SOAR MODEL VERIFICATION REPORT

Prepared for

U.S. Nuclear Regulatory Commission
Contract No. NRC–02–07–006

Prepared by

Ron Janetzke[1]
Christopher Markley[2]
Osvaldo Pensado[1]
Keith Compton[2]
George Adams[1]
Razvan Nes[1]
Sitakanta Mohanty[1]

[1]Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

[2]U.S. Nuclear Regulatory Commission
Washington, DC

February 2012

CONTENTS

FIGURES

Figures Page

FIGURES (continued)

Figures Page

FIGURES (continued)

Figures Page

FIGURES (continued)

Figures Page

FIGURES (continued)

Figures Page

TABLES

Tables Page

ACKNOWLEDGMENTS

The authors would like to recognize the model developers of SOAR Version 1.0 (Markley, et al., 2011) for their assistance in defining test cases, as well as support from R.W. Rice to perform a number of runs in Chapters 4 and 5. This report is an independent product of the Center for Nuclear Waste Regulatory Analyses (CNWRA®) under Contract No. NRC–02–07–006 and does not necessarily reflect the view or regulatory position of the U.S. Nuclear Regulatory Commission (NRC). The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of any licensing action that may be under consideration at NRC. 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. The authors would like to thank K. Axler for the technical review, D. Pickett for the programmatic review, and T. Wilt for his assistance to facilitate the review effort and carry out model runs. The authors also appreciate B. Street, L. Selvey, and A. Ramos for providing word processing support and L. Mulverhill for editorial support in preparation of this document.

QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT DATA

DATA: The **S**coping of **O**ptions and **A**nalyzing **R**isk (SOAR) model was developed outside a formal quality control program for software development [CNWRA Technical Operating Procedure (TOP)–18, Development and Control of Scientific and Engineering Software]. However, simplified procedures (mutually agreed upon by NRC and CNWRA staffs) were implemented for model development that included version control and verification testing. This report documents a systematic effort for model verification.

ANALYSES AND CODES: SOAR was developed using GoldSim (GoldSim Technology Group, LLC, 2010). The SOAR model utilizes the Microsoft® Access® Database (Microsoft Corporation, 2007) to track input parameters.

REFERENCES

GoldSim Technology Group, LLC. “GoldSim Probabilistic Simulation Environment User’s Guide.” Vols. 1 and 2. Issaquah, Washington: GoldSim Technology Group, LLC. 2010.

Markley, C., O. Pensado, J.-P. Gwo, J. Winterle, T. Ahn, R. Benke, T. Cao, H. Gonzalez, A. Gray, X. He, R. Janetzke, H. Jung, G. Oberson, P. Shukla, T. Sippel, S. Stothoff, and L. Tipton. “SOAR: A Model for Scoping of Options and Analyzing Risk: Version 1.0, User Guide.” Accession Number ML112440119. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 2011.

Microsoft Corporation. “Microsoft Access Database 2007.” Redmond, Washington: Microsoft Corporation. 2007

EXECUTIVE SUMMARY

This report describes the verification of the **S**coping of **O**ptions and **A**nalyzing **R**isk (SOAR) model, a tool jointly developed by the U.S. Nuclear Regulatory Commission (NRC) and the Center for Nuclear Waste Regulatory Analyses (CNWRA®) staffs, to provide timely risk and performance insights for a variety of potential high-level waste (HLW) disposal options. The verification activities, aimed at ensuring that models in SOAR were appropriately implemented, are an important aspect of the SOAR development cycle as it moved toward its release as SOAR Version 1.0. Verification activities involved tasks such as deterministic testing [e.g., running the probabilistic SOAR model deterministically using high and low input parameter values (Chapter 3)], probabilistic testing [i.e., Monte Carlo runs with controlled (i.e., discrete) variations to one parameter at a time over its entire range (Chapter 4)], and comparison with published information (i.e., benchmarking). Verification activities involved visual inspection of equations and qualitative comparison of results with respect to expected values. Intermediate results and system-level responses as a function of time were inspected to ensure that trends were reasonable and explainable with respect to the changes to the input values. For deterministic verification calculations, different combinations of waste form, waste package material, and geochemical environments were used with the intention of testing the major model components. For the probabilistic verification, calculations were carried out for selected radionuclides for a variety of combinations of fuel mass, enrichment, and burnup; alternative waste forms; environmental chemistry (oxidizing versus reducing); waste package corrosion rate; backfill integrity; water volume in the waste package; porous/fractured media hydraulic gradient; and disturbed zone characteristics.

The benchmarking activity focused on providing confidence that SOAR can simulate different process corresponding to different geologic repository programs. This activity involved two selected repository system models with calculations available in the literature: Swedish (SKB, 2011) and Japanese (JNC, 2000). Only portions of these systems were selected for modeling by the SOAR code. This report documents the specific changes to SOAR needed to emulate the test problems. The maximum difference between the SOAR result and the Japanese model was within one order of magnitude. The difference in results is attributed to the difference in the number of radionuclides being tracked, the number of isotopes associated with some of the radionuclides, finite difference discretization of the diffusive buffer material pathway, buffer material geometry (cylindrical versus one dimensional representation), and timestepping. The maximum difference between the SOAR result and the Swedish model was within an order of magnitude. The difference in results is attributed to the difference in radionuclide inventory, dose conversion factors, and gap fraction inventory. Although exhaustive verification is possible for any computer code if abundant time and resources are available, the level of verification carried out on the SOAR model is considered to be appropriate given that this code is intended to be used as a generic tool for scoping computations.

References:

JNC. “H12: Project To Establish the Scientific and Technical Basis for HLW Disposal in Japan. Supporting Report 3: Safety Assessment of the Geological Disposal System.” Ibaraki, Japan: Japan Nuclear Cycle Development Institute. April 2000.

Svensk Kärnbränslehantering AB (SKB). “Long-Term Safety for the Final Repository for Spent Nuclear Fuel at Forsmark.” Vol. 1: Main Report of the SR-Site Project. SKB TR–11–01. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Company. March 2011.

1 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) developed a performance assessment model named **S**coping of **O**ptions and **A**nalyzing **R**isk (SOAR) (Markley, et al., 2011). This model is one of the elements identified in NRC's Plan for Integrating Spent Nuclear Fuel Regulatory Activities (NRC, 2010a), which focuses on achieving a predictable, effective, and efficient regulatory program. Considering the current uncertainty in the U.S. national policy for high-level waste (HLW) disposal, the SOAR model is designed with the goal of maximizing flexibility to consider a variety of disposal options. The simplified model abstractions and associated parameter inputs are built upon the knowledge and experience gained by the NRC staff and the Center for Nuclear Waste Regulatory Analyses (CNWRA®), and from other domestic and international performance assessments for a variety of geologic disposal options. The model is parameterized with data available in existing literature from international disposal programs for a variety of engineered and geologic materials. Many of the input parameters are stochastically sampled from broad ranges of values to account for uncertainty and variability. The insights gained from analyses with the SOAR model will be used to assist the NRC staff to focus its evolving regulatory program for HLW disposal on characteristics of geologic disposal important to waste isolation. The model will also assist the staff in identifying regulatory research and development activities related to physical processes (e.g., radionuclide solubility, water flow) and characteristics (e.g., waste package materials, waste form inventories and characteristics, host-rock types) on which a regulatory program should focus.

This report documents SOAR Version 1.0 verification activities. A general description of the verification activities of the models implemented in SOAR is given in Chapter 2. Chapter 3 documents the results of formal tests, mostly designed by SOAR model developers, but implemented by independent testers. Chapter 4 presents a library of SOAR results varying one parameter at a time, to provide analysts with trends in SOAR outputs. Chapter 5 compares results derived with SOAR, and appropriate modifications, to results published in the literature on performance assessments of geologic disposal systems. SOAR modifications and the modeled systems are detailed in Chapter 5. In general, comparison tests were not designed to yield identical results, but to produce similar trends and magnitudes in radionuclide release rates or dose estimates.

2 GENERAL DESCRIPTION OF VERIFICATION ACTIVITIES

In this chapter, activities aimed at enhancing confidence in the models implemented in SOAR are discussed. The model review and testing conducted to gain model confidence are summarized in the following bullets.

- All GoldSim model elements (e.g., data elements, mixing cells, pipe pathways, selectors, results elements) were inspected to ensure correct computations and algorithms were implemented, correct units were used, and inputs and outputs were connected to the correct elements. For most model elements, text descriptions were added to help users understand the purpose of the element.

- Individual realizations were run using high and low input parameter values, and results were inspected to ensure intermediate outputs and system-level responses were reasonable. For example, the model was run using the highest and lowest waste form degradation rate and results compared against the expectation that higher waste form degradation rates resulted in proportionally higher release.

- Different combinations of waste form, waste package material, and geochemical environment were run, and intermediate-level and system-level outputs were evaluated to verify that the model selected the correct inputs and computational algorithms appropriate to the model settings.

- The initial inventory of radionuclides was varied from very small to very large values to check a proportional output response.

- In addition to these initial testing efforts, developers at the U.S. Nuclear Regulatory Commission (NRC) and Center for Nuclear Waste Regulatory Analyses (CNWRA®) carried out a more detailed verification effort. The effort included development of a number of test plans, test reports, and a status spreadsheet and focused on testing all of the major model components. These tests are documented in Chapter 3.

A brief summary of the system modeled in SOAR is provided. The SOAR model includes a source model, components to compute radionuclide transport in geologic media, and a biosphere dose model. The source model includes descriptions of four waste forms, radionuclide inventories, and waste form dissolution rates. The source model also incorporates abstractions for waste package failure, transport through a buffer material (a diffusive barrier that surrounds the waste packages), and transport through a drift and radionuclide discharge into nearby fractures. The radionuclide discharge is used as input to the geologic media transport computations. From a broad perspective, the SOAR system has a number of features that were extensively used in the verification activities. For example, if solubility constraints in the model for the engineered barrier system are disabled, the system offers a linear response to changes in the inventory (e.g., doubling the inventory would double the dose). However, if solubility constraints are enabled, the dose response is less than linear to changes in the inventory. Radionuclides that are fission products and activation products are modeled as mutually independent. On the other hand, actinides are connected by decay chains; solubility constraints can also link the release of isotopes of an element. Thus, it is straightforward in some instances to anticipate the effect of input parameters on releases of fission and activation products, but not on radionuclides that are part of a decay chain or that share element mass with other modeled isotopes. The radionuclide transport pathway is modeled as a one-dimensional pathway, from the source to the biosphere. This simplification allowed for designing tests and anticipating results arising from changes in pathway lengths. In this report, the term “software verification” refers to checking whether model abstractions and equations were properly implemented in SOAR. The verification checking was implemented by quantitative and qualitative tests. In the quantitative tests, outputs were checked against limiting cases or against expected outputs independently computed. In the qualitative tests, trends of outputs were compared to general expectations of the development team, rather than to a set of precise predetermined values.

The SOAR code was developed with the GoldSim language, which is an icon-based, high-level programming language. As such, it does not lend itself to traditional verification techniques associated with sequential languages (e.g., FORTRAN, C++) frequently used for modeling physical phenomena. However, it can automatically perform many of the checks that would be required for a sequential language. For example, GoldSim can automatically check for proper parameter types, consistent units of physical quantities, and meaningful syntax. It can also automatically establish a proper connection between functional elements. Because these concepts are part of the basic GoldSim product, they were not the main focus of the verification effort. Rather, many test activities focused on performing visual inspections of equations in the GoldSim elements, determining their logical relationship to other programming elements, and analyzing results.

Teams of analysts developed the multidiscipline models, or model components, in SOAR. Giving all team members full edit and review access to all of the model components presented an opportunity to check the work of other team members. Many self-checks of this nature were performed during code development, including visual inspection of equations and review of the logical structure of each model component. A first level of confidence in the code was attained during development using this self-checking technique. Also, the availability of intermediate values and outputs enabled the inspection of the output response of each component to changes in input values.

A model that represents a physical process with inherent uncertainties requires the ability to vary the value of model parameters to represent ranges of possible conditions. Flexible parameter values are also required to investigate relevant scenarios that may differ from base models. Parameters are also used to implement specific features of the model or otherwise control the operation of the model during execution. During the model development, a number of input parameters were revised. In general, modifying input parameters in a SOAR model component does not affect the functionality of another independent model component. Therefore, in general, tests on a particular model component were not repeated when input parameters for other model components changed. Numerous preliminary input parameter values were used in development testing.

During the code development process, repeated tests were commonly executed by inputting many different values for the relevant parameters to check the behavior of the component being constructed. This process frequently used the dashboards to enter the new values, with the intention to test the dashboard interface, as well as the corresponding model component. In this way the mechanics of the parameter entry dialog and the propagation of the parameter value to the model components were evaluated. The dashboard interface also enabled the convenient testing of parameter minimum and maximum value limits. During code development, no formal documentation was prepared to establish agreement with external calculations; however, the output was continually checked to ensure self-consistency. Qualitative testing was also performed on input values and mode selectors available in dashboards.

The SOAR model has the ability to consider up to four different waste form types. While the model components for each waste form type share similarities, separate independent tests were performed for each type. Integrated tests were also performed to test the capability of the model to handle cases with simultaneous presence of multiple waste forms. These kinds of tests were performed during the development of the Waste Form model component and during formal testing phases.

Once the model was considered to be relatively mature, formal verification tests were implemented. These formal verification tests, documented in Chapter 3, were mostly high-level tests that focused on one specific model component at a time. Each test was summarized in a test report. These formal tests exercised the operation of model component dashboards, input parameter values, and switches. These test reports included the qualitative analysis of intermediate output values from the particular model component under test. By studying the qualitative trends of outputs, or changes in outputs in response to changes in inputs, a conclusion was reached as to whether an aspect of a model was appropriately implemented. The SOAR model was revised when necessary to address issues identified during the formal testing phase.

Formal tests were organized into six groups, each identified with one of the following two letter abbreviations:

(1) Waste Form (WF)
(2) Waste Package (WP)
(3) Near Field (NF)
(4) Far Field (FF)
(5) Dashboard (DB)
(6) Disruptive Events (DE)

Each group tested one or more aspects of the target component. To isolate the aspect/parameter for a test, other parameters or switches were often configured to disable parts of the model that could potentially influence the results more than the aspect being tested. The testing of a particular aspect was, in general, compared to a reference run and a suite of other runs with different inputs.

The verification effort was documented in Microsoft® Word® and Excel® files on a hard drive NRC and CNWRA developers shared. The documentation consisted of test plans, test reports, and a status spreadsheet. The test plan identified the test objective, specified the criteria for a successful test, and was generated prior to each test. Test results were documented in a test report summary that displayed the data in text or chart form as output by SOAR and displayed test status.

In the SOAR model, mass conservation constraints are enforced by using GoldSim elements (e.g., species elements, cell pathways, pipe pathways, and source container elements), which perform mass balance computations in detail while accounting for radioactive decay and ingrowth. The GoldSim software developers have extensively tested those mass balance solutions. Additional testing was needed to verify that model abstractions were properly implemented and that the computational modules were adequately interconnected. The testing was not intended to be exhaustive, but to represent a balance between available time and resources, and the intended use of SOAR as a generic tool for scoping computations. This balance resulted in the execution of a limited number of tests, which are considered to be sufficient for the intent of SOAR. Additional tests for internal consistency could be aimed at database value propagation, convergence of statistical results as a function of increasing number of realizations, and dependence of results on the number of timesteps. Quantitative tests can be defined; for example, the SOAR model could be compared to external codes that perform a subset of similar calculations. This type of test is time consuming to implement because inputs must be identical for results to match, the model or code used as comparison must be thoroughly understood, and SOAR and the comparison code must be adjusted to yield comparable outputs. In Chapter 5, a limited effort was aimed at qualitatively simulating geologic disposal systems with performance assessments documented in the literature. At this time, the extent of the verification applied to SOAR is considered to be sufficient given the intent of SOAR for scoping computations and given that tests show the flexibility of SOAR to model scenarios of geologic disposal.

3 VERIFICATION SUMMARY REPORTS

3.1 Summary Report Template

The verification effort was documented as Microsoft® Word® and Excel® files on a shared drive. The documentation consisted of

- Test plans that identified the test objective, specified the criteria for a successful test, and were generated prior to each test

- A test report that displayed test results in text or chart form as provided by the **S**coping of **O**ptions and **A**nalyzing **R**isk (SOAR) program

- A test status spreadsheet

The plan contained the following elements:

Test Title: Identifies the scenario or the configuration of the code to be tested, or some other unique aspect of the test

Model Component: Identifies the component to be tested

Test Objective: Identifies the model behavior, parameter, or result that represents a certain physical phenomenon

Assumptions: Identifies any assumptions or limitations of the test

Test Configuration: Identifies conditions, parameter settings, component modes, and dashboard settings required for the test

Result Parameters: Identifies the final or intermediate parameters that are to be analyzed to determine the success or failure of the test

Success Criteria: Specifies the conditions that must be met for a successful test

Test results were documented in a test report that contained all of the information of the test plan, the test results, and the status of the test. The test report for each test contained the following elements:

Test ID: A unique identifier for the test consisting of two alphabetic characters, corresponding to one of the six test groupings mentioned in Chapter 2, followed by two numeric characters (e.g., WP01 for waste package test #1)

Test Title: Identifies the scenario or the configuration of the code to be tested, or some other unique aspect of the test

Model Component: Identifies the component to be tested

Analyst: The name of the analyst performing the test

Date: Date on which the test was performed

Test Environment: Identifies the computer on which the test was performed and the version of the GoldSim software used for the test

SOAR Version: Identifies the version of the SOAR code used for the test

Run Directory: Specifies the directory used to store the input used for the test and results of the code execution

Test Objective: Identifies the model behavior, parameter, or result that represents a certain physical phenomenon

Assumptions: Identifies any assumptions or limitations of the test

Test Configuration: Identifies conditions, parameter settings, component modes, and dashboard settings required for the test

Result Parameters: Identifies the final or intermediate parameters that are to be analyzed to determine the success or failure of the test

Success Criteria: Specifies the conditions that must be met for a successful test

Results: Indicates the success or failure of the test with respect to each of the success criteria

3.2 Verification Status File

Documentation of the tests also included the Verification Status file—a single sheet Excel file containing columns for test ID, title, test plan file name, test report file name, and the status of the test. Table 3-1 presents the verification status file, summarizing the results of the tests. Following Table 3-1, the detailed Verification Test Reports documenting this SOAR verification effort are included.

Table 3-1. Test Identification				
Test ID	**Title**	**Test Plan File**	**Test Report Files**	**Test Status**
	Waste Form			
WF01	Radionuclide Release Rate versus All Zero Degradation Rates	WF01TestPlan.docx	WF01TestReport.docx	PASS
WF02	Radionuclide Release Rate versus CSNF_9e−7 Degradation Rate	WF02TestPlan.docx	WF02TestReport.docx	PASS
WF03	Radionuclide Release Rate versus CSNF_9.2e−5 Degradation Rate	WF03TestPlan.docx	WF03TestReport.docx	PASS
WF04	Radionuclide Release Rate versus CSNF_6.e−4 Degradation Rate	WF04TestPlan.docx	WF04TestReport.docx	PASS
WF05	Radionuclide Release Rate versus sMOX_9.e−7 Degradation Rate	WF05TestPlan.docx	WF05TestReport.docx	PASS
WF06	Radionuclide Release Rate versus sMOX_9.2e−5 Degradation Rate	WF06TestPlan.docx	WF06TestReport.docx	PASS
WF07	Radionuclide Release Rate versus sMOX_6.e−4 Degradation Rate	WF07TestPlan.docx	WF07TestReport.docx	PASS
WF08	Radionuclide Release Rate versus HLWg_1.5e−6 Degradation Rate	WF08TestPlan.docx	WF08TestReport.docx	PASS
WF09	Radionuclide Release Rate versus HLWg_4.e−5 Degradation Rate	WF09TestPlan.docx	WF09TestReport.docx	PASS
WF10	Radionuclide Release Rate versus HLWg_2.e−4 Degradation Rate	WF10TestPlan.docx	WF10TestReport.docx	PASS
WF11	Radionuclide Release Rate versus HLWc_1.5e−8 Degradation Rate	WF11TestPlan.docx	WF11TestReport.docx	PASS
WF12	Radionuclide Release Rate versus HLWc_4.e−7 Degradation Rate	WF12TestPlan.docx	WF12TestReport.docx	PASS
WF13	Radionuclide Release Rate versus HLWc_2.e−6 Degradation Rate	WF13TestPlan.docx	WF13TestReport.docx	PASS
WF14	Basecase Run for Radionuclide Release Tests Involving Adjustment of Inventory	WF14TestPlan.docx	WF14TestReport.docx	PASS
WF15	Radionuclide Release in Reprocessing HLW Glass with Initial Inventory Factor of 1.2	WF15TestPlan.docx	WF15TestReport.docx	PASS
WF16	*Omitted*	—	—	—
WF17	Radionuclide Release in Reprocessing HLW Glass with Initial Inventory Factor of 1.5	WF17TestPlan.docx	WF17TestReport.docx	PASS

Table 3-1. Test Identification (continued)				
Test ID	**Title**	**Test Plan File**	**Test Report Files**	**Test Status**
WF18	Basecase Run for Radionuclide Release Tests Involving Adjustment of the HLW Ceramic Initial Inventory	WF18TestPlan.docx	WF18TestReport.docx	PASS
WF19	*Omitted*	—	—	—
WF20	*Omitted*	—	—	—
WF21	*Omitted*	—	—	—
WF22	*Omitted*	—	—	—
WF23	Radionuclide Release from Reprocessed HLW Ceramic Waste with Initial Inventory Factor of 3.75	WF23TestPlan.docx	WF23TestReport.docx	PASS
WF24	Radionuclide-Specific (I-129) Release from Reprocessed HLW Ceramic Waste	WF24TestPlan.docx	WF24TestReport.docx	PASS
WF25	Radionuclide-Specific (I-129 & Cs-135) Release from Reprocessed HLW Ceramic Waste	WF25TestPlan.docx	WF25TestReport.docx	PASS
WF26	Basecase for Runs Regarding the Fraction of Initial Inventory Available for Release and the Degradation Rate Multiplier	WF26TestPlan.docx	WF26TestReport.docx	PASS
WF27	Radionuclide Release with the Fraction of Initial Inventory Available for Release at 0.10	WF27TestPlan.docx	WF27TestReport.docx	PASS
WF28	Radionuclide Release with the Fraction of Initial Inventory Available for Release at 0.30	WF28TestPlan.docx	WF28TestReport.docx	PASS
WF29	*Omitted*	—	—	—
WF30	Radionuclide Release with the Degradation Rate Multiplier at 5	WF30TestPlan.docx	WF30TestReport.docx	PASS
WF31	Radionuclide Release with the Degradation Rate Multiplier at 0.2	WF31TestPlan.docx	WF31TestReport.docx	PASS
Waste Package				
WP01	WP Failure Time and Breached Area for Cu_porous_rock_oxidizing_2.5cm_Reference case	WP01TestPlan.docx	WP01TestReport_11_30_2010	PASS
WP02	WP Failure Time and Breached Area for Cu_porous_rock_oxidizing_2.5cm_10X corrosion rate	WP02TestPlan.docx	WP02TestReport_11_30_2010	PASS
WP03	WP Failure Time and Breached Area for Cu_fractured_rock_reducing_2.5cm_reference case	WP03TestPlan.docx	WP03TestReport_12_01_2010	PASS

Table 3-1. Test Identification (continued)				
Test ID	**Title**	**Test Plan File**	**Test Report Files**	**Test Status**
		Waste Package		
WP04	WP Failure Time and Breached Area for Cu_fractured_rock_reducing_2.5cm_10X corrosion rate	WP04TestPlan.docx	WP04TestReport_12_01_2010	PASS
WP05	WP Failure Time and Breached Area for Cu_fractured_rock_reducing_0.5 cm_Effects of material thickness	WP05TestPlan.docx	WP05TestReport_12_01_2010	PASS
WP06	WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0 cm_Reference case	WP06TestPlan.docx	WP06TestReport_12_02_2010	PASS
WP07	WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0 cm_5X corrosion rate	WP07TestPlan.docx	WP07TestReport_12_03_2010	PASS
WP08	WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0 cm_0.1X corrosion rate	WP08TestPlan.docx	WP08TestReport_12_03_2010	PASS
WP09	WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0 cm_0.1X corrosion rate	WP09TestPlan.docx	WP09TestReport_12_06_2010	PASS
WP10	WP Failure Time and Breached Area for SS_porous_rock_oxidizing_5.0 cm_Reference case	WP10TestPlan.docx	WP10TestReport_12_06_2010	PASS
WP11	WP Failure Time and Breached Area for SS_fractured_rock_reducing_5.0 cm_Reference case	WP11TestPlan.docx	WP11TestReport_12_06_2010	PASS
WP12	WP Failure Time and Breached Area for SS_fractured_rock_reducing_5.0 cm_2X the breach area fraction	WP12TestPlan.docx	WP12TestReport_12_08_2010	PASS
WP13	WP Failure Time and Breached Area for Ti_porous_rock_oxidizing_1.0 cm_Reference case	WP13TestPlan.docx	WP13TestReport_12_08_2010	PASS
WP14	WP Failure Time and Breached Area for Ti_fractured_rock_reducing_1.0 cm_Reference case	WP14TestPlan.docx	WP14TestReport_12_08_2010	PASS

Table 3-1. Test Identification (continued)

Test ID	Title	Test Plan File	Test Report Files	Test Status
Near Field				
NF01	Basecase for Runs with Adjusted Buffer Geometry and Near-Field Transport Properties	NF01TestPlan.docx	NF01TestReport.docx	PASS
NF02	Backfill Effects Case with Backfill Submodel Disabled	NF02TestPlan.docx	NF02TestReport.docx	PASS
NF03	Backfill Effects Case with Length 0.08, Diffusion 1, and Kd 0	NF03TestPlan.docx	NF03TestReport.docx	PASS
Far Field				
FF01	Release Rates at the End of Leg 3—Reference Case	FF01TestPlan.docx	FF01_Test_Report.docx	PASS
FF02	Release Rates at the End of Leg 3, Diffusive Medium in Leg 1	FF02TestPlan.docx	FF02_Test_Report.docx	PASS
FF03	Release Rates at the End of Leg 3, Diffusive Medium in Leg 2	FF03TestPlan.docx	FF03_Test_Report.docx	PASS
FF04	Release Rates at the End of Leg 3, Diffusive Medium in Leg 3	FF04TestPlan.docx	FF04_Test_Report.docx	PASS
Dashboard				
DB01	Dashboard Range Test for Level 1 Parameters Set at Maximum Permissible Values	DB01TestPlan.docx	DB01TestReport.docx	PASS
Disruptive Events				
DE01	Radionuclide Dose for Single Event Reference Case	DE01TestPlan.docx	DB01TestReport.docx	PASS
DE02	Radionuclide Dose for Single Event Disruptive Event	DE02TestPlan.docx	DB02TestReport.docx	PASS
DE03	Radionuclide Dose for Multiple Event Reference Case	DE03TestPlan.docx	DB03TestReport.docx	PASS
DE04	Radionuclide Dose for Multiple Disruptive Events	DE04TestPlan.docx	DB041TestReport.docx	PASS
DE05	Radionuclide Dose for WP Failure Rate Reference Case	DE05TestPlan.docx	DB05TestReport.docx	PASS
DE06	Radionuclide Dose for WP Failure Rate Disruptive Event	DE06TestPlan.docx	DB06TestReport.docx	PASS

SOAR Verification Test Reports

Test ID: WF01
Test Title: Radionuclide Release Rate versus All Zero Degradation Rates
Analyst: Ron Janetzke
Date: December 6, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate depending on waste form degradation rate. The degradation rate for all waste forms is set to zero to check the response from the WF model calculation results.
Assumptions: None
Test Configuration:

Dashboard	Waste package material:	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

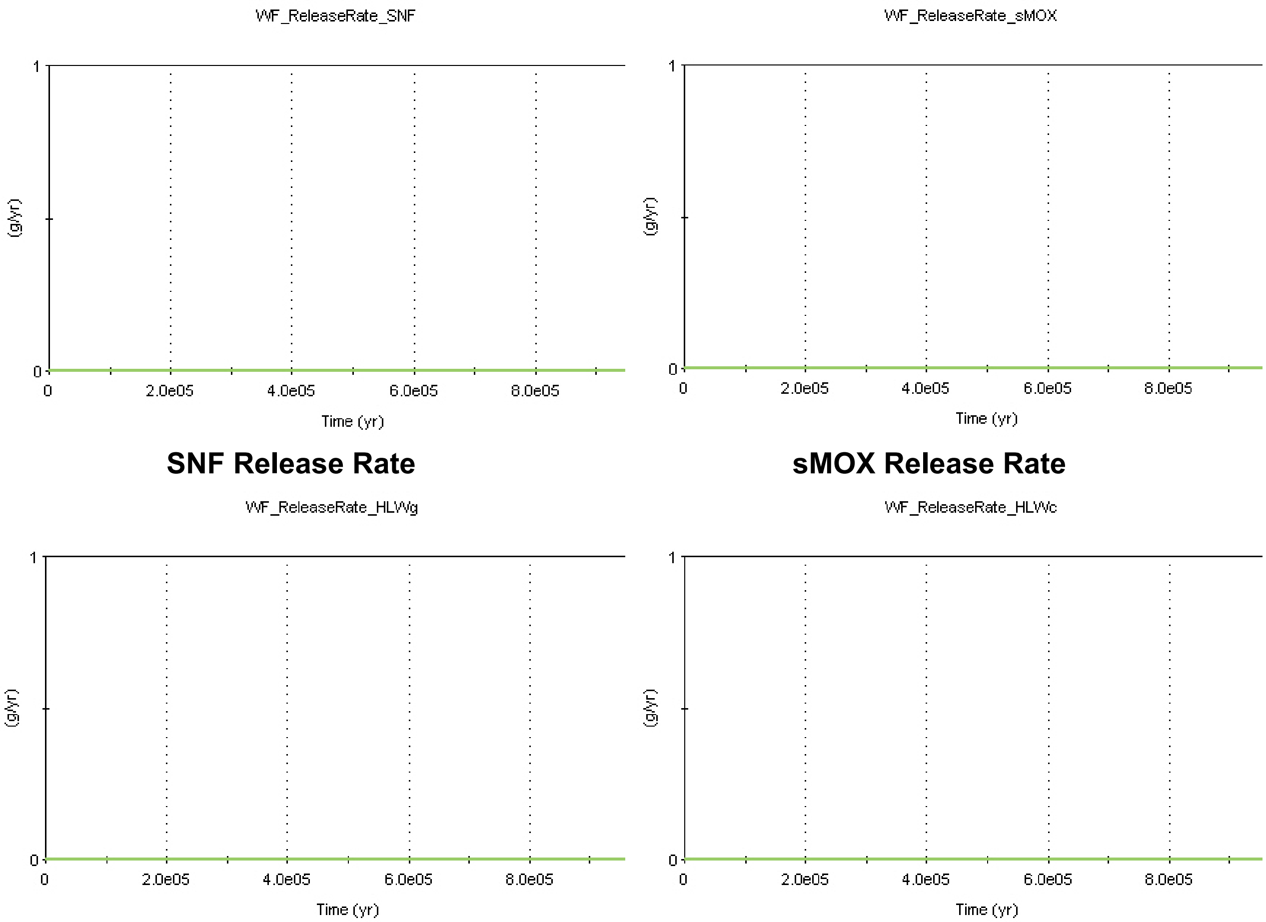
SOAR Verification Test Reports (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

Success Criteria:
(1) All of the waste form release rates should be 0.
(2) The zero degradation rates should be reflected in all of the \Results\Waste_Form_Results* displays.

Results:

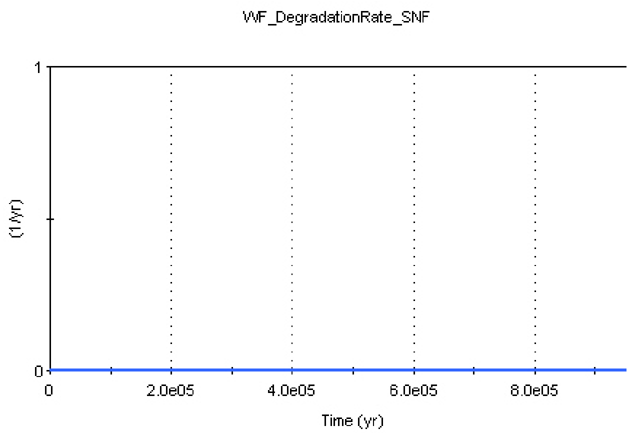
The release rates for all waste forms are 0.



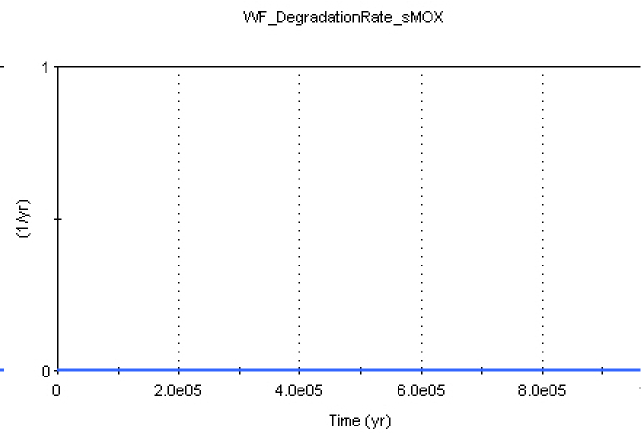
SNF Release Rate **sMOX Release Rate**

HLWg Release Rate **HLWc Release Rate**

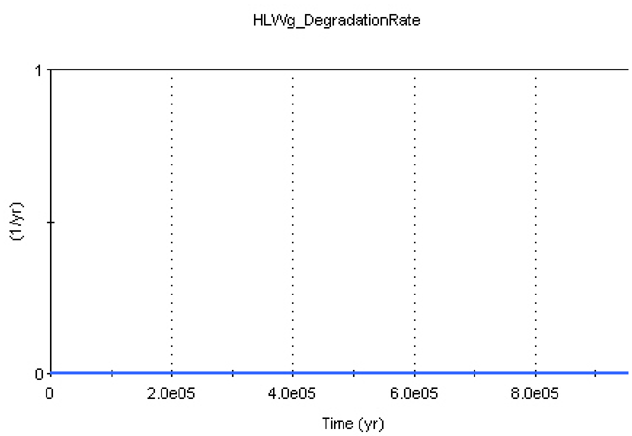
The fuel degradation rates for all fuel types are 0.



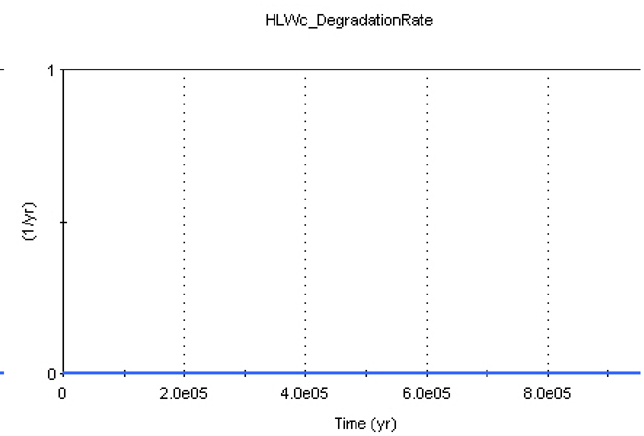
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF02
Test Title: Radionuclide Release Rate versus CSNF_9e-7
Analyst: Ron Janetzke
Date: December 6, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Object: Verify the WF calculation performed by SOAR in terms of radionuclide release rate and cumulative release amount depending on CSNF waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF01.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checker
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	Uniform, 0, (9.0e−7)
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

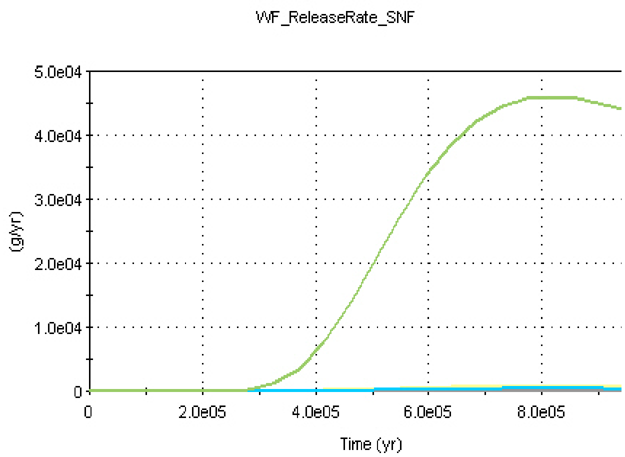
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

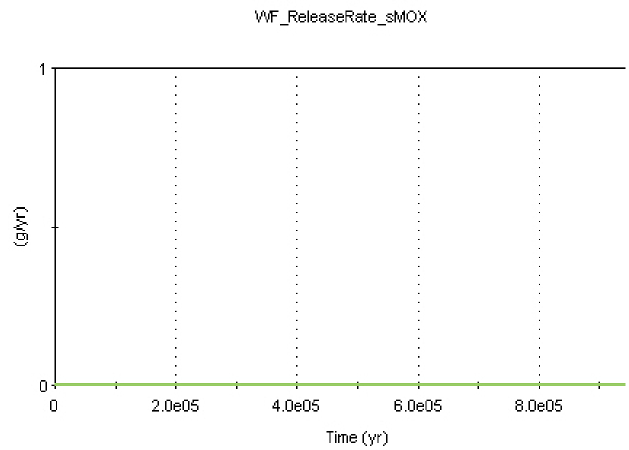
Success Criteria:
(1) The CSNF degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF display.
(2) The CSNF waste form release rates should be higher than the 0 case, and all other waste forms should be equal to the 0 degradation rate case.

Results:

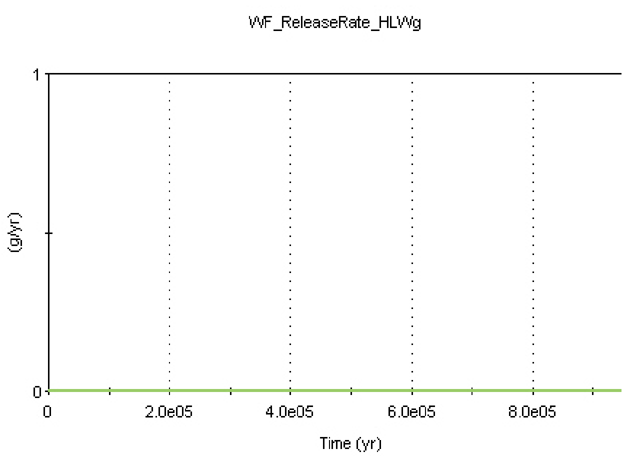
The release rates for all waste forms are 0, except for the SNF, which is greater than the basecase (WF01).



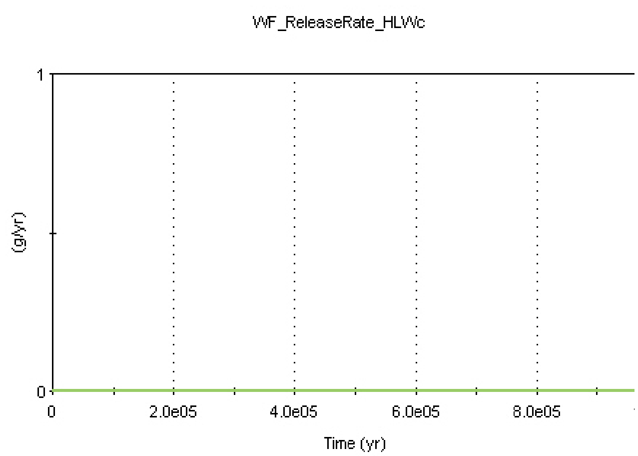
SNF Release Rate



sMOX Release Rate

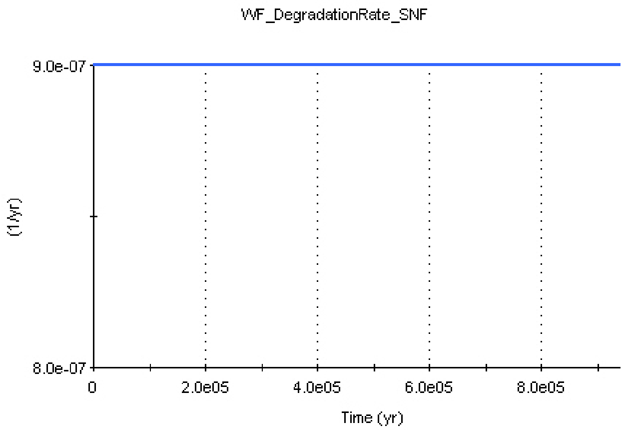


HLWg Release Rate

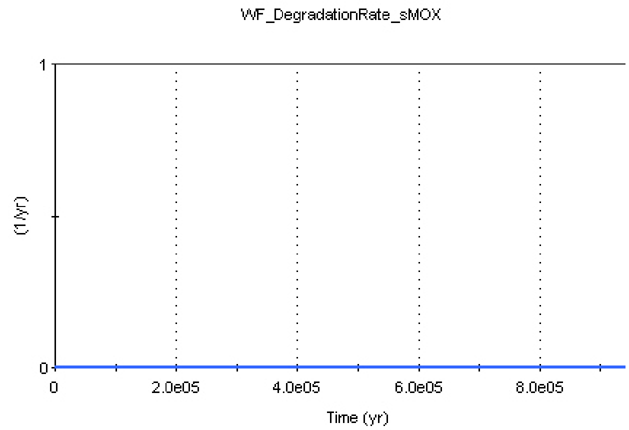


HLWc Release Rate

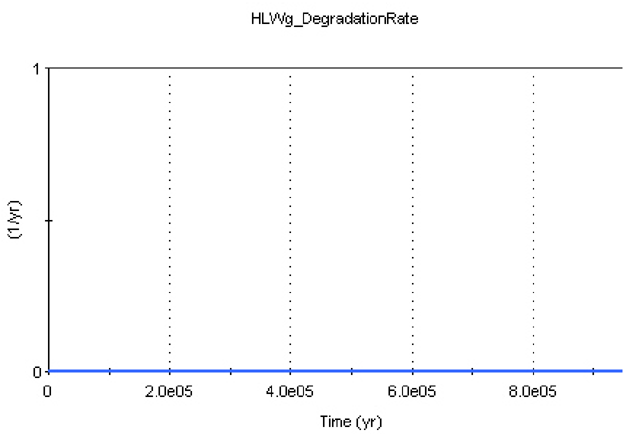
The fuel degradation rates for all fuel types are 0, except for SNF, which equals the mean value of 9.0e−7 1/yr.



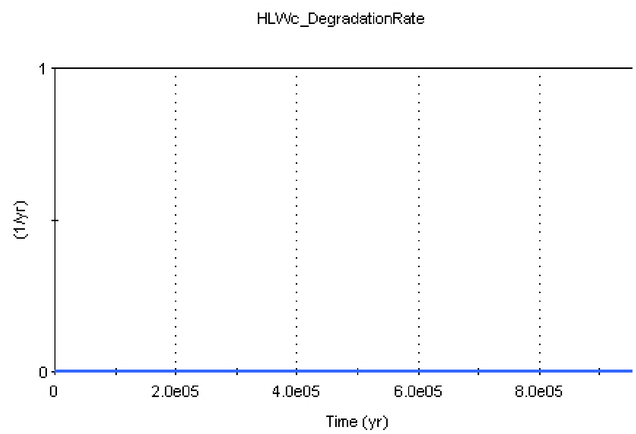
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate

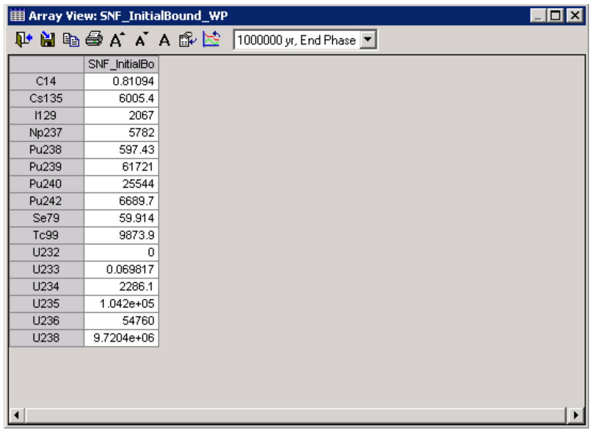


HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

Tests WF01 and WF02 were run using the same inventory. The following table shows the inventory per WP (SOAR parameter name SNF_InitialBound_WP) used to verify the models implemented in SOAR.



	SNF_InitialBo
C14	0.81094
Cs135	6005.4
I129	2067
Np237	5782
Pu238	597.43
Pu239	61721
Pu240	25544
Pu242	6689.7
Se79	59.914
Tc99	9873.9
U232	0
U233	0.069817
U234	2286.1
U235	1.042e+05
U236	54760
U238	9.7204e+06

Inventory Per WP Used in WP01 and WP02

SOAR Verification Test Report

Test ID: WF03
Test Title: Radionuclide Release Rate versus CSNF_9.2e−5 Degradation Rate
Analyst: Ron Janetzke
Date: December 6, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on CSNF waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF02.
Assumptions: None
Test Configuration:

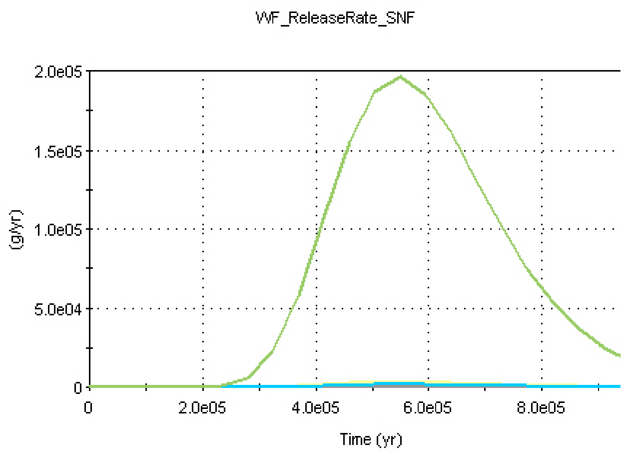
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	9.2e−5
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

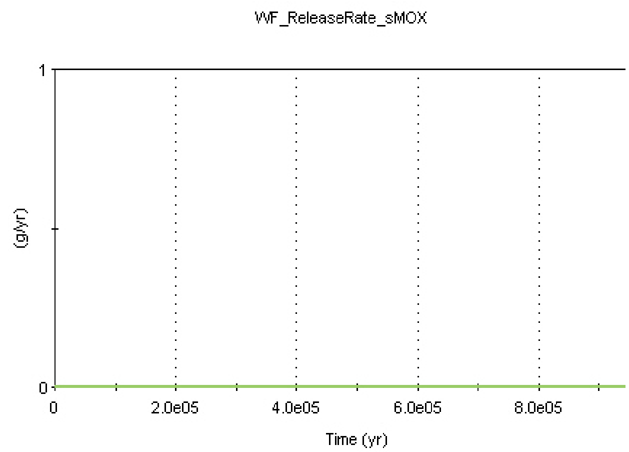
Success Criteria:
(1) The CSNF degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF display.
(2) The CSNF waste form release rates should be higher than test WF02, and all other waste forms should be equal to the 0 degradation rate case.

Results:

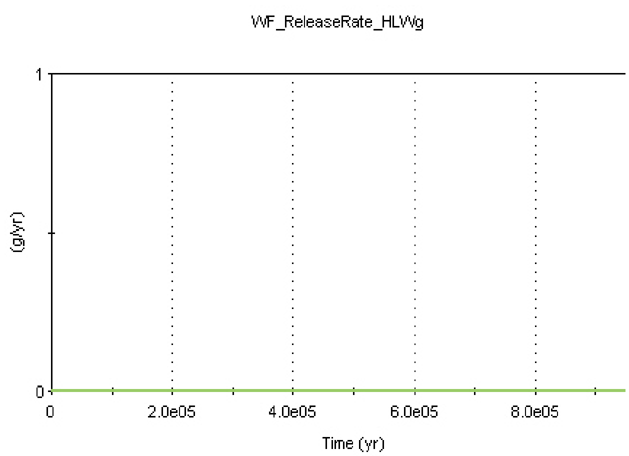
The release rates for all waste forms are 0, except for the SNF, which is greater than the reference case (WF02). The fuel degradation rates for all fuel types are 0, except for SNF, which equals the mean value of 9.2e-5.



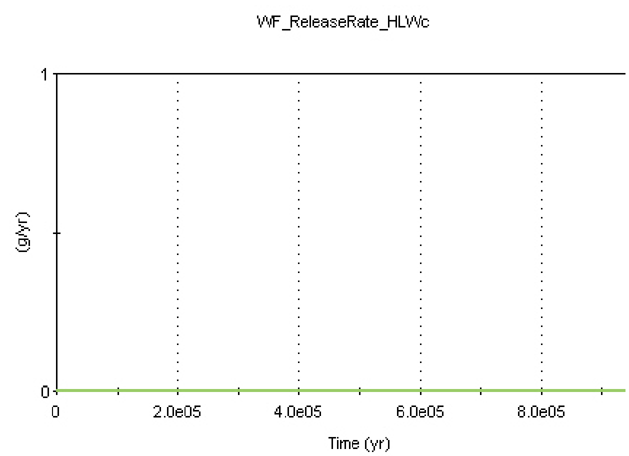
SNF Release Rate



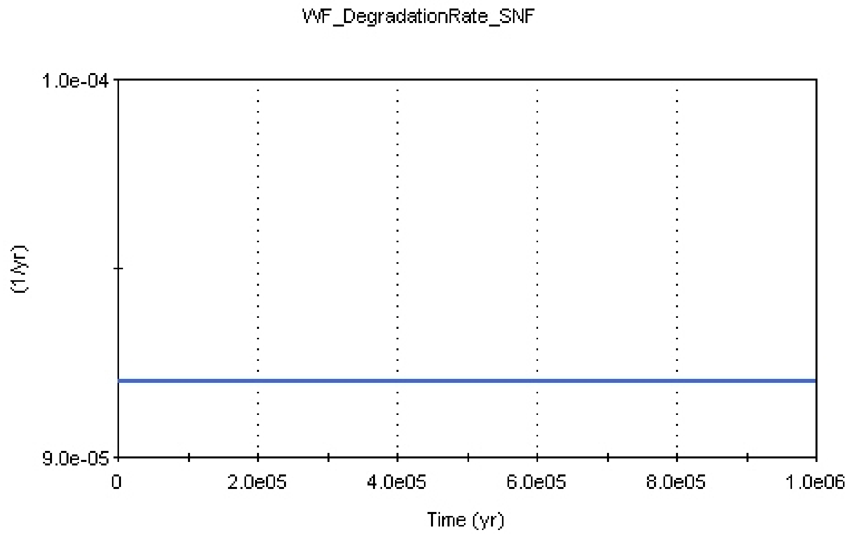
sMOX Release Rate



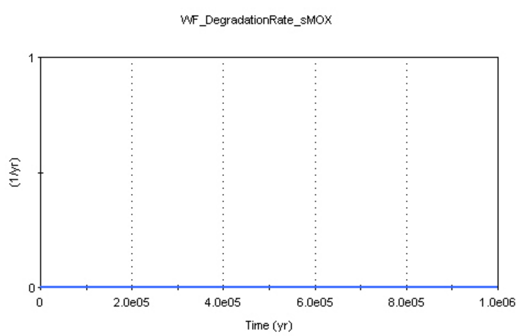
HLWg Release Rate



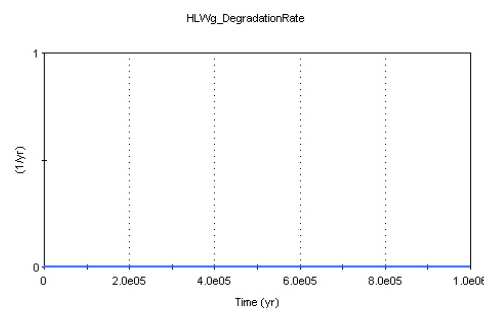
HLWc Release Rate



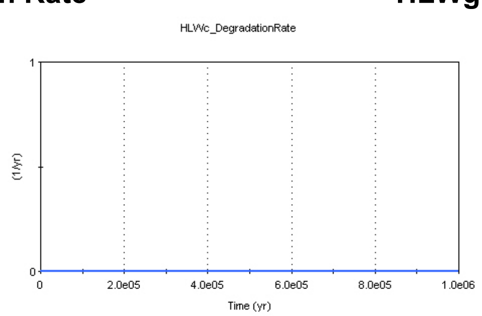
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF04
Test Title: Radionuclide Release Rate versus CSNF_6.e−4 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on CSNF waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF03.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	6.e−4
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

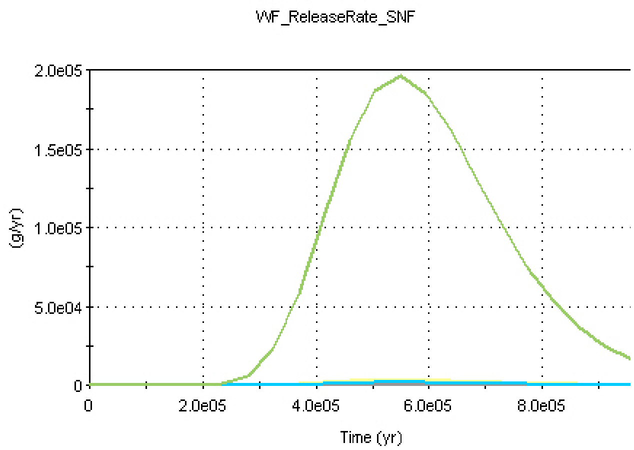
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

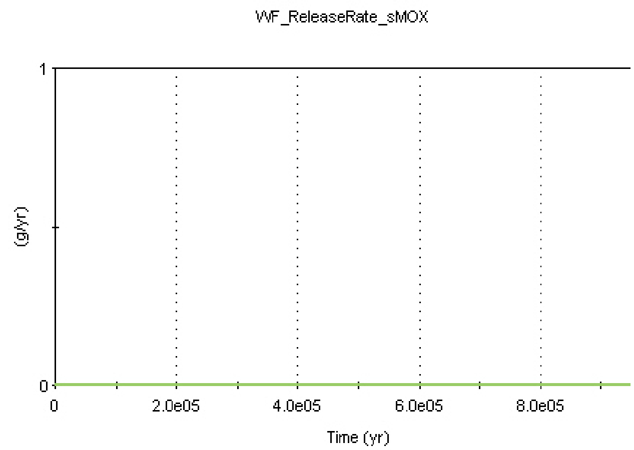
Success Criteria:
(1) The CSNF degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF display.
(2) The CSNF waste form release rates should be higher than test WF02, and all other waste forms should be equal to the 0 degradation rate case.

Results:

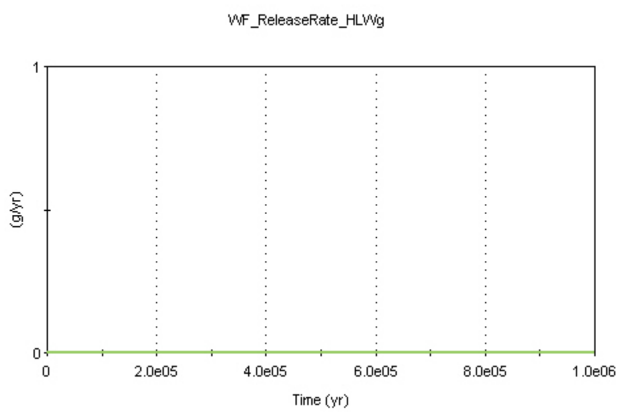
The release rates for all waste forms are 0, except for the SNF, which is greater than the reference case (WF03).



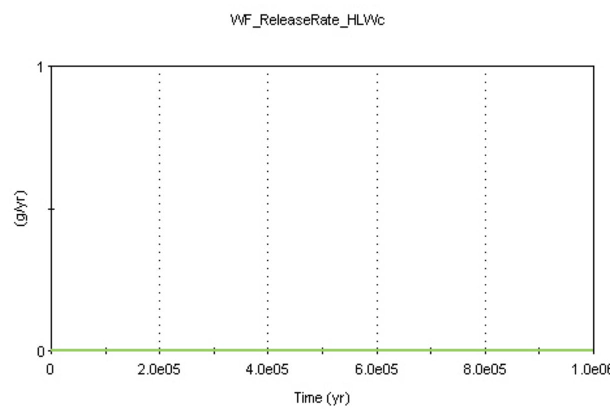
SNF Release Rate



sMOX Release Rate

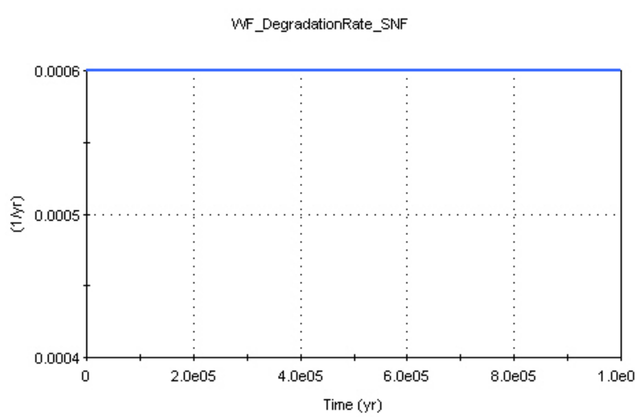


HLWg Release Rate

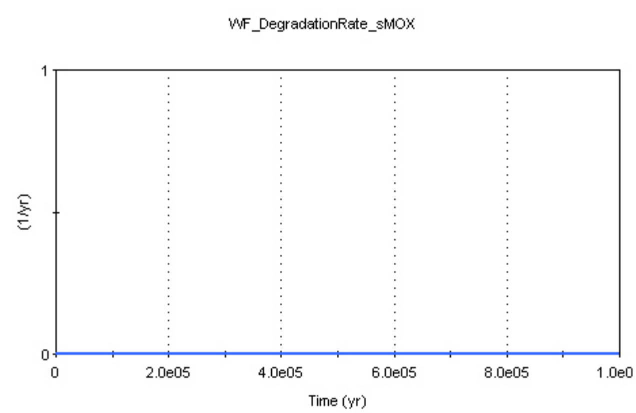


HLWc Release Rate

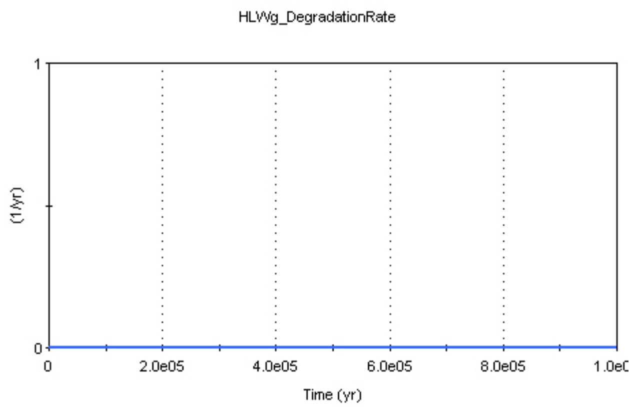
The fuel degradation rates for all fuel types are 0, except for SNF, which equals the mean value of 6.e−4.



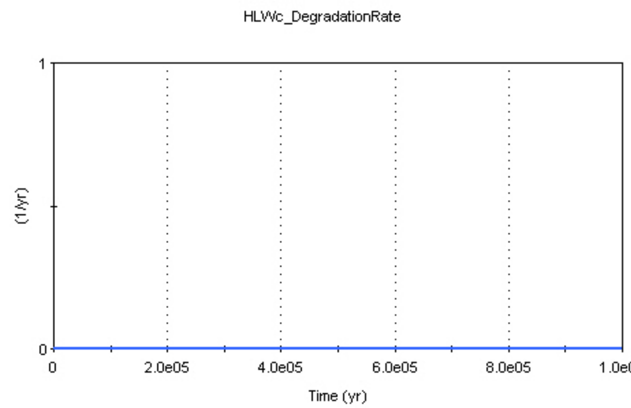
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF05
Test Title: Radionuclide Release Rate versus sMOX_9.e−7 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on sMOX waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF01.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	9.e−7
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

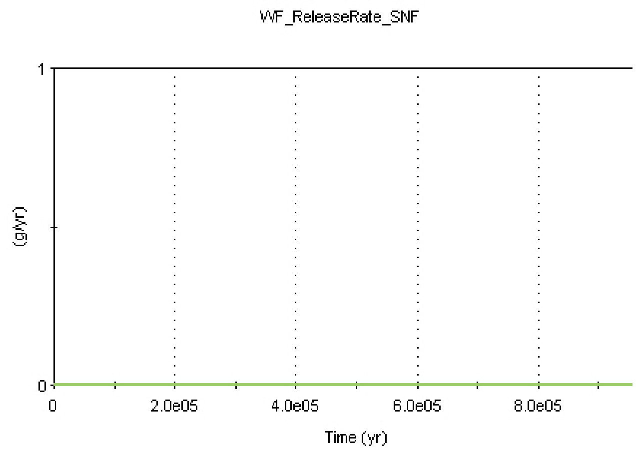
Success Criteria:

(1) The sMOX degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ sMOX _Degradation_Calcs\WF_DegradationRate_ sMOX display.

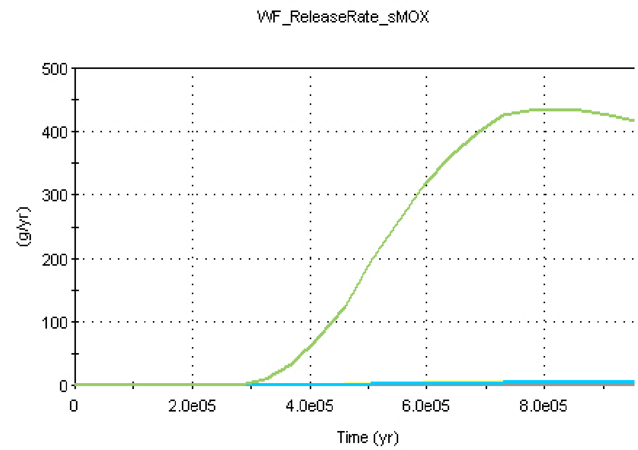
(2) The sMOX waste form release rates should be higher than test WF01, and all other waste forms should be equal to the 0 degradation rate case.

Results:

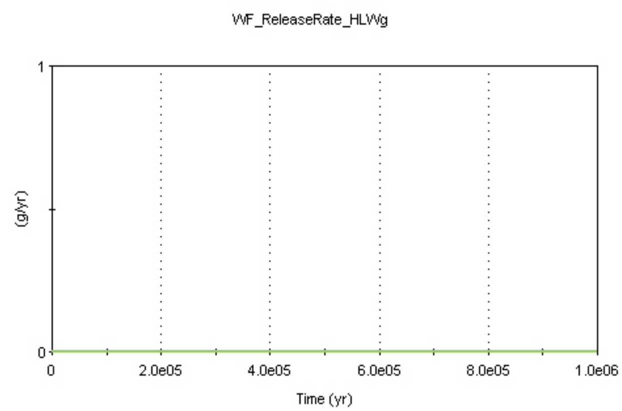
The release rates for all waste forms are 0, except for the sMOX, which is greater than the reference case (WF01).



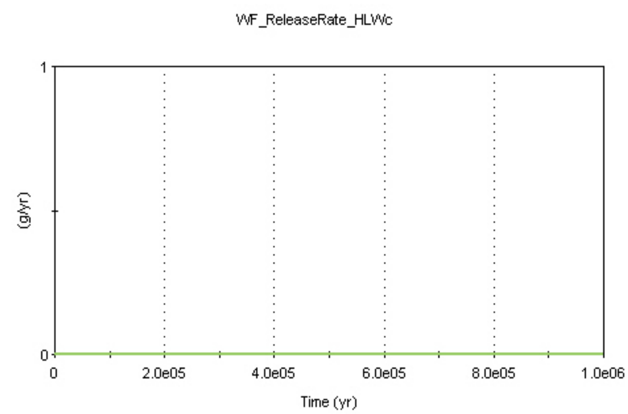
SNF Release Rate



sMOX Release Rate

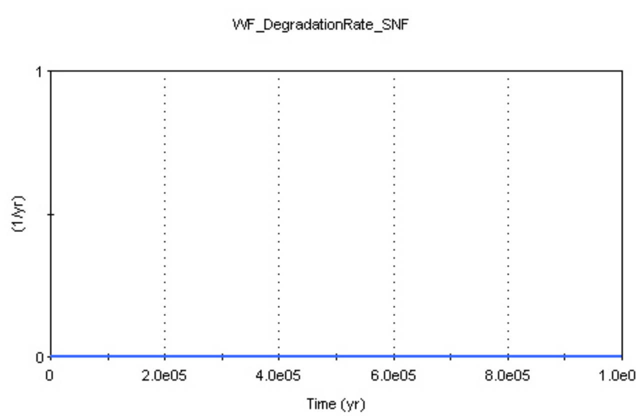


HLWg Release Rate

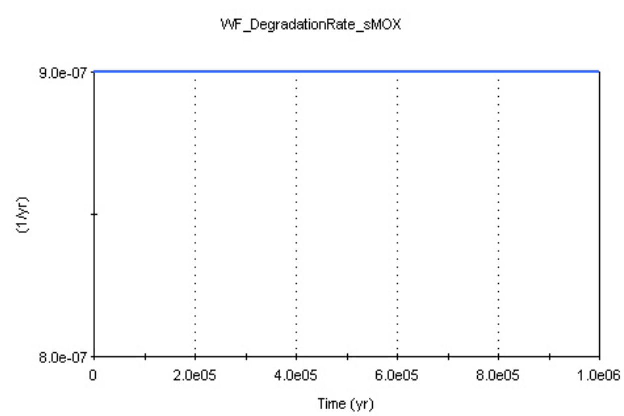


HLWc Release Rate

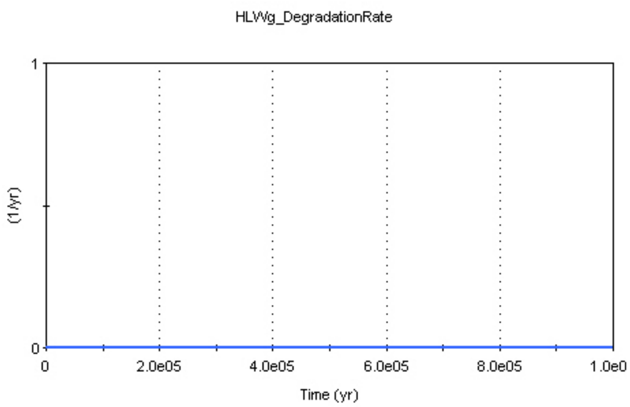
The fuel degradation rates for all fuel types are 0, except for sMOX, which equals the mean value of 9.e−7.



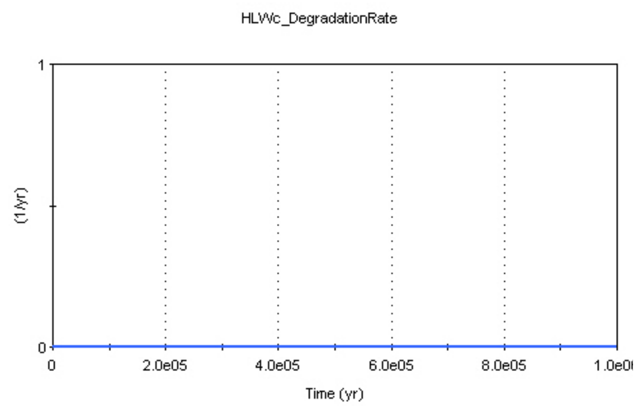
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF06
Test Title: Radionuclide Release Rate versus sMOX_9.2e−5 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on sMOX waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF05.
Assumptions: None
Test Configuration:

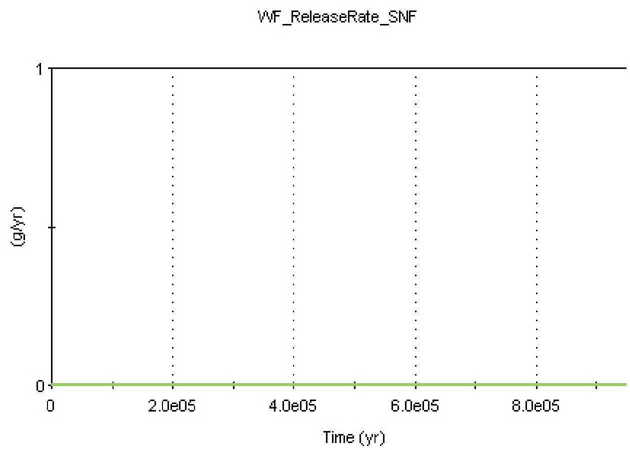
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	9.2e−5
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

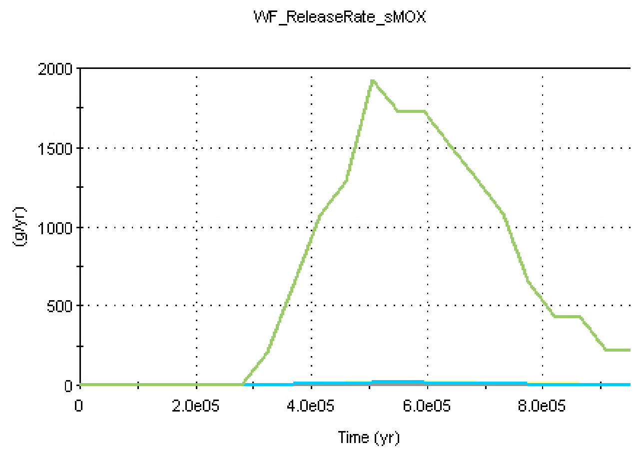
Success Criteria:
(1) The sMOX degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\sMOX_Degradation_Calcs\WF_DegradationRate_ sMOX display.
(2) The sMOX waste form release rates should be higher than test WF05, and all other waste forms should be equal to the 0 degradation rate case.

Results:

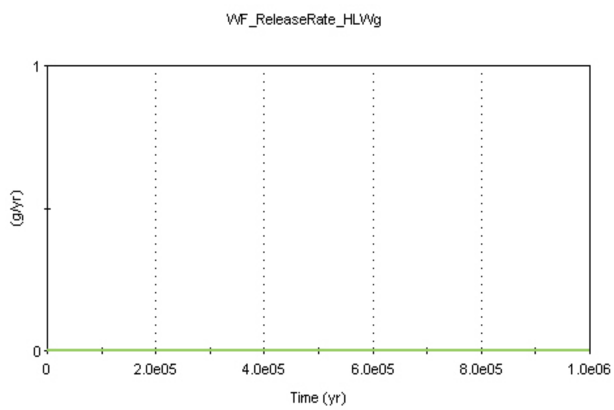
The release rates for all waste forms are 0, except for the sMOX, which is greater than the reference case (WF05).



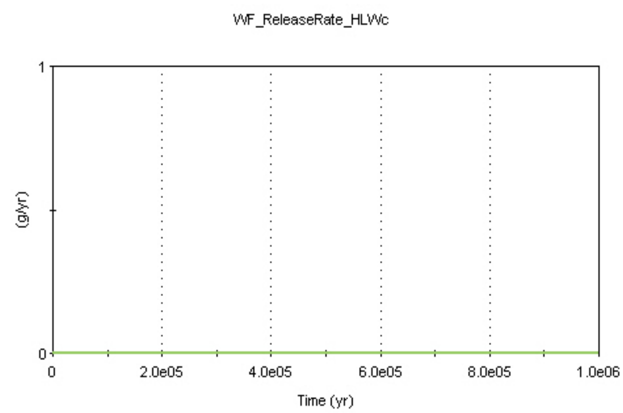
SNF Release Rate



sMOX Release Rate

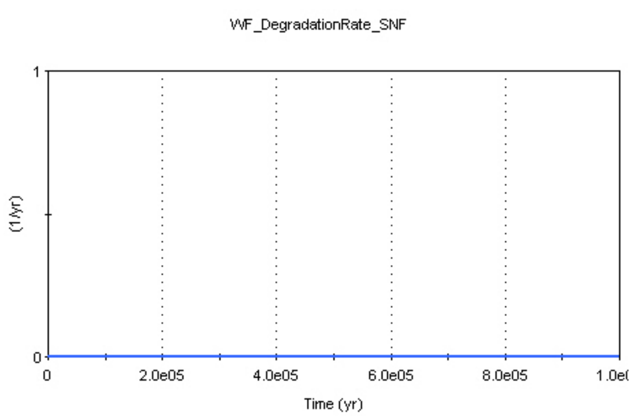


HLWg Release Rate

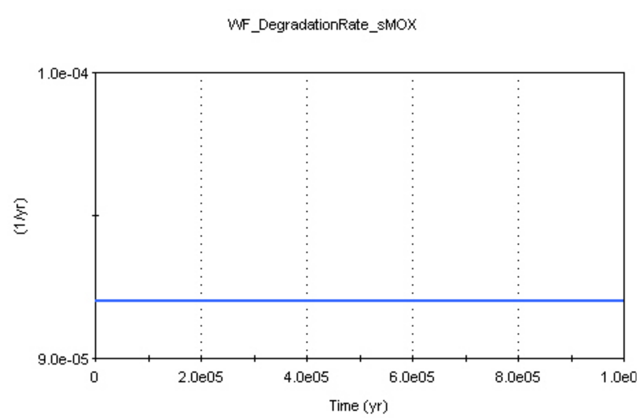


HLWc Release Rate

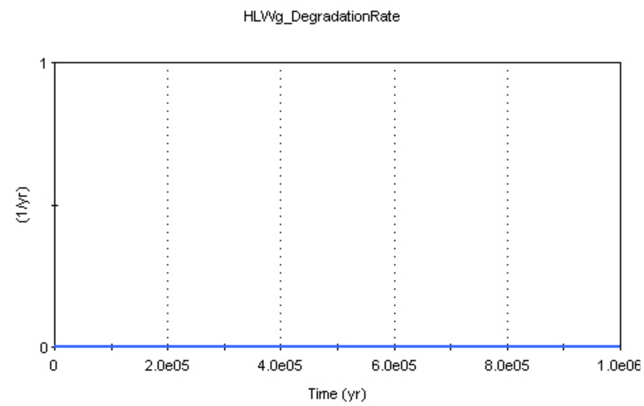
The fuel degradation rates for all fuel types are 0, except for sMOX, which equals the mean value of 9.2e−5.



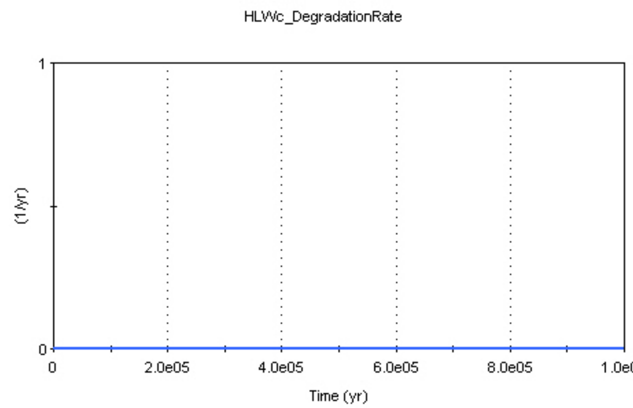
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF07
Test Title: Radionuclide Release Rate versus sMOX_6.e−4 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on sMOX waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF06.
Assumptions: None
Test Configuration:

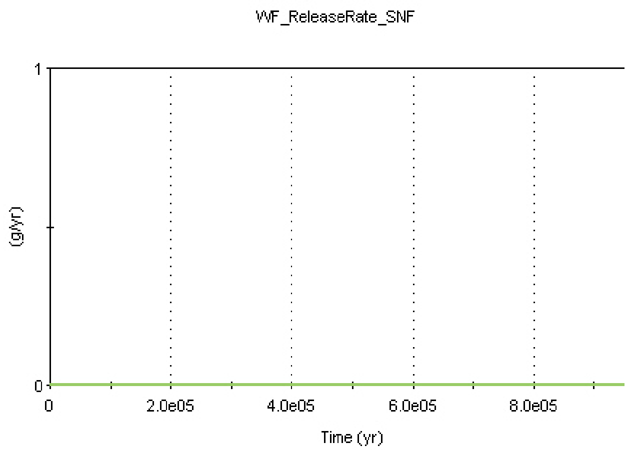
Stimulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	6.e−4
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

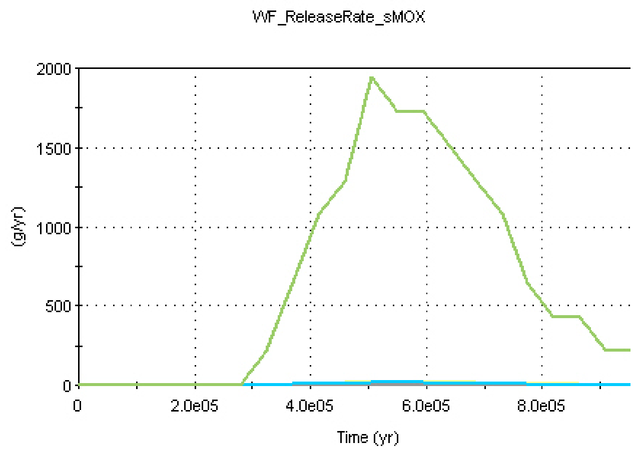
Success Criteria:
(1) The sMOX degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ sMOX _Degradation_Calcs\WF_DegradationRate_ sMOX display.
(2) The sMOX waste form release rates should be higher than test WF06, and all other waste forms should be equal to the 0 degradation rate case.

Results:

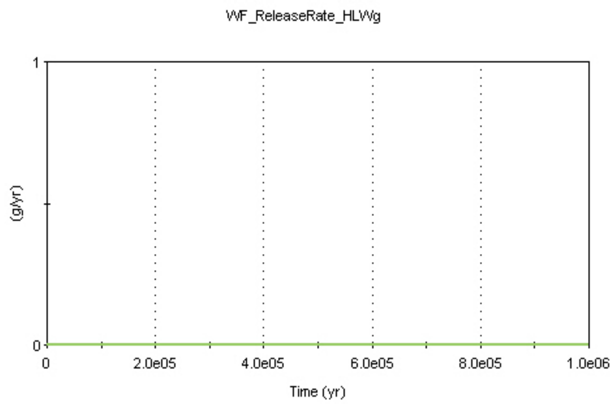
The release rates for all waste forms are 0, except for the sMOX, which is greater than the reference case (WF06).



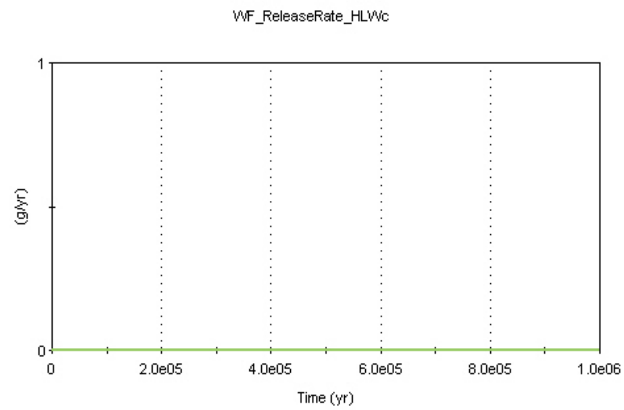
SNF Release Rate



sMOX Release Rate

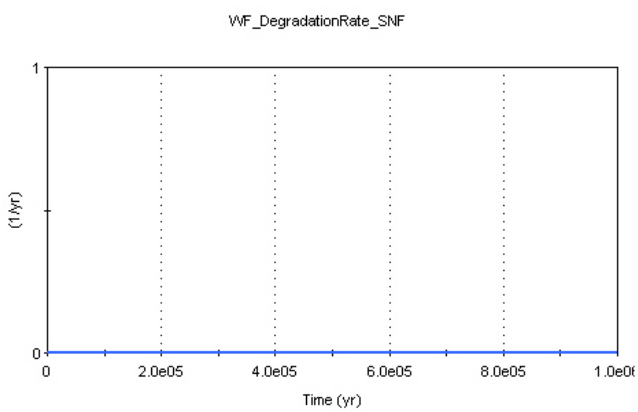


HLWg Release Rate

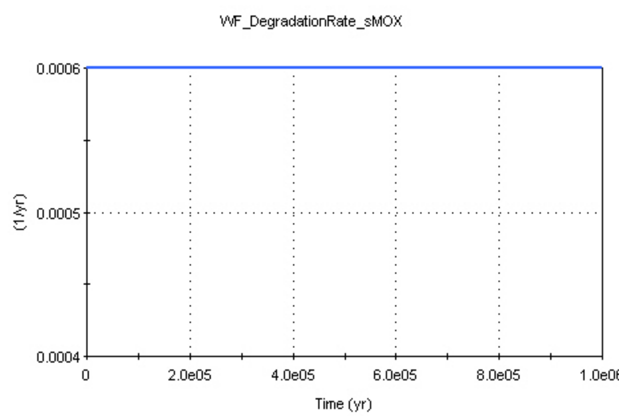


HLWc Release Rate

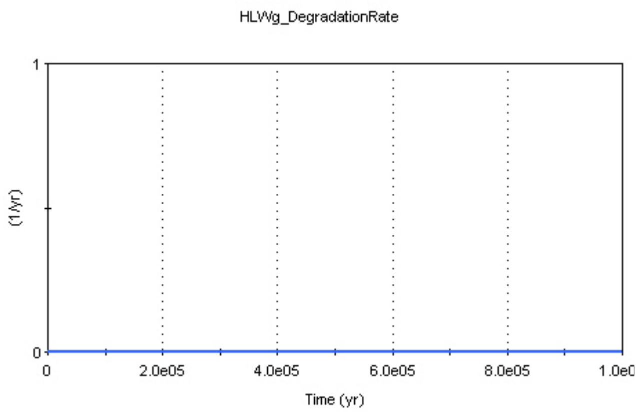
The fuel degradation rates for all fuel types are 0, except for sMOX, which equals the mean value of 6.e−4.



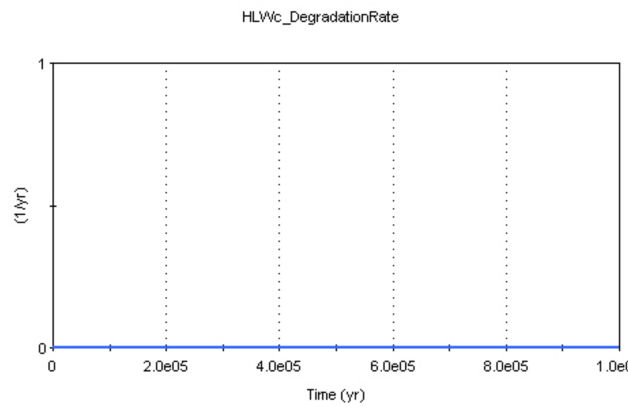
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF08
Test Title: Radionuclide Release Rate versus HLWg_1.5e−6 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWg waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF01.
Assumptions: None
Test Configuration

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Uniform Min = 0 Max = 2 * 1.5e−6
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

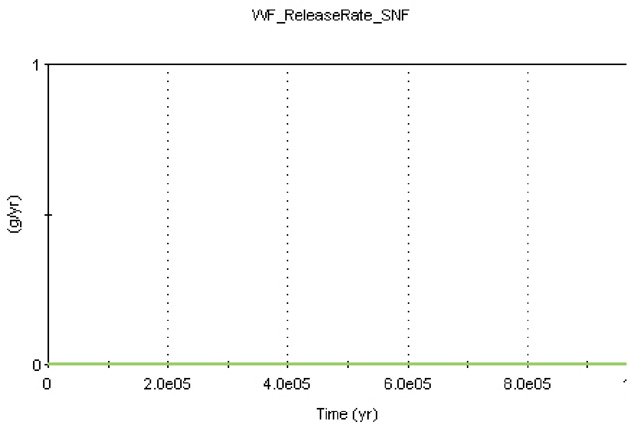
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

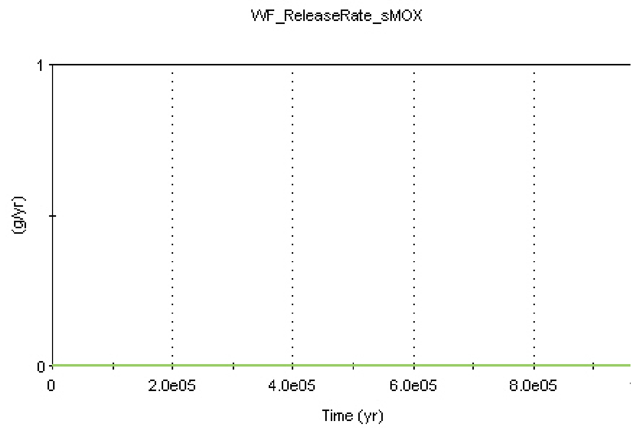
Success Criteria:
(1) The HLWg degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ HLWg _Degradation_Calcs\WF_DegradationRate_HLWg display.
(2) The HLWg waste form release rates should be higher than test WF01, and all other waste forms should be equal to the 0 degradation rate case.

Results:

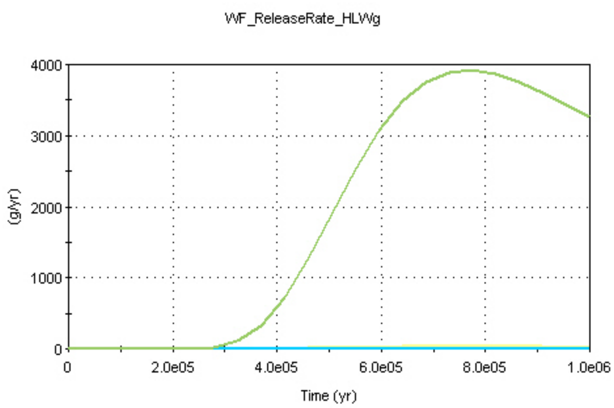
The release rates for all waste forms are 0, except for the HLWg, which is greater than the reference case (WF01).



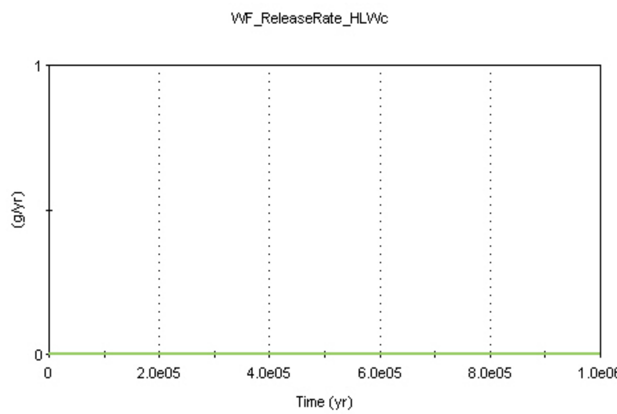
SNF Release Rate



sMOX Release Rate

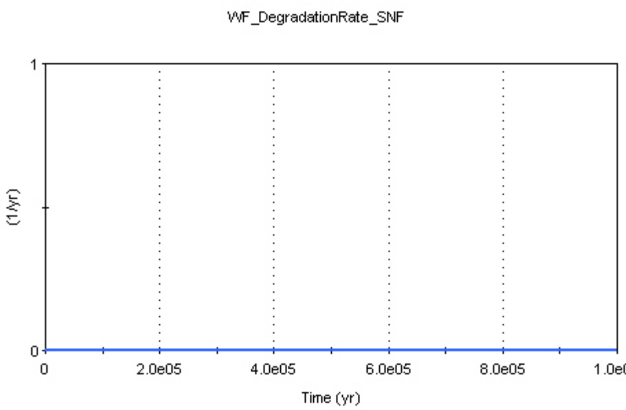


HLWg Release Rate

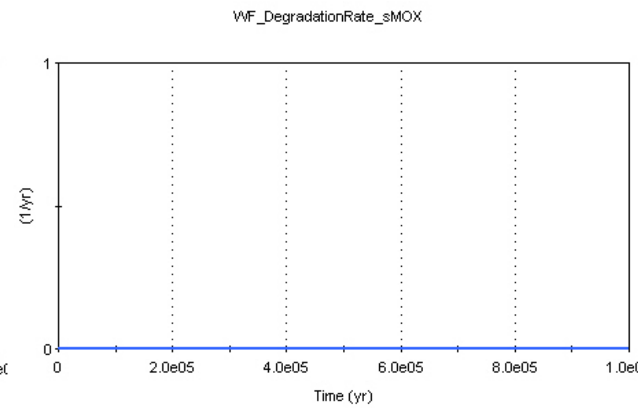


HLWc Release Rate

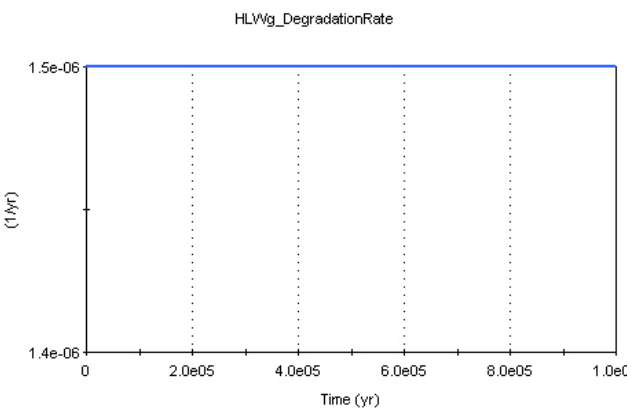
The fuel degradation rates for all fuel types are 0, except for HLWg, which equals the mean value of 1.5e−6.



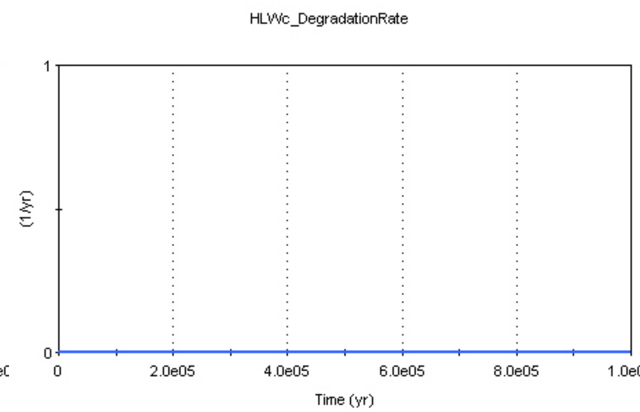
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF09
Test Title: Radionuclide Release Rate versus HLWg_4.e−5 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWg waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF08.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Uniform M = 0 Max = 2 * 4.e−5
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

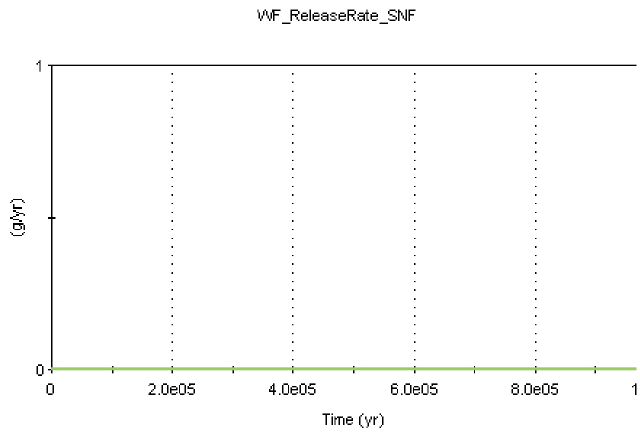
Success Criteria:

(1) The HLWg degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\HLWg _Degradation_Calcs\WF_DegradationRate_HLWg display.

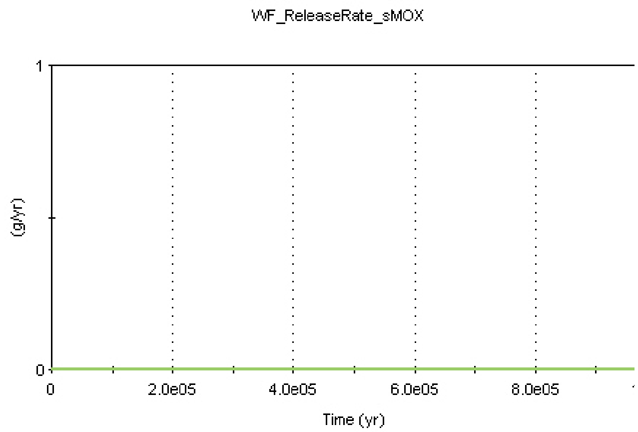
(2) The HLWg waste form release rates should be higher than test WF08, and all other waste forms should be equal to the 0 degradation rate case.

Results:

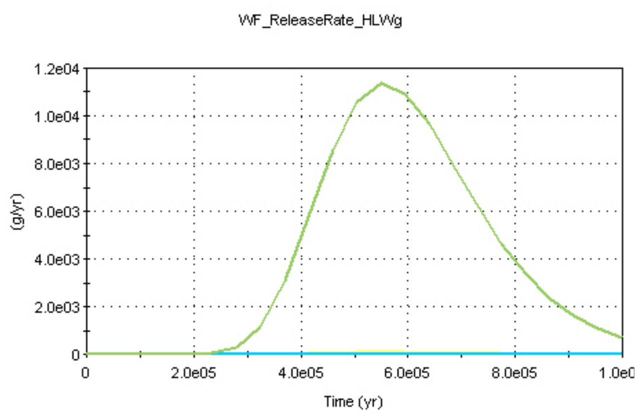
The release rates for all waste forms are 0, except for the HLWg, which is greater than the reference case (WF08).



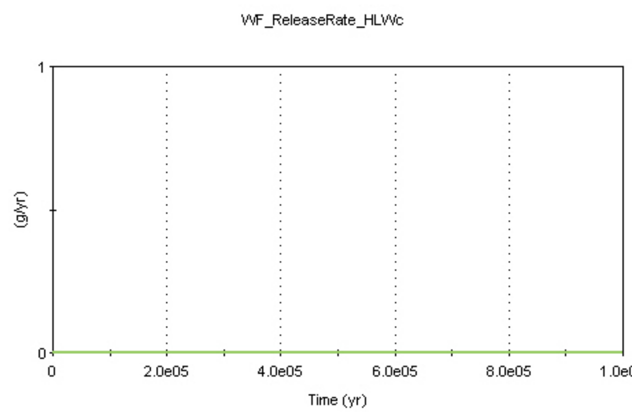
SNF Release Rate



sMOX Release Rate

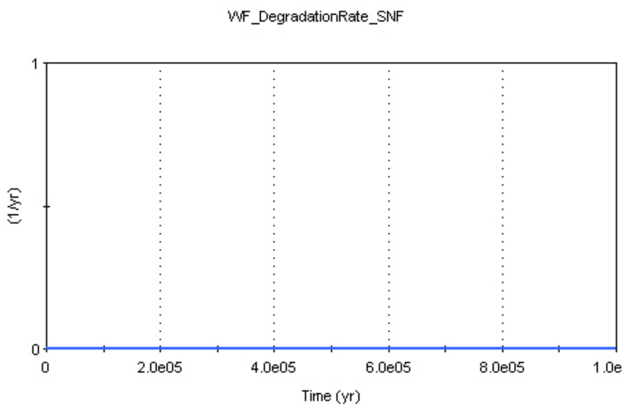


HLWg Release Rate

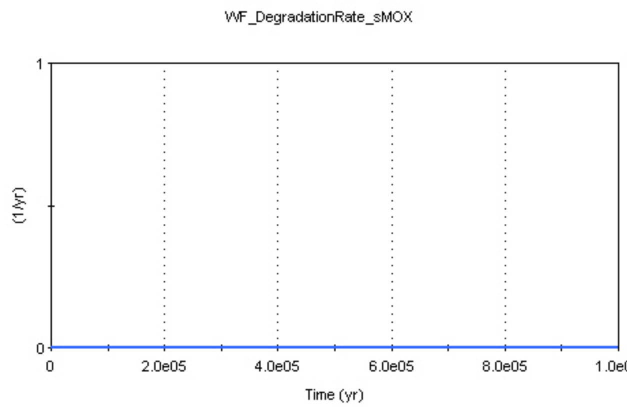


HLWc Release Rate

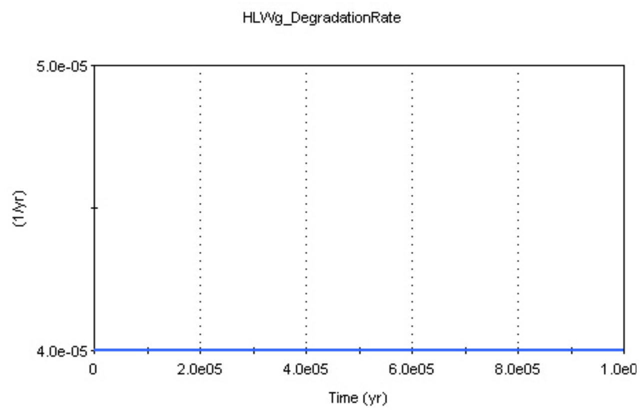
The fuel degradation rates for all fuel types are 0, except for HLWg, which equals the mean value of 4.e−5.



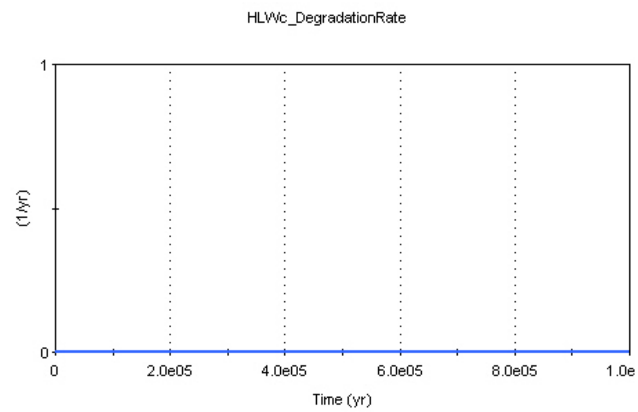
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF10
Test Title: Radionuclide Release Rate versus HLWg_2.e−4 Degradation Rate
Analyst: Ron Janetzke
Date: December 8, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWg waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF09.
Assumptions: None
Test Configuration

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Uniform M = 0 Max = 2 * 2.e−4
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Discrete, 1, 0

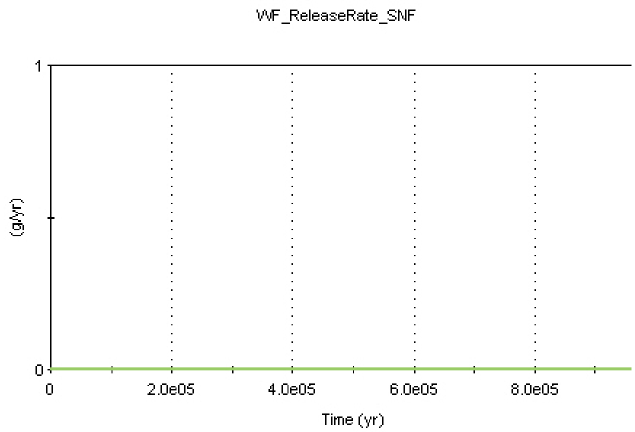
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

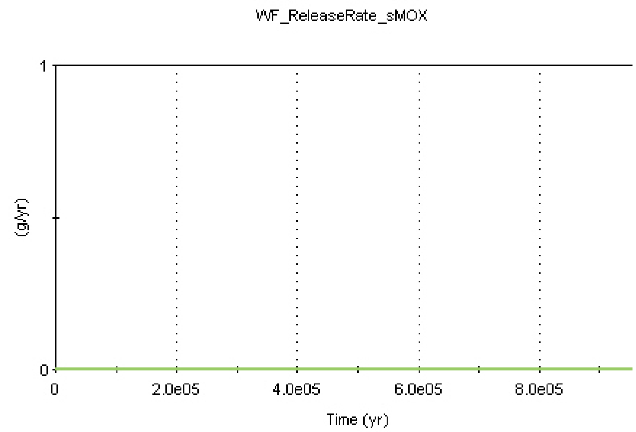
Success Criteria:
(1) The HLWg degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ HLWg_Degradation_Calcs\WF_DegradationRate_HLWg display.
(2) The HLWg waste form release rates should be higher than test WF09, and all other waste forms should be equal to the 0 degradation rate case.

Results:

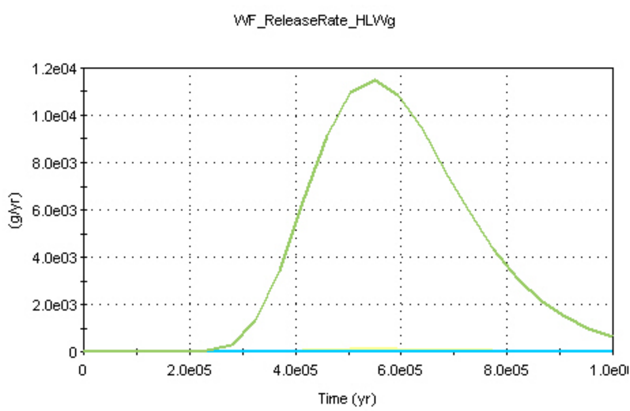
The release rates for all waste forms are 0, except for the HLWg, which is greater than the reference case (WF09).



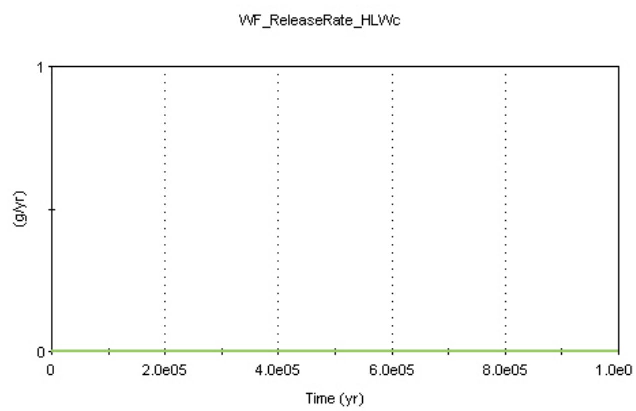
SNF Release Rate



sMOX Release Rate

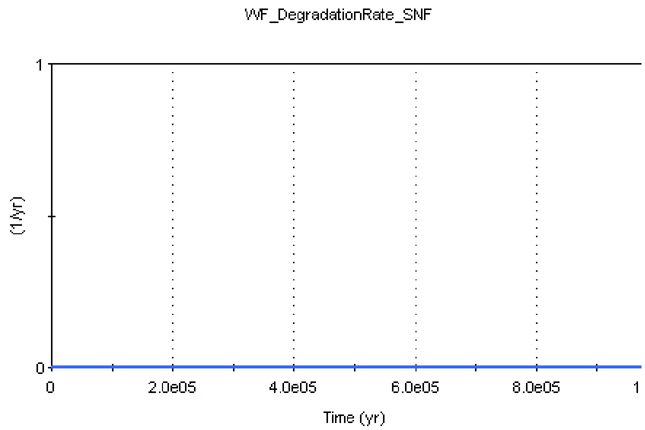


HLWg Release Rate

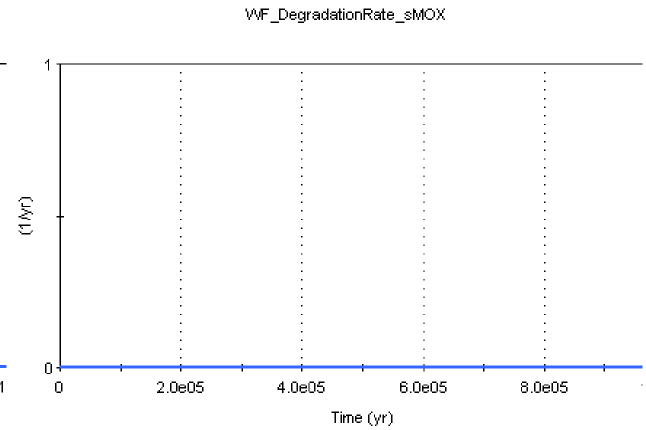


HLWc Release Rate

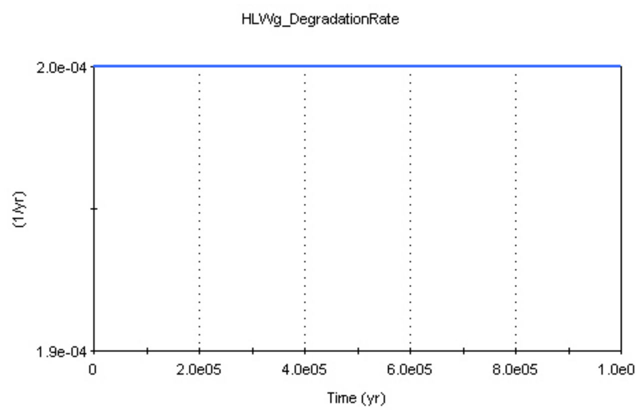
The fuel degradation rates for all fuel types are 0, except for HLWg, which equals the mean value of 2.e−4.



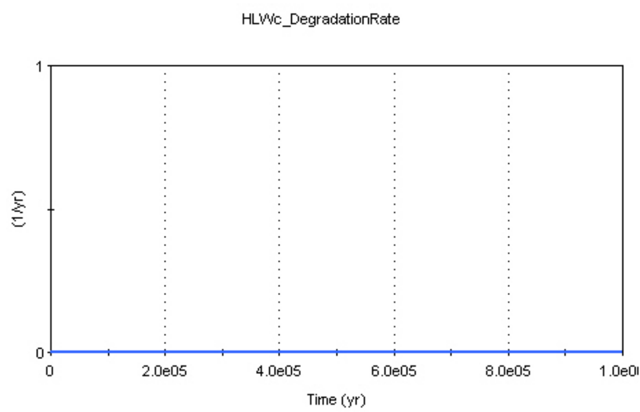
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID:	WF11
Test Title:	Radionuclide Release Rate versus HLWc_1.5e−8 Degradation Rate
Analyst:	Ron Janetzke
Date:	December 8, 2010
Test Environment:	ALBY, GoldSim 10.11
SOAR Version:	Beta 6.4
Run Directory:	D:\RonJ-\SOAR\V6_4
Test Objective:	Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWc waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF01.
Assumptions:	None

Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Uniform Min = 0 Max = 2 * 1.5e−8

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

Success Criteria:

(1) The HLWc degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ HLWc _Degradation_Calcs\WF_DegradationRate_ HLWc display.

(2) The HLWc waste form release rates should be higher than test WF01, and all other waste forms should be equal to the 0 degradation rate case.

Edit Vector: HLWc_Inventory_2010.Definition

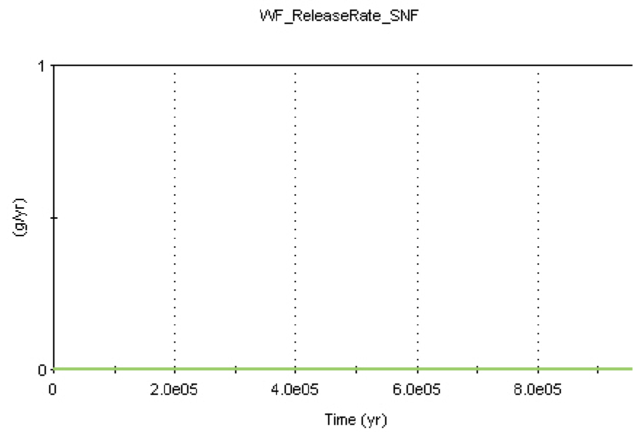
	Value
C14	0 tonne
Cs135	2.19e0 tonne
I129	1.25e0 tonne
Np237	2.39e0 tonne
Pu238	6.74e-1 tonne
Pu239	9.63e0 tonne
Pu240	7.96e-1 tonne
Pu242	6.71e-2 tonne
Se79	1.21e-1 tonne
Tc99	1.75e1 tonne
U232	7.04e-6 tonne
U233	3.35e-1 tonne
U234	4.02e-1 tonne
U235	2.43e1 tonne
U236	1.03e0 tonne
U238	4.08e3 tonne

OK

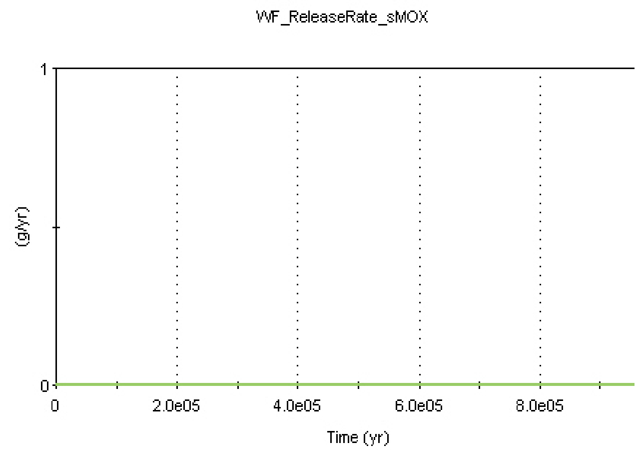
HLWc_Inventory_2010

Results:

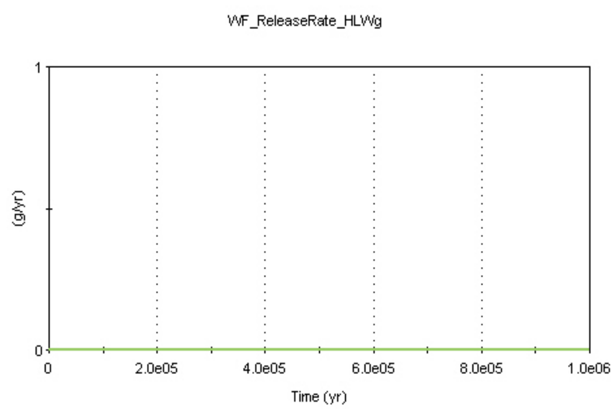
The release rates for all waste forms are 0, except for the HLWc, which is greater than the reference case (WF01).



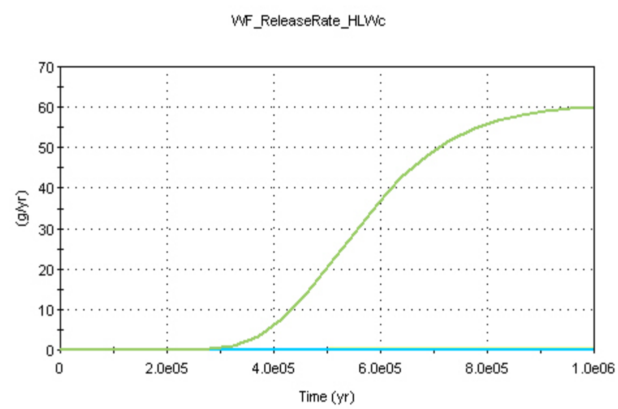
SNF Release Rate



sMOX Release Rate

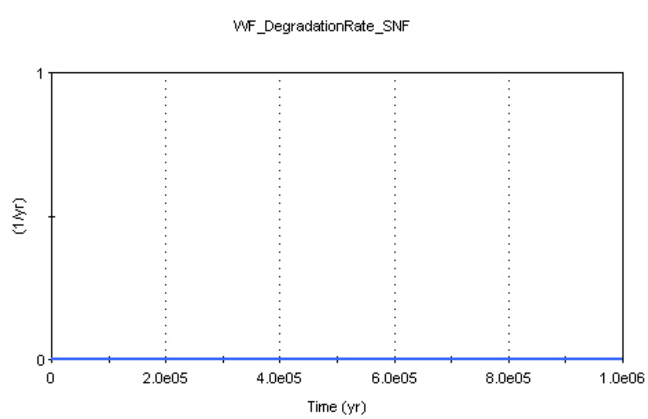


HLWg Release Rate

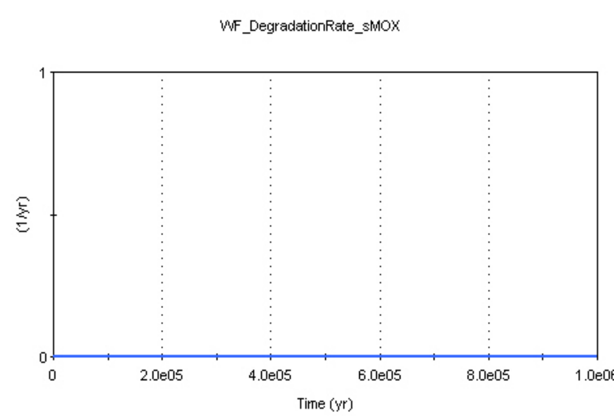


HLWc Release Rate

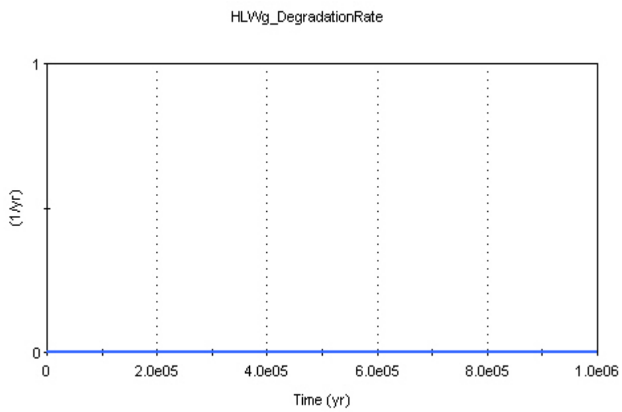
The fuel degradation rates for all fuel types are 0, except for HLWc, which equals the mean value of 1.5e−8.



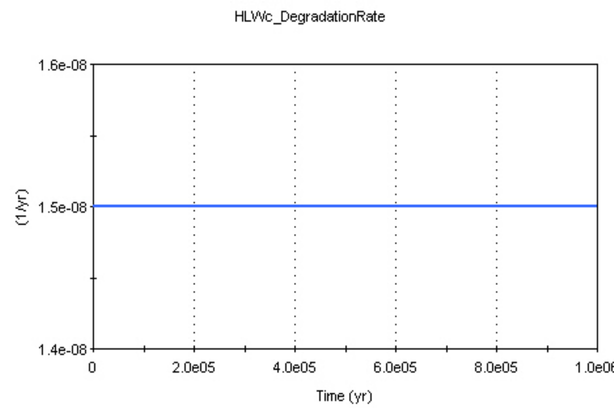
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF12
Test Title: Radionuclide Release Rate versus HLWc_4.e−7 Degradation Rate
Analyst: Ron Janetzke
Date: December 9, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWc waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF11.
Assumptions: None
Test Configuration:

Stimulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Uniform Min = 0 Max = 2 * 4.e−7

SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

Success Criteria:
(1) The HLWc degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\HLWc _Degradation_Calcs\WF_DegradationRate_HLWc display.
(2) The HLWc waste form release rates should be higher than test WF11, and all other waste forms should be equal to the 0 degradation rate case.

Edit Vector: HLWc_Inventory_2010.Definition

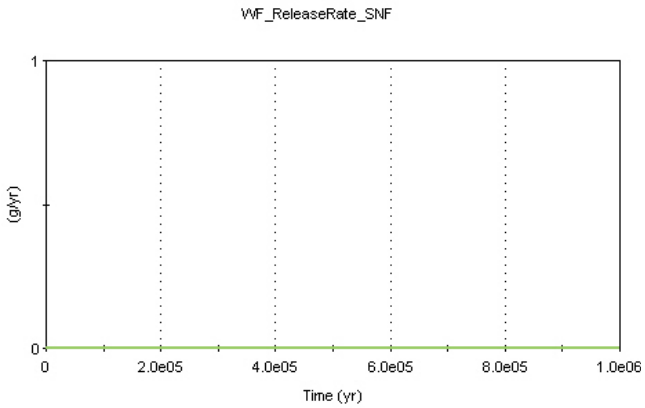
	Value
C14	0 tonne
Cs135	2.19e0 tonne
I129	1.25e0 tonne
Np237	2.39e0 tonne
Pu238	6.74e-1 tonne
Pu239	9.63e0 tonne
Pu240	7.96e-1 tonne
Pu242	6.71e-2 tonne
Se79	1.21e-1 tonne
Tc99	1.75e1 tonne
U232	7.04e-6 tonne
U233	3.35e-1 tonne
U234	4.02e-1 tonne
U235	2.43e1 tonne
U236	1.03e0 tonne
U238	4.08e3 tonne

OK

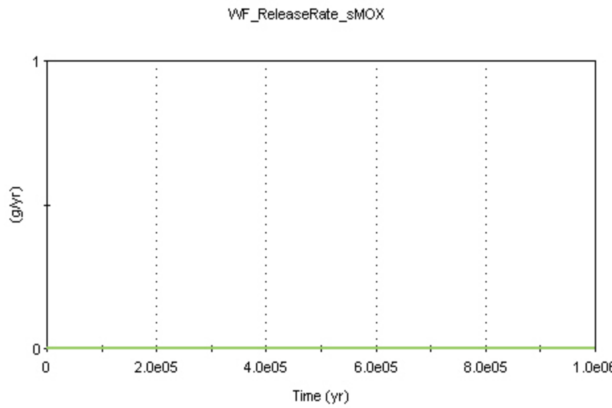
HLWc_Inventory_2010

Results:

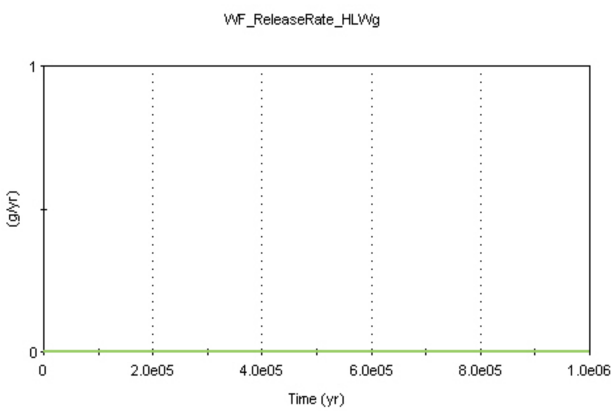
The release rates for all waste forms are 0, except for the HLWc, which is greater than the reference case (WF01).



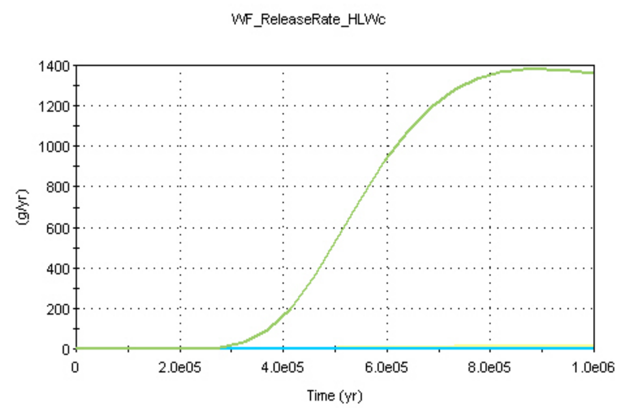
SNF Release Rate



sMOX Release Rate

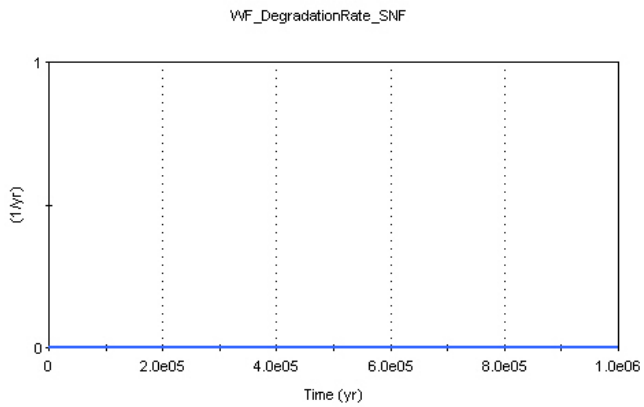


HLWg Release Rate

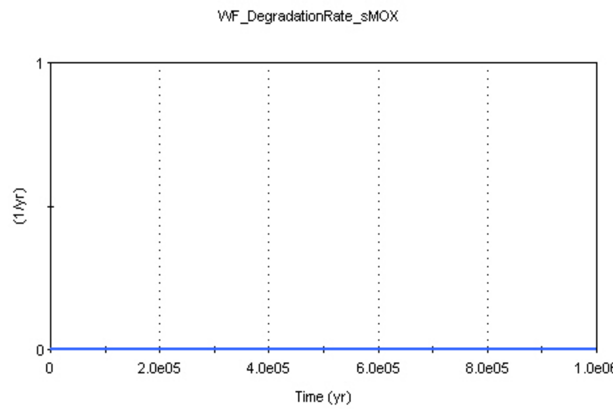


HLWc Release Rate

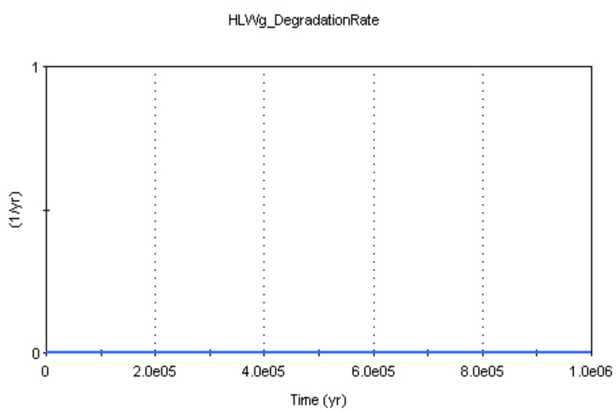
The fuel degradation rates for all fuel types are 0, except for HLWc, which equals the mean value of 1.5e−8.



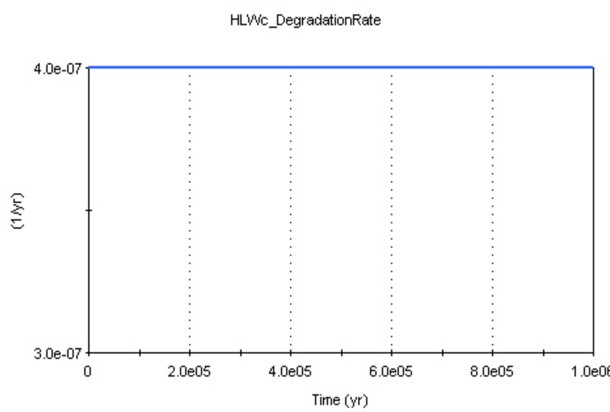
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF13
Test Title: Radionuclide Release Rate versus HLWc_2.e−6 Degradation Rate
Analyst: Ron Janetzke
Date: December 9, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: D:\RonJ-\SOAR\V6_4
Test Objective: Verify the WF calculation performed by SOAR in terms of radionuclide release rate amount depending on HLWc waste form degradation rate. The degradation rate for all other waste forms will be set to zero, and the results from the WF model calculation will be compared to the results of test WF12.
Assumptions: None
Test Configuration

Stimulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Waste package material	Copper
	Define waste package thickness	Checked
	Waste package thickness	0.5 cm
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg Two, Geologic Media	Fractured Rock
	Far Field Leg Three, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Far Field Leg Two, Redox Condition	Reducing
	Far Field Leg Three, Redox Condition	Reducing
	Spent Nuclear Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
	Spent Mixed-Oxide Fuel, Enable Combined Oxic/Anoxic Degradation Rate	Checked
Level 2	Spent_Nuclear_Fuel\SNF_Degradation_Calcs\SNF_DegRates\DegRate_SNF_Combined	0
	Spent_Mixed_Oxide_Fuel\sMOX_Degradation_Calcs\sMOX_DegRates\DegRate_sMOX_Combined	0
	High_Level_Waste_Glass\HLWg_Degradation_Calcs\HLWg_DegRates\DegRate_HLW_Glass	Data Source: None Discrete, 1, 0
	High_Level_Waste_Ceramic\HLWc_Degradation_Calcs\HLWc_DegRates\DegRate_HLW_Ceramic	Uniform Min = 0 Max = 2 * 2.e−6

Result Parameters: Time histories of the following parameters are used in the analysis:
\Waste_Form_Component\Spent_Nuclear_Fuel\SNF_Degradation_Calcs\WF_DegradationRate_SNF
\Waste_Form_Component\ Spent_Mixed_Oxide_Fuel \sMOX_Degradation_Calcs\WF_DegradationRate_sMOX
\Waste_Form_Component\ High_Level_Waste_Glass \HLWg_Degradation_Calcs\WF_DegradationRate_HLWg
\Waste_Form_Component\ High_Level_Waste_Ceramic \HLWc_Degradation_Calcs\WF_DegradationRate_HLWc
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ ReleaseRate_HLWc_Result

Success Criteria:

(1) The HLWc degradation rate should be reflected in the \Waste_Form_Component\Spent_Nuclear_Fuel\ HLWc _Degradation_Calcs\WF_DegradationRate_ HLWc display.

(2) The HLWc waste form release rates should be higher than test WF12, and all other waste forms should be equal to the 0 degradation rate case.

Edit Vector: HLWc_Inventory_2010.Definition

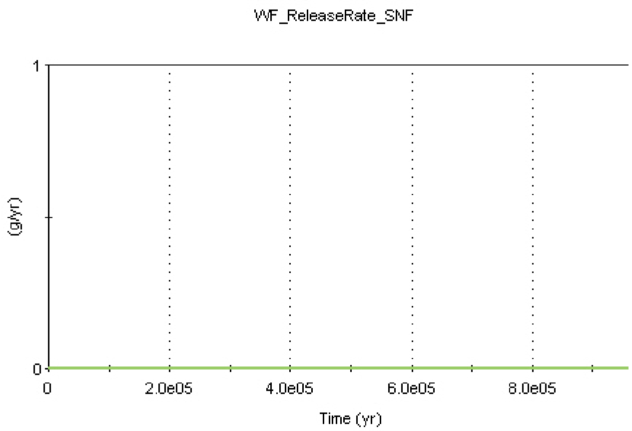
	Value
C14	0 tonne
Cs135	2.19e0 tonne
I129	1.25e0 tonne
Np237	2.39e0 tonne
Pu238	6.74e-1 tonne
Pu239	9.63e0 tonne
Pu240	7.96e-1 tonne
Pu242	6.71e-2 tonne
Se79	1.21e-1 tonne
Tc99	1.75e1 tonne
U232	7.04e-6 tonne
U233	3.35e-1 tonne
U234	4.02e-1 tonne
U235	2.43e1 tonne
U236	1.03e0 tonne
U238	4.08e3 tonne

OK

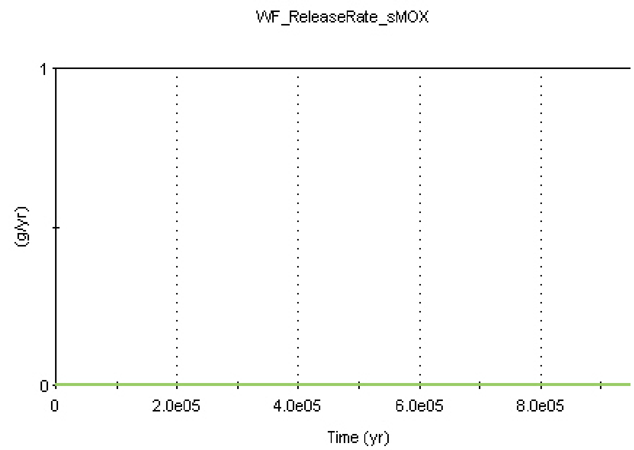
HLWc_Inventory_2010

Results:

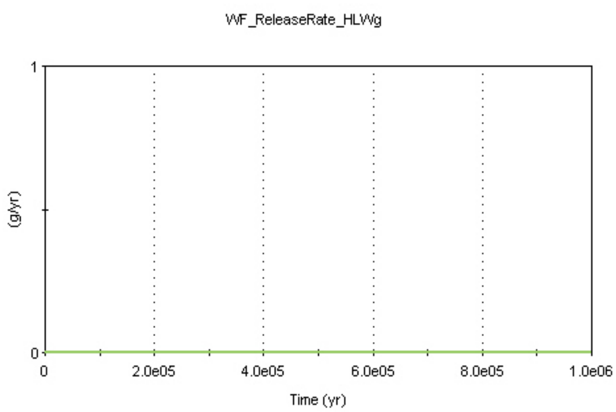
The release rates for all waste forms are 0, except for the HLWc, which is greater than the reference case (WF01).



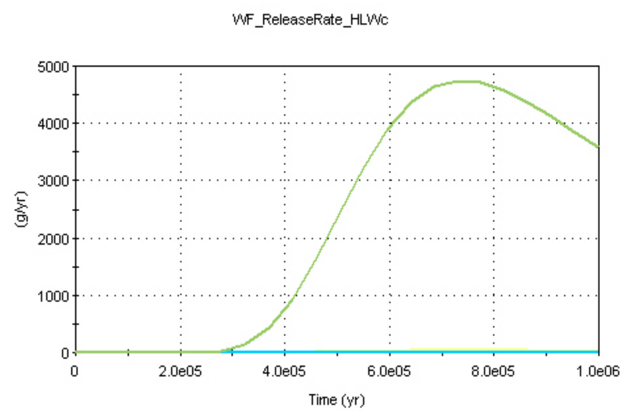
SNF Release Rate



sMOX Release Rate

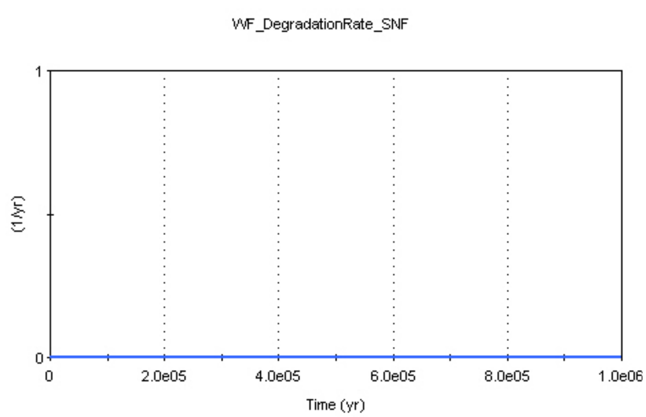


HLWg Release Rate

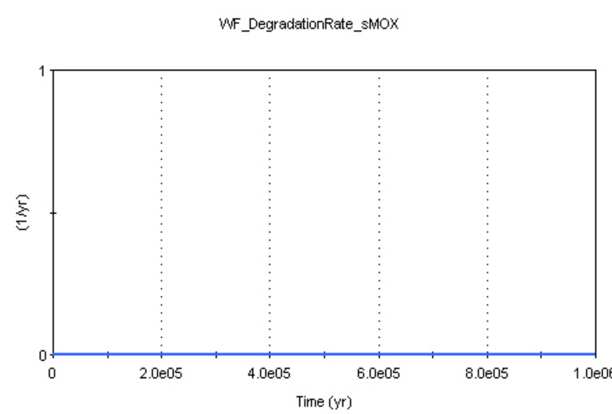


HLWc Release Rate

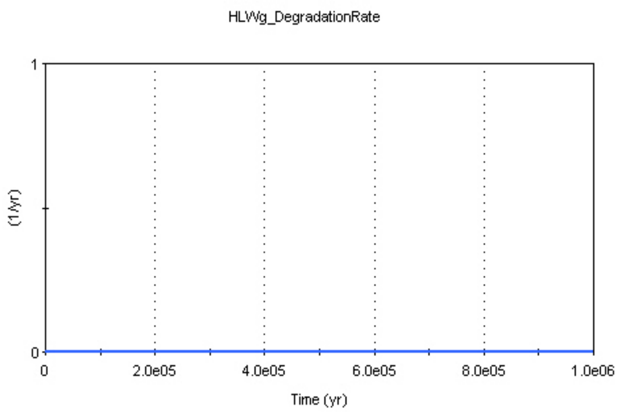
The fuel degradation rates for all fuel types are 0, except for HLWc, which equals the mean value of 1.5e−8.



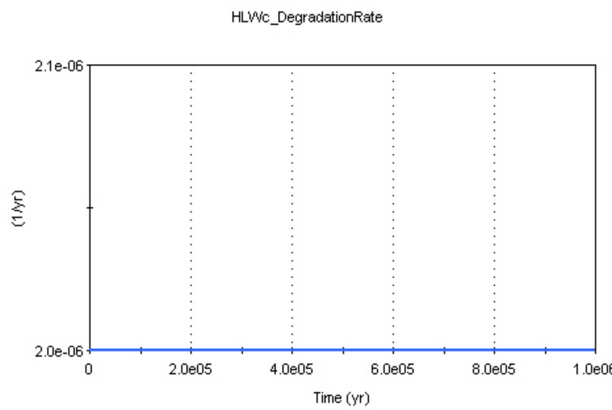
SNF Degradation Rate



sMOX Degradation Rate



HLWg Degradation Rate



HLWc Degradation Rate

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF14

Test Title: Basecase Run for Radionuclide Release Tests Involving Adjustment of Inventory

Analyst: Ron Janetzke

Date: December 10, 2010

Test Environment: ALBY, GoldSim 10.11

SOAR Version: Beta 7.2

Run Directory: D:\RonJ-\SOAR\V7_2

Test Objective: This run is configured for the basecase that is to be compared to runs of various waste inventories selected to simulate waste from reprocessing activities.

Assumptions: None

Test Configuration:

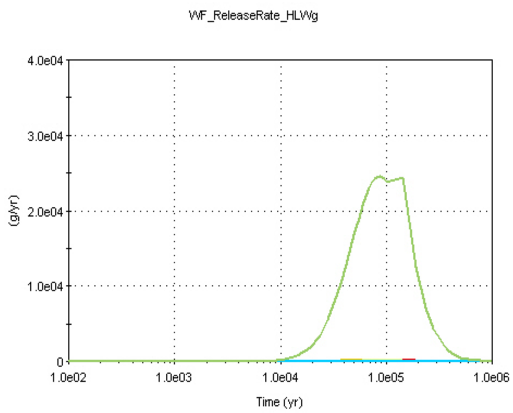
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material: Carbon Steel	Carbon Steel
	Media: Fractured Rock	Fractured Rock
	Redox: Reducing	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel =0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 4140 High-Level Waste (ceramic) = 0

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (glass)
High_Level_Waste_Glass\HLWg_Inventory_Calcs\HLWg_Initial_Inventory

Success Criteria:
(1) The run should produce a chart of Waste Form Release Rate\High-Level Waste (glass) with no errors.
(2) The run should produce a table of High_Level_Waste_Glass\HLWg_Inventory_Calcs\HLWg_Initial_Inventory with no errors.

Results:

The run produced the following chart and table without errors.



HLWg Release Rate

Array View: HLWg_Initial_Inventory — 1000000 yr, End Phase

	HLWg_Initial_I
C14	0.0083181
Cs135	27.086
I129	2.6771
Np237	14.473
Pu238	1.46
Pu239	9.8091
Pu240	1.1035
Pu242	0.15559
Se79	0.2005
Tc99	38.898
U232	4.0011e-05
U233	0.26859
U234	0.56977
U235	8.7822
U236	1.628
U238	4032.9

HLWg Initial Inventory

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF15
Test Title: Radionuclide Release in Reprocessing HLW Glass with Initial Inventory Factor of 1.2
Analyst: Ron Janetzke
Date: December 10, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: D:\RonJ-\SOAR\V7_2
Test Objective: Radionuclide inventory varies in reprocessing waste forms, which have various radionuclide loading configurations. These waste forms include high-level waste (HLW) glass. Tests will be conducted for realistic ranges of radionuclide inventory by varying the initial inventory of HLW glass.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 4140 High-Level Waste (ceramic) = 0
Level 2	High_Level_Waste_Glass\HLWg_ Inventory_Calcs\HLWg_Inventory_2010	(see Edit Vector dialog below)

Edit Vector: HLWg_Inventory_2010.Definition

	Value
C14	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[C14] * 1.2
Cs135	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Cs135] * 1.2
I129	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[I129] * 1.2
Np237	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Np237] * 1.2
Pu238	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu238] * 1.2
Pu239	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu239] * 1.2
Pu240	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu240] * 1.2
Pu242	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu242] * 1.2
Se79	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Se79] * 1.2
Tc99	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Tc99] * 1.2
U232	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U232] * 1.2
U233	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U233] * 1.2
U234	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U234] * 1.2
U235	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U235] * 1.2
U236	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U236] * 1.2
U238	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U238] * 1.2

OK

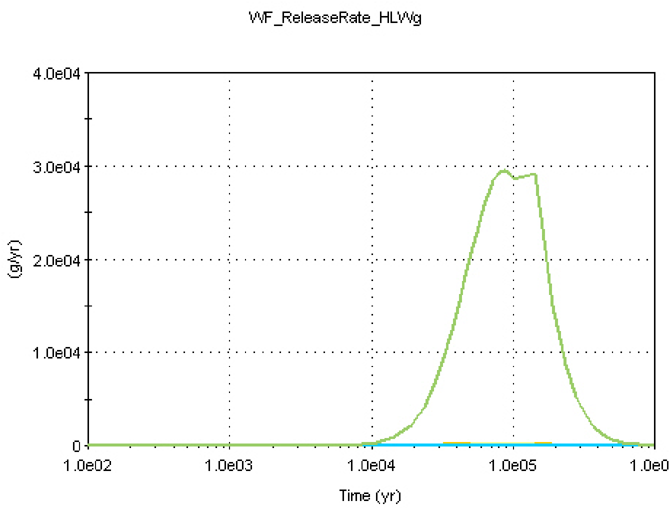
SOAR Verification Test Report

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (glass)
High_Level_Waste_Glass\HLWg_Inventory_Calcs\HLWg_Initial_Inventory

Success Criteria:
(1) The release rate of radionuclides from the waste form should be 1.2 times that of the basecase (WF14).
(2) The initial inventory of HLWg should be 1.2 times greater than that of the basecase (WF14).

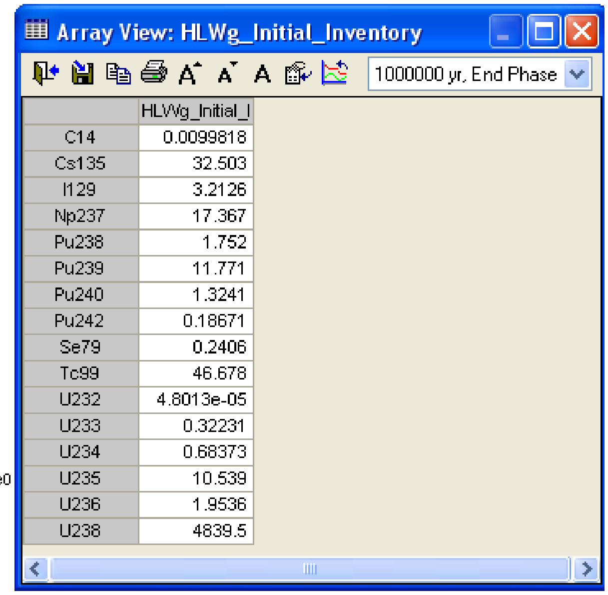
Results:

The HLWg release rates are 1.2 times the basecase.



HLWg Release Rate

The HLWg initial inventory is 1.2 times the basecase.



	HLWg_Initial_I
C14	0.0099818
Cs135	32.503
I129	3.2126
Np237	17.367
Pu238	1.752
Pu239	11.771
Pu240	1.3241
Pu242	0.18671
Se79	0.2406
Tc99	46.678
U232	4.8013e-05
U233	0.32231
U234	0.68373
U235	10.539
U236	1.9536
U238	4839.5

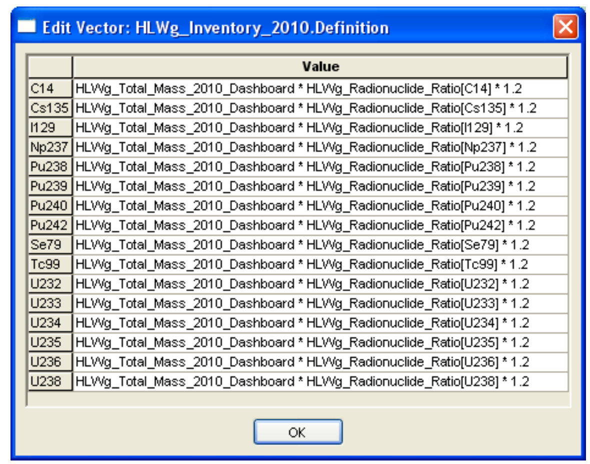
HLWg Initial Inventory

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF17
Test Title: Radionuclide Release in Reprocessing HLW Glass with Initial Inventory Factor of 1.5
Analyst: Ron Janetzke
Date: December 10, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: D:\RonJ-\SOAR\V7_2
Test Objective: Radionuclide inventory varies in reprocessing waste forms, which have various radionuclide loading configurations. These waste forms include high-level waste (HLW) glass. Tests will be conducted for realistic ranges of radionuclide inventory by varying the initial inventory of HLW glass.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 4140 High-Level Waste (ceramic) = 0
Level 2	High_Level_Waste_Glass\HLWg_Inventory_Calcs\HLWg_Inventory_2010	

Edit Vector: HLWg_Inventory_2010.Definition

	Value
C14	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[C14] * 1.2
Cs135	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Cs135] * 1.2
I129	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[I129] * 1.2
Np237	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Np237] * 1.2
Pu238	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu238] * 1.2
Pu239	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu239] * 1.2
Pu240	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu240] * 1.2
Pu242	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Pu242] * 1.2
Se79	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Se79] * 1.2
Tc99	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[Tc99] * 1.2
U232	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U232] * 1.2
U233	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U233] * 1.2
U234	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U234] * 1.2
U235	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U235] * 1.2
U236	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U236] * 1.2
U238	HLWg_Total_Mass_2010_Dashboard * HLWg_Radionuclide_Ratio[U238] * 1.2

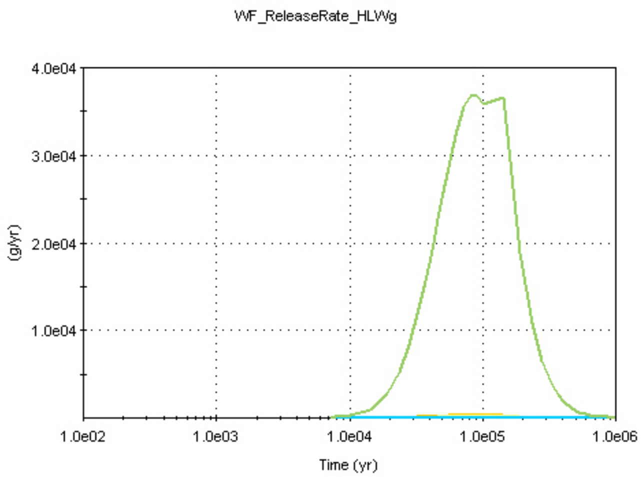
OK

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (glass)
High_Level_Waste_Glass\HLWg_Inventory_Calcs\HLWg_Initial_Inventory

Success Criteria:
(1) The release rate of radionuclides from the waste form should be 1.5 times greater than that of the basecase (WF14).
(2) The initial inventory of HLWg should be 1.5 times greater than that of the basecase (WF14).

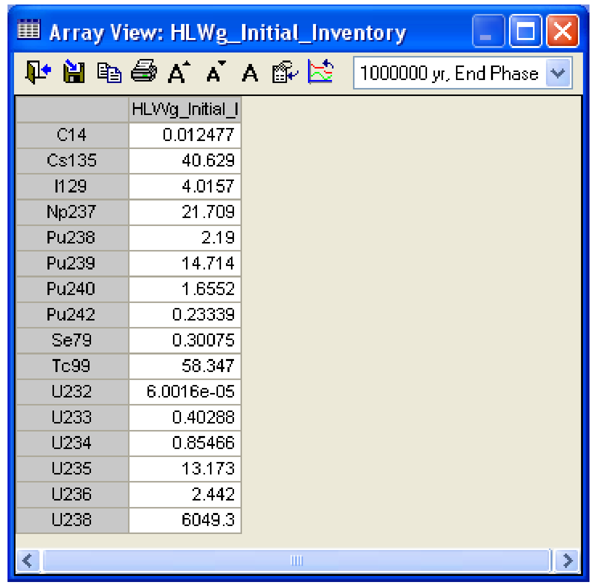
Results:

The HLWg release rates are 1.5 times the basecase.



HLWg Release Rate

The HLWg initial inventory is 1.5 times the basecase.



	HLWg_Initial_I
C14	0.012477
Cs135	40.629
I129	4.0157
Np237	21.709
Pu238	2.19
Pu239	14.714
Pu240	1.6552
Pu242	0.23339
Se79	0.30075
Tc99	58.347
U232	6.0016e-05
U233	0.40288
U234	0.85466
U235	13.173
U236	2.442
U238	6049.3

HLWg Initial Inventory

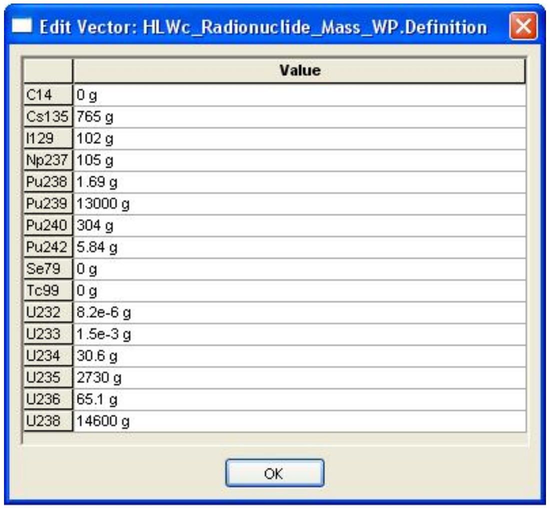
Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF18
Test Title: Basecase Run for Radionuclide Release Tests Involving Adjustment of the HLW Ceramic Initial Inventory
Analyst: Ron Janetzke
Date: December 10, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: D:\RonJ-\SOAR\V7_2
Test Objective: This run is configured for the basecase that is to be compared to runs of HLWc initial inventories selected to simulate waste from reprocessing activities.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 0 High-Level Waste (ceramic) = 108
Level 2	HLWc Mass	(see dialog below)
	HLWc_DegradationRate	4.06e-7 1/yr


Edit Vector: HLWc_Radionuclide_Mass_WP.Definition

	Value
C14	0 g
Cs135	765 g
I129	102 g
Np237	105 g
Pu238	1.69 g
Pu239	13000 g
Pu240	304 g
Pu242	5.84 g
Se79	0 g
Tc99	0 g
U232	8.2e-6 g
U233	1.5e-3 g
U234	30.6 g
U235	2730 g
U236	65.1 g
U238	14600 g

OK

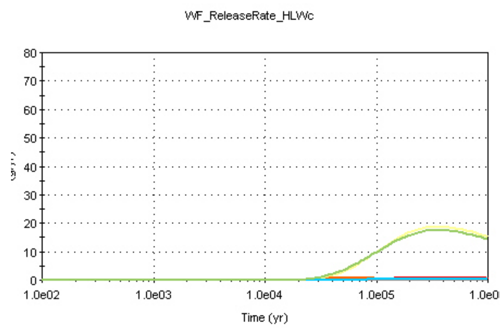
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (ceramic)
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Radionuclide_Ratio
\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result

Success Criteria:
(1) The run should produce a chart of Waste Form Release Rate\High-Level Waste (ceramic) with no errors.
(2) The run should produce a table of High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory with no errors.

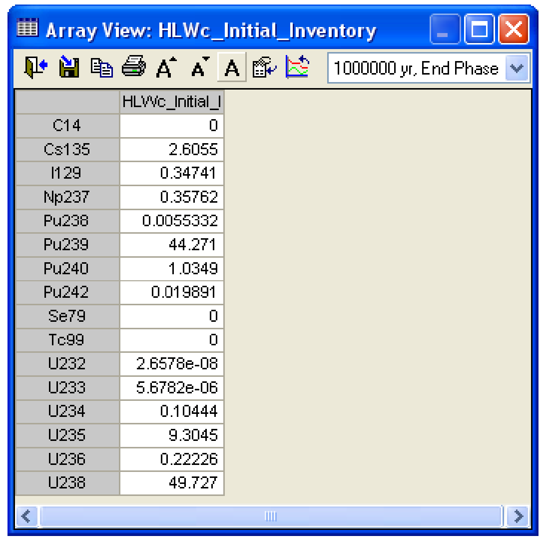
Results:

The HLWc release rate chart was produced without a run-time error.



HLWc Release Rate—General Chart

The HLWc inventory tables were produced without a run-time error.



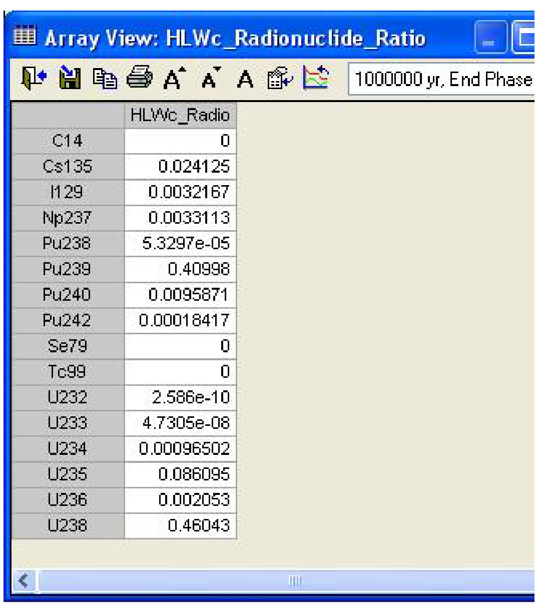
Array View: HLWc_Initial_Inventory

1000000 yr, End Phase

	HLWc_Initial_I
C14	0
Cs135	2.6055
I129	0.34741
Np237	0.35762
Pu238	0.0055332
Pu239	44.271
Pu240	1.0349
Pu242	0.019891
Se79	0
Tc99	0
U232	2.6578e-08
U233	5.6782e-06
U234	0.10444
U235	9.3045
U236	0.22226
U238	49.727

HLWc Initial Inventory

The release rate for I-129 is found on the Results pane.

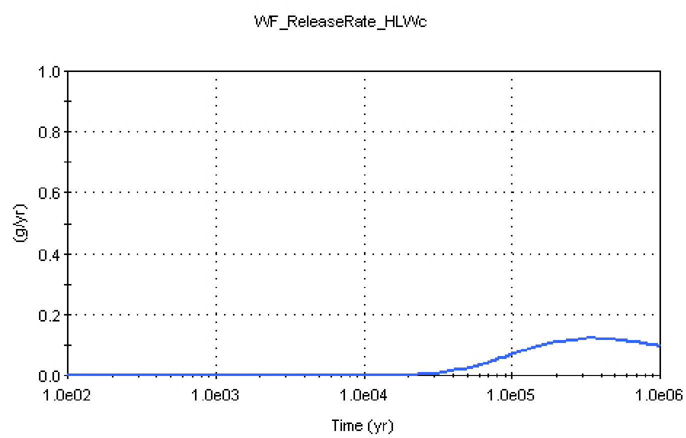


Array View: HLWc_Radionuclide_Ratio

1000000 yr, End Phase

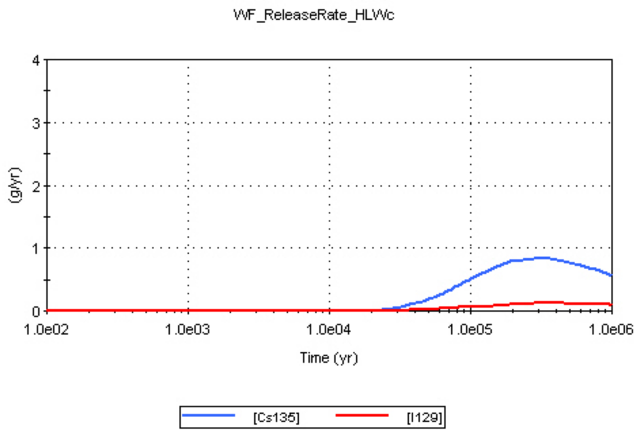
	HLWc_Radio
C14	0
Cs135	0.024125
I129	0.0032167
Np237	0.0033113
Pu238	5.3297e-05
Pu239	0.40998
Pu240	0.0095871
Pu242	0.00018417
Se79	0
Tc99	0
U232	2.586e-10
U233	4.7305e-08
U234	0.00096502
U235	0.086095
U236	0.002053
U238	0.46043

HLWc_Radionuclide_Ratio



\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result for I-129

The release rates for I-129 and Cs-135 are also found on the Results pane.



\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result

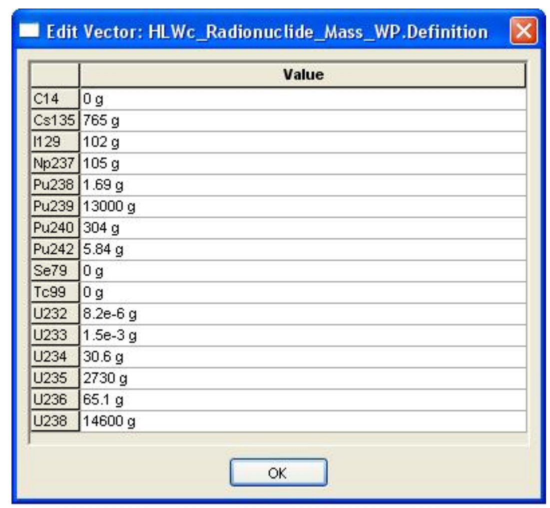
Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF23
Test Title: Radionuclide Release from Reprocessed HLW Ceramic Waste with Initial Inventory Factor of 3.75
Analyst: Ron Janetzke
Date: December 13, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: D:\RonJ-\SOAR\V7_2
Test Objective: This run is configured for the basecase that is to be compared to runs of HLWc initial inventories selected to simulate waste from reprocessing activities.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 0 High-Level Waste (ceramic = 108
Level 2	Set the HLWc_Inventory_2010 equation to: HLWc_Total_Mass_2010_Dashboard* HLWc_Radionuclide_Ratio * 3.75 HLWc mass	



	Value
C14	0 g
Cs135	765 g
I129	102 g
Np237	105 g
Pu238	1.69 g
Pu239	13000 g
Pu240	304 g
Pu242	5.84 g
Se79	0 g
Tc99	0 g
U232	8.2e-6 g
U233	1.5e-3 g
U234	30.6 g
U235	2730 g
U236	65.1 g
U238	14600 g

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (ceramic)
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory

Success Criteria:

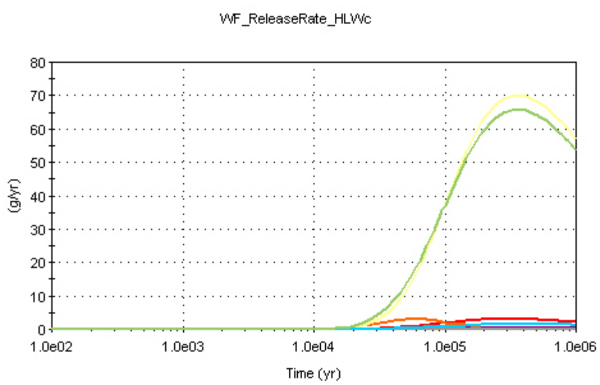
(1) The run should produce a chart of Waste Form Release Rate\High-Level Waste (ceramic) with release rates that are 3.75 times that of the basecase (WF18).

(2) The run should produce a table of High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory that is 3.75 times that of the basecase (WF18).

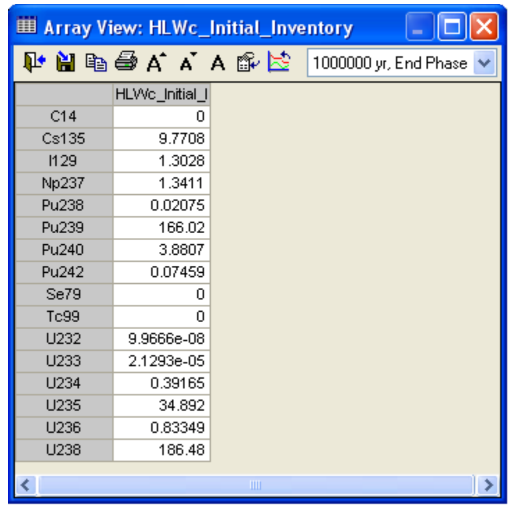
Results:

The HLWc release rate is 3.75 times that of the basecase (WF18).

The HLWc inventory is 3.75 times that shown in the basecase (WF18).



HLWc Release Rate



	HLWc_Initial_I
C14	0
Cs135	9.7708
I129	1.3028
Np237	1.3411
Pu238	0.02075
Pu239	166.02
Pu240	3.8807
Pu242	0.07459
Se79	0
Tc99	0
U232	9.9666e-08
U233	2.1293e-05
U234	0.39165
U235	34.892
U236	0.83349
U238	186.48

HLWc Initial Inventory

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF24

Test Title: Radionuclide Specific (I-129) Release from Reprocessed HLW Ceramic Waste

Analyst: Ron Janetzke

Date: December 13, 2010

Test Environment: ALBY, GoldSim 10.11

SOAR Version: Beta 7.2

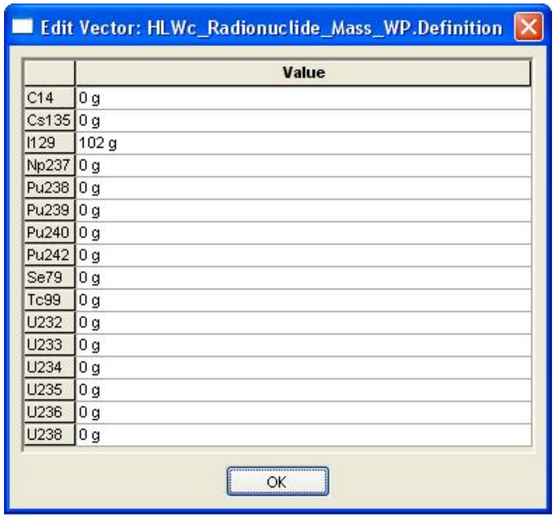
Run Directory: D:\RonJ-\SOAR\V7_2

Test Objective: Radionuclide inventory varies in reprocessing waste forms, which have various radionuclide loading configurations. These waste forms include high-level waste (HLW) ceramic. Tests will be conducted by selecting the default HLWc inventory for I-129 while setting all other inventories to 0. All other waste forms are not present.

Assumptions: None

Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 0 High-Level Waste (ceramic) = 108
Level 2	HLWc Initial Mass per WP	



Edit Vector: HLWc_Radionuclide_Mass_WP.Definition

	Value
C14	0 g
Cs135	0 g
I129	102 g
Np237	0 g
Pu238	0 g
Pu239	0 g
Pu240	0 g
Pu242	0 g
Se79	0 g
Tc99	0 g
U232	0 g
U233	0 g
U234	0 g
U235	0 g
U236	0 g
U238	0 g

OK

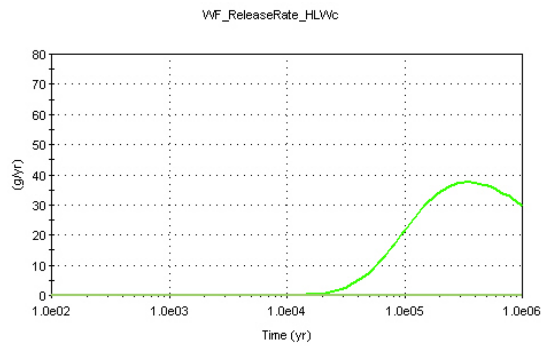
SOAR Verification Test Report (continued)

Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (ceramic)
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Radionuclide_Ratio

Success Criteria:
(1) The initial inventory values should be zero for all radionuclides except I-129, which should be the I-129 fuel ratio times the total mass displayed on the dashboard.
(2) The release rates for all radionuclides should be zero except for I-129, which should be the same as the basecase (WF18) adjusted for the difference in the WP mass ratio for I-129.

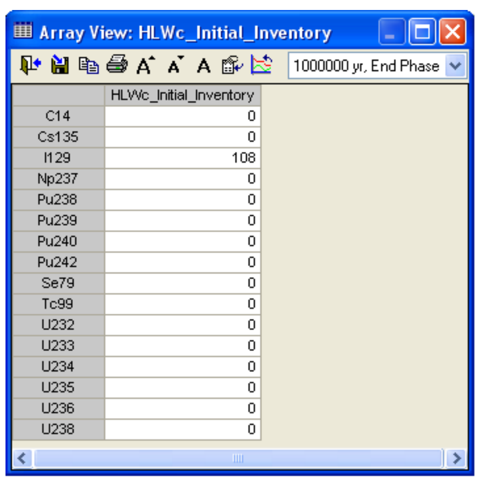
Results:

The HLWc release rate is 0 for all radionuclides except I-129. The release rate for I-129 is the same as the basecase, times the release rate factor shown here. Release rate factor = I129_mass_ratio_WF24/I129_mass_ratio_WF18 = 1.0/0.0032167 ~ 310.88, where I129_mass_ratio_WF24 is the I129 mass ratio used for the WF24 test case with I129 mass/HLW initial inventory = 108/108 = 1.0 and I129_mass_ratio_WF18 is the I-129 mass ratio used for the basecase WF18 (i.e., 0.0032167). This release rate factor accounts for the increase in inventory of a given radionuclide when all of the mass present is attributed to one radionuclide rather than a mix. The release rates are 310 times the I-129 release rates in WF18.



I-129 HLWc Release Rate

The HLWc inventory is zero except for I-129, which is the I-129 fuel ratio (1.0) times the total mass displayed on the dashboard (108).



Array View: HLWc_Initial_Inventory

1000000 yr, End Phase

	HLWc_Initial_Inventory
C14	0
Cs135	0
I129	108
Np237	0
Pu238	0
Pu239	0
Pu240	0
Pu242	0
Se79	0
Tc99	0
U232	0
U233	0
U234	0
U235	0
U236	0
U238	0

HLWc Initial Inventory

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

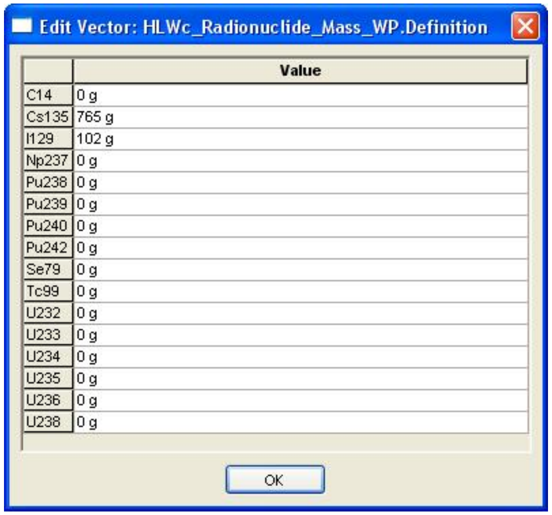
The GoldSim models for tests WF18 and WF24, available as electronic files and summarized in Table 3-2, give WF release rates in a ratio of 310.87.

Table 3-2. GoldSim Model Release Rates for WF 18 and WF 24			
Year	WF 24	WF 18	WF 24/ WF 18
14500	0.40466	0.001302	310.8704
19000	0.40429	0.001301	310.8727
23500	1.2125	0.0039	310.8815
28000	2.0197	0.006497	310.8713
32500	2.8252	0.009088	310.8715
37000	4.0332	0.012974	310.8679
41500	5.2389	0.016852	310.877
46000	6.4419	0.020722	310.8725
50500	7.6423	0.024583	310.8774
55000	9.2439	0.029735	310.8761
59500	10.439	0.033578	310.8881
64000	12.034	0.03871	310.8757
68500	13.222	0.042533	310.8645
73000	14.408	0.046346	310.879
77500	15.994	0.051449	310.871
82000	17.174	0.055244	310.8754
86500	18.351	0.059029	310.8811
91000	19.525	0.062806	310.8779
95500	20.293	0.065278	310.8704
100000	21.462	0.069039	310.8678
145000	29.622	0.095287	310.8714
190000	33.818	0.10878	310.8844
235000	35.928	0.11557	310.8765
280000	37.196	0.11965	310.8734
325000	37.64	0.12108	310.8688
370000	37.678	0.1212	310.8746
415000	37.318	0.12004	310.8797
460000	36.964	0.1189	310.8831
505000	36.224	0.11652	310.8823
550000	35.891	0.11545	310.8792
595000	35.171	0.11314	310.8626
640000	34.467	0.11087	310.8776
685000	33.776	0.10865	310.8698
730000	33.489	0.10772	310.8893
775000	32.818	0.10557	310.8648
820000	32.16	0.10345	310.8748
865000	31.515	0.10138	310.8601
910000	30.884	0.099345	310.8762
955000	30.265	0.097354	310.8758
1.00E+06	29.658	0.095403	310.8707

SOAR Verification Test Report

Test ID: WF25
Test Title: Radionuclide Specific (I-129 and Cs-135) Release from Reprocessed HLW Ceramic Waste
Analyst: Ron Janetzke
Date: December 14, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: D:\RonJ-\SOAR\V7_2
Test Objective: Radionuclide inventory varies in reprocessing waste forms, which have various radionuclide loading configurations. These waste forms include high-level waste (HLW) ceramic. Tests will be conducted by selecting the default HLWc inventory for I-129 and Cs-135 while setting all other inventories to 0. All other waste forms are not present.
Assumptions: None
Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	2010 Radionuclide Inventory (Metric Tons)	Spent Nuclear Fuel = 0 Spent Mixed-Oxide Fuel = 0 High-Level Waste (glass) = 0 High-Level Waste (ceramic) = 108
Level 2	HLWc Initial Mass per WP	


Edit Vector: HLWc_Radionuclide_Mass_WP.Definition

	Value
C14	0 g
Cs135	765 g
I129	102 g
Np237	0 g
Pu238	0 g
Pu239	0 g
Pu240	0 g
Pu242	0 g
Se79	0 g
Tc99	0 g
U232	0 g
U233	0 g
U234	0 g
U235	0 g
U236	0 g
U238	0 g

OK

SOAR Verification Test Report (continued)

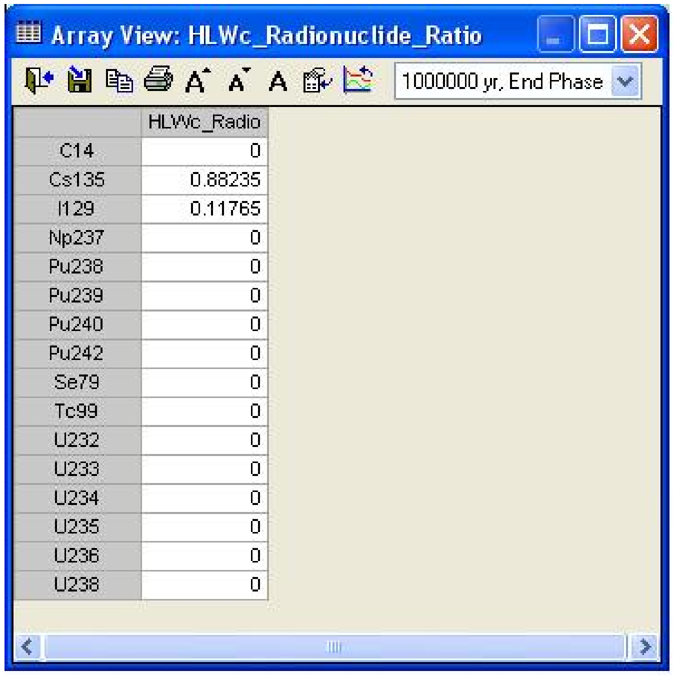
Result Parameters: Time histories of the following parameters are used in the analysis:
Waste Form Release Rate\High-Level Waste (ceramic)
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Initial_Inventory
High_Level_Waste_Ceramic\HLWc_Inventory_Calcs\HLWc_Radionuclide_Ratio

Success Criteria:

(1) The initial inventory values should be zero for all radionuclides except I-129 and Cs-135, which should be their fuel ratios times the total mass displayed on the dashboard.

(2) The release rates for all radionuclides should be zero except for I-129 and Cs-135, which should be the same as the basecase (WF18) values adjusted for the difference in the WP mass ratio for I-129 and Cs-135.

Results:


Array View: HLWc_Radionuclide_Ratio

1000000 yr, End Phase

	HLWc_Radio
C14	0
Cs135	0.88235
I129	0.11765
Np237	0
Pu238	0
Pu239	0
Pu240	0
Pu242	0
Se79	0
Tc99	0
U232	0
U233	0
U234	0
U235	0
U236	0
U238	0

Radionuclide Mass Ratios

The HLWc release rate is 0 for all radionuclides except I-129 and Cs-135. The release rates for I-129 and Cs-135 are the same as the basecase, times the following release rate factors:

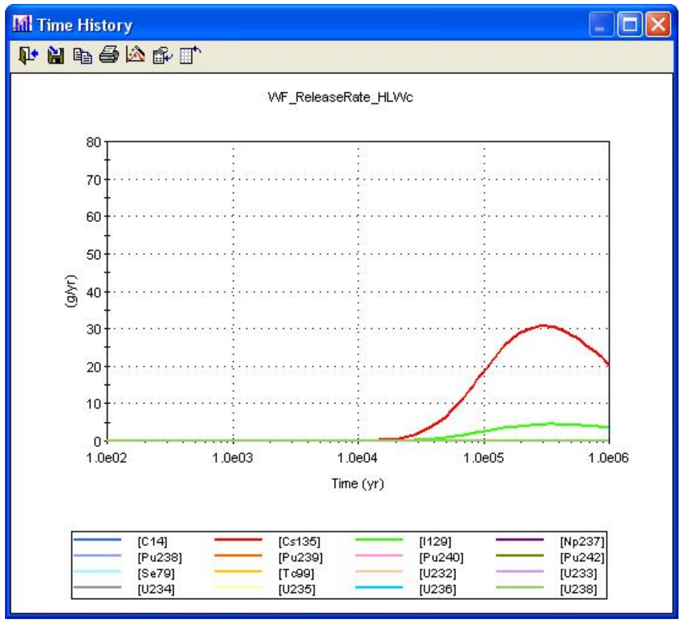
3.2.1 I-29 Release Rate Factor

I129_mass_ratio_WF25/I129_mass_ratio_WF18 = 0.11765/0.0032167 = 36.57, where
I129_mass_ratio_WF25 is the I-129 mass ratio used for the WF25 test case and
I129_mass_ratio_WF18 is the I-129 mass ratio used for the basecase WF18

3.2.2 Cs-135 Release Rate Factor

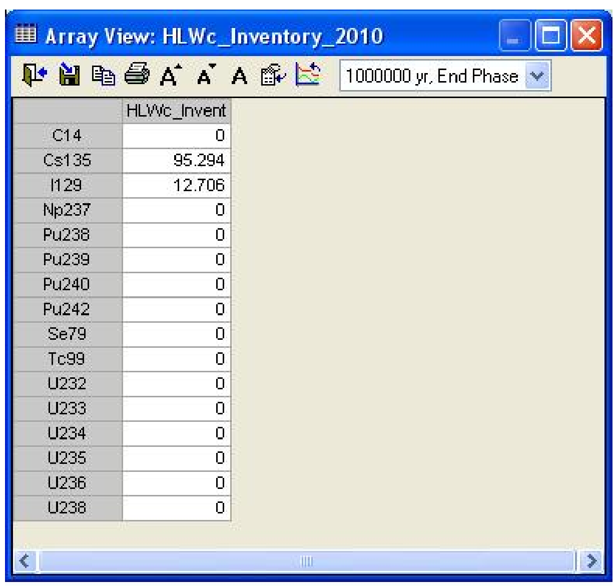
Cs135_mass_ratio_WF25/Cs135_mass_ratio_WF18 = 0.88235 / 0.024125 = 36.57, where
Cs135_mass_ratio_WF25 is the Cs-135 mass ratio used for the WF25 test case and
Cs135_mass_ratio_WF18 is the Cs-135 mass ratio used for the basecase WF18

These release rate factors account for the increase in inventory of a given radionuclide when the mass present is attributed to fewer than the original radionuclide set. The release rates are 36 times the release rates in WF18 for both I-129 and Cs-135. The value 36.57 resulted from the data in HLWc_Radionuclide_Mass_WP.Definition tables of tests WF18 and WF25. The total mass in HLWc_Radionuclide_Mass_WP.Definition table of WF18 is 31709.2 g, the cumulative mass of I-129 and Cs-135 in table HLWc_Radionuclide_Mass_WP.Definition of test WF25 is 102 + 765 = 867 g, and 31709.2/867 = 36.57.



HLWc Release Rate

The HLWc inventory is zero except for I-129 and Cs-135, which are the fuel ratios (0.118 and 0.882, respectively) times the total mass displayed on the dashboard (108 tonnes).



	HLWc_Invent
C14	0
Cs135	95.294
I129	12.706
Np237	0
Pu238	0
Pu239	0
Pu240	0
Pu242	0
Se79	0
Tc99	0
U232	0
U233	0
U234	0
U235	0
U236	0
U238	0

HLWc Initial Inventory

Disposition:

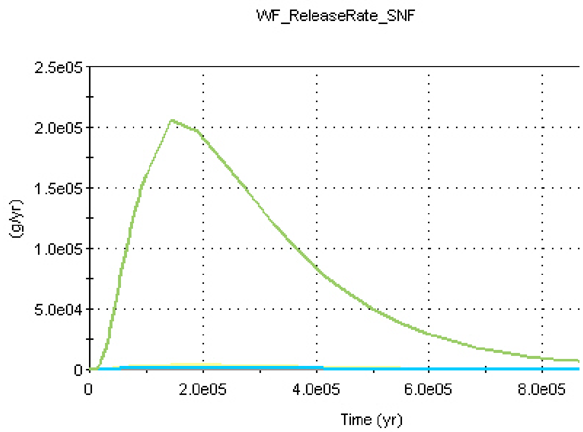
(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

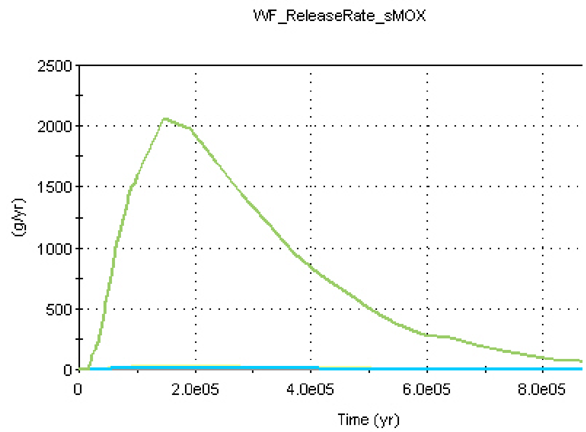
SOAR Verification Test Report

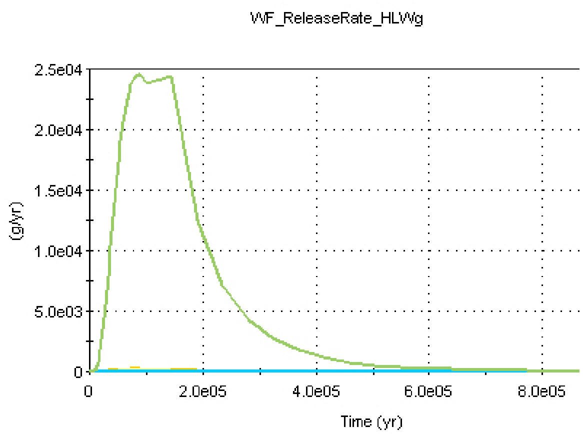
Test ID:	WF26		
Test Title:	Basecase for Runs Regarding the Fraction of Initial Inventory Available for Release and the Degradation Rate Multiplier		
Analyst:	Ron Janetzke		
Date:	December 17, 2010		
Test Environment:	ALBY, GoldSim 10.11		
SOAR Version:	Beta 8.1		
Run Directory:	D:\RonJ-\SOAR\V8_1		
Test Objective:	Provide a basecase data set that can be used in the analysis of intact cladding by adjusting the fraction of initial inventory available and in the analysis of waste form fragment size by adjusting the degradation rate multiplier.		
Assumptions:	None		
Test Configuration:	Simulation Settings	Monte Carlo	Deterministic, Mean Values
		Timesteps	95
	Dashboard	Material	Carbon Steel
		Media	Fractured Rock
		Redox	Reducing
		Fraction of Initial Inventory Available for Release for all fuel types	1
		Degradation Rate Multiplier for all fuel types	1
Result Parameters:	\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result \Results\Waste_Form_Results\WF_ReleaseRate_sMOX_Result \Results\Waste_Form_Results\WF_ReleaseRate_HLWg_Result \Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result \Results\Waste_Form_Results\WF_CumRelease_SNF_Result \Results\Waste_Form_Results\WF_CumRelease_sMOX_Result \Results\Waste_Form_Results\WF_CumRelease_HLWg_Result \Results\Waste_Form_Results\WF_CumRelease_HLWc_Result		
Success Criteria:	(1) The run should generate charts of the result parameters without a run-time error.		

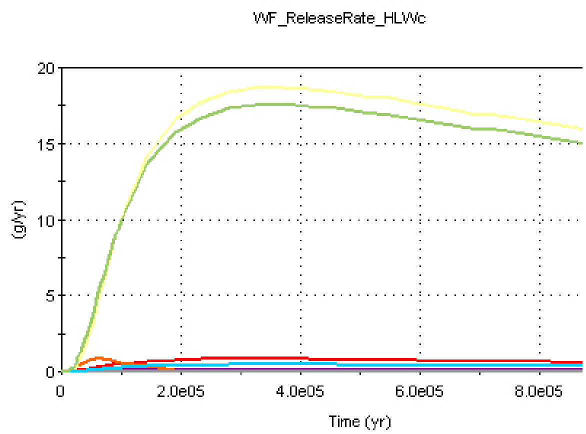
Results:

The following charts were generated without run-time errors.

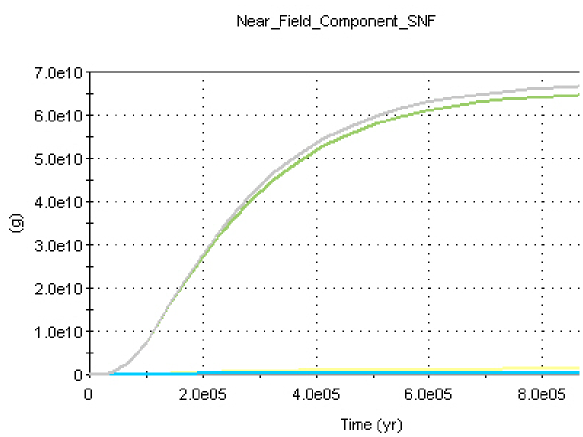


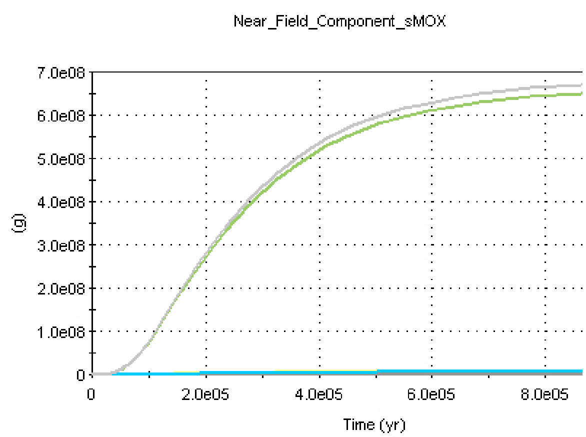


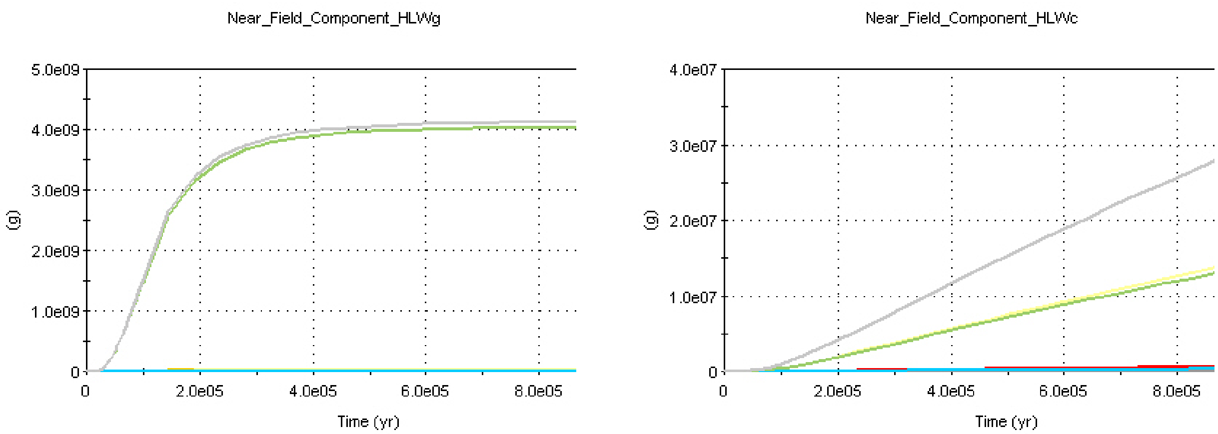




Radionuclide Release Rates







Radionuclide Cumulative Release

Disposition:

(1) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: WF27
Test Title: Radionuclide Release with the Fraction of Initial Inventory Available for Release at 0.10
Analyst: Ron Janetzke
Date: December 17, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.1
Run Directory: D:\RonJ-\SOAR\V8_1
Test Objective: Provide a test of input that is representative of intact cladding protection by adjusting the fraction of initial inventory available for release parameter on the dashboard.
Assumptions: None
Test Configuration:

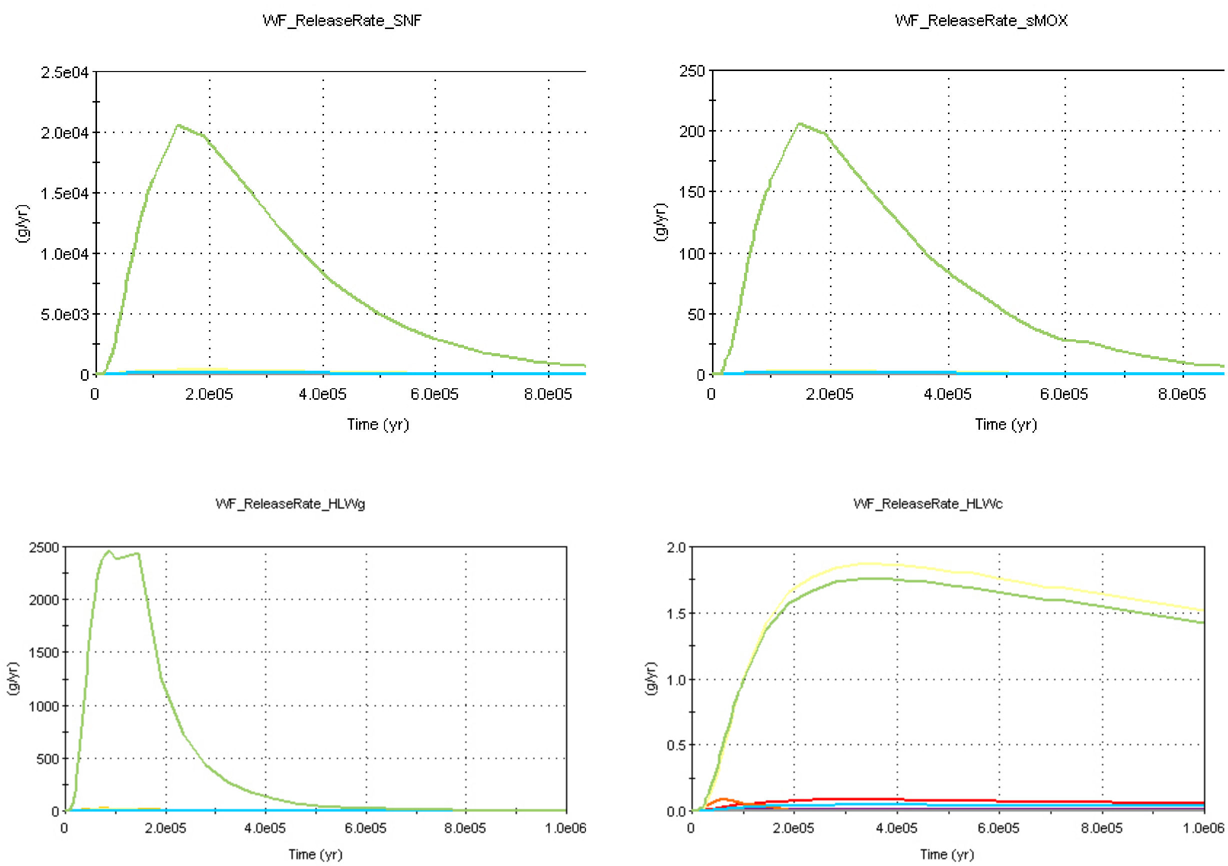
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	Fraction of Initial Inventory Available for Release for all fuel types	0.10
	Degradation Rate Multiplier for all fuel types	1

Result Parameters:
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result
\Results\Waste_Form_Results\WF_CumRelease_SNF_Result
\Results\Waste_Form_Results\WF_CumRelease_sMOX_Result
\Results\Waste_Form_Results\WF_CumRelease_HLWg_Result
\Results\Waste_Form_Results\WF_CumRelease_HLWc_Result

Success Criteria:
(1) The waste form release rates for all fuel types should be 10 percent those of the basecase (WF26).
(2) The waste form cumulative release curve for all fuel types should be 10 percent that of basecase (WF26).

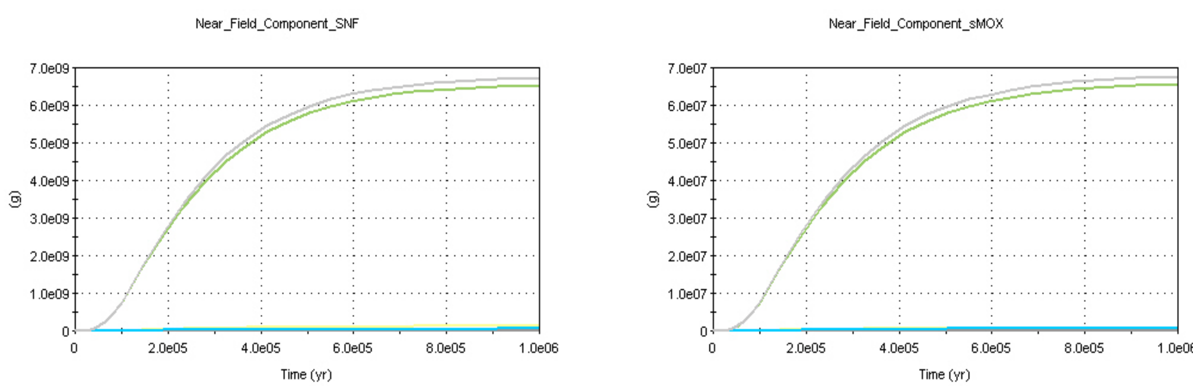
Results:

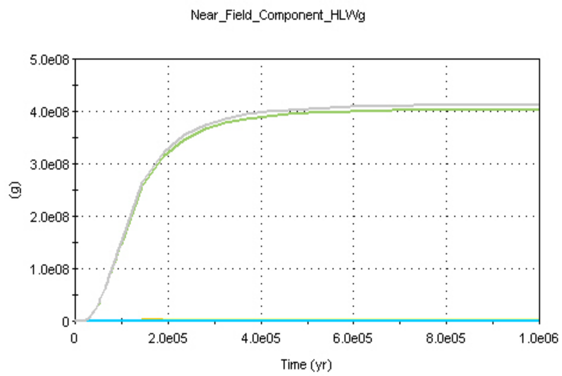
All release rates are 10 percent of the basecase (WF26) release rates.

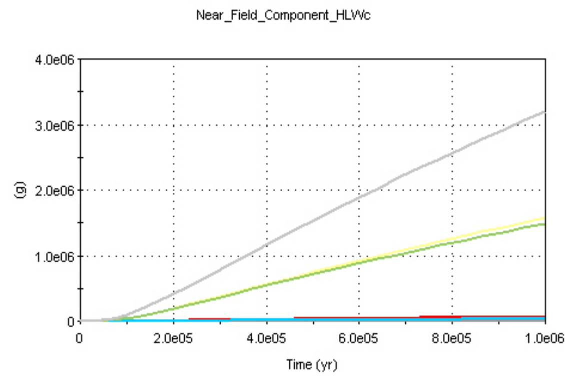


Radionuclide Release Rates

All cumulative releases are 10 percent of the basecase (WF26).







Radionuclide Cumulative Releases

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: WF28

Test Title: Radionuclide Release with the Fraction of Initial Inventory Available for Release at 0.30

Analyst: Ron Janetzke

Date: December 17, 2010

Test Environment: ALBY, GoldSim 10.11

SOAR Version: Beta 8.1

Run Directory: D:\RonJ-\SOAR\V8_1

Test Objective: Provide a test of input that is representative of intact cladding protection by adjusting the fraction of initial inventory available for release parameter on the dashboard.

Assumptions: None

Test Configuration:

Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	Fraction of Initial Inventory Available for Release for all fuel types	0.30
	Degradation Rate Multiplier for all fuel types	1

Result Parameters:
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result
\Results\Waste_Form_Results\WF_CumRelease_SNF_Result
\Results\Waste_Form_Results\WF_CumRelease_sMOX_Result
\Results\Waste_Form_Results\WF_CumRelease_HLWg_Result
\Results\Waste_Form_Results\WF_CumRelease_HLWc_Result

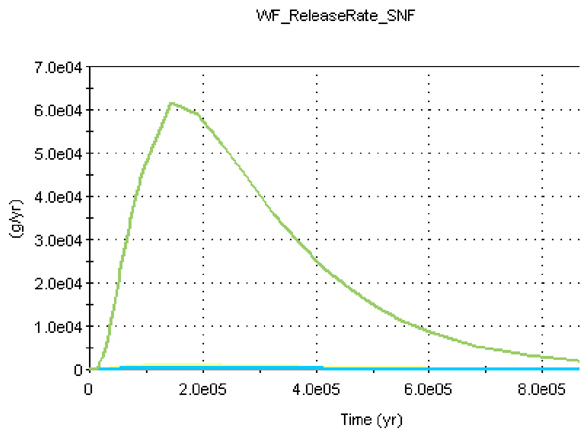
Success Criteria:

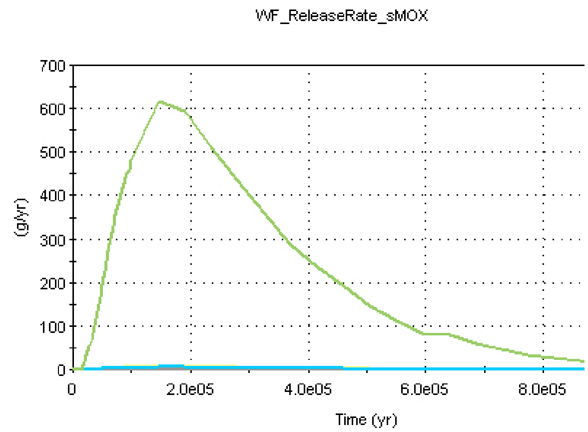
(1) The waste form release rates for all fuel types should be 30 percent those of the basecase (WF26).

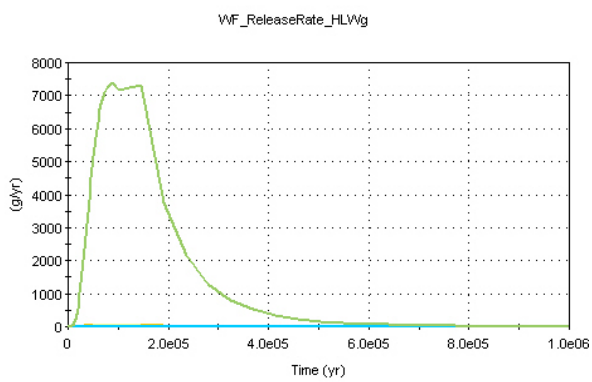
(2) The waste form cumulative release curve for all fuel types should be 30 percent that of basecase (WF26).

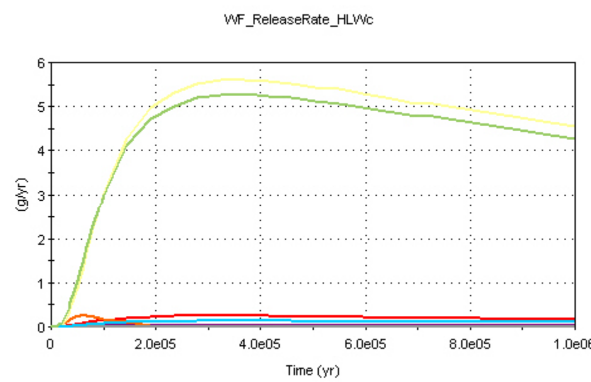
Results:

All release rates are 30 percent of the basecase (WF26) release rates.



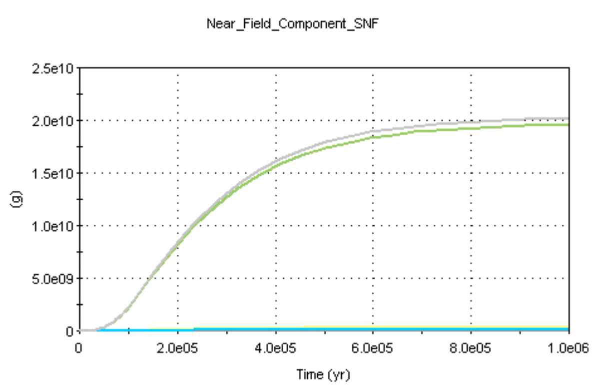


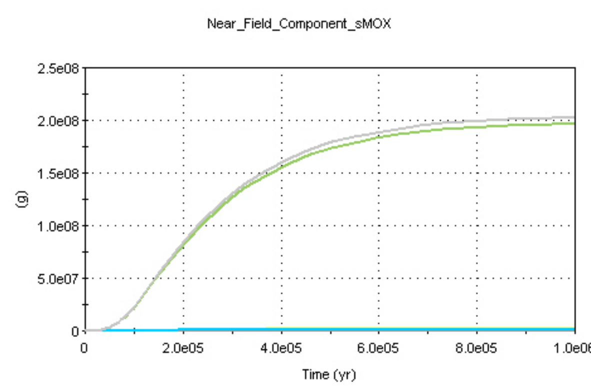


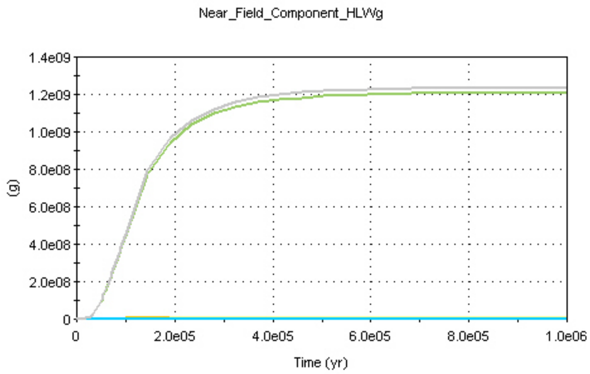


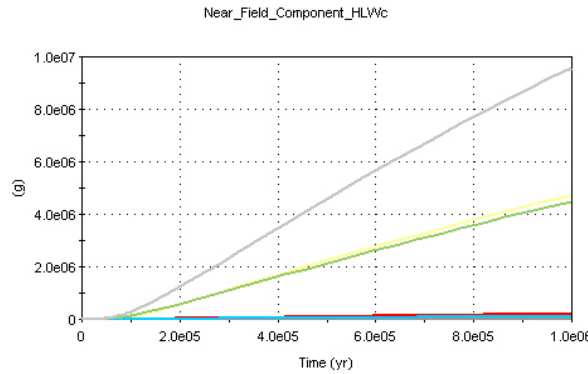
Radionuclide Release Rates

All cumulative releases are 30percent of the basecase (WF26) release rates.









Radionuclide Cumulative Releases

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: WF30
Test Title: Radionuclide Release with the Degradation Rate Multiplier at 5
Analyst: Ron Janetzke
Date: December 17, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.1
Run Directory: D:\RonJ-\SOAR\V8_1
Test Objective: Provide a test of input that is representative of variable waste form fragment sizes by adjusting the degradation rate multiplier parameter on the dashboard.
Assumptions: None
Test Configuration:

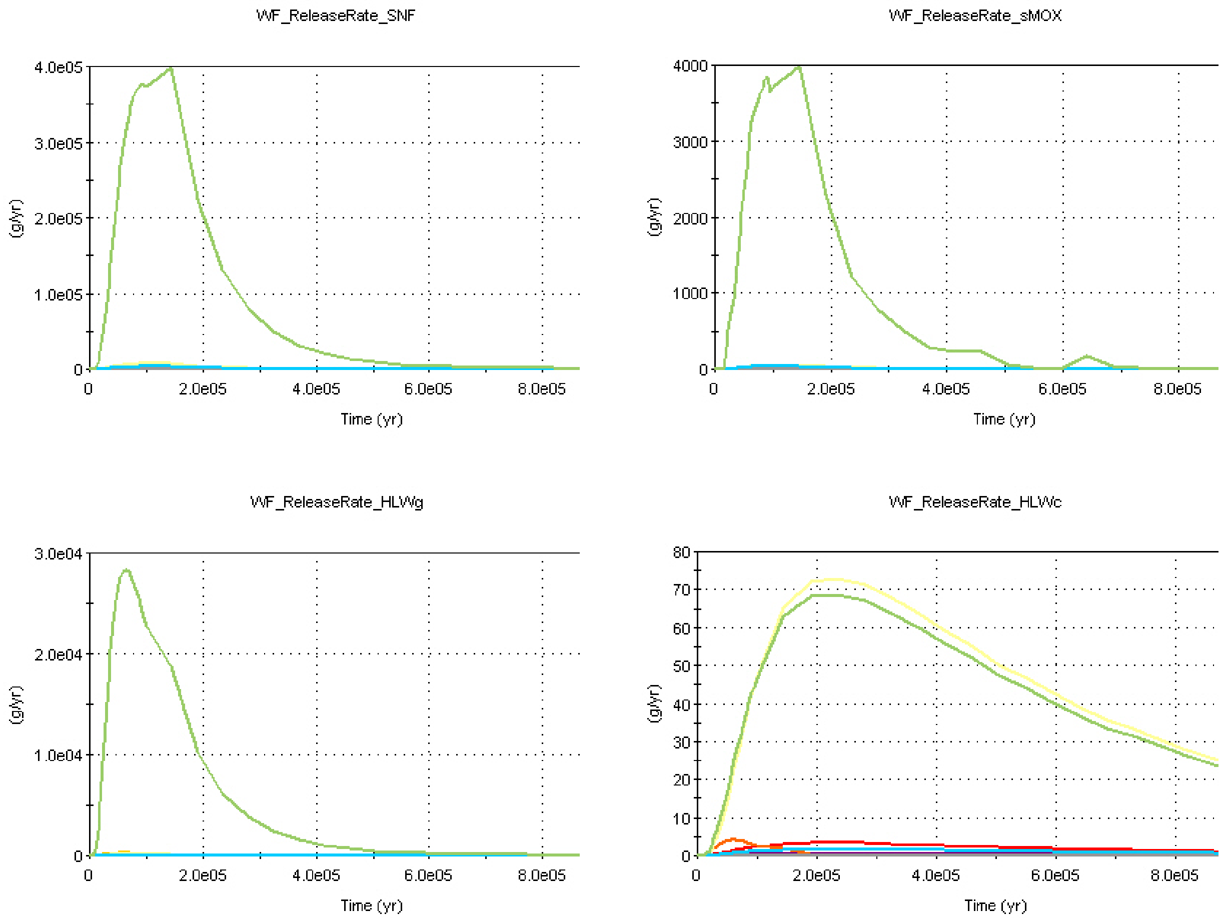
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	Fraction of Initial Inventory Available for Release for all fuel types	1
	Degradation Rate Multiplier for all fuel types	5

Result Parameters:
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result

Success Criteria:
(1) The waste form release rates for all fuel types should be greater than those of the base case (WF26).

Results:

All fuel types have releases that are greater than the basecase (WF26).



Radionuclide Release Rates

Disposition:

(1) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: WF31
Test Title: Radionuclide Release with the Degradation Rate Multiplier at 0.2
Analyst: Ron Janetzke
Date: December 17, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.1
Run Directory: D:\RonJ-\SOAR\V8_1
Test Objective: Provide a test of input that is representative of variable waste form fragment sizes by adjusting the degradation rate multiplier parameter on the dashboard.
Assumptions: None
Test Configuration:

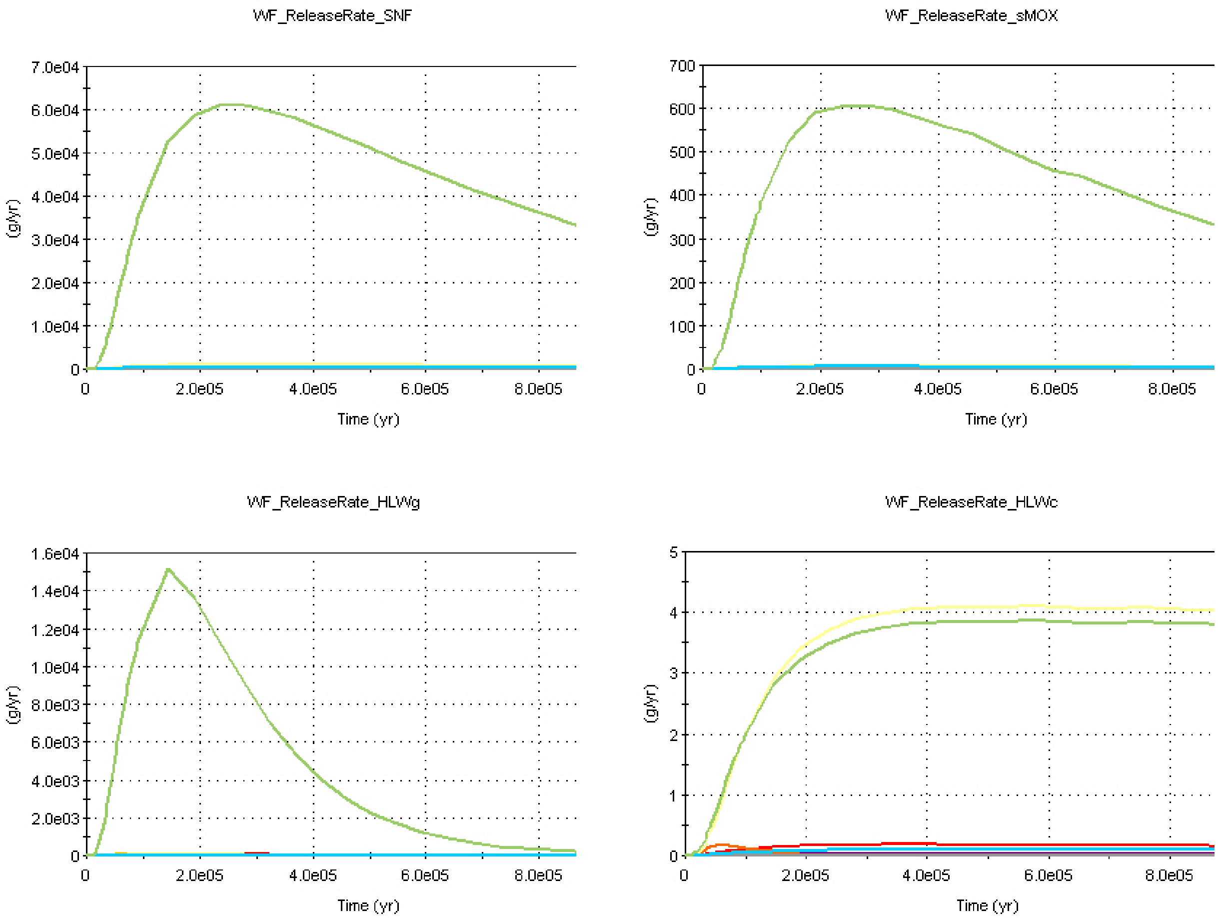
Simulation Settings	Monte Carlo	Deterministic, Mean Values
	Timesteps	95
Dashboard	Material	Carbon Steel
	Media	Fractured Rock
	Redox	Reducing
	Fraction of Initial Inventory Available for Release for all fuel types	1
	Degradation Rate Multiplier for all fuel types	0.2

Result Parameters:
\Results\Waste_Form_Results\WF_ReleaseRate_SNF_Result
\Results\Waste_Form_Results\WF_ReleaseRate_sMOX_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWg_Result
\Results\Waste_Form_Results\WF_ReleaseRate_HLWc_Result

Success Criteria:
(1) The waste form release rates for all fuel types should be less than those of the base case (WF26).

Results:

All fuel types have releases that are less than the basecase (WF26).



Radionuclide Release Rates

Disposition:

(1) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: WP01
Test Title: WP Failure Time and Breached Area for Cu_porous_rock_oxidizing_2.5cm
Analyst: Razvan Nes
Date: November 30, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V6.4
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Copper
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	2.5 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Cu_GC_Ox_Low	0.04 μm/yr
	Cu_GC_Ox_High	7.0 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the waste package (WP) failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-1}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{2.5}{7.0} = 3.571 \times 10^3 \text{ years} \tag{3-2}$$

$$t_{gc} = 10^4 \times \frac{2.5}{0.04} = 6.250 \times 10^5 \text{ years} \tag{3-3}$$

These values satisfactorily agree with the output values in WP01GCFractionWPFailedTable.txt and WP01GCFractionWP Failed.BMP files. The graph in Figure 3-1, created in WP01GCFractionFailedExcel.xls, is based on the data in WP01GCFractionWP FailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.999, which are the values of the fractions marking the initiation and the completion of the WPs' failure due to general corrosion. Figure 3-2 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-4}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} = 1.0$ after 6.250×10^5 years). Based on the data in WP01GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = 40.0 m^2.

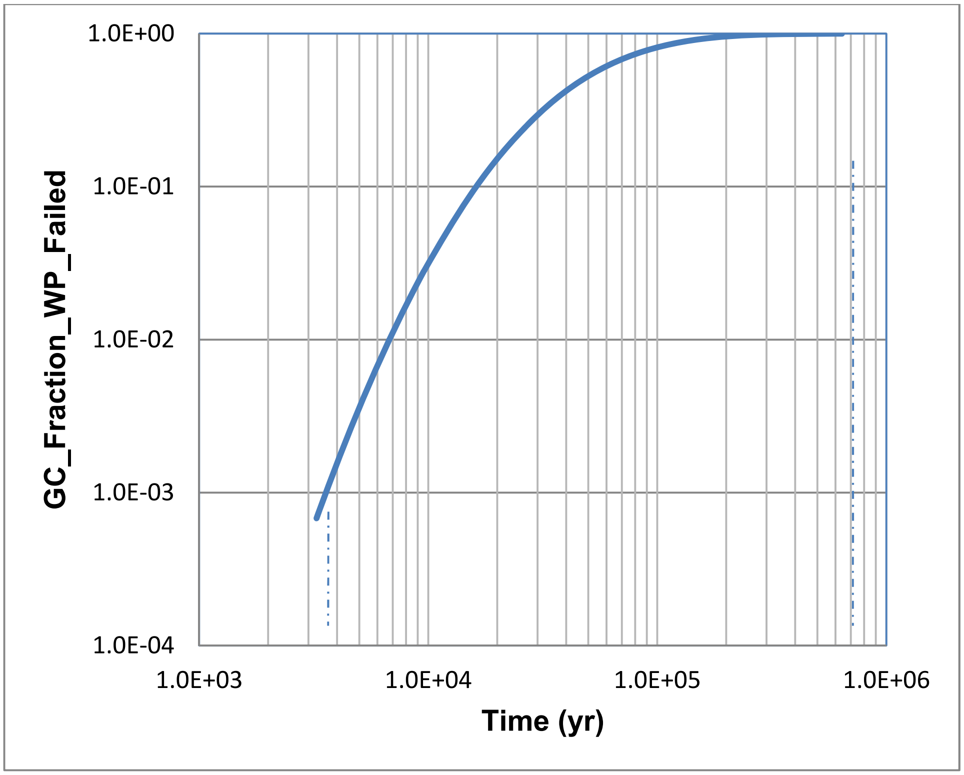


Figure 3-1. WP Failure Fraction From General Corrosion

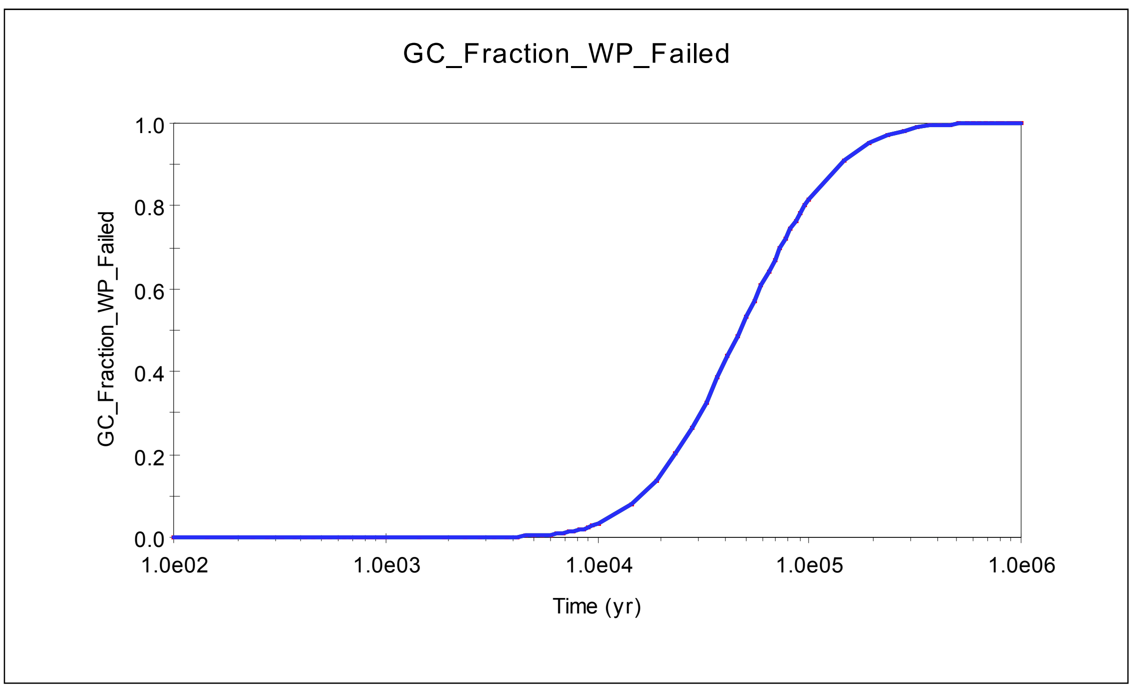


Figure 3-2. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions, after 6.250×10^5 years , the breached area per failed WP equals the area A of the WP

$$\mathrm{WP}_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 40.0\ m^2 \quad (3\text{-}5)$$

The value agrees with the output value in WP01BreachArea.BMP and WP01BreachAreaTable.txt files. Figure 3-3 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP01BreachArea.BMP. The chart shows that WP breach area equals zero over the first 3,571 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur during the first 3,571-year period.

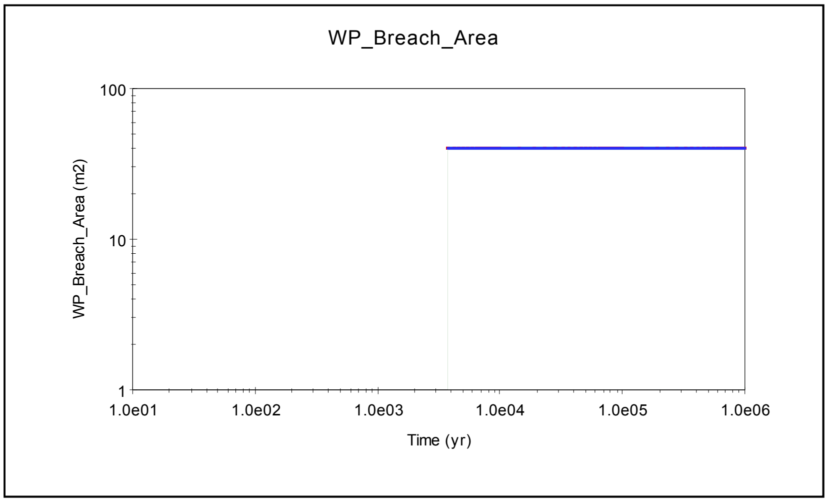


Figure 3-3. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP02

Test Title: WP Failure Time and Breached Area for Cu_porous_rock_oxidizing_2.5cm _10X Corrosion Rate

Analyst: Razvan Nes

Date: November 30, 2010

Test Environment: Frisco, GoldSim 10.11

SOAR Version: Beta 6.4

Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V6.4

Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).

Assumptions: None

Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Copper
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	2.5 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Data Source	None
	Cu_GC_Ox_Low	0.04 µm/yr
	Cu_GC_Ox_High	7.0 µm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-6}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{2.5}{70.0} = 3.571 \times 10^2 \text{ years} \tag{3-7}$$

$$t_{gc} = 10^4 \times \frac{2.5}{0.4} = 6.250 \times 10^4 \text{ years} \tag{3-8}$$

These values satisfactorily agree with the output values in WP02GCFractionWPFailedTable.txt and WP02GCFractionWPFailed.BMP files. The graph in Figure 3-4, created in WP02GCFractionFailedExcel.xls, is based on the data in WP02GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.999, which are the values of the fractions marking the initiation and the completion of the WPs' failure due to general corrosion. Figure 3-5 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-9}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} = 1.0$ after 6.250×10^4 years). Based on the data in WP02GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = $40.0\ m^2$.

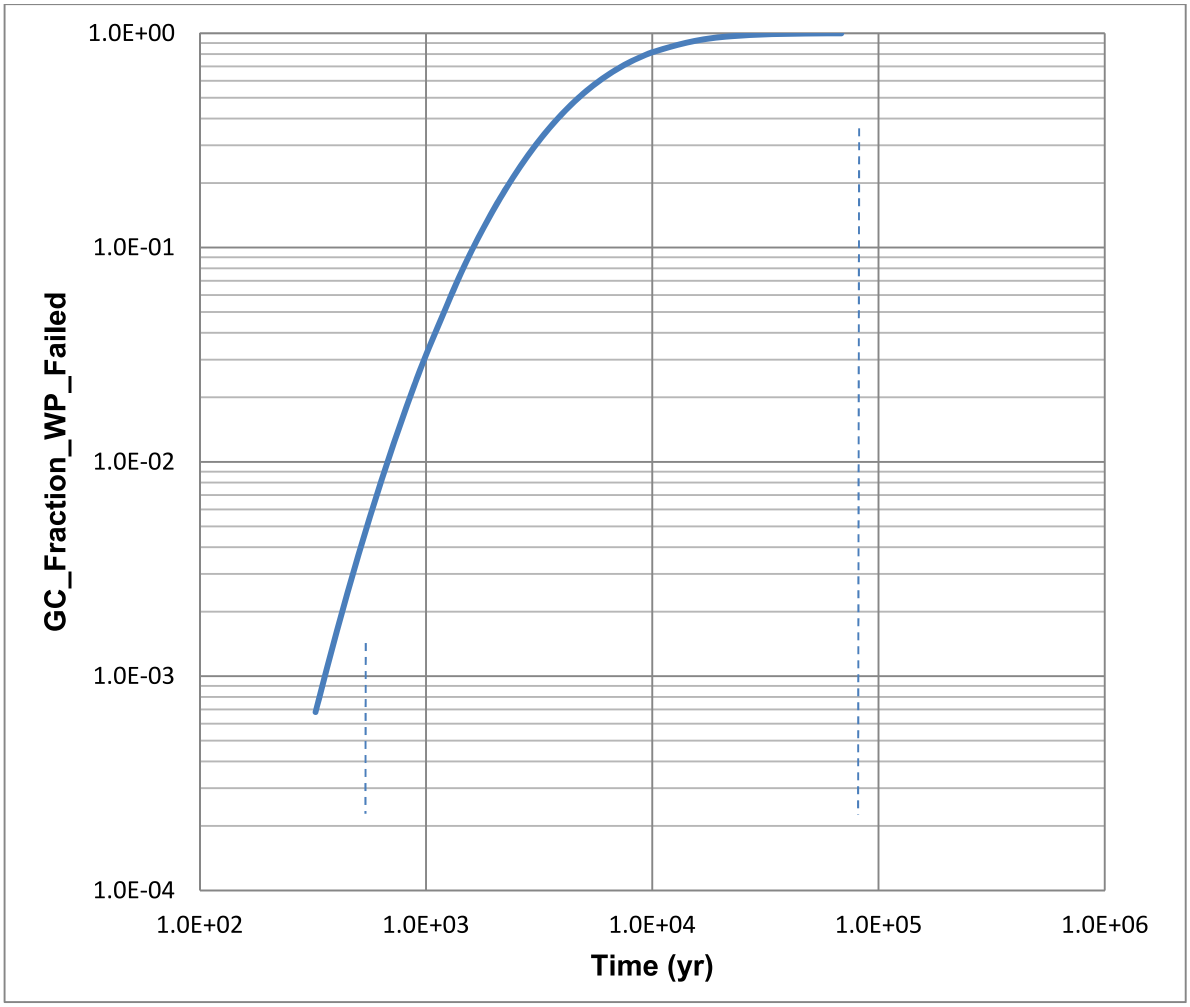


Figure 3-4. WP Failure Fraction From General Corrosion

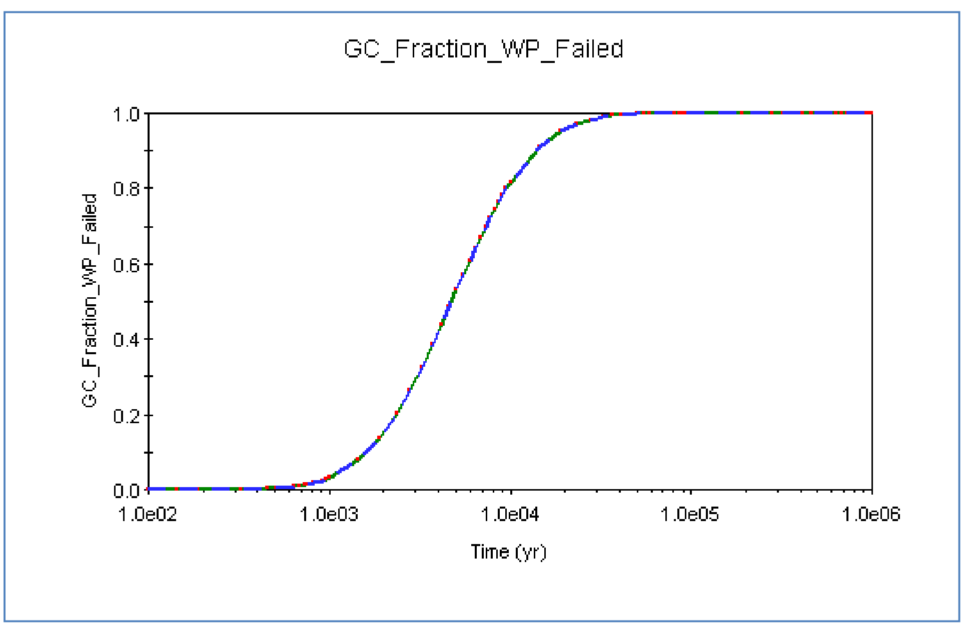


Figure 3-5. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions, after 6.250×10^4 years, the breached area per failed WP equals the area A of the WP

$$WP_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 40.0\ m^2 \qquad (3\text{-}10)$$

The value agrees with the output value in WP02BreachArea.BMP and WP02BreachAreaTable.txt files. Figure 3-6 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP02BreachArea.BMP. The chart shows that WP breach area equals zero over the first 357 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the first 357-year period.

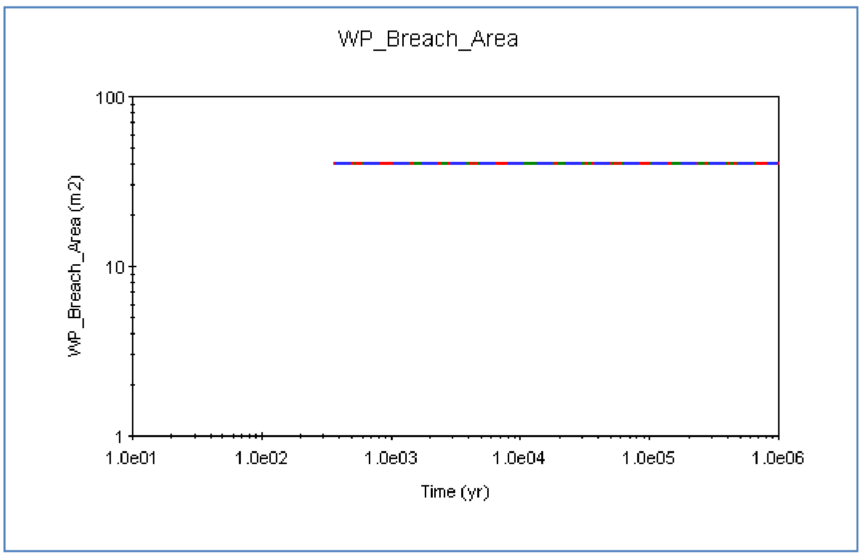


Figure 3-6. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP03
Test Title: WP Failure Time and Breached Area for Cu_fractured_rock_reducing_2.5cm _Effects of Material Thickness
Analyst: Razvan Nes
Date: December 01, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 6.4
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V6.4
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Copper
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	2.5 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Cu_GC_Ox_Low	0.004 µm/yr
	Cu_GC_Ox_High	0.02 µm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters: Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-11}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{2.5}{0.02} = 1.250 \times 10^6 \text{ years} \tag{3-12}$$

$$t_{gc} = 10^4 \times \frac{2.5}{0.004} = 6.250 \times 10^6 \text{ years} \tag{3-13}$$

These values satisfactorily agree with the output values in WP03GCFractionWPFailedTable.txt and WP03GCFractionWPFailed.BMP files. The graph in Figure 3-7, created in WP03GCFractionFailedExcel.xls, is based on the data in WP03GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0 and 1 million years. Both WP03GCFractionWPFailedTable.txt and WP03GCFractionWPFailed.BMP files confirm that the 0.001 and 0.999 fractions of failed WPs due to general corrosion occur after more than 1 million years; however, the resolution of the original output chart shown in Figure 3-8 cannot read fractions lower than one or more orders of magnitude than 0.001.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-14}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses is negligible (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} \sim 0$). Based on the data in WP03GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = 40.0 m^2. Figure 3-8 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

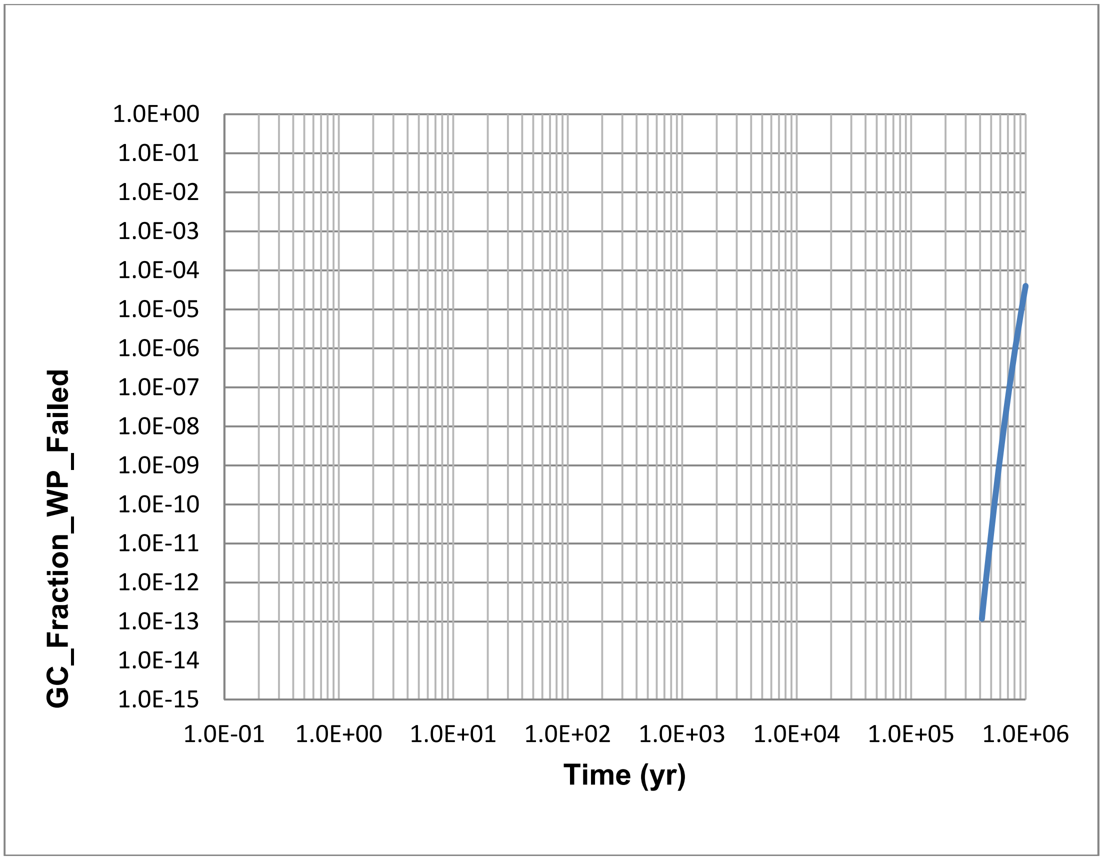


Figure 3-7. WP Failure Fraction From General Corrosion

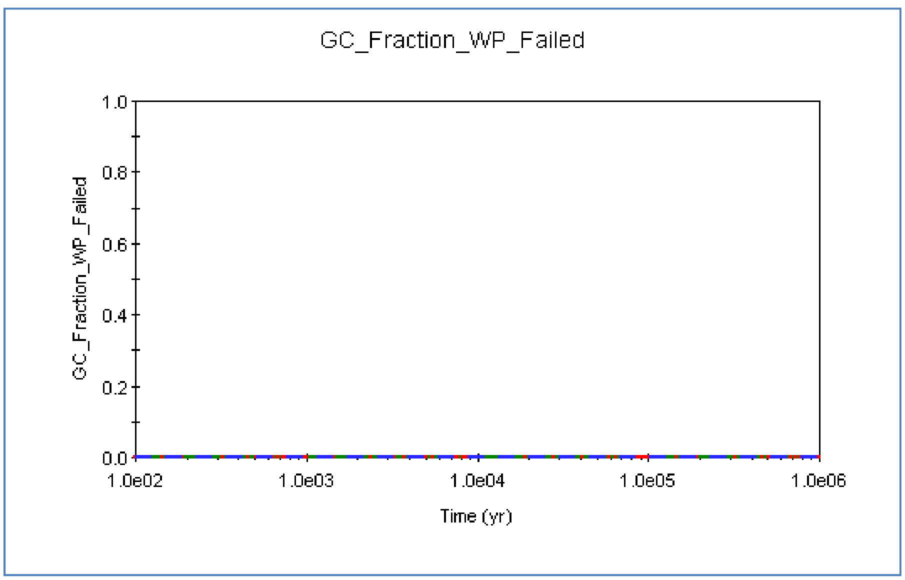


Figure 3-8. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions, over the 1-million-year simulation, the breached area per failed WP is negligible

$$\mathrm{WP}_{\text{breached area}} = (0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 0\ m^2 \qquad (3\text{-}15)$$

The value agrees with the output value in WP03BreachArea.BMP and WP03BreachAreaTable.txt files. Figure 3-9 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP03BreachArea.BMP. The chart shows that WP breach area equals zero over the first 1 million years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the 1-million-year simulation period.

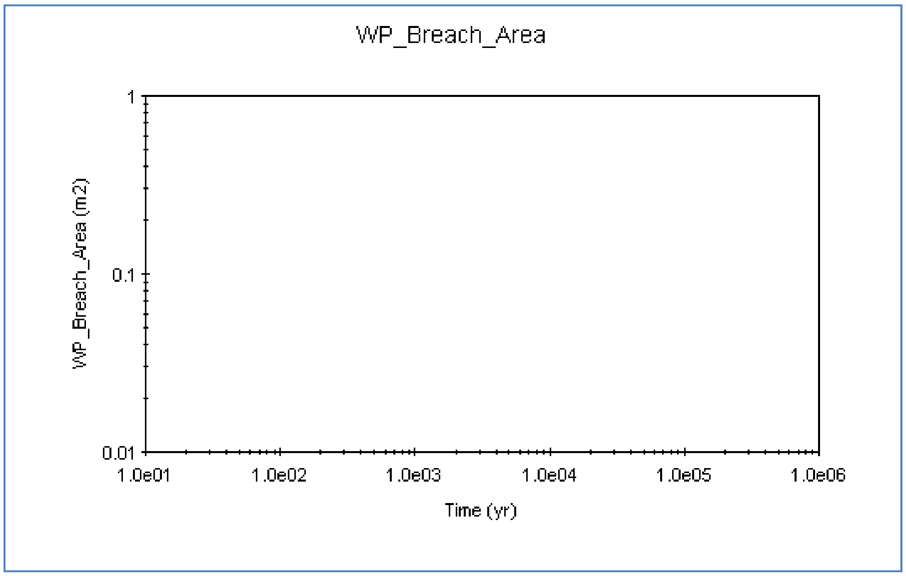


Figure 3-9. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP04

Test Title: WP Failure Time and Breached Area for Cu_fractured_rock_reducing_2.5cm _10X Corrosion Rate

Analyst: Razvan Nes

Date: December 01, 2010

Test Environment: Frisco, GoldSim 10.11

SOAR Version: Beta 6.4

Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V6.4

Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).

Assumptions: None

Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Copper
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	2.5 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Data Source	None
	Cu_GC_Ox_Low	0.04 μm/yr
	Cu_GC_Ox_High	0.2 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-16}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{2.5}{0.2} = 1.250 \times 10^5 \text{ years} \tag{3-17}$$

$$t_{gc} = 10^4 \times \frac{2.5}{0.04} = 6.250 \times 10^5 \text{ years} \tag{3-18}$$

These values satisfactorily agree with the output values in WP04GCFractionWPFailedTable.txt and WP04GCFractionWPFailed.BMP files. The graph in Figure 3-10, created in WP04GCFractionFailedExcel.xls, is based on the data in WP04GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.999, which are the values of the fractions marking the initiation and the completion of the WPs' failure due to general corrosion. Figure 3-11 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-19}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} = 1.0$, after 6.250×10^5 years). Based on the data in WP04GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = 40.0 m^2.

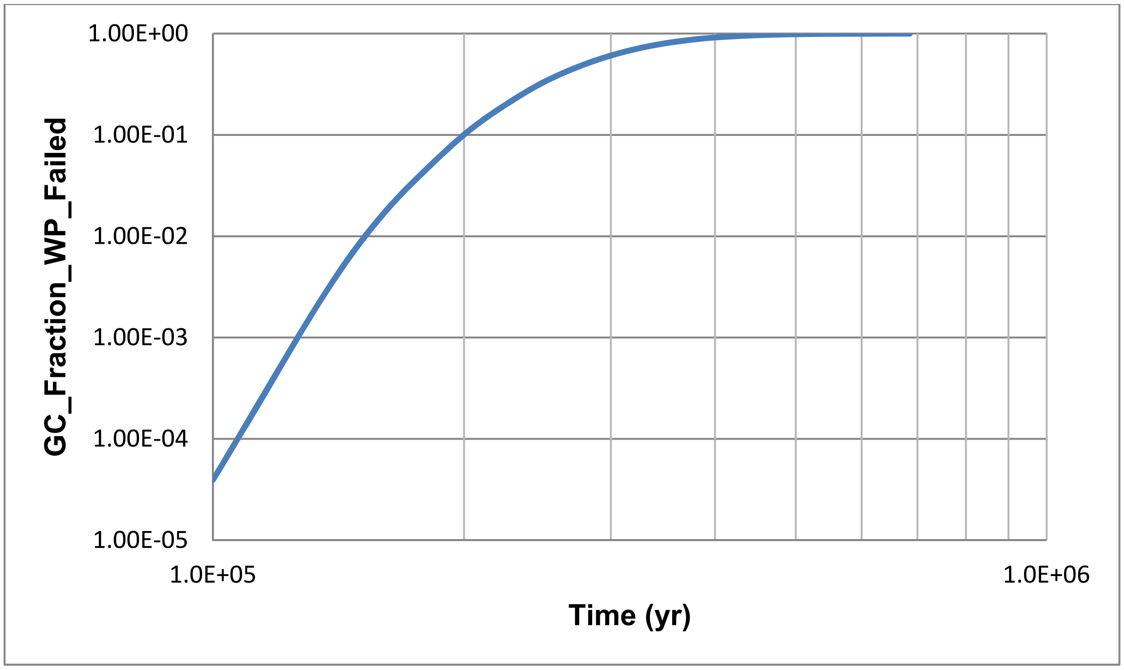


Figure 3-10. WP Failure Fraction From General Corrosion

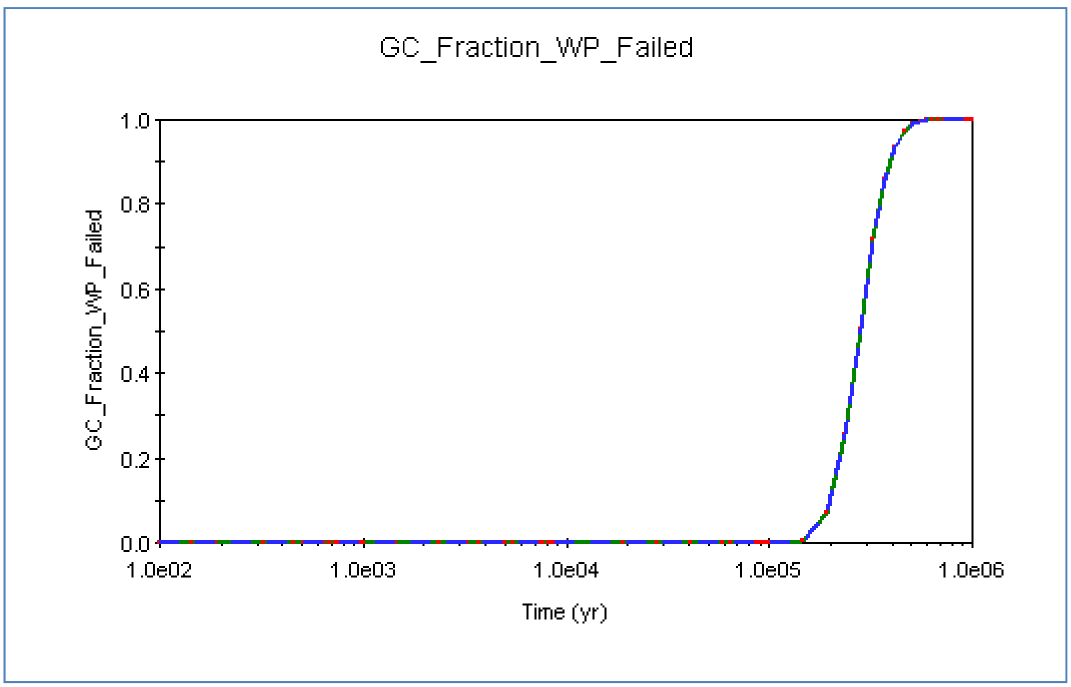


Figure 3-11. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions, after 6.250×10^5 years, the breached area per failed WP equals the area A of the WP

$$\text{WP}_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 40.0\ m^2 \tag{3-20}$$

The value agrees with the output value in WP04BreachArea.BMP and WP04BreachAreaTable.txt files. Figure 3-12 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP04BreachArea.BMP. The chart shows that WP breach area equals zero over the first 1.250×10^5 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the 1.250×10^5 -year period.

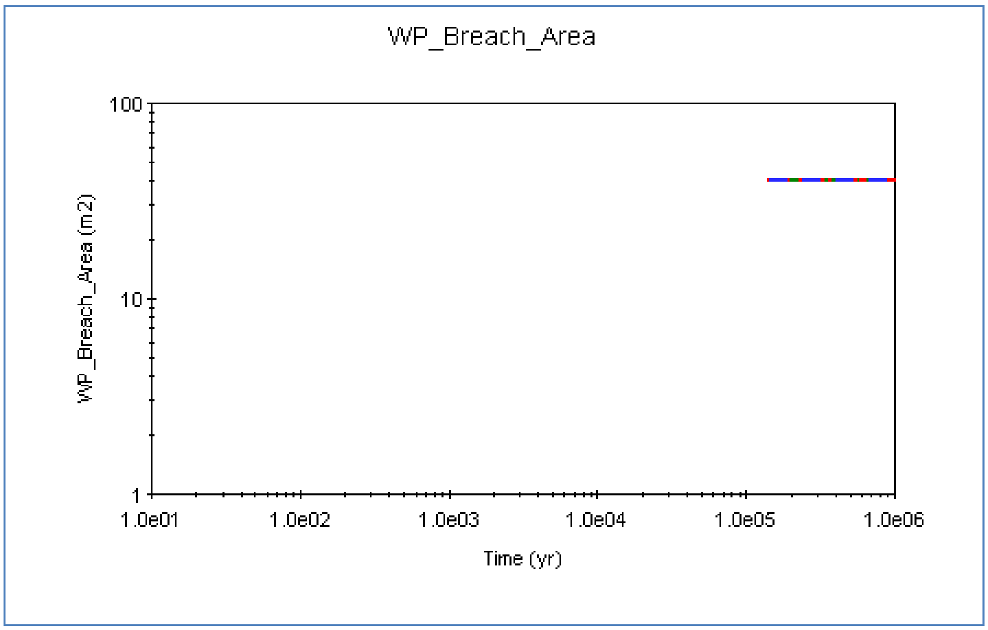


Figure 3-12. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP05

Test Title: WP Failure Time and Breached Area for Cu_fractured_rock_reducing_0.5cm _Effects of Material Thickness

Analyst: Razvan Nes

Date: December 01, 2010

Test Environment: Frisco, GoldSim 10.11

SOAR Version: Beta 6.4

Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V6.4

Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).

Assumptions: None

Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Copper
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	0.5 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Data Source	None
	Cu_GC_Ox_Low	0.004 μm/yr
	Cu_GC_Ox_High	0.02 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time $\mathrm{t_{gc}}$ as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate $\mathrm{R_{gc}}$(μm/yr)

$$\mathrm{t_{gc}} = 10^4 \times \frac{\mathrm{L}}{\mathrm{R_{gc}}} \tag{3-21}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$\mathrm{t_{gc}} = 10^4 \times \frac{0.5}{0.02} = 2.500 \times 10^5 \text{ years} \tag{3-22}$$

$$\mathrm{t_{gc}} = 10^4 \times \frac{0.5}{0.004} = 1.250 \times 10^6 \text{ years} \tag{3-23}$$

These values satisfactorily agree with the output values in WP05GCFractionWPFailedTable.txt and WP05GCFractionWPFailed.BMP files. The graph in Figure 3-13, created in WP05GCFractionFailedExcel.xls, is based on the data in WP05GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0 and 10^6 years. Both WP05GCFractionWPFailedTable.txt and WP05GCFraction WPFailed.BMP files confirm that the 0.999 fraction of failed WPs due to general corrosion occurs after more than 1 million years. Figure 3-14 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$\mathrm{WP_{breached\ area}} = \left(\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{gc\ breached\ area}} + \frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{lc\ breached\ area}}\right)\mathrm{A} \tag{3-24}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses is less than one (i.e., $\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}} < 1.0$). Based on the data in WP05GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $\mathrm{f_{gc\ breached\ area}} = \mathrm{f_{lc\ breached\ area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = $40.0\ m^2$.

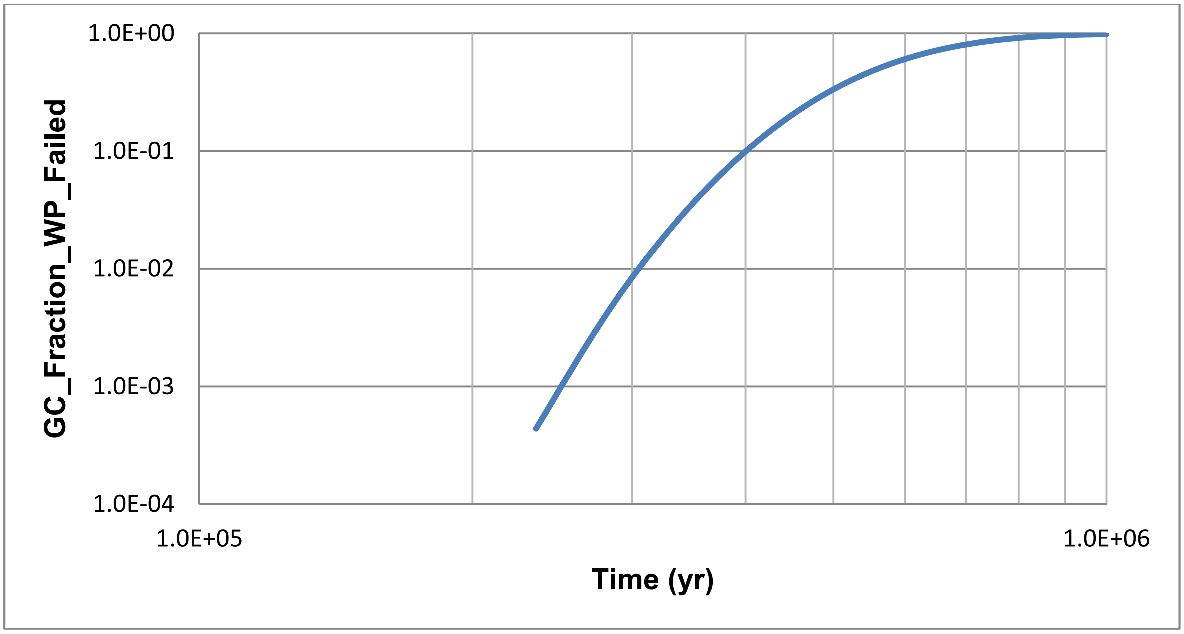


Figure 3-13. WP Failure Fraction From General Corrosion

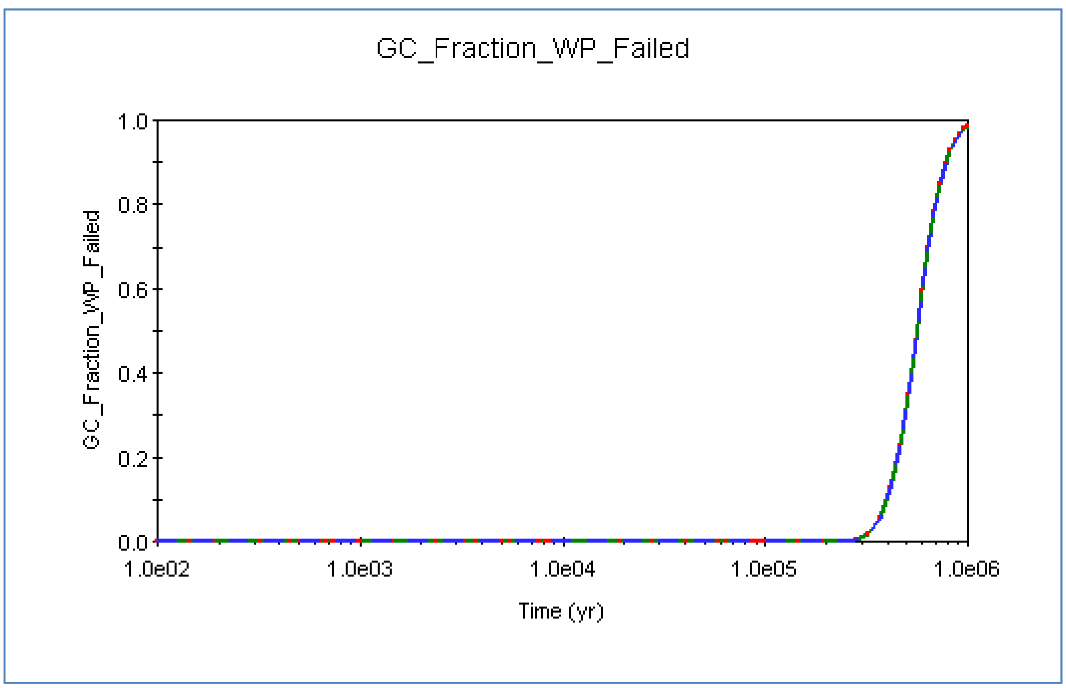


Figure 3-14. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions the breached area per failed WP equals

$$\mathrm{WP}_{\text{breached area}} < (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 < 40.0\ m^2 \tag{3-25}$$

The value agrees with the output value in WP05BreachArea.BMP and WP05BreachAreaTable.txt files. Figure 3-15 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP05BreachArea.BMP. The chart shows that WP breach area equals zero over the first 2.500×10^5 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the 2.500×10^5 -year period.

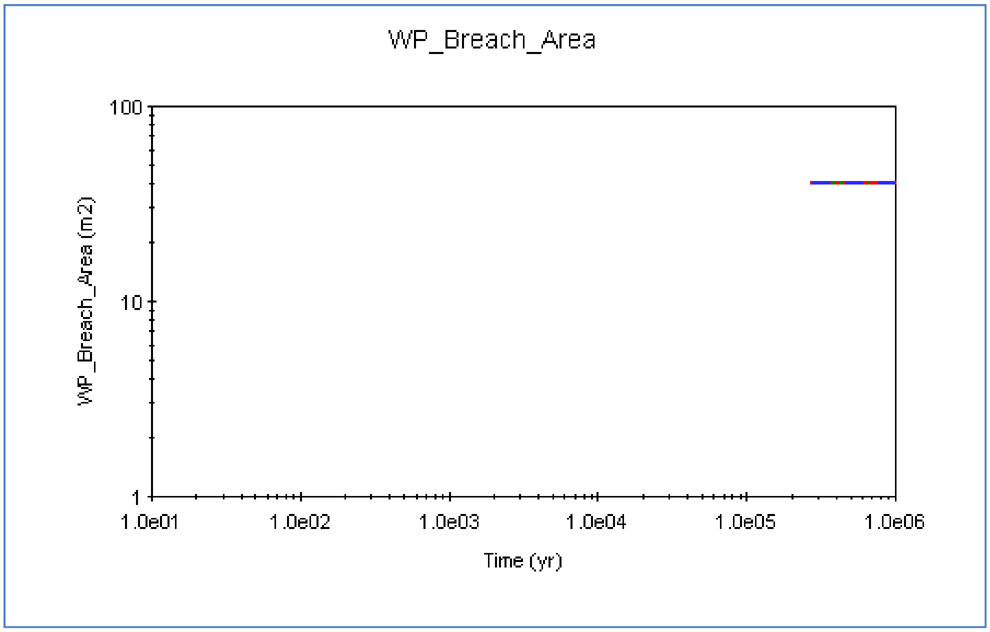


Figure 3-15. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP06
Test Title: WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0cm _Reference Case
Analyst: Razvan Nes
Date: December 02, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Carbon Steel
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	10.0 cm
	Distribution of general corrosion rates	Uniform
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
	Type of disruptive event	None
Level 2	Cu_GC_Ox_Low	15.0 μm/yr
	Cu_GC_Ox_High	150.0 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach fraction implemented

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-26}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.0 and 1.0 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{10.0}{150.0} = 666.7 \text{ years} \tag{3-27}$$

$$t_{gc} = 10^4 \times \frac{10.0}{15.0} = 6{,}667 \text{ years} \tag{3-28}$$

These values satisfactorily agree with the output values in WP06GCFractionWPFailedTable.txt and WP06GCFractionWPFailed.BMP files. The graph in Figure 3-16, created in WP06GCFractionFailedExcel.xls, is based on the data in WP06GCFractionWPFailed Table.txt and shows the fraction of failed WPs between 0.0 and 1.0, which are the values of the fractions marking the initiation and the completion of the WPs failure due to general corrosion. Extrapolating the data in WP06GCFractionWPFailedTable.txt leads to 665.8 and 6,652 years, times at which WP failure is initiated and is completed, respectively. These results agree within 0.1–0.2 percent with Eq. (4-3).

$$t_{gc} = 6400 + \frac{(1 - 0.98227)(6400 - 5950)}{(0.98227 - 0.95061)} = 6{,}652 \text{ years} \tag{3-29}$$

$$t_{gc} = 685 - \frac{(0.011782 - 0.0)(730 - 685)}{(0.039414 - 0.011782)} = 665.8 \text{ years} \tag{3-30}$$

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-31}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} = 1.0$ after 6,667 years).

Based on the data in WP06GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for SOAR Waste Package Model Component, A = constant = $40.0\ m^2$. Figure 3-17 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

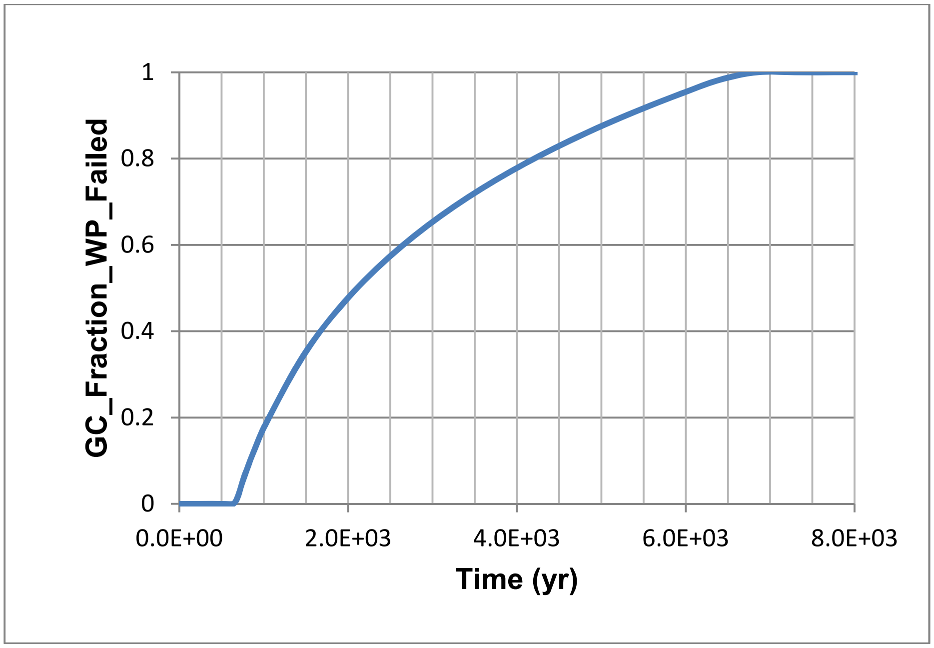


Figure 3-16. WP Failure Fraction From General Corrosion

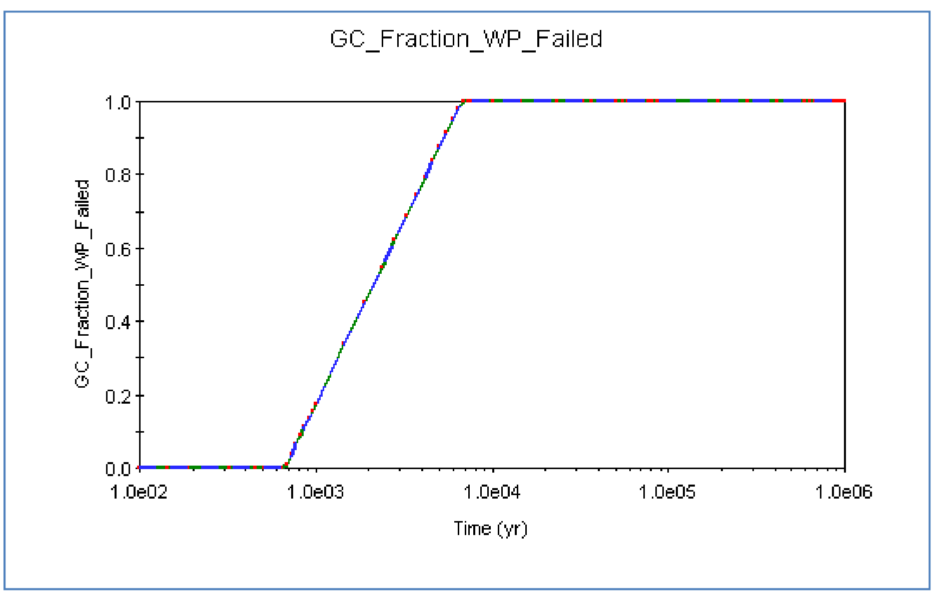


Figure 3-17. WP Failure Fraction From General Corrosion, SOAR Output File

With these assumptions the breached area per failed WP equals the area A of the WP

$$\mathrm{WP}_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40 = 40\ m^2 \qquad (3\text{-}32)$$

Therefore the WP breach fraction is 1.0 after 6,667 years.

The value agrees with the output value in WP06BreachArea.BMP and WP06BreachAreaTable.txt files. Figure 3-18 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP06BreachArea.BMP. The chart shows that the WP breach area equals zero over the first approximately 667 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.0, and it does not occur within the first 667-year period.

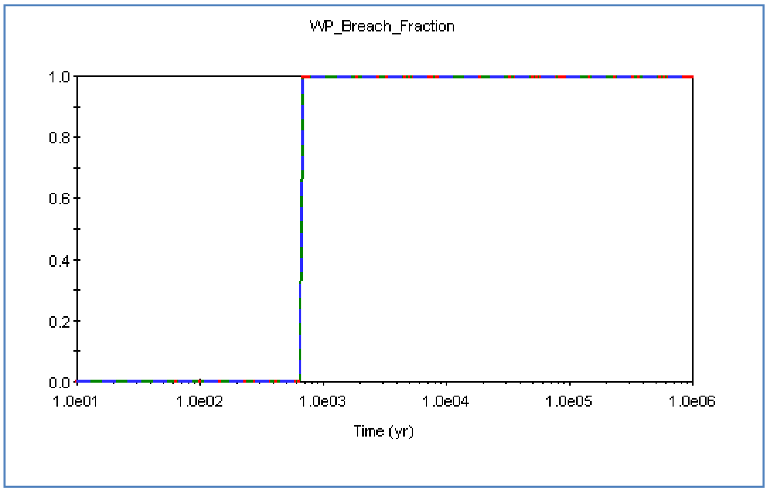


Figure 3-18. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP07

Test Title: WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0cm _5X Corrosion Rates

Analyst: Razvan Nes

Date: December 03, 2010

Test Environment: Frisco, GoldSim 10.11

SOAR Version: Beta 7.2

Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2

Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).

Assumptions: None

Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Carbon Steel
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	10.0 cm
	Distribution of general corrosion rates	Uniform
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
	Type of disruptive event	None
Level 2	Data Source	None
	Cu_GC_Ox_Low	75.0 μm/yr
	Cu_GC_Ox_High	750.0 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach fraction implemented

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time $\mathrm{t_{gc}}$ as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate $\mathrm{R_{gc}}$(µm/yr)

$$\mathrm{t_{gc}} = 10^4 \times \frac{\mathrm{L}}{\mathrm{R_{gc}}} \tag{3-33}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.0 and 1.0 of the WPs have failed, respectively

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{750.0} = 133.3 \text{ years} \tag{3-34}$$

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{75.0} = 1333 \text{ years} \tag{3-35}$$

These values satisfactorily agree with the output values in WP07GCFractionWPFailedTable.txt and WP07GCFractionWP Failed.BMP files. The graph in Figure 3-19, created in WP07GCFractionFailedExcel.xls, is based on the data in WP07GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.0 and 1.0, which are the values of the fractions marking the initiation and the completion of the WPs' failure due to general corrosion. Extrapolating the data in WP07GCFractionWPFailedTable.txt leads to 131.0 and 1,281 years, times at which WP failure is initiated and is completed, respectively. These results satisfactorily agree with Eq. (4-3)

$$t_{gc} = 145 - \frac{(0.036429 - 0.0)(190 - 145)}{(0.15381 - 0.036429)} = 131.0\ yr \tag{3-36}$$

$$t_{gc} = 1000 + \frac{(1 - 0.87506)(1000 - 955)}{(0.87506 - 0.85506)} = 1281\ yr \tag{3-37}$$

The times for the beginning and the end of the WP failure process are, in this case, five times shorter than the times in WP06TestReport_12_02_2010, consistent with corrosion rates five times higher.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$\mathrm{WP_{breached\ area}} = \left(\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{gc\ breached\ area}} + \frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{lc\ breached\ area}}\right)\mathrm{A} \tag{3-38}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}} = 1.0$ after $1{,}333$ years). Based on the data in WP07GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}} = 0.00$). In both cases, minimum general corrosion breach area fraction and

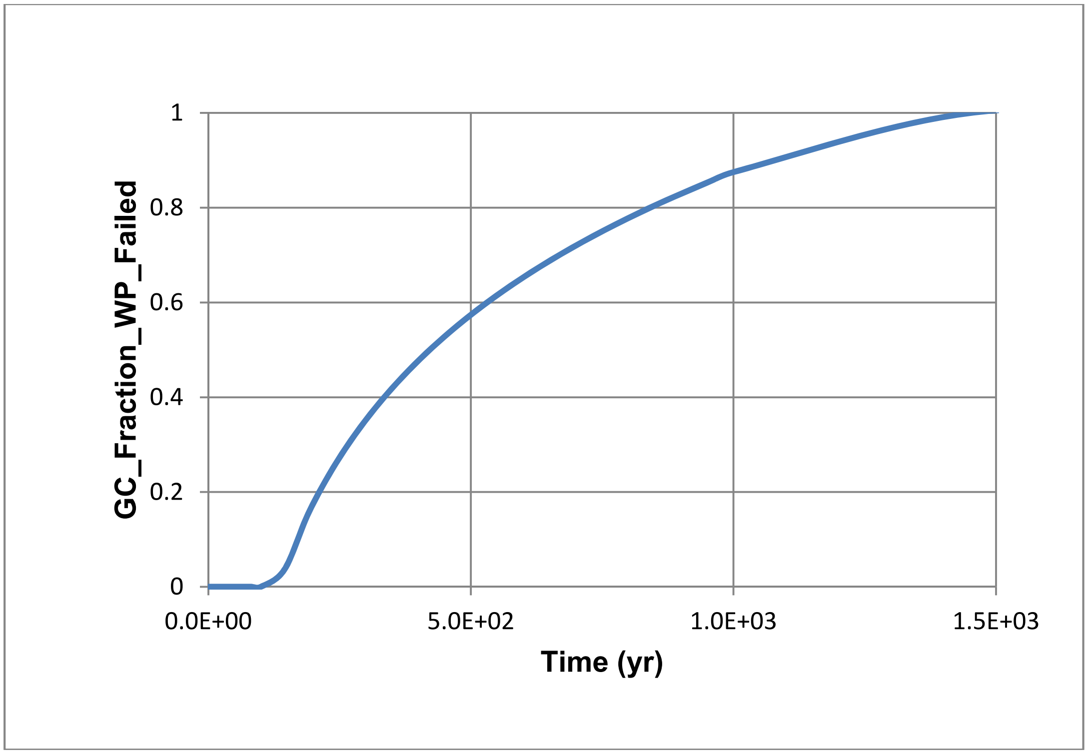


Figure 3-19. WP Failure Fraction From General Corrosion

maximum general corrosion breach area fraction are set to one (i.e., $f_{gc\ breached\ area} = f_{lc\ breached\ area} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = $40.0\ m^2$. Figure 3-20 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

With these assumptions the breached area per failed WP equals the area A of the WP after 1,333 years

$$WP_{breached\ area} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40 = 40\ m^2 \tag{3-39}$$

Therefore the corresponding WP breach fraction is 1.0.

The value agrees with the output value in WP07BreachArea.BMP and WP07BreachAreaTable.txt files. Figure 3-21 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP07BreachArea.BMP. The chart shows that the WP breach area equals zero over the first approximately 133 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.0, so it does not occur within the first approximately 133-year period.

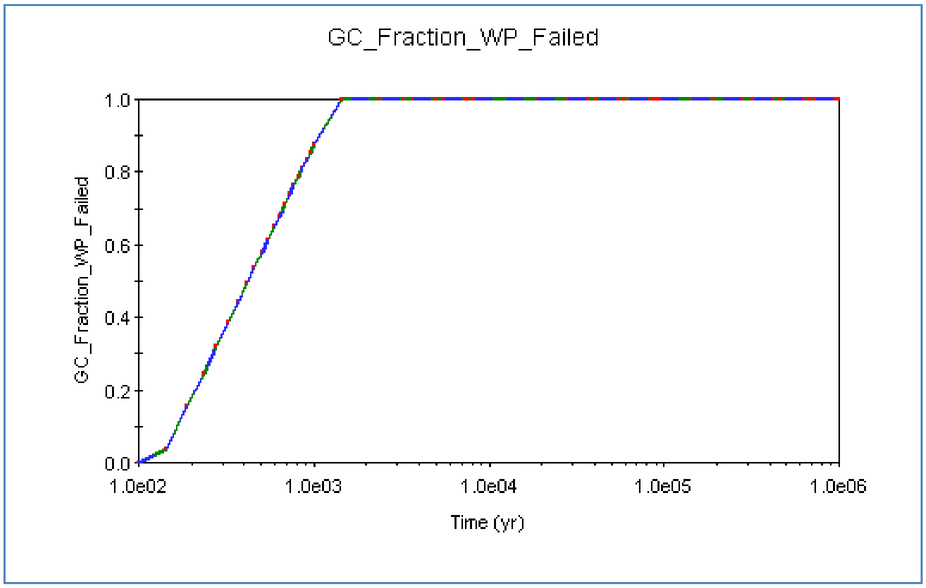


Figure 3-20. WP Failure Fraction From General Corrosion, SOAR Output File

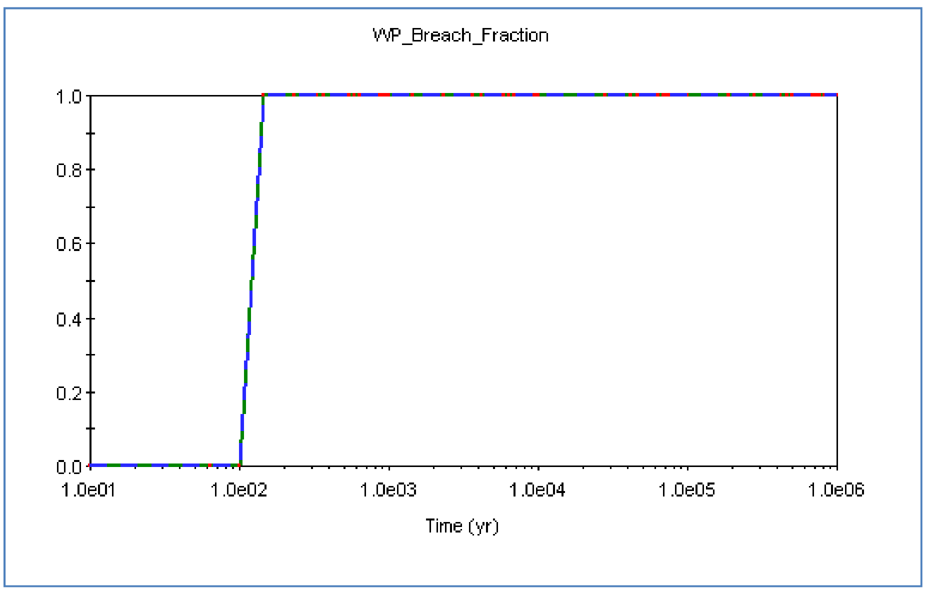


Figure 3-21. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID:	WP08		
Test Title:	WP Failure Time and Breached Area for CS_porous_rock_oxidizing_10.0cm _0.1X Corrosion Rates		
Analyst:	Razvan Nes		
Date:	December 03, 2010		
Test Environment:	Frisco, GoldSim 10.11		
SOAR Version:	Beta 7.2		
Run Directory:	Gryphon, D:\Public\razvan\SOAR_beta_V7.2		
Test Objective:	Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).		
Assumptions:	None		
Test Configuration:	Simulation Settings	Number of realizations	10
		Number of timesteps	95
	Dashboard	Waste package material	Carbon Steel
		Far Field Leg One, Geologic Media	Porous Rock
		Far Field Leg One, Redox Condition	Oxidizing
		Define waste package thickness	On
		Waste package thickness	10.0 cm
		Distribution of general corrosion rates	Uniform
		Scale of distribution of general corrosion rates	Logarithmic
		Minimum general corrosion breach area fraction	1.0
		Maximum general corrosion breach area fraction	1.0
		Disable localized corrosion	Checked
		Type of disruptive event	None
	Level 2	Data Source	None
		Cu_GC_Ox_Low	1.5 μm/yr
		Cu_GC_Ox_High	15.0 μm/yr
		Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm
Result Parameters:	Results_Waste_Package, Waste package failure fraction from general corrosion Results_Waste_Package, Waste package failure fraction from localized corrosion Results_Waste_Package, Waste package breach fraction implemented		
Success Criteria:	Output should agree with equations in NRC (2010b, Chapter 4.2.2).		

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time $\mathrm{t_{gc}}$ as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate $\mathrm{R_{gc}}$(μm/yr)

$$\mathrm{t_{gc}} = 10^4 \times \frac{\mathrm{L}}{\mathrm{R_{gc}}} \tag{3-40}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.0 and 1.0 of the WPs have failed, respectively

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{15.0} = 6667 \text{ years} \tag{3-41}$$

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{1.5} = 6.667 \times 10^4 \text{ years} \tag{3-42}$$

These values satisfactorily agree with the output values in WP08GCFractionWPFailedTable.txt and WP08GCFractionWP Failed.BMP files. The graph in Figure 3-22, created in WP08GCFractionFailedExcel.xls, is based on the data in WP08GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.0 and 1.0, which are the values of the fractions marking the initiation and the completion of the WPs failure due to general corrosion. Extrapolating the data in WP08GCFractionWPFailedTable.txt leads to 6,658 and 6.652×10^4 years, times at which WP failure is initiated and is completed, respectively. These results agree within 0.1–0.2 percent with Eq. (4-3).

$$t_{gc} = 6{,}850 - \frac{(0.011782 - 0.0)(7300 - 6850)}{(0.39414 - 0.011782)} = 6{,}658 \text{ years} \tag{3-43}$$

$$t_{gc} = 64{,}000 + \frac{(1 - 0.98227)(64000 - 59500)}{(0.98227 - 0.95061)} = 6.652 \times 10^5 \text{ years} \tag{3-44}$$

The times for the beginning and the end of the WP failure process are, in this case, 10 times longer than the times in WP06TestReport_12_02_2010, consistent with corrosion rates 5 times lower.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$\mathrm{WP_{breached\ area}} = \left(\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{gc\ breached\ area}} + \frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{lc\ breached\ area}}\right)\mathrm{A} \tag{3-45}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}} = 1.0$ after 6.667×10^4 years). Based on the data in WP08GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $\mathrm{f_{gc\ breached\ area}} = \mathrm{f_{lc\ breached\ area}} = 1.0$). Figure 3-23 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

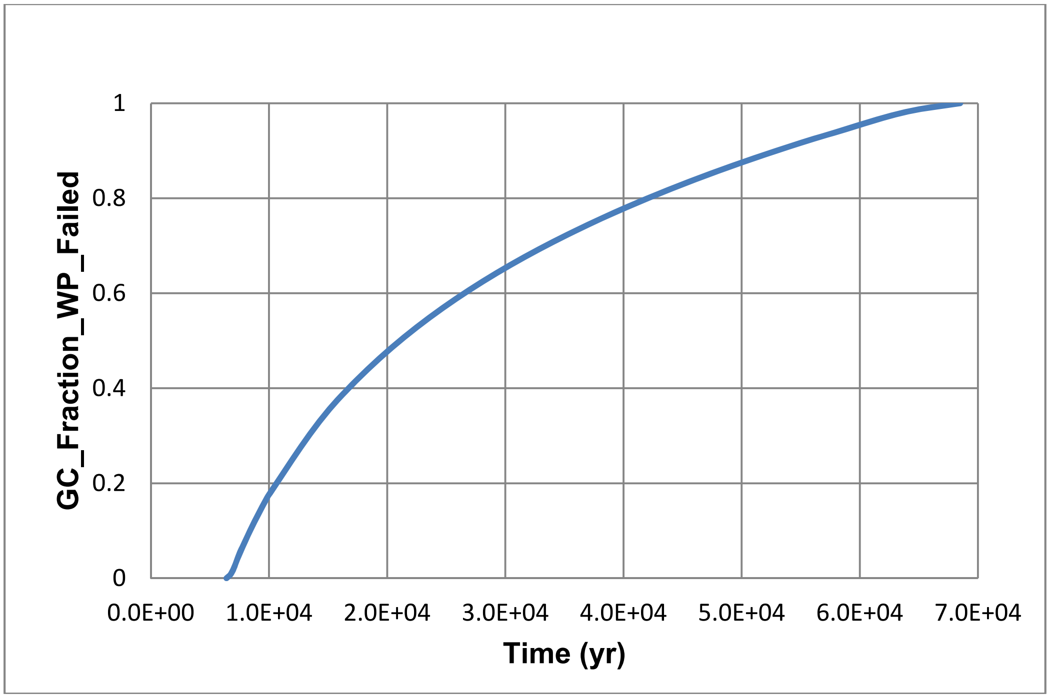


Figure 3-22. WP Failure Fraction From General Corrosion

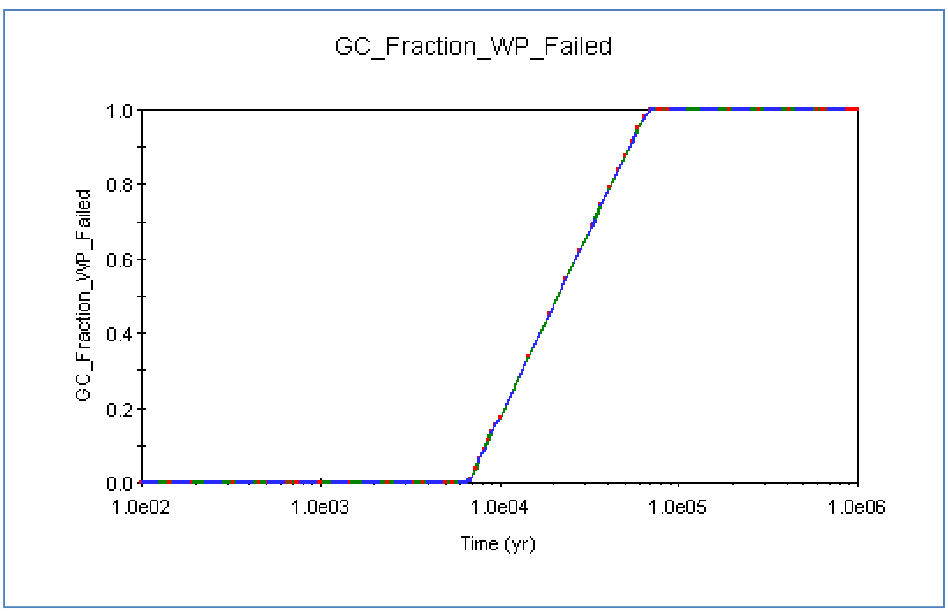


Figure 3-23. WP Failure Fraction From General Corrosion, SOAR Output File

As per Beta-SOAR User Guide (NRC, 2010b, Table A–2), Default Parameter for SOAR Waste Package Model Component, A = constant = $40.0\ m^2$. With these assumptions, after 6.667×10^4 years, the breached area per failed WP equals the area A of the WP

$$\mathrm{WP}_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40 = 40\ m^2 \quad (3\text{-}46)$$

Therefore the WP breach fraction is 1.0.

The value agrees with the output value in WP08BreachArea.BMP and WP08BreachAreaTable.txt files. Figure 3-24 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP08BreachArea.BMP. The chart shows that WP breach area equals zero over the first approximately 6,700 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.0, so it does not occur within the first approximately 6,700-year period.

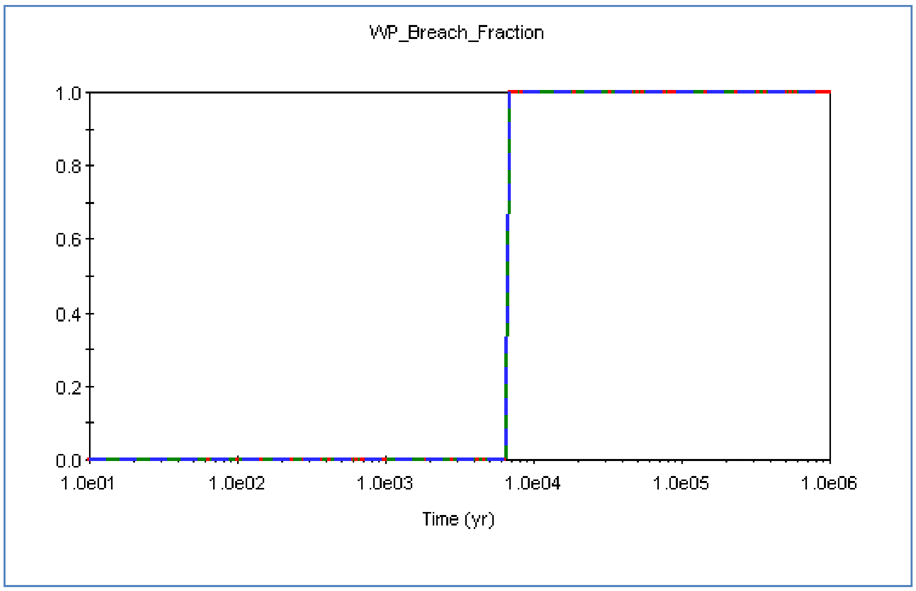


Figure 3-24. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP09

Test Title: WP Failure Time and Breached Area for Carbon Steel_fractured_rock_reducing_10.0cm _Reference Case

Analyst: Razvan Nes

Date: December 6, 2010

Test Environment: Frisco, GoldSim 10.11

SOAR Version: Beta 7.2

Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2

Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).

Assumptions: None

Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Carbon Steel
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	10.0 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
	Type of disruptive event	None
Level 2	Cu_GC_Ox_Low	0.1 µm/yr
	Cu_GC_Ox_High	10.0 µm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time $\mathrm{t_{gc}}$ as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate $\mathrm{R_{gc}}$(μm/yr)

$$\mathrm{t_{gc}} = 10^4 \times \frac{\mathrm{L}}{\mathrm{R_{gc}}} \tag{3-47}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{10.0} = 1.0 \times 10^4 \text{ years} \tag{3-48}$$

$$\mathrm{t_{gc}} = 10^4 \times \frac{10.0}{0.1} = 1.0 \times 10^6 \text{ years} \tag{3-49}$$

These values satisfactorily agree with the output values in WP09GCFractionWPFailedTable.txt and WP09GCFractionWPFailed.BMP files. The graph in Figure 3-25, created in WP09GCFractionFailedExcel.xls, is based on the data in WP09GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.999, which are the values of the fractions marking the initiation and the completion of the WPs' failure due to general corrosion.

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$\mathrm{WP_{breached\ area}} = \left(\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{gc\ breached\ area}} + \frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{lc\ breached\ area}}\right)\mathrm{A} \tag{3-50}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}} = 1.0$) at the end of the 1-million-year simulation. Based on the data in WP08GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $\mathrm{f_{gc\ breached\ area}} = \mathrm{f_{lc\ breached\ area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for SOAR Waste Package Model Component, A = constant = $40.0\ m^2$.

With these assumptions, after 1.0×10^6 years, the breached area per failed WP equals the area A of the WP

$$\mathrm{WP_{breached\ area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40 = 40\ m^2 \tag{3-51}$$

and the WP breach fraction is 1.0.

Figure 3-26 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

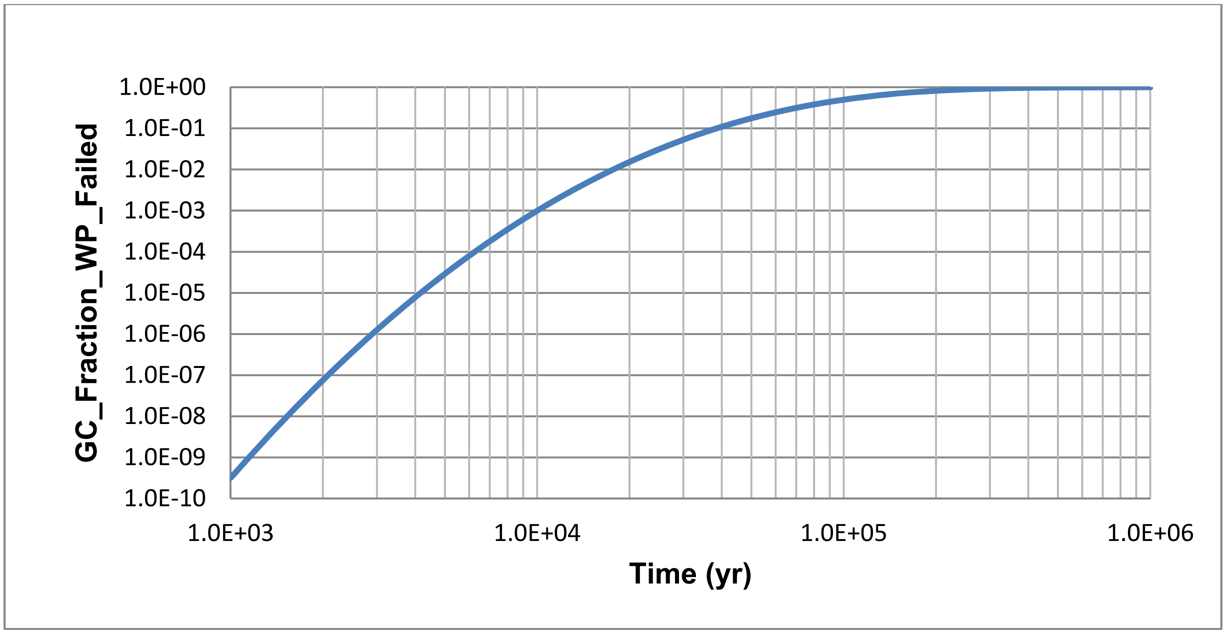


Figure 3-25. WP Failure Fraction From General Corrosion

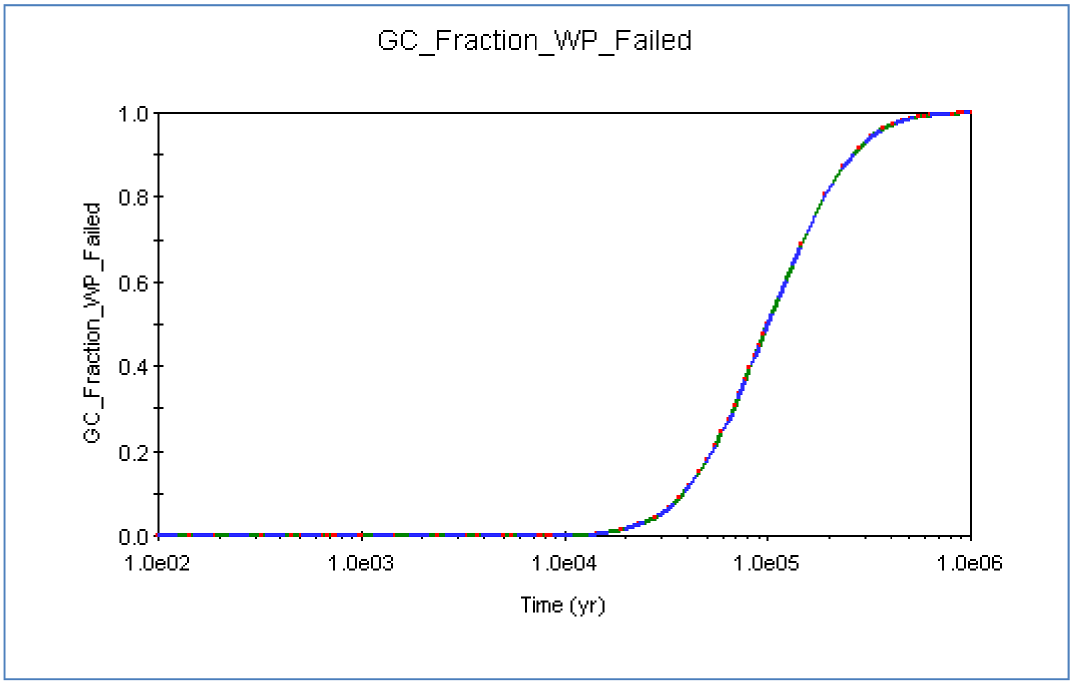


Figure 3-26. WP Failure Fraction From General Corrosion, SOAR Output File

The value agrees with the output value in WP08BreachArea.BMP and WP08BreachAreaTable.txt files. Figure 3-27 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP08BreachArea.BMP. The chart shows that the WP breach area equals zero over the first 10,000 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the first approximately 10,000-year period.

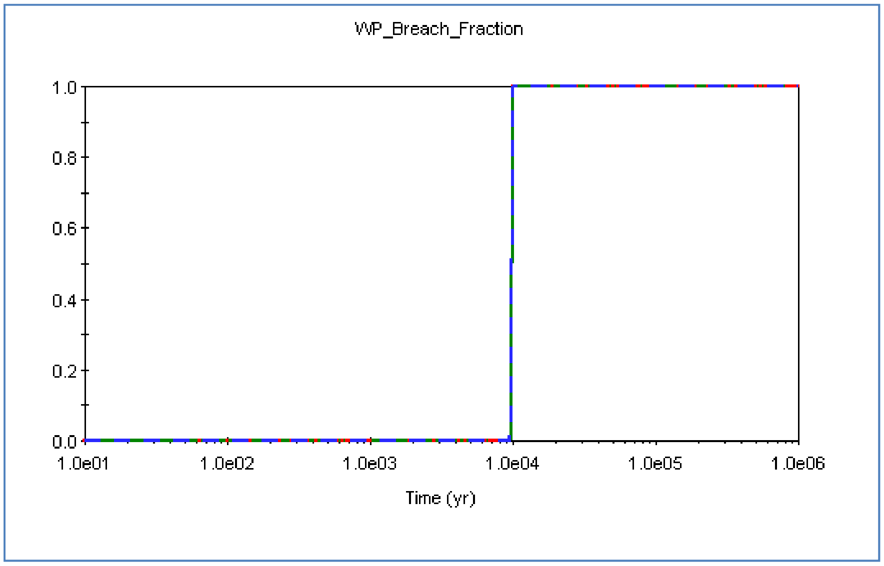


Figure 3-27. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP10
Test Title: WP Failure Time and Breached Area for Stainless Steel_porous_rock_oxidizing_5.0cm _Reference Case
Analyst: Razvan Nes
Date: December 6, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Stainless Steel
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	5.0 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
	Type of disruptive event	None
Level 2	Cu_GC_Ox_Low	0.01 μm/yr
	Cu_GC_Ox_High	3.0 μm/yr
	LC_FailureTime_Period_I	Log-Uniform, 30–280 yr
	LC_FailureTime_Period_II	Log-Uniform, 280–100,000 yr
	SS_LC_Period_I_Oxidizing	Triangular, 0.25, 0.45, 0.5 μm/yr
	SS_LC_Period_II_Oxidizing	0.0
	LC_FractioAreaBreached	Triangular, 0.001, 0.1216, 0.2 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters: Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-52}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{5.0}{3.0} = 1.667 \times 10^4 \text{ years} \tag{3-53}$$

$$t_{gc} = 10^4 \times \frac{5.0}{0.01} = 5.0 \times 10^6 \text{ years} \tag{3-54}$$

These values satisfactorily agree with the output values in WP10GCFractionWPFailedTable.txt and WP10GCFractionWP Failed.BMP files. The graph in Figure 3-28, created in WP10GCFractionFailedExcel.xls, is based on the data in WP10GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 (initiation of the failure due to general corrosion) and the fraction of failed WPs at the end of the 1-million year simulation period. Both WP10GCFractionWPFailedTable.txt and WP10GCFractionWPFailed.BMP files confirm that the 0.999 fraction of failed WPs due to general corrosion occurs in more than 1 million years, consistent with the value of 5 million years calculated with NRC [2010b, Eq. (4-3)]. Figure 3-28 also indicates that the failure process is initiated at approximately 1.7×10^4 years, consistent with 1.667×10^4 years calculated with Eq. (4-3). SOAR output file WP10GCFractionWPFailedTable.txt indicates that the WP failure fraction from general corrosion at the end of simulation period is 0.9109, less than 0.999.

WP failure fraction due to localized corrosion illustrated in Figure 3-30 starts approximately 30 years into the simulation and reaches a plateau starting at approximately 280 years at a mean value of approximately 0.45. Figure 3-29 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion. Figure 3-30 shows the original SOAR output chart of the fraction of failed WPs due to localized corrosion.

(2) The WP breach fraction over a 1-million-year simulation time is shown in Figure 3-31. The breach fraction shows a first plateau between 280 and 1.667×10^4 years. Based on the output data in WP10BreachAreaTable.txt, the WP10BreachAreaExcel.xls file was generated, as well as the plot shown in Figure 3-32. A constant WP area of 40 m^2 is considered in all calculations.

As expected, the mean WP failed area due to general corrosion and localized corrosion is less than 10 m^2 between approximately 280 and 1.667×10^4 years. After the general corrosion process is initiated, the WP breach area increases to 40 m^2.

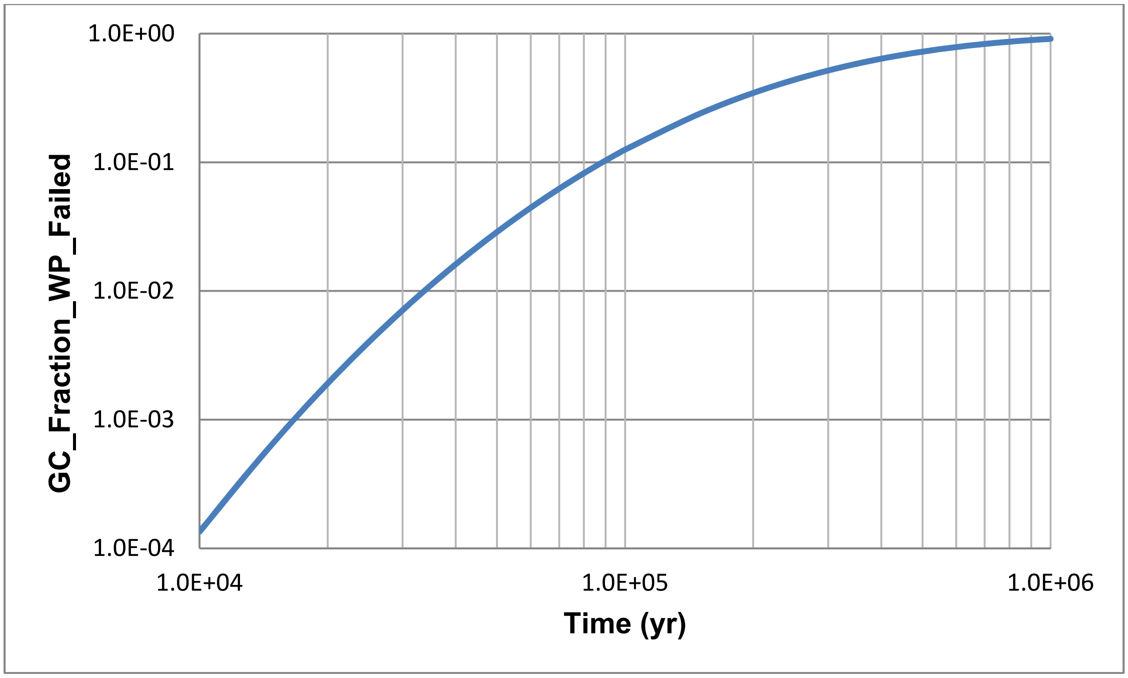


Figure 3-28. WP Failure Fraction From General Corrosion

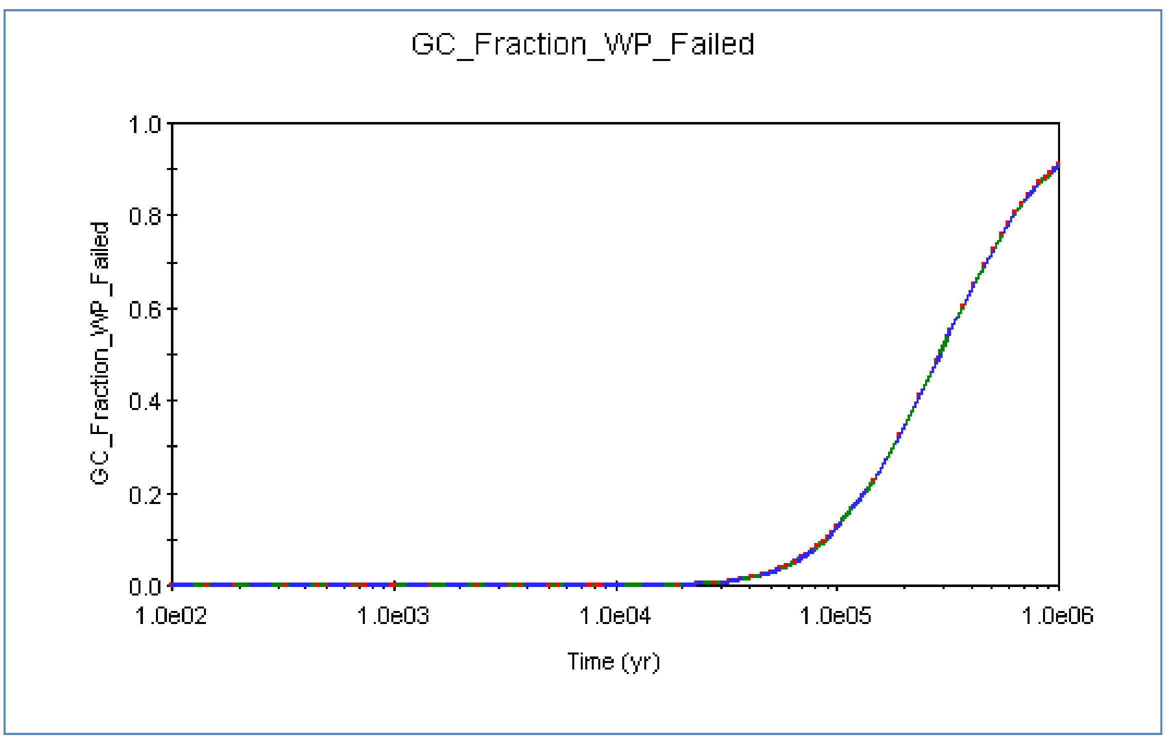


Figure 3-29. WP Failure Fraction From General Corrosion, SOAR Output File

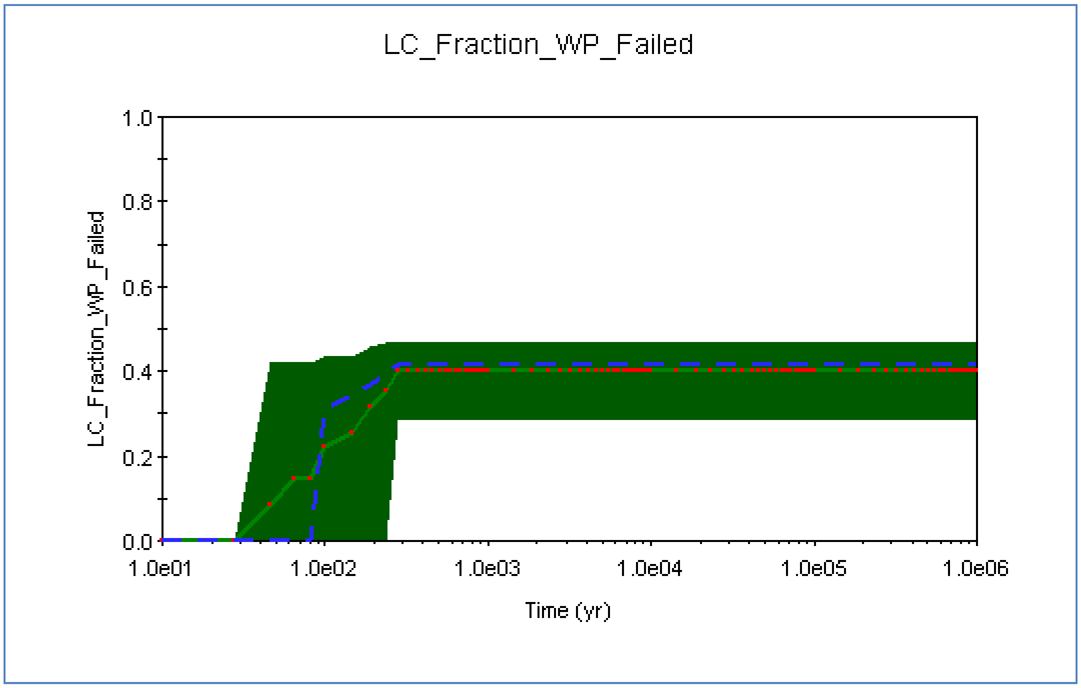


Figure 3-30. WP Failure Fraction From Localized Corrosion, SOAR Output File

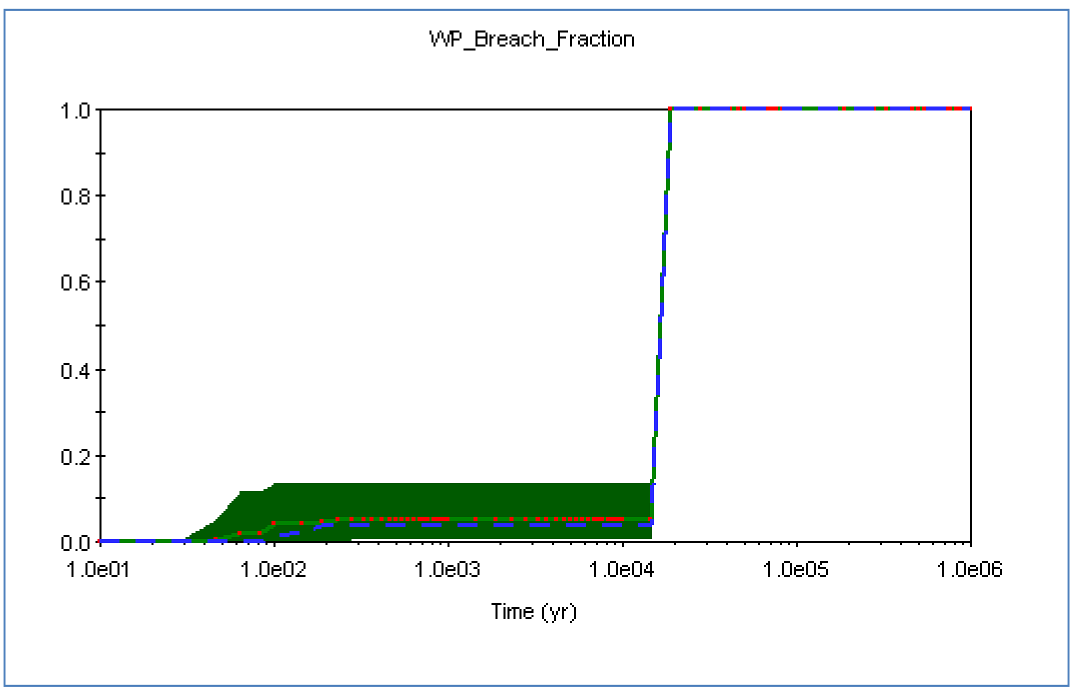


Figure 3-31. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

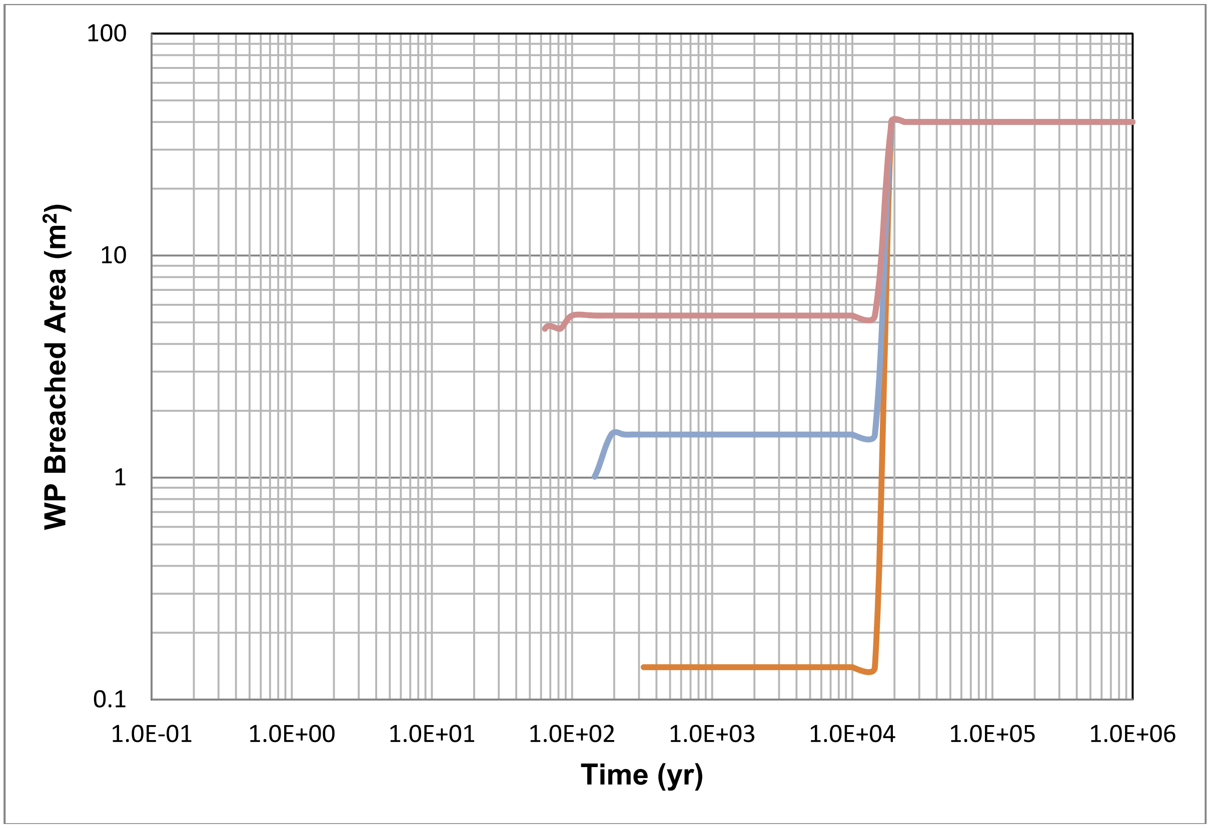


Figure 3-32. SOAR Output Chart of the Breached Area Per Failed WP

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID:	WP11		
Test Title:	WP Failure Time and Breached Area for Stainless Steel_fractured_rock_reducing_5.0cm _Reference Case		
Analyst:	Razvan Nes		
Date:	December 7, 2010		
Test Environment:	Frisco, GoldSim 10.11		
SOAR Version:	Beta 7.2		
Run Directory:	Gryphon, D:\Public\razvan\SOAR_beta_V7.2		
Test Objective:	Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).		
Assumptions:	None		
Test Configuration:	Simulation Settings	Number of realizations	10
		Number of timesteps	95
	Dashboard	Waste package material	Stainless Steel
		Far Field Leg One, Geologic Media	Fractured Rock
		Far Field Leg One, Redox Condition	Reducing
		Define waste package thickness	On
		Waste package thickness	5.0 cm
		Distribution of general corrosion rates	Normal
		Scale of distribution of general corrosion rates	Logarithmic
		Minimum general corrosion breach area fraction	1.0
		Maximum general corrosion breach area fraction	1.0
		Disable localized corrosion	Checked
		Type of disruptive event	None
	Level 2	Cu_GC_Anox_Low	0.003 μm/yr
		Cu_GC_Anox_High	0.1 μm/yr
		LC_FailureTime_Period_I	Log-Uniform, 30–280 yr
		LC_FailureTime_Period_II	Log-Uniform, 280–100,000
		SS_LC_Period_I_Reducing	Triangular, 0.0, 0.125, 0.25 μm/yr
		SS_LC_Period_II_ Reducing	Uniform, 0.01, 0.1 μm/yr
		LC_FractioAreaBreached	Log-Triangular, 0.001, 0.1216, 0.2 μm/yr
		Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm
Result Parameters:	Results_Waste_Package, Waste package failure fraction from general corrosion Results_Waste_Package, Waste package failure fraction from localized corrosion Results_Waste_Package, Waste package breach area		
Success Criteria:	Output should agree with equations in NRC (2010b, Chapter 4.2.2).		

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-55}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{5.0}{0.1} = 5.0 \times 10^5 \text{ years} \tag{3-56}$$

$$t_{gc} = 10^4 \times \frac{5.0}{0.003} = 1.667 \times 10^7 \text{ years} \tag{3-57}$$

These values satisfactorily agree with the output values in WP11GCFractionWPFailedTable.txt and WP11GCFractionWP Failed.BMP files. The graph in Figure 3-33, created in WP11GCFractionFailedExcel.xls, is based on the data in WP11GCFractionWPFailed Table.txt and shows that the fraction of failed WPs above 0.001, which is the value of the fraction marking the initiation of the WPs failure due to general corrosion, occurs at 5.0×10^5 years into the simulation, consistent with NRC [2010b, Eq. (4-3)]. WP11GCFractionWPFailedTable.txt and WP11GCFractionWPFailed.BMP files confirm that the 0.999 fraction of failed WPs due to general corrosion occurs in more than 1 million years, consistent with the value of 1.667×10^7 years calculated with Eq. (4-3). Figure 3-34 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

WP failure fraction due to localized corrosion illustrated in Figure 3-35 starts approximately 30 years into the simulation and reaches a plateau approximately 280 years into the simulation time, at a mean value of approximately 0.15. Figure 3-36 shows the original SOAR output chart of the fraction of failed WPs due to localized corrosion.

(2) The WP breach fraction over a 1-million-year simulation time is shown in Figure 3-36. The breach fraction shows a plateau value between 280 and 5.0×10^5 years. Based on the output data in WP11BreachAreaTable.txt, the WP11BreachAreaExcel.xls file was generated, as well as the plot shown in Figure 3-37. A constant WP area of 40 m^2 is considered in all calculations.

As expected, the mean WP failed area due to GC and LC is less than 10 m^2 between 280 and approximately 5.0×10^5 years. After the general corrosion is initiated, the WP breach area increases to 40 m^2.

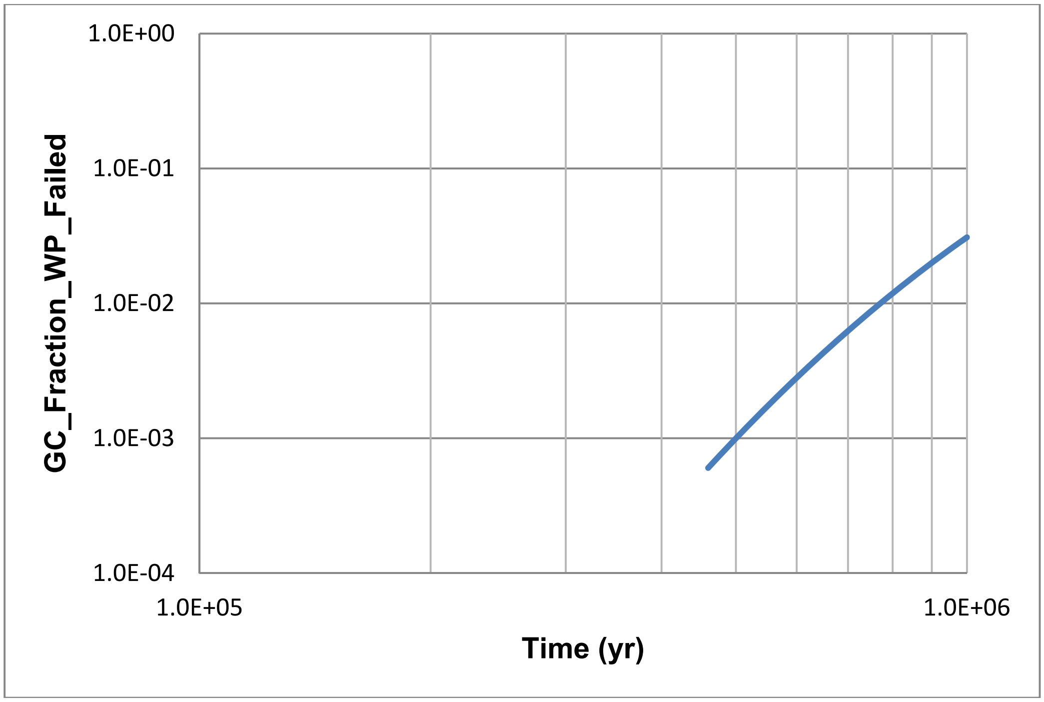


Figure 3-33. WP Failure Fraction From General Corrosion

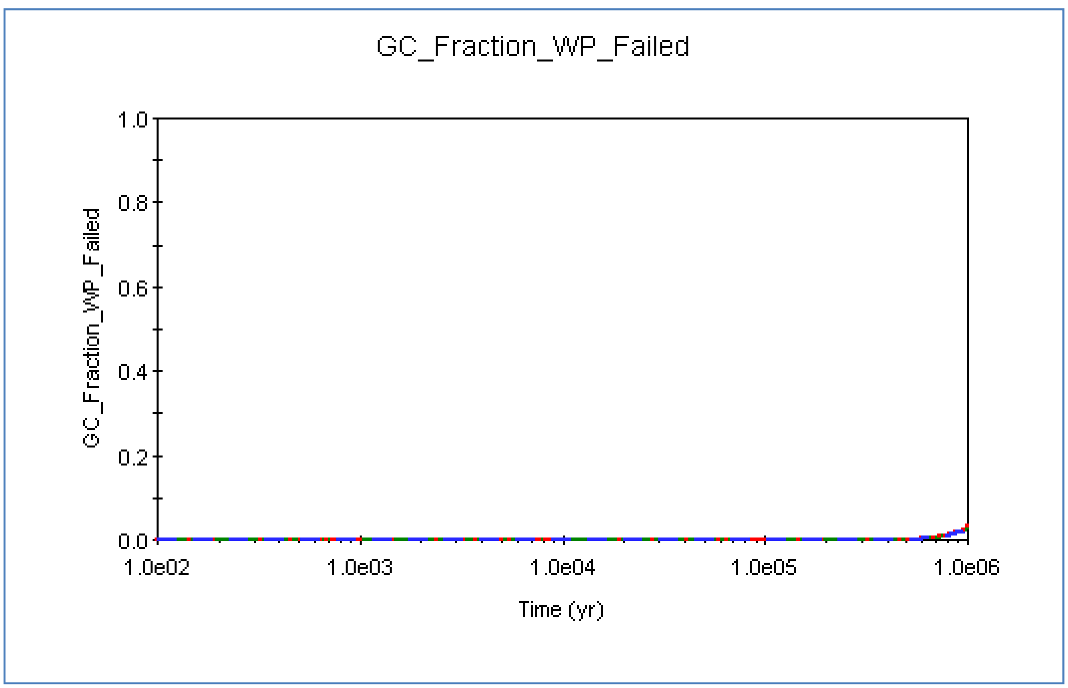


Figure 3-34. WP Failure Fraction From General Corrosion, SOAR Output File

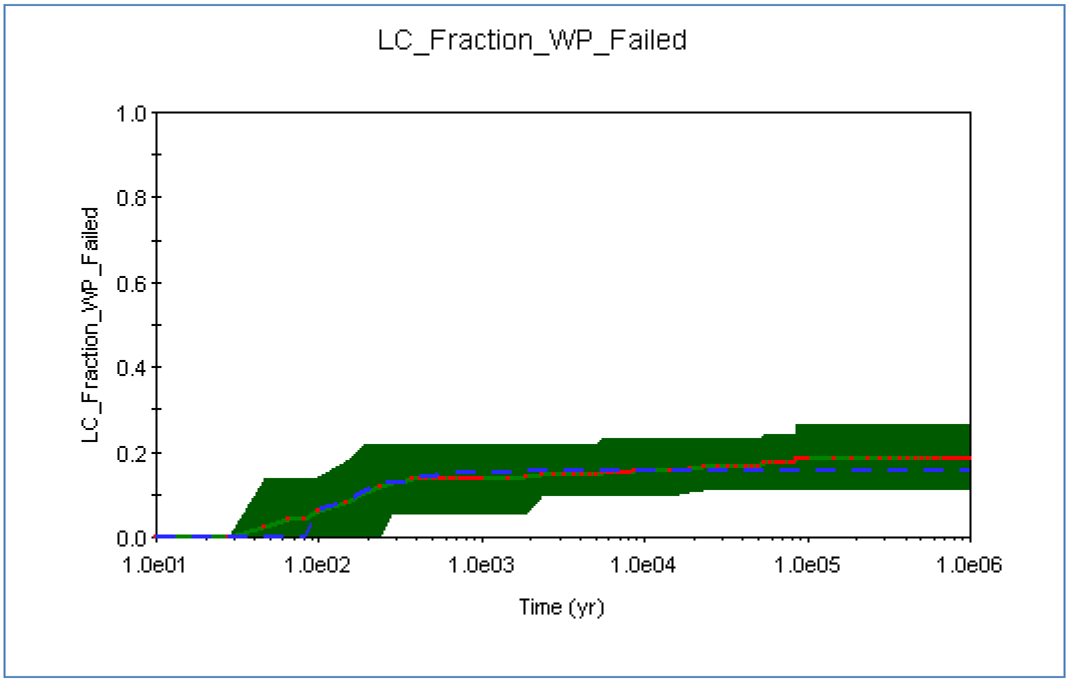


Figure 3-35. WP Failure Fraction From Localized Corrosion, SOAR Output File

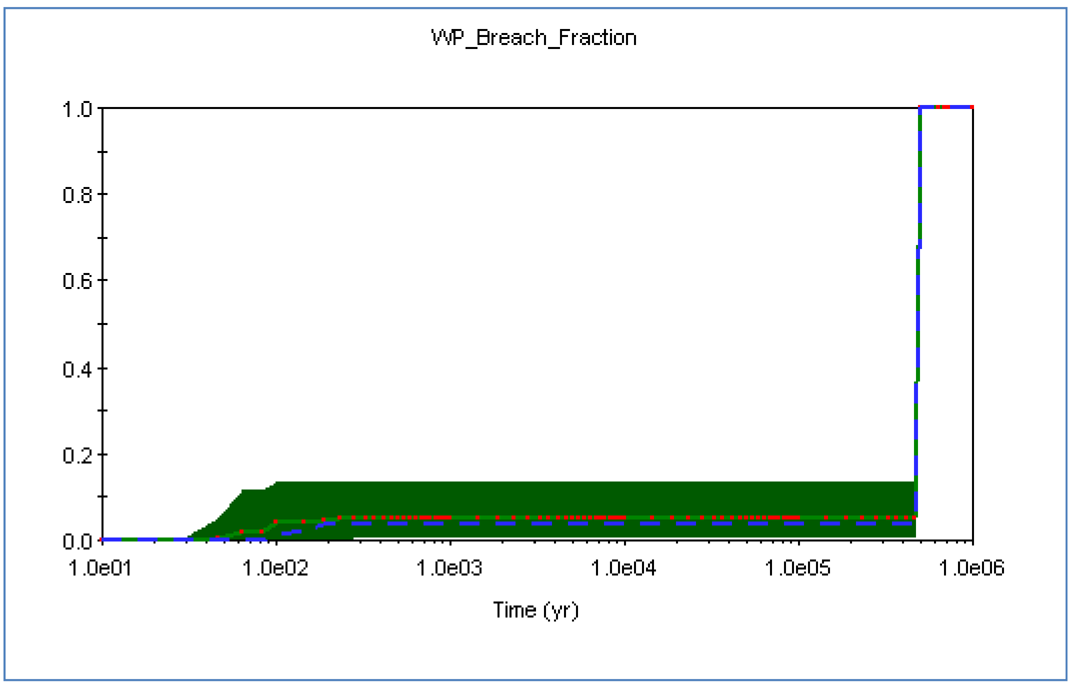


Figure 3-36. SOAR Output Chart of the Breached Area Per Failed WP Due to General Corrosion

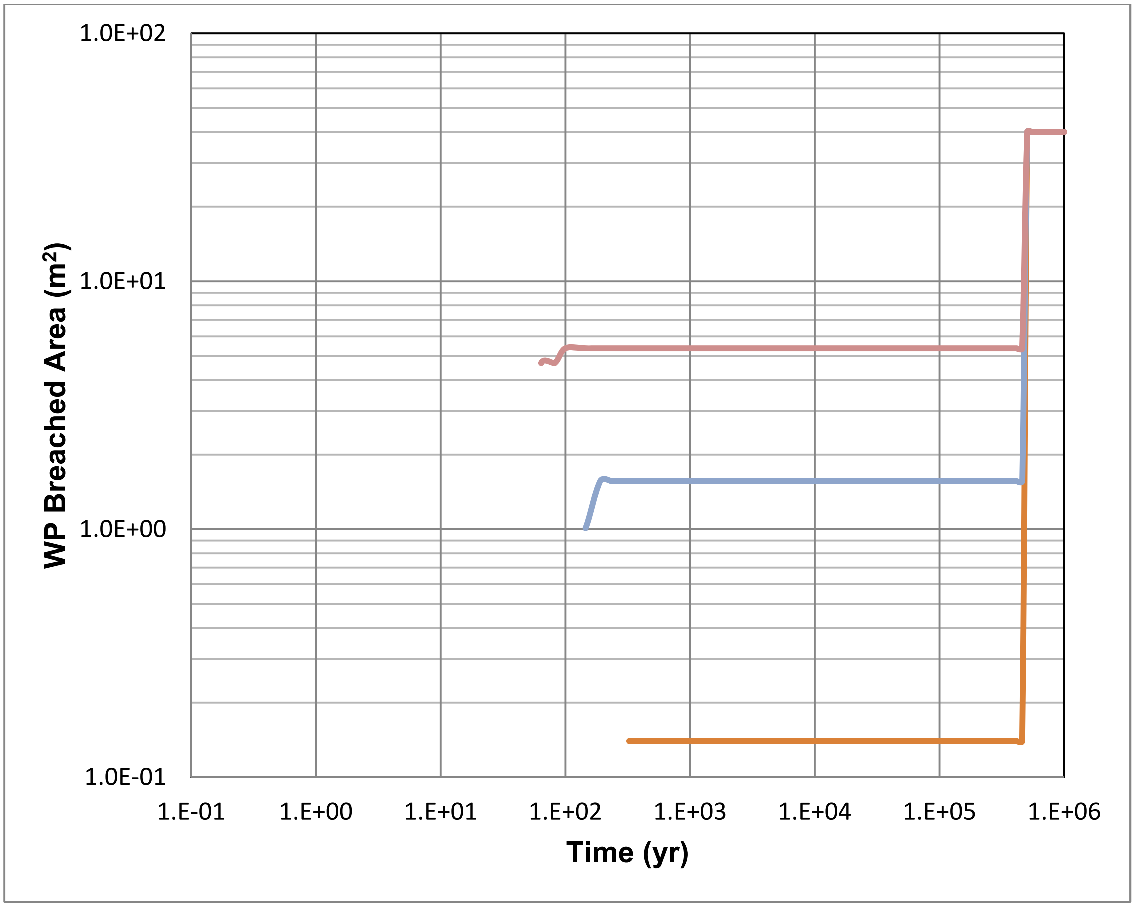


Figure 3-37. SOAR Output Chart of the Breached Area Per Failed WP

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP12
Test Title: WP Failure Time and Breached Area for Stainless Steel_fractured_rock_reducing_5.0cm _2X the Breach Area Fraction
Analyst: Razvan Nes
Date: December 8, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Stainless Steel
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	5.0 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Not Checked
	Type of disruptive event	None
Level 2	Data Source	None
	Cu_GC_Anox_Low	0.003 µm/yr
	Cu_GC_Anox_High	0.1 µm/yr
	LC_FailureTime_Period_I	Log-Uniform, 30–280 yr
	LC_FailureTime_Period_II	Log-Uniform, 280–100,000
	SS_LC_Period_I_Reducing	Triangular, 0.0, 0.125, 0.25 µm/yr
	SS_LC_Period_II_ Reducing	Uniform, 0.01, 0.1 µm/yr
	LC_FractioAreaBreached	Log-Triangular, 0.002, 0.2432, 0.4 µm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

SOAR Verification Test Report (continued)

Result Parameters:	Results_Waste_Package, Waste package failure fraction from general corrosion Results_Waste_Package, Waste package failure fraction from localized corrosion Results_Waste_Package, Waste package breach area
Success Criteria:	Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-58}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{5.0}{0.1} = 5.0 \times 10^5 \text{ years} \tag{3-59}$$

$$t_{gc} = 10^4 \times \frac{5.0}{0.003} = 1.667 \times 10^7 \text{ years} \tag{3-60}$$

These values satisfactorily agree with the output values in WP12GCFractionWPFailedTable.txt and WP12GCFractionWPFailed.BMP files. The graph in Figure 3-38, created in WP12GCFractionFailedExcel.xls, is based on the data in WP12GCFractionWPFailedTable.txt and shows the fraction of failed WPs above 0.001, which is the value of the fraction marking the initiation of the WPs' failure due to general corrosion. WP12GCFractionWPFailedTable.txt and WP12GCFractionWPFailed.BMP files confirm that the 0.999 fraction of failed WPs due to general corrosion occurs in more than 1 million years, consistent with the value of 1.667×10^7 years calculated with NRC [2010b, Eq. (4-3)]. Figure 3-39 also indicates that the failure process is initiated at approximately 5.0×10^5 years, consistent with that calculated with Eq. (4-3).

WP failure fraction due to localized corrosion illustrated in Figure 3-40 starts approximately 30 years into the simulation and reaches a plateau approximately 280 years into the simulation time, at a mean value of approximately 0.15.

(2) The WP breach fraction over a 1-million-year simulation time is shown in Figure 3-41. The breach fraction shows a plateau value between 280 and 5×10^5 years. Based on the output data in WP12BreachAreaTable.txt, the WP12BreachAreaExcel.xls file was generated, as well as the plot shown in Figure 3-42. A constant WP area of 40 m^2 is considered in all calculations.

As expected, the mean WP failed area due to GC and LC is less than 10 m^2 between approximately 280 and 5.0×10^5 years. After the general corrosion process is initiated, the WP breach area increases to 40 m^2.

Figure 3-39 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion. Figure 3-40 shows the original SOAR output chart of the fraction of failed WPs due to localized corrosion.

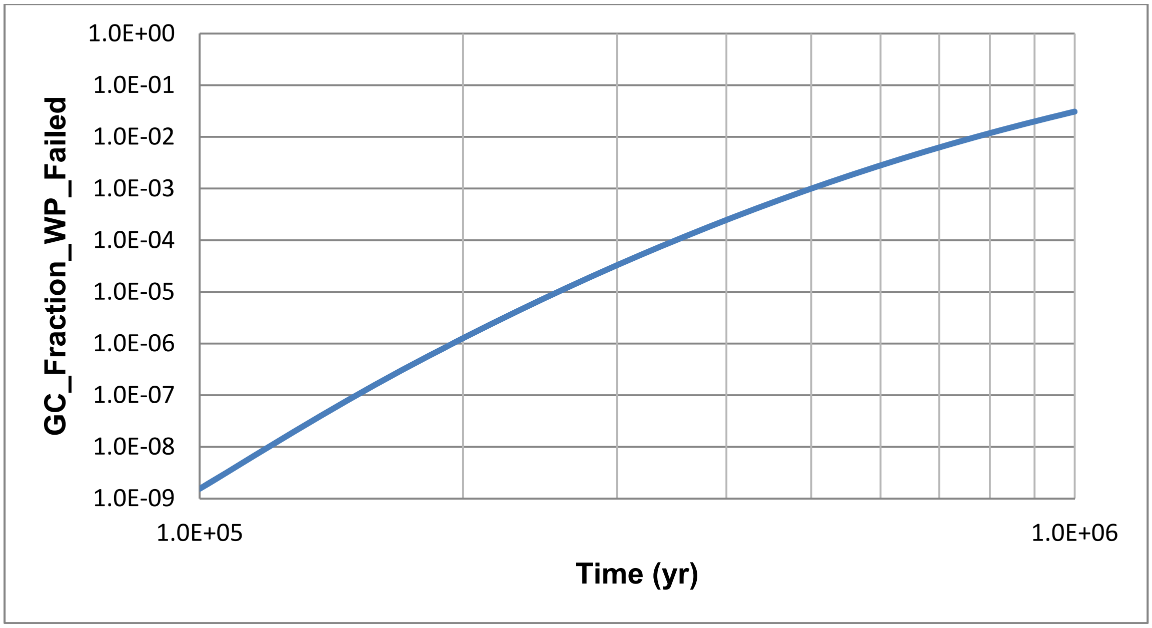


Figure 3-38. WP Failure Fraction From General Corrosion

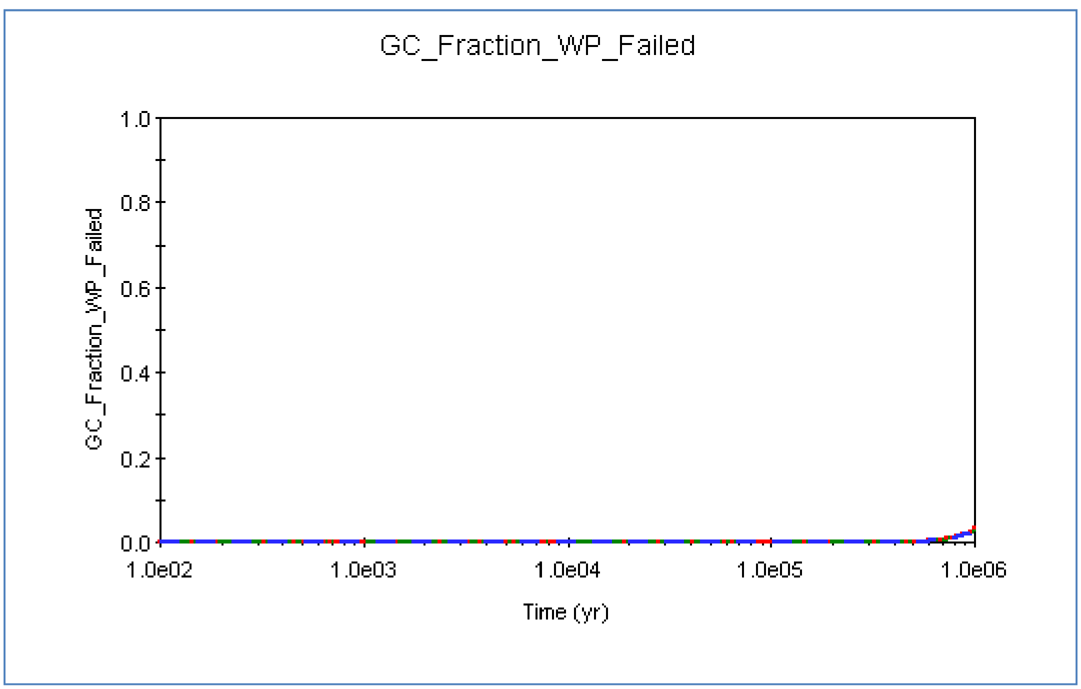


Figure 3-39. WP Failure Fraction From General Corrosion, SOAR Output File

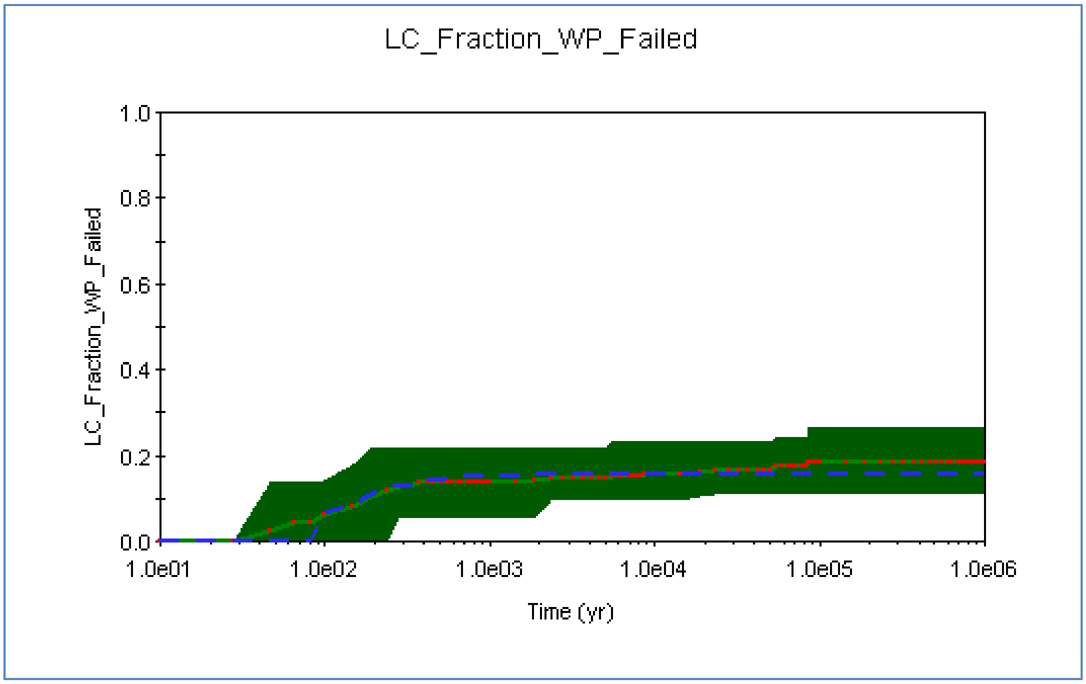


Figure 3-40. WP Failure Fraction From Localized Corrosion, SOAR Output File

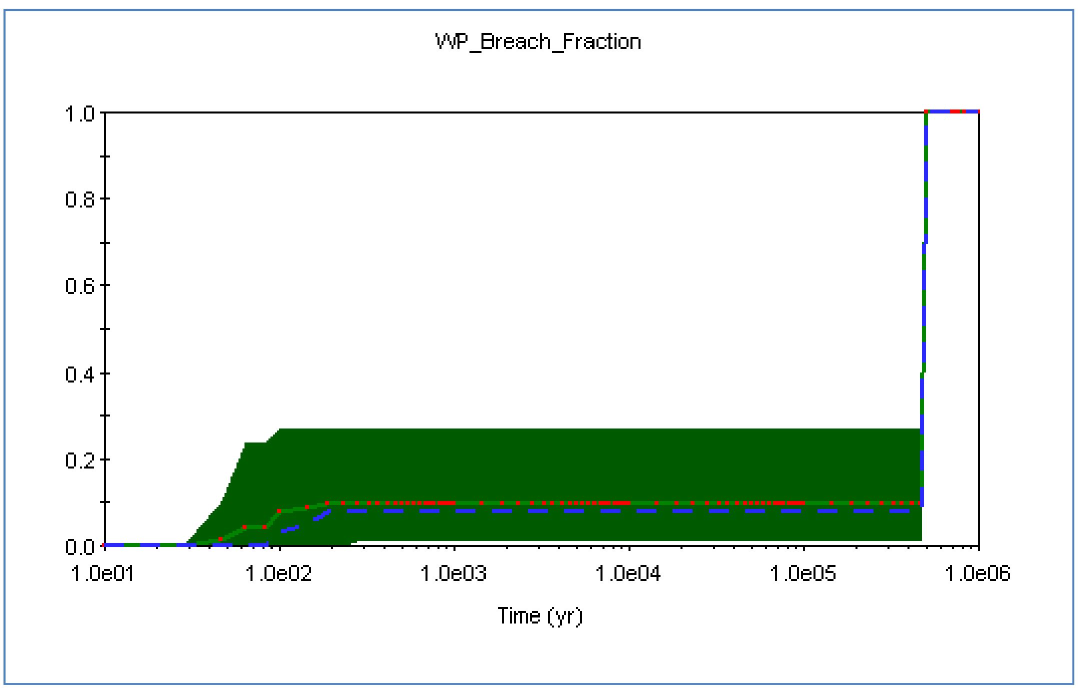


Figure 3-41. SOAR Output Chart of the Breached Area Per Failed WP Due To General Corrosion

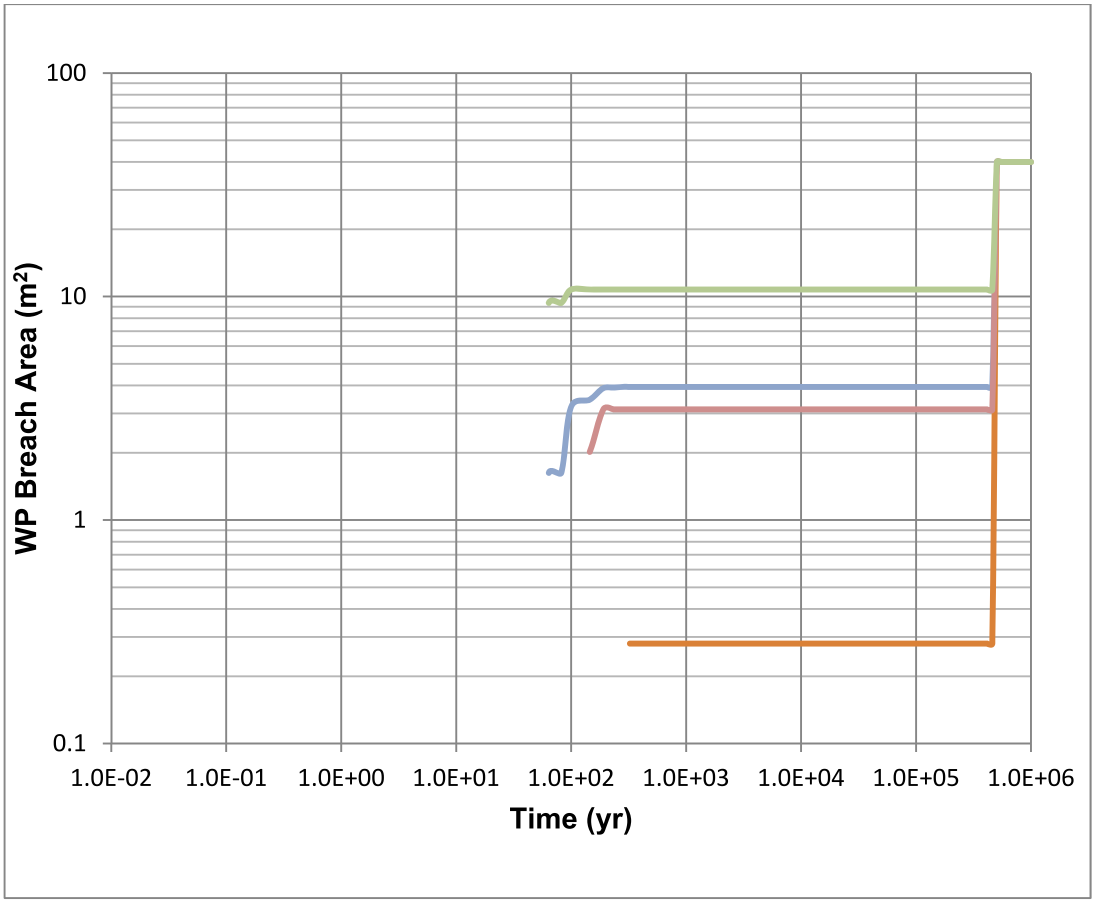


Figure 3-42. SOAR Output Chart of the Breached Area Per Failed WP

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP13
Test Title: WP Failure Time and Breached Area for Ti_porous_rock_oxidizing_1.0 cm _Reference Case
Analyst: Razvan Nes
Date: December 8, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Titanium
	Far Field Leg One, Geologic Media	Porous Rock
	Far Field Leg One, Redox Condition	Oxidizing
	Define waste package thickness	On
	Waste package thickness	1.0 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Ti_GC_Ox_Low	0.008 μm/yr
	Ti_GC_Ox_High	0.2 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time t_{gc} as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate R_{gc}(μm/yr)

$$t_{gc} = 10^4 \times \frac{L}{R_{gc}} \tag{3-61}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$t_{gc} = 10^4 \times \frac{1.0}{0.2} = 5.0 \times 10^4 \text{ years} \tag{3-62}$$

$$t_{gc} = 10^4 \times \frac{1.0}{0.008} = 1.25 \times 10^6 \text{ years} \tag{3-63}$$

These values satisfactorily agree with the output values in WP13GCFractionWPFailedTable.txt and WP13GCFractionWPFailed.BMP files. The graph in Figure 3-43, created in WP13GCFractionFailedExcel.xls, is based on the data in WP13GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.996, which are the values of the fractions marking the initiation of the WPs failure due to general corrosion and the fraction of the WPs failed due to general corrosion at the end of the 1-million-year simulation. The model shows that the WP failure by general corrosion is 0.999 (complete) later than 1 million years, consistent with the value 1.25×10^6 years calculated with NRC [2010b, Eq. (4-3)].

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$WP_{\text{breached area}} = \left(\frac{f_{gc}}{f_{\text{failed WP}}} f_{\text{gc breached area}} + \frac{f_{lc}}{f_{\text{failed WP}}} f_{\text{lc breached area}}\right) A \tag{3-64}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{f_{gc}}{f_{\text{failed WP}}} = 1.0$, after 5.0×10^4 years). Based on the data in WP13GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{f_{lc}}{f_{\text{failed WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $f_{\text{gc breached area}} = f_{\text{lc breached area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = $40.0\ m^2$.

With these assumptions the breached area per failed WP equals the area A of the WP after 5.0×10^4 years. Figure 3-44 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

$$WP_{\text{breached area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 40.0\ m^2 \tag{3-65}$$

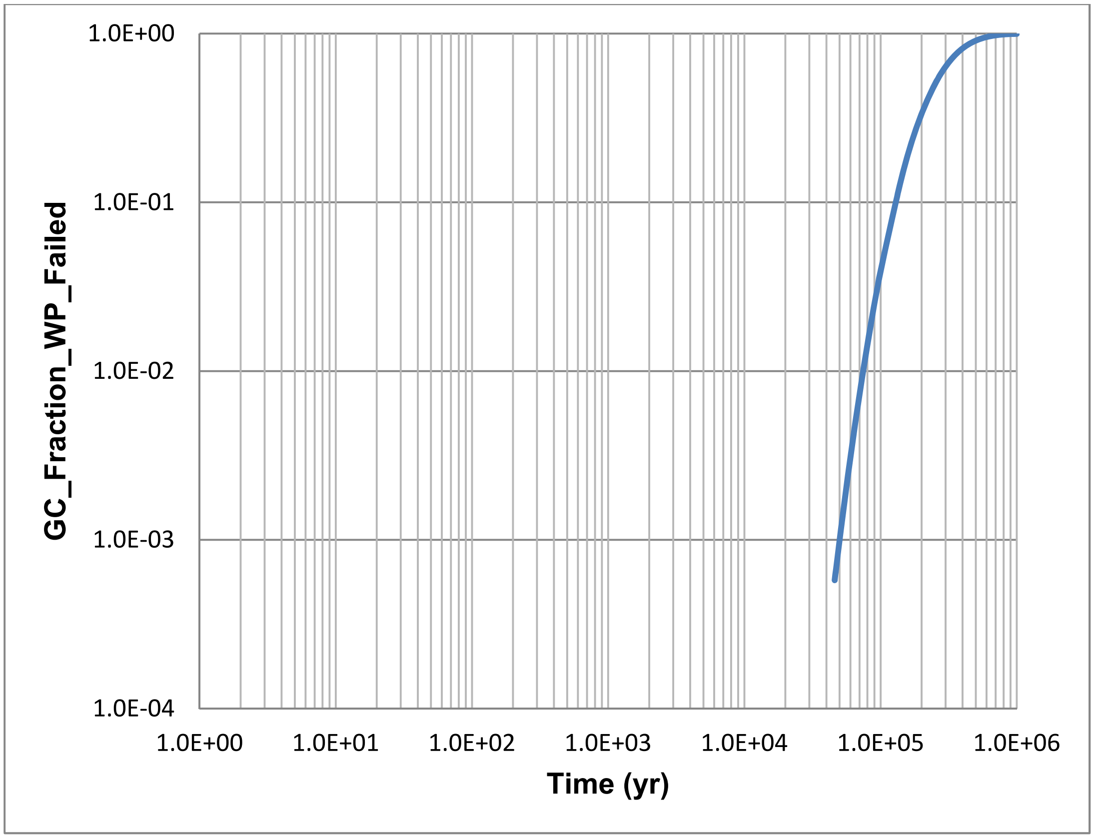


Figure 3-43. WP Failure Fraction From General Corrosion

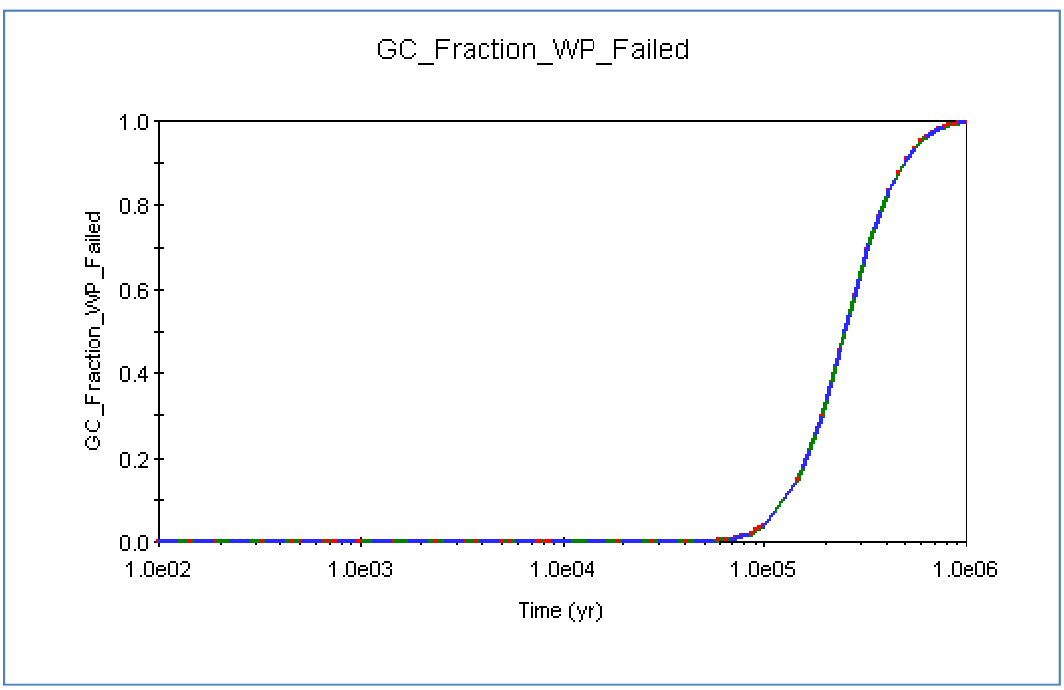


Figure 3-44. WP Failure Fraction From General Corrosion, SOAR Output File

The value agrees with the output value in WP13BreachArea.BMP and WP13BreachAreaTable.txt files. Figure 3-45 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP13BreachArea.BMP. The chart shows that WP breach area equals zero over the first 5.0×10^4 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the initial 5.0×10^4-year period.

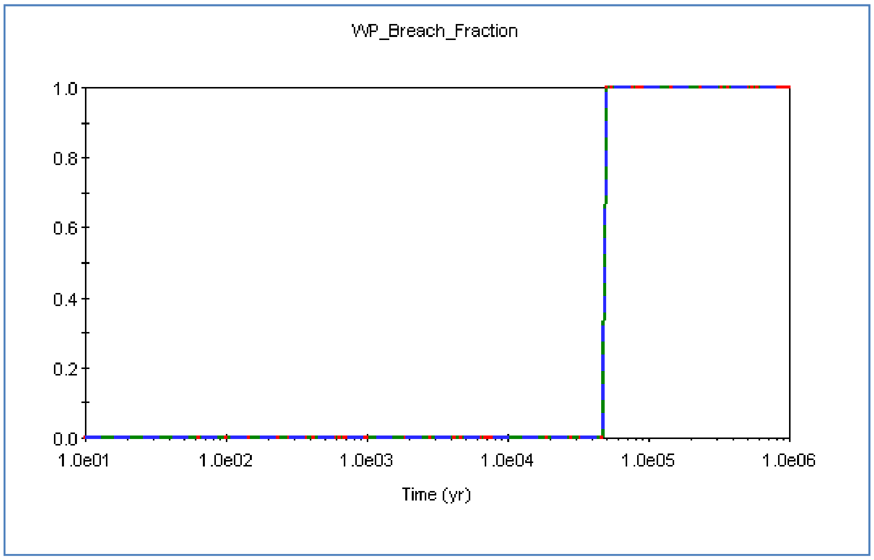


Figure 3-45. SOAR Output Chart of the Breached Area Fraction Per Failed WP Due To General Corrosion

Disposition:

Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

Test ID: WP14
Test Title: WP Failure Time and Breached Area for Ti_fractured_rock_reducing_1.0 cm _Reference Case
Analyst: Razvan Nes
Date: December 8, 2010
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 7.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V7.2
Test Objective: Verify the consistency of failure times and breached areas from the Waste Package component model with hand calculations. Hand calculations will use the equations in NRC (2010b, Chapter 4.2.2).
Assumptions: None
Test Configuration:

Simulation Settings	Number of realizations	10
	Number of timesteps	95
Dashboard	Waste package material	Titanium
	Far Field Leg One, Geologic Media	Fractured Rock
	Far Field Leg One, Redox Condition	Reducing
	Define waste package thickness	On
	Waste package thickness	1.0 cm
	Distribution of general corrosion rates	Normal
	Scale of distribution of general corrosion rates	Logarithmic
	Minimum general corrosion breach area fraction	1.0
	Maximum general corrosion breach area fraction	1.0
	Disable localized corrosion	Checked
Level 2	Ti_GC_Ox_Low	0.008 μm/yr
	Ti_GC_Ox_High	0.2 μm/yr
	Dashboard_WastePackage, Waste package thickness, Properties, Maximum Value	10 cm

Result Parameters:
Results_Waste_Package, Waste package failure fraction from general corrosion
Results_Waste_Package, Waste package failure fraction from localized corrosion
Results_Waste_Package, Waste package breach area

Success Criteria: Output should agree with equations in NRC (2010b, Chapter 4.2.2).

Results:

(1) Using NRC [2010b, Eq. (4-3)], we calculate the WP failure time $\mathrm{t_{gc}}$ as the time in years at which the corrosion front penetrates the material thickness L (cm) given the general corrosion rate $\mathrm{R_{gc}}$(μm/yr)

$$\mathrm{t_{gc}} = 10^4 \times \frac{\mathrm{L}}{\mathrm{R_{gc}}} \tag{3-66}$$

Introducing into Eq. (4-3) the bounding values of the lognormal distribution function of the GC_Rate_Inputs gives the time range at which 0.001 and 0.999 of the WPs have failed, respectively

$$\mathrm{t_{gc}} = 10^4 \times \frac{1.0}{0.2} = 5.0 \times 10^4 \text{ years} \tag{3-67}$$

$$\mathrm{t_{gc}} = 10^4 \times \frac{1.0}{0.008} = 1.25 \times 10^6 \text{ years} \tag{3-68}$$

These values satisfactorily agree with the output values in WP14GCFractionWPFailedTable.txt and WP14GCFractionWPFailed.BMP files. The graph in Figure 3-46, created in WP14GCFractionFailedExcel.xls, is based on the data in WP14GCFractionWPFailedTable.txt and shows the fraction of failed WPs between 0.001 and 0.996, which are the values of the fractions marking the initiation of the WPs' failure due to general corrosion and the fraction of the WPs failed due to general corrosion at the end of the 1-million-year simulation. The model shows that the WP failure by general corrosion is 0.999 (complete) later than 1 million years, consistent with the value 1.25×10^6 years calculated with NRC [2010b, Eq. (4-3)].

(2) Using NRC [2010b, Eq. (4-4)], we calculate the breached area per failed WP

$$\mathrm{WP_{breached\ area}} = \left(\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{gc\ breached\ area}} + \frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}}\mathrm{f_{lc\ breached\ area}}\right)\mathrm{A} \tag{3-69}$$

The only corrosion mechanism responsible for WP breaching considered here is general corrosion, so the first term in the parentheses equals one (i.e., $\frac{\mathrm{f_{gc}}}{\mathrm{f_{failed\ WP}}} = 1.0$) after 5.0×10^4 years. Based on the data in WP14GCFractionWPFailedTable, the second term in parentheses equals zero (i.e., $\frac{\mathrm{f_{lc}}}{\mathrm{f_{failed\ WP}}} = 0.0$). In both cases, the minimum general corrosion breach area fraction and maximum general corrosion breach area fraction are set to one (i.e., $\mathrm{f_{gc\ breached\ area}} = \mathrm{f_{lc\ breached\ area}} = 1.0$). As per NRC (2010b, Table A–2), in the default parameter for the SOAR Waste Package Model Component, A = constant = $40.0\ m^2$.

With these assumptions the breached area per failed WP equals, after 5.0×10^4 years, the area A of the WP

$$\mathrm{WP_{breached\ area}} = (1.0 \times 1.0 + 0.0 \times 1.0) \times 40.0 = 40.0\ m^2 \tag{3-70}$$

This leads to a WP breach fraction of 1.0. Figure 3-47 shows the original SOAR output chart of the fraction of failed WPs due to general corrosion.

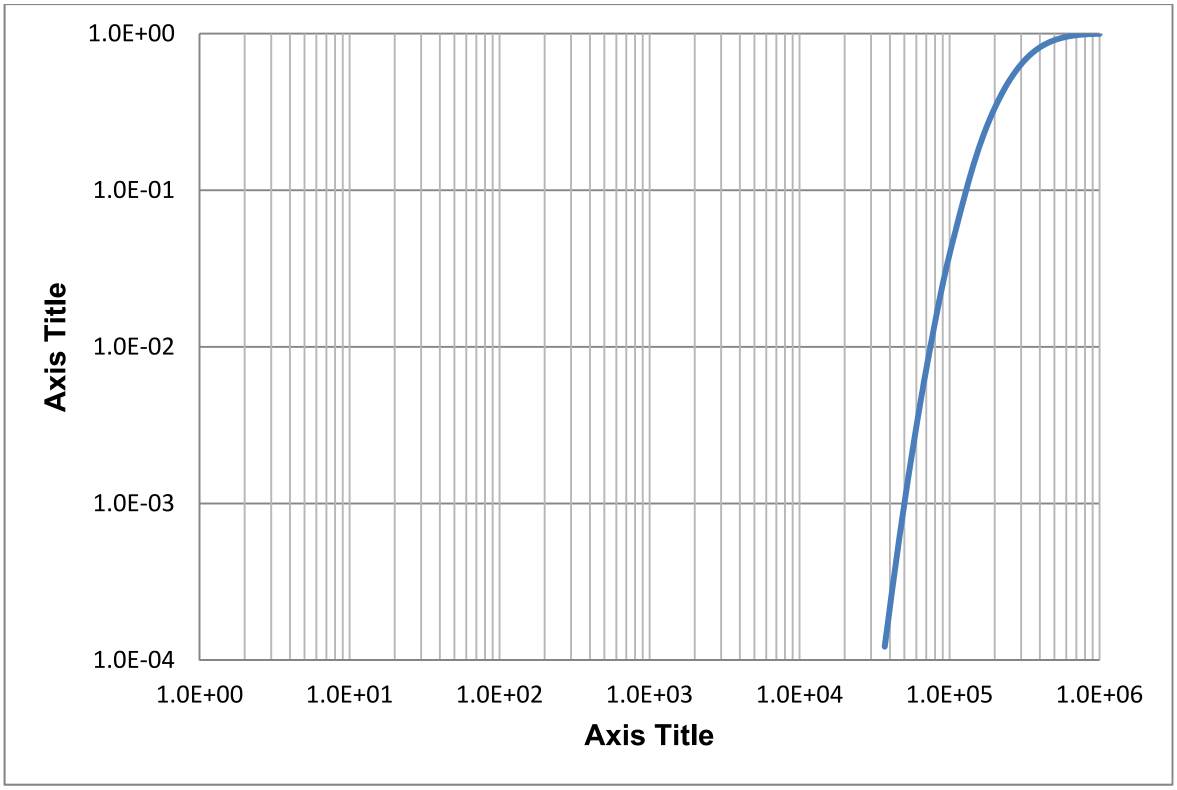


Figure 3-46. WP Failure Fraction From General Corrosion

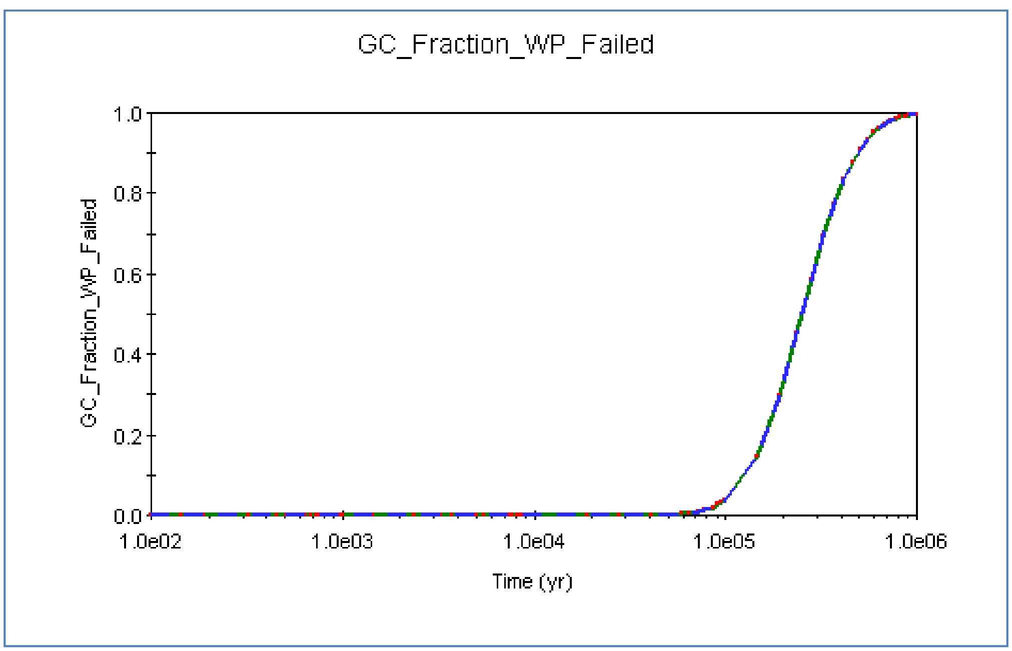


Figure 3-47. WP Failure Fraction From General Corrosion, SOAR Output File

The value agrees with the output value in WP14BreachArea.BMP and WP14BreachAreaTable.txt files. Figure 3-48 shows the original SOAR output chart of the breached area per failed WP due to general corrosion, as per WP14BreachArea.BMP. The chart shows that the WP breach area equals zero over the first 5.0×10^4 years. This is consistent with the model because the WP failure is initiated when the fraction of failed WPs exceeds 0.001, so it does not occur within the first 5.0×10^4 -year time period.

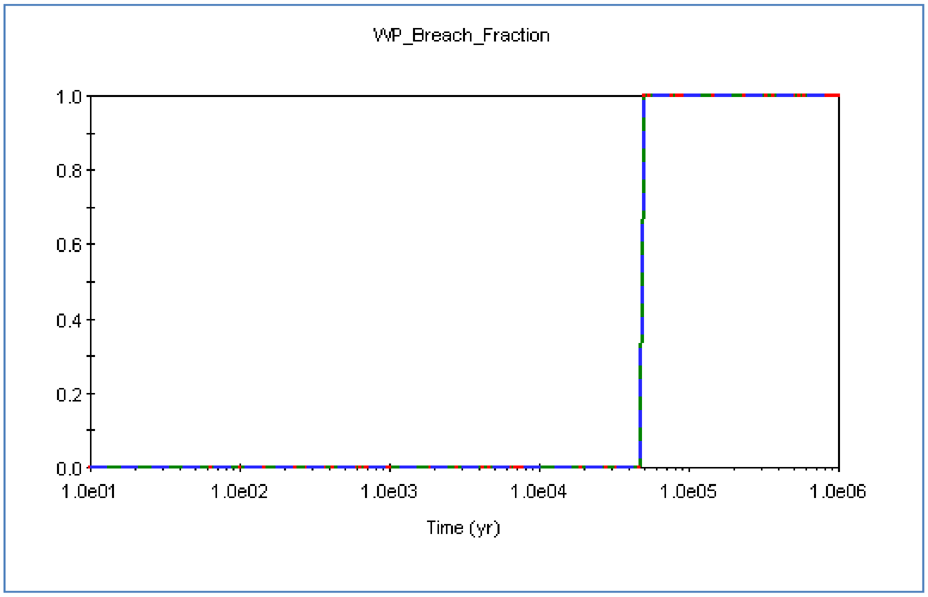


Figure 3-48. SOAR Output Chart of the Breached Area Fraction Per Failed WP Due To General Corrosion

Disposition:

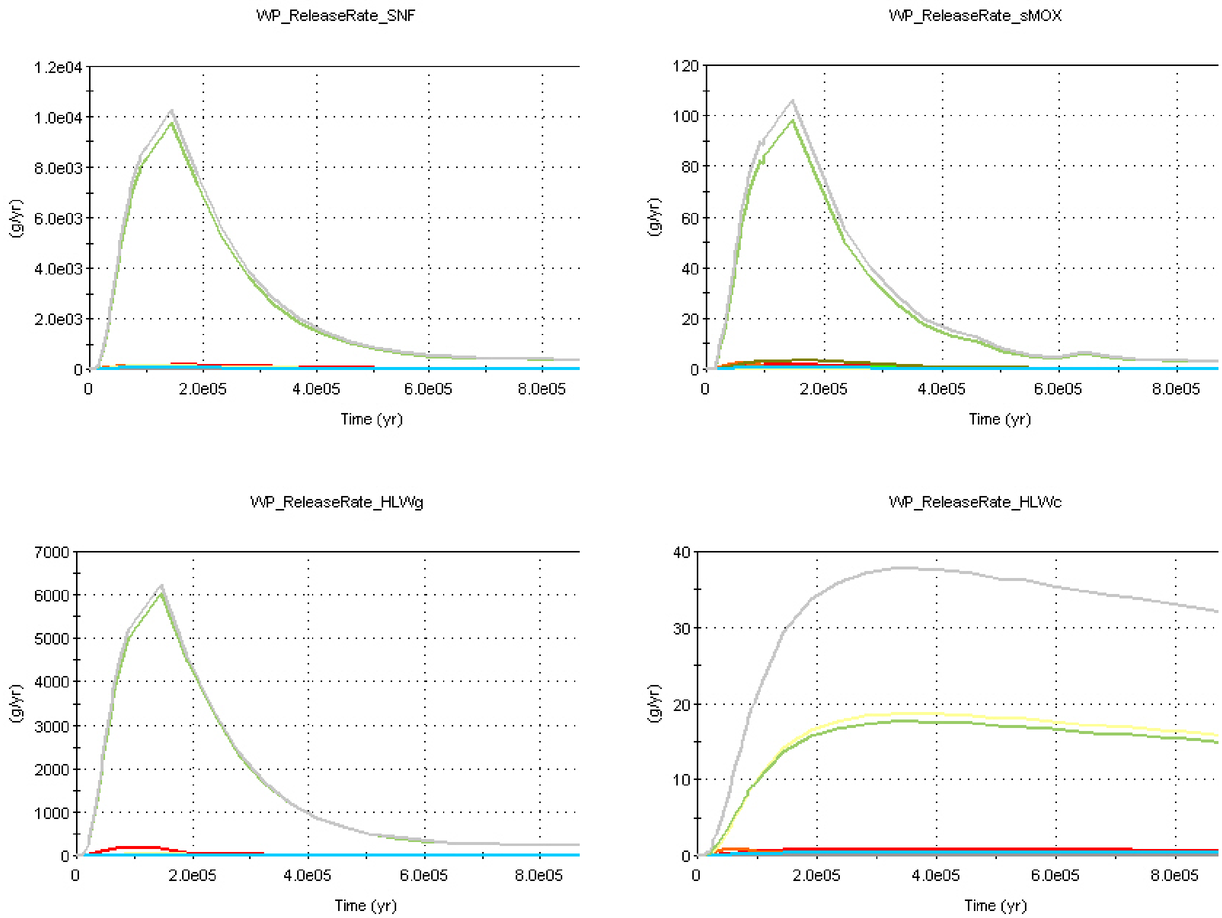
Criterion 1 (Eq. 4-3): **PASS**
Criterion 2 (Eq. 4-4): **PASS**

SOAR Verification Test Report

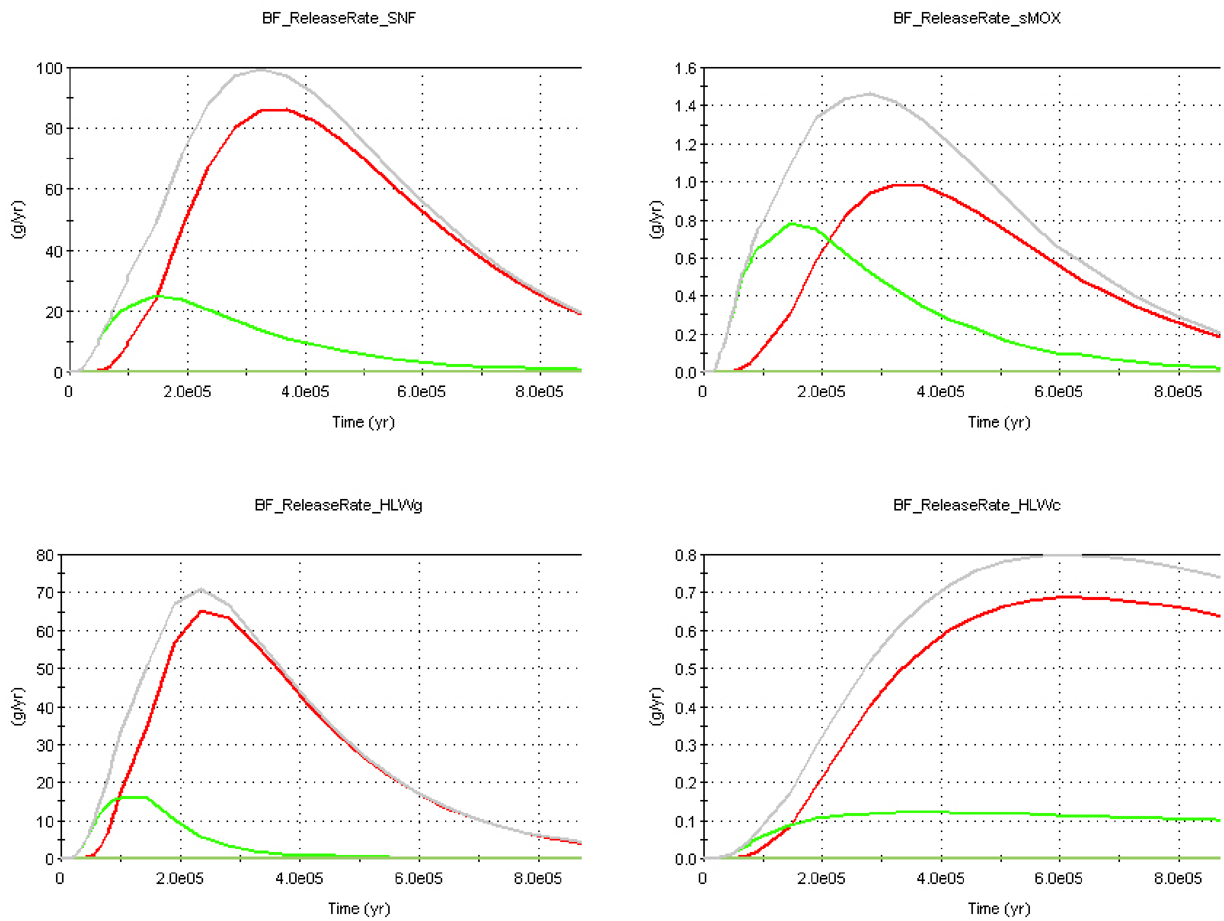
Test ID:	NF01		
Test Title:	Basecase for Runs with Adjusted Buffer Geometry and Near-Field Transport Properties		
Analyst:	Ron Janetzke		
Date:	December 28, 2010		
Test Environment:	ALBY, GoldSim 10.11		
SOAR Version:	Beta 8.1		
Run Directory:	D:\RonJ-\SOAR\V8_1		
Test Objective:	Verify that the code runs to completion with the backfill effects enabled.		
Assumptions:	None		
Test Configuration:	Waste Package Dashboard	Material	Carbon Steel
	Near Field Dashboard	Bypass the backfill	Unchecked
		Enable degradation of the backfill	Unchecked
		Minimum time of Initial backfill failure	1 yr
		Maximum time of Initial backfill failure	1e+6 yr
		Minimum expected lifetime of backfill	1 yr
		Maximum expected lifetime of backfill	1e+6 yr
		Minimum fraction of backfill cracked	0
		Maximum fraction of backfill cracked	1
Result Parameters:	\Results\Near_Field_Results\WP_ReleaseRate_SNF_Result \Results\Near_Field_Results\WP_ReleaseRate_sMOX_Result \Results\Near_Field_Results\WP_ReleaseRate_HLWg_Result \Results\Near_Field_Results\WP_ReleaseRate_HLWc_Result \Results\Near_Field_Results\BF_ReleaseRate_SNF_Result \Results\Near_Field_Results\BF_ReleaseRate_sMOX_Result \Results\Near_Field_Results\BF_ReleaseRate_HLWg_Result \Results\Near_Field_Results\BF_ReleaseRate_HLWc_Result \Results\Near_Field_Results\NF_ReleaseRate_SNF_Result \Results\Near_Field_Results\NF_ReleaseRate_sMOX_Result \Results\Near_Field_Results\NF_ReleaseRate_HLWg_Result \Results\Near_Field_Results\NF_ReleaseRate_HLWc_Result		
Success Criteria:	The model result mode should be entered upon completion of the model run with no GoldSim or system errors exhibited.		

Results:

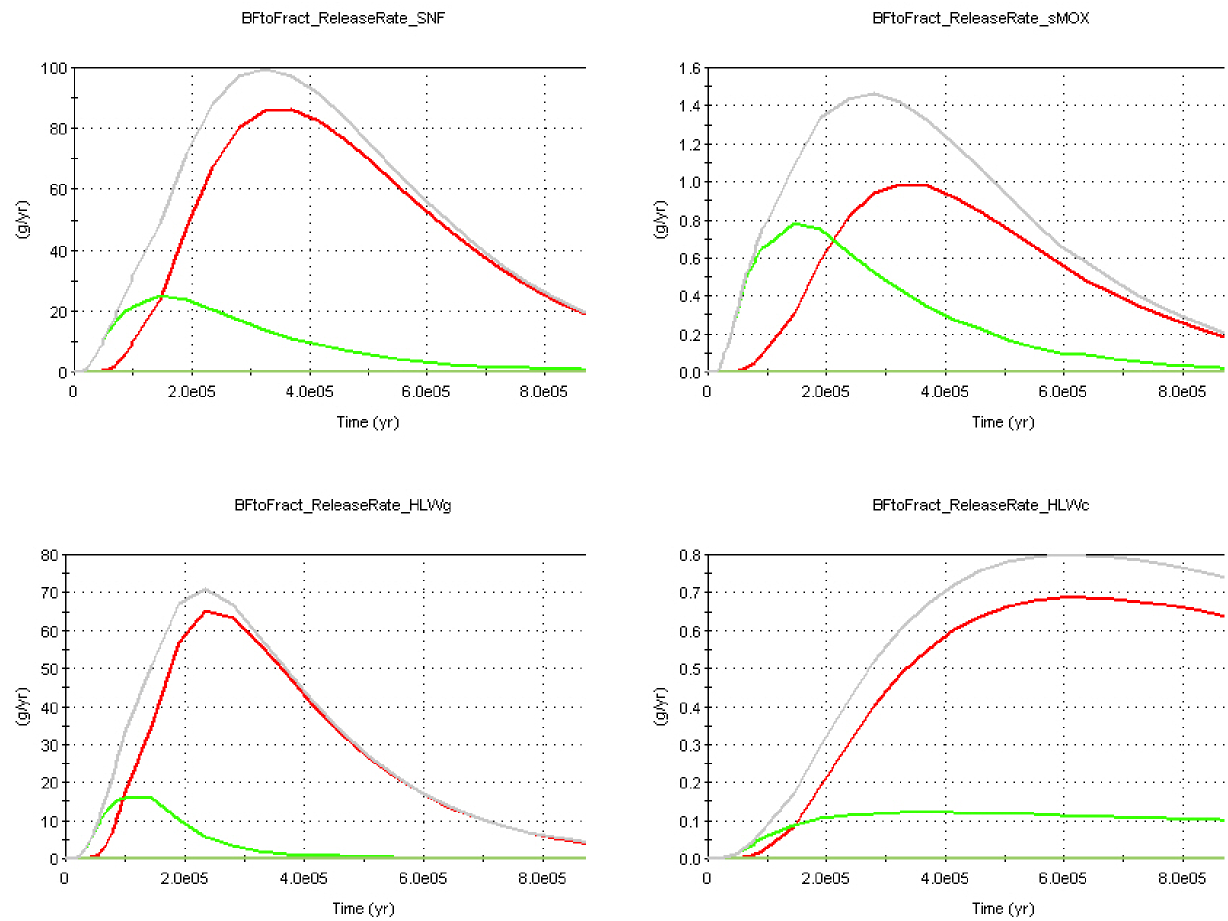
Run completed with no errors with the following displays generated.



WP Release Rates



BF Release Rates



NF Release Rates

Disposition:

Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: NF02
Test Title: Backfill Effects Case with Backfill Submodel Disabled
Analyst: Ron Janetzke
Date: December 28, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.1
Run Directory: D:\RonJ-\SOAR\V8_1
Test Objective: Verify that the release rates are higher with the backfill submodel disabled.
Assumptions: None
Test Configuration:

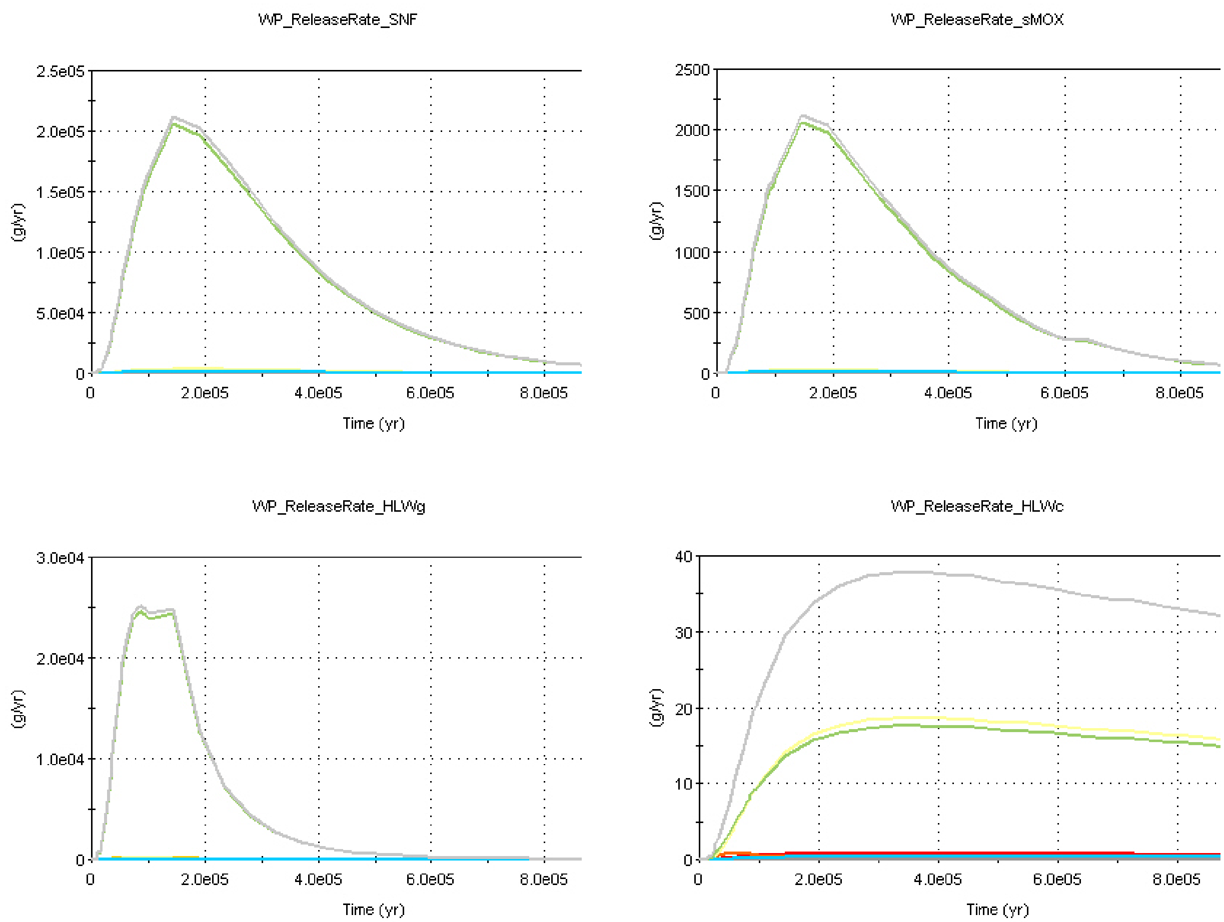
Waste Package Dashboard	Material	Carbon Steel
Near Field Dashboard	Bypass the backfill	Checked
	Enable degradation of the backfill	Unchecked
	Minimum time of Initial backfill failure	1 yr
	Maximum time of Initial backfill failure	1e+6 yr
	Minimum expected lifetime of backfill	1 yr
	Maximum expected lifetime of backfill	1e+6 yr
	Minimum fraction of backfill cracked	0
	Maximum fraction of backfill cracked	1

Result Parameters:
\Results\Near_Field_Results\WP_ReleaseRate_SNF_Result
\Results\Near_Field_Results\WP_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\WP_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\WP_ReleaseRate_HLWc_Result
\Results\Near_Field_Results\BF_ReleaseRate_SNF_Result
\Results\Near_Field_Results\BF_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\BF_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\BF_ReleaseRate_HLWc_Result
\Results\Near_Field_Results\NF_ReleaseRate_SNF_Result
\Results\Near_Field_Results\NF_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\NF_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\NF_ReleaseRate_HLWc_Result

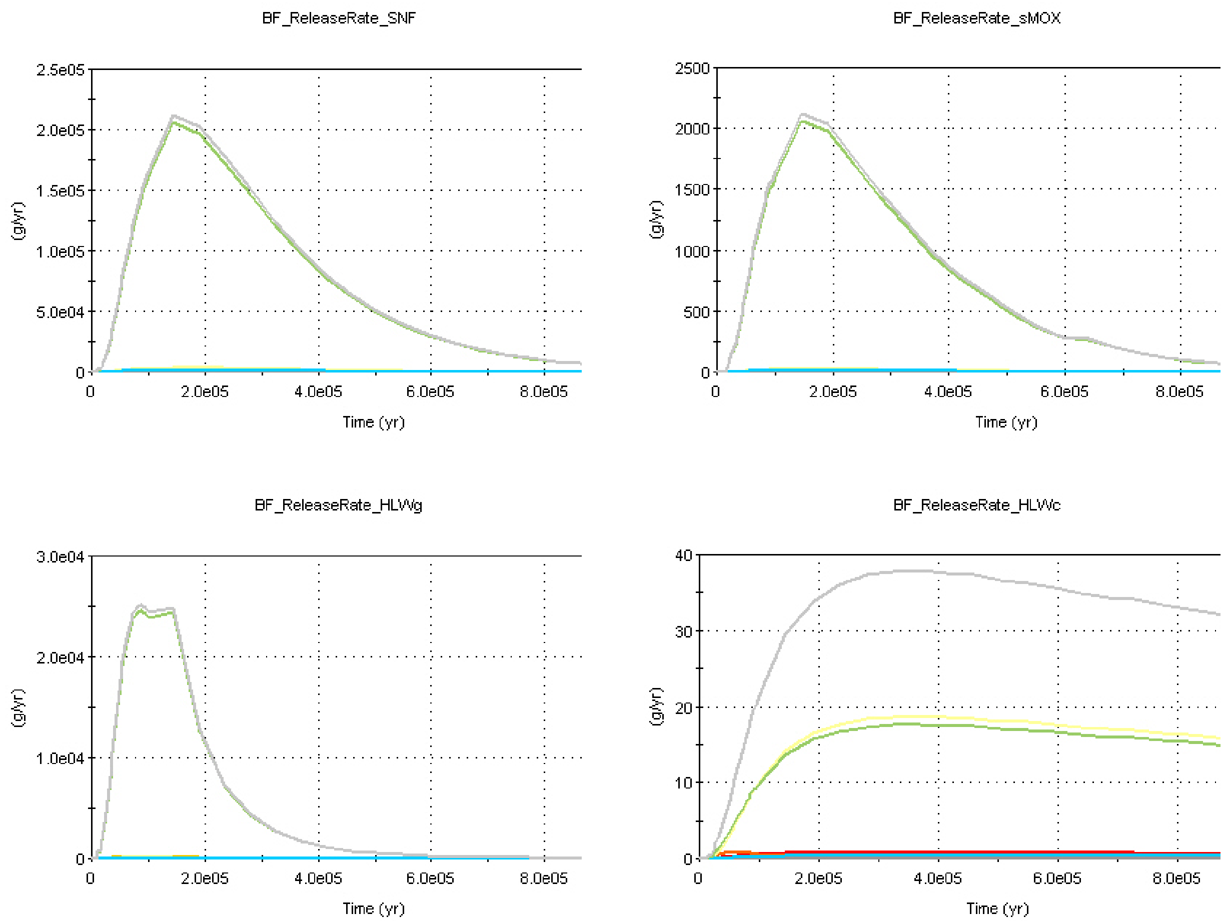
Success Criteria: The result charts should show the release rates are higher compared to the basecase, NF01.

Results:

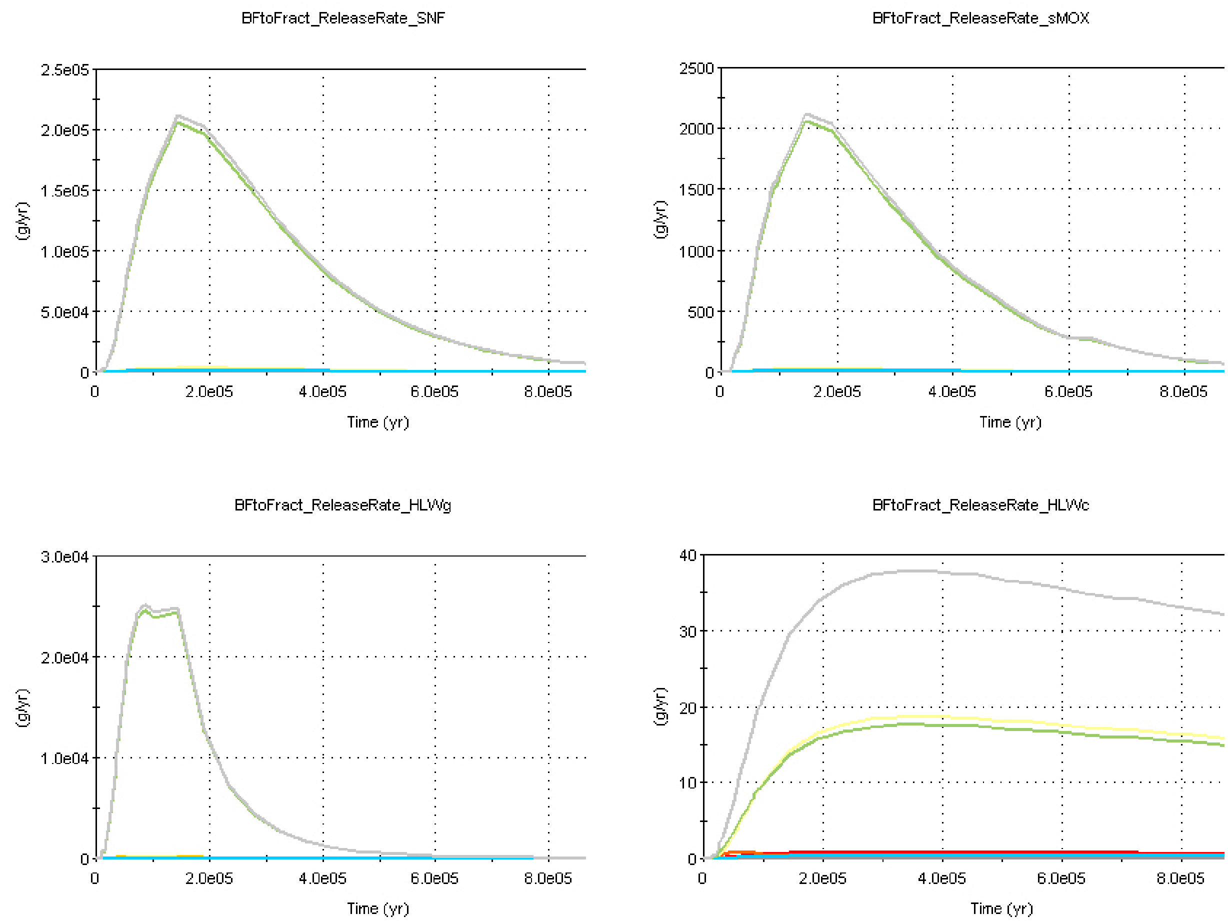
All release rates are greater than the basecase NF01. Release rates for WP, BF, and NF are the same in the present test because the backfill was bypassed, as illustrated in the Near Field Dashboard.



WP Release Rates



BF Release Rates



NF Release Rates

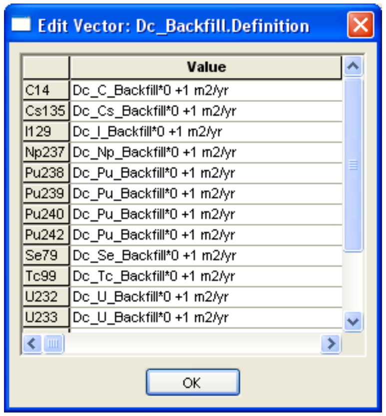
Disposition:

Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: NF03
Test Title: Backfill Effects Case with Backfill Submodel Disabled
Analyst: Ron Janetzke
Date: December 28, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.1
Run Directory: D:\RonJ-\SOAR\V8_1
Test Objective: Verify that a short and fast transport leg will have similar release rates compared to the WP release.
Assumptions: None
Test Configuration:

Waste Package Dashboard	Material	Carbon Steel
Near Field Dashboard	Bypass the backfill	Unchecked
	Enable degradation of the backfill	Unchecked
	Minimum time of Initial backfill failure	1 yr
	Maximum time of Initial backfill failure	1e+6 yr
	Minimum expected lifetime of backfill	1 yr
	Maximum expected lifetime of backfill	1e+6 yr
	Minimum fraction of backfill cracked	0
	Maximum fraction of backfill cracked	1
Level 2	Model_Inputs\Near_Field_Common_Inputs\NF_Parameters\BF_Dimensions\NF_Length_A	1.08

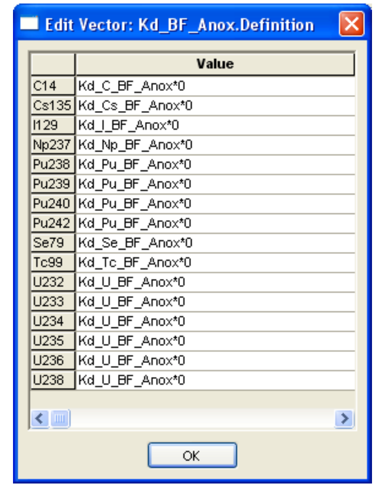

Edit Vector: Dc_Backfill.Definition

	Value
C14	Dc_C_Backfill*0 +1 m2/yr
Cs135	Dc_Cs_Backfill*0 +1 m2/yr
I129	Dc_I_Backfill*0 +1 m2/yr
Np237	Dc_Np_Backfill*0 +1 m2/yr
Pu238	Dc_Pu_Backfill*0 +1 m2/yr
Pu239	Dc_Pu_Backfill*0 +1 m2/yr
Pu240	Dc_Pu_Backfill*0 +1 m2/yr
Pu242	Dc_Pu_Backfill*0 +1 m2/yr
Se79	Dc_Se_Backfill*0 +1 m2/yr
Tc99	Dc_Tc_Backfill*0 +1 m2/yr
U232	Dc_U_Backfill*0 +1 m2/yr
U233	Dc_U_Backfill*0 +1 m2/yr

OK

SOAR Verification Test Report (continued)

Test Configuration: Model_Inputs\Near_Field_Common_Inputs\NF_Parameters\BF_Kd\Kd_BF_Anox

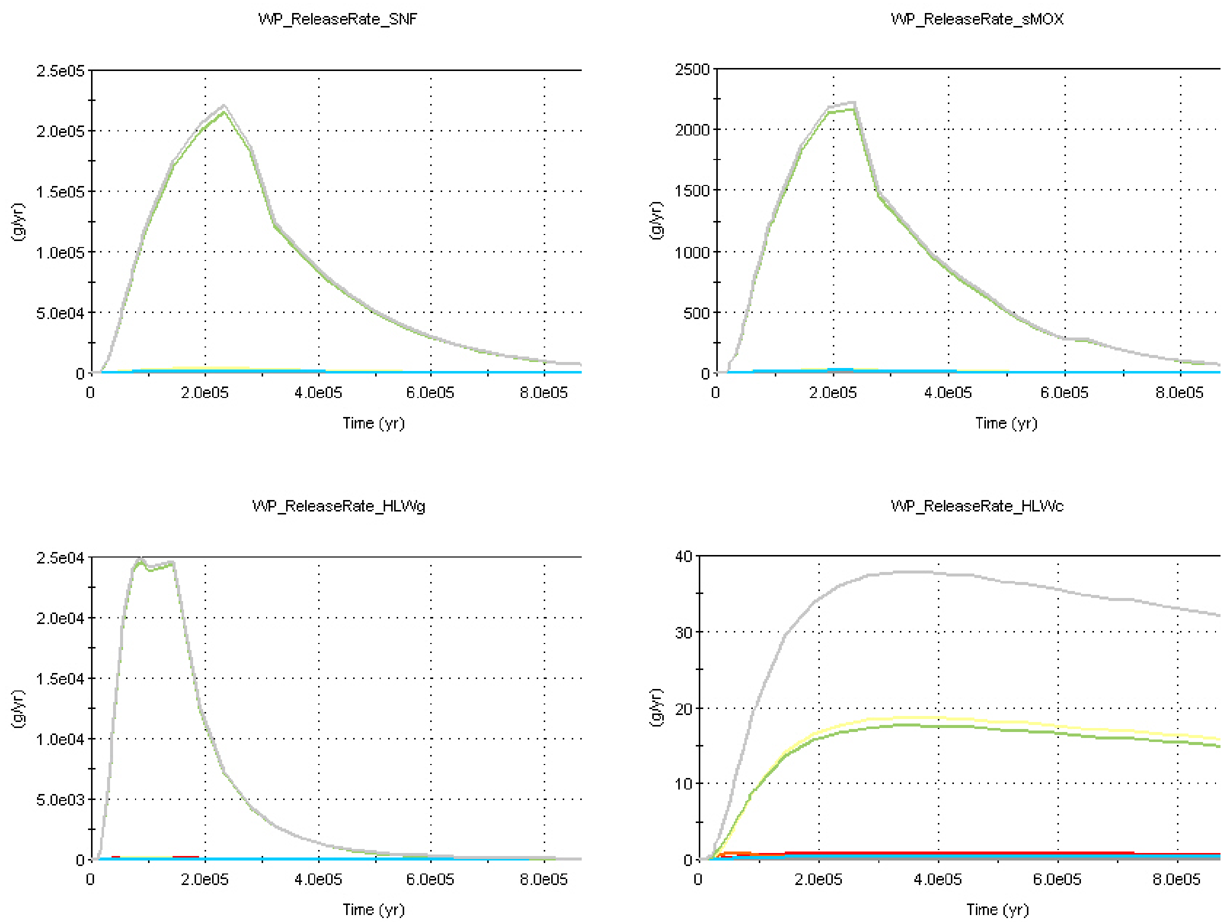


Result Parameters:
\Results\Near_Field_Results\WP_ReleaseRate_SNF_Result
\Results\Near_Field_Results\WP_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\WP_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\WP_ReleaseRate_HLWc_Result
\Results\Near_Field_Results\BF_ReleaseRate_SNF_Result
\Results\Near_Field_Results\BF_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\BF_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\BF_ReleaseRate_HLWc_Result
\Results\Near_Field_Results\NF_ReleaseRate_SNF_Result
\Results\Near_Field_Results\NF_ReleaseRate_sMOX_Result
\Results\Near_Field_Results\NF_ReleaseRate_HLWg_Result
\Results\Near_Field_Results\NF_ReleaseRate_HLWc_Result

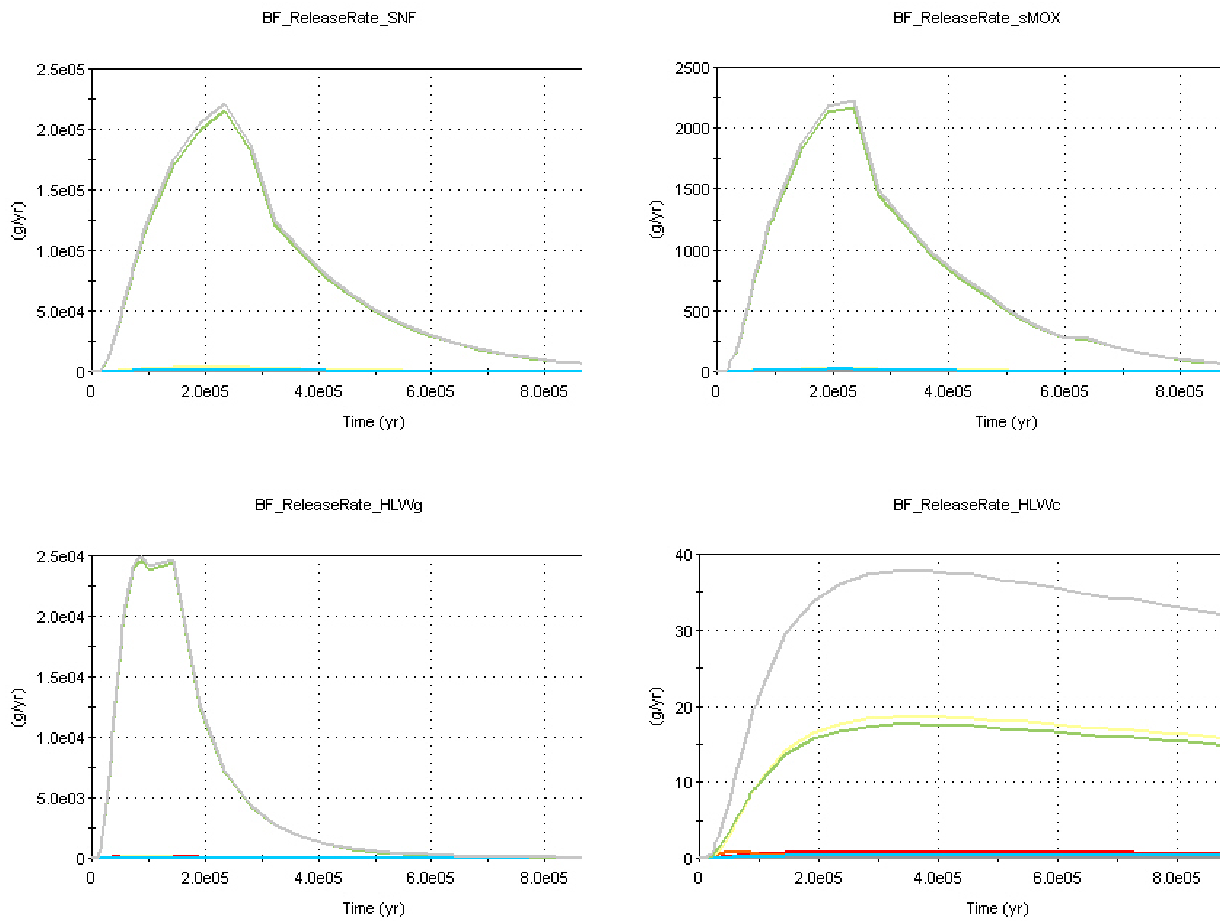
Success Criteria:
(1) The WP release rates for all four fuel types should match the WP release rates of the basecase, NF02.
(2) The buffer and buffer to fracture release rates should be the same as the WP release rates for each respective fuel type.

Results:

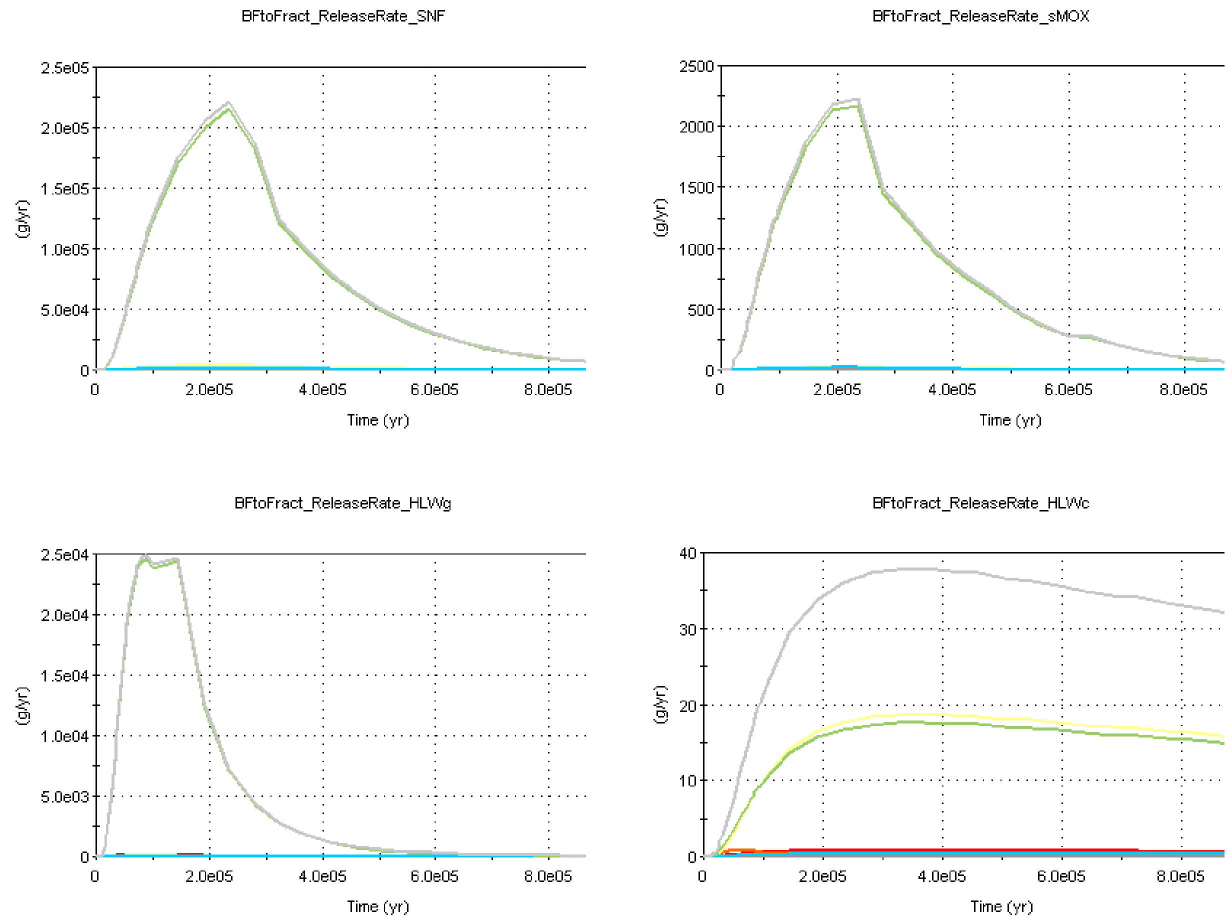
All WP release rates match the WP release rates in NF02. To expedite transport through the backfill, the transport properties of the backfill were adjusted: diffusion coefficients were maximized and distribution coefficients were minimized. This explains why all three release rates are the same for the respective fuel types.



WP Release Rates



BF Release Rates



NF Release Rates

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: FF01
Test Title: Release Rates at the End of Leg 3 Reference Case
Analyst: Razvan Nes
Date: February 10, 2011
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 8.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V8.2_TDRW
Test Objective: Verify that the model runs properly and provides meaningful results as plots and tables of the release rates at the end of Leg 3 of the far field.
Assumptions: None
Test Configuration:

Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
Dashboard Far Field	Far Field Leg One Geologic Medium	Fractured Rock
	Far Field Leg One Redox Condition	Reducing
	Far Field Leg One Transport Length (km)	1.67
	Far Field Leg Two Geologic Medium	Fractured Rock
	Far Field Leg Two Redox Condition	Reducing
	Far Field Leg Two Transport Length (km)	1.67
	Far Field Leg Three Geologic Medium	Fractured Rock
	Far Field Leg Three Redox Condition	Reducing
	Far Field Leg Three Transport Length (km)	1.67

Result Parameters: Results Far Field Leg 3 Release Rates Chart/Table
Success Criteria: Output should provide radionuclide release rates at the end of Leg 3.

Results:

The radionuclide release rates chart is shown in Figure 3-49, available in output file FF01 Leg 3 Release Rate.bmp. The release rates are consistent with the ones in output file FF01 Leg3 Release Rates Table.txt.

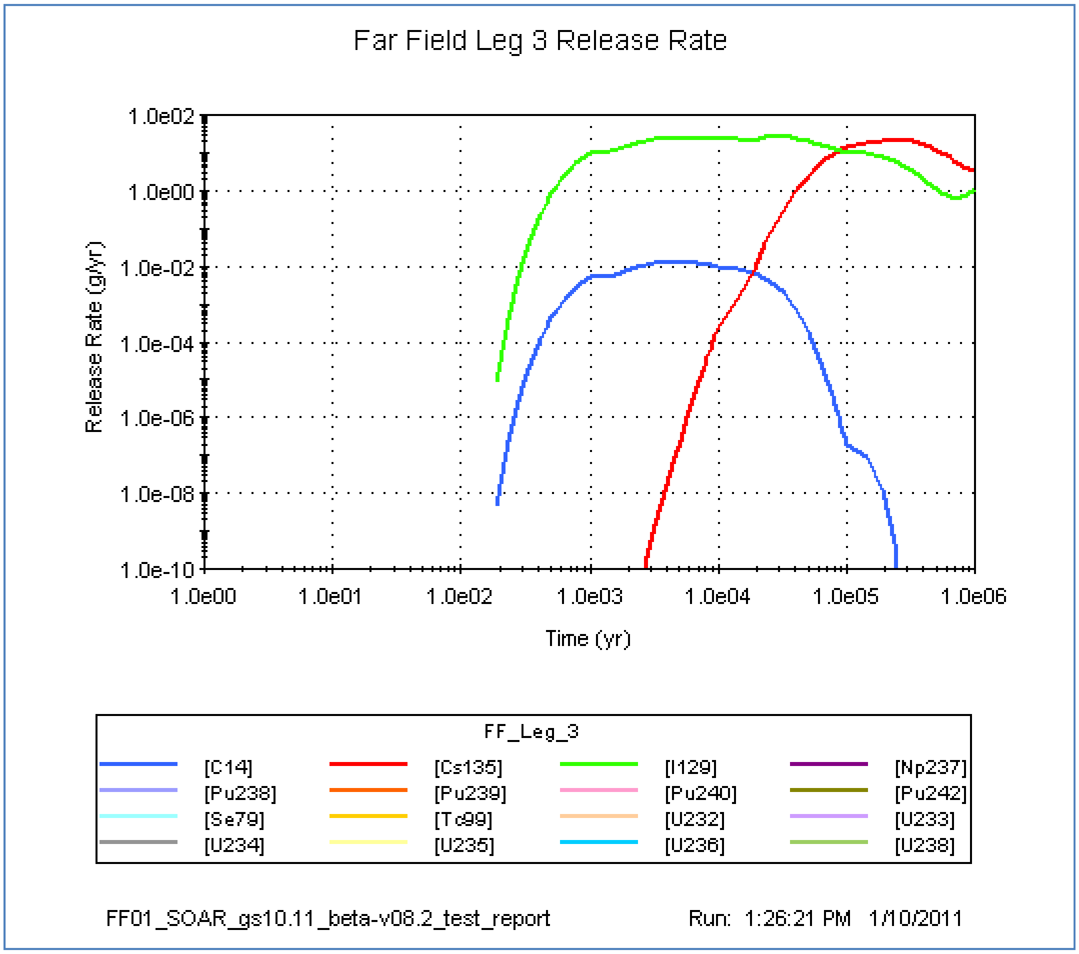


Figure 3-49. Far Field Leg 3 Radionuclide Release Rates

Disposition:

PASS

SOAR Verification Test Report

Test ID:	FF02		
Test Title:	Release Rates at the End of Leg 3, Diffusive Medium in Leg 1		
Analyst:	Razvan Nes		
Date:	February 11, 2011		
Test Environment:	Frisco, GoldSim 10.11		
SOAR Version:	Beta 8.2		
Run Directory:	Gryphon, D:\Public\razvan\SOAR_beta_V8.2_TDRW		
Test Objective:	Verify that the release rates at the end of Leg 3 are insensitive to permutations of the properties (length and rock type) of the three legs of the far field.		
Assumptions:	None		
Test Configuration:	Simulation Settings	Deterministic Simulation	On
		Element Mean Values	On
		Number of realizations	1
		Number of timesteps	95
	Dashboard Far Field	Far Field Leg One Geologic Medium	Fractured Rock
		Far Field Leg One Redox Condition	Reducing
		Far Field Leg One Transport Length (km)	0.001
		Far Field Leg Two Geologic Medium	Fractured Rock
		Far Field Leg Two Redox Condition	Reducing
		Far Field Leg Two Transport Length (km)	1.67
		Far Field Leg Three Geologic Medium	Fractured Rock
		Far Field Leg Three Redox Condition	Reducing
		Far Field Leg Three Transport Length (km)	1.67
Result Parameters:	Results Far Field Leg 3 Release Rates Chart/Table		
Success Criteria:	(1) The radionuclide release rates for Leg 3 should exhibit reasonable suppression and retardation effects, due to diffusion in the porous rock, relative to the output of reference case FF01. (2) The release rates for Leg 3 should be the same as FF03 and FF04, where the diffusive leg is assigned to Legs 2 and 3, respectively.		

Results:

The radionuclide release rates chart is shown in Figure 3-50, available in output file FF02 Leg 3 Release Rate.bmp. The release rates are consistent with the ones in output file FF02 Leg 3 Release Rates Table.txt. The chart presented in Figure 3-50 is also identical with Far Field Leg3 Radionuclide Release Rates as per FF03 Leg 3 Release Rate.bmp and FF04 Leg 3 Release Rate.bmp, where the diffusive medium is located in Legs 2 and 3, respectively. The effect of the diffusive leg in the far field is illustrated with the differences between the plots in FF02Leg3ReleaseRates.bmp and the reference case presented in FF01Leg3ReleaseRates.bmp. As expected, the plot in FF02Leg3ReleaseRates.bmp shows retardation for two of the featured radionuclides, C-14 and Cs-135, that have higher distribution coefficients. Note that charts show only radionuclides that contribute to the release rates by more than 10^{-10} g/yr.

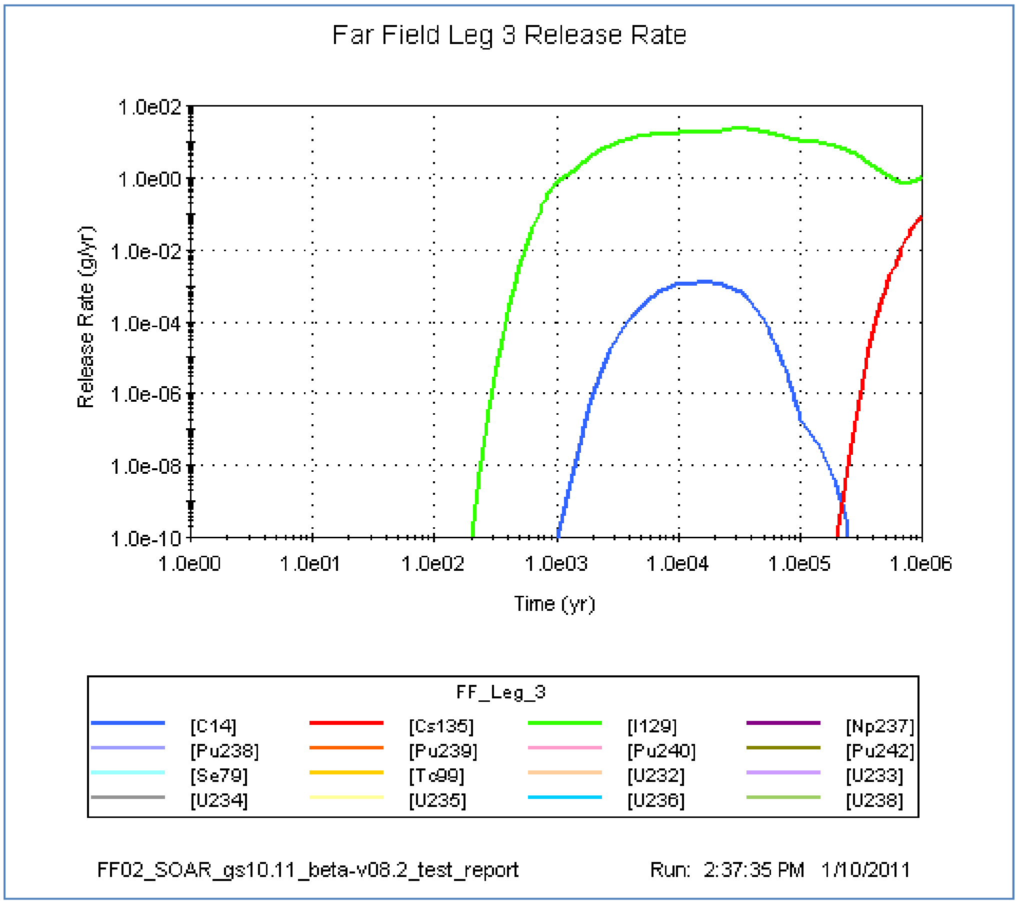


Figure 3-50. Far Field Leg 3 Radionuclide Release Rates

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID:	FF03		
Test Title:	Release Rates at the End of Leg 3, Diffusive Medium in Leg 2		
Analyst:	Razvan Nes		
Date:	February 11, 2011		
Test Environment:	Frisco, GoldSim 10.11		
SOAR Version:	Beta 8.2		
Run Directory:	Gryphon, D:\Public\razvan\SOAR_beta_V8.2_TDRW		
Test Objective:	Verify that the release rates at the end of Leg 3 are insensitive to permutations of the properties (length and rock type) of the three legs of the far field.		
Assumptions:	None		
Test Configuration:	Simulation Settings	Deterministic Simulation	On
		Element Mean Values	On
		Number of realizations	1
		Number of timesteps	95
	Dashboard Far Field	Far Field Leg One Geologic Medium	Fractured Rock
		Far Field Leg One Redox Condition	Reducing
		Far Field Leg One Transport Length (km)	1.67
		Far Field Leg Two Geologic Medium	Fractured Rock
		Far Field Leg Two Redox Condition	Reducing
		Far Field Leg Two Transport Length (km)	0.001
		Far Field Leg Three Geologic Medium	Fractured Rock
		Far Field Leg Three Redox Condition	Reducing
		Far Field Leg Three Transport Length (km)	1.67
Result Parameters:	Results Far Field Leg 3 Release Rates Chart/Table		

Success Criteria:

(1) The radionuclide release rates for Leg 3 should exhibit reasonable suppression and retardation effects, due to diffusion in the porous rock, relative to the output of reference case FF01.

(2) The release rates for Leg 3 should be the same as FF02 and FF04, where the diffusive leg is assigned to Legs 1 and 3, respectively.

Results:

The radionuclide release rates chart is shown in Figure 3-51, available in output file FF03 Leg 3 Release Rate.bmp. The release rates are consistent with the ones in output file FF03 Leg 3 Release Rates Table.txt. The chart presented in Figure 3-51 is also identical with Far Field Leg 3 Radionuclide Release Rates as per FF02 Leg 3 Release Rate.bmp and FF04 Leg 3 Release Rate.bmp, where the diffusive medium is located in Legs 1 and 3, respectively. The effect of the diffusive leg in the far field is illustrated with the differences between the plots in FF03Leg3ReleaseRates.bmp and the reference case presented in FF01Leg3ReleaseRates.bmp. As expected, the plot in FF03Leg3ReleaseRates.bmp shows retardation for two of the featured radionuclides, C-14 and Cs-135, that have higher distribution coefficients. Note that charts show only radionuclides that contribute to the release rates by more than 10^{-10} g/yr.

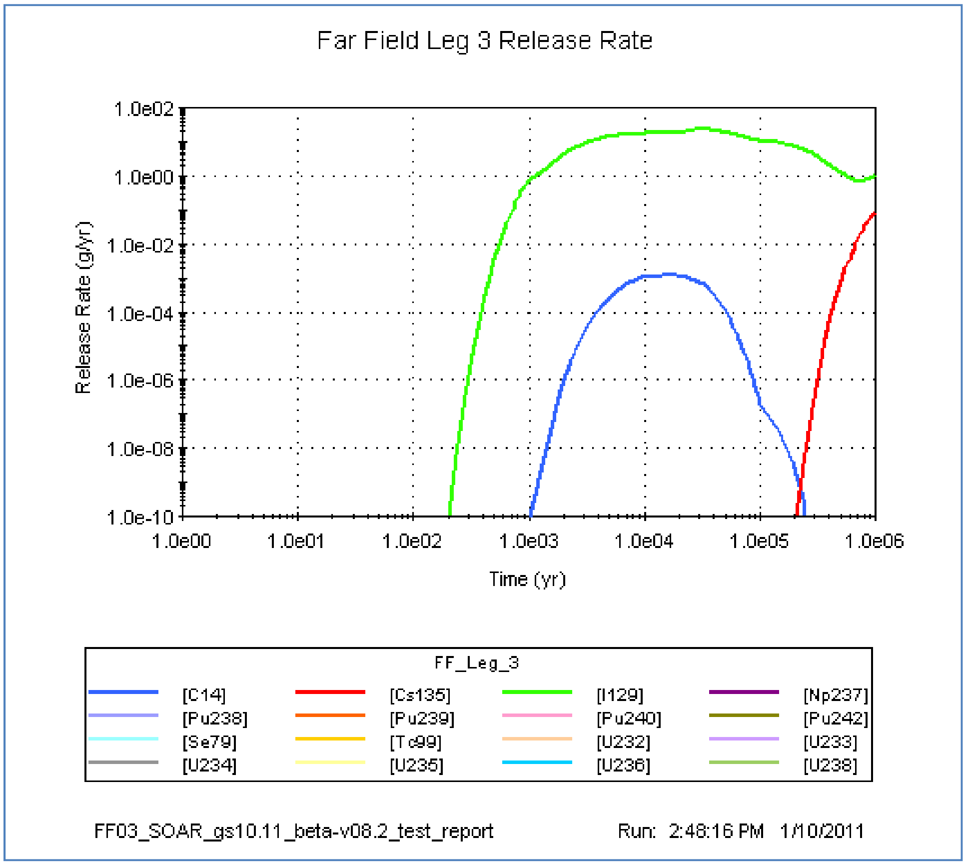


Figure 3-51. Far Field Leg 3 Radionuclide Release Rates

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: FF04
Test Title: Release Rates at the End of Leg 3, Diffusive Medium in Leg 3
Analyst: Razvan Nes
Date: February 11, 2011
Test Environment: Frisco, GoldSim 10.11
SOAR Version: Beta 8.2
Run Directory: Gryphon, D:\Public\razvan\SOAR_beta_V8.2_TDRW
Test Objective: Verify that the release rates at the end of Leg 3 are insensitive to permutations of the properties (length and rock type) of the three legs of the far field.
Assumptions: None
Test Configuration:

Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
Dashboard Far Field	Far Field Leg One Geologic Medium	Fractured Rock
	Far Field Leg One Redox Condition	Reducing
	Far Field Leg One Transport Length (km)	1.67
	Far Field Leg Two Geologic Medium	Fractured Rock
	Far Field Leg Two Redox Condition	Reducing
	Far Field Leg Two Transport Length (km)	1.67
	Far Field Leg Three Geologic Medium	Fractured Rock
	Far Field Leg Three Redox Condition	Reducing
	Far Field Leg Three Transport Length (km)	0.001

Result Parameters: Results Far Field Leg 3 Release Rates Chart/Table
Success Criteria:

(1) The radionuclide release rates for Leg 3 should exhibit reasonable suppression and retardation effects, due to diffusion in the porous rock, relative to the output of reference case FF01.
(2) The release rates for Leg 3 should be the same as FF02 and FF03, where the diffusive leg is assigned to Legs 1 and 2, respectively.

Results:

The radionuclide release rates chart is shown in Figure 3-52, available in output file FF04 Leg 3 Release Rate.bmp. The release rates are consistent with the ones in output file FF04 Leg 3 Release Rates Table.txt. The chart presented in Figure 3-52 is also identical with Far Field Leg 3 Radionuclide Release Rates as per FF02 Leg 3 Release Rate.bmp and FF03 Leg 3 Release Rate.bmp, where the diffusive medium is located in Legs 1 and 2, respectively. The effect of the diffusive leg in the far field is illustrated with the differences between the plots in FF04Leg3ReleaseRates.bmp and the reference case presented in FF01Leg3ReleaseRates.bmp. As expected, the plot in FF04Leg3ReleaseRates.bmp shows retardation for two of the featured radionuclides, C-14 and Cs-135, that have higher distribution coefficients. Note that charts show only radionuclides that contribute to the release rates by more than 10^{-10} g/yr.

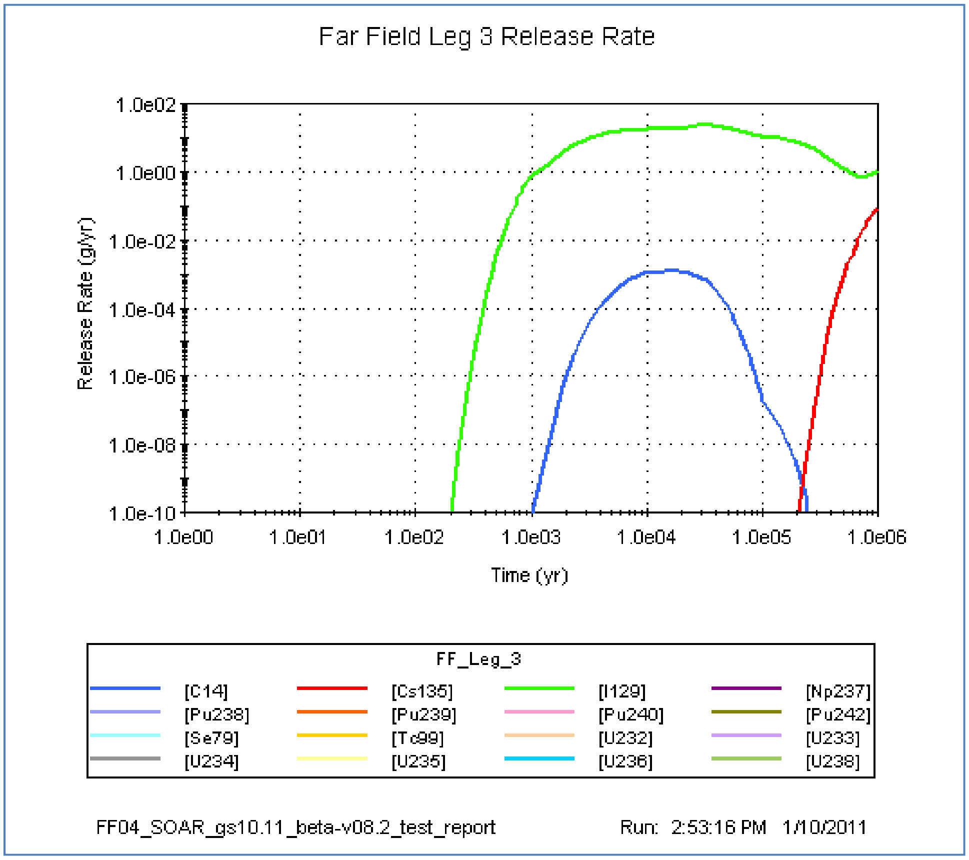


Figure 3-52. Far Field Leg 3 Radionuclide Release Rates

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**

SOAR Verification Test Report

Test ID: DB01
Test Title: Dashboard Range Test for Level 1 Parameters Set at Maximum Permissible Values
Analyst: Ron Janetzke
Date: December 16, 2010
Test Environment: ALBY, GoldSim 10.11
SOAR Version: Beta 8.0
Run Directory: D:\RonJ-\SOAR\V8_0
Test Objective: Verify that the code runs to completion with the dashboard parameters set at their maximum permissible values as controlled by the dashboard authoring tool.
Assumptions: It is assumed that the setting all parameters to their maximum value does not present any self-inconsistencies in the SOAR code.
Test Configuration:

Simulation Settings	Monte Carlo	Probabilistic, 10 realizations
	Timesteps	95
Waste Form Dashboard	Length of Aging Prior to Disposal (years): 2010 Inventories only	300
	2010 Radionuclide Inventory (Metric Tons)\ Spent Nuclear Fuel	67892
	2010 Radionuclide Inventory (Metric Tons)\ Spent Mixed-Oxide Fuel	677
	2010 Radionuclide Inventory (Metric Tons)\ High-Level Waste (glass)	4140
	2010 Radionuclide Inventory (Metric Tons)\ High-Level Waste (ceramic)	108
	Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)\Spent Nuclear Fuel	1.e6
	Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)\Spent Mixed-Oxide Fuel	1.e6
	Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)\High-Level Waste (glass)	1.e6
	Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)\High-Level Waste (ceramic)	1.e6
	Total Disposed Mass per Waste Package (grams)\Spent Nuclear Fuel	1.e10
	Total Disposed Mass per Waste Package (grams) \Spent Mixed-Oxide Fuel	1.e10

SOAR Verification Test Report (continued)

Test Configuration:		Total Disposed Mass per Waste Package (grams) \High-Level Waste (glass)	1.e10
		Total Disposed Mass per Waste Package (grams) \High-Level Waste (ceramic)	1.e10
		Fraction of Initial Inventory Available for Release: \Spent Nuclear Fuel	1
		Fraction of Initial Inventory Available for Release: \Spent Mixed-Oxide Fuel	1
		Fraction of Initial Inventory Available for Release: \High-Level Waste (glass)	1
		Fraction of Initial Inventory Available for Release: \High-Level Waste (ceramic)	1
		Degradation Rate Multiplier\Spent Nuclear Fuel	1.0e6
		Degradation Rate Multiplier\Spent Mixed-Oxide Fuel	1.0e6
		Degradation Rate Multiplier\ High-Level Waste (glass)	1.0e6
		Degradation Rate Multiplier\ High-Level Waste (ceramic)	1.0e6
		Enable Combined Oxic/Anoxic Degradation Rates\Spent Nuclear Fuel = checked	Checked
		Enable Combined Oxic/Anoxic Degradation Rates\ Spent Mixed-Oxide Fuel	Checked
		Initial U235 Enrichment (percent)\Spent Nuclear Fuel	6
		Burnup Value (GWe/MTU)\ Spent Nuclear Fuel	60
		Waste Form Loading Factor (percent)\ High-Level Waste (glass)	100
		Waste Form Loading Factor (percent)\High-Level Waste (ceramic)	100
	Waste Package Dashboard	Check to define waste package thickness (default values used if unchecked)	Checked
		Waste package thickness (cm)	1
		Minimum general corrosion breach area fraction	1
		Maximum general corrosion breach area fraction	1
	Near Field Dashboard	Enable radionuclide sorption in transition region between buffer and far field	Checked
		Water volume inside the waste package (cubic meters)	10

SOAR Verification Test Report (continued)

Test Configuration:		Near field flow factor (only used if repository host rock is fractured rock)	1
		Multiplier to define cross section of transition region (region between buffer and far field)	1
		Enable degradation of the backfill (diffusive barrier)	Checked
		Minimum time of initial backfill failure (year)	1.e6
		Maximum time of initial backfill failure (year)	1.e6
Test Configuration:		Minimum expected lifetime of backfill (year)	1.e6
		Maximum expected lifetime of backfill (year)	1.e6
		Minimum fraction of backfill cracked	1
		Maximum fraction of backfill cracked	1
	Far Field Dashboard	Far Field Leg One\Transport length (km)	33
		Far Field Leg One\Effective Porosity Reduction Factor	1
		Far Field Leg Two\ Transport length (km)	33.3
		Far Field Leg Two\ Effective Porosity Reduction Factor	1
		Far Field Leg Three\ Effective Porosity Reduction Factor	1
		Far Field Leg Three\ Transport length (km)	33.3
	Biosphere Dashboard	Capture Fraction	1

Result Parameters: None required.

Success Criteria: The model result mode should be entered upon completion of the model run with no GoldSim or system errors exhibited.

Results:

Run completed with no errors, and all displays were generated.

Disposition:

Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: DE01

Test Title: Radionuclide Dose for Single Event Reference Case

Analyst: Ron Janetzke

Date: March 9, 2011

Test Environment: ZALBY, GoldSim 10.11

SOAR Version: Beta 8.4

Run Directory: D:\RonJ-\SOAR\V8_4\DE01

Test Objective: Verify that the model runs properly and provides meaningful results as plots and tables of the fraction of waste package failures, the breach area fraction, and the radionuclide dose.

Assumptions: A total simulation time much less than 1 million years is satisfactory to test the operation of the disruptive event model.

Test Configuration:

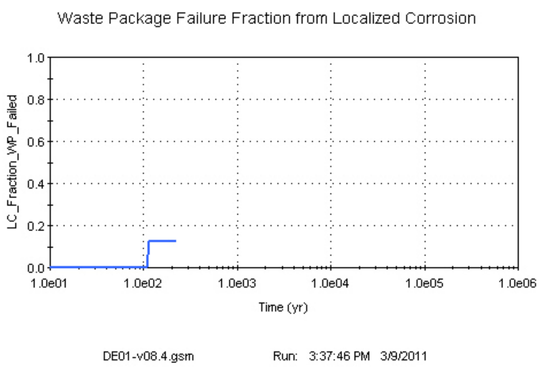
Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
	Simulation time	224 yr
Dashboard Waste Package	Disable general corrosion	Checked
Dashboard Disruptive Events	Type of disruptive event	None

Result Parameters:
\Results\G_Fraction_WP_Failed_LC
\Results\G_Fraction_WP_Failed_Disruptiv
\Results\G_Fraction_WPs_Failed
\Results\LC_FractionBreached_Result
\Results\G_WP_BreachFraction_Disruptive
\Results\WP_Breach_Fraction_Result
\Disposal_System\Model_Inputs\Disruptive_Events\Single_Event_Probability_SM\Single_Event_Time_Result
\Results\G_Annual_Dose_RN

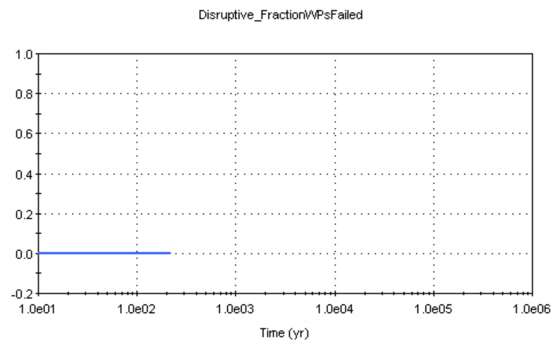
Success Criteria: The test is passed if the model successfully ran and produced quantities for the waste package failure fraction, breach fraction, and biosphere radionuclide dose, in plots and tables.

Results:

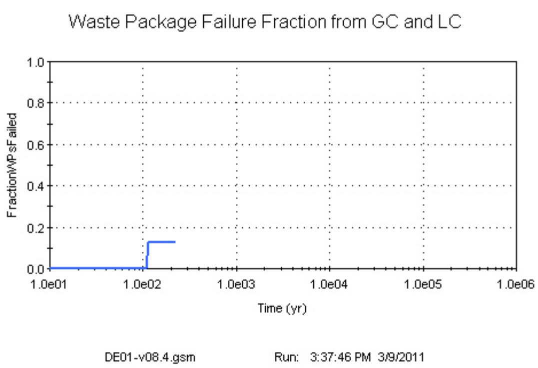
Run completed with no errors with the following displays generated.



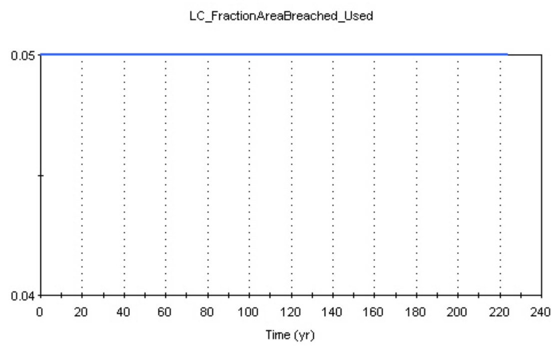
Waste Package Failure Fraction From Localized Corrosion



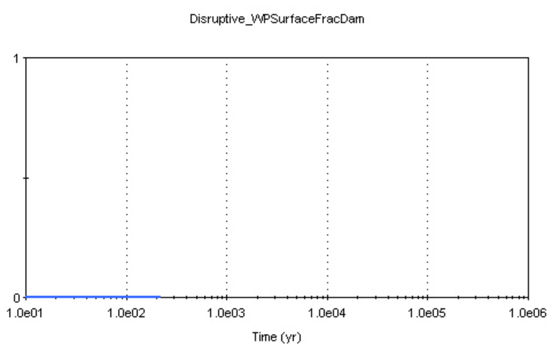
Waste Package Failure Fraction From Disruptive Events



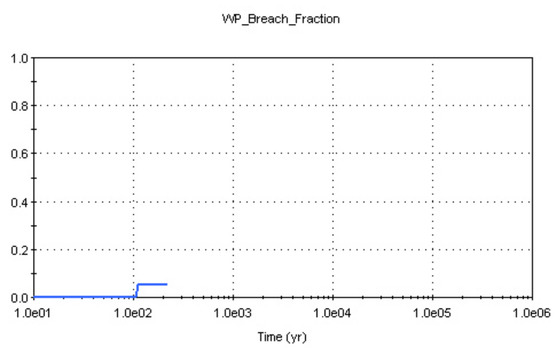
Waste Package Failure Fraction Implemented



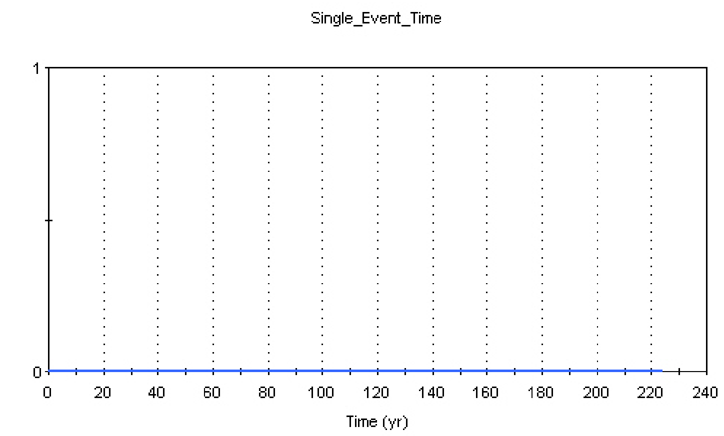
Waste Package Breach Fraction From Localized Corrosion



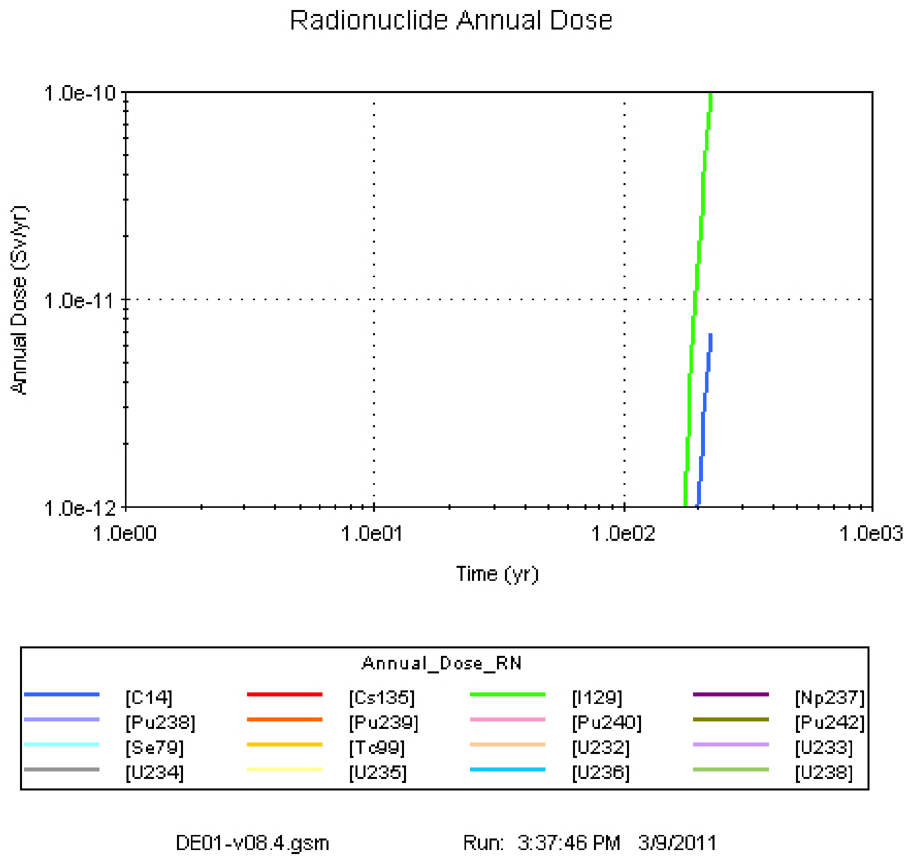
Waste Package Breach Fraction From Disruptive Events



Waste Package Breach Fraction Implemented



Single Disruptive Event Time



Radionuclide Annual Dose

Disposition:

Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: DE02
Test Title: Radionuclide Dose for Single Event Disruptive Event
Analyst: Ron Janetzke
Date: March 9, 2011
Test Environment: ZALBY, GoldSim 10.11
SOAR Version: Beta 8.4
Run Directory: D:\RonJ-\SOAR\V8_4\DE02
Test Objective: Verify that the radionuclide annual dose is similar to the radionuclide dose for a similar nondisruptive case relative to fraction of WP failed and breach area fraction.
Assumptions: A total simulation time much less than 1 million years is satisfactory to test the operation of the disruptive event model.
Test Configuration:

Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
	Simulation time	224 yr
Dashboard Waste Package	Disable general corrosion	Checked
	Disable localized corrosion	Checked
Dashboard Disruptive Events	Type of disruptive event	Single Failure Event
	Event probability	1.0
	Minimum fraction of waste packages damaged	0.125
	Maximum fraction of waste packages damaged	0.125
	Minimum damage area per waste package	0.05
	Maximum damage area per waste package	0.05

Result Parameters:
\Results\G_Fraction_WP_Failed_LC
\Results\G_Fraction_WP_Failed_Disruptiv
\Results\G_Fraction_WPs_Failed
\Results\LC_FractionBreached_Result
\Results\G_WP_BreachFraction_Disruptive
\Results\WP_Breach_Fraction_Result
\Disposal_System\Model_Inputs\Disruptive_Events\Single_Event_Probability_SM\Single_Event_Time_Result
\Results\G_Annual_Dose_RN

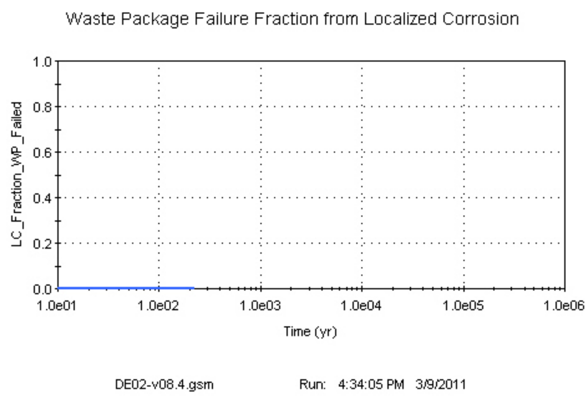
SOAR Verification Test Report (continued)

Success Criteria:

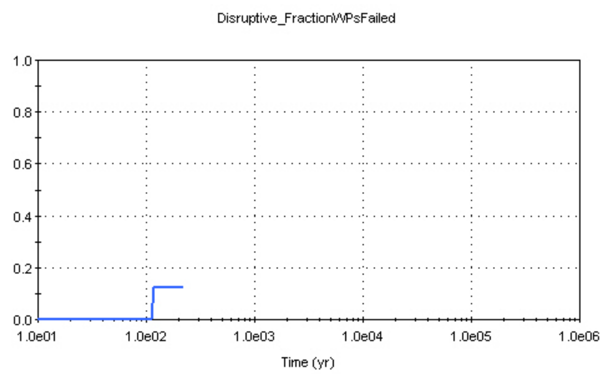
(1) The “Waste Package Failure Fraction from Localized Corrosion” plot should show no failures.
(2) The “Waste Package Failure Fraction from Disruptive Events” plot should show a 0.125 failure fraction at the failure time.
(3) The “Waste Package Failure Fraction Implemented” plot should show a 0.125 failure fraction at the failure time.
(4) The “Waste Package Breach Fraction from Localized Corrosion” plot should show no breach area.
(5) The “Waste Package Breach Fraction from Disruptive Events” plot should show a 0.05 breach area fraction at the failure time.
(6) The “Waste Package Breach Fraction Implemented” plot should show a 0.05 breach area fraction at the failure time.
(7) The “Single Disruptive Event Time” plot should show a failure time of about 112 years.
(8) The “Radionuclide Dose” plot should match the radionuclide Dose plot from test DE01.

Results:

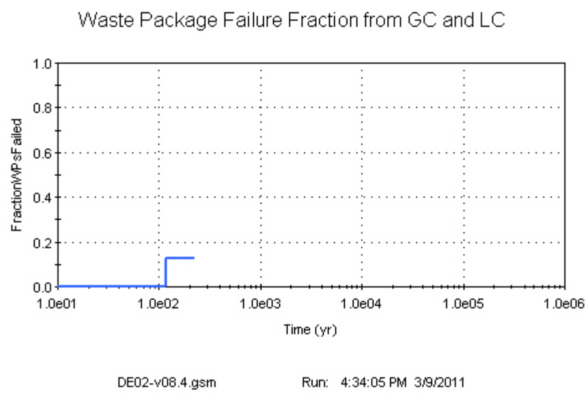
Run completed with no errors with the following displays generated.



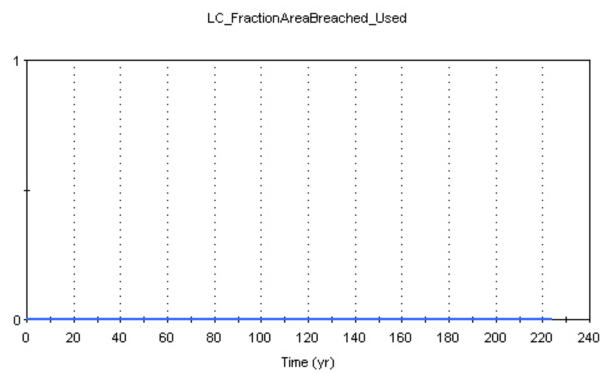
Waste Package Failure Fraction From Localized Corrosion



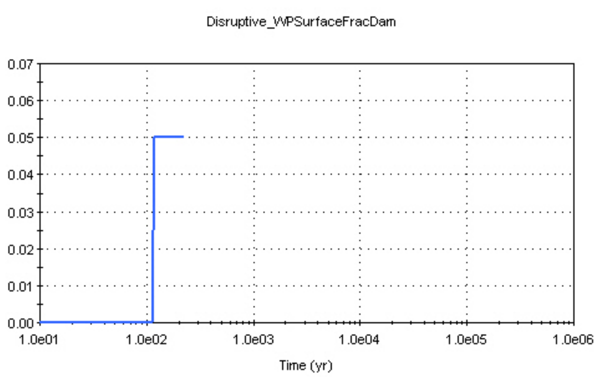
Waste Package Failure Fraction From Disruptive Events



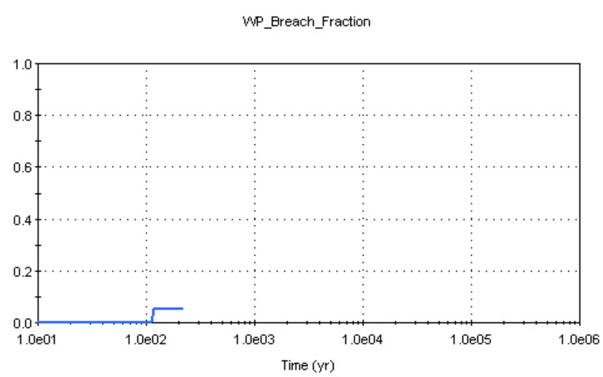
Waste Package Failure Fraction Implemented



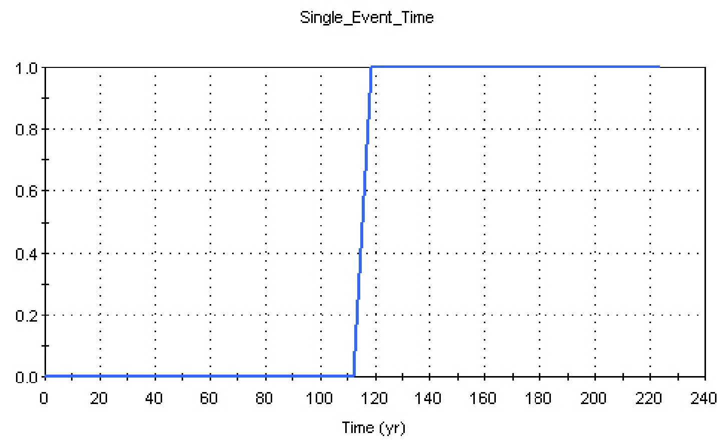
Waste Package Breach Fraction From Localized Corrosion



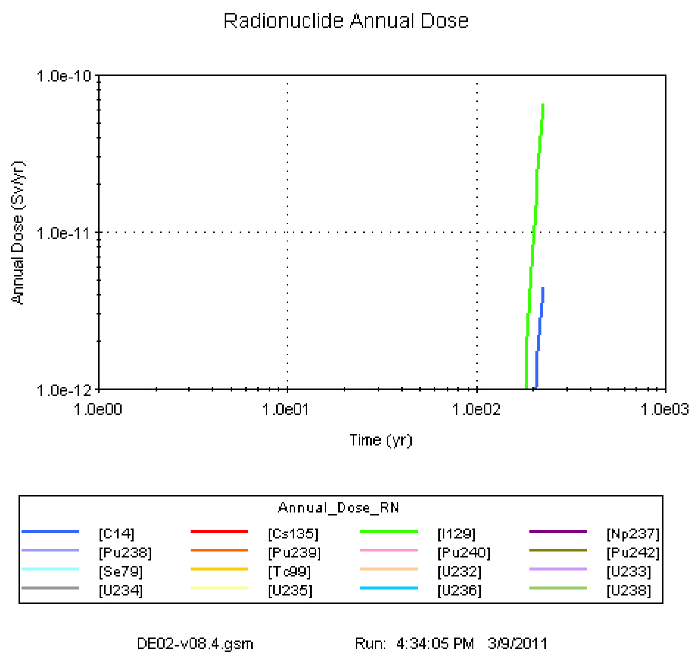
Waste Package Breach Fraction From Disruptive Events



Waste Package Breach Fraction Implemented



Single Disruptive Event Time



Radionuclide Annual Dose

Disruptive event time was set to match LC from test DE01. GoldSim results of test DE02 are Disruption_FractionWPsFailed = 0.0 at timestep 112.4 years and Disruption_FractionWPsFailed = 0.125 at 118.6 years (approximately 120 years). The resolution of the timesteps does not allow the plots to show “step function” graphs.

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**
(3) Criterion 3: **PASS**
(4) Criterion 4: **PASS**
(5) Criterion 5: **PASS**
(6) Criterion 6: **PASS**
(7) Criterion 7: **PASS**
(8) Criterion 8: **PASS**

SOAR Verification Test Report

Test ID: DE03

Test Title: Radionuclide Dose for Multiple Event Reference Case

Analyst: Ron Janetzke

Date: March 10, 2011

Test Environment: ZALBY, GoldSim 10.11

SOAR Version: Beta 8.4

Run Directory: D:\RonJ-\SOAR\V8_4\DE03

Test Objective: Verify that the model runs properly and provides meaningful results as plots and tables of the fraction of waste package failures, the breach area fraction, and the radionuclide dose.

Assumptions: None

Test Configuration:

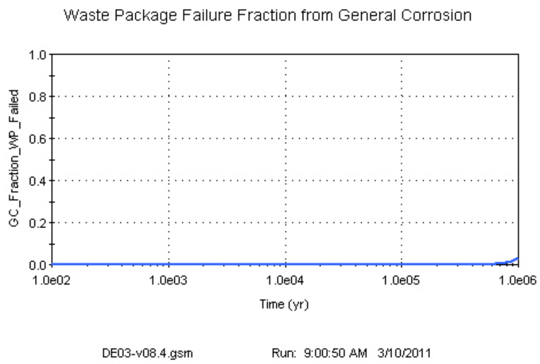
Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
	Simulation time	1.0e6 yr
Dashboard Waste Package	Breach area computation method	Weighted Average
	Disable localized corrosion	Checked
Dashboard Disruptive Events	Type of disruptive event	None

Result Parameters:
\Results\G_Fraction_WP_Failed_GC
\Results\G_Fraction_WP_Failed_Disruptiv
\Results\G_Fraction_WPs_Failed
\Results\GC_FractionBreached_Result
\Results\G_WP_BreachFraction_Disruptive
\Results\WP_Breach_Fraction_Result
\Disposal_System\Model_Inputs\Disruptive_Events\Multiple_Event_Probability_SM\Multiple_Event_Time_Result
\Results\G_Annual_Dose_RN

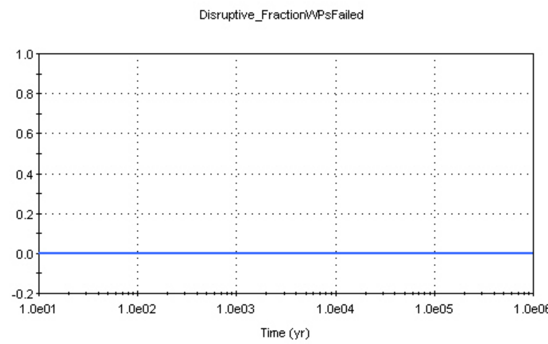
Success Criteria: The test is passed if the model successfully ran and produced quantities for the waste package failure fraction, breach fraction, and biosphere radionuclide dose, in plots and tables.

Results:

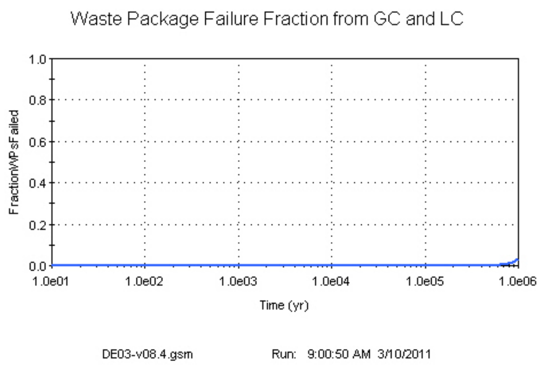
Run completed with no errors with the following displays generated.



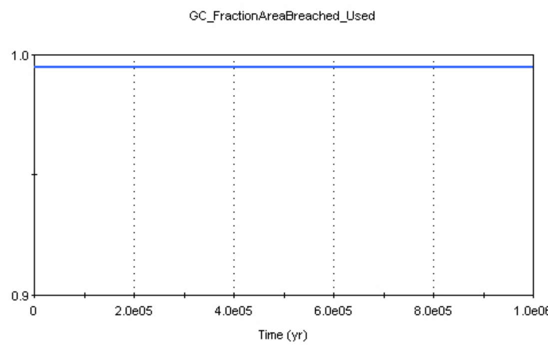
Waste Package Failure Fraction From General Corrosion



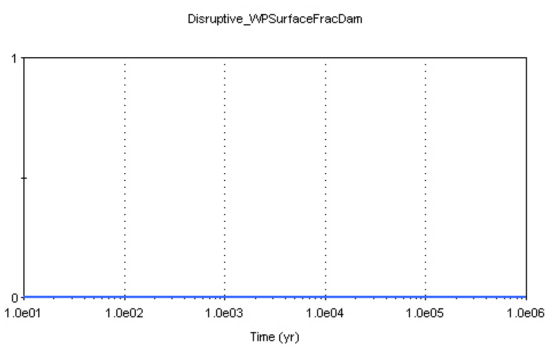
Waste Package Failure Fraction From Disruptive Events



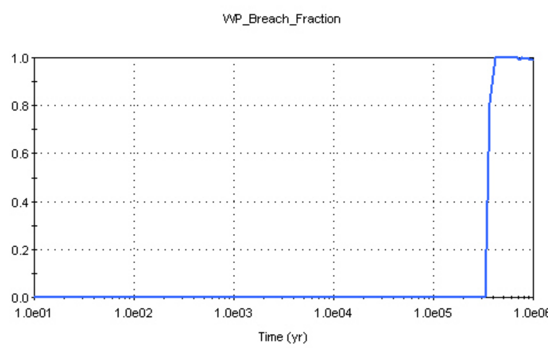
Waste Package Failure Fraction Implemented



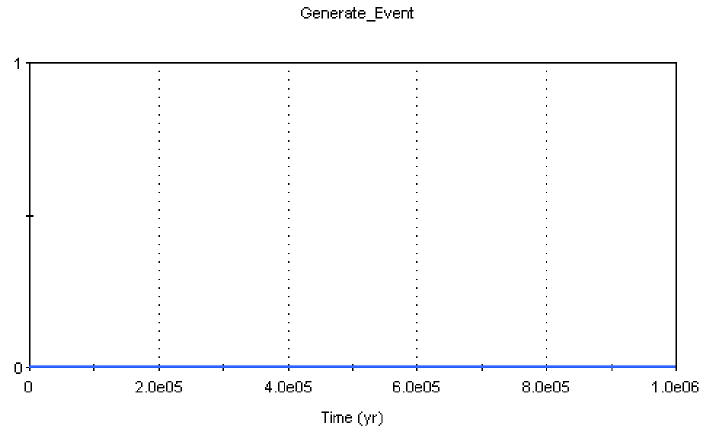
Waste Package Breach Fraction From General Corrosion



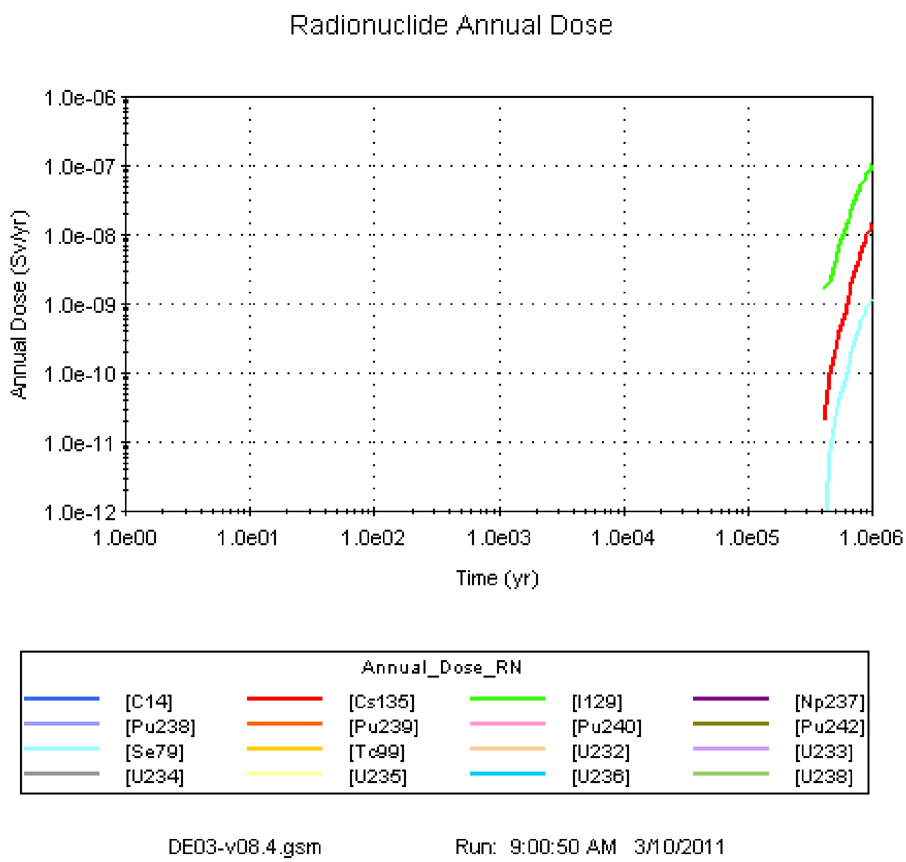
Waste Package Breach Fraction From Disruptive Events



Waste Package Breach Fraction Implemented



Multiple Disruptive Event Time



Radionuclide Annual Dose

Disposition:

(1) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: DE04

Test Title: Radionuclide Dose for Multiple Disruptive Events

Analyst: Ron Janetzke

Date: March 10, 2011

Test Environment: ZALBY, GoldSim 10.11

SOAR Version: Beta 8.4

Run Directory: D:\RonJ-\SOAR\V8_4\DE04

Test Objective: Verify that the radionuclide annual dose is similar to the radionuclide dose for a similar nondisruptive case relative to fraction of WP failed and breach area fraction.

Assumptions: None

Test Configuration:

Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
	Simulation time	1.0e6 yr
Dashboard Waste Package	Breach area computation method	Weighted Average
	Disable localized corrosion	Checked
	Disable general corrosion	Checked
Dashboard Disruptive Events	Type of disruptive event	Multiple Failure Events
	Damage Fraction	0.015 (for all recurrence rates)
	Damage Area	0.995 (for all recurrence rates)

Result Parameters:

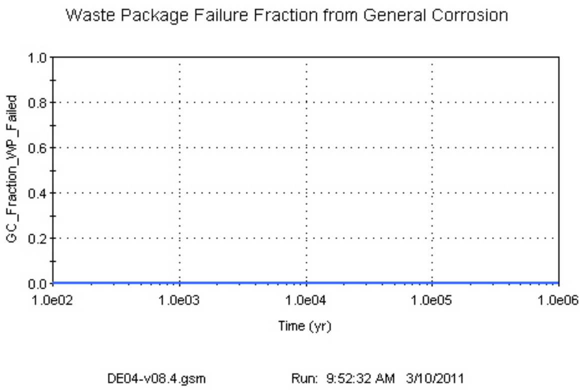
\Results\G_Fraction_WP_Failed_GC
\Results\G_Fraction_WP_Failed_Disruptiv
\Results\G_Fraction_WPs_Failed
\Results\GC_FractionBreached_Result
\Results\G_WP_BreachFraction_Disruptive
\Results\WP_Breach_Fraction_Result
\Disposal_System\Model_Inputs\Disruptive_Events\Multiple_Event_Probability_SM\Multiple_Event_Time_Result
\Results\G_Annual_Dose_RN

SOAR Verification Test Report (continued)

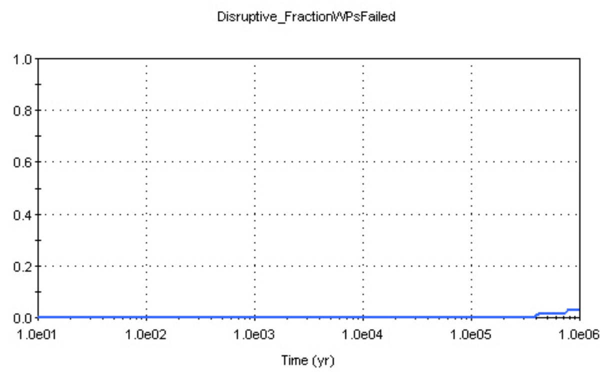
(1) The “Waste Package Failure Fraction from General Corrosion” plot should show no failures.
(2) The “Waste Package Failure Fraction from Disruptive Events” plot should show a 0.015 failure fraction for multiple failure times.
(3) The “Waste Package Failure Fraction Implemented” plot should show a 0.015 failure fraction for multiple failure times.
(4) The “Waste Package Breach Fraction from General Corrosion” plot should show no breach area.
(5) The “Waste Package Breach Fraction from Disruptive Events” plot should show a 0.995 breach area fraction for multiple failure times.
(6) The “Waste Package Breach Fraction Implemented” plot should show a 0.995 breach area fraction for multiple failure times.
(7) The “Multiple Disruptive Event Time” plot should show an initial failure time of about 370,000 years.
(8) The “Radionuclide Dose” plot should match the radionuclide Dose plot from test DE03.

Results:

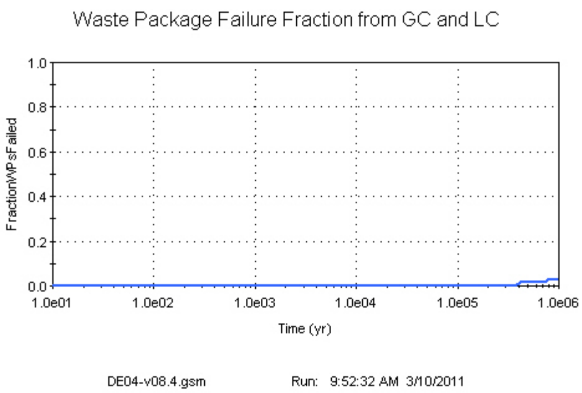
Run completed with no errors with the following displays generated.



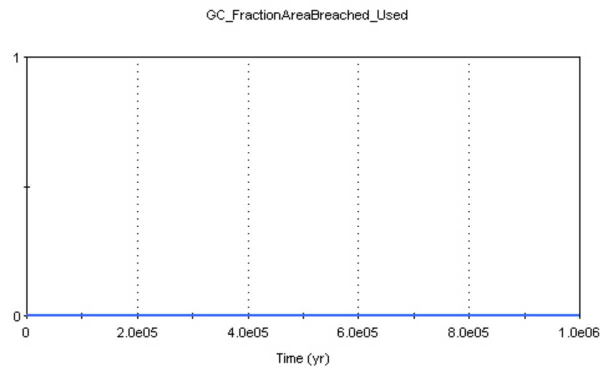
Waste Package Failure Fraction From General Corrosion



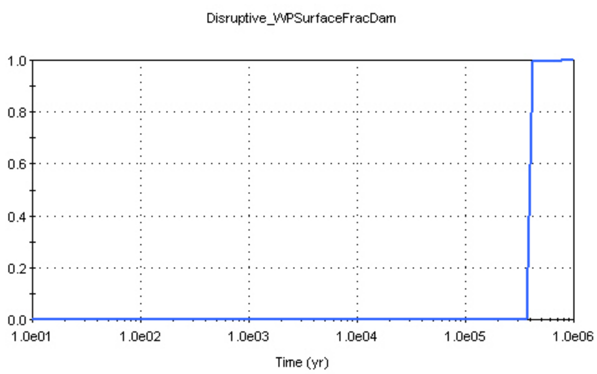
Waste Package Failure Fraction From Disruptive Events



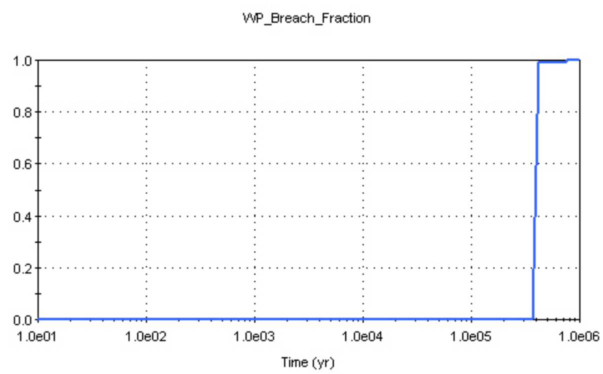
Waste Package Failure Fraction Implemented



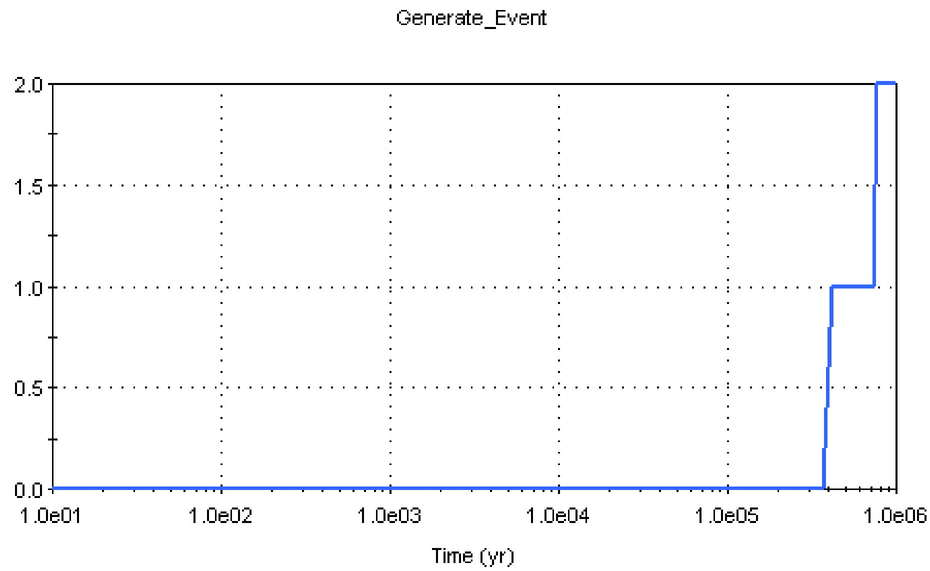
Waste Package Breach Fraction From General Corrosion



Waste Package Breach Fraction From Disruptive Events

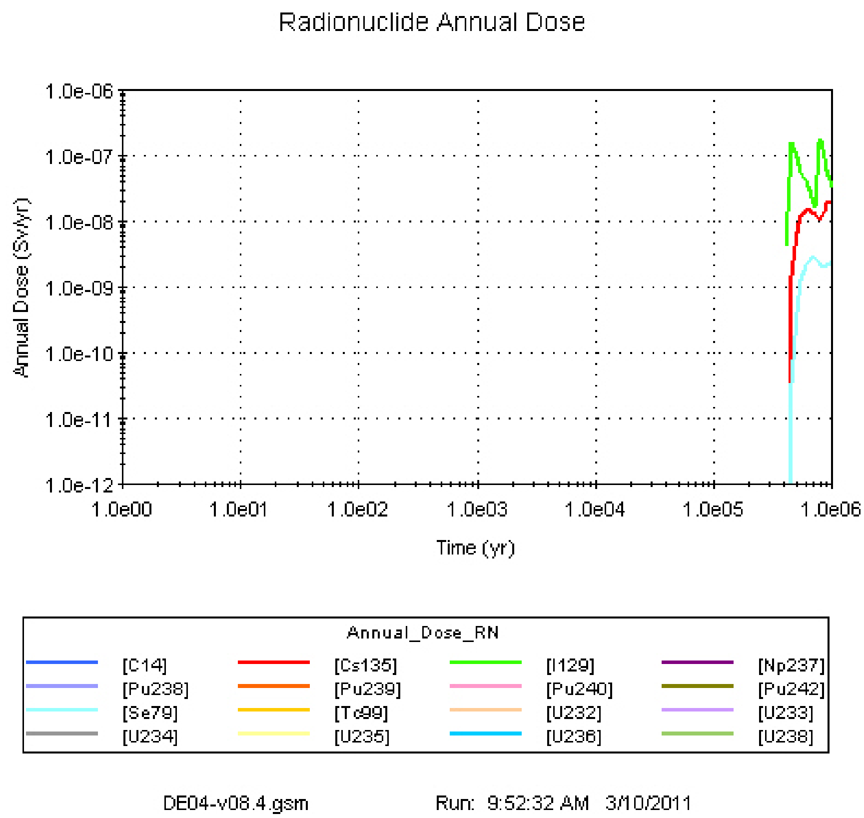


Waste Package Breach Fraction Implemented



Cumulative Number of Multiple Disruptive Events

The dose is slightly higher at initial release times due to the slightly higher WP failure fraction around 370,000 years. The initiation time is satisfactory, as are the final dose values at the end of the simulation, and compares favorably with the DE03 reference case.



Radionuclide Annual Dose

Disposition:

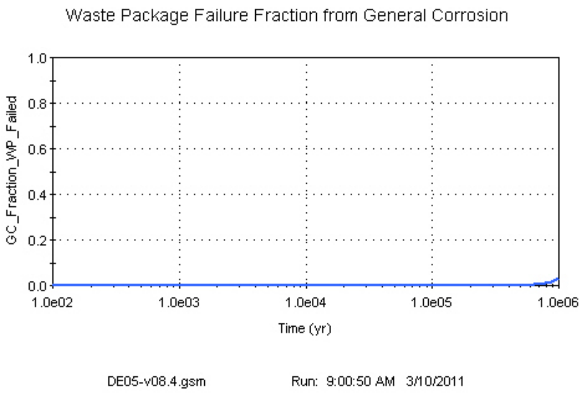
(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**
(3) Criterion 3: **PASS**
(4) Criterion 4: **PASS**
(5) Criterion 5: **PASS**
(6) Criterion 6: **PASS**
(7) Criterion 7: **PASS**
(8) Criterion 8: **PASS**

SOAR Verification Test Report

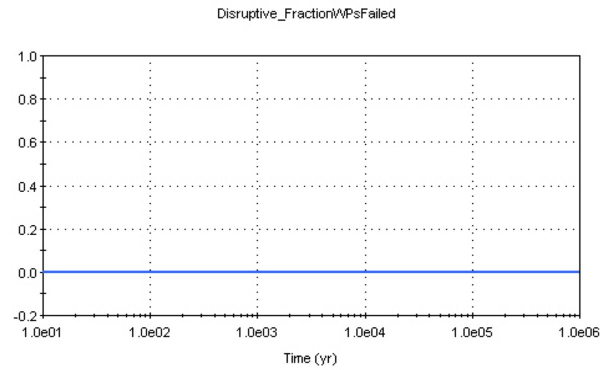
Test ID:	DE05		
Test Title:	Radionuclide Dose for WP Failure Rate Reference Case		
Analyst:	Ron Janetzke		
Date:	March 21, 2011		
Test Environment:	ZALBY, GoldSim 10.11		
SOAR Version:	Beta 8.4		
Run Directory:	D:\RonJ-\SOAR\V8_4\DE05		
Test Objective:	Verify that the model runs properly and provides meaningful results as plots and tables of the fraction of waste package failures, the breach area fraction, and the radionuclide dose.		
Assumptions:	None		
Test Configuration:	Simulation Settings	Deterministic Simulation	On
		Element Mean Values	On
		Number of realizations	1
		Number of timesteps	95
		Simulation time	1.0e6 yr
	Dashboard Waste Package	Breach area computation method	Weighted Average
		Disable localized corrosion	Checked
	Dashboard Disruptive Events	Type of disruptive event	None
Result Parameters:	\Results\G_Fraction_WP_Failed_GC \Results\G_Fraction_WP_Failed_Disruptiv \Results\G_Fraction_WPs_Failed \Results\GC_FractionBreached_Result \Results\G_WP_BreachFraction_Disruptive \Results\WP_Breach_Fraction_Result \Results\G_Annual_Dose_RN		
Success Criteria:	The test is passed if the model successfully ran and produced quantities for the waste package failure fraction, breach fraction, and biosphere radionuclide dose, in plots and tables.		

Results:

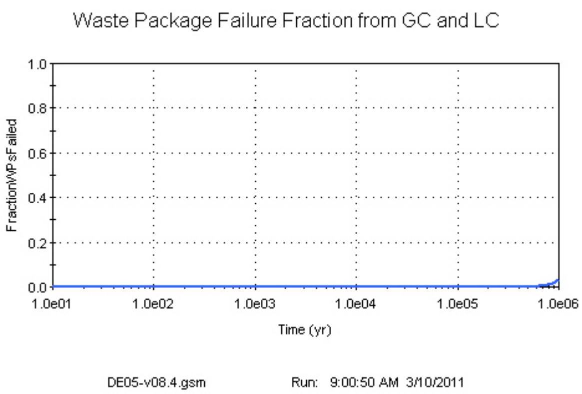
The run completed with no errors with the following displays generated.



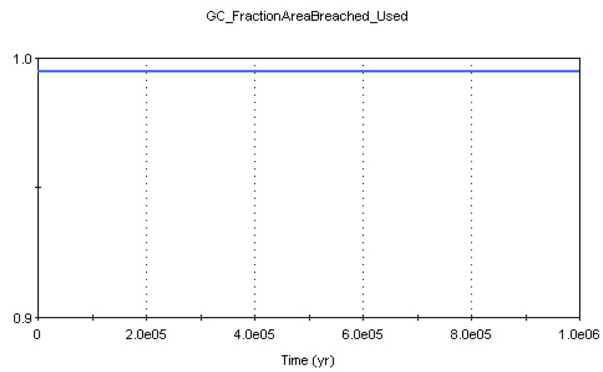
Waste Package Failure Fraction From General Corrosion



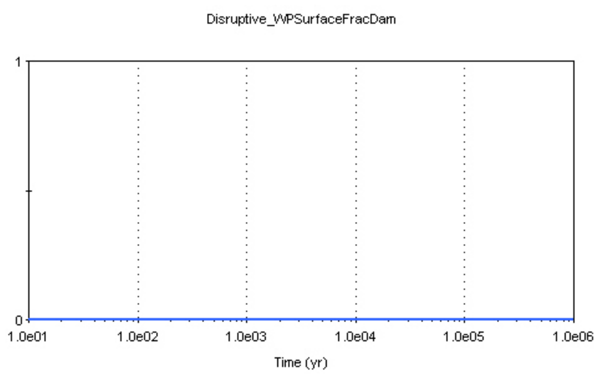
Waste Package Failure Fraction From Disruptive Events



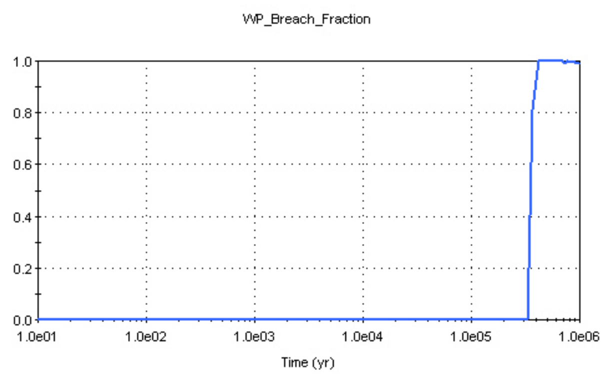
Waste Package Failure Fraction Implemented



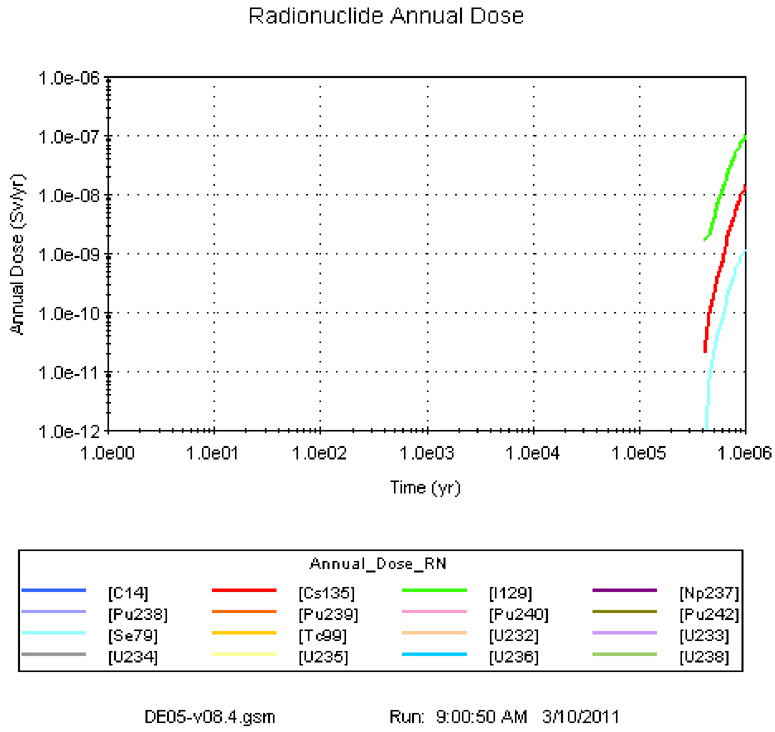
Waste Package Breach Fraction From General Corrosion



Waste Package Breach Fraction From Disruptive Events



Waste Package Breach Fraction Implemented



Radionuclide Annual Dose

Disposition:

(1) Criterion 1: **PASS**

SOAR Verification Test Report

Test ID: DE06

Test Title: Radionuclide Dose for WP Failure Rate Disruptive Event

Analyst: Ron Janetzke

Date: March 21, 2011

Test Environment: ZALBY, GoldSim 10.11

SOAR Version: Beta 8.4

Run Directory: D:\RonJ-\SOAR\V8_4\DE06

Test Objective: Verify that the radionuclide annual dose is similar to the radionuclide dose for a similar nondisruptive case relative to fraction of WP failed and breach area fraction.

Assumptions: None

Test Configuration:

Simulation Settings	Deterministic Simulation	On
	Element Mean Values	On
	Number of realizations	1
	Number of timesteps	95
	Simulation time	1.0e6 yr
Dashboard Waste Package	Breach area computation method	Weighted Average
	Disable localized corrosion	Checked
	Disable general corrosion	Checked
Dashboard Disruptive Events	Type of disruptive event	Waste Package Failure Rate
	Start time of waste package failure (year)	370000
	End time of waste package failure (year)	1.0ed6
	Minimum waste package failure rate (waste packages per year)	0.0004
	Maximum waste package failure rate (waste packages per year)	0.00066
	Minimum waste package breach fraction	0.995
	Maximum waste package breach fraction	0.995

Result Parameters:

\Results\G_Fraction_WP_Failed_GC
\Results\G_Fraction_WP_Failed_Disruptiv
\Results\G_Fraction_WPs_Failed
\Results\GC_FractionBreached_Result
\Results\G_WP_BreachFraction_Disruptive
\Results\WP_Breach_Fraction_Result
\Results\G_Annual_Dose_RN

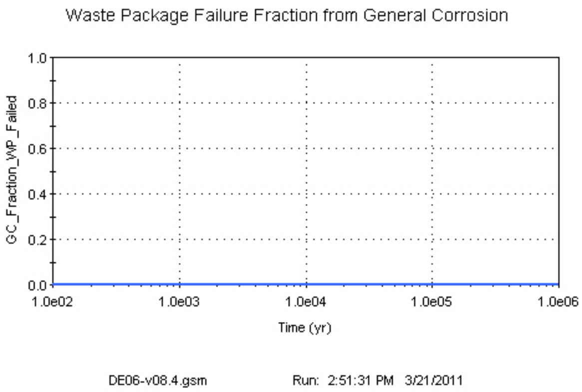
SOAR Verification Test Report (continued)

Success Criteria:

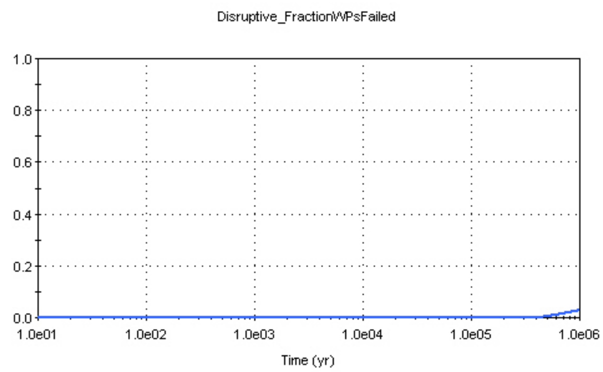
(1) The “Waste Package Failure Fraction from General Corrosion” plot should show no failures.
(2) The “Waste Package Failure Fraction from Disruptive Events” plot should be 0 until 370,000 and rise to 0.03 at 10.e6 years.
(3) The “Waste Package Failure Fraction Implemented” plot should be 0 until 370,000 and rise to 0.03 at 10.e6 years.
(4) The “Waste Package Breach Fraction from General Corrosion” plot should show no breach area.
(5) The “Waste Package Breach Fraction from Disruptive Events” plot should show a 0.995 breach area fraction after 370000 years.
(6) The “Waste Package Breach Fraction Implemented” plot should show a 0.995 breach area fraction after 370,000 years.
(7) The Failure Fraction curves will not match exactly because the control parameters for the WP failure disruptive event do not provide controls at a sufficient level. However, the start time of failures and the final fraction failed can be controlled somewhat, and they should be within a factor of 2 relative to test DE05. The “Radionuclide Dose” plots should be within +/− an order of magnitude relative to test DE05, because an exact match is not possible with the different failure curves generated by the different tests.

Results:

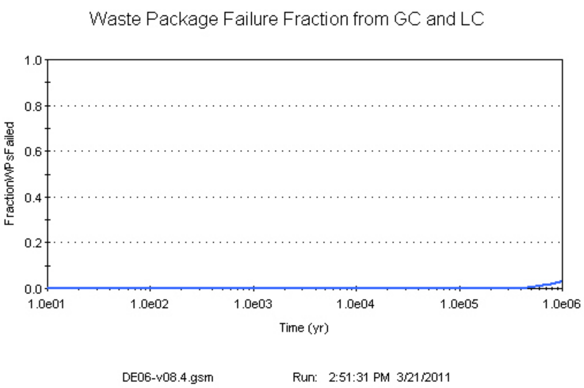
The run completed with no errors with the following displays generated.



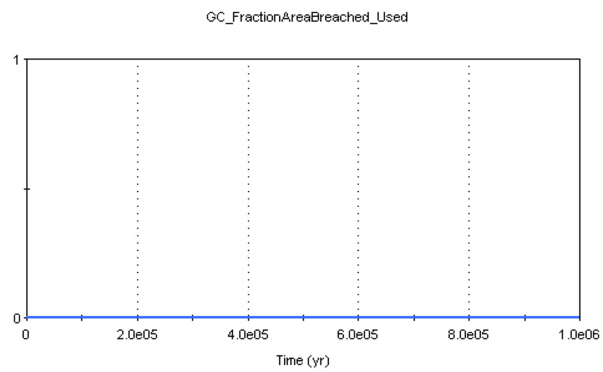
Waste Package Failure Fraction From General Corrosion



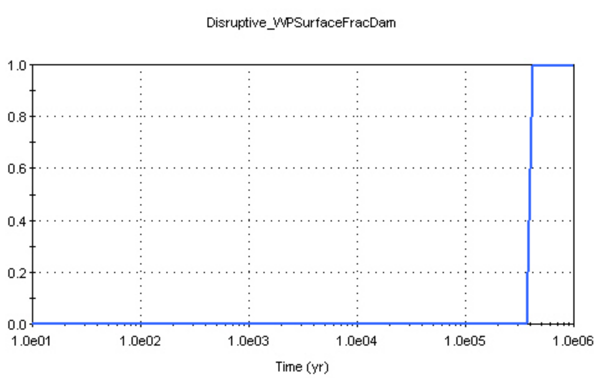
Waste Package Failure Fraction From Disruptive Events



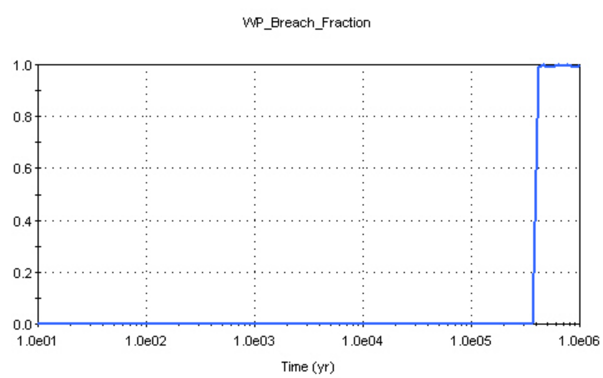
Waste Package Failure Fraction Implemented



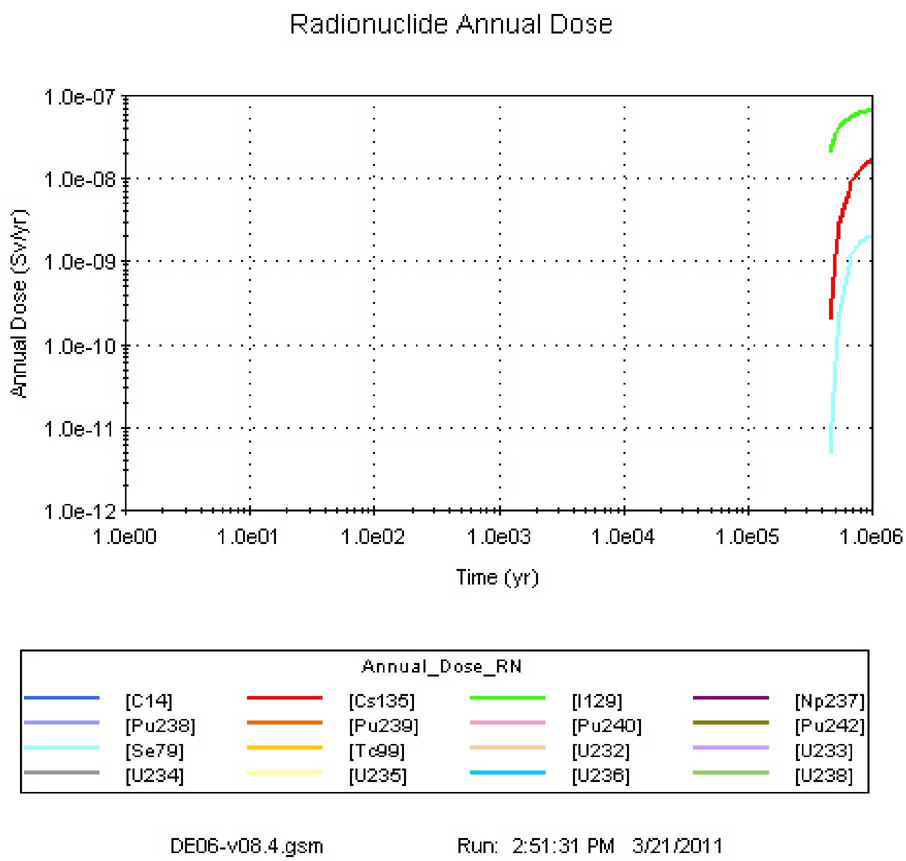
Waste Package Breach Fraction From General Corrosion



Waste Package Breach Fraction From Disruptive Events



Waste Package Breach Fraction Implemented



Radionuclide Annual Dose

Disposition:

(1) Criterion 1: **PASS**
(2) Criterion 2: **PASS**
(3) Criterion 3: **PASS**
(4) Criterion 4: **PASS**
(5) Criterion 5: **PASS**
(6) Criterion 6: **PASS**
(7) Criterion 7: **PASS**

4 SOAR MODEL RUNS

In this chapter, a library of results is compiled to show trends arising from the variation of one parameter at a time. The objective is to show the dose response to changes in inputs controlled from the dashboard. Each run included 150 Monte Carlo realizations. The runs were grouped in simulation sets. Each simulation set is a family of runs with a single parameter varying discretely over a broad range. The results are presented in summary reports for each simulation. Each summary report describes the objective of the simulation and the changed parameters, and it includes dose versus time plots. In all of the runs, except Simulation 7, the waste package was assumed to fail instantaneously. Doses for I-129 and Np-237 are included to exhibit representative results for fission products and actinides. No interpretation of the results is provided. Table 4-1 summarizes the simulations included in this chapter and the parameter varied for each simulation.

Table 4-1. Summary of the Simulations Including the Primary Input Evaluated in Each Simulation

Simulation	Description	Primary Input Evaluated
1	Waste Form Degradation Rate	Degradation rate multiplier
2	Initial Enrichment	Initial U-235 enrichment (%)
3	Burnup	Burnup value (GWd/MTU)
4	Alternative Waste Forms	Radionuclide inventory of spent nuclear fuel, spent mixed-oxide fuel, high-level waste (glass), and high-level waste (ceramic)
5	High-Level Waste Loading	Waste form loading factor (%)
6	Mass Per Waste Package	Total disposed mass per waste package (grams)
7	Waste Package General Corrosion Rate	General corrosion rate of waste package material
8	Waste Package Breach Area	General corrosion breach area fraction
9	Buffer Integrity	Time of initial backfill failure (year) and fraction of backfill cracked
10	Waste Package Water Volume	Water volume inside the waste package (cubic meters)
11	Hydraulic Conductivity	Hydraulic gradient (sediments and porous rock only)
12	Redox	Geologic media for all three far field legs to “unconsolidated sediments,” “fractured rock,” and “porous rock” in an oxidizing environment and in a reducing environment
13	Disturbed Zone Characteristics	Enable radionuclide sorption in the transition region between the buffer and the far field

To define the Base Scenario, the SOAR Version 1.0.02 default settings are used except for the following Input Control changes. These changes are for all 13 simulations except as otherwise noted.

- Run each simulation for 150 realizations, and save histories for 150 realizations.
- Set “Minimum waste package failure rate (waste packages per year)” equal to 0.999e6, “Maximum waste package failure rate (waste packages per year)” equal to 1e6, “End time of waste package failure (year)” equal to 1.01, and “Type of disruptive event” as “Waste package failure rate” to simulate instant waste package failure.
- Activate “Bypass the backfill (diffusive barrier).”
- Set all 2010 inventories equal to zero.

Simulation 1: Waste Form Degradation Rate

Objective:	Show the effect on dose of varying degradation rate for spent nuclear fuel in both oxidizing and reducing environments.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT. — Set “degradation rate multiplier” equal to 1e-2, 1e-4, 1e-6, and 1e-8 (and others as needed) in separate simulations. — Set the Redox condition as “Oxidizing” and “Reducing” for far-field Legs 1, 2, and 3 in separate simulations.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

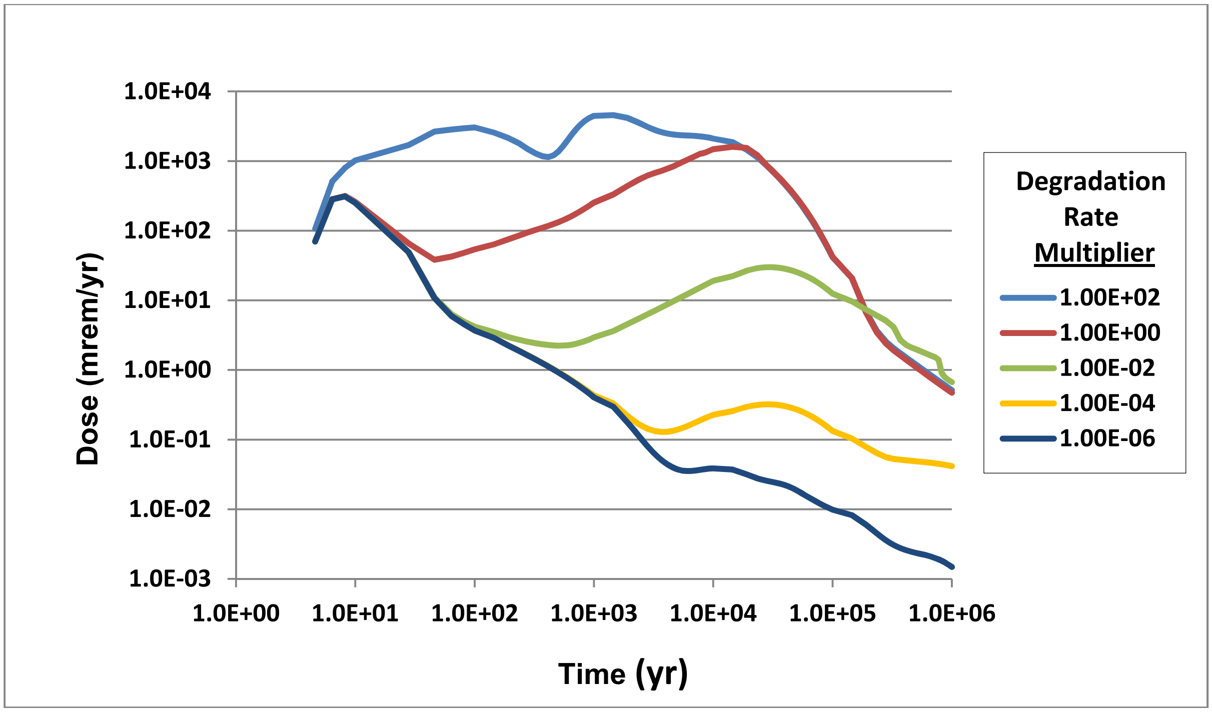


Figure 4-1. Total Dose for Simulation 1: Waste Form Degradation Rate—Oxidizing

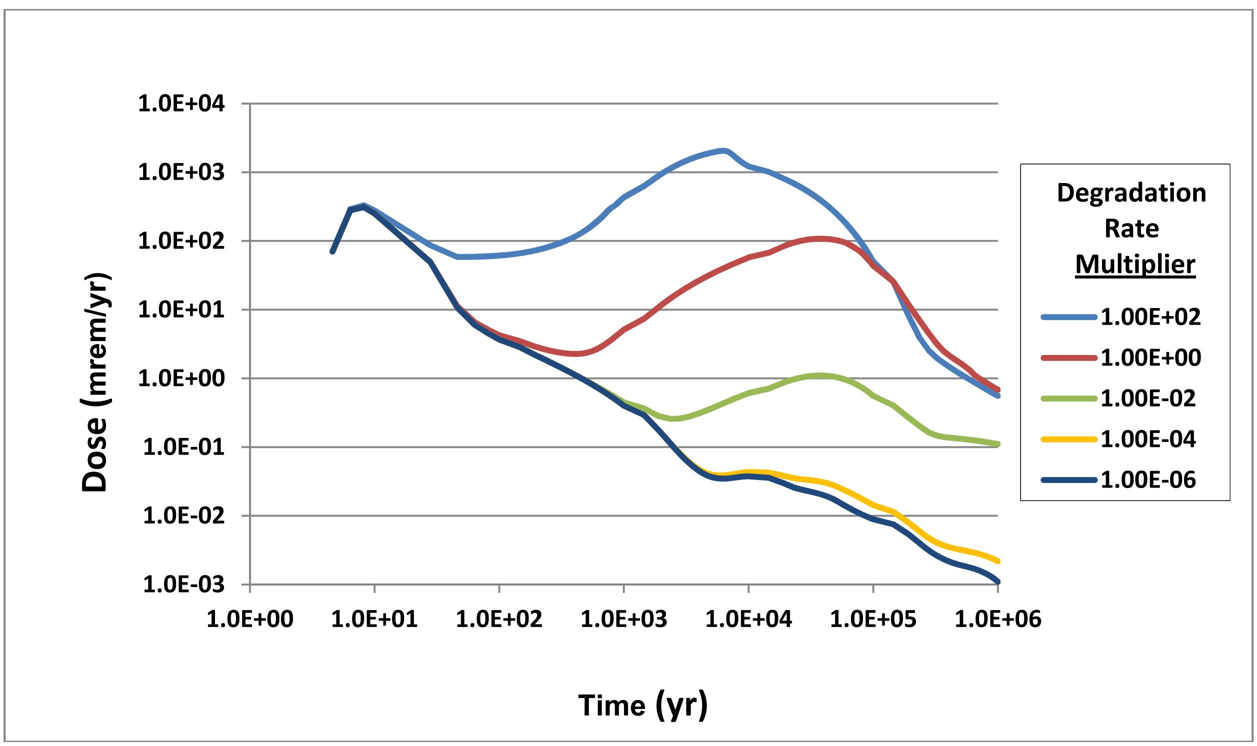


Figure 4-2. Total Dose for Simulation 1: Waste Form Degradation Rate—Reducing

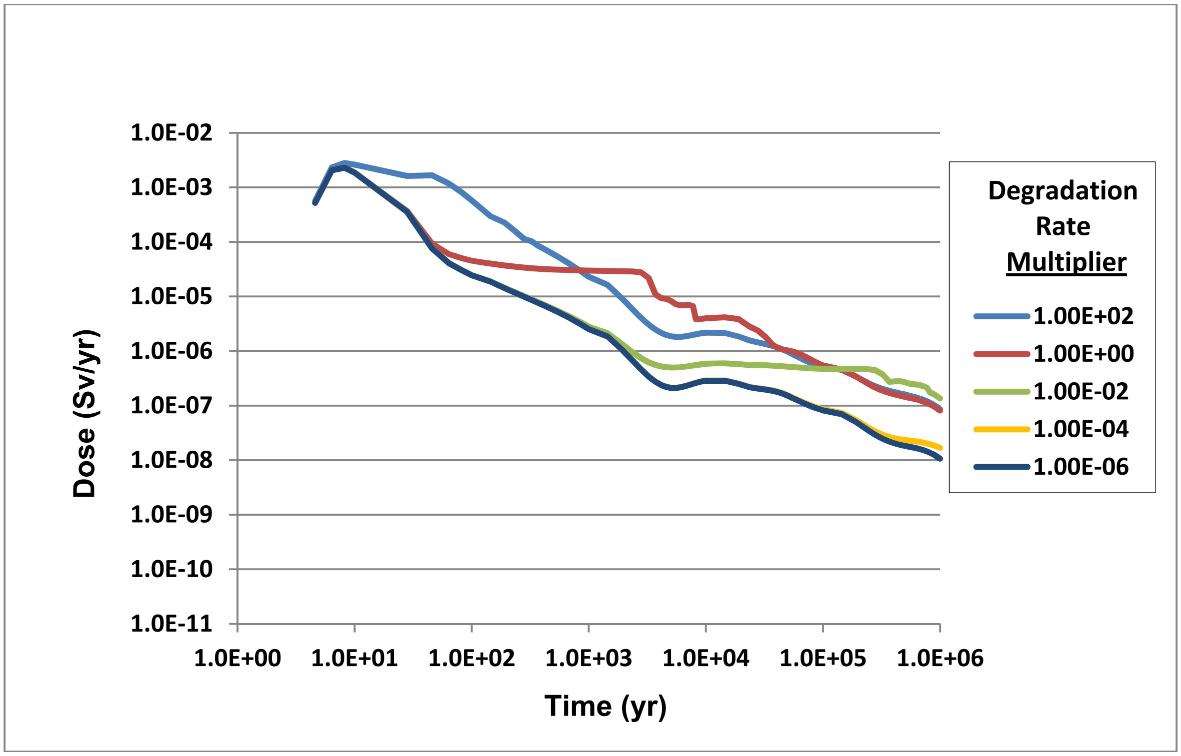


Figure 4-3. I-129 Dose for Simulation 1: Waste Form Degradation Rate—Oxidizing

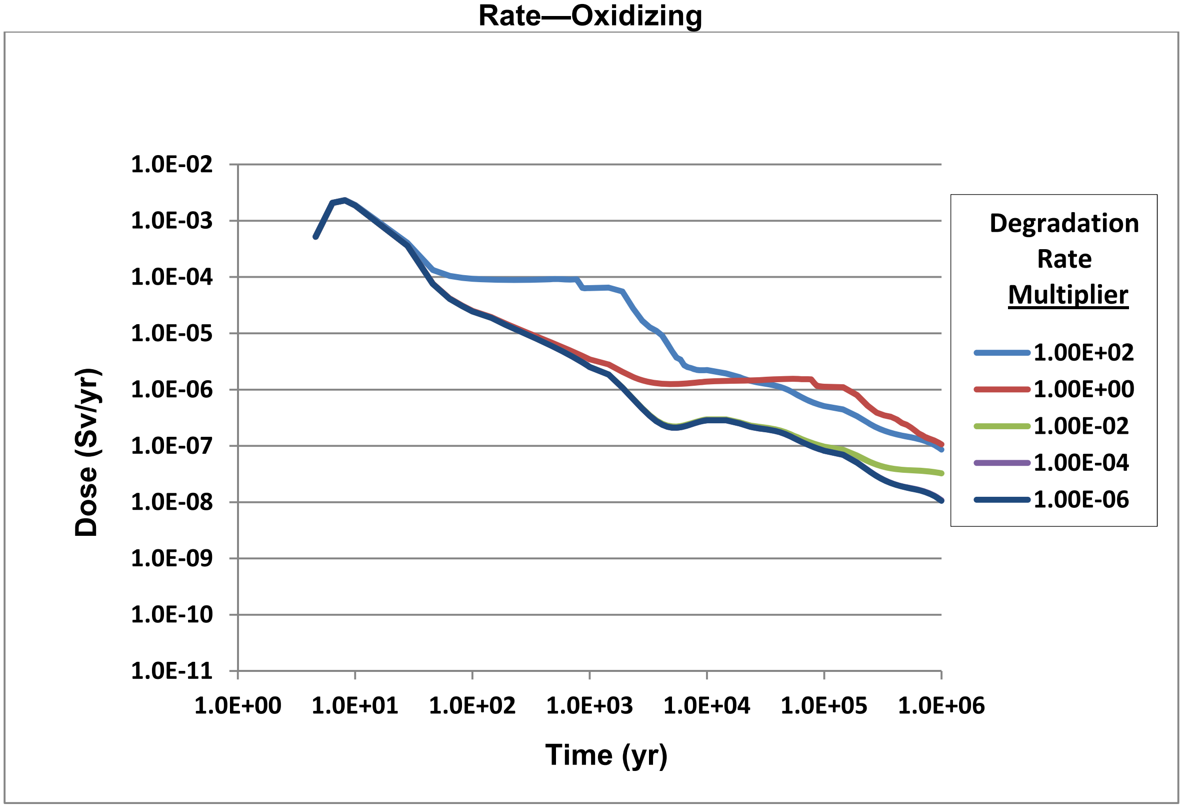


Figure 4-4. I-129 Dose for Simulation 1: Waste Form Degradation Rate—Reducing

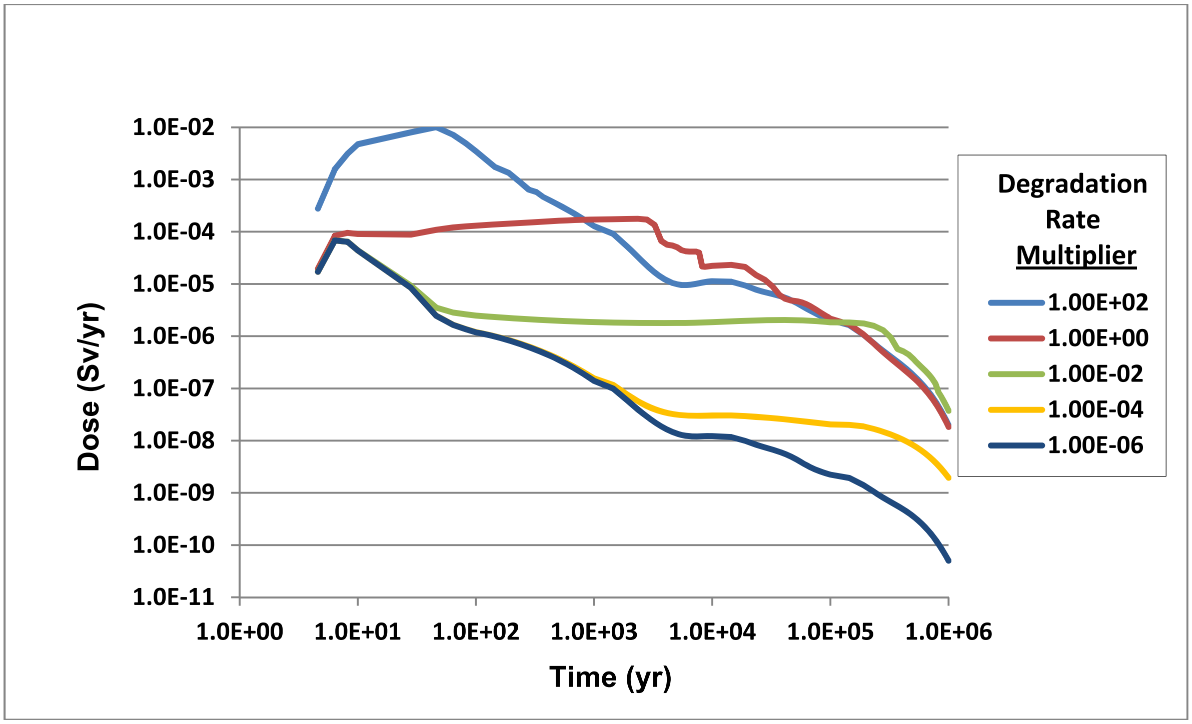


Figure 4-5. Tc-99 Dose for Simulation 1: Waste Form Degradation Rate—Oxidizing

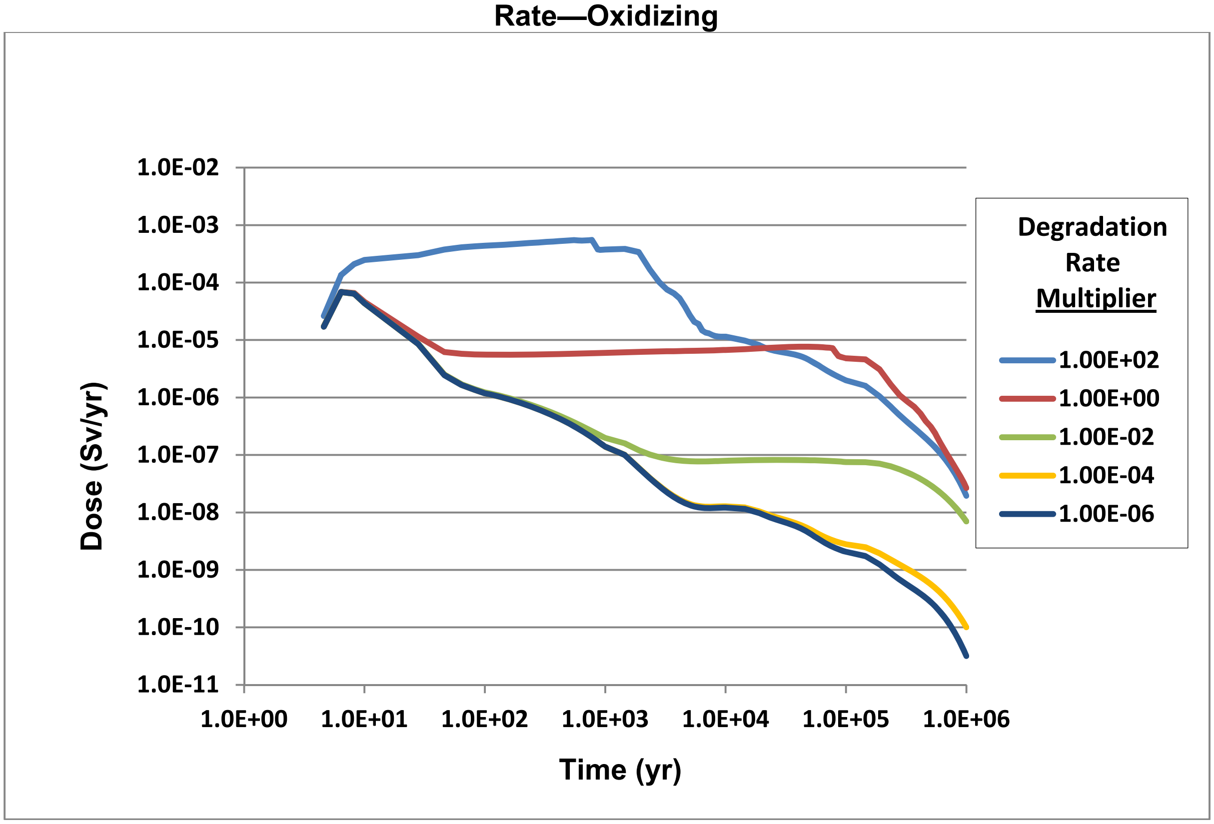


Figure 4-6. Tc-99 Dose for Simulation 1: Waste Form Degradation Rate—Reducing

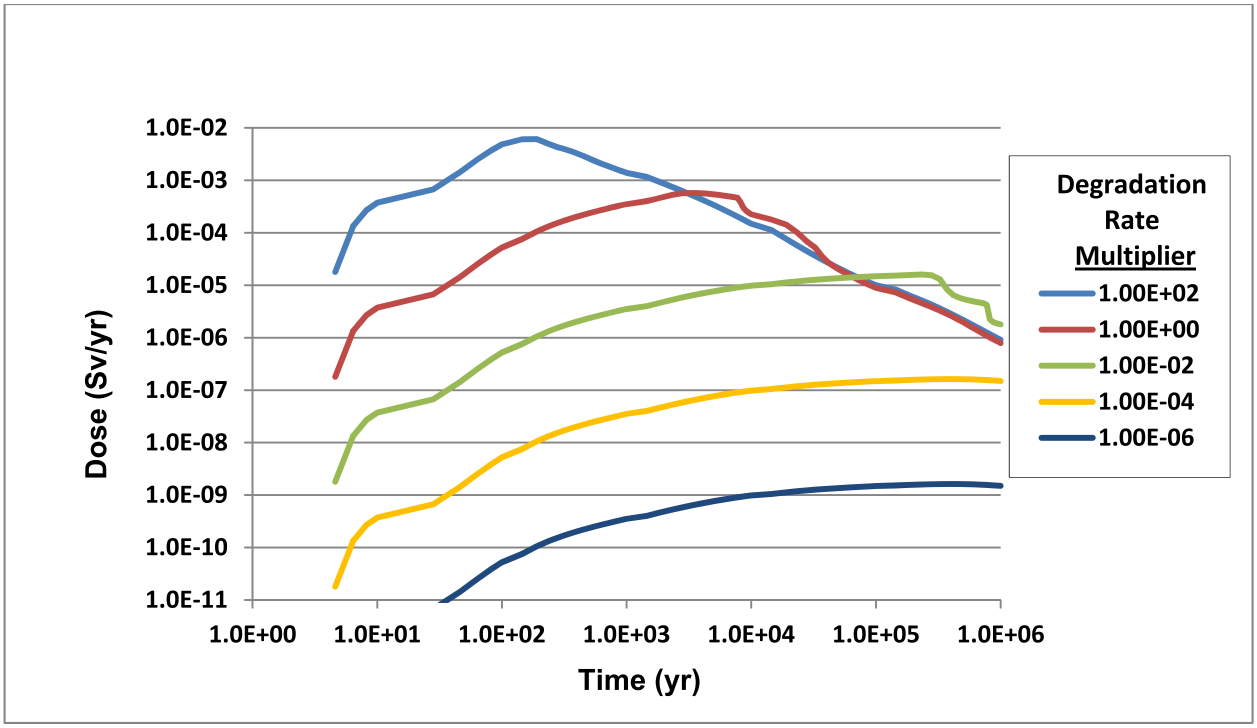


Figure 4-7. Np-237 Dose for Simulation 1: Waste Form Degradation Rate—Oxidizing

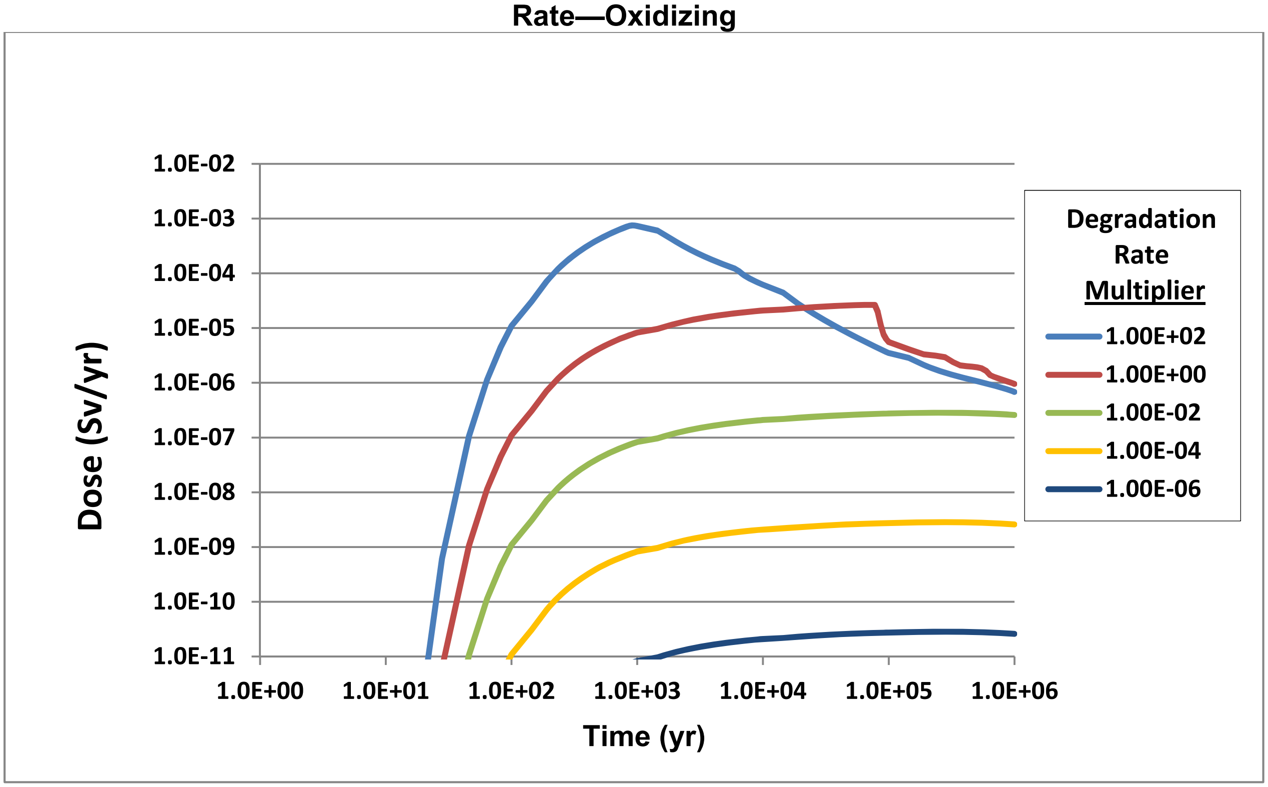


Figure 4-8. Np-237 Dose for Simulation 1: Waste Form Degradation Rate—Reducing

Simulation 2: Initial Enrichment

Objective: Show the effect on dose of varying the U-235 enrichment for spent nuclear fuel in both oxidizing and reducing environments.

Test Environment: GoldSim_Player_10.5SP1

SOAR Version: 1.0.02

Input Control Changes:

- Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT.
- Set “Initial U235 Enrichment (percent)” equal to 2, 4, and 6 in separate simulations.
- Set the Redox condition as “Oxidizing” and “Reducing” for far-field Legs 1, 2, and 3 in separate simulations.

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

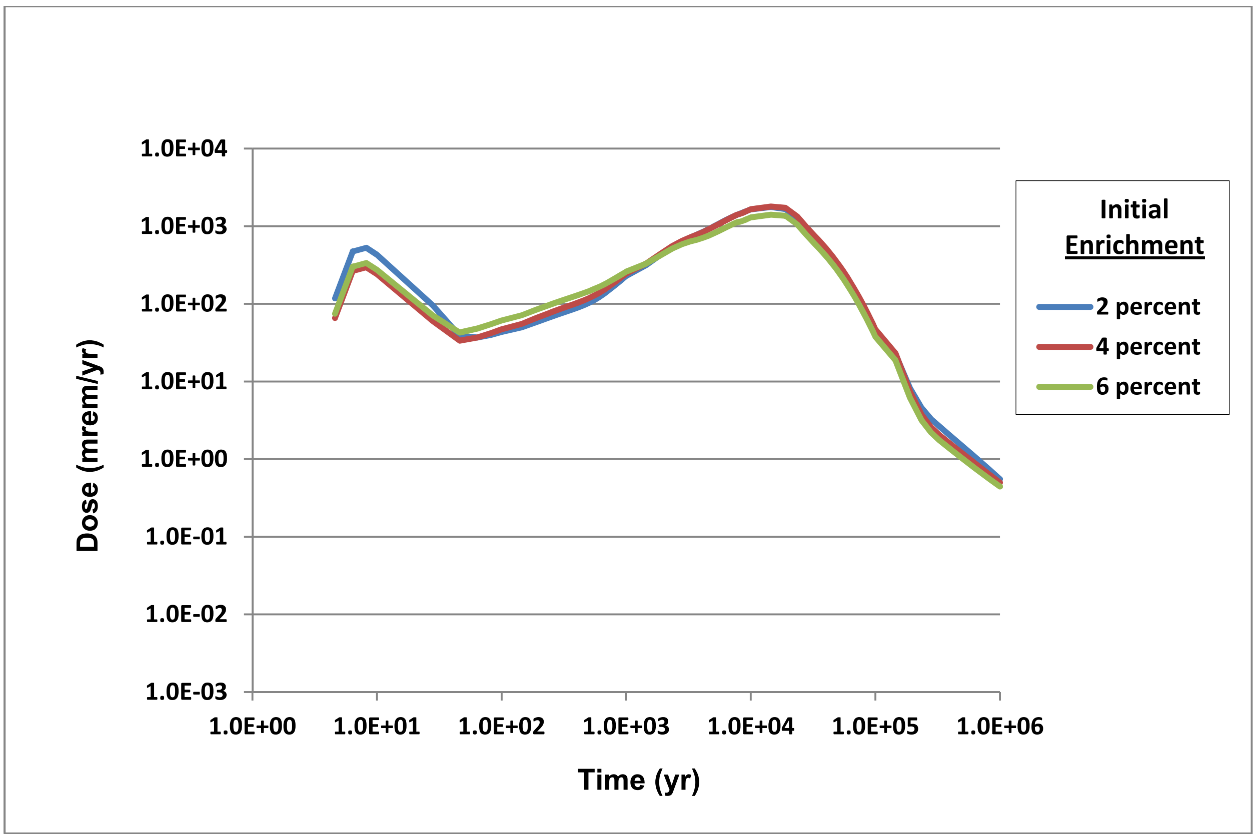


Figure 4-9. Total Dose for Simulation 2: Initial Enrichment—Oxidizing

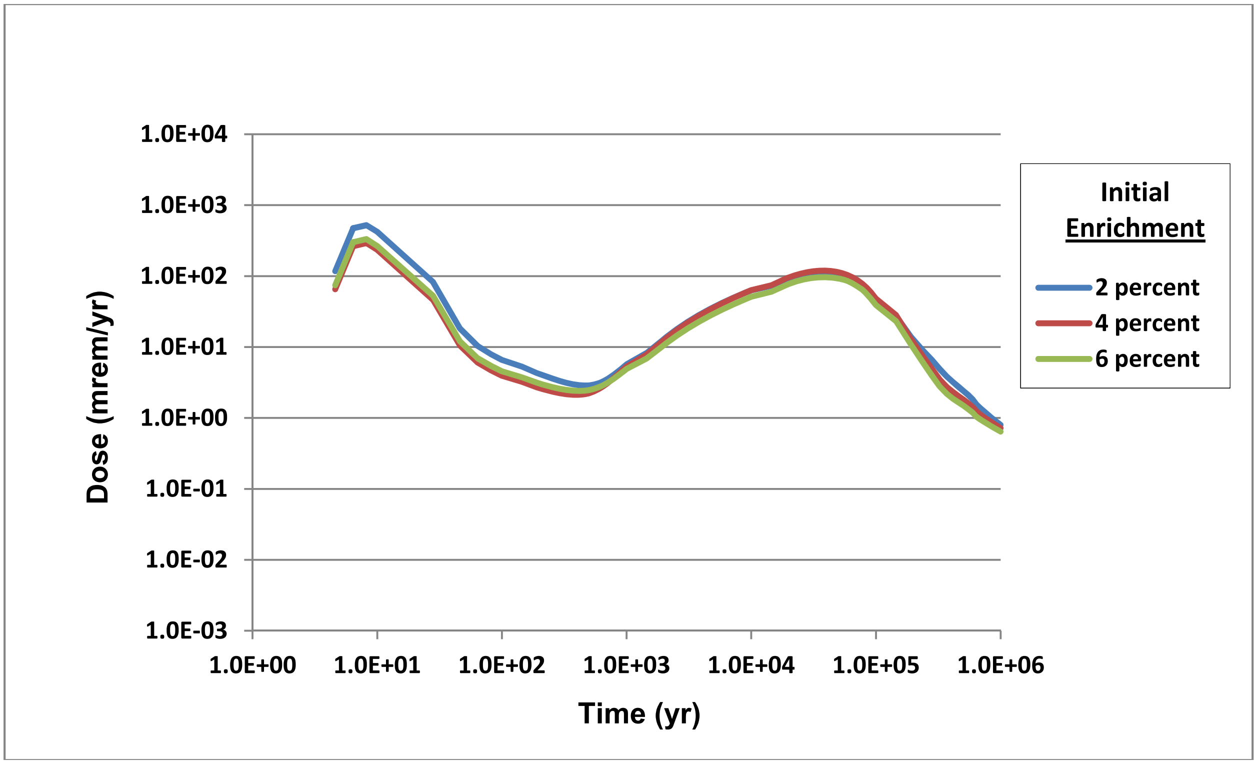


Figure 4-10. Total Dose for Simulation 2: Initial Enrichment—Reducing

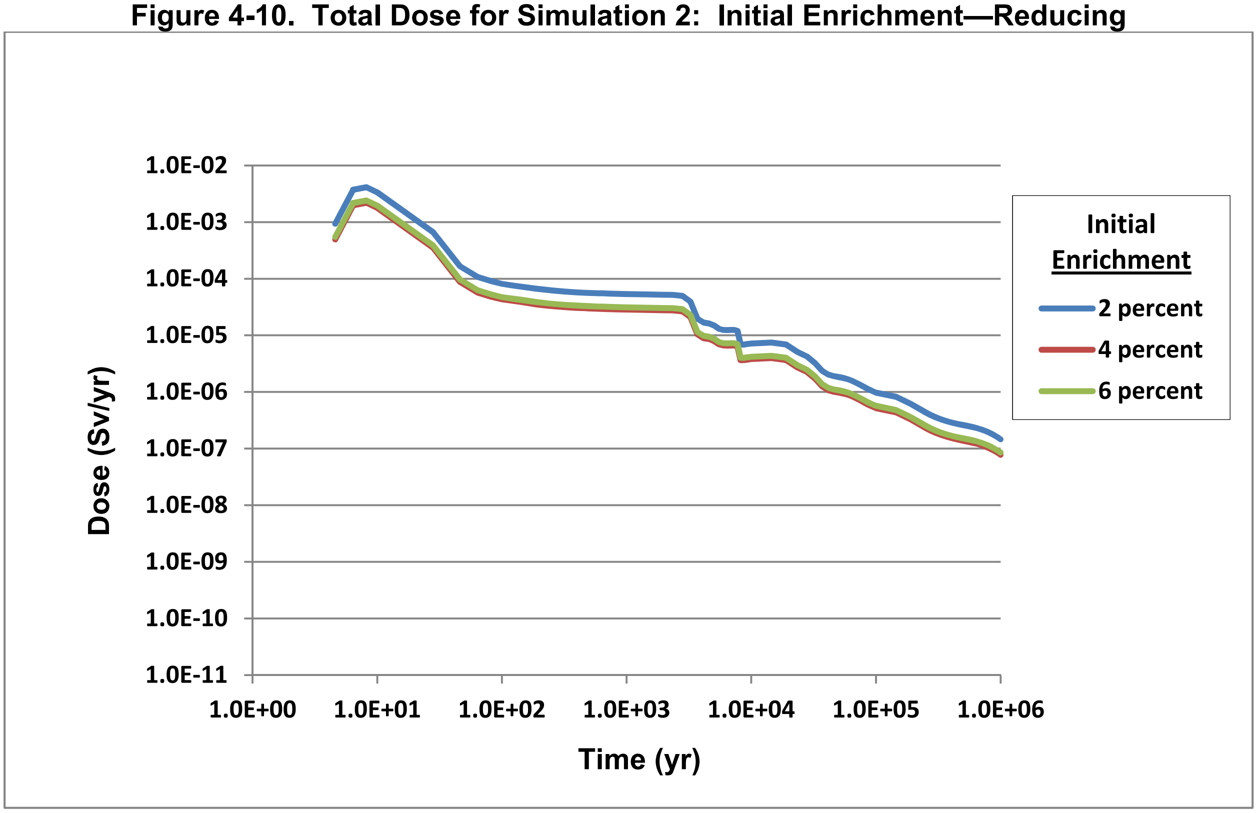


Figure 4-11. I-129 Dose for Simulation 2: Initial Enrichment—Oxidizing

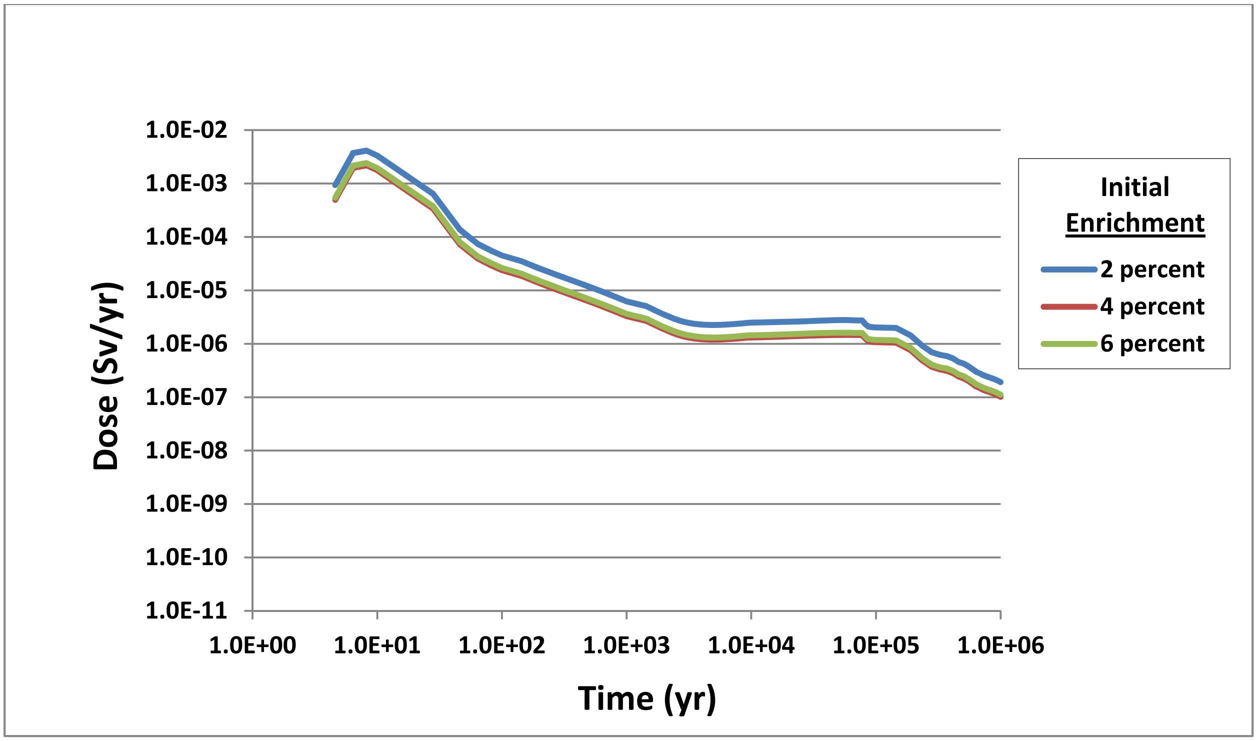


Figure 4-12. I-129 Dose for Simulation 2: Initial Enrichment—Reducing

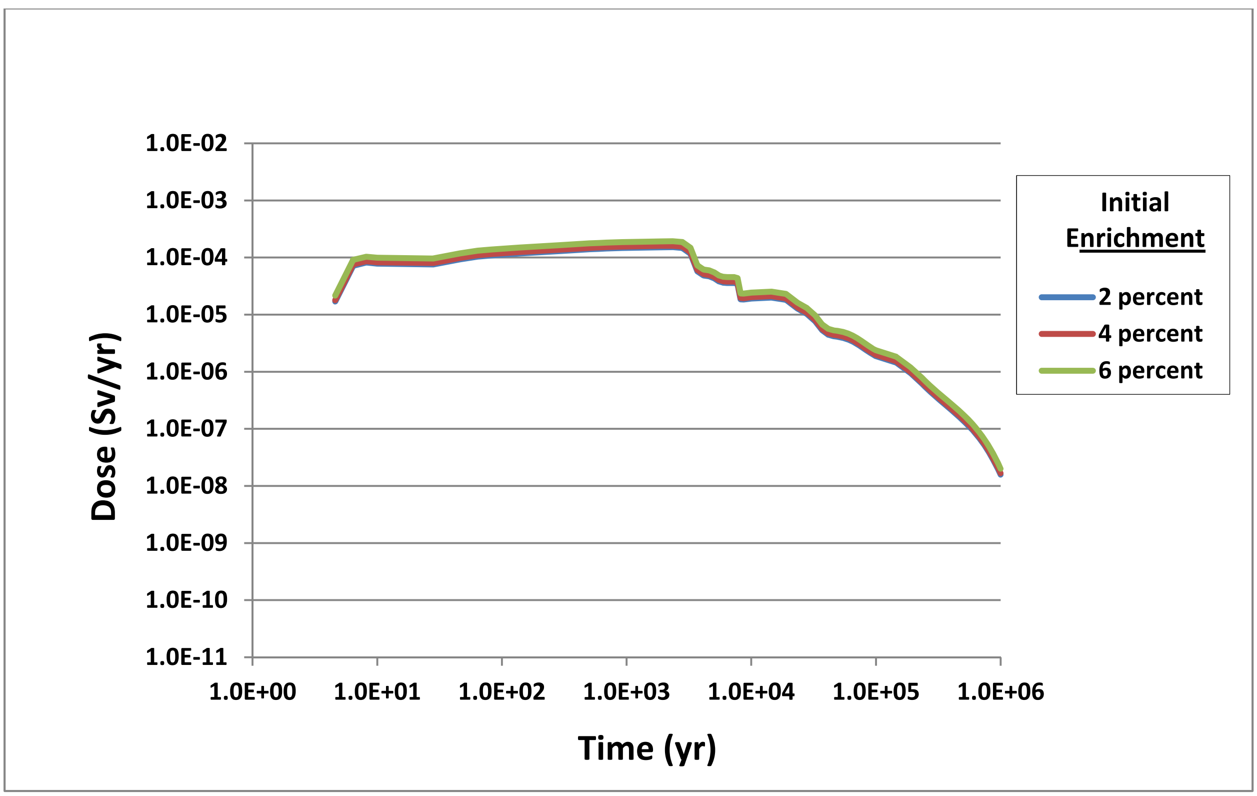


Figure 4-13. Tc-99 Dose for Simulation 2: Initial Enrichment—Oxidizing

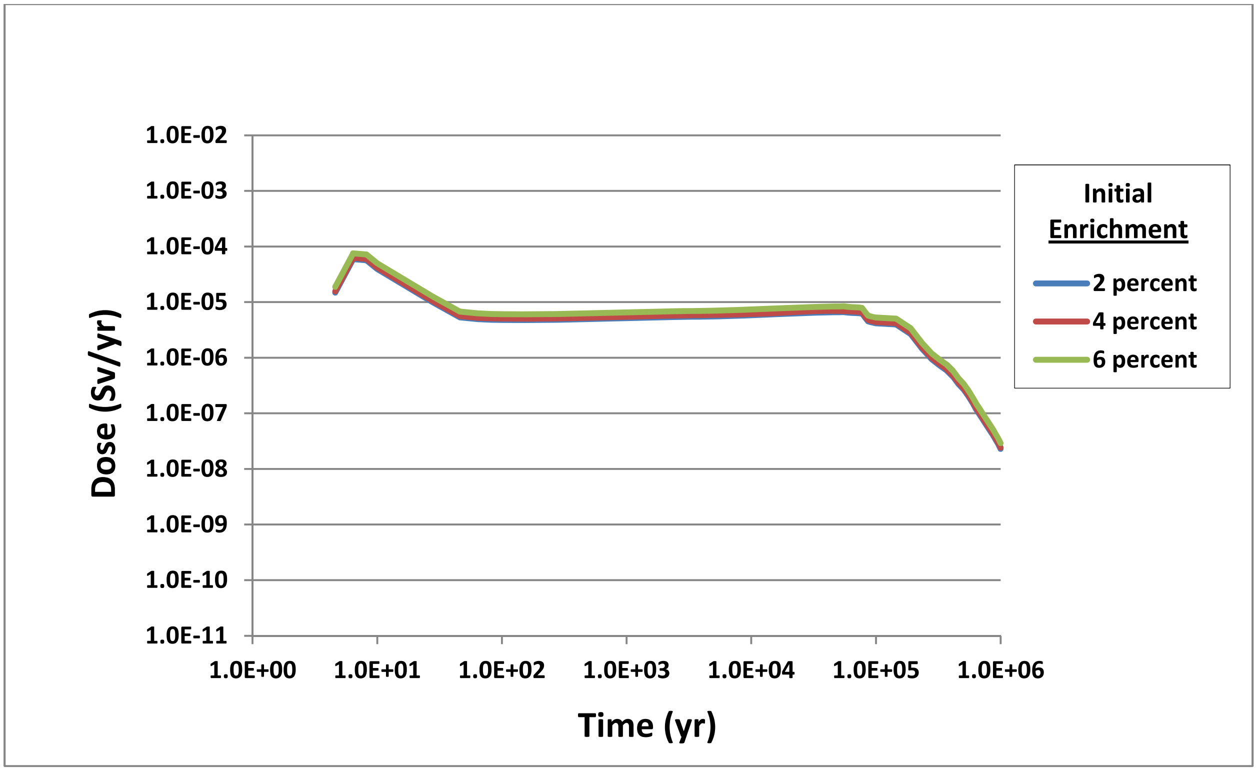


Figure 4-14. Tc-99 Dose for Simulation 2: Initial Enrichment—Reducing

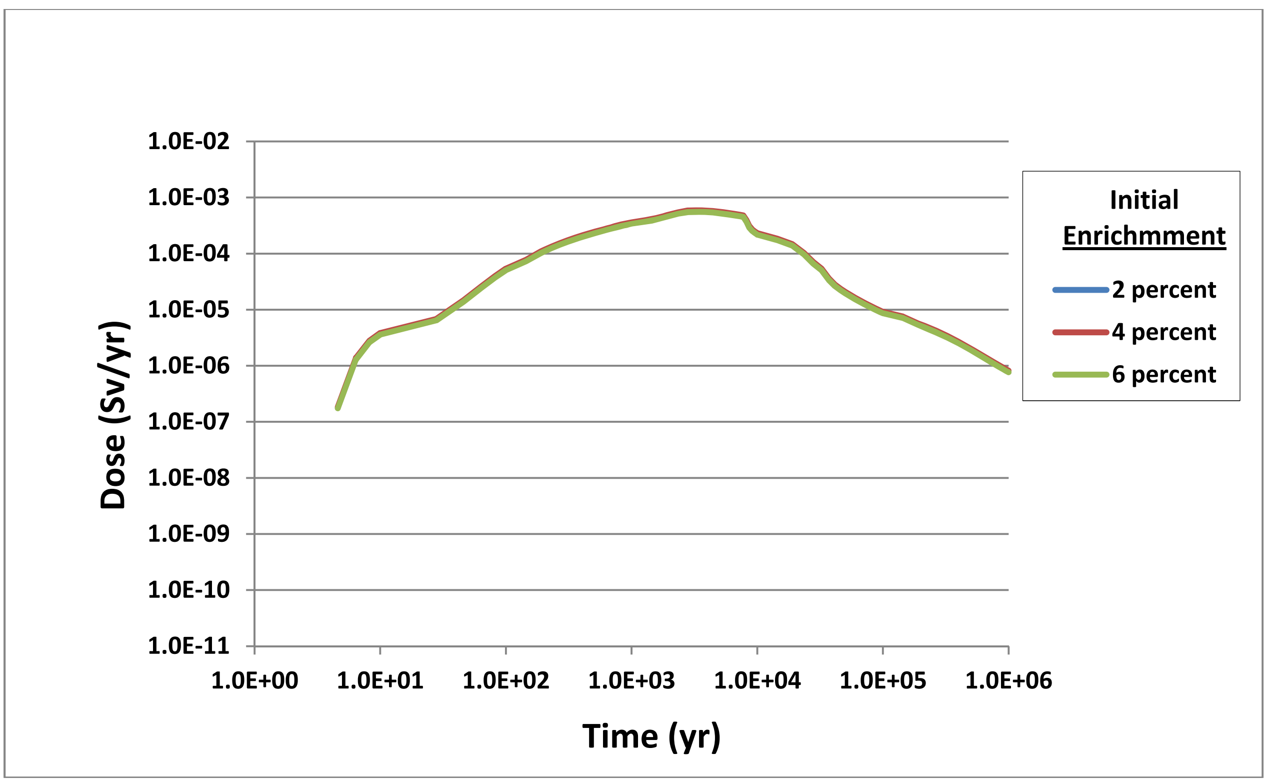


Figure 4-15. Np-237 Dose for Simulation 2: Initial Enrichment—Oxidizing

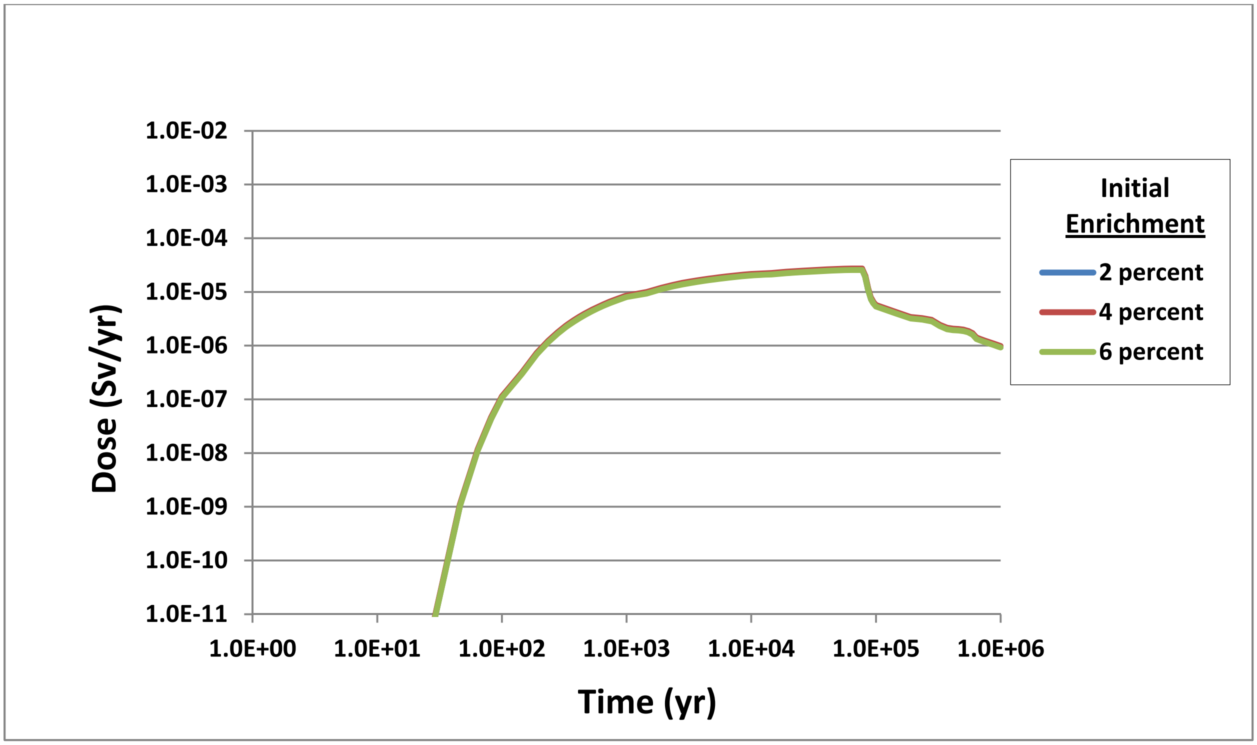


Figure 4-16. Np-237 Dose for Simulation 2: Initial Enrichment—Reducing

Simulation 3: Burnup

Objective:	Show the effect on dose of varying the burnup for spent nuclear fuel in both oxidizing and reducing environments.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set "Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)" for spent nuclear fuel equal to 100,000 MT. — Set "Burnup value (GWd/MTU)" equal to 25 and 40 in separate simulations. — Set the Redox condition as "Oxidizing" and "Reducing" for far-field Legs 1, 2, and 3 in separate simulations.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

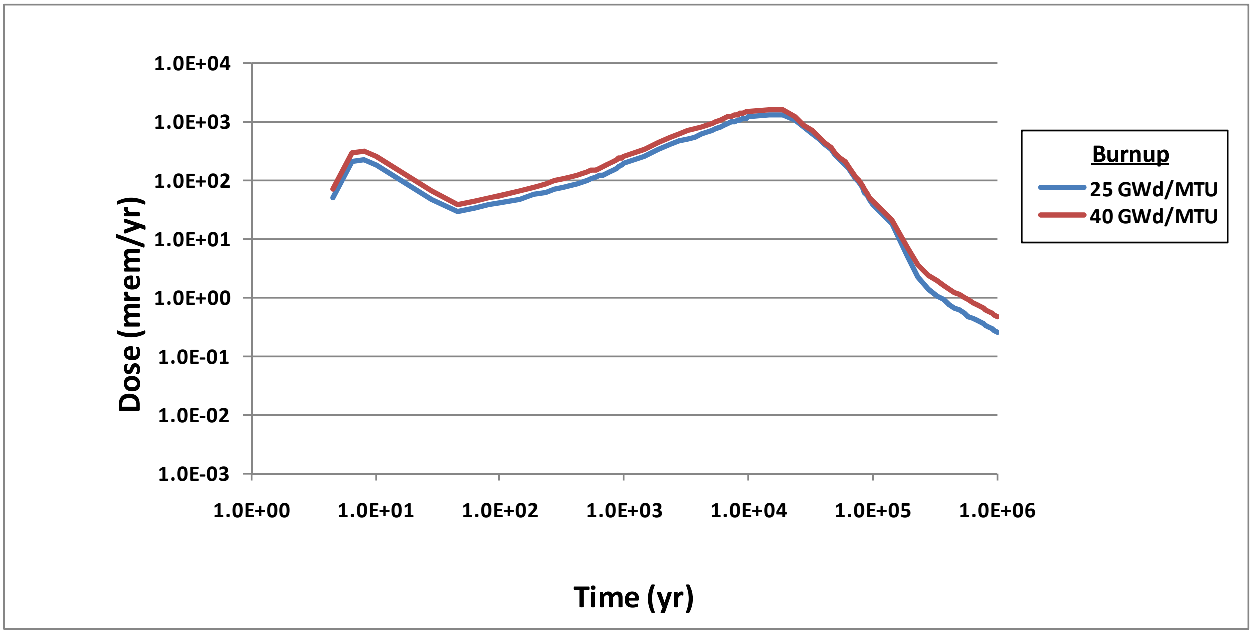


Figure 4-17. Total Dose for Simulation 3: Burnup—Oxidizing

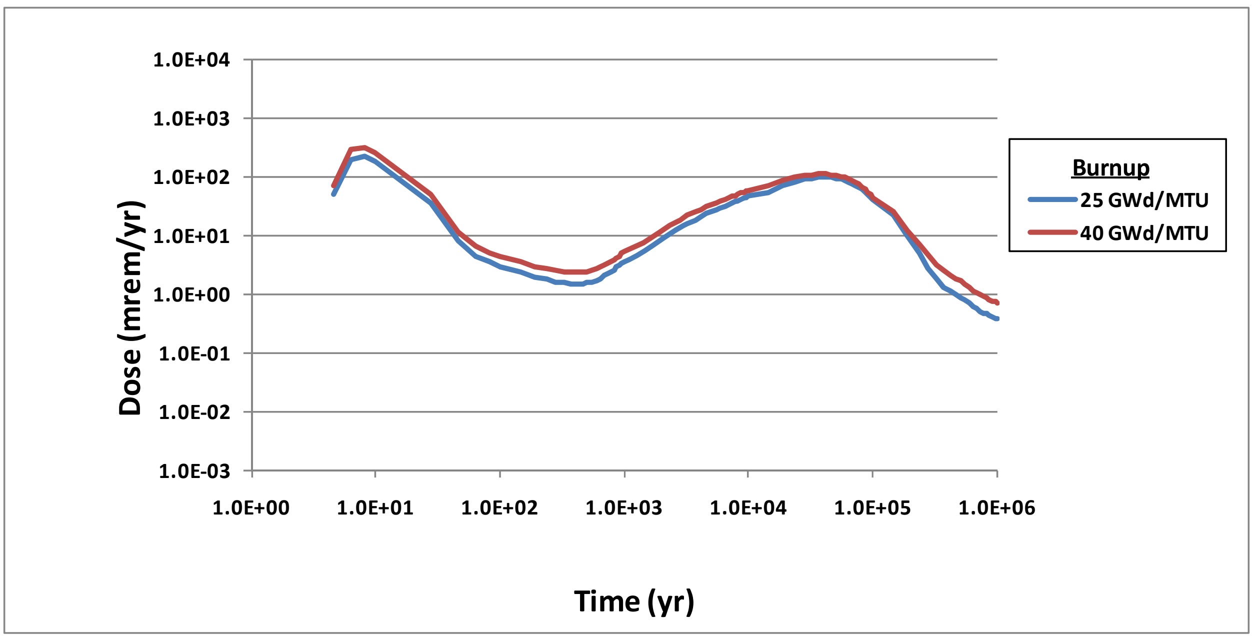


Figure 4-18. Total Dose for Simulation 3: Burnup—Reducing

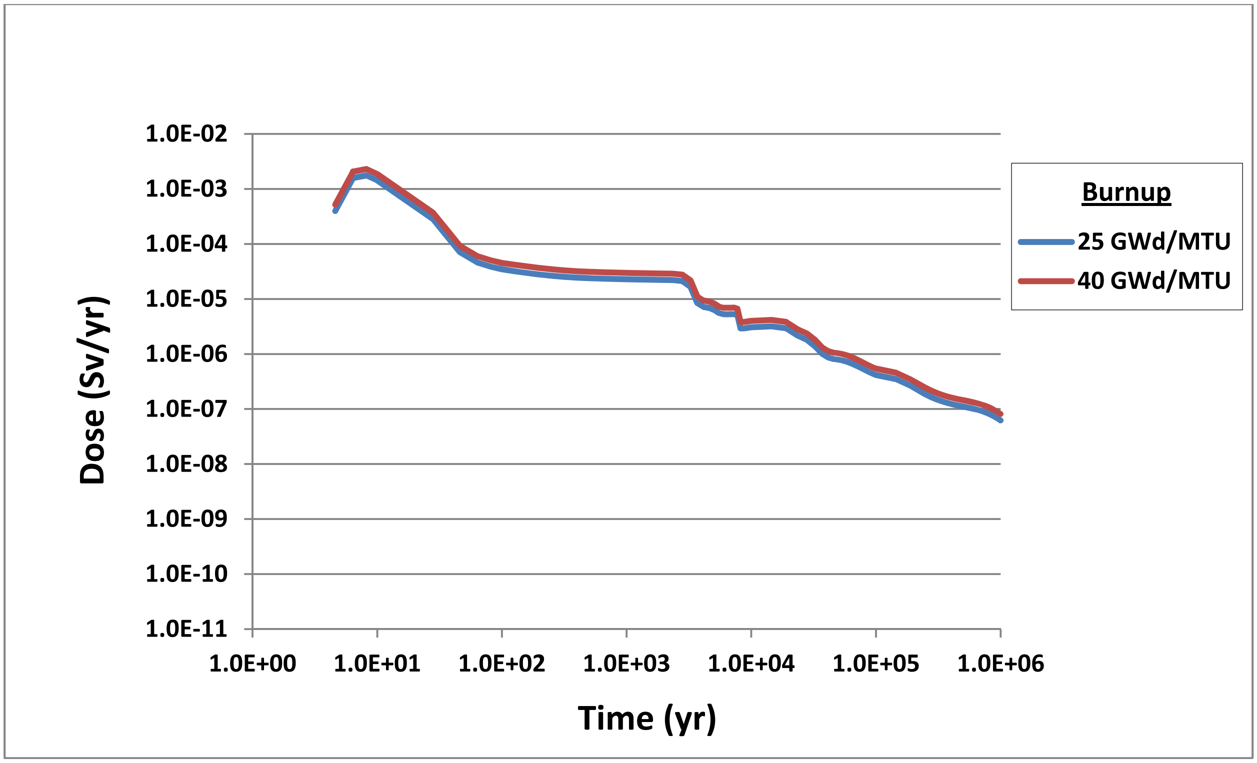


Figure 4-19. I-129 Dose for Simulation 3: Burnup—Oxidizing

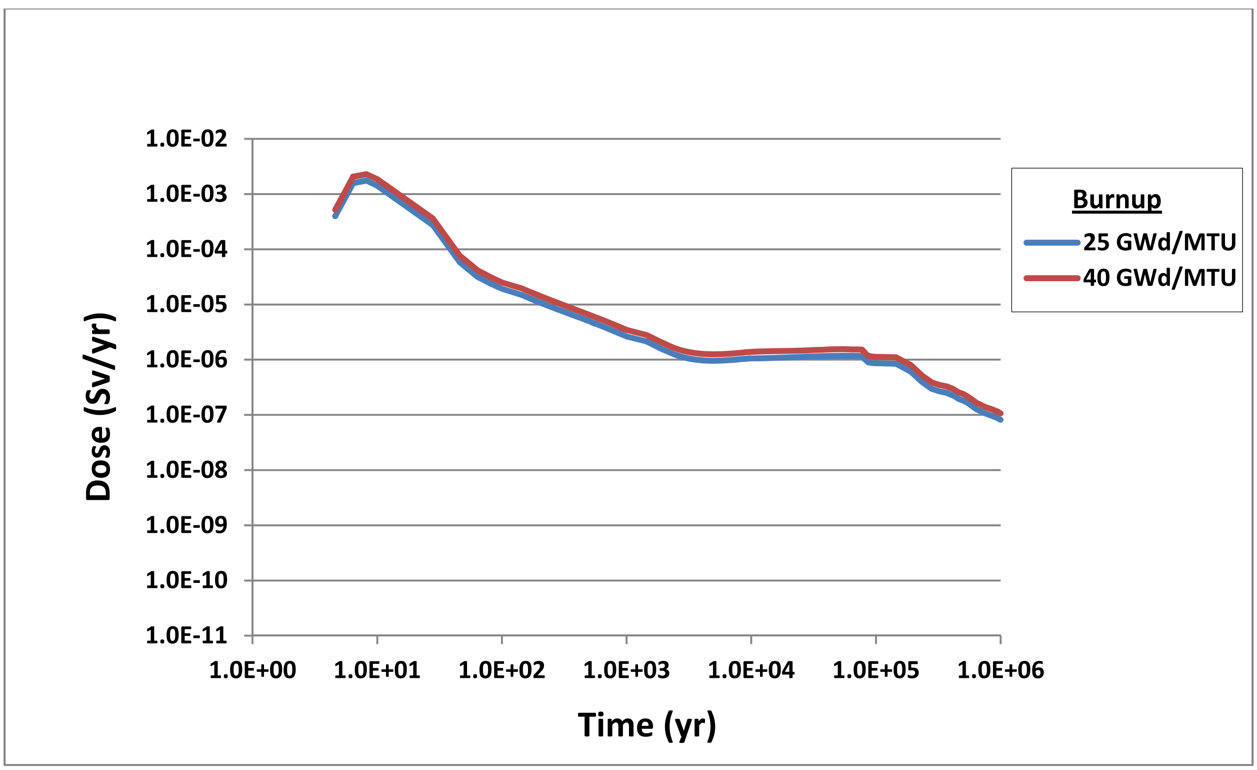


Figure 4-20. I-129 Dose for Simulation 3: Burnup—Reducing

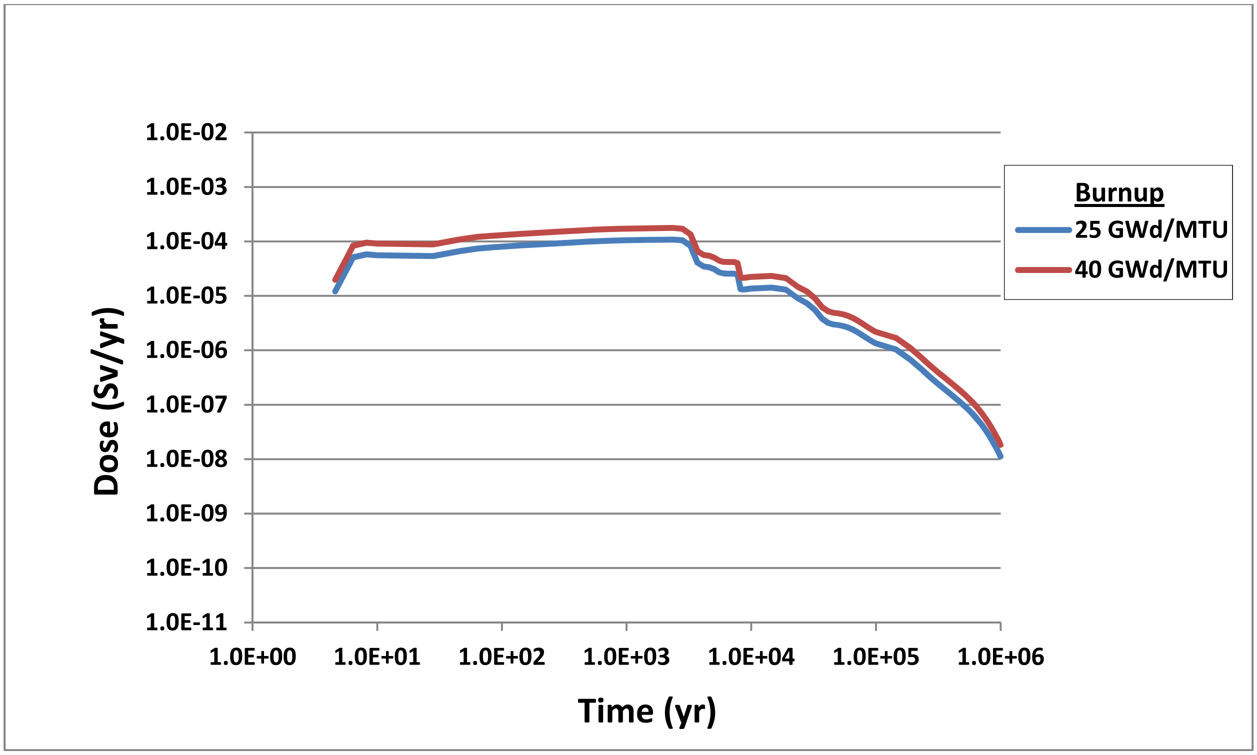


Figure 4-21. Tc-99 Dose for Simulation 3: Burnup—Oxidizing

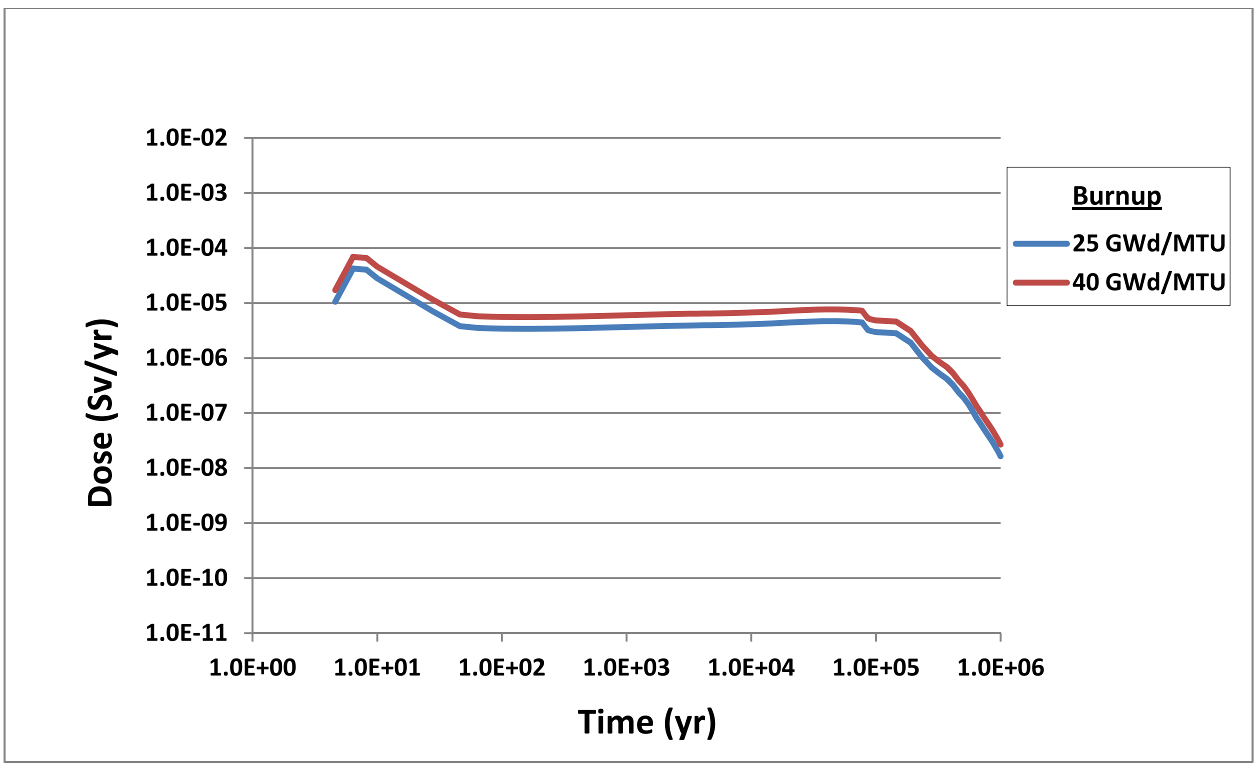


Figure 4-22. Tc-99 Dose for Simulation 3: Burnup—Reducing

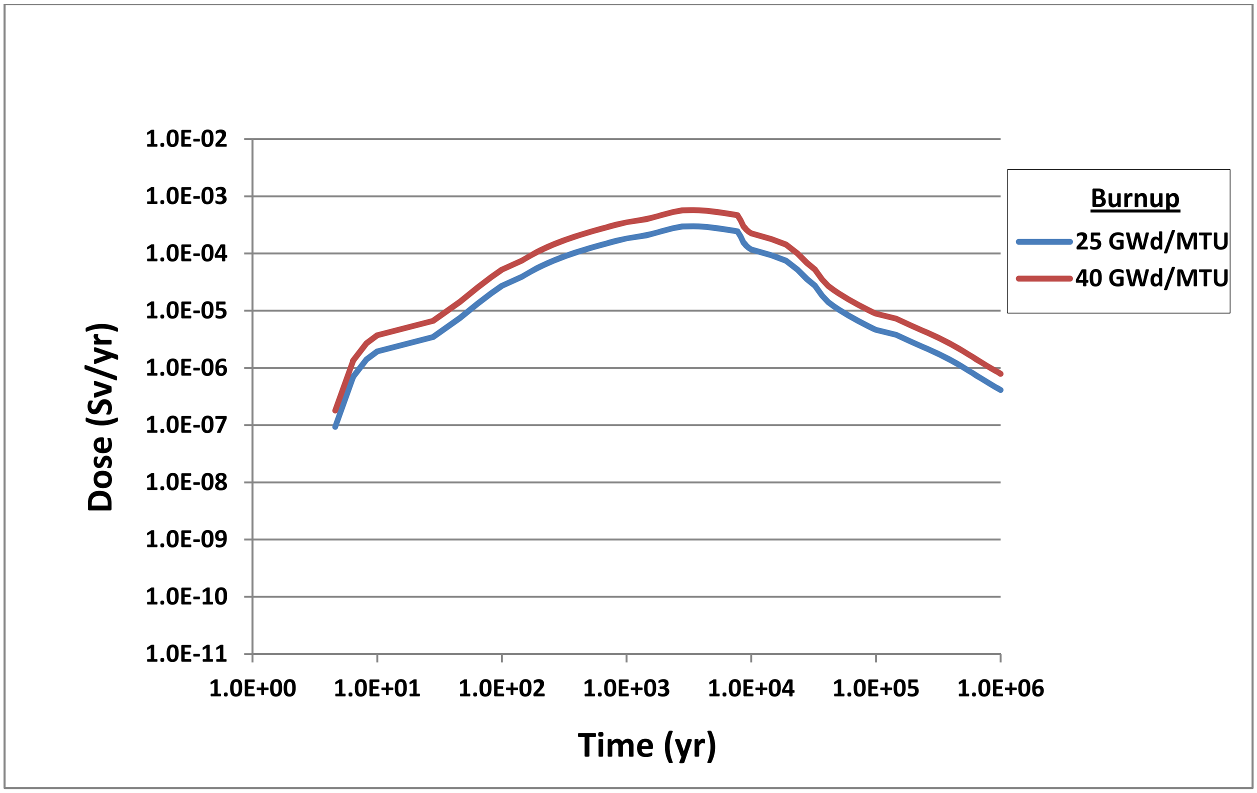


Figure 4-23. Np-237 Dose for Simulation 3: Burnup—Oxidizing

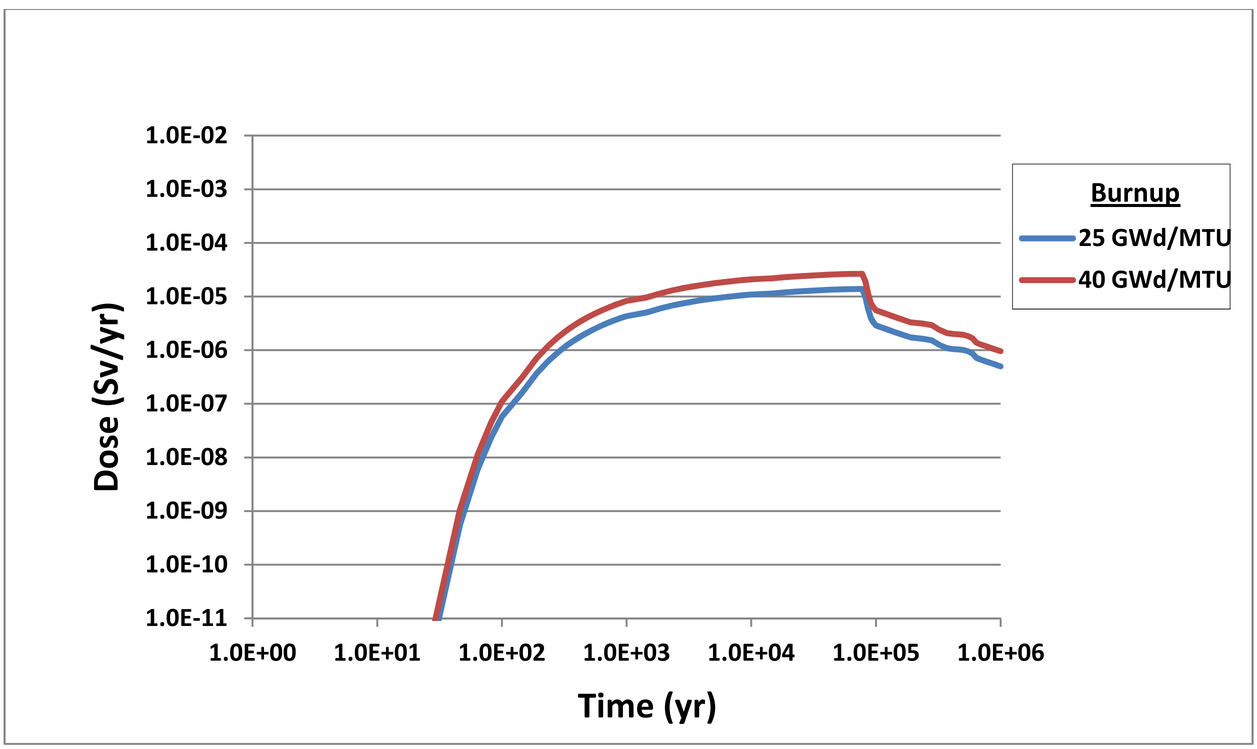


Figure 4-24. Np-237 Dose for Simulation 3: Burnup—Reducing

Simulation 4: Alternative Waste Forms

Objective:	Show the effect on dose of the waste form type [i.e., spent nuclear fuel, spent mixed-oxide fuel, high-level waste (glass), and high-level waste (ceramic)] in both oxidizing and reducing environments.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set "Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)" for spent nuclear fuel, spent mixed-oxide fuel, high-level waste (glass), and high-level waste (ceramic) equal to 100,000 MT in separate simulations. — Set the Redox condition as "Oxidizing" and "Reducing" for far-field Legs 1, 2, and 3 in separate simulations.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

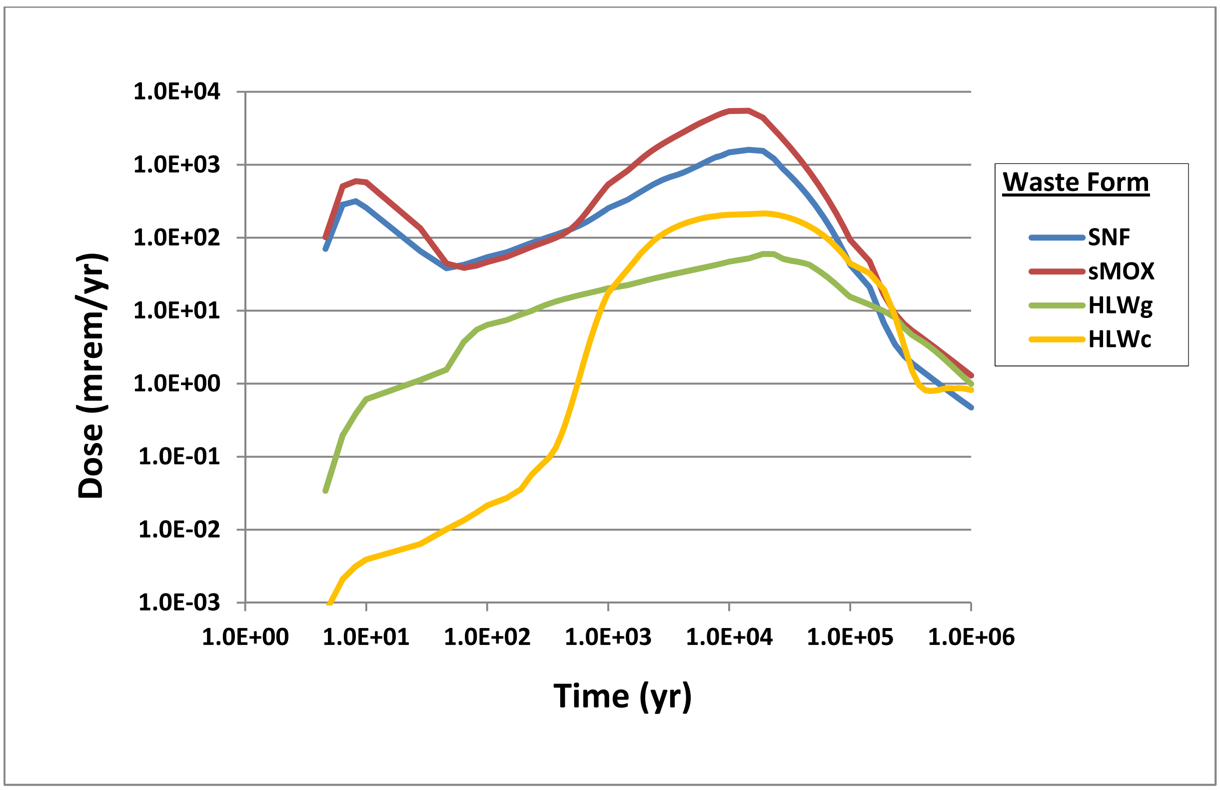


Figure 4-25. Total Dose for Simulation 4: Alternative Waste Forms—Oxidizing

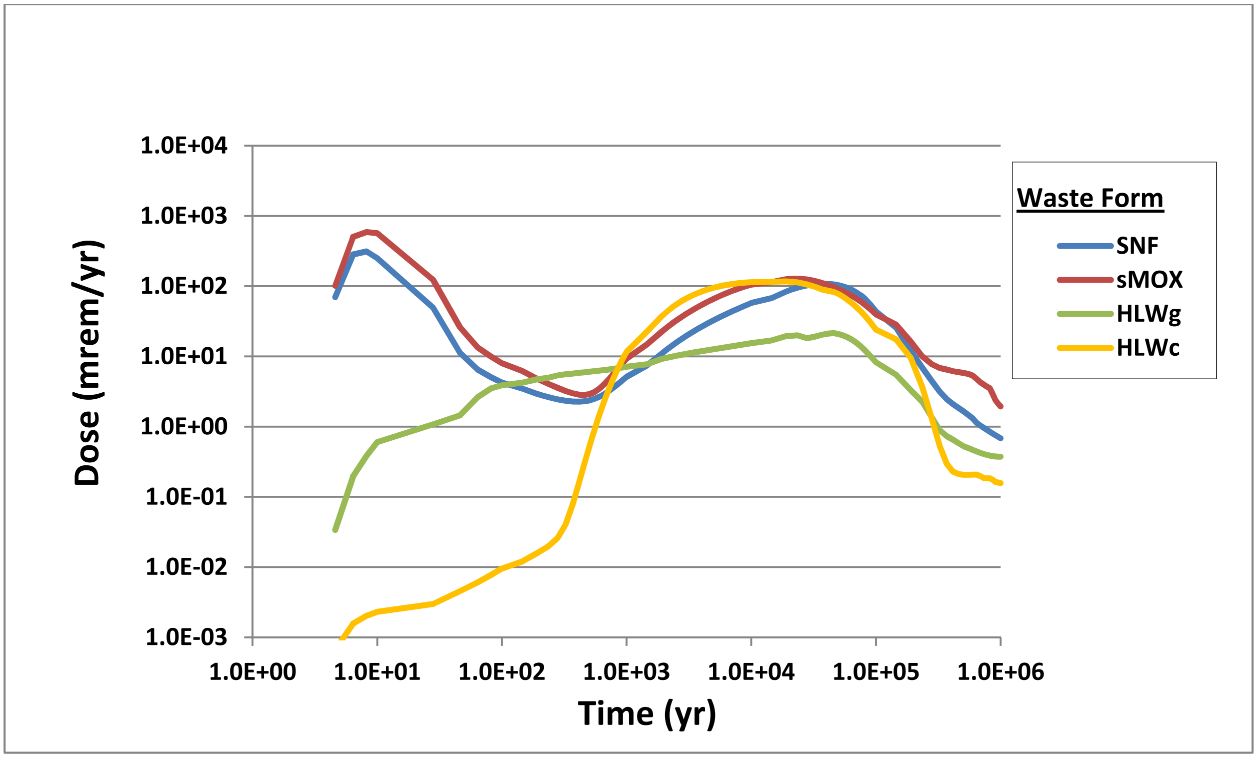


Figure 4-26. Total Dose for Simulation 4: Alternative Waste Forms—Reducing

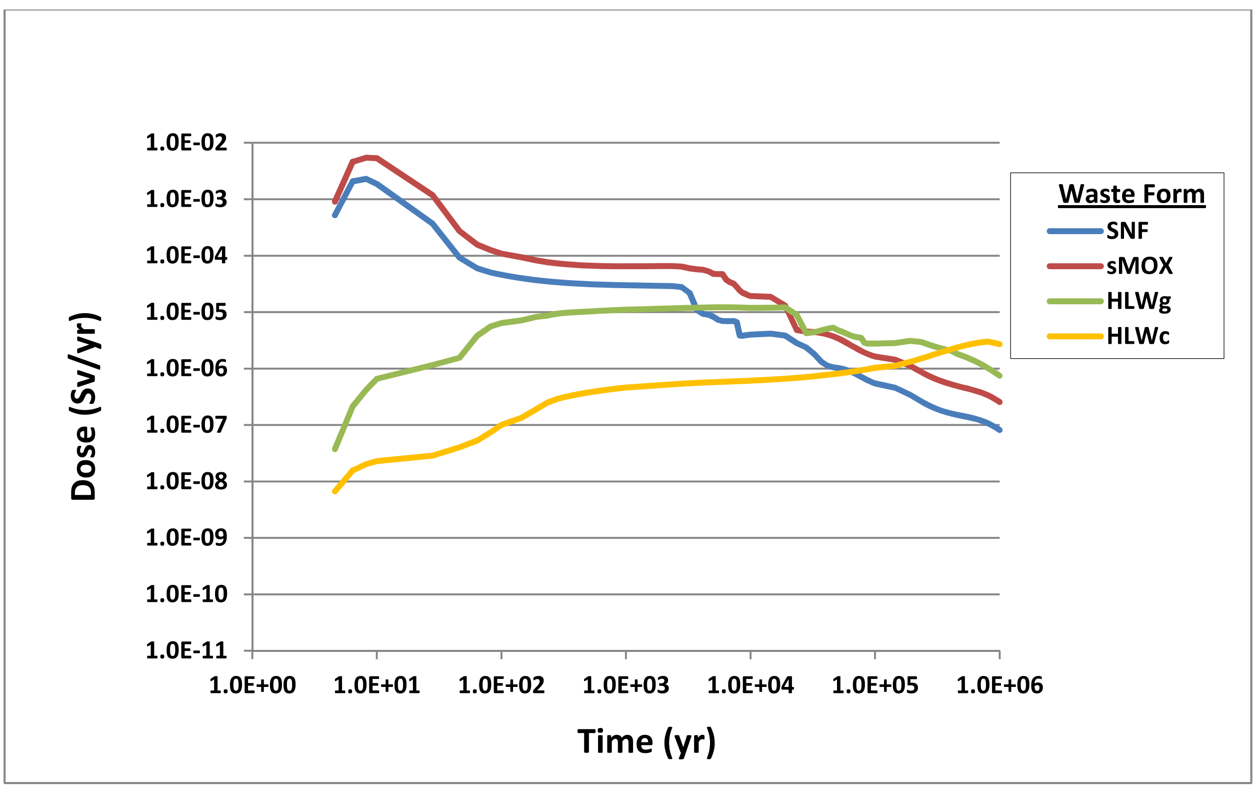


Figure 4-27. I-129 Dose for Simulation 4: Alternative Waste Forms—Oxidizing

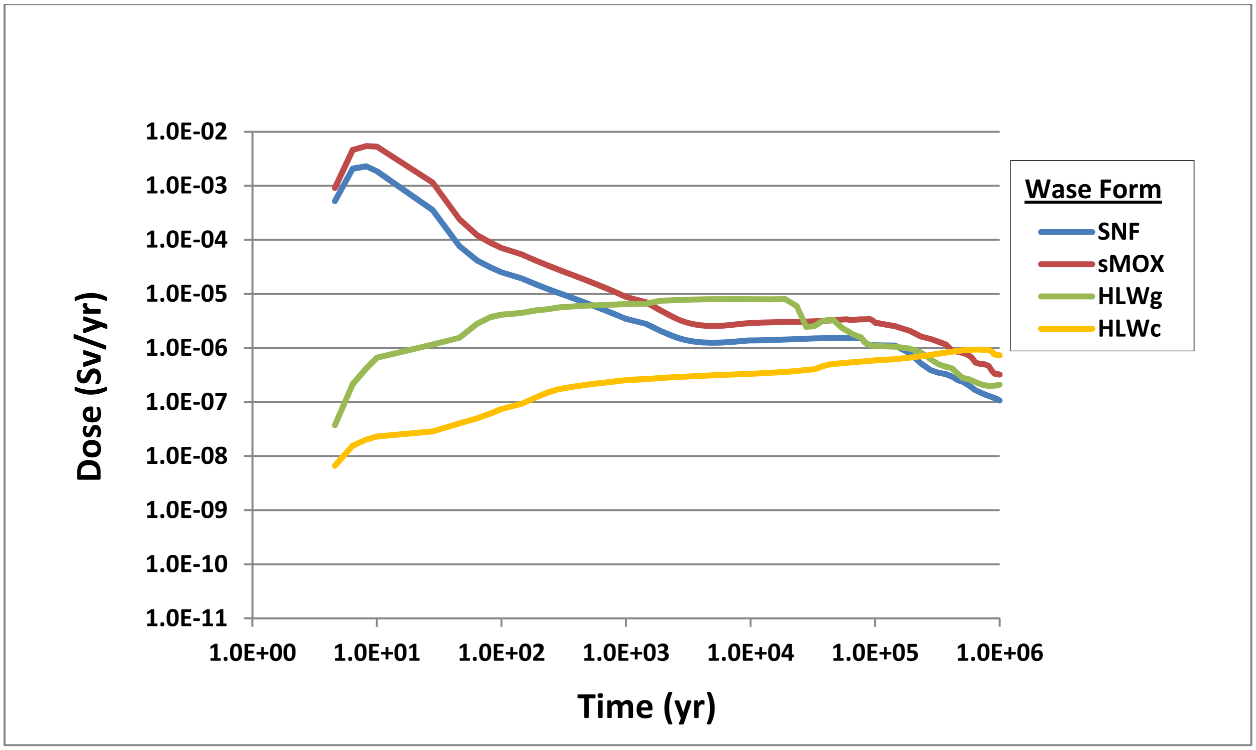


Figure 4-28. I-129 Dose for Simulation 4: Alternative Waste Forms—Reducing

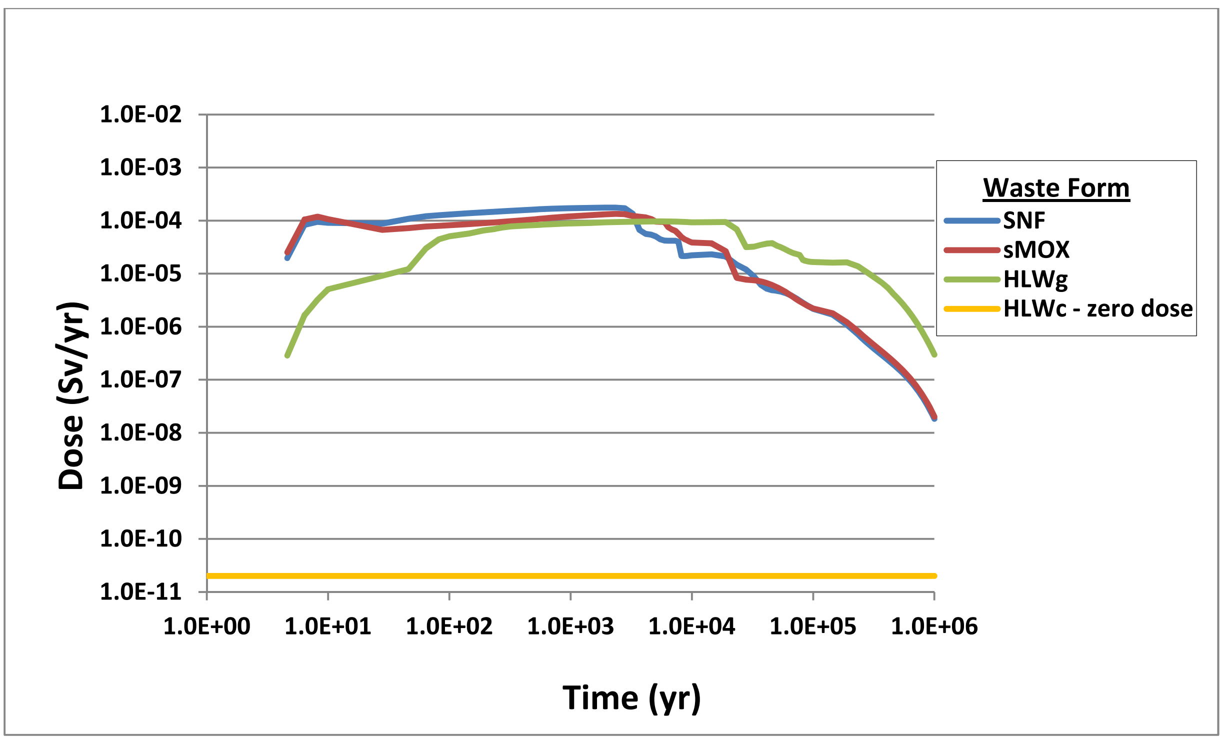


Figure 4-29. Tc-99 Dose for Simulation 4: Alternative Waste Forms—Oxidizing

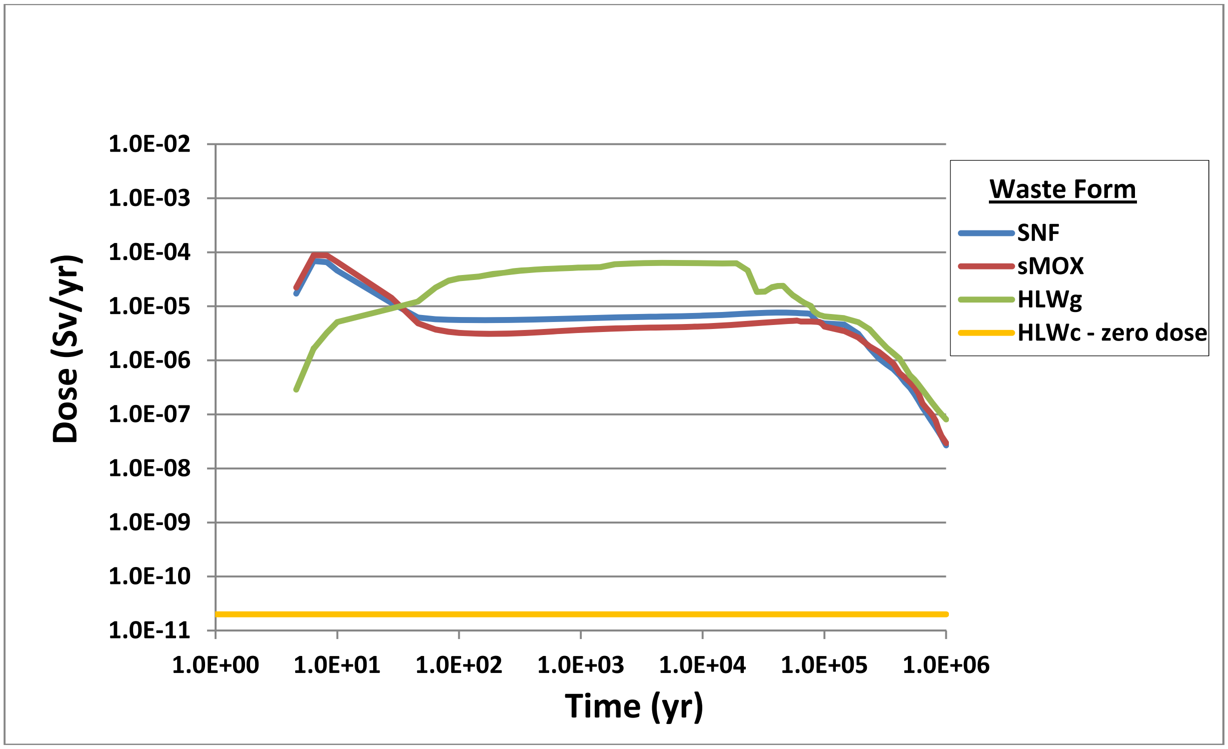


Figure 4-30. Tc-99 Dose for Simulation 4: Alternative Waste Forms—Reducing

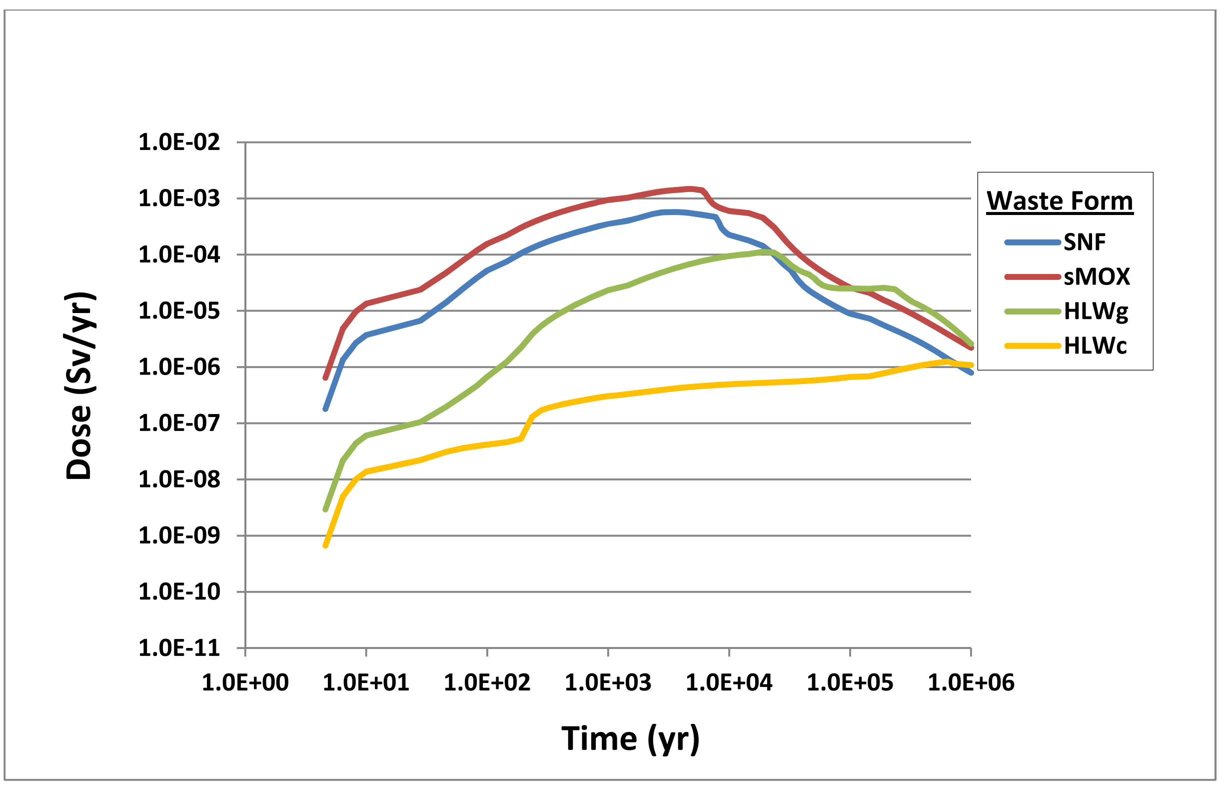


Figure 4-31. Np-237 Dose for Simulation 4: Alternative Waste Forms—Oxidizing

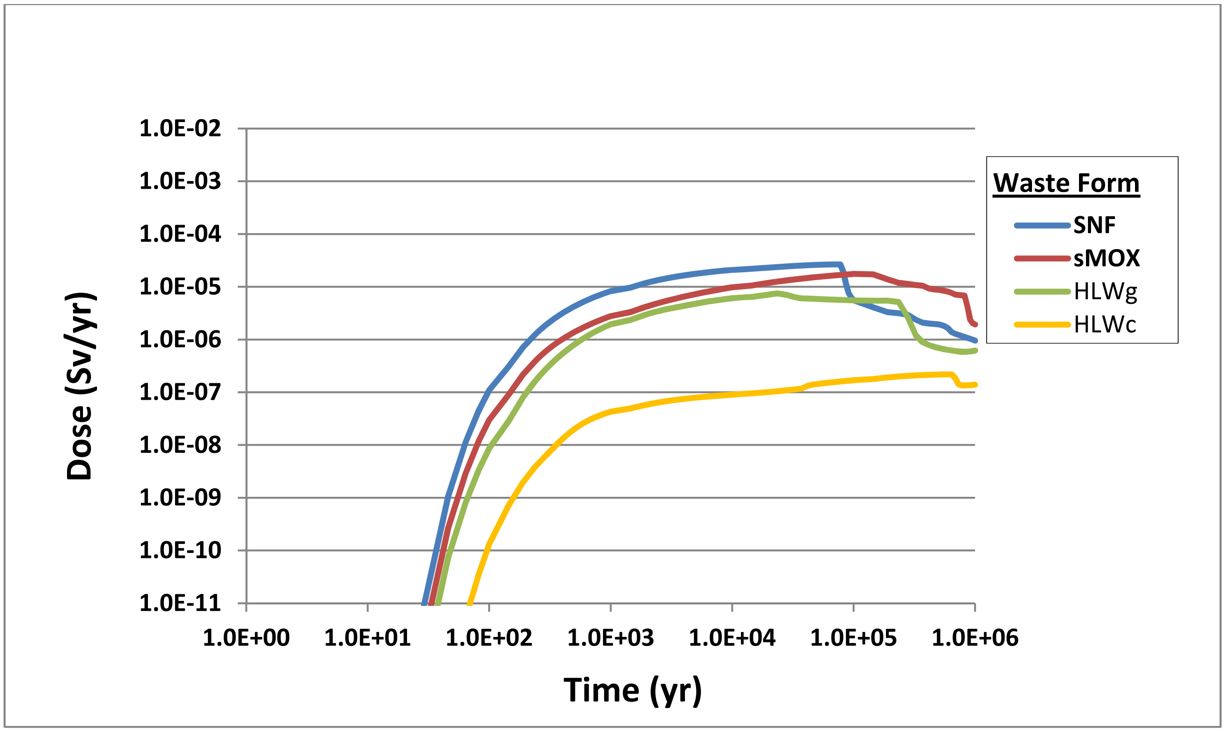


Figure 4-32. Np-237 Dose for Simulation 4: Alternative Waste Forms—Reducing

Simulation 5: HLW Loading

Objective:	Show the effect on dose of varying the high-level waste loading (glass and ceramic) in an oxidizing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for high-level waste (glass) and high-level waste (ceramic) equal to 100,000 MT in separate simulations. — Set “Waste form loading factor (percent)” equal to 1, 5, 10, 25, 50, and 100 (and others as needed) in separate simulations. — Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

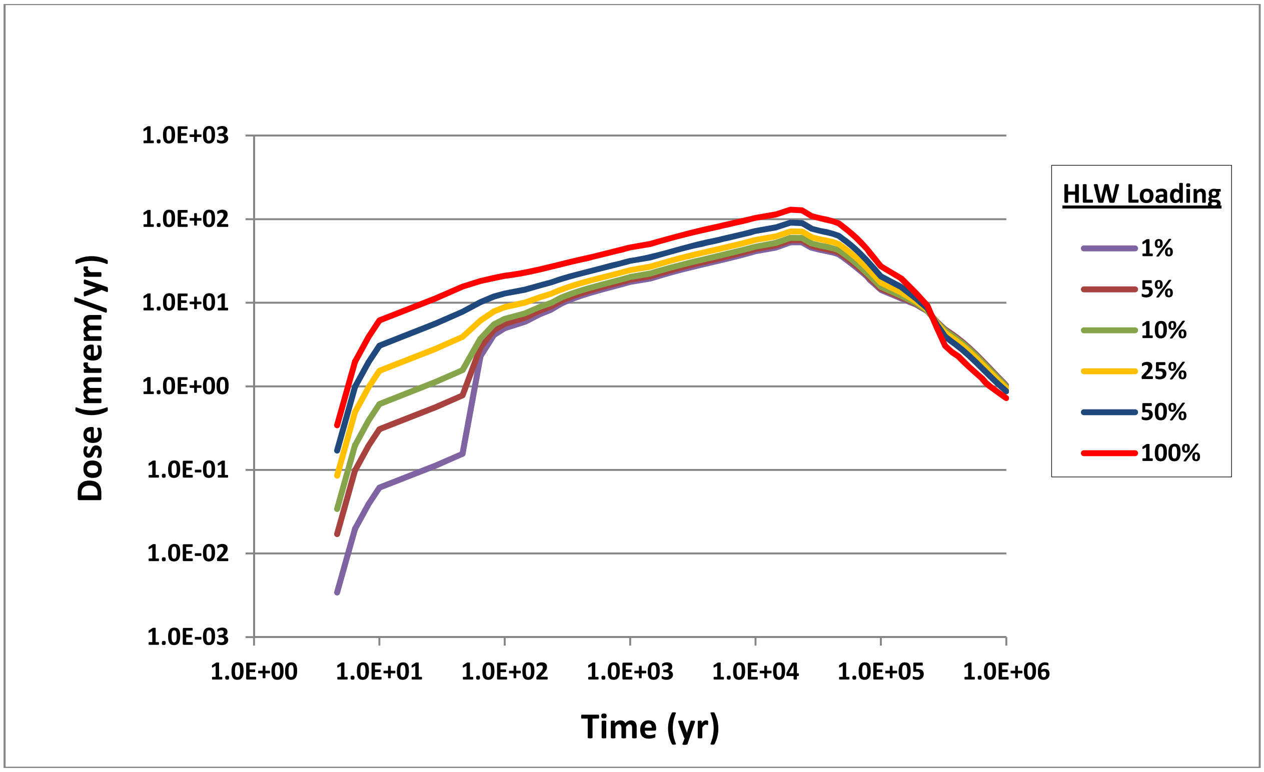


Figure 4-33. Total Dose for Simulation 5: High-Level Waste (Glass) Loading—Oxidizing

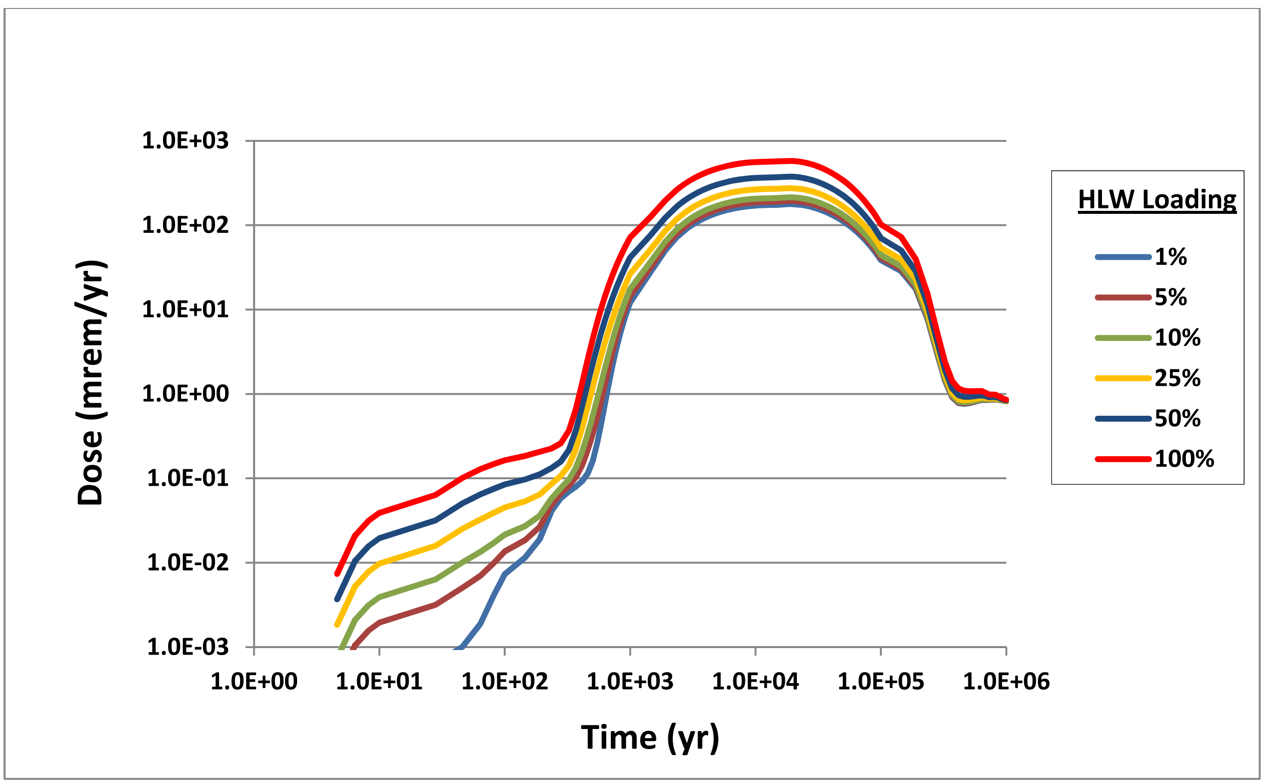


Figure 4-34. Total Dose for Simulation 5: High-Level Waste (Ceramic) Loading—Oxidizing

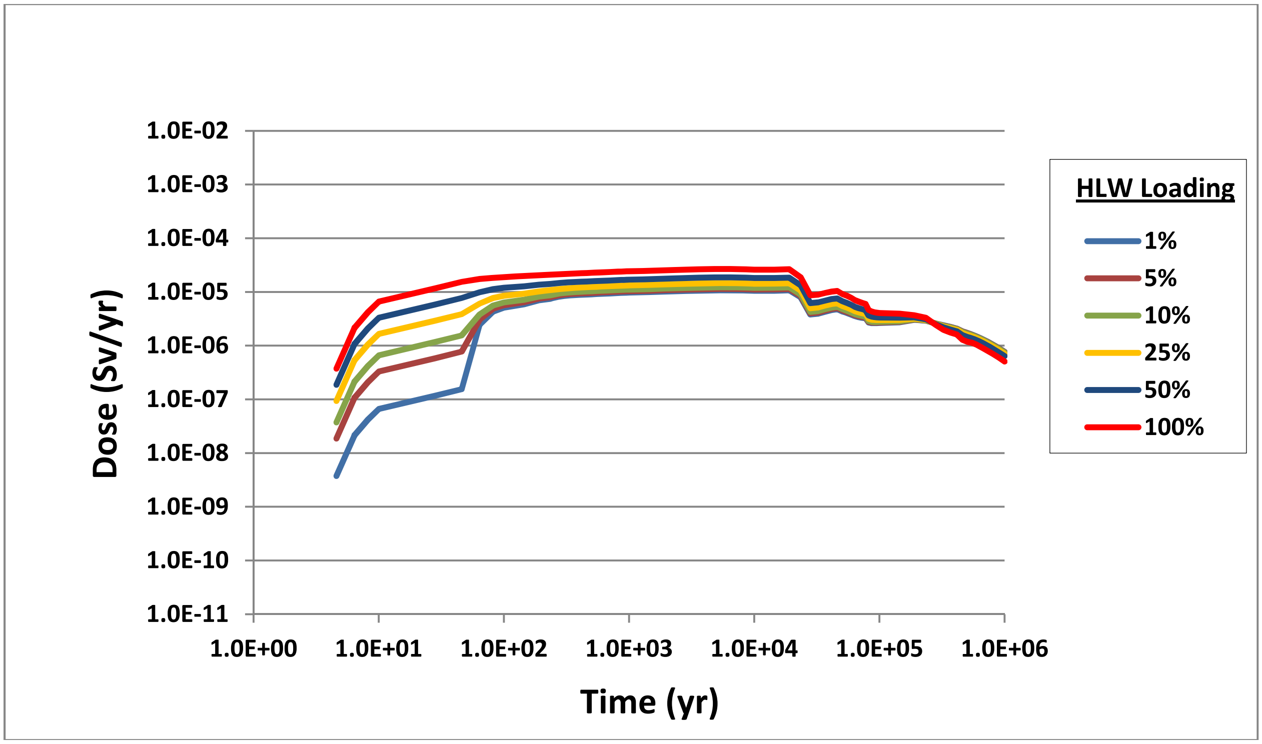


Figure 4-35. I-129 Dose for Simulation 5: High-Level Waste (Glass) Loading—Oxidizing

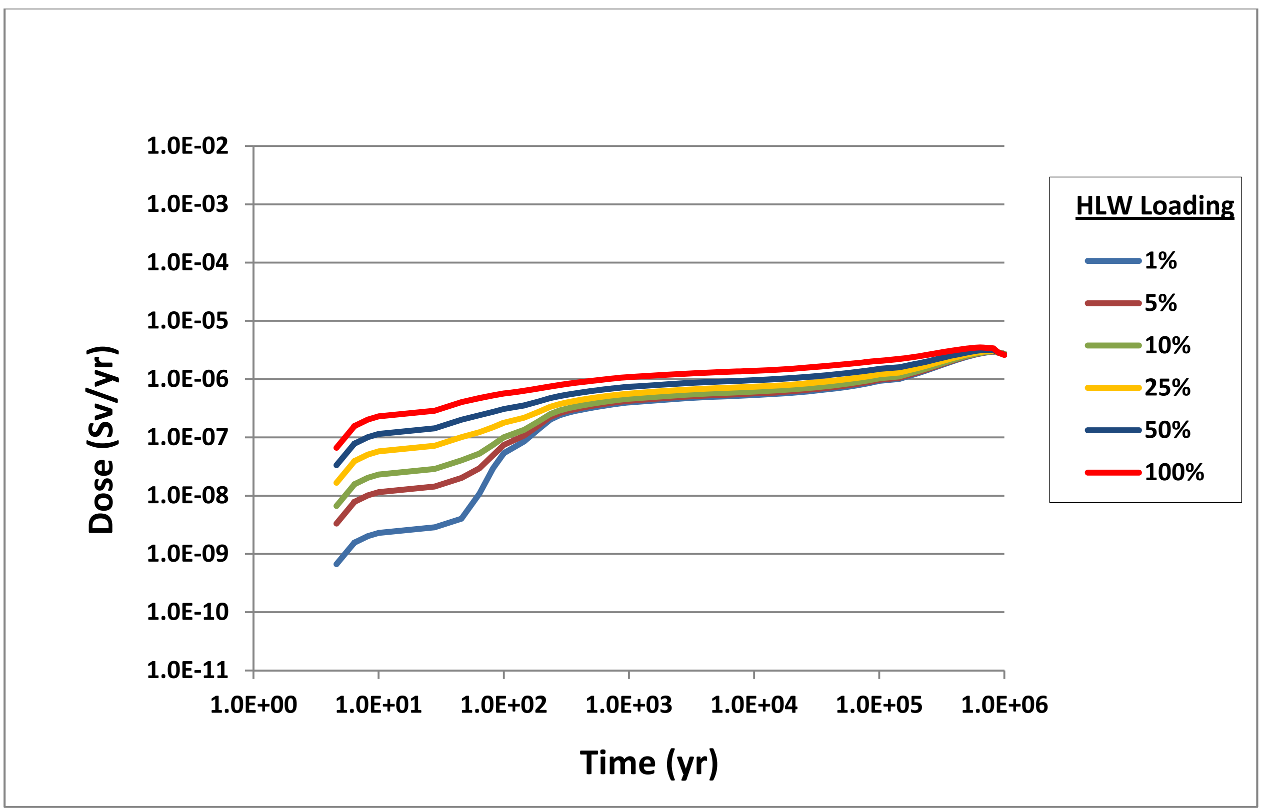


Figure 4-36. I-129 Dose for Simulation 5: High-Level Waste (Ceramic) Loading—Oxidizing

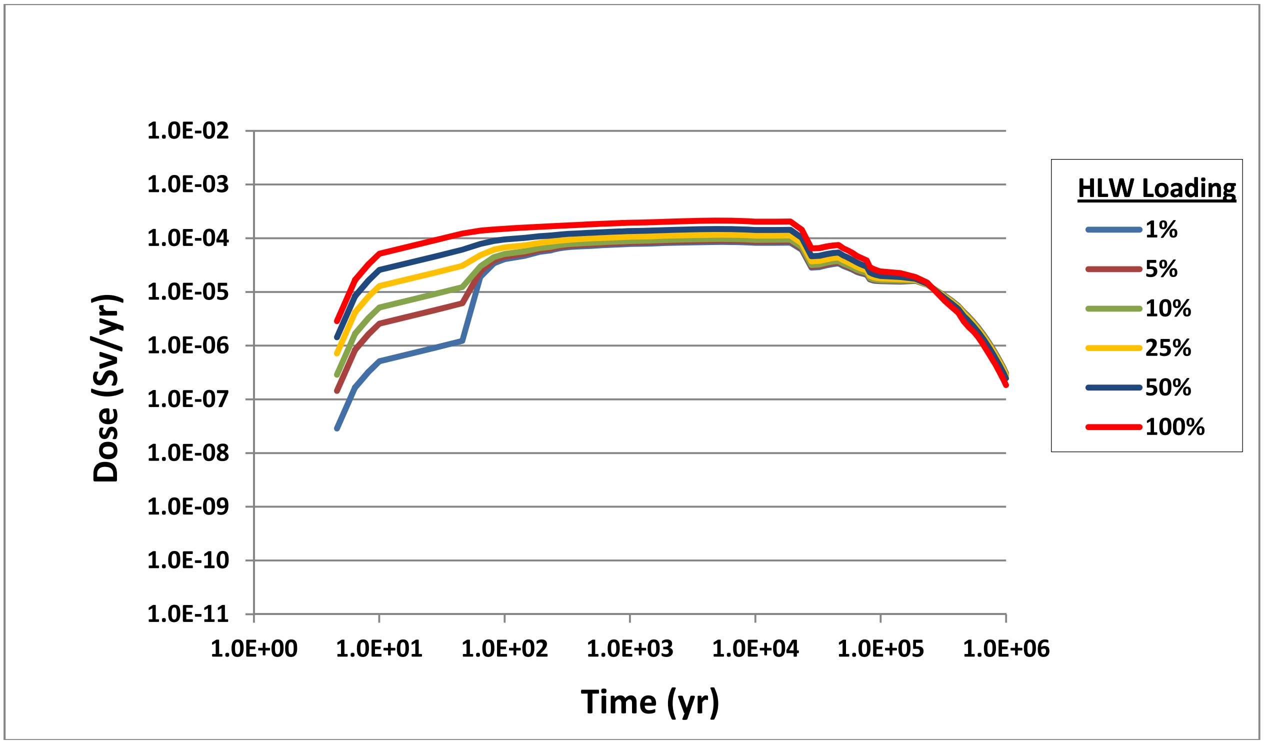


Figure 4-37. Tc-99 Dose for Simulation 5: High-Level Waste (Glass) Loading—Oxidizing

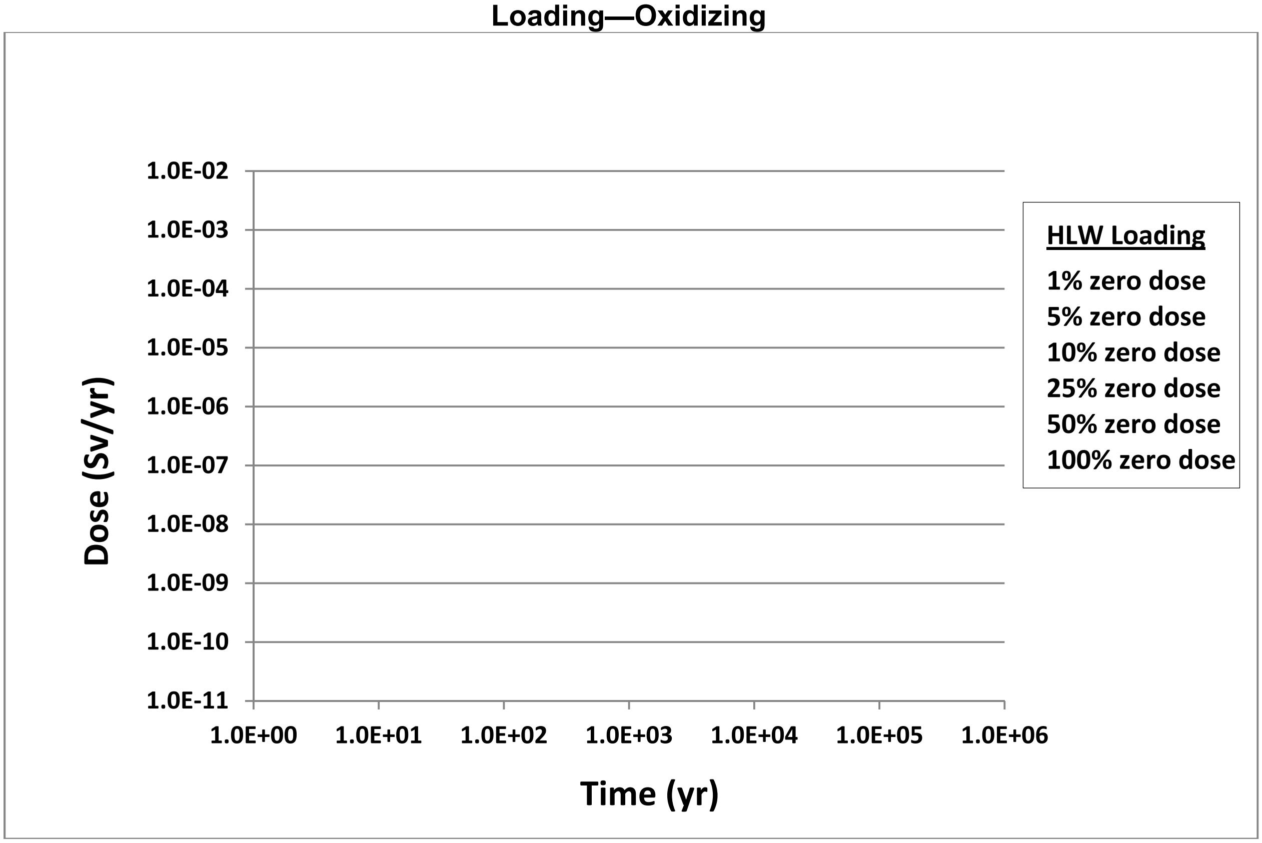


Figure 4-38. Tc-99 Dose for Simulation 5: High-Level Waste (Ceramic) Loading—Oxidizing

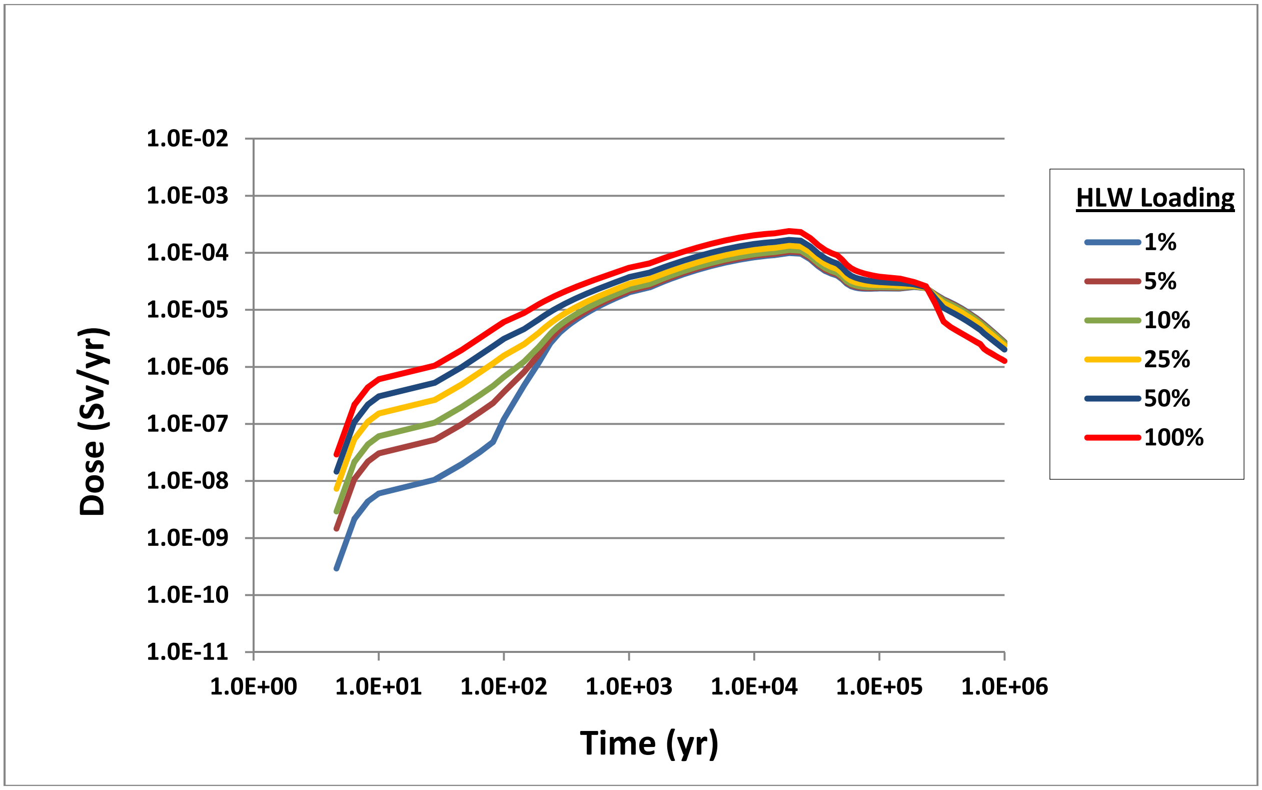


Figure 4-39. Np-237 Dose for Simulation 5: High-Level Waste (Glass) Loading—Oxidizing

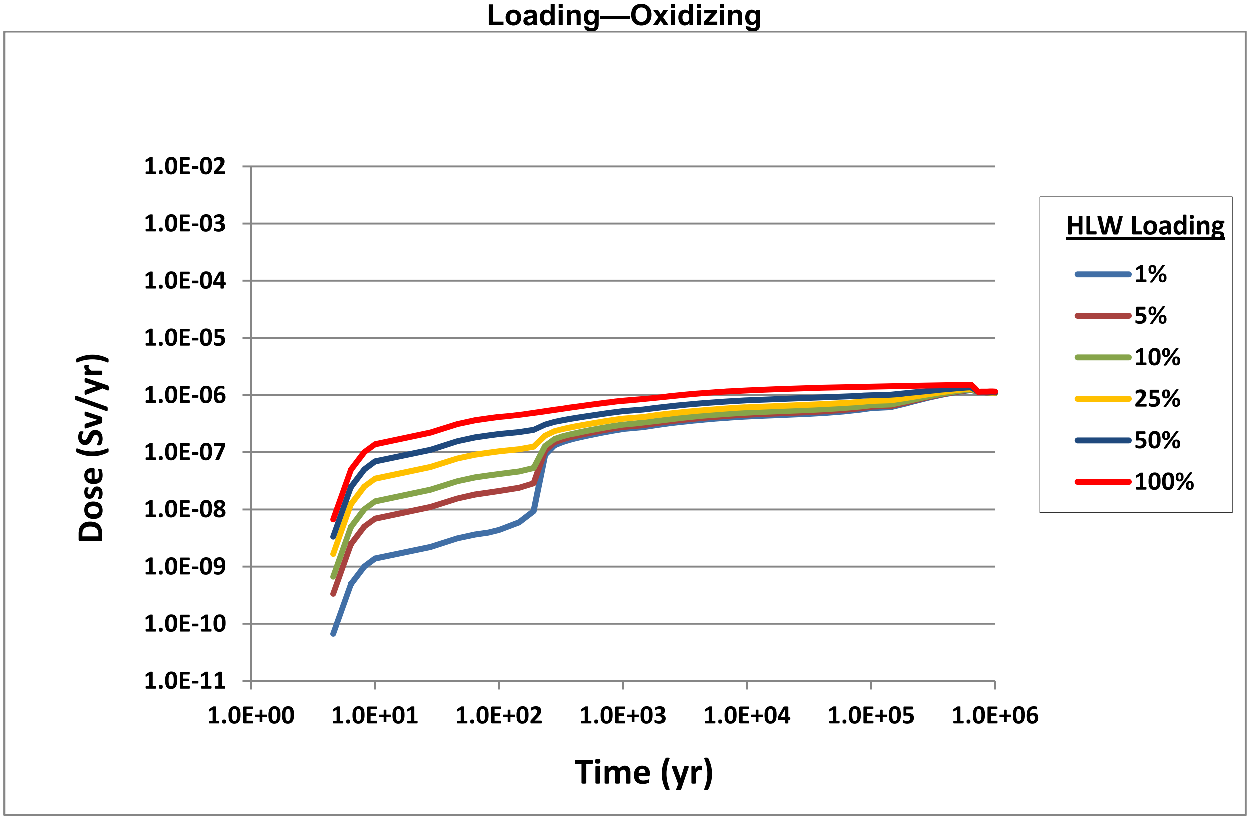


Figure 4-40. Np-237 Dose for Simulation 5: High-Level Waste (Ceramic) Loading—Oxidizing

Simulation 6: Mass Per Waste Package

Objective:	Show the effect on dose of varying the total mass disposed for high-level waste (glass and ceramic) per waste package in an oxidizing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for high-level waste (glass) and high-level waste (ceramic) equal to 100,000 MT in separate simulations. — Set “Total Disposed Mass per Waste Package (grams)” equal to 100, 1,000, 10,000, and 100,000 (and others as needed) in separate simulations. — Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

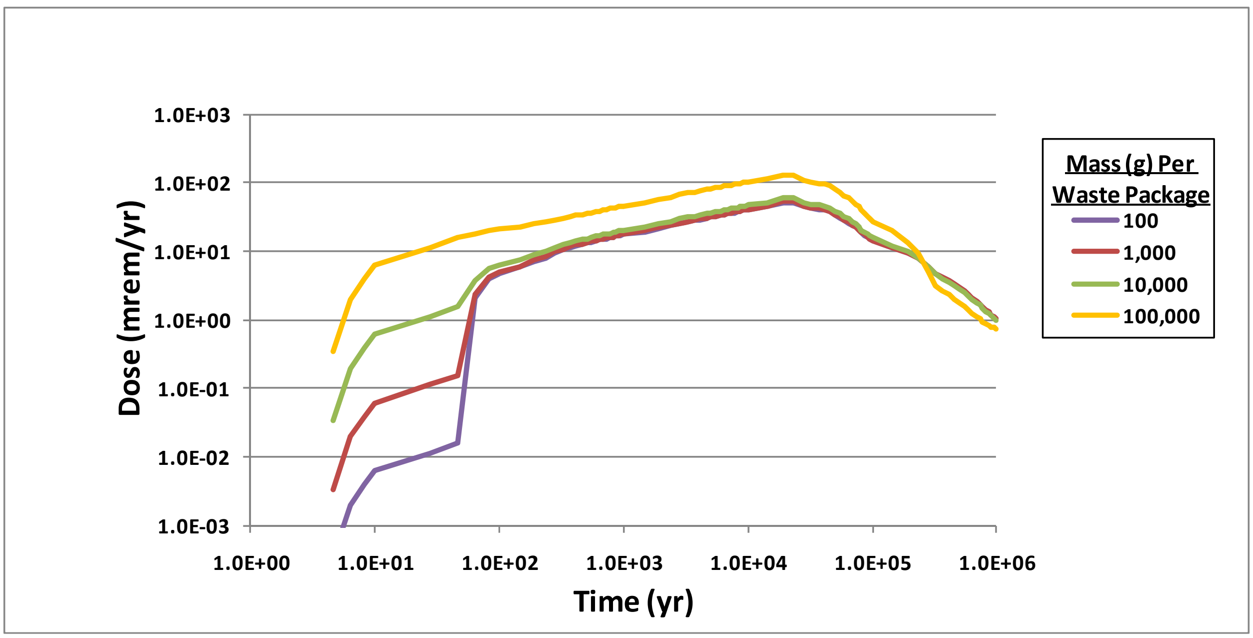


Figure 4-41. Total Dose for Simulation 6: High-Level Waste (Glass) Mass Per Waste Package—Oxidizing

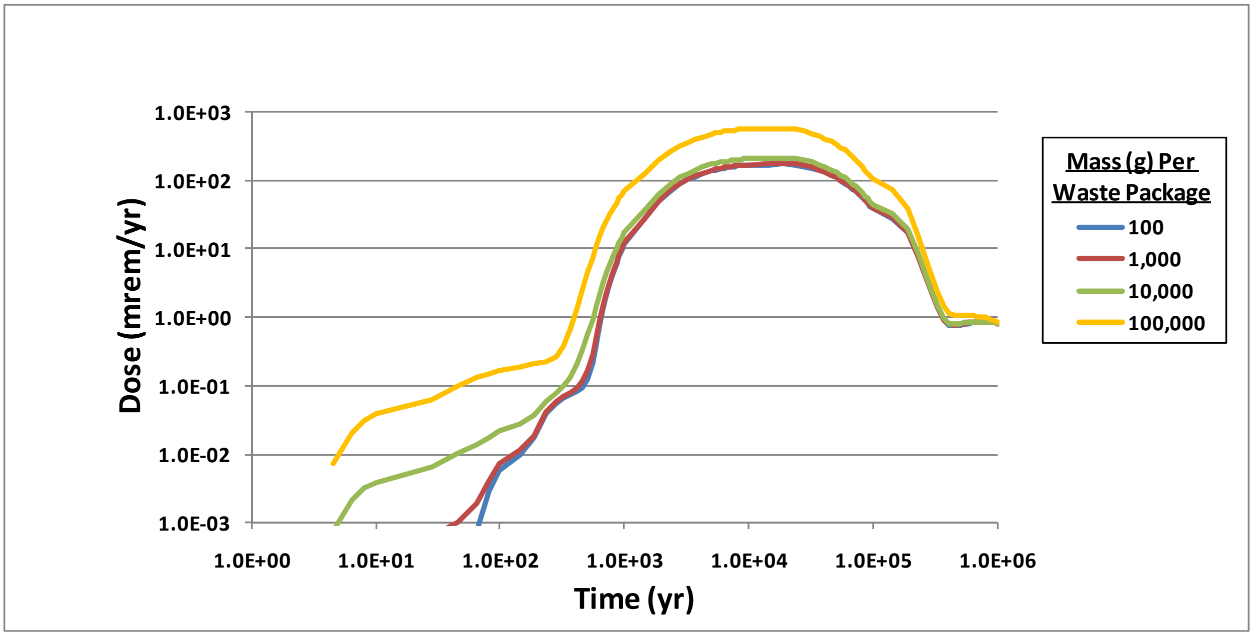


Figure 4-42. Total Dose for Simulation 6: High-Level Waste (Ceramic) Mass Per Waste Package—Oxidizing

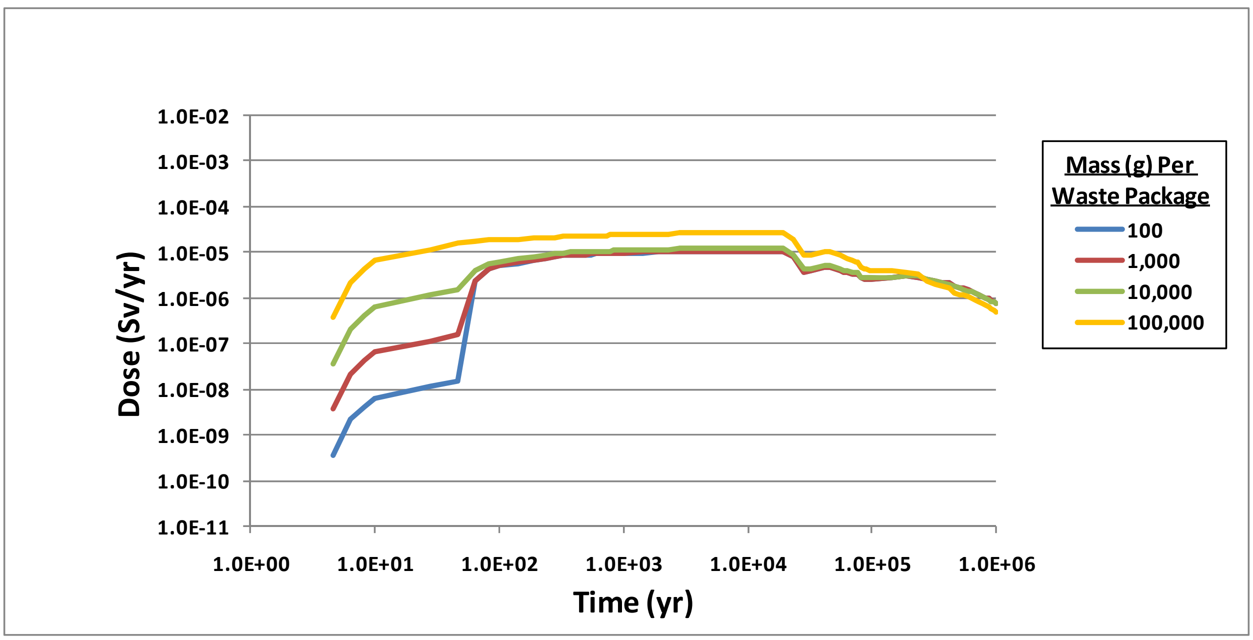


Figure 4-43. I-129 Dose for Simulation 6: High-Level Waste (Glass) Mass Per Waste Package—Oxidizing

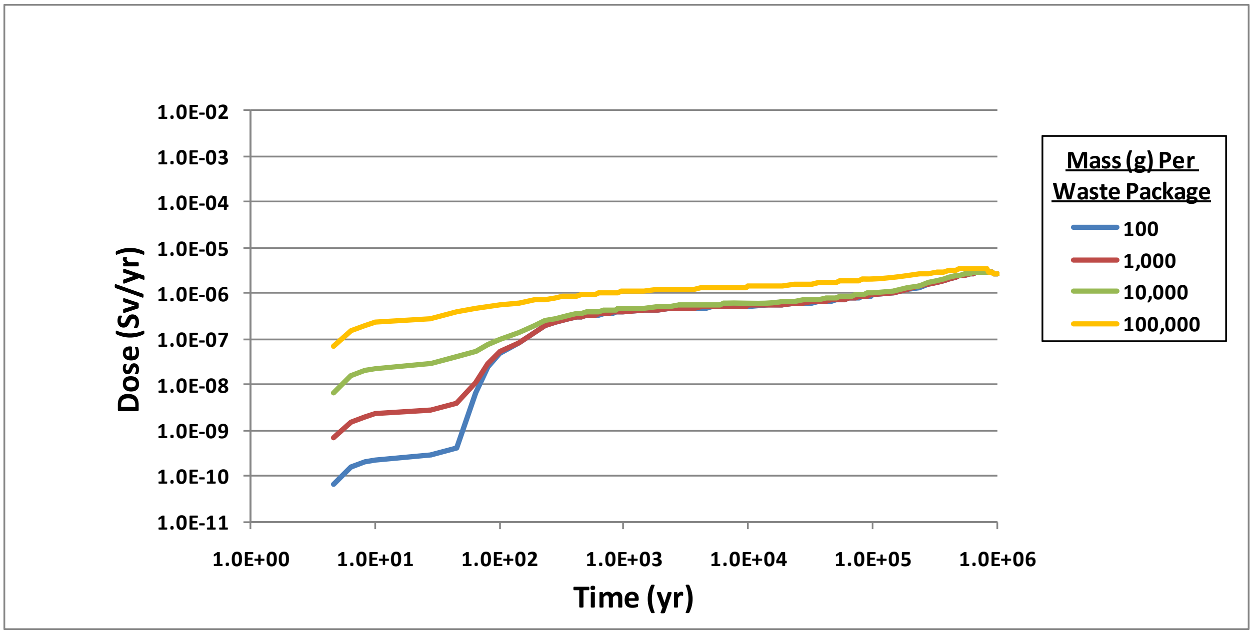


Figure 4-44. I-129 Dose for Simulation 6: High-Level Waste (Ceramic) Mass Per Waste Package—Oxidizing

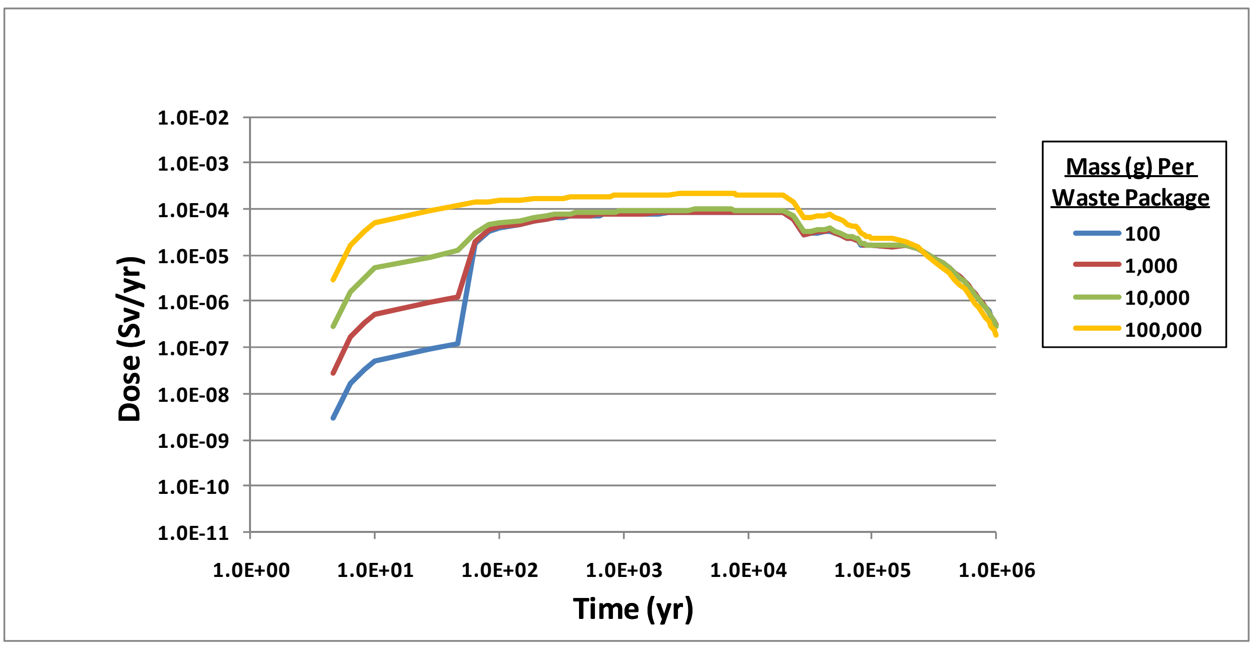


Figure 4-45. Tc-99 Dose for Simulation 6: High-Level Waste (Glass) Mass Per Waste Package—Oxidizing

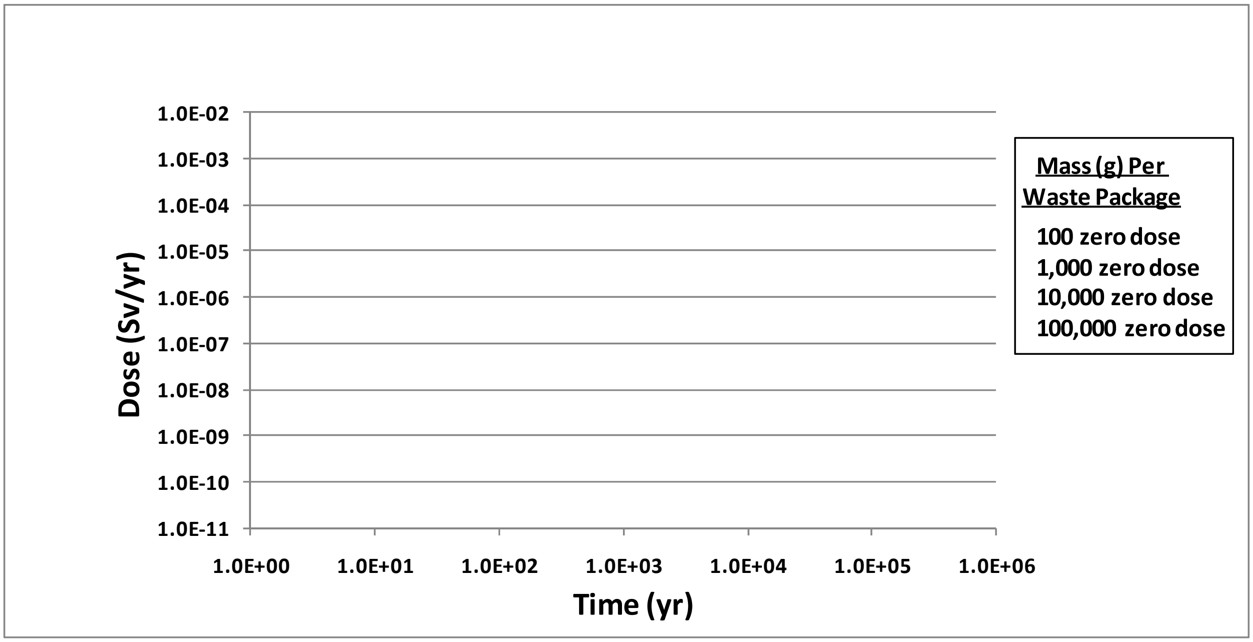


Figure 4-46. Tc-99 Dose for Simulation 6: High-Level Waste (Ceramic) Mass Per Waste Package—Oxidizing

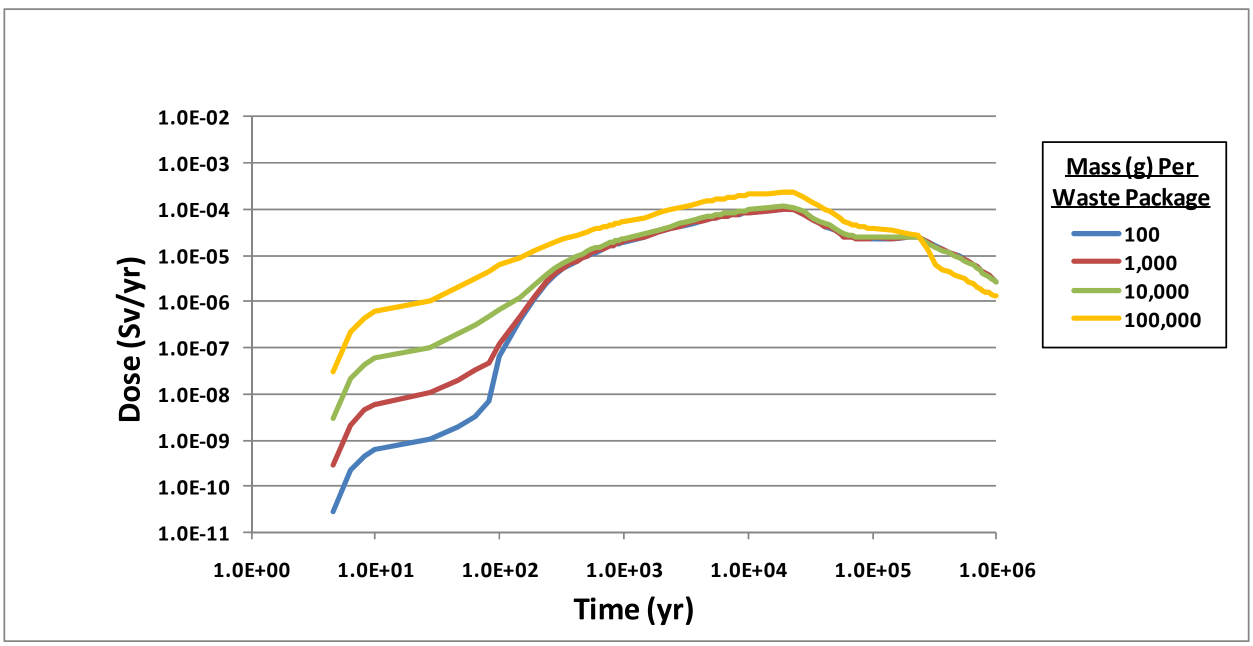


Figure 4-47. Np-237 Dose for Simulation 6: High-Level Waste (Glass) Mass Per Waste Package—Oxidizing

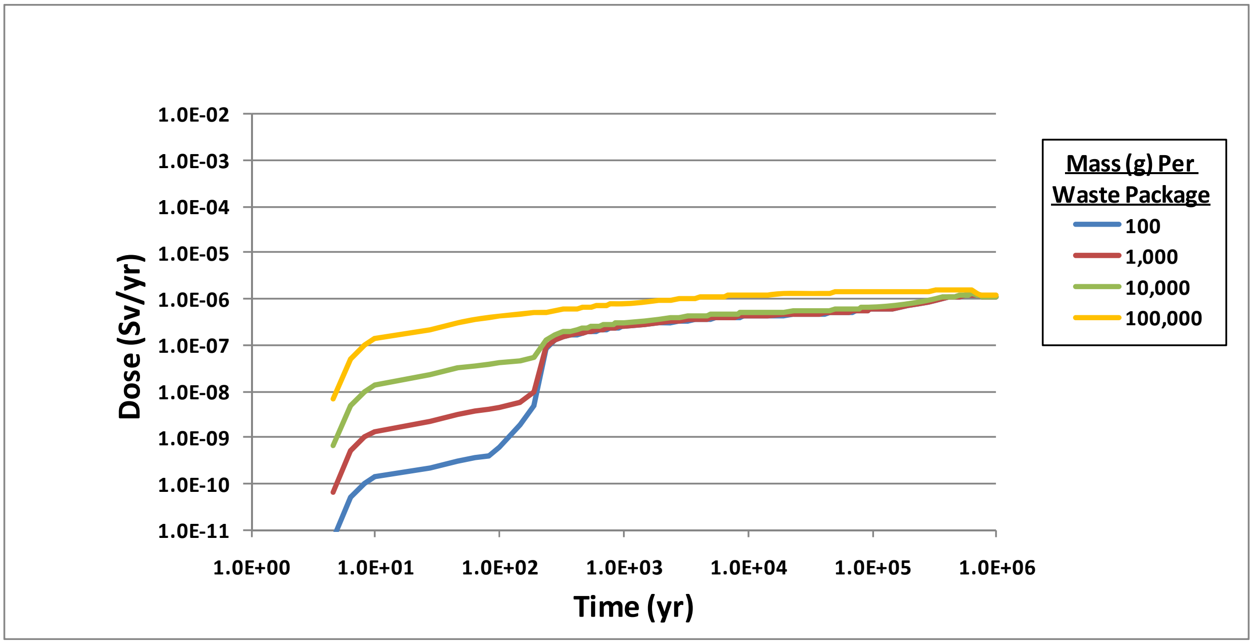


Figure 4-48. Np-237 Dose for Simulation 6: High-Level Waste (Ceramic) Mass Per Waste Package—Oxidizing

Simulation 7: Waste Package General Corrosion Rate

Objective:	Show the effect on dose of varying the general corrosion rate in an oxidizing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02 (This is a special version of the code that is not available to the user. It provides for the direct input of general corrosion rates on the dashboard to enable early failure of the waste package by corrosion.)
Input Control Changes:	— Modified dashboard to allow a user-defined material for the waste package. The user can define the bounds of the corrosion rate distribution in the modified dashboard. — Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT. — Set “Waste package material” as “User defined,” “Distribution of general corrosion rates” as “Uniform,” and “Scale of distribution of general corrosion rates” as “Linear.”

— Set “User-defined low bound GC (µm/yr)” and “User-defined high bound GC (µm/yr)” as 1e-3 to 1e-2, 1e-2 to 1e-1, 1e-1 to 1e0, 1e0 to 1e1, 1e1 to 1e2, and 1e2 to 1e3 µm/yr, respectively, in separate simulations.

— Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.

— Activate “Check to define waste package thickness (default values used if unchecked)” and set “Waste package thickness (cm): (only used if above is checked)” equal to 5 cm.

— Set “Type of disruptive event” as “None.”

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

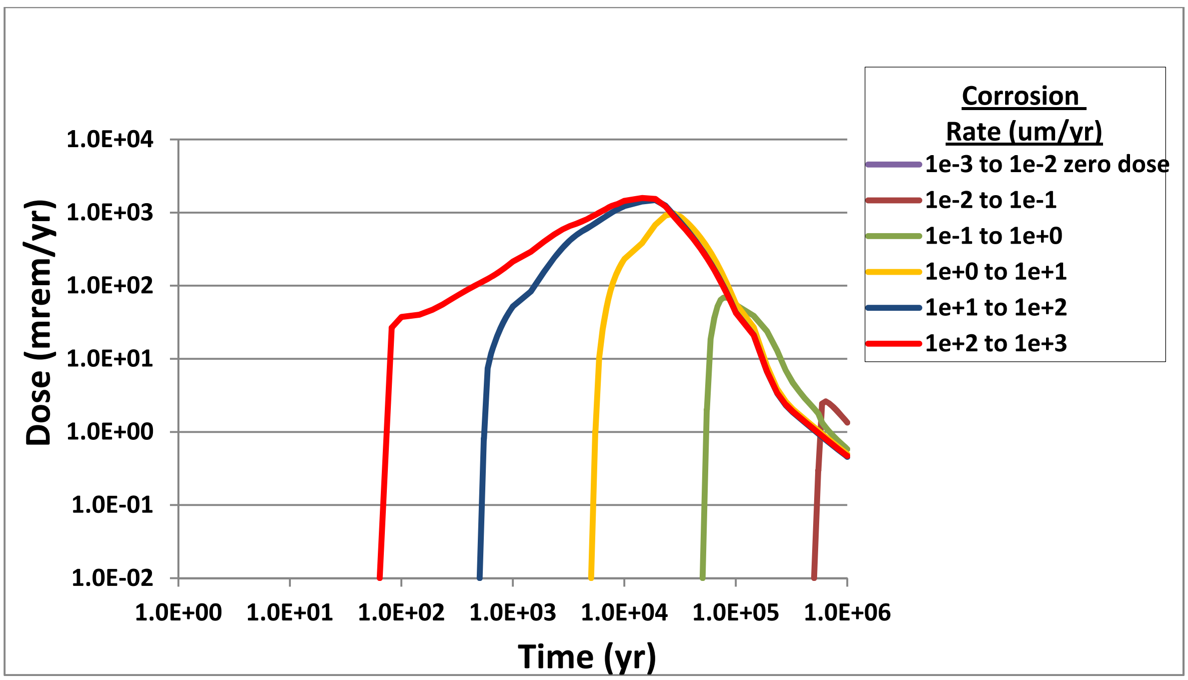


Figure 4-49. Total Dose for Simulation 7: Waste Package General Corrosion Rate and 5-cm Waste Package Thickness—Oxidizing

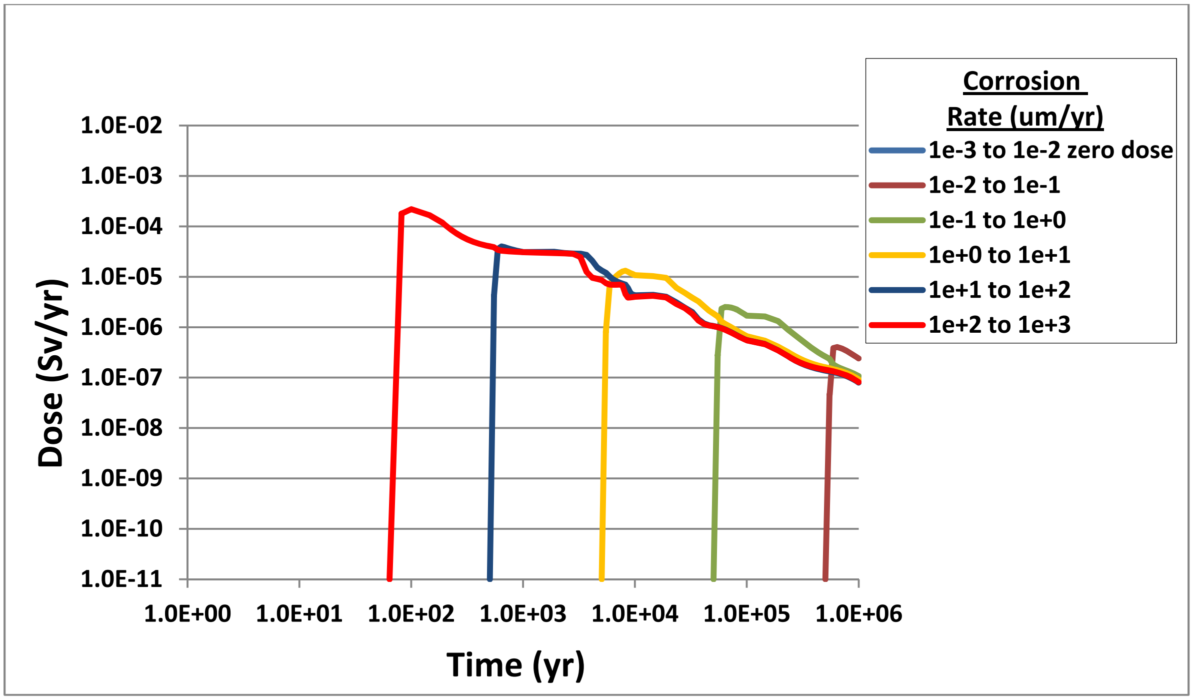


Figure 4-50. I-129 Dose for Simulation 7: Waste Package General Corrosion Rate and 5-cm Waste Package Thickness—Oxidizing

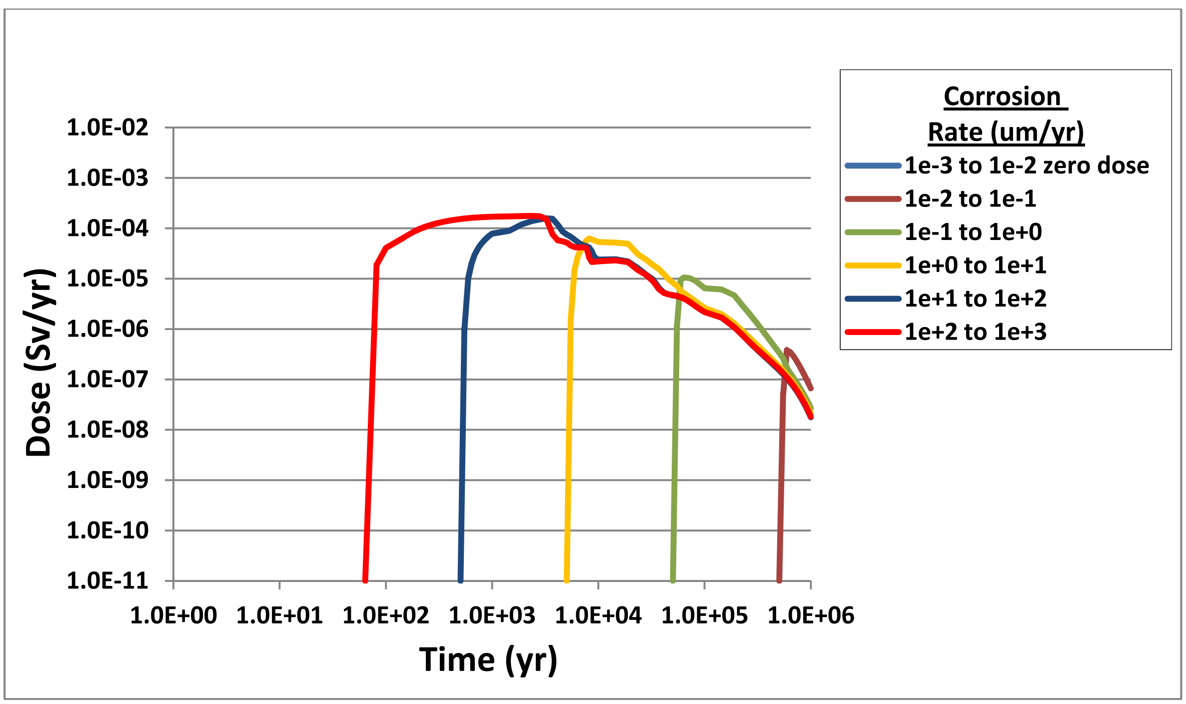


Figure 4-51. Tc-99 Dose for Simulation 7: Waste Package General Corrosion Rate and 5-cm Waste Package Thickness—Oxidizing

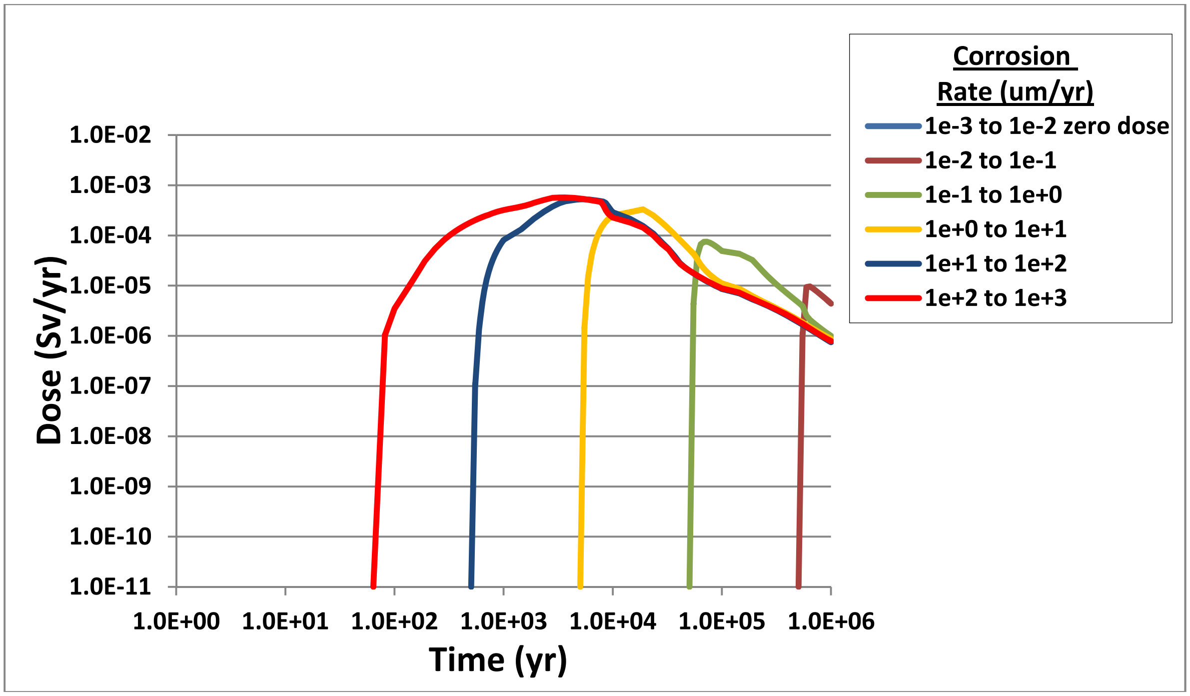


Figure 4-52. Np-237 Dose for Simulation 7: Waste Package General Corrosion Rate and 5-cm Waste Package Thickness—Oxidizing

Simulation 8: Waste Package Breach Area

Objective:	Show the effect on dose of varying the waste package breach area in an oxidizing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
	(This is a special version of the code that is not available to the user. It provides for the direct input of general corrosion rates on the dashboard to enable early waste package failure by corrosion.)
Input Control Changes:	— Modified dashboard to allow a user-defined material for the waste package. The user can define the bounds of the corrosion rate distribution in the modified dashboard.
	— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT.
	— Set “Minimum general corrosion breach area fraction” and “Maximum general corrosion breach area fraction” equal to 1e-2 to 1.01e-2, 1e-4 to 1.01e-4, and 1e-6 to 1.01e-6, respectively, in separate simulations.

— Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.

— Set “User-defined low bound GC (um/yr)” and “User- defined high bound GC (um/yr)” equal to .999e6 and 1e6.

— Set “Type of disruptive event” as “none.”

— Deactivate “Bypass the backfill (diffusive barrier).”

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

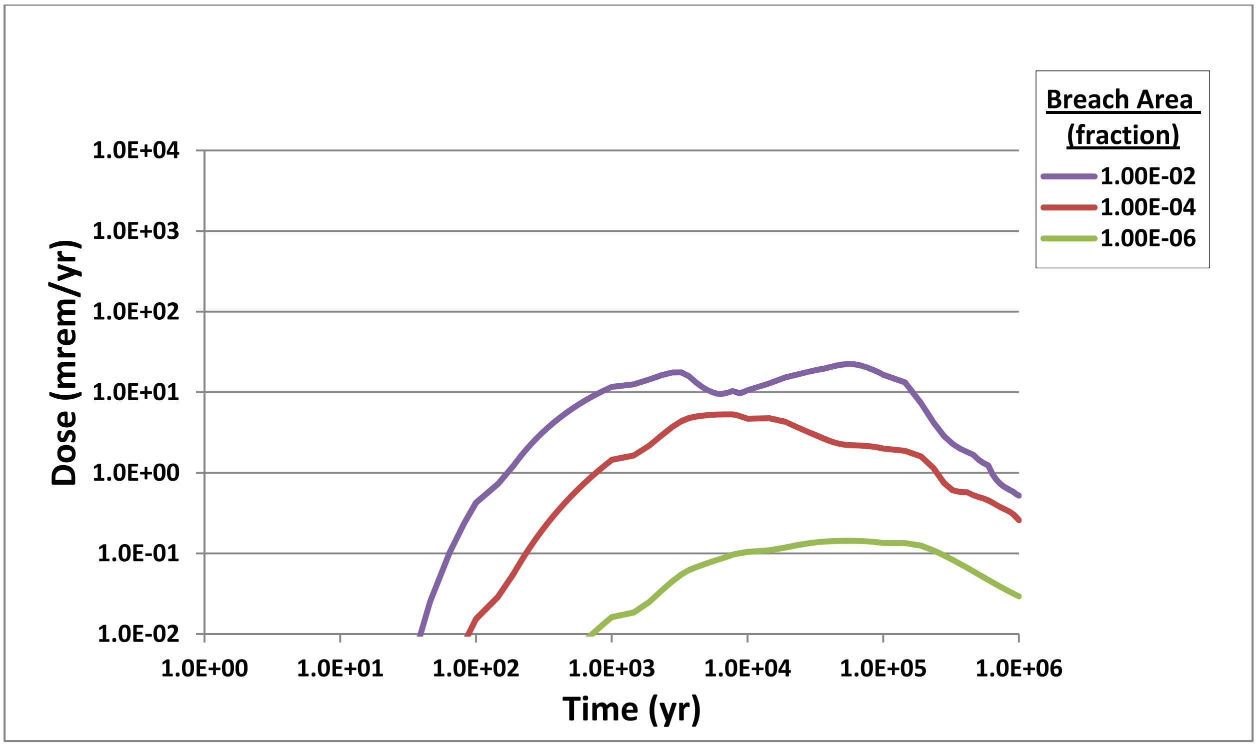


Figure 4-53. Total Dose for Simulation 8: Waste Package Breach Area With General Corrosion Rate 1e6 um/yr and Not Bypassing the Backfill—Oxidizing

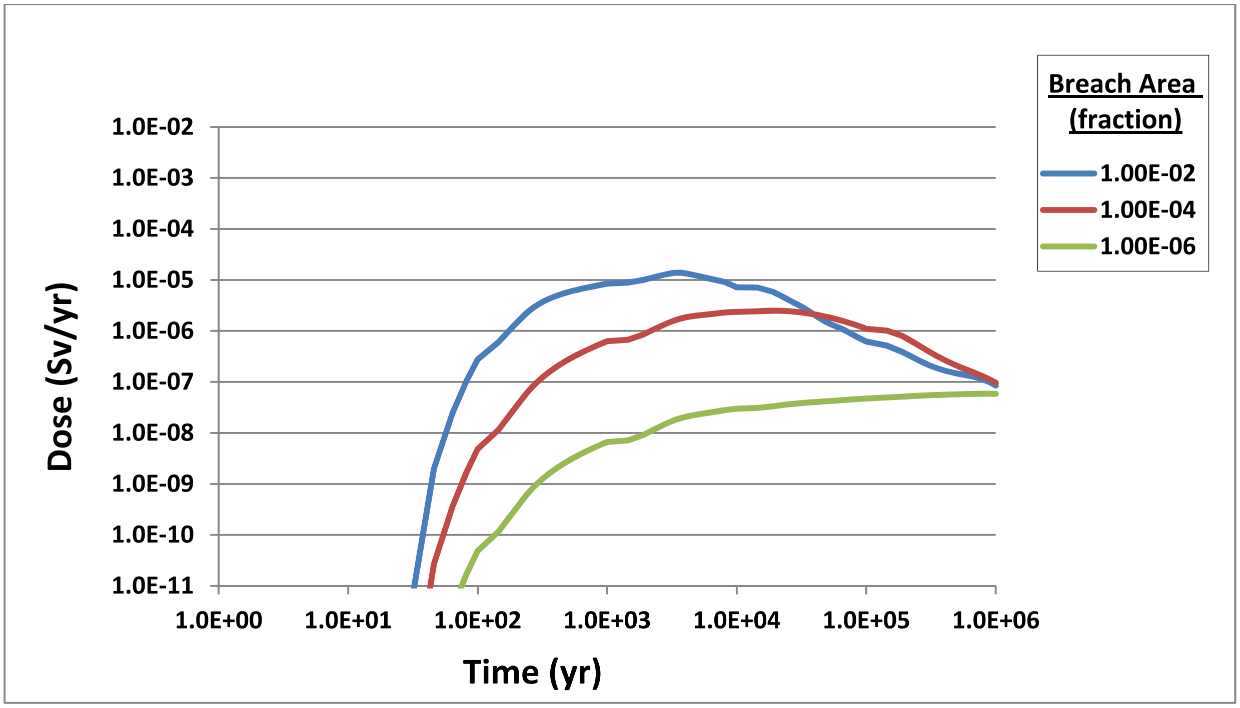


Figure 4-54. I-129 Dose for Simulation 8: Waste Package Breach Area With General Corrosion Rate 1e6 um/yr and Not Bypassing the Backfill—Oxidizing

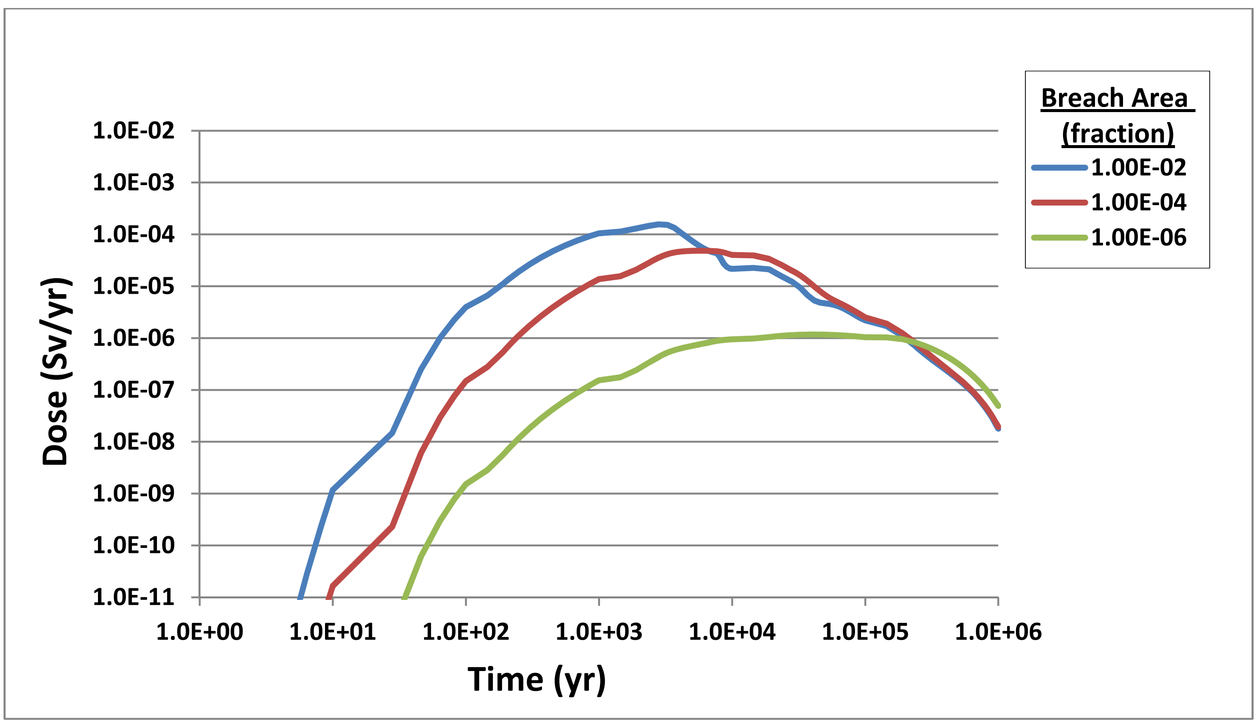


Figure 4-55. Tc-99 Dose for Simulation 8: Waste Package Breach Area With General Corrosion Rate 1e6 um/yr and Not Bypassing the Backfill—Oxidizing

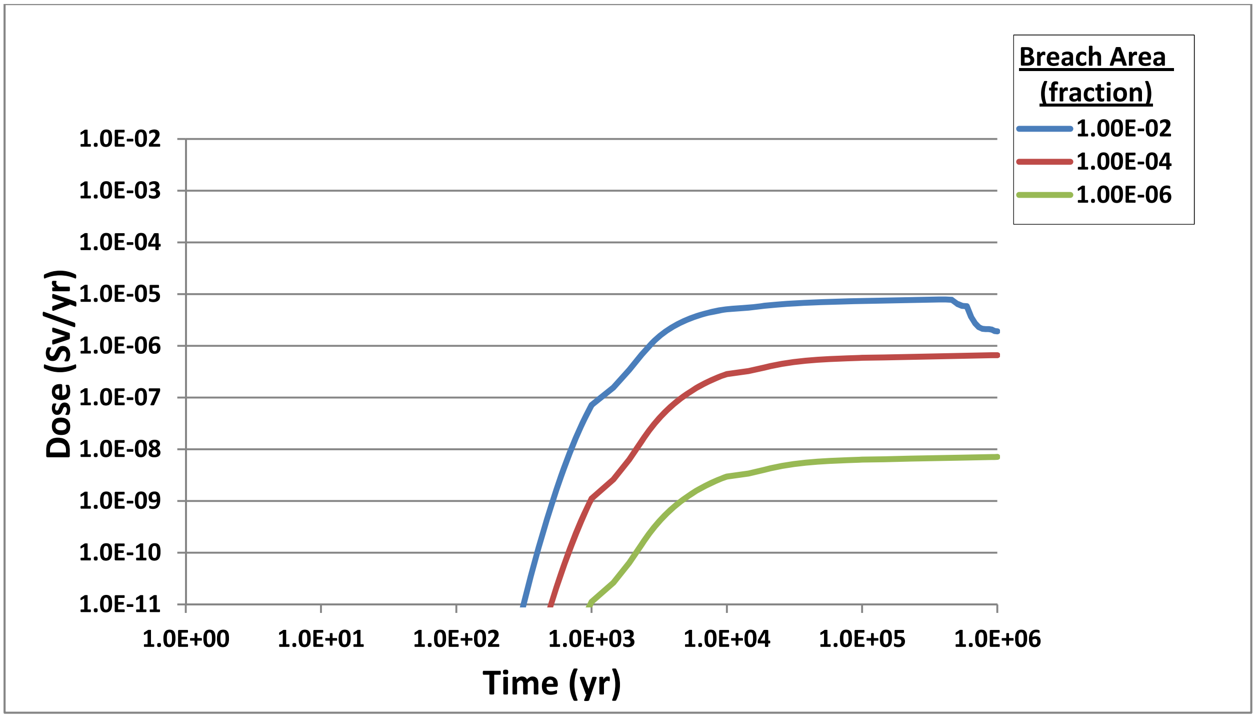


Figure 4-56. Np-237 Dose for Simulation 8: Waste Package Breach Area With General Corrosion Rate 1e6 um/yr and Not Bypassing the Backfill—Oxidizing

Simulation 9: Buffer Integrity

Objective:	For spent nuclear fuel in an oxidizing environment, show the effect on dose of (i) the percentage of buffer degradation when the expected lifetime of the backfill is fixed at 1 year and (ii) the expected lifetime of the backfill when the percentage of buffer degradation is fixed at 50 percent.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	For varying fraction of backfill cracked,

— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT.

— Deactivate “Bypass the backfill (diffusive barrier),” and activate “Enable degradation of the backfill (diffusive barrier).”

— Set “Minimum time of initial backfill failure (year)” and “Maximum time of initial backfill failure (year)” equal to 1 and 1.1 year, respectively.

— Set “Minimum expected lifetime of backfill (year)” and “Maximum expected lifetime of backfill (year)” equal to 1 and 1.1 year, respectively.

— Set “Minimum fraction of backfill cracked” equal to 0.0, 0.0001, 0.001, 0.01, 0.1, and 0.99 in separate simulations with corresponding “Maximum fraction of backfill cracked” set equal to 0.0000001, 0.000101, 0.00101, 0.0101, 0.101, and 1.

— Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.

For varying backfill lifetime,

— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT.

— Deactivate “Bypass the backfill (diffusive barrier),” and activate “Enable degradation of the backfill (diffusive barrier).”

— Set “Minimum time of initial backfill failure (year)” and “Maximum time of initial backfill failure (year)” equal to 1 and 1.1 year, respectively.

— Set “Minimum expected lifetime of backfill (year)” and “Maximum expected lifetime of backfill (year)” equal to 1e0 to 1.01e0, 1e1 to 1.01e1, 1e2 to 1.01e2, 1e3 to 1.01e3, 1e4 to 1.01e4, 1e5 to 1.01e5, and 0.99e6 to 1.0e6 years, respectively, in separate simulations.

— Set “Minimum fraction of backfill cracked” and “Maximum fraction of backfill cracked” equal to 0.5e0 to 0.501e0.

— Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

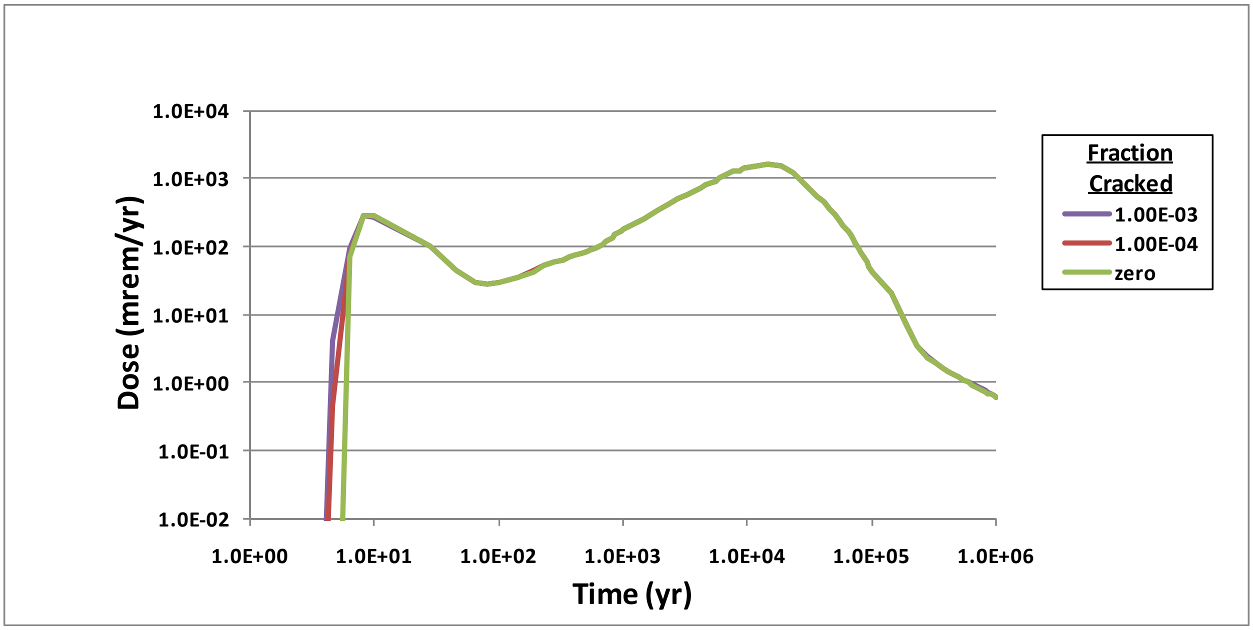


Figure 4-57. Total Dose for Simulation 9: Buffer Integrity With Varying Fraction Backfill Cracked—Oxidizing

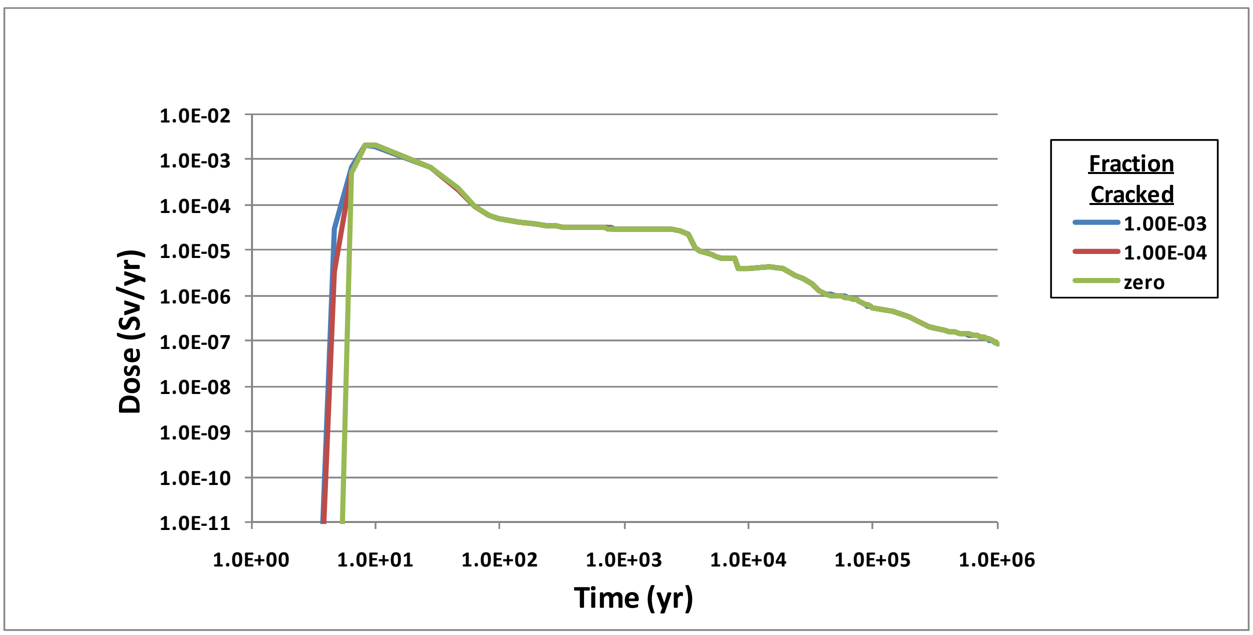


Figure 4-58. I-129 Dose for Simulation 9: Buffer Integrity With Varying Fraction Backfill Cracked—Oxidizing

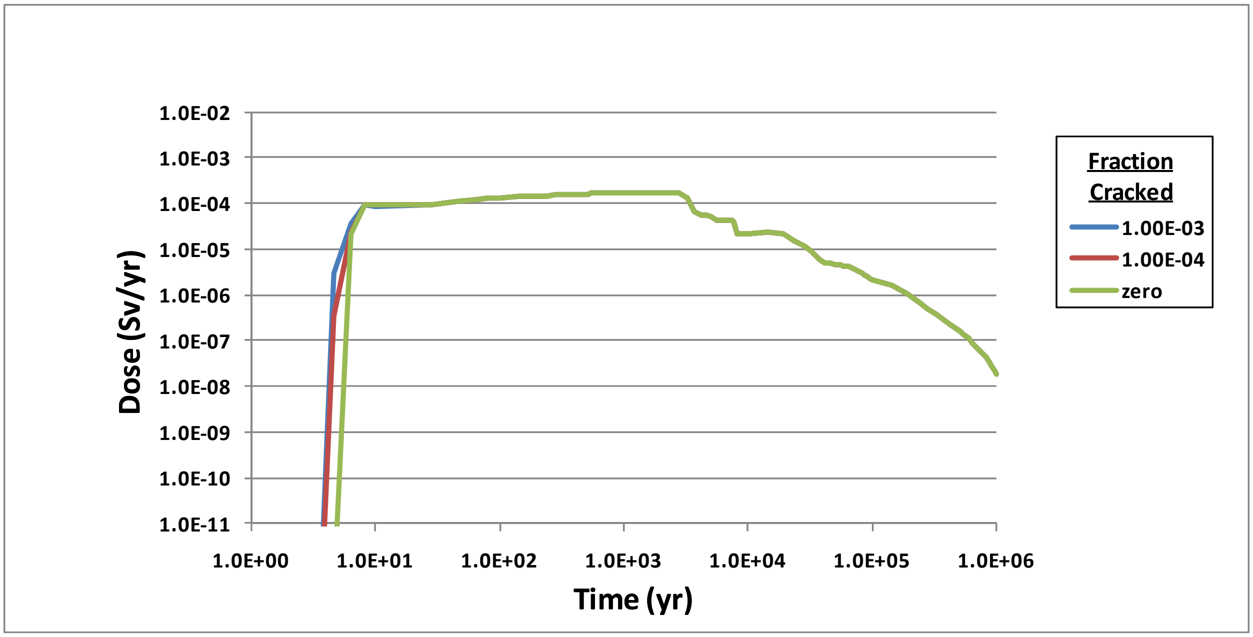


Figure 4-59. Tc-99 Dose for Simulation 9: Buffer Integrity With Varying Fraction Backfill Cracked—Oxidizing

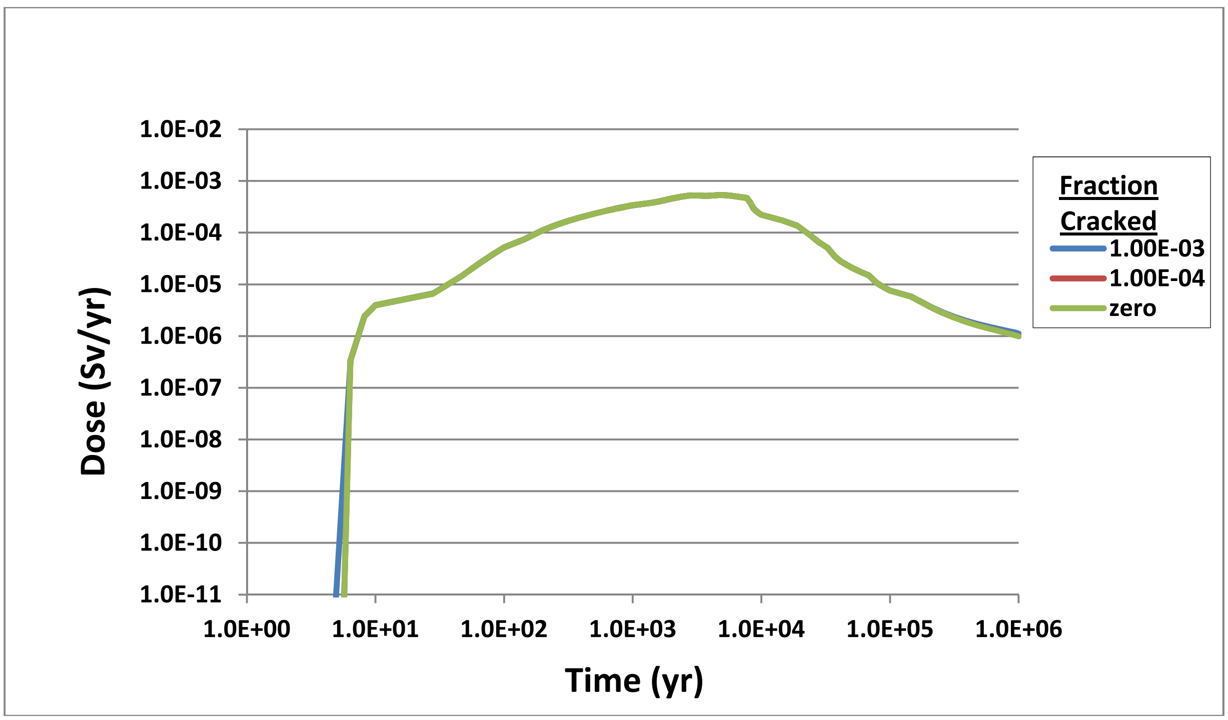


Figure 4-60. Np-237 Dose for Simulation 9: Buffer Integrity With Varying Fraction Backfill Cracked—Oxidizing

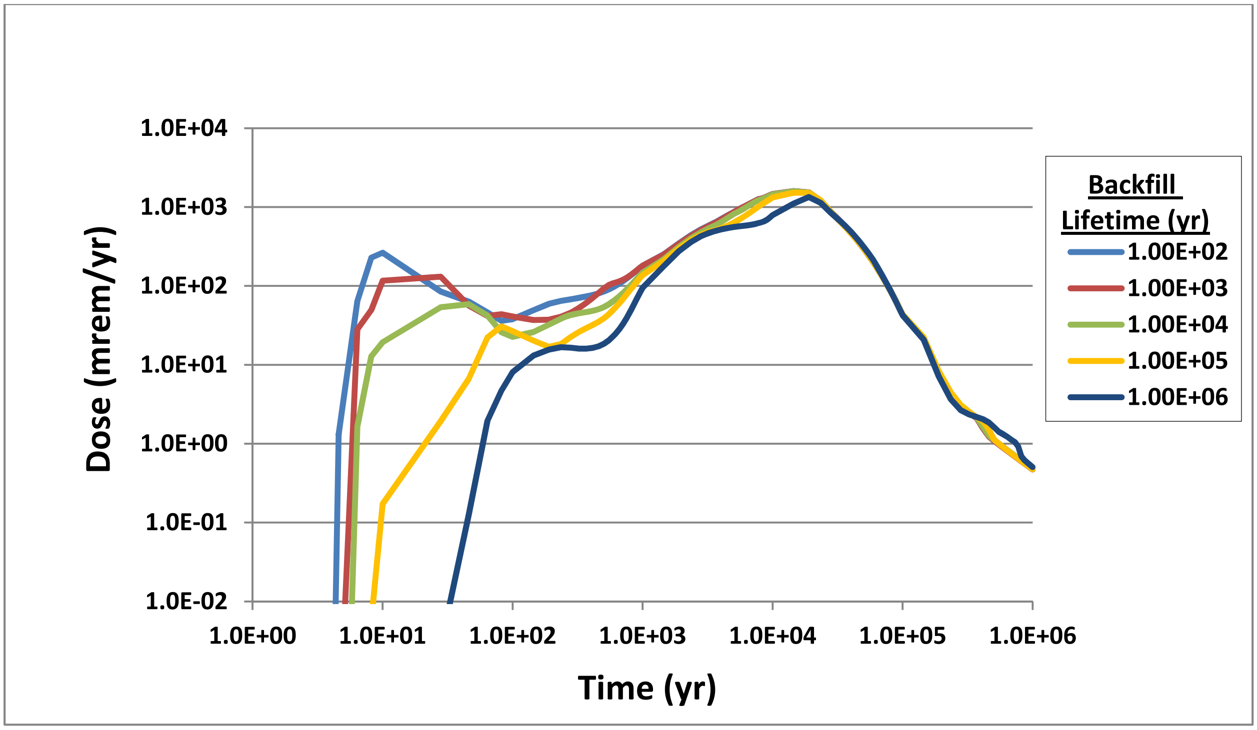


Figure 4-61. Total Dose for Simulation 9: Buffer Integrity With Varying Backfill Lifetime—Oxidizing

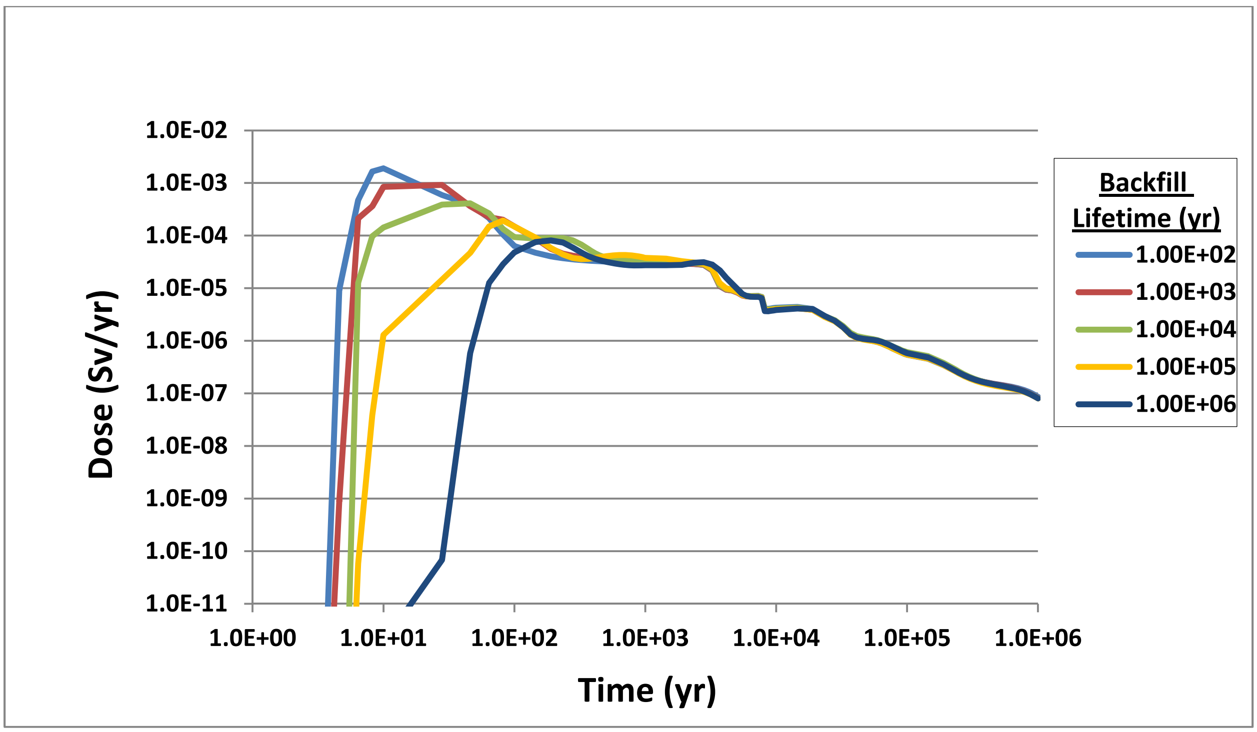


Figure 4-62. I-129 Dose for Simulation 9: Buffer Integrity With Varying Backfill Lifetime—Oxidizing

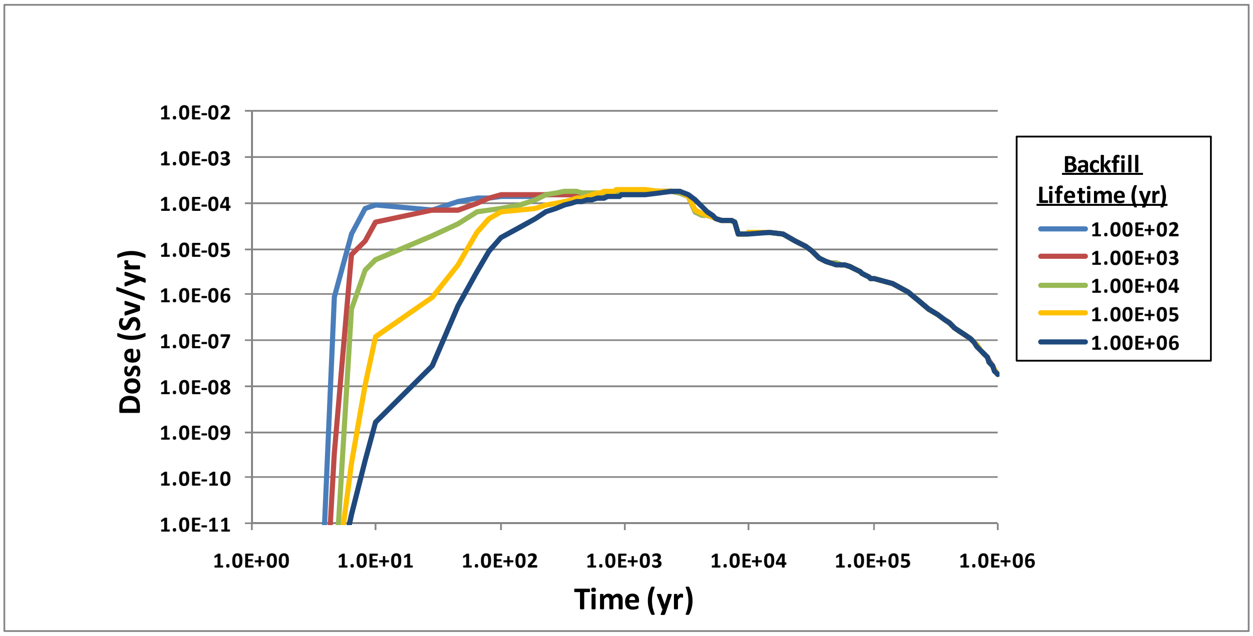


Figure 4-63. Tc-99 Dose for Simulation 9: Buffer Integrity With Varying Backfill Lifetime—Oxidizing

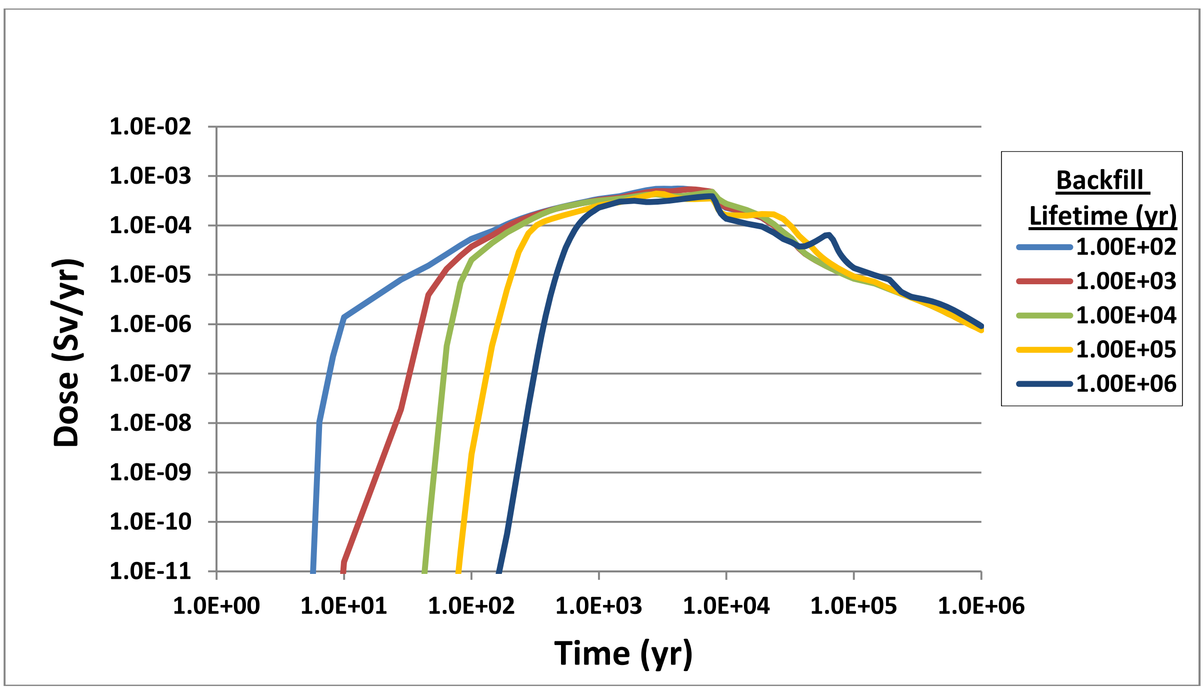


Figure 4-64. Np-237 Dose for Simulation 9: Buffer Integrity With Varying Backfill Lifetime—Oxidizing

Simulation 10: Waste Package Water Volume

Objective:	Show the effect on dose of varying the volume of water inside the waste package in an oxidizing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02a
Input Control Changes:	— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT. — Set “Water volume inside the waste package (cubic meters)” equal to 0.01, 0.1, 1.0, and 10 m^3 in separate simulations. — Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

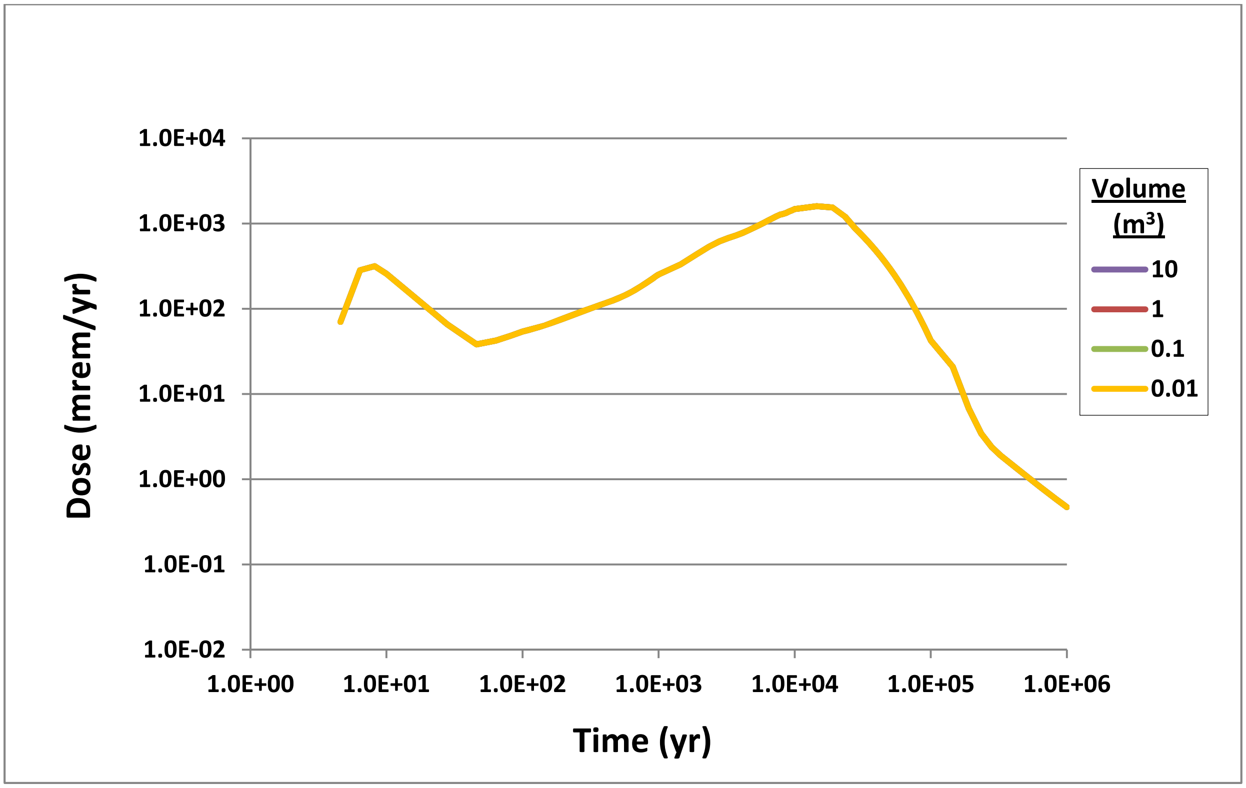


Figure 4-65. Total Dose for Simulation 10: Waste Package Water Volume—Oxidizing

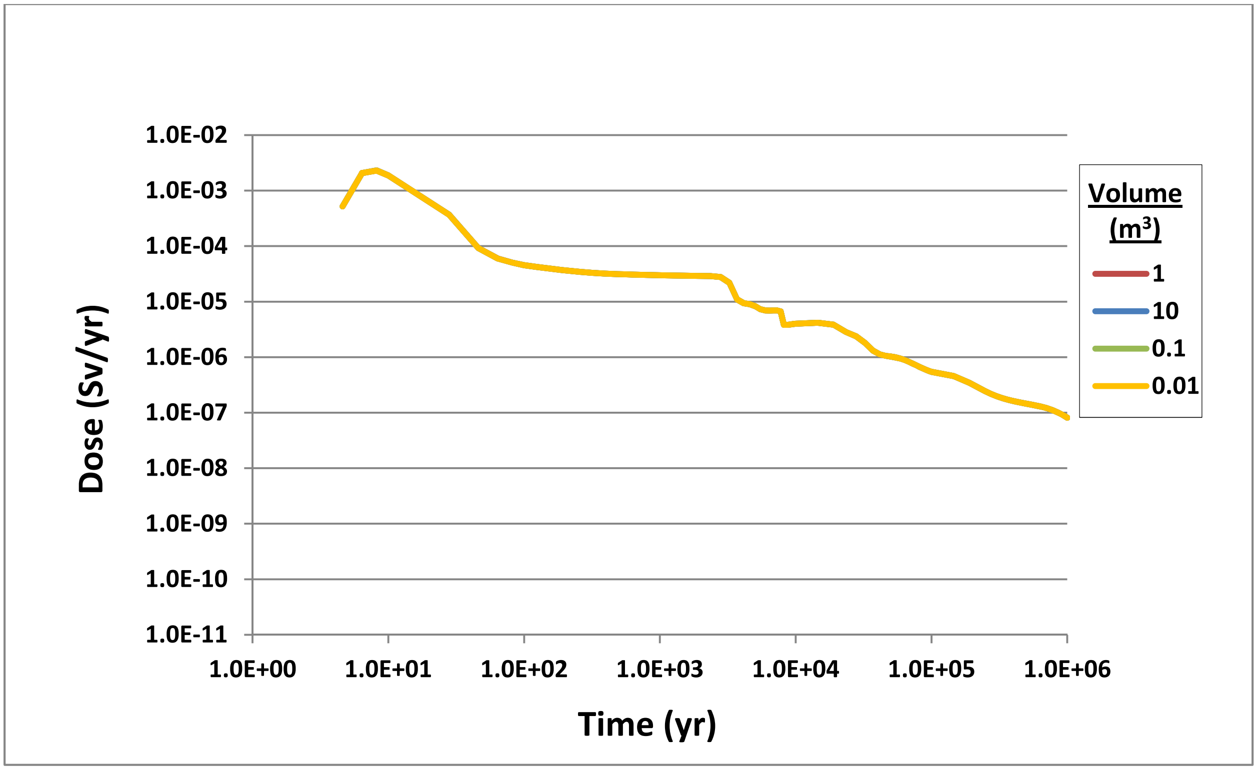


Figure 4-66. I-129 Dose for Simulation 10: Waste Package Water Volume—Oxidizing

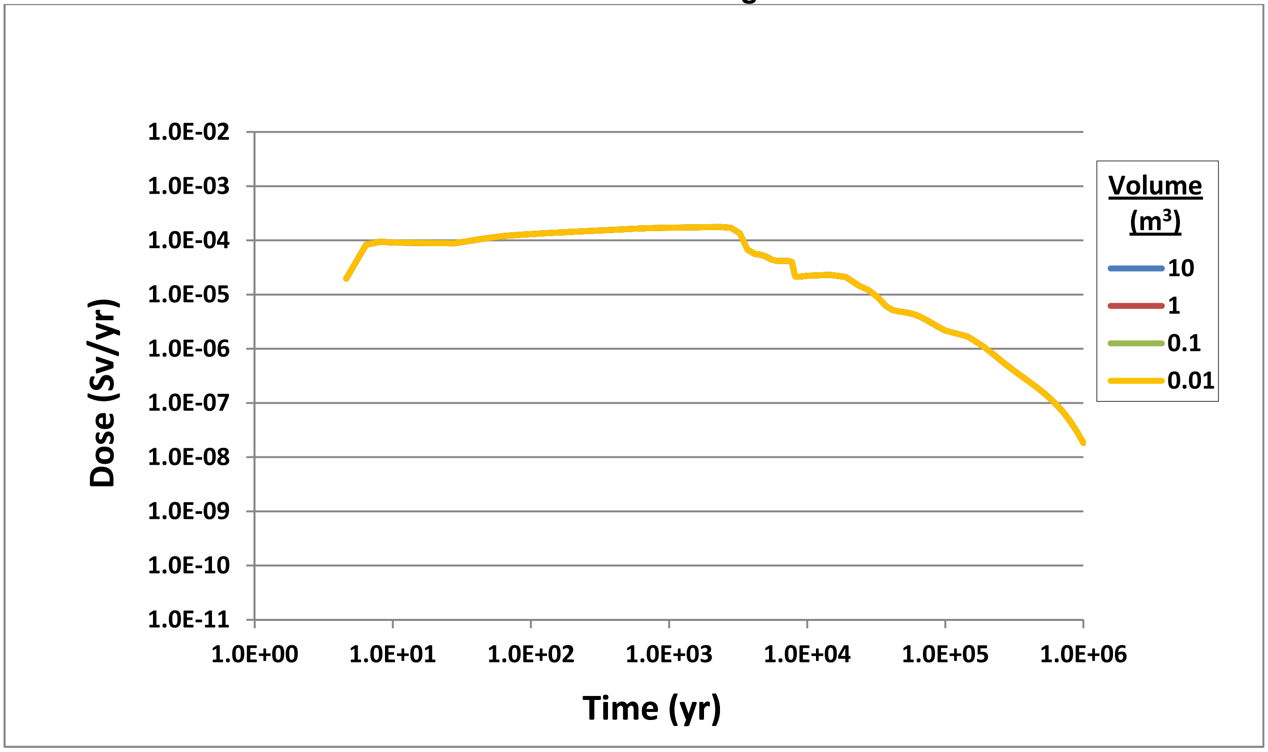


Figure 4-67. Tc-99 Dose for Simulation 10: Waste Package Water Volume—Oxidizing

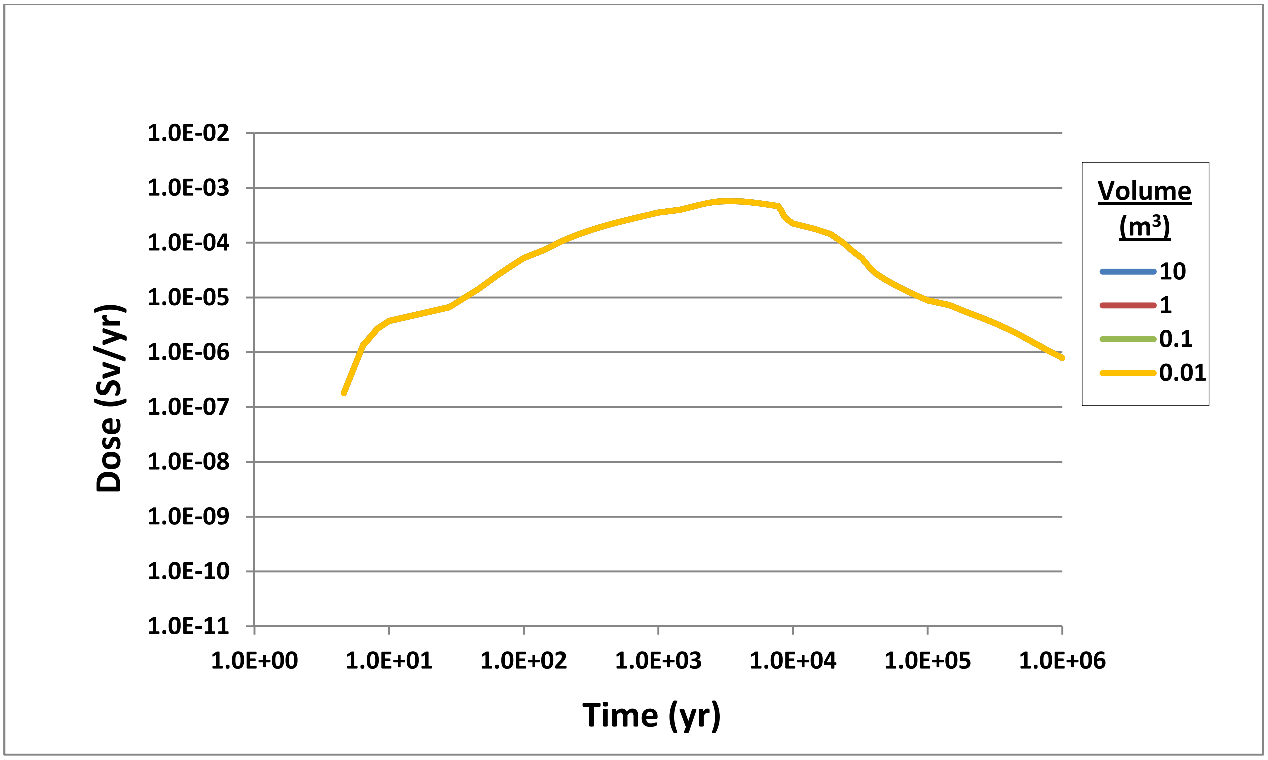


Figure 4-68. Np-237 Dose for Simulation 10: Waste Package Water Volume—Oxidizing

Simulation 11: Hydraulic Gradient

Objective: Show the effect on dose of varying the hydraulic gradient in the far field with fractured rock and porous rock in an oxidizing environment.

Test Environment: GoldSim_Player_10.5SP1

SOAR Version: 1.0.02a

Input Control Changes:

— Set “Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)” for spent nuclear fuel equal to 100,000 MT.

— Set “Hydraulic gradient (sediments and porous rock only)” equal to 1, 1e-2, 1e-4, 1e-6, and 1e-8, as needed, for far-field Legs 1, 2, and 3 in separate simulations.

— Set “Geologic media” as “Fractured Rock” and “Porous Rock” for far field Legs 1, 2, and 3 in separate simulations.

— Set the Redox condition as “Oxidizing” for far-field Legs 1, 2, and 3.

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

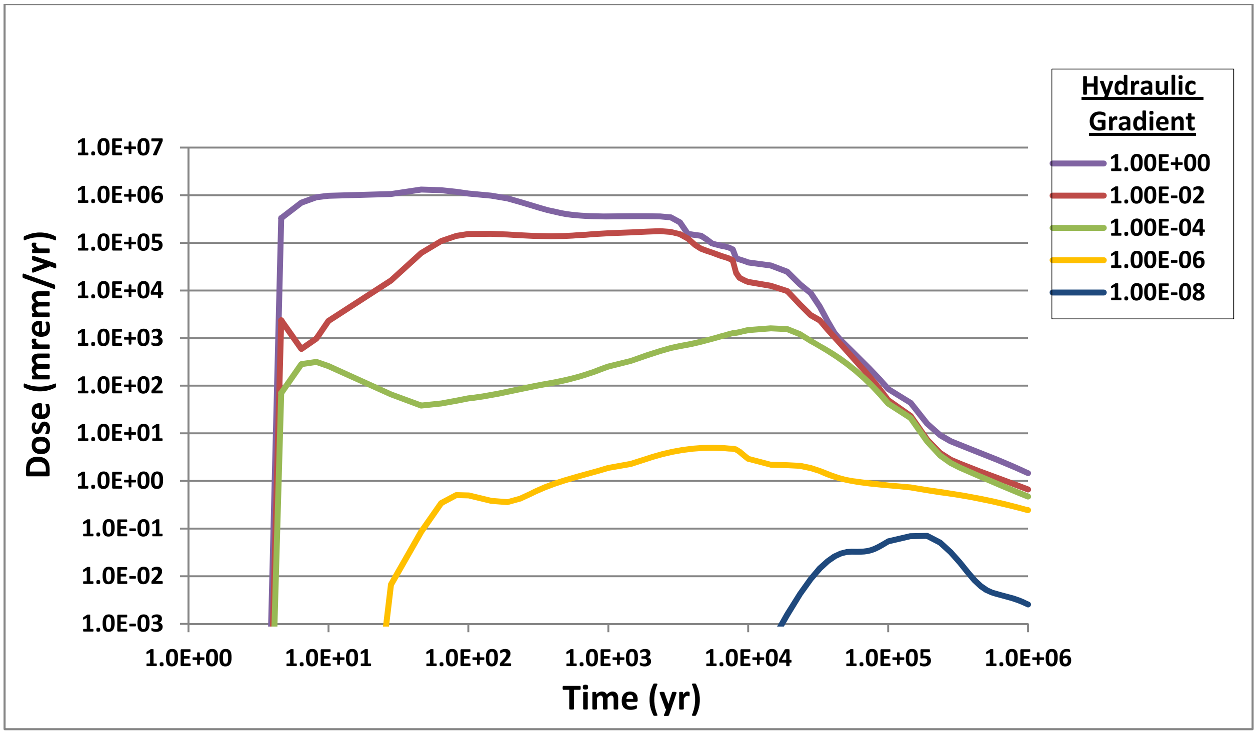


Figure 4-69. Total Dose for Simulation 11: Hydraulic Gradient With Fractured Rock—Oxidizing

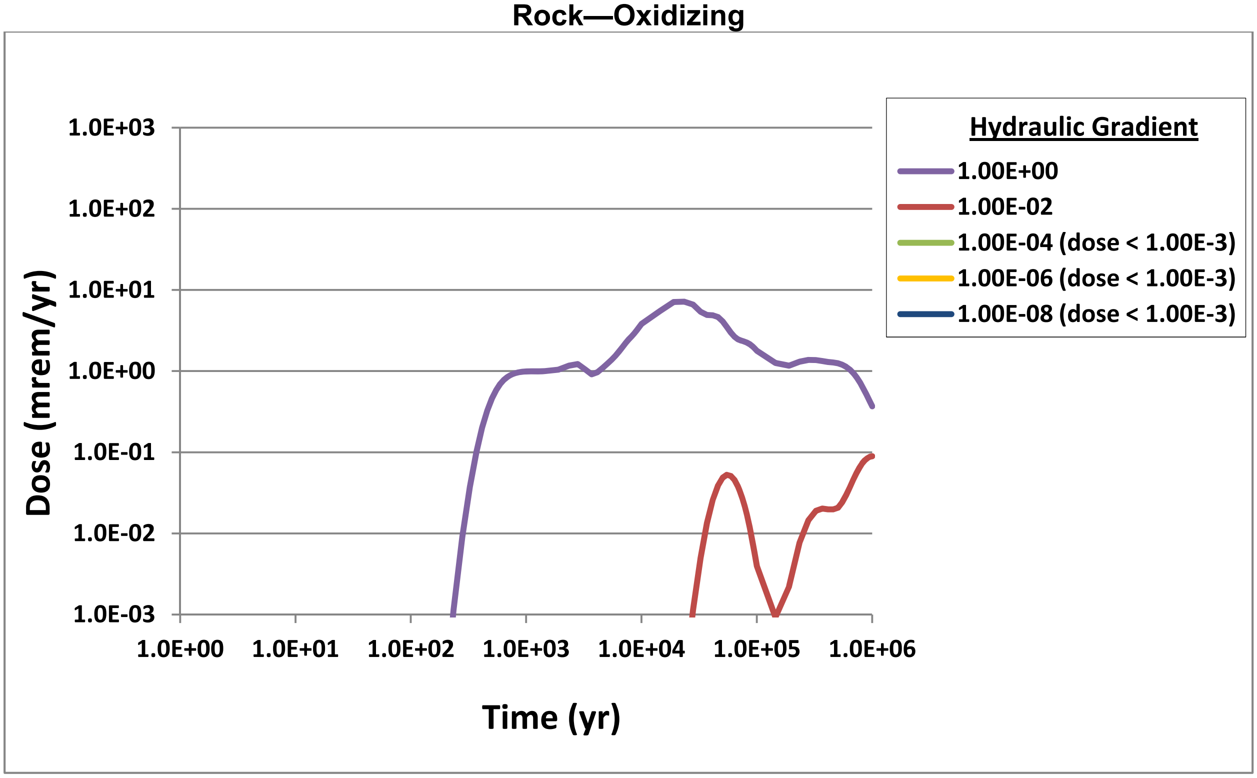


Figure 4-70. Total Dose for Simulation 11: Hydraulic Gradient With Porous Rock—Oxidizing

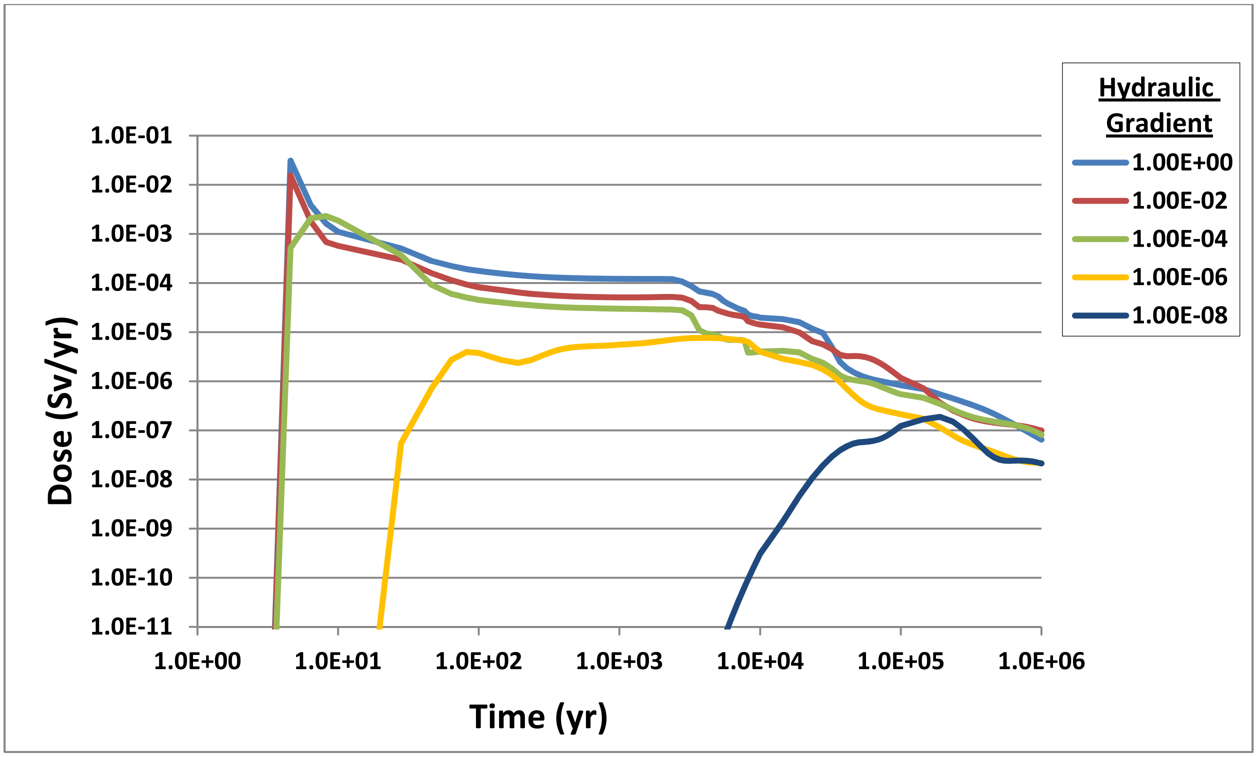


Figure 4-71. I-129 Dose for Simulation 11: Hydraulic Gradient With Fractured Rock—Oxidizing

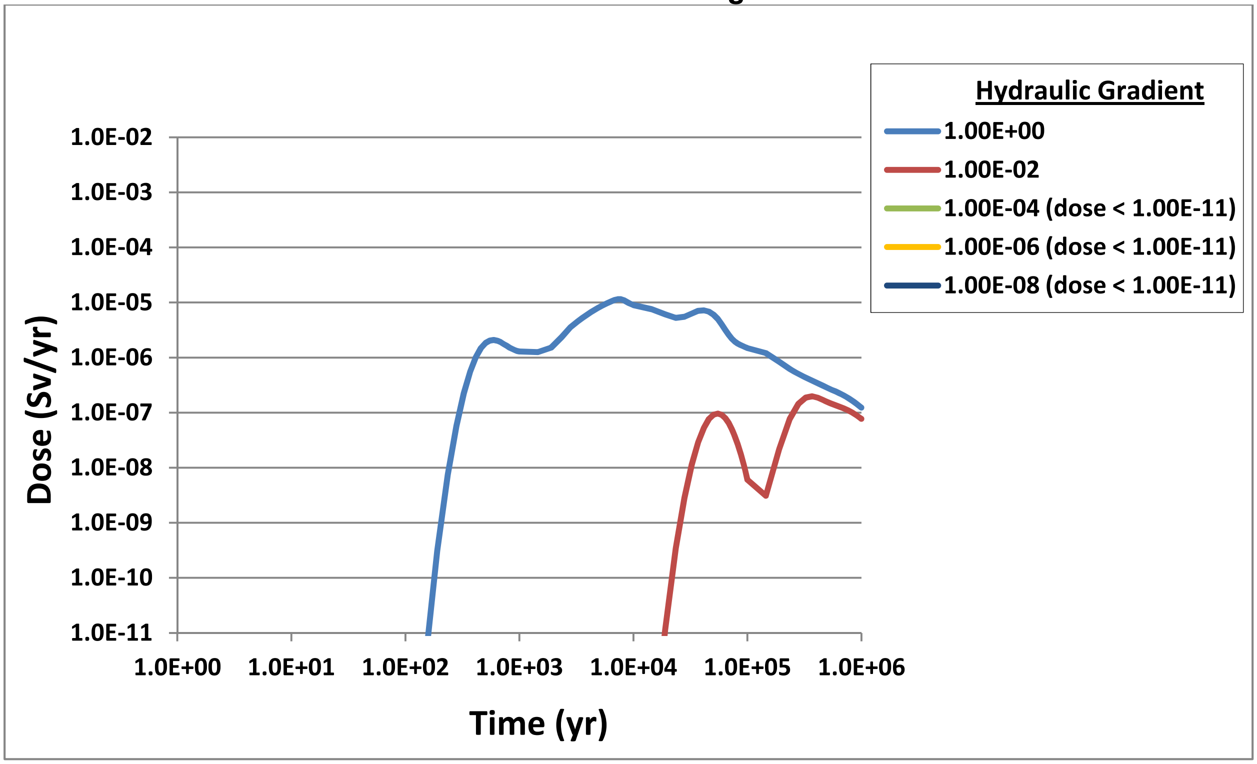


Figure 4-72. I-129 Dose for Simulation 11: Hydraulic Gradient With Porous Rock—Oxidizing

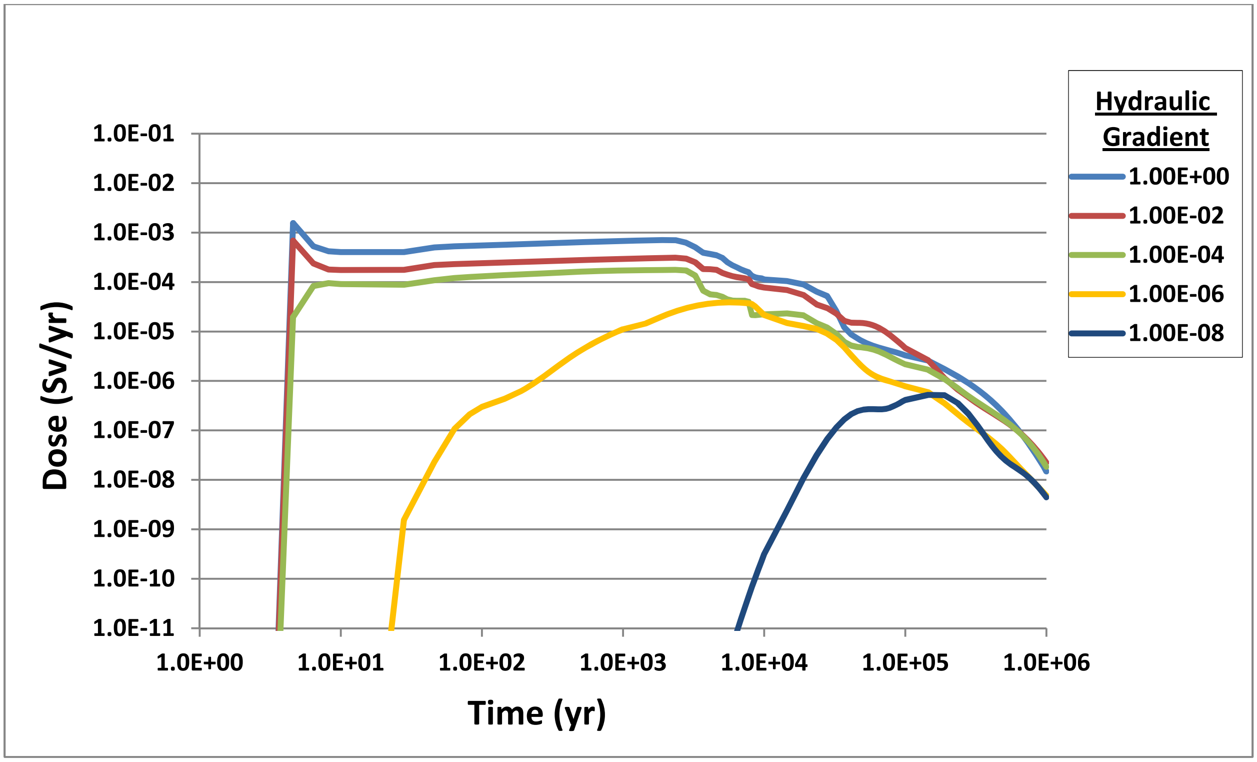


Figure 4-73. Tc-99 Dose for Simulation 11: Hydraulic Gradient with Fractured Rock—Oxidizing

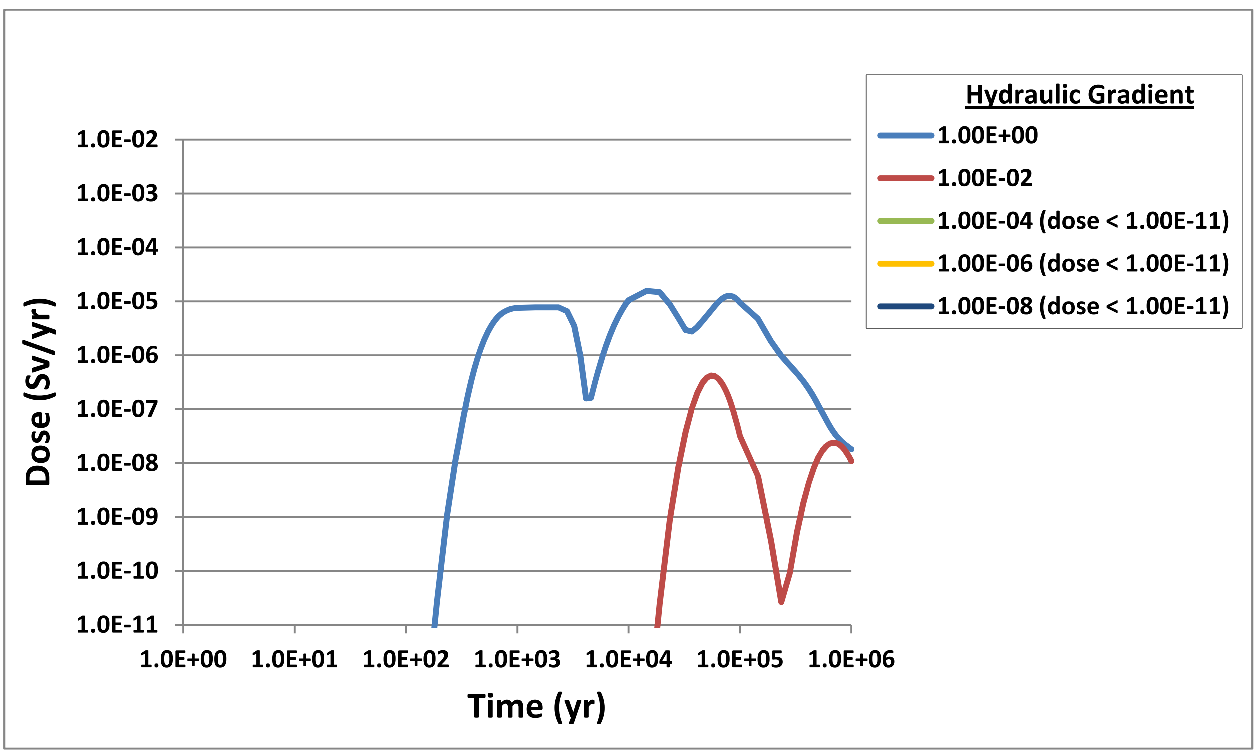


Figure 4-74. Tc-99 Dose for Simulation 11: Hydraulic Gradient With Porous Rock—Oxidizing

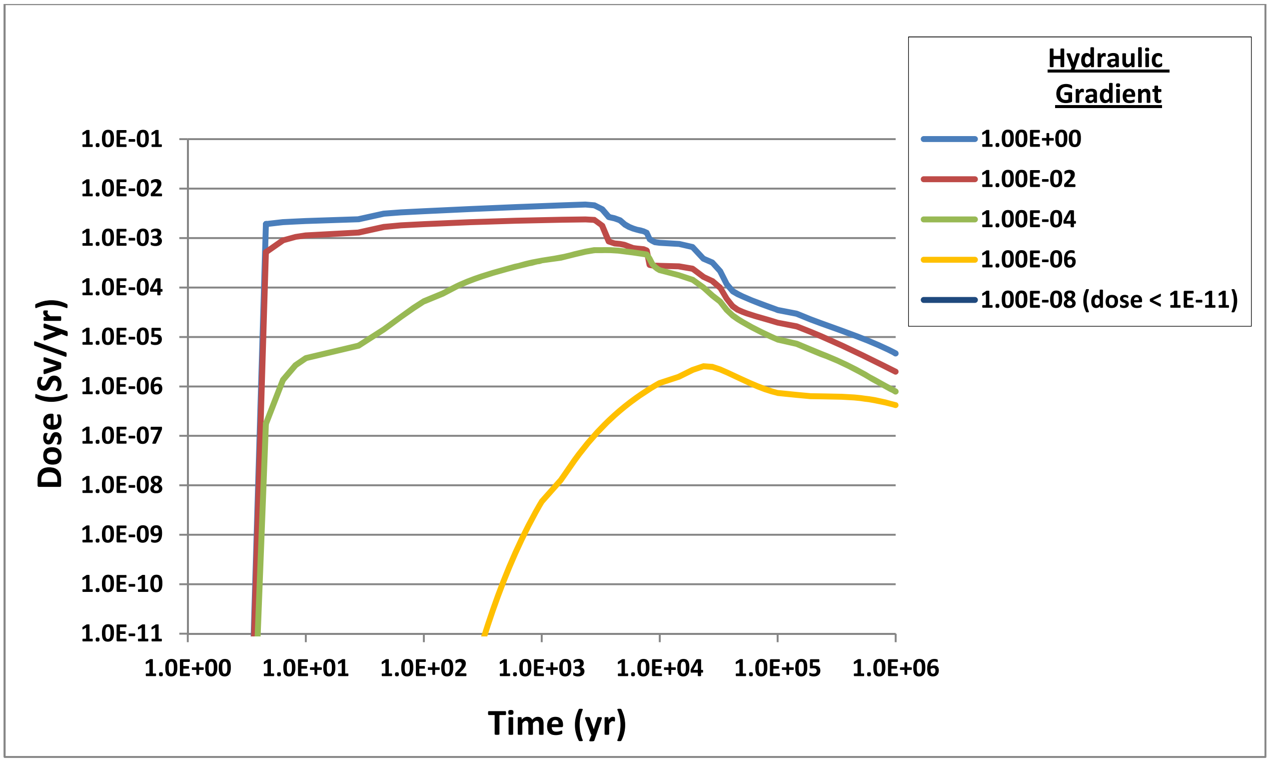


Figure 4-75. Np-237 Dose for Simulation 11: Hydraulic Gradient With Fractured Rock—Oxidizing

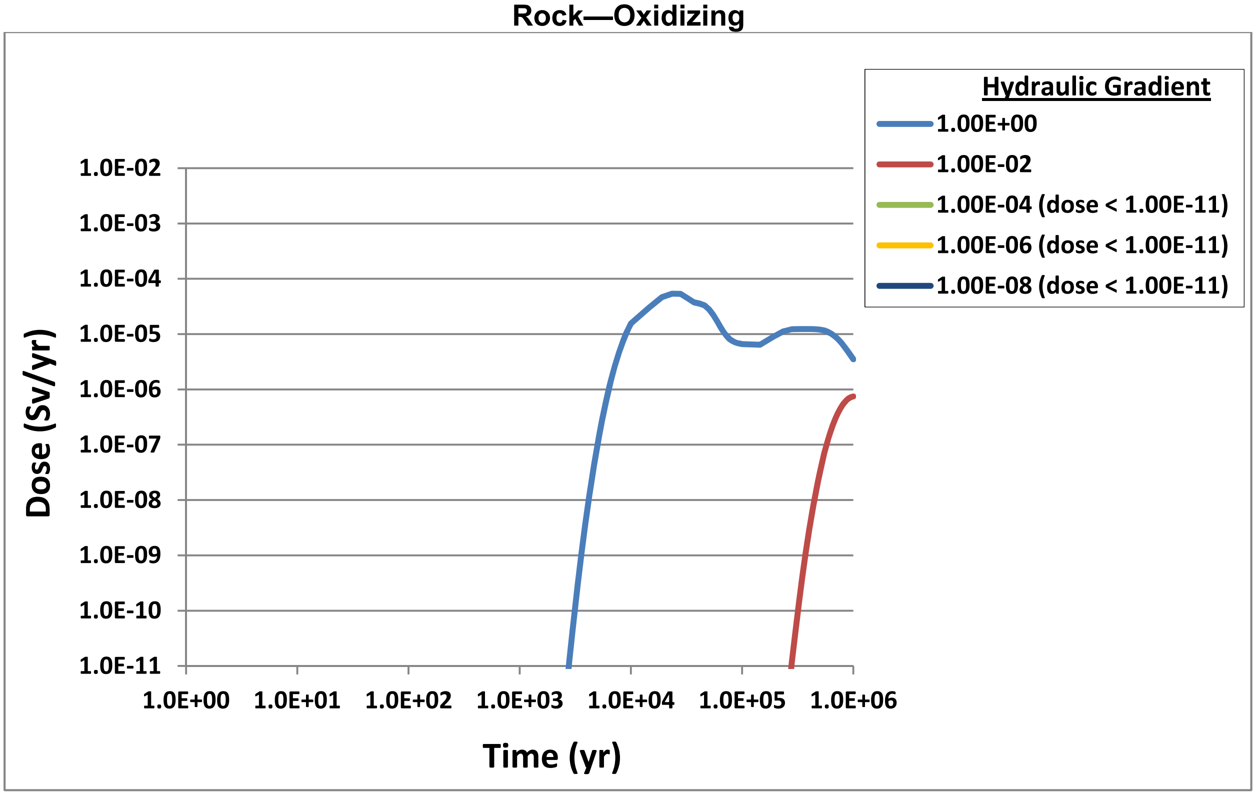


Figure 4-76. Np-237 Dose for Simulation 11: Hydraulic Gradient With Porous Rock—Oxidizing

Simulation 12: Redox

Objective:	Show the effect on dose of unconsolidated sediments, fractured rock, and porous rock in an oxidizing environment and in a reducing environment.
Test Environment:	GoldSim_Player_10.5SP1
SOAR Version:	1.0.02
Input Control Changes:	— Set "Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)" for spent nuclear fuel equal to 100,000 MT. — Set Geologic Media for all three far-field legs to "Unconsolidated Sediments," "Fractured Rock," and "Porous rock" in separate simulations. — Set the Redox condition as "Oxidizing" and "Reducing" for far-field Legs 1, 2, and 3 in separate simulations.
Results:	Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237.

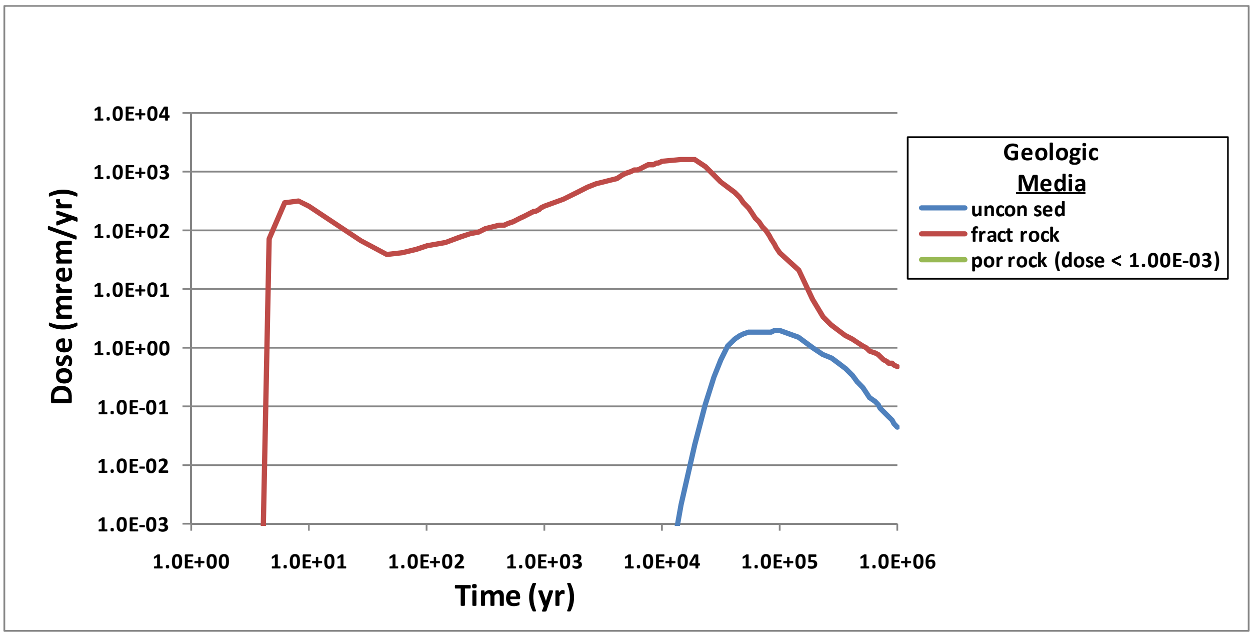


Figure 4-77. Total Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Oxidizing

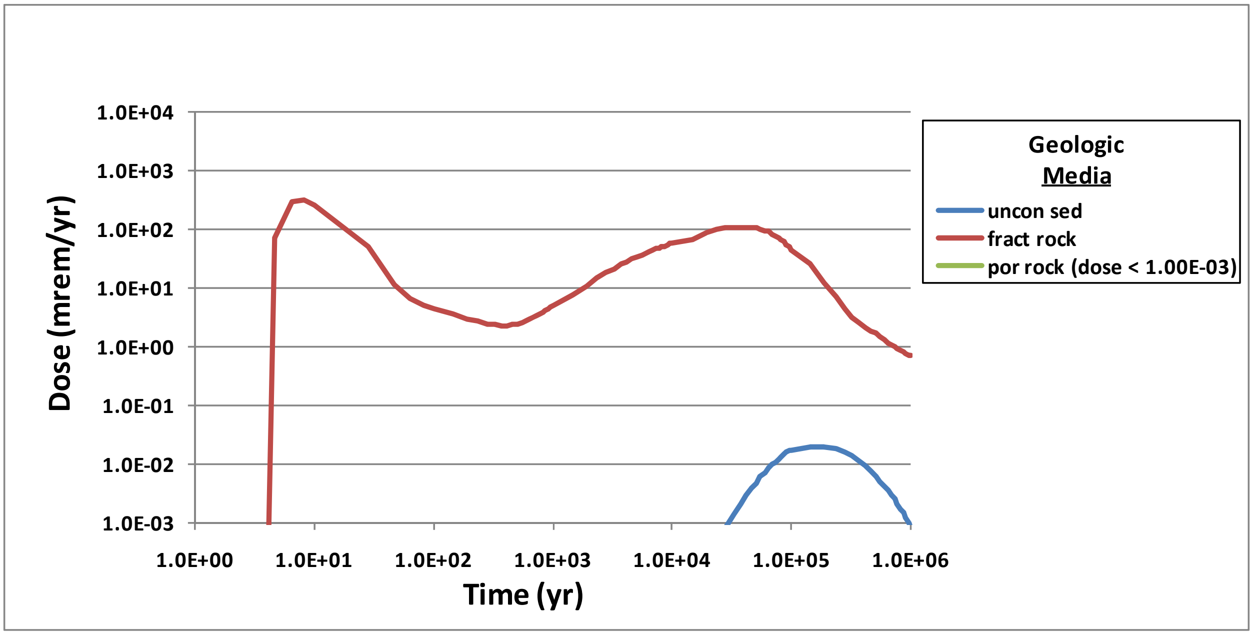


Figure 4-78. Total Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Reducing

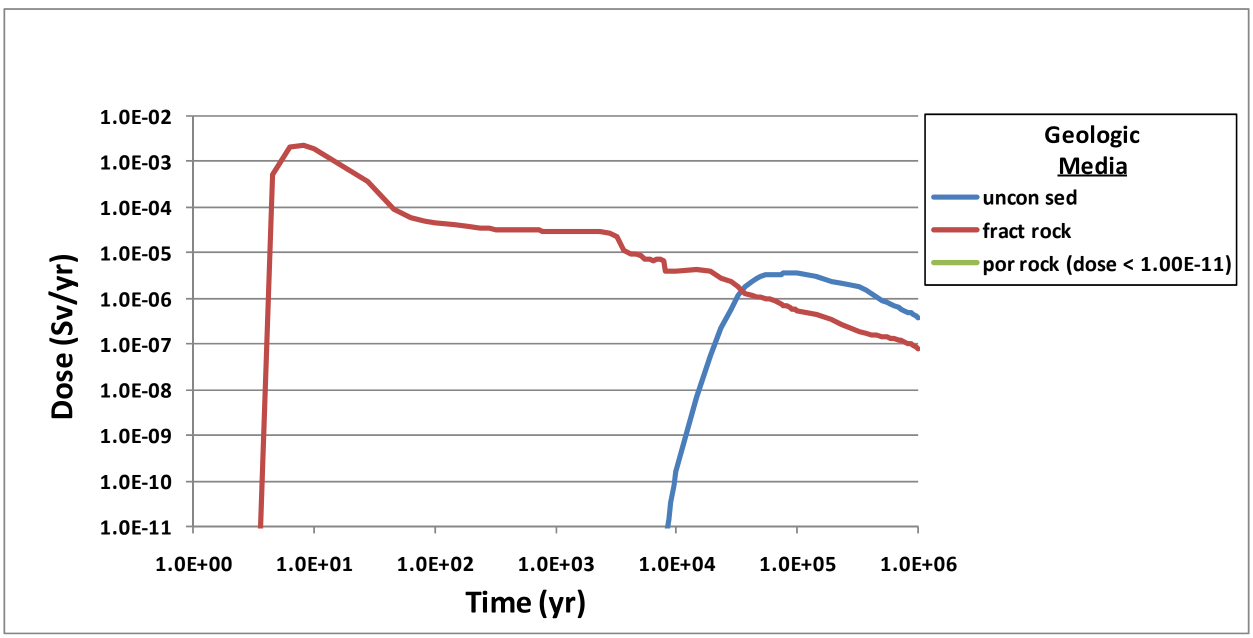


Figure 4-79. I-129 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Oxidizing

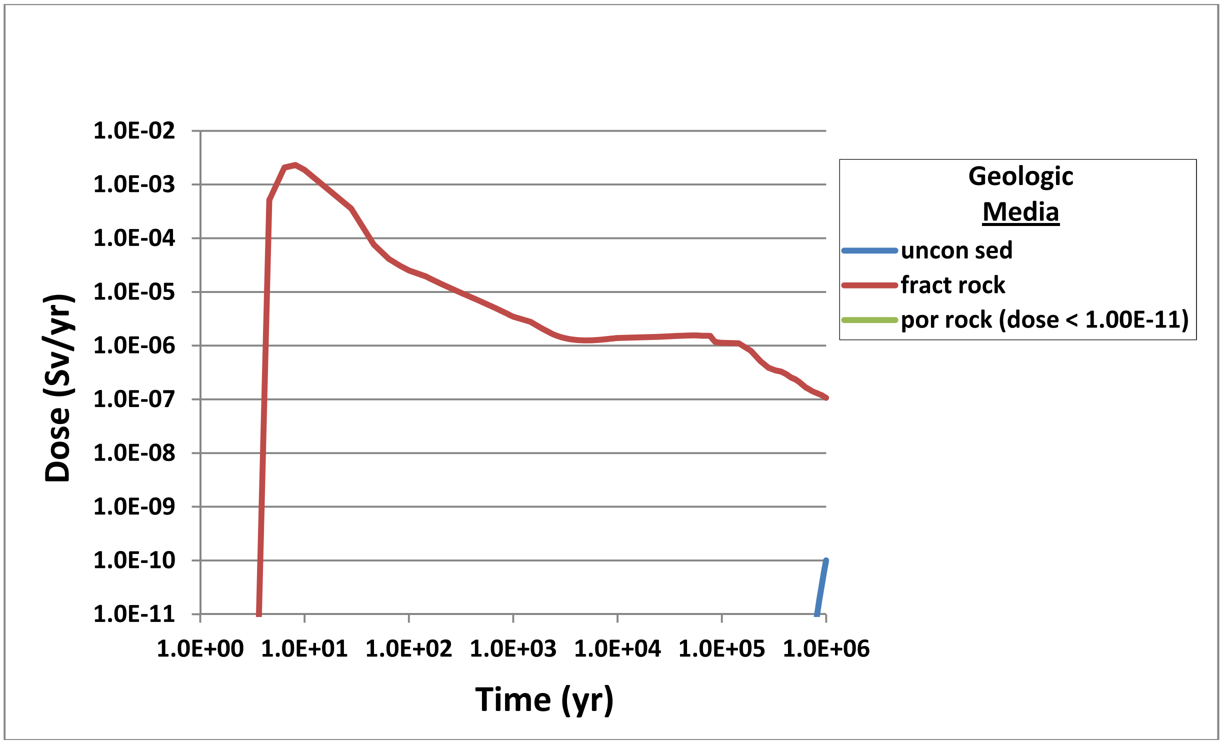


Figure 4-80. I-129 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Reducing

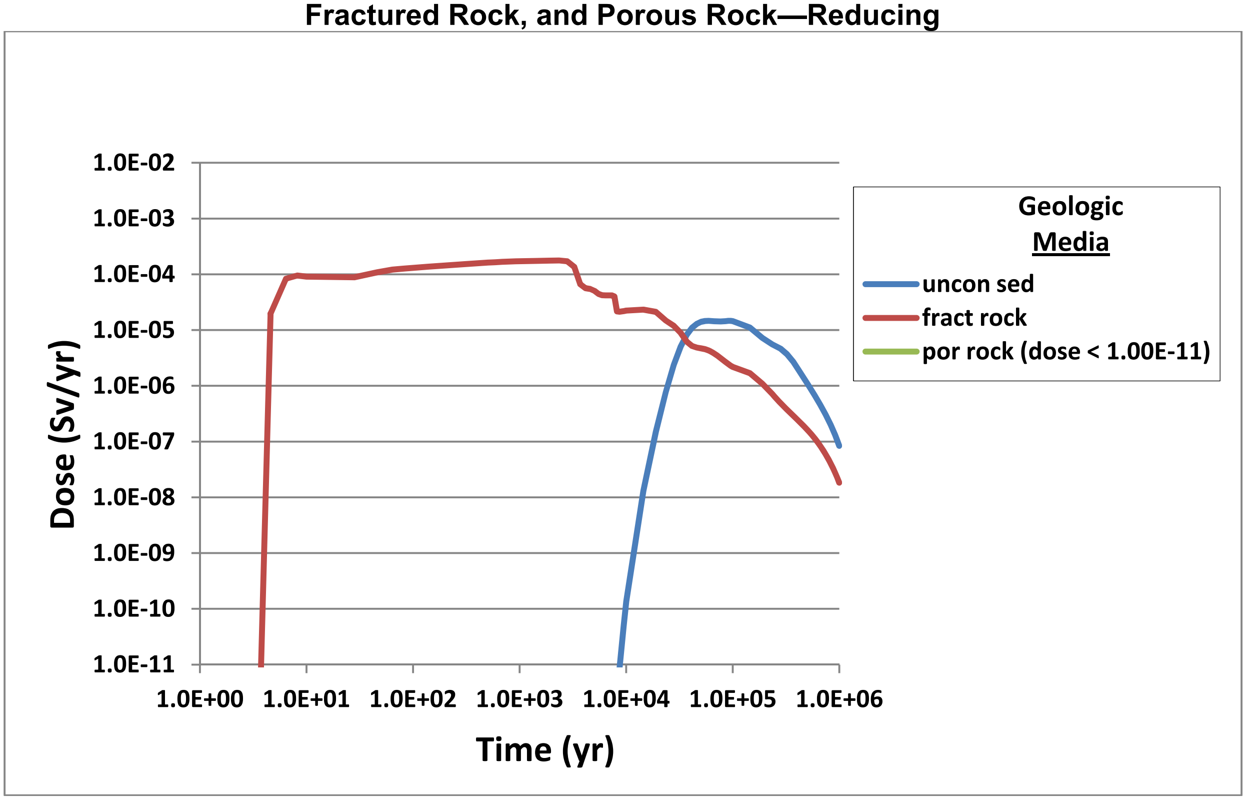


Figure 4-81. Tc-99 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Oxidizing

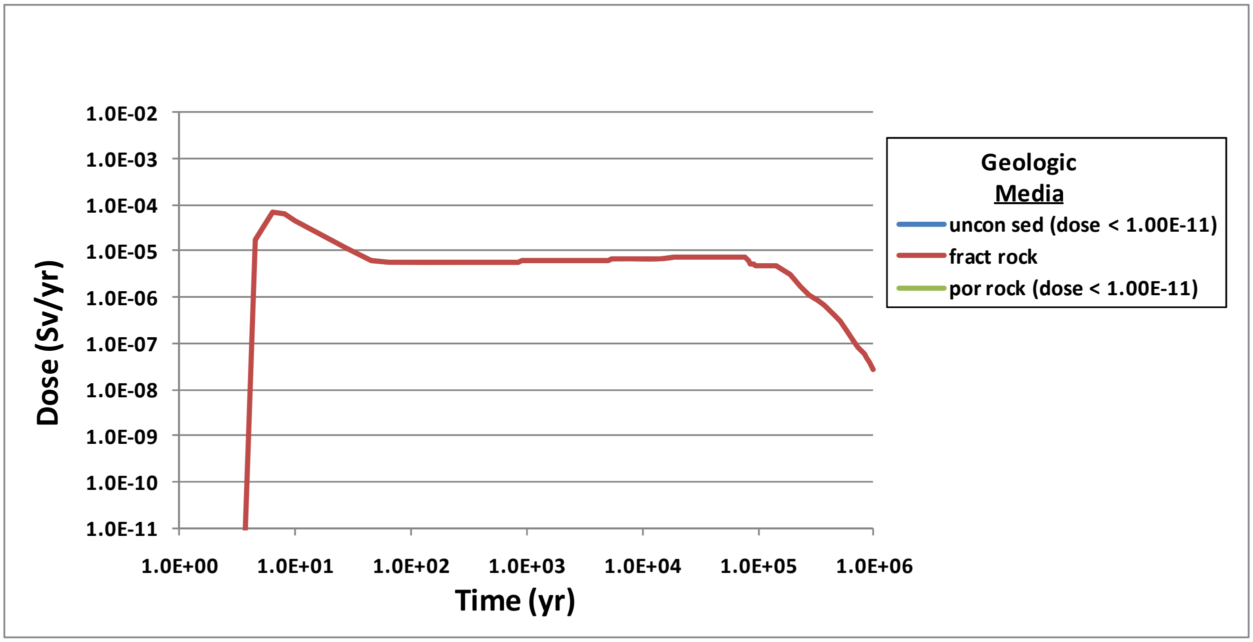


Figure 4-82. Tc-99 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Reducing

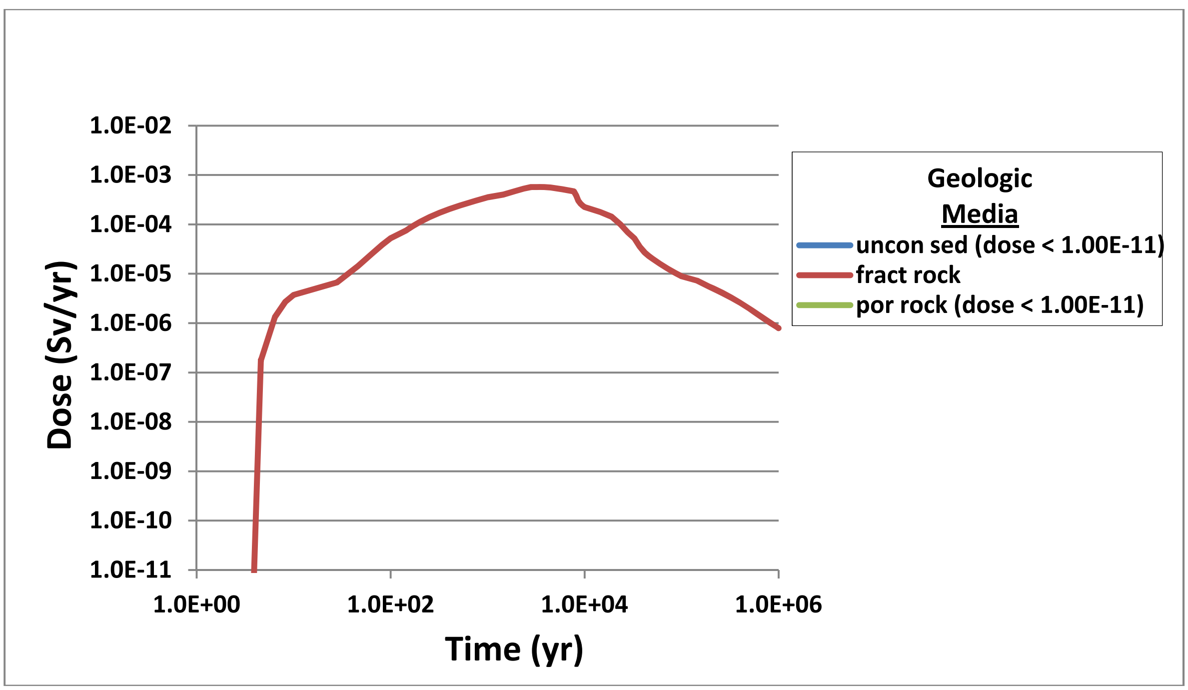


Figure 4-83. Np-237 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Oxidizing

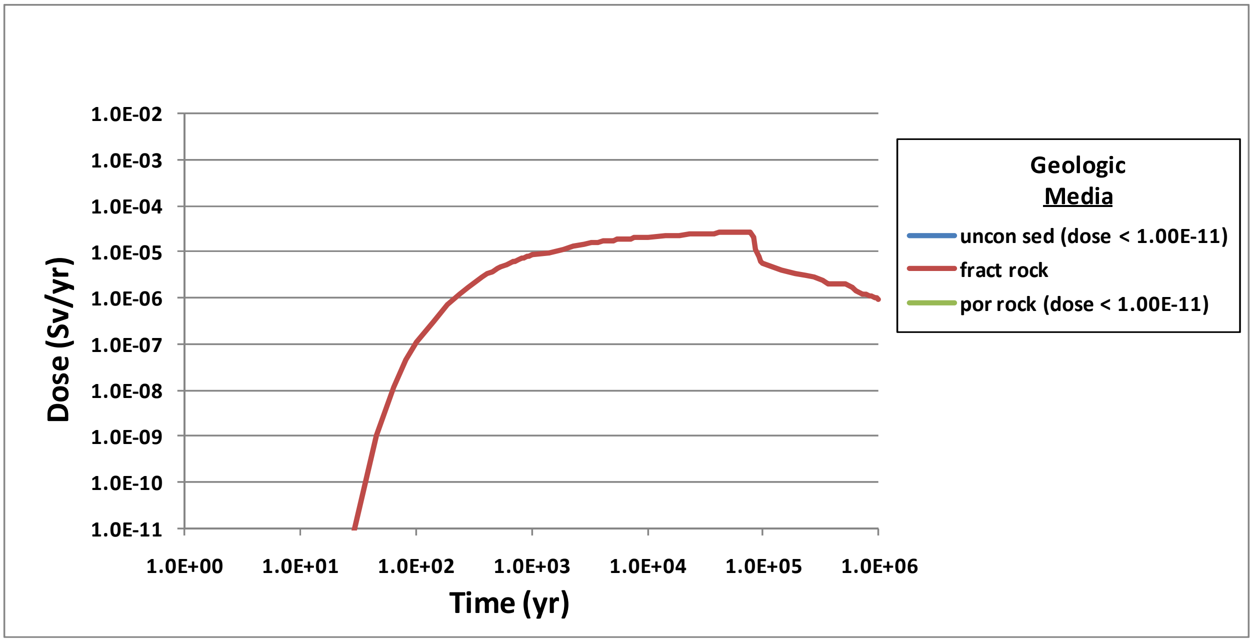


Figure 4-84. Np-237 Dose for Simulation 12: Redox in Unconsolidated Sediments, Fractured Rock, and Porous Rock—Reducing

Simulation 13: Disturbed Zone Characteristics

Objective: Show the effect on dose of radionuclide sorption in the transition region between the buffer and the far field in an oxidizing environment and in a reducing environment.

Test Environment: GoldSim_Player_10.5SP1

SOAR Version: 1.0.02

Input Control Changes:

— Set "Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)" for spent nuclear fuel equal to 100,000 MT.

— Activate and deactivate "Enable radionuclide sorption in the transition region between the buffer and the far field" in separate simulations.

— Set the Redox condition as "Oxidizing" and "Reducing" for far-field Legs 1, 2, and 3 in separate simulations.

Results: Simulations were performed, and results are provided on the following pages. Plots include time histories of total dose and individual dose for I-129, Tc-99, and Np-237. As a general note, "active" curves are hidden below the "inactive" curves and are better visible under higher magnification.

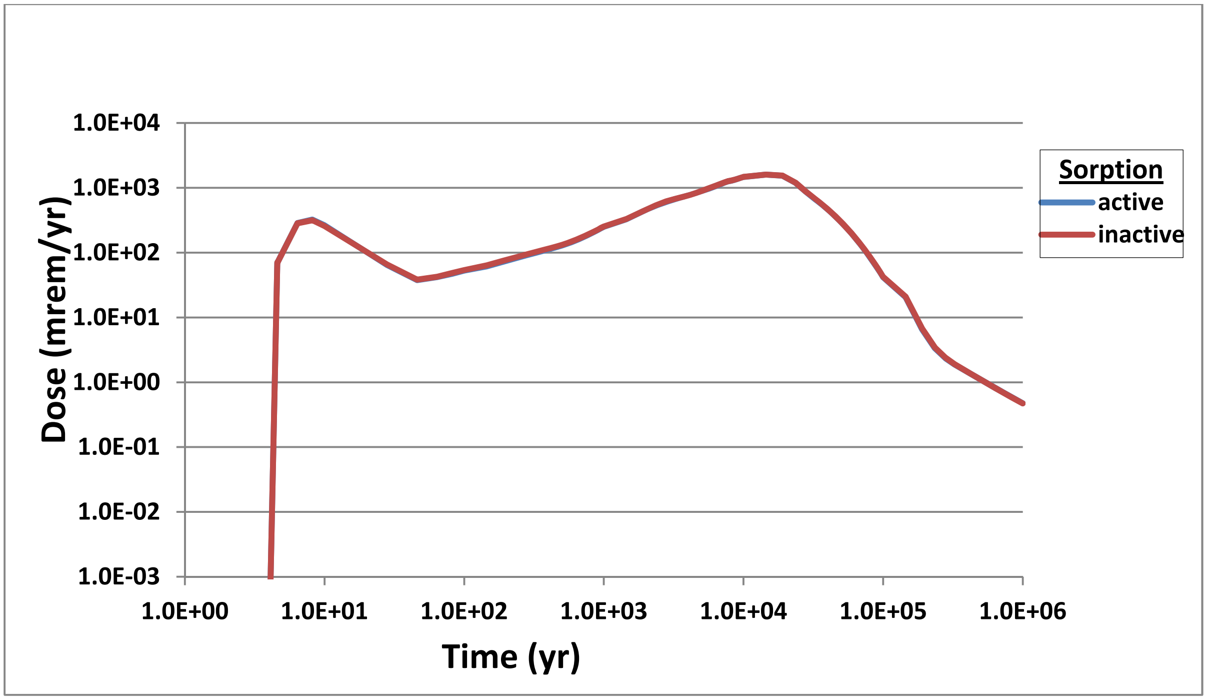


Figure 4-85. Total Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Oxidizing

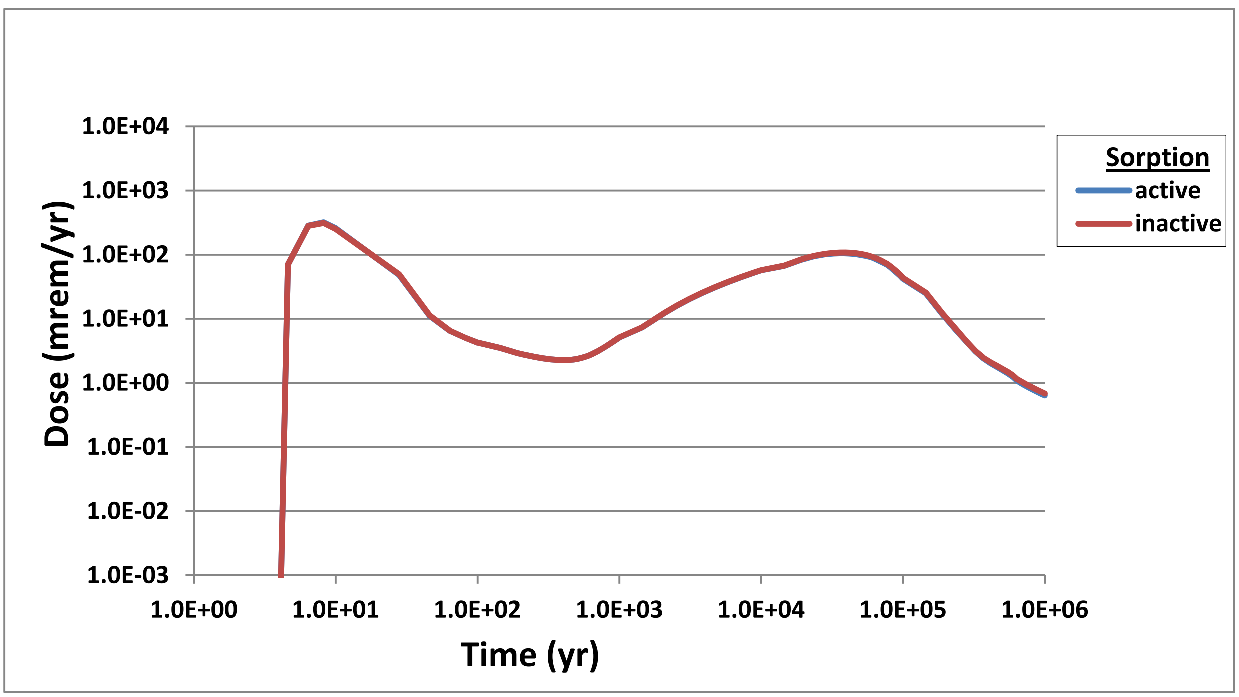


Figure 4-86. Total Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Reducing

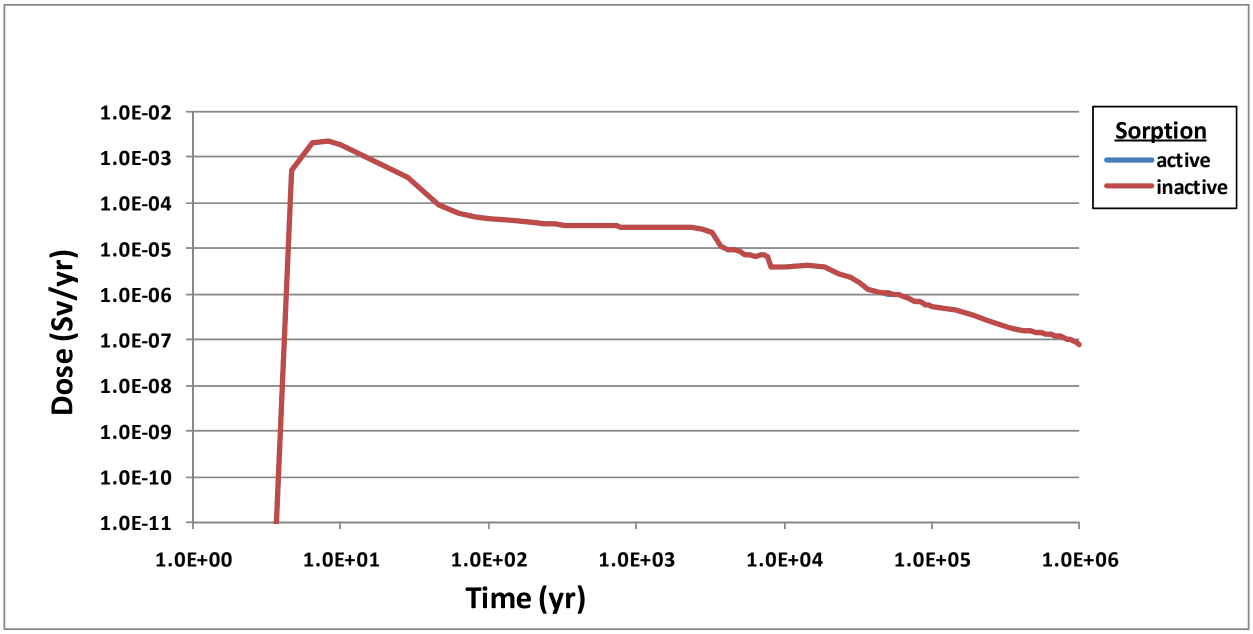


Figure 4-87. I-129 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Oxidizing

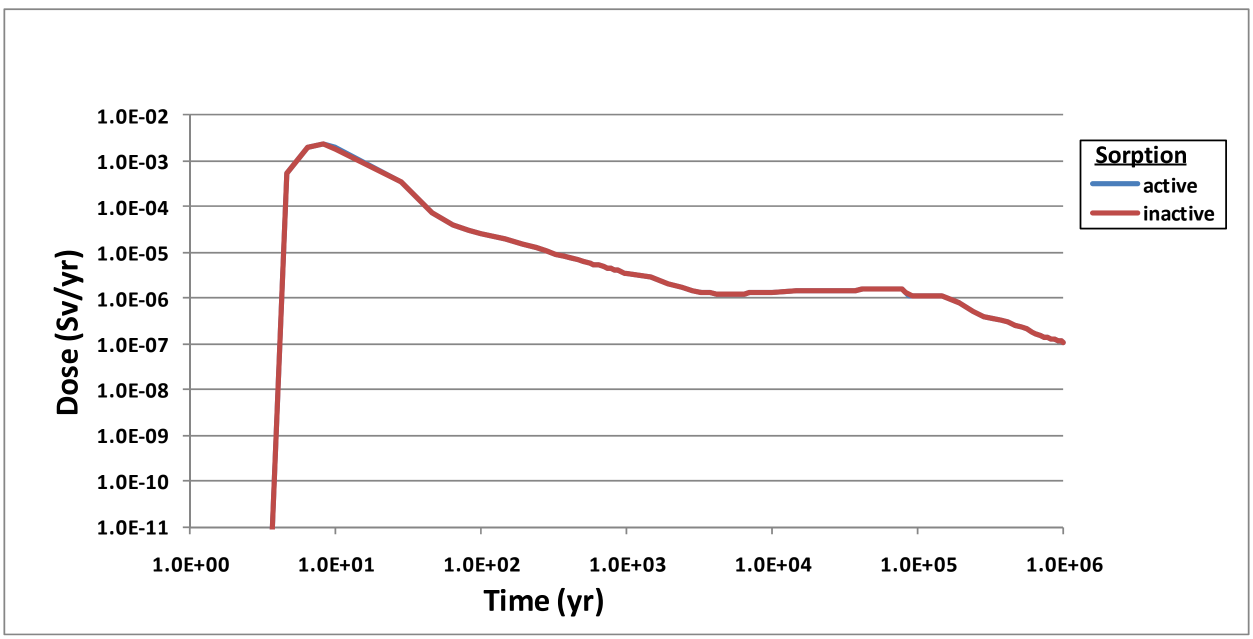


Figure 4-88. I-129 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Reducing

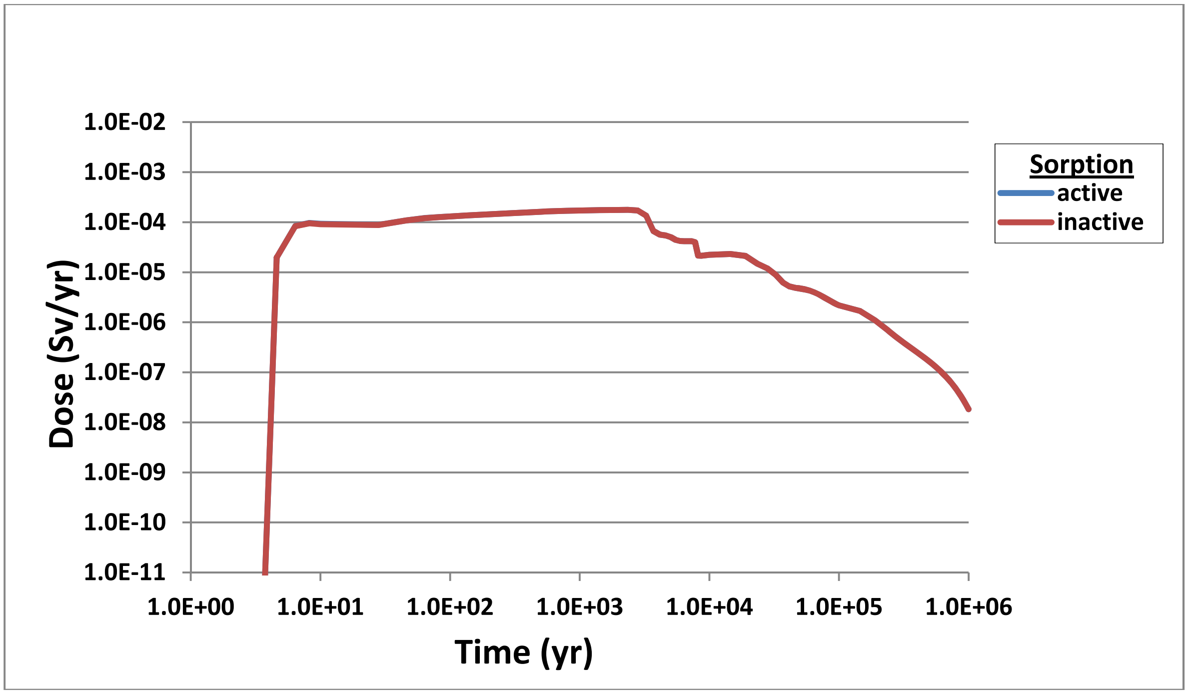


Figure 4-89. Tc-99 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Oxidizing

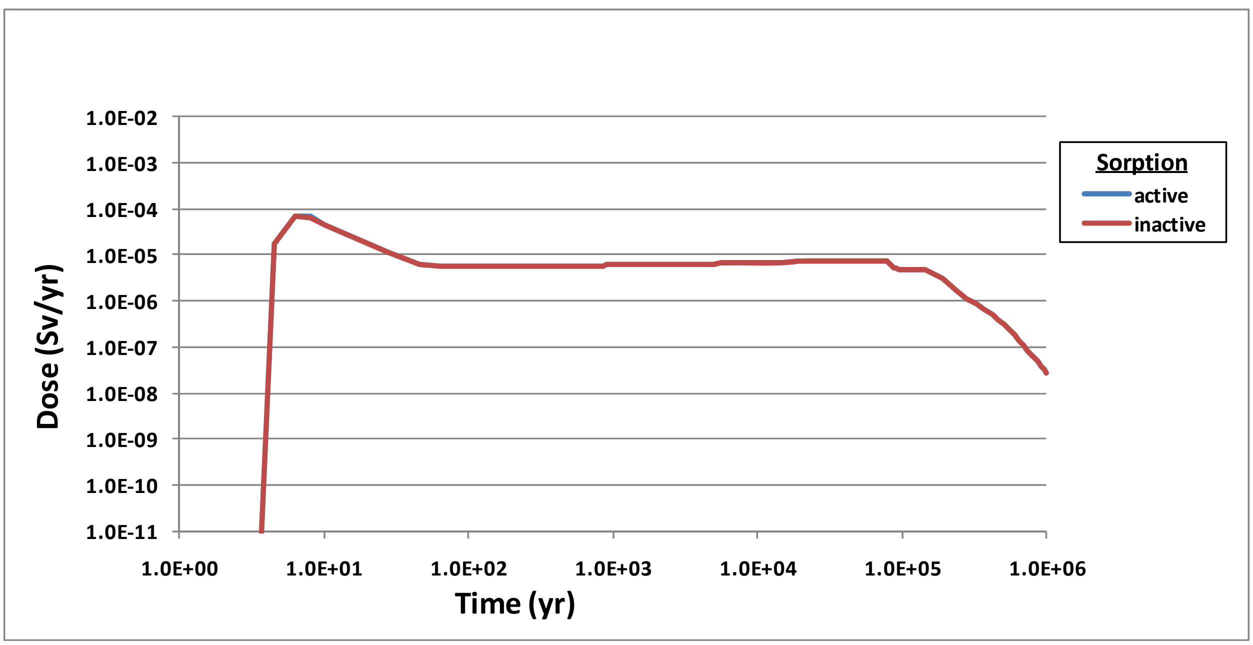


Figure 4-90. Tc-99 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Reducing

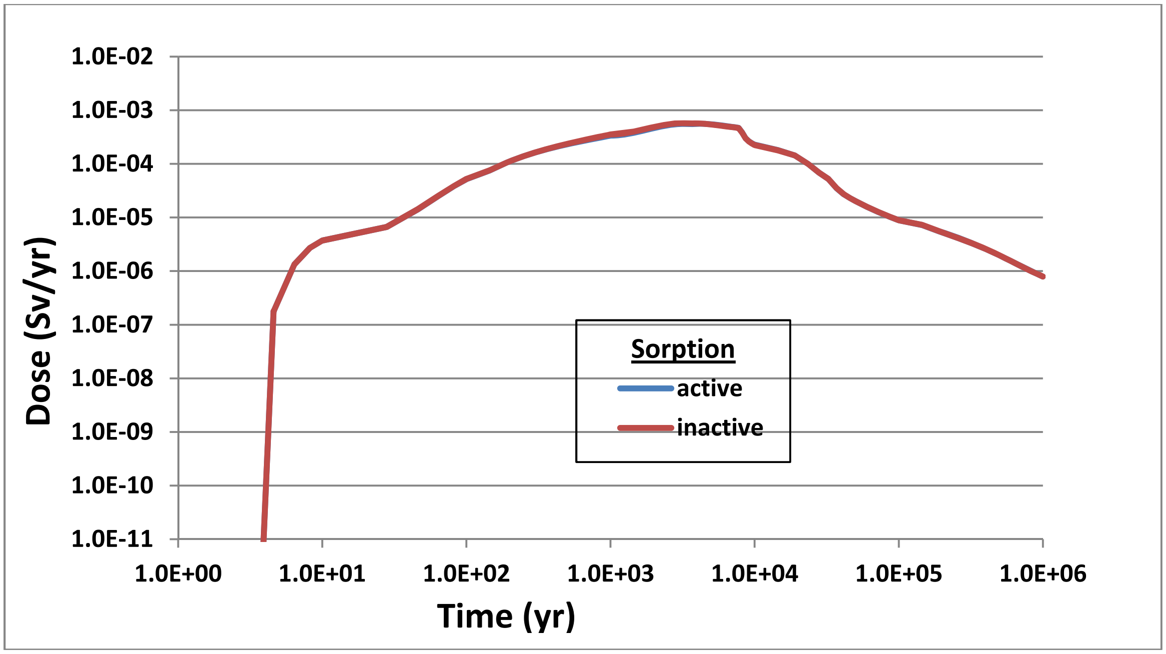


Figure 4-91. Np-237 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Oxidizing

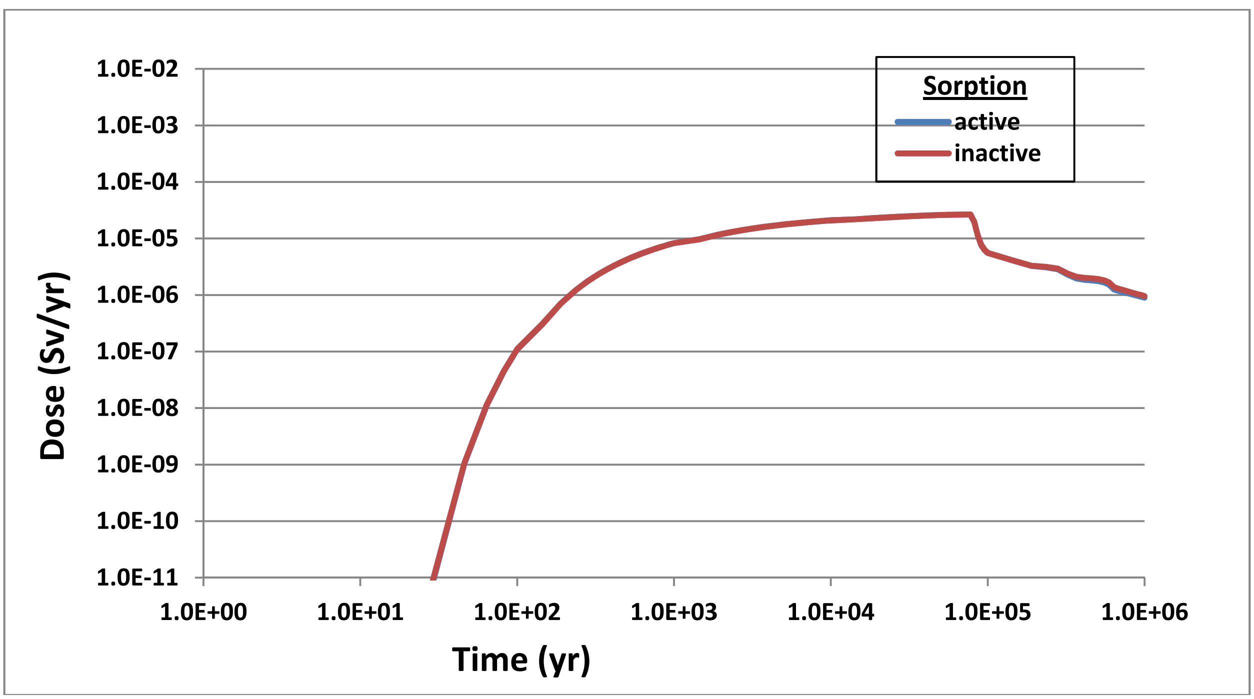


Figure 4-92. Np-237 Dose for Simulation 13: Disturbed Zone Characteristics With and Without Sorption in the Transition Region—Reducing

5 COMPARISON TO LITERATURE RESULTS

This chapter presents the results from benchmarking of the **S**coping of **O**ptions and **A**nalyzing **R**isk (SOAR) model (Markley, et al., 2011) against system-level assessments of two geologic repository programs for which data and results were readily available in the literature: (i) the Japanese repository system as described in Japan Nuclear Cycle Development Institute (JNC, 2000) and (ii) a Swedish repository system as described in Svensk Kärnbränslehantering AB (SKB, 2011). Benchmarking involved adjusting the SOAR model and the associated parameters, as needed, to simulate these systems as described in the cited literature. Only selected cases and selected model outputs were considered, for which input data were readily available, and for which it was considered that SOAR could be minimally modified to emulate particular outputs. The objective of the comparison exercise was not to accurately reproduce results reported in the literature, but to produce comparable trends and magnitudes in release rates and dose estimates. Details on the simulated system and the SOAR model changes are provided in the subsections.

5.1 Simulation of Engineered Barrier System Release Rates of Japanese Geologic Disposal System

Objective

The test objective was to simulate engineered barrier system (EBS) release rates for the Japanese geologic disposal system as defined in JNC (2000) using SOAR and appropriate input parameter and minor model modifications. JNC (2000, Figure 5.3.5-5) reports release rates away from the buffer material per waste package (in units of Bq/yr) as a function of time. Release rates from the buffer material computed with a modified version of SOAR were compared to these JNC data.

System Description

The engineered barrier system described in JNC (2000) includes a glass waste form, enclosed in a cylindrical waste package, surrounded by bentonite buffer material (a cylindrical annulus 0.7 m thick). The rate of glass waste dissolution (in units of mass/units of time) was assumed constant. The time for the glass waste mass (405 kg in a waste package) to fully degrade was computed as 65,225 years after failure of the waste package. The JNC model considered radionuclide dissolution from the vitrified high-level waste (HLW), diffusive transport through buffer material, radionuclide ingrowth and decay, and solubility constraints in the buffer material (JNC, 2000). The terminus of the buffer material was modeled as a boundary with a constant outgoing flow (0.001 m^3/yr per waste package) and no diffusive mass exchange. The JNC report defined release rates from the EBS as the release leaving the buffer material. JNC considered stable isotopes in the EBS transport model. Stable isotopes could reduce the rate of release of radioactive isotopes, due to shared solubility constraints.

SOAR Model Changes

The EBS system modeled in SOAR is similar to the JNC (2000) model. The SOAR model also considers a constant waste form dissolution rate (in units of mass/time) and diffusive transport through the buffer material. To simulate the JNC system, diffusion in the transition region (region between the buffer material and the nearest fracture) was disabled by making the diffusion coefficient zero in that region. The outgoing flow in the last mixing cell for the buffer material was set to 0.001 m^3/yr. The inventory per waste package was adjusted to match inventories specified in JNC (2000, Table 5.3.1-2). Inventories of the radionuclides tracked in SOAR but not in the JNC model were set to 0. The JNC model assumes all waste packages fail simultaneously at 1,000 years after disposal. In the modified SOAR model, it was assumed that all waste packages fail 1 year after the emplacement. This was accomplished by making the following selections in the Disruptive Events dashboard:

- Disable localized corrosion
- Disable general corrosion
- Type of disruptive event: Waste Package Failure Rate
- Start time of waste package failure (year): 1
- End time of waste package failure (year): 10^6
- Minimum waste package breach fraction: 0.99999
- Maximum waste package breach fraction: 1

SOAR results in Figures 5-1 through 5-5 were shifted in time by 999 years to be directly comparable to the JNC results.

In the Waste Form dashboard, the total inventory of radionuclides in the form of HLW glass in the SOAR model was set to 220 MT. The total mass of all other waste forms was set to 0. The Total Disposed Mass per Waste Package (grams) (HLW) was set equal to 5,500 grams. Note that this is the mass of the tracked radionuclides in SOAR and does not include any glass substrate mass. These selections give a total number of waste packages of 40,000 (consistent with JNC, 2000). The Reference Case (JNC, 2000) assumes approximately 65,000 years for the vitrified waste to completely degrade. In the SOAR model, it was assumed that the vitrified waste completely degrades after 65,225 years, and this was used as an input in the model reflecting a fractional release for the glass waste form equal to 1.53×10^{-5} yr^{-1} in the GoldSim element named DegRate_HLW_Glass.

Backfill elemental solubilities, elemental distribution coefficients, effective diffusion coefficients, and groundwater flow rate through the excavated disturbed zone were defined in JNC (2000, Table 5.3.5-1). The following changes were made to the Near Field dashboard:

- Disable degradation of the backfill (diffusive barrier)
- Transport length (m): 0.7 m
- Transport cross section (m^2): 10.22 m^2

The transport length of 0.7 m and the transport cross section of 10.22 m^2 are consistent with the dimensions in JNC (2000, Figure 5.3.1-1), in the sense that the buffer volume in the JNC and SOAR descriptions is the same. To facilitate the location of parameter changes to the model file, new GoldSim elements with the prefix H12_ were inserted into the model file (e.g., H12_Flow, H12_GlassSurface, H12_BF_CrossSection, H12_BF_Length, H12_BF_Volume, H12_Buffer_Kd, H12_Solubility, H12_Diff_BFtoFrac, H12_DissRate). Because results from the reference case in JNC (2000) are deterministic, the Simulation Settings dashboard in the SOAR model was set to one simulation using element mean values. For consistency with the H12 JNC model, the duration of the SOAR simulation was set to 10 million years. An additional GoldSim element was inserted to compute release rates per waste package (total release rate divided by the number of waste packages) in units of Bq/yr.

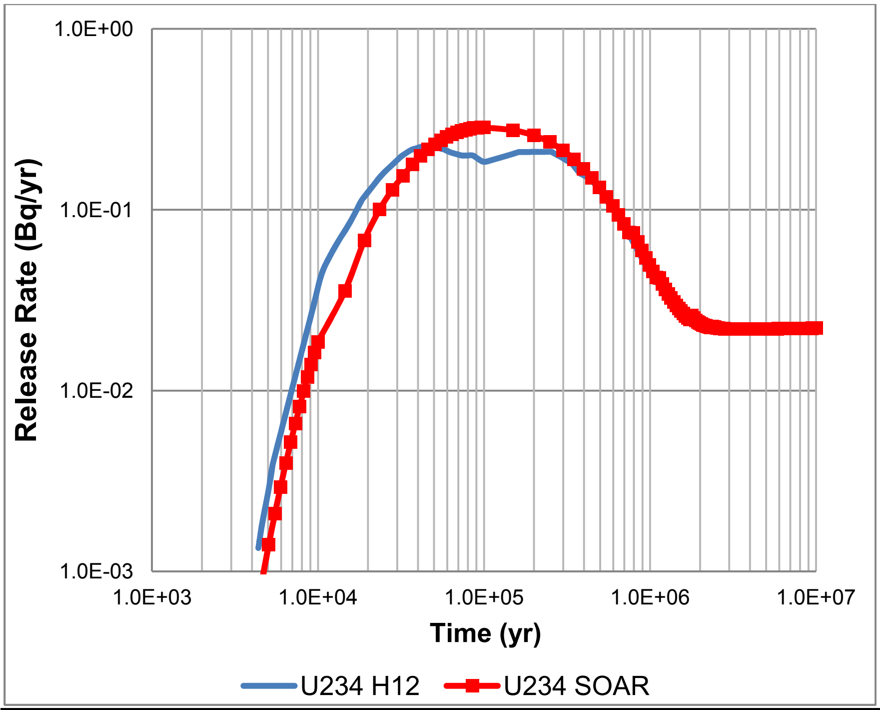


Figure 5-1. Comparison Between JNC and SOAR Models for U-234 Release Rates

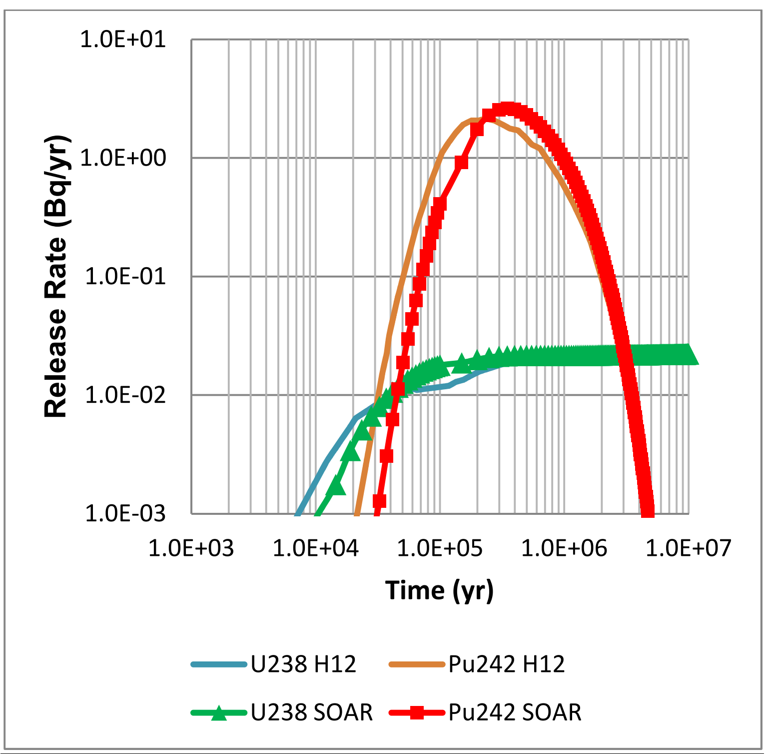


Figure 5-2. Comparison Between JNC and SOAR Models for U-238 and Pu-242 Release Rates

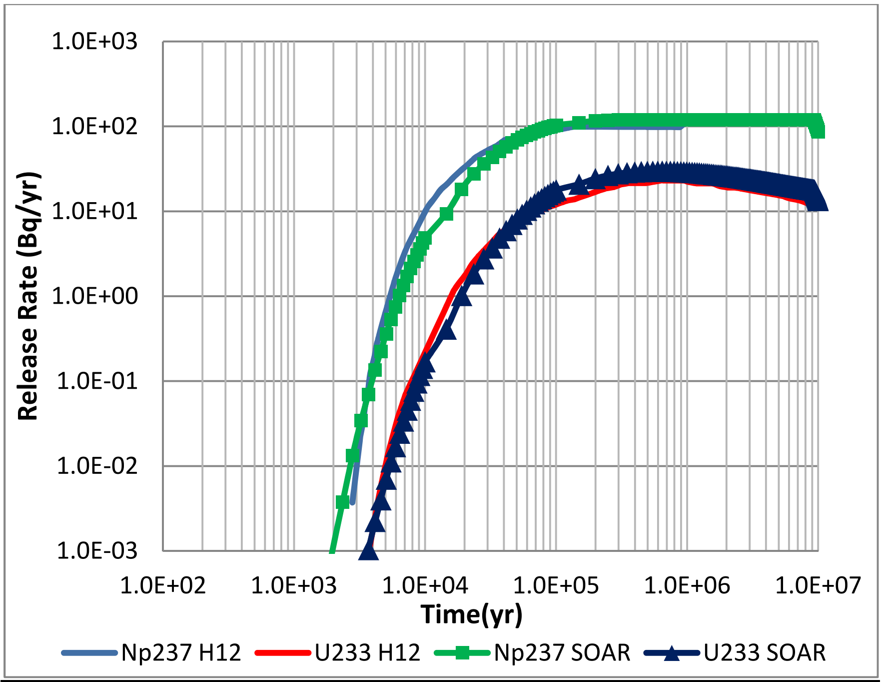


Figure 5-3. Comparison Between JNC and SOAR Models for Np-237 and U-233 Release Rates

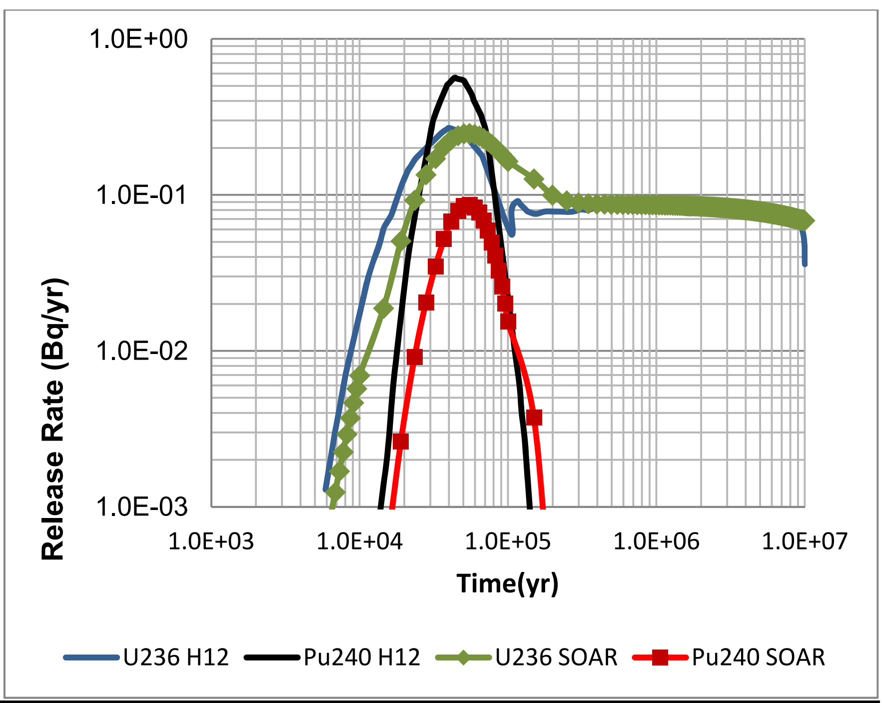


Figure 5-4. Comparison Between JNC and SOAR Models for U-236 and Pu-240 Release Rates

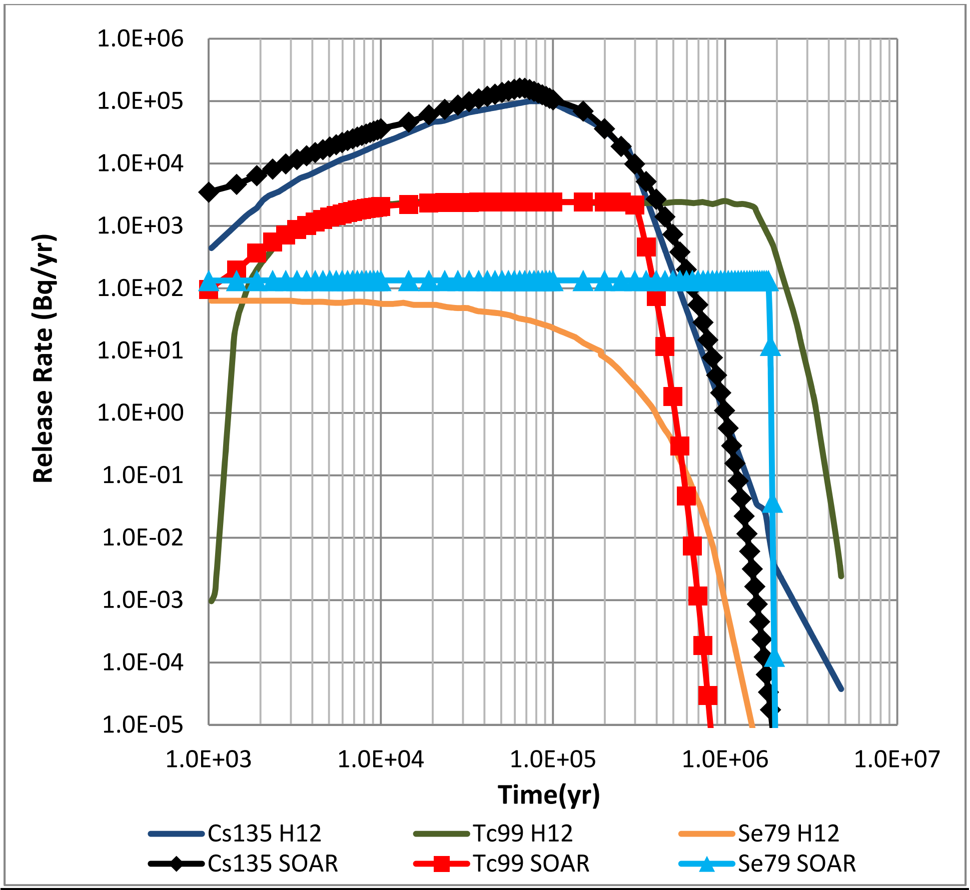


Figure 5-5. Comparison Between JNC and SOAR Models for Cs-135, Tc-99 and Se-79 Release Rates

Results

The release rates for the following radionuclides were compared: Se-79, Tc-99, Cs-135, U-233, U-234, U-235, U-236, U-238, Np-237, Pu-240, and Pu-242. The release rates, in Bq/yr units, for these radionuclides are illustrated in Figures 5-1 through 5-5. Release rates of the SOAR model satisfactorily agree with data from JNC (2000, Figure 5.3.5-5) for most of radionuclides considered in the comparison. The highest release rate is that of Cs-135, which is a relatively long-lived and highly soluble radionuclide. The SOAR and JNC models assumed infinite solubility for Cs-135, and Figure 5-5 shows similar trends and release magnitudes. The largest discrepancy in the results is in the Se-79 releases (Figure 5-5), because (i) the half-lives used for this radionuclide were different [2.9×10^5 years in SOAR (De Canniere, et al., 2010) versus 6.5×10^4 years in the JNC model] and (ii) the JNC model considered the presence of a stable isotope of selenium in the waste form, which limits the Se-79 release. Such a stable isotope is not considered in the species tracked by SOAR. Actinide (uranium, neptunium, and plutonium) release rates compare well in the two models, Figures 5-1 through 5-4. In the case of uranium and plutonium releases, there is agreement between the models even if the number of isotopes modeled is different, which is somewhat surprising. For example, SOAR considers six isotopes of uranium while the JNC model considers five and SOAR considers four isotopes of plutonium while JCN considers five. Isotopes of an element share a single solubility; thus, releases of an element's isotopes are correlated. Because the SOAR and JNC models track a different number of radionuclides, one would expect the results to be different. However, but the differences are minor, except for the Pu-240 release (Figure 5-4). The differences are also explained by the finite difference discretization of the diffusive buffer material pathway, the cylindrical geometry in the JNC model for the buffer material transport versus the one-dimensional description in the SOAR model, and timestepping.

5.2 Simulation of Dose Associated With Engineered Barrier System Release Rates of Swedish Geologic Disposal System

Objective

The objective of the second benchmarking exercise was to simulate EBS release rates and doses for the Swedish geologic disposal system, as defined in SKB (2010a,b, 2011). These documents present calculations for a spent nuclear fuel repository at Forsmark, Sweden. The exercise was to simulate releases and determine dose using SOAR and appropriate input parameters for deterministic and probabilistic calculations with minor model modifications. SKB (2010a, Figures 5-1 and 5-2) reports dose (in units of μSV/yr) as a function of time. Dose computed by SOAR was compared to SKB results for selected radionuclides, including Se-79, Tc-99, I-129, Np-237, Pu-239, and Pu-242.

System Description

The SKB engineered barrier system and the geologic disposal system modeled in SOAR have common components, including waste form inventories and releases, transport in a buffer surrounding the canister, and transport in the near field, far field, and biosphere. The scenario selected for comparison is described in SKB (2010a, Sections 5.2.1 and 5.2.2). This scenario considers failure of 1 canister at 100,000 years from shear load. In this scenario, there is no retention in the geosphere, and hence the release calculated for the near field (i.e., release rates away from the buffer material) is the same as that for the far field (at the geosphere–biosphere interface). To model this scenario with SOAR, only input data were changed in SOAR (as described in the next section) and no changes to the computation model were needed.

SOAR Data Changes

To represent SKB's model for the benchmarking study, data corresponding to the scenario described in SKB (2010a, Sections 5.2.1 and 5.2.2) were used to modify the default dataset in the SOAR dashboard and the associated database. SOAR models were not modified for this analysis. Table 5-1 lists the changes to waste form, waste package, far-field parameters, databases, and simulation settings.

Results

Two simulation cases considered for comparison include (i) a deterministic case with median values for parameters with distributions and (ii) a probabilistic case with 100 realizations. In both cases, the modeled scenario was 1 canister failure at 100,000 years with no retention in the near field or far field. As mentioned previously, the radionuclides evaluated in this benchmark exercise were Se-79, Tc-99, I-129, Np-237, Pu-239, and Pu-242, which were the common radionuclides in SKB (2010a) and in SOAR.

Dose results in units of μSV/yr are presented in Figure 5-6 for the deterministic case and in Figure 5-7 for the probabilistic case. Each graph compares dose results from SKB (2010a) and

Table 5-1. SOAR Dashboard Data and Database Changes for Modeling the Swedish Disposal System Scenario		
SOAR Parameter Name and Units	**Parameter Value**	**Source**
SOAR Dashboard Data: Waste Form		
2010 SNF Radionuclide Inventory (metric tons)	1.08×10^4	SKB (2010b, Table 3-3); all other inventories zeroed out
Total Disposed SNF Mass per Waste Package (grams)	1.77×10^6	SKB (2010b, Table 3-3); all other inventories zeroed out
Degradation Rate Multiplier	6.00×10^{-2}	Multiplier used in SOAR to give mean value of the probability distribution in SKB (2011, p. 661): dissolution rate; triangular distribution; 1×10^{-8} (minimum), 1×10^{-7} (mode), 1×10^{-6} (maximum)
Length of Aging Prior to Disposal (years)	37	SKB (2010c, Table 6-3)
SOAR Dashboard Data: Waste Package		
Waste Package Material	Copper	SKB (2011)
SOAR Dashboard Data: Simulation Settings		
Number of Realizations	100	Set for probabilistic case; deterministic case uses 50th quantile
Timesteps	5 timesteps per each of the time ranges (e.g., 0–1 yr, 1–10 yr, 10–100 yr) and 200 timesteps for the period between 1e+5 and 1e+6 yr	Set so timesteps smaller (i.e., 450 years) following waste package failure at 100,000 years
SOAR Dashboard Data: Disruptive Events		
Type of Disruptive Event	Waste Package Failure Rate	Only disruptive failure is considered
Start Time of Waste Package Failure (year)	99,999	Sets failure time at 100,000 years
End Time of Waste Package Failure (year)	100,000	Sets failure time at 100,000 years
Minimum Waste Package Failure Rate (Waste Packages per Year)	1	Sets 1 waste failure
Maximum Waste Package Failure Rate (Waste Packages per Year)	1	Sets 1 waste failure
Minimum Waste Package Breach Fraction	1	Set so all waste package inventory is available for release
Disable Localized Corrosion	Checked	Only disruptive failure is considered
Disable General Corrosion	Checked	Only disruptive failure is considered

Table 5-1. SOAR Dashboard Data and Database Changes for Modeling the Swedish Disposal System Scenario (continued)		
SOAR Dashboard Data: Near Field		
Multiplier To Define Cross Section of Transition Region (RegionField)	1.3	SKB (2010a, Table G-6)
Transport Length (m)	0.25	SKB (2010a, Section G.5)
Transport Cross Section (m^2)	2.186	SKB (2010a, Table G-6)
SOAR Dashboard Data: Far Field		
Transport Length (km)	0.001	SKB (2010a, Section 5.2.1), there is no retention in the geosphere, Legs 1, 2, and 3
Effective Porosity Reduction Factor	0.01	SKB (2010a, Section 5.2.1), there is no retention in the geosphere, Legs 1, 2, and 3
Hydraulic Gradient (Sediments and Porous Rock Only)	1	SKB (2010a, Section 5.2.1), there is no retention in the geosphere, Legs 1, 2, and 3
SOAR Database		
UnboundFraction_SNF_Cs135	0	Set Unbound Fraction to zero
UnboundFraction_SNF_I129	0	Set Unbound Fraction to zero
UnboundFraction_SNF_Se79	0	Set Unbound Fraction to zero
UnboundFraction_SNF_TC99	0	Set Unbound Fraction to zero
UnboundFraction_SNF_C14	0	Set Unbound Fraction to zero
SNF_Inventory_2010_default	C-14: 3.09×10^{3}, Cs-135: 5.54×10^{6}, I-129: 2.13×10^{6}, Np-237: 6.82×10^{6}, Pu-238: 2.11×10^{6}, Pu-239: 6.13×10^{7}, Pu-240: 3.02×10^{7}, Pu-242: 7.69×10^{6}, Se-79: 6.57×10^{4}, Tc-99: 1.08×10^{7}, U-232: 5.76×10^{-2}, U-233: 1.36×10^{2}, U-234: 2.6×10^{6}, U-235: 8.26×10^{7}, U-236: 5.63×10^{7}, U-238: 1.05×10^{10}	SKB (2010b, Table 3-3), Radionuclide Inventories
WaterFlowToBiosphere (ac-ft/yr)	8.10×10^{-4}	SKB (2010a, Figure G-7)
Water_Consumption_Rate (L/yr)	1.00×10^{3}	Setting the same as WaterFlowToBiosphere parameter value
Ingestion_Dose_Coefficient	C-14: 5.44×10^{-12}, Cs-135: 3.96×10^{-14}, I-129: 6.46×10^{-10}, Np-237: 4.83×10^{-11}, Pu-238: 1.78×10^{-12} (Scaled using Pu-239), Pu-239: 1.94×10^{-12}, Pu-240: 1.88×10^{-12}, Pu-242: 1.89×10^{-12}, Se-79: 1.21×10^{-9}, Tc-99: 8.98×10^{-13}, U-232: 1.62×10^{-11} (Scaled using U-233), U-233: 2.5×10^{-12}, U-234: 3.62×10^{-12}, U-235: 2.76×10^{-12}, U-236: 1.85×10^{-12}, U-238: 1.85×10^{-12})	SKB (2010b, Table 7-13) and SKB (2010a, Table 3-7, Basic LDF)

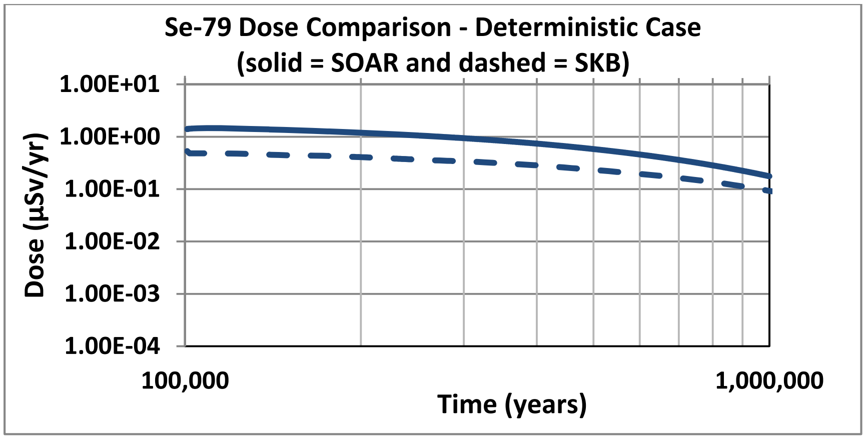
SOAR simulations for one radionuclide of interest at a time. Both figures use the same scale to get a perspective on the relative contribution from radionuclide toward overall (i.e., total) dose.

For the deterministic case in Figure 5-6, Se-79 and I-129 dose estimates from SOAR are greater than SKB's estimates by less than an order of magnitude. The Np-237 dose estimate from SOAR was less than SKB's dose estimate by less than an order of magnitude. Pu-242, Tc-99, and Pu-242 dose estimates from SOAR are slightly greater than the corresponding estimates from SKB (2010a) until about 300,000 years; after 300,000 years, the SOAR and SKB (2010a) doses are essentially identical.

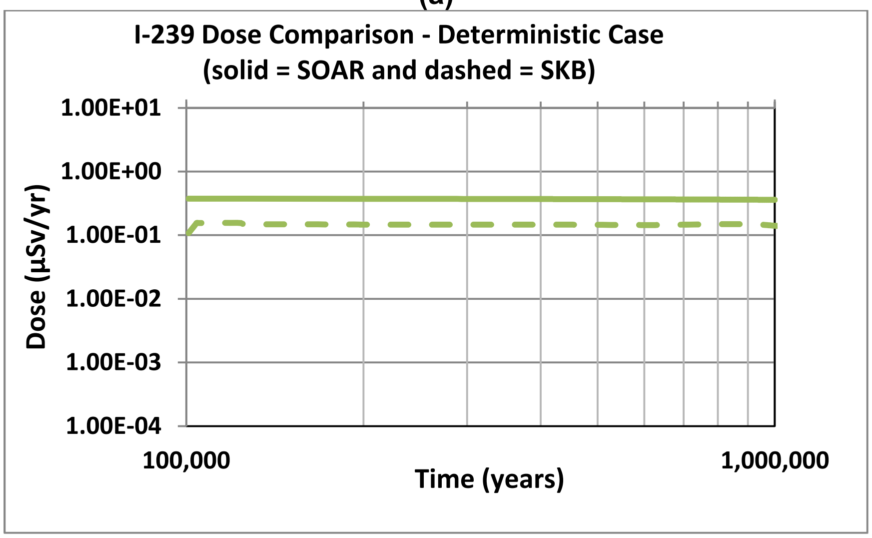
In the probabilistic case, the Se-79 and I-129 dose estimates from SOAR are greater than SKB's dose estimates by less than an order of magnitude (see Figure 5-7a and b). The Np-237, Pu-242, and Tc-99 doses (see Figure 5-7c, d, and e) estimated by SOAR are less than SKB's corresponding estimates by less than an order of magnitude. For Pu-239, the maximum dose calculated by SOAR (Figure 5-7f) is approximately 10^{-4} µSV/yr compared to SKB's corresponding dose estimate of 10^{-3} µSV/yr, which corresponds to the lower limit of values shown in SKB (2010a, Figure 5-1). Note that 10^{-3} µSV/yr represents the lower limit (cutoff value) below which SKB (2010a) does not present any dose values in Figure 5-1.

For the probabilistic case, the dose estimates from SOAR for the three radionuclides (Np-237, Pu-242, and Tc-99) are essentially identical to SKB's estimates, whereas all other dose results in the deterministic and probabilistic cases exhibit a difference between SKB and SOAR doses of at most one order of magnitude.

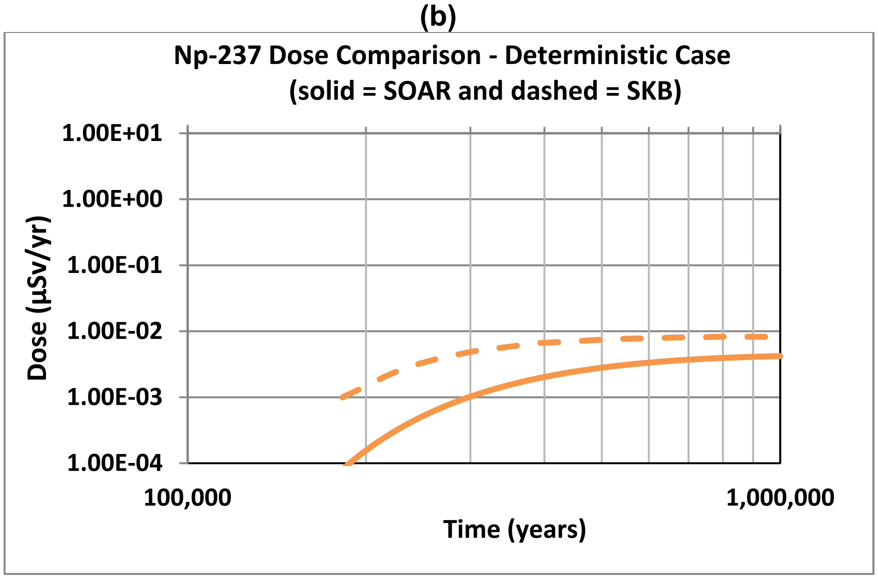
The differences in SOAR and SKB doses appear to be related to input data sets. The details of data used in the SKB analysis were not readily available. Other than the figures, only general descriptions of the scenarios modeled were available in this report. To the extent possible, all data were made consistent in SOAR with the SKB data by modifying dashboard data or the SOAR database; however, it was not possible to verify consistency for all data sets. The differences between the SOAR and SKB results are most likely attributable to the following data: dose conversion factors, radionuclide inventory, and gap fraction inventory. However, a more in-depth study would be needed to confirm this. Each of these is qualitatively described in SKB reports, although specific values used in each scenario are not described. For example, the SKB reports present inventories for a number of different canisters and also describe an inventory of an average canister, but the inventory of the canister used in this benchmark exercise SKB (2010a, Sections 5.2.1 and 5.2.2) is not specified.



(a)

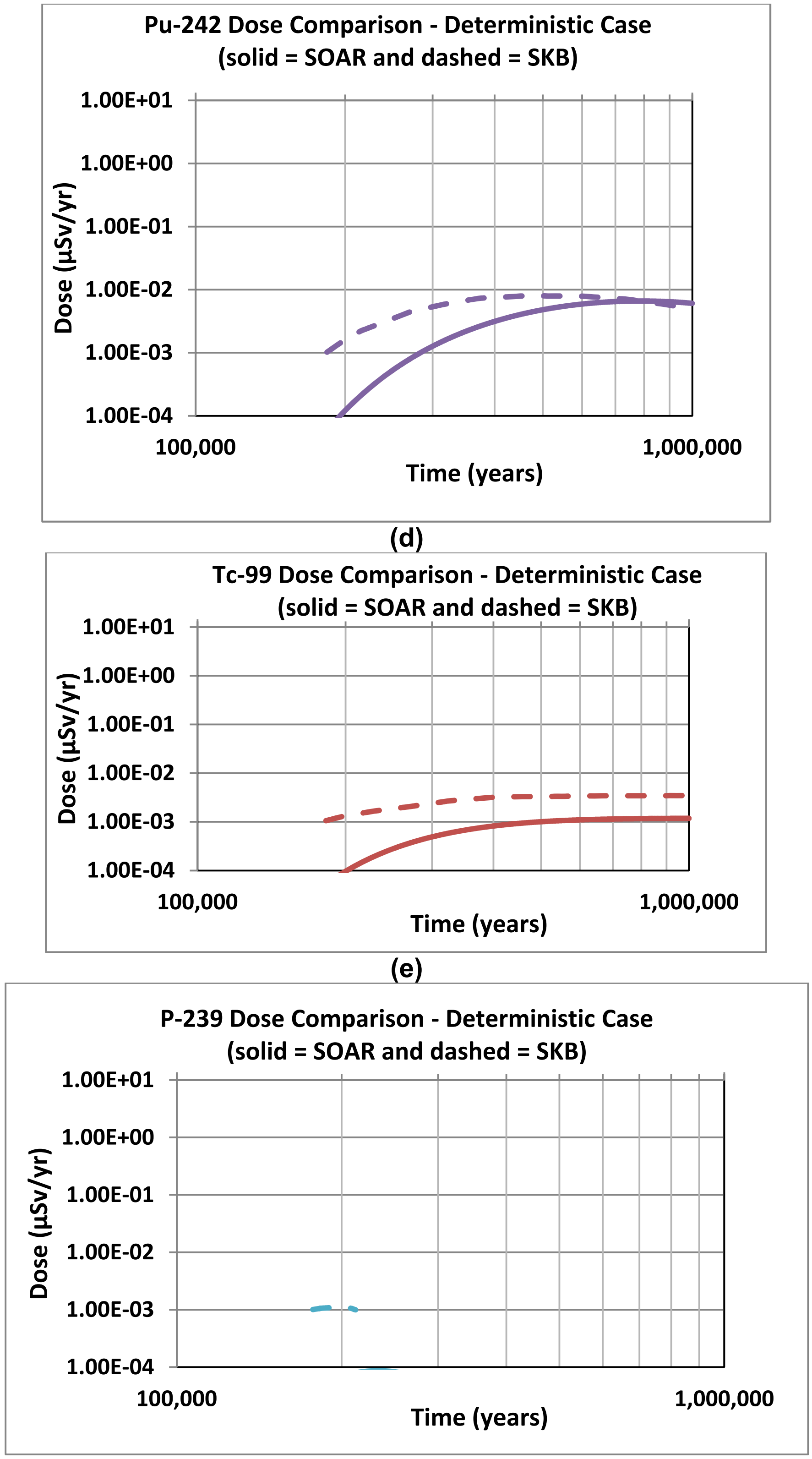


(b)



(c)

Figure 5-6. Comparison Between SKB (2010a) and SOAR Model Results for Radionuclide-Specific Doses (Deterministic Case)

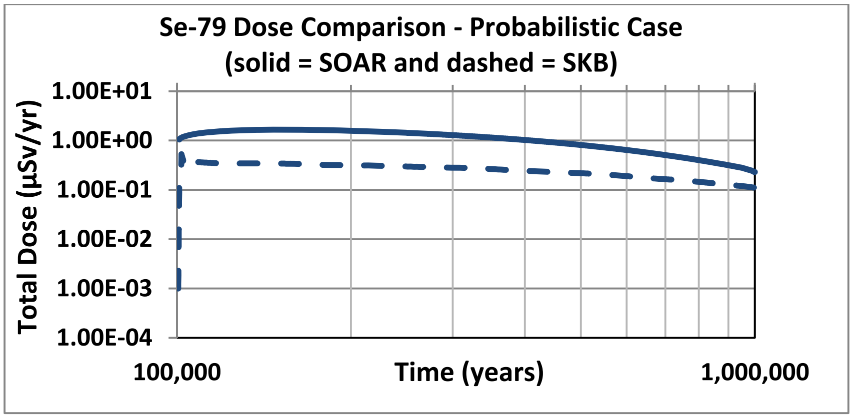


(d)

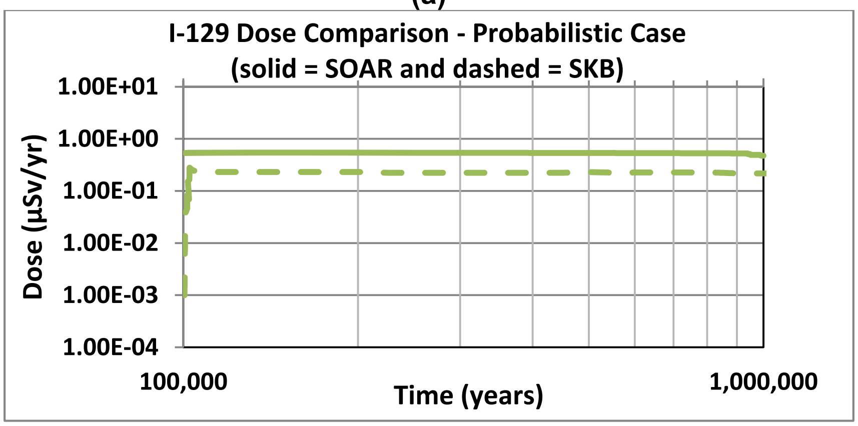
(e)

(f)

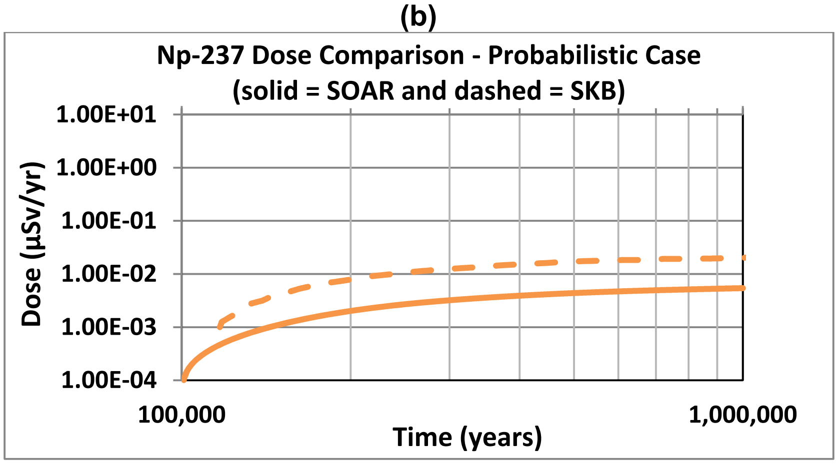
Figure 5-6. Comparison Between SKB (2010a) and SOAR Model Results for Radionuclide-Specific Doses (Deterministic Case) (continued)



(a)

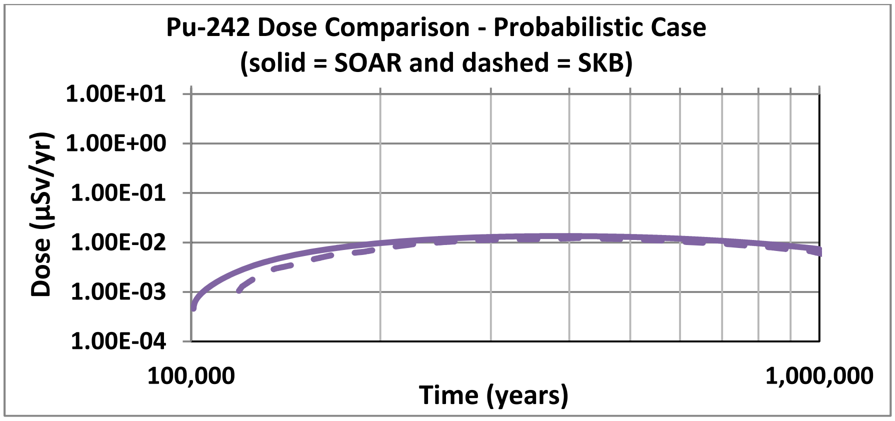


(b)

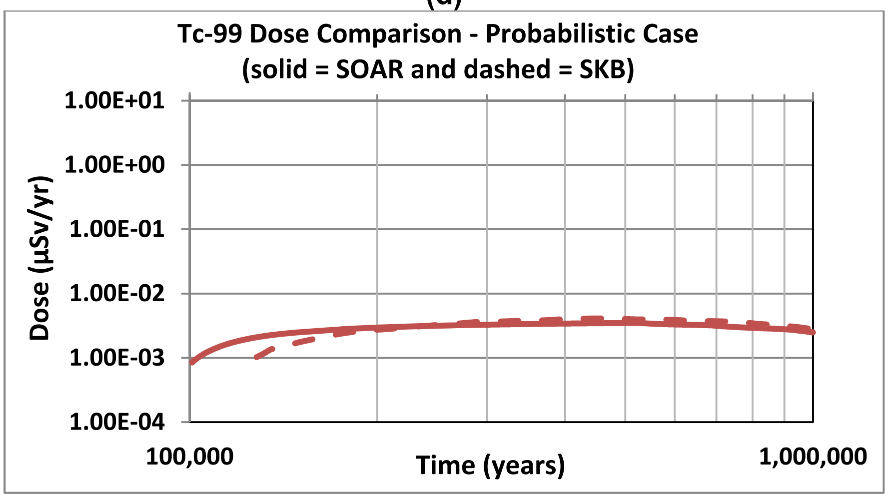


(c)

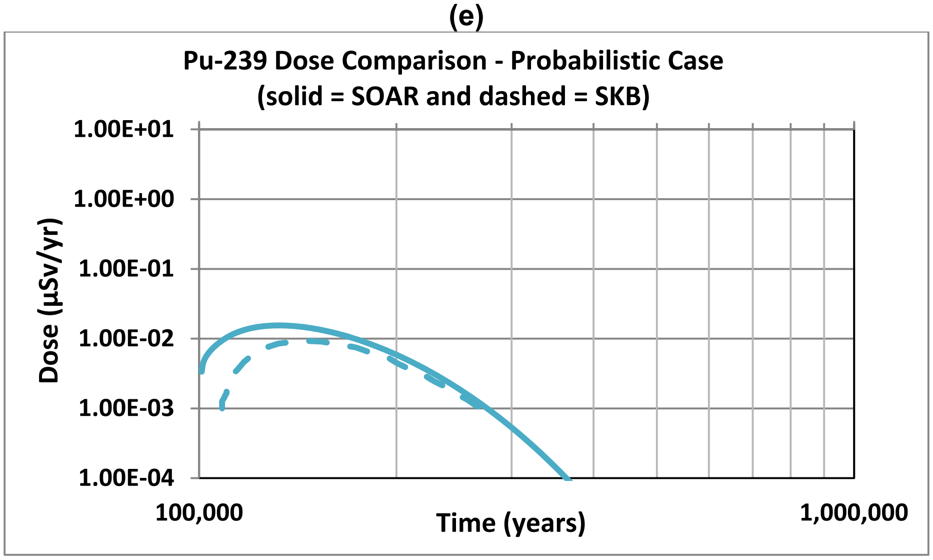
Figure 5-7. Comparison Between SKB (2010a) and SOAR Model Results for Radionuclide-Specific Doses (Probabilistic Case)



(d)



(e)



(f)

Figure 5-7. Comparison Between SKB (2010a) and SOAR Model Results for Radionuclide-Specific Doses (Probabilistic Case) (continued)

6 REFERENCES

De Canniere, P., A. Maes, S. Williams, C. Bruggeman, T. Beauwens, N. Maes, and M. Cowper. "Behaviour of Selenium in Boom Clay." SCK CEN ref: CO 90 01 1467.01 RP.W&D.037-NIROND ref: CCHO2004/00/00 DS251-A44/2.1. External Report of the Belgian Nuclear Research Centre, SCK CEN-ER-120. Mol, Belgium: SCK•CEN. May 2010.

JNC. (Japan Nuclear Cycle Development Institute). "H12: Project To Establish the Scientific and Technical Basis for HLW Disposal in Japan. Supporting Report 3: Safety Assessment of the Geological Disposal System." Ibaraki, Japan: Japan Nuclear Cycle Development Institute. April 2000.

Markley, C., O. Pensado, J.-P. Gwo, J. Winterle, T. Ahn, R. Benke, T. Cao, H. Gonzalez, A. Gray, X. He, R. Janetzke, H. Jung, G. Oberson, P. Shukla, T. Sippel, S. Stothoff, and L. Tipton. "SOAR: A Model for Scoping of Options and Analyzing Risk: Version 1.0, User Guide." ML112440119. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 2011.

NRC (U.S. Nuclear Regulatory Commission). "Plan for Integrating Spent Nuclear Fuel Regulatory Activities." ML1012410380. Washington, DC: NRC. 2010a.

_____. "Performance Assessment: A Model for Scoping of Options and Analyzing Risk, Beta Version (β-SOAR) User Guide." ML102160622. Washington, DC: NRC and San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. September 2010b.

SKB (Svensk Kärnbränslehantering AB). "Long-Term Safety for the Final Repository for Spent Nuclear Fuel at Forsmark." Vol. 1: Main Report of the SR-Site Project. SKB TR–11–01. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Company. March 2011.

SKB. "Radionuclide Transport Report for the Safety Assessment SR-Site." SKB TR–10–50. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Company. December 2010a.

SKB. "Data Report for the Safety Assessment SR-Site." SKB TR–10–52. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Company. December 2010b.

SKB. "Spent Nuclear Fuel for Disposal in the KBS-3 Repository." SKB TR–10–13. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Company. 2010c.