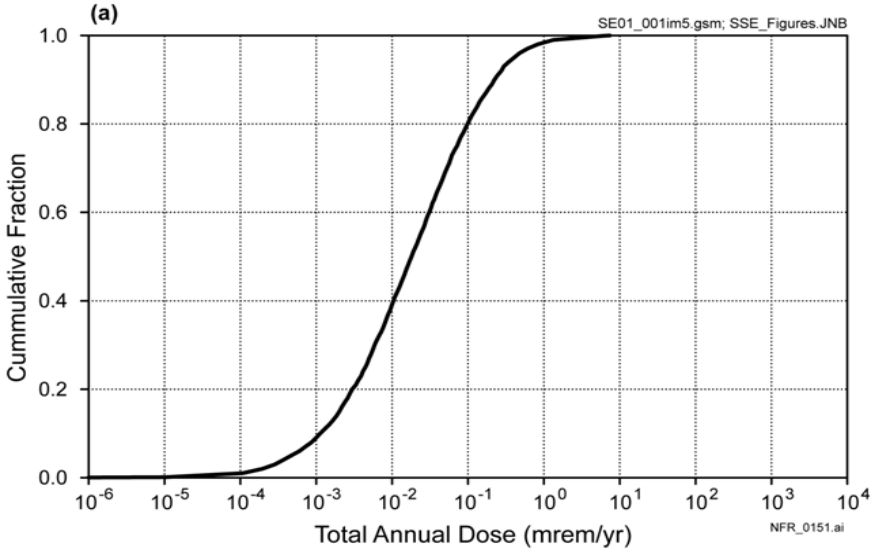

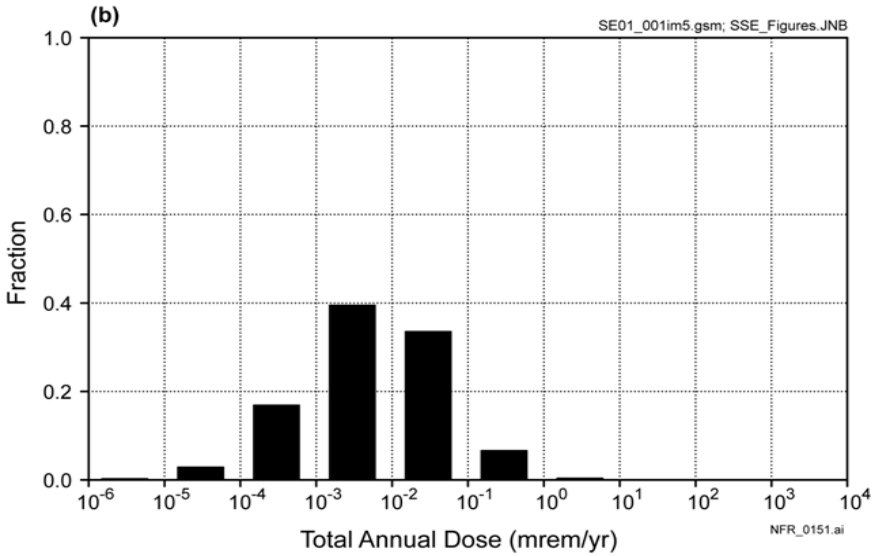

- **Cumulative Fraction and Histogram of Realizations Reaching Particular Annual Dose Rates at the Peak of the Mean within 10,000 years Calculated by the Revised Supplemental TSPA Model**

Implementation

As for a future life, every man must judge for himself between conflicting vague probabilities.

from Life and Letters
Charles Robert Darwin, 1809-1882