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2004 Annual Summary Report for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site Nye County, Nevada

Review of the Performance Assessments and Composite Analyses

Prepared for

National Nuclear Security Administration
Nevada Site Office

Prepared by

Under Contract Number
DE-AC08-96NV11718

January 2005

DISCLAIMER

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EXECUTIVE SUMMARY

The *Maintenance Plan for the Performance Assessments and Composite Analyses for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site* (Bechtel Nevada, 2000) requires an annual review to assess the adequacy of the performance assessments (PAs) and composite analyses (CAs) for each of the facilities, and reports the results in an annual summary report to the U.S. Department of Energy Headquarters. The Disposal Authorization Statements for the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) also require that such reviews be made and that secondary or minor unresolved issues be tracked and addressed as part of the maintenance plan (U.S. Department of Energy [DOE], 2002, 2000a, 1999a, 1999b).

The U.S. Department of Energy National Nuclear Security Administration Nevada Site Office performed annual reviews in fiscal year (FY) 2004 by evaluating operational factors and research results that impact the continuing validity of the PA and CA results. This annual summary report presents data and conclusions from the FY 2004 review, and determines the adequacy of the PAs and CAs. Operational factors, such as the waste form and containers, facility design, waste receipts, closure plans, as well as monitoring results and research and development (R&D) activities were reviewed in FY 2004 for the determination of the adequacy of the PAs. Likewise, the environmental restoration activities at the Nevada Test Site relevant to the sources of residual radioactive material that are considered in the CAs, the land-use planning, and the results of the environmental monitoring and R&D activities were reviewed for the determination of the adequacy of the CAs.

Waste operations, R&D, and monitoring results for FY 2004 were reviewed and compared with the assumptions and conceptual models of the Area 5 RWMS PA. Important developments include:

- Development and application of the Area 5 RWMS v3.0mod GoldSim® PA model
- Development of new closure inventory estimates based on disposals through FY 2004, including a preliminary inventory estimate for Pit 13 (P13U), a deeper pit developed at the Area 5 RWMS for disposal of radium-226- (Ra-226)-bearing waste
- Evaluation of five new or revised waste streams by special analysis

In FY 2004, there were no operational changes, monitoring results, or R&D results for the Area 3 RWMS that would impact PA validity. However since FY 1991, waste volume and inventory at the Area 3 RWMS has increased significantly and current inventory estimates differ significantly from the FY 1996 PA inventory. The Area 3 RWMS inventory is still less than the Area 5 RWMS inventory. The effects of the increasing inventory should be evaluated with the GoldSim Area 3 RWMS model expected in FY 2005. The conclusions of the Area 3 PA remain valid, but a quantitative evaluation of the inventory changes should be performed in FY 2005.

Significant changes at the Area 5 RWMS in FY 2004 include increasing inventory estimates for numerous radionuclides and development of a deeper disposal unit (Pit 13 [P13U]) for disposal of Ra-226-bearing waste. Differences between the FY 1993 PA inventory and the current FY 2004 inventory continue to grow, with the most significant development in FY 2004 being a large increase in the technetium-99 (Tc-99) inventory. Disposal of the Defense National Stockpile Center thorium nitrate waste in Pit 13 began in FY 2004. A final closure cover 7.9 meters (26 feet) thick is planned for Pit 13 to attenuate the radon-222 (Rn-222) flux from the thorium nitrate. The current FY 2004 Area 5 RWMS inventory estimate, including the Pit 13 inventory, was evaluated with the Area 5 RWMS v3.0mod GoldSim model and a reasonable expectation of compliance with all performance objectives was found.

Important developments affecting the Area 5 RWMS that have occurred since preparation of the PA include:

- Development of the probabilistic Area 5 RWMS v3.0mod GoldSim model with many updated input parameters and processes
- Development of new closure inventory estimates that are increasingly different from the PA inventories
- The reduction of the compliance period from 10,000 to 1,000 years, in accordance with the implementation of DOE Order 435.1.

An update of the Area 5 RWMS PA is planned in FY 2005 to quantitatively assess the impact of these and other minor changes occurring since preparation of the PA.

The CAs for the Area 3 and Area 5 RWMSs were evaluated for continuing adequacy. Radionuclide source terms, long-range land-use plans, R&D program results, and monitoring results were considered. No significant changes were identified that would alter CA results or conclusions. Inclusion of the Frenchman Flat Underground Test Area (UGTA) in the Area 5 RWMS CA will be delayed beyond the FY 2003 date reported in the CA. The completion date for the corrective action decision document (CADD) for the Frenchman Flat UGTA corrective action unit (CAU) is currently FY 2008. Therefore, revision of the Area 5 RWMS CA is scheduled for FY 2009. The revision of the Area 3 RWMS is expected in FY 2021, following the completion of the Yucca Flat CAU CADD, scheduled for FY 2020.

Near-term R&D efforts will focus on continuing development of the Area 3 and Area 5 RWMS PA models and updating of important site characterization parameters based on results of sensitivity analyses. Composite analysis and decision analysis modules are planned for the Area 5 RWMS GoldSim model. Development of an Area 3 RWMS GoldSim model based on the Area 5 RWMS PA model is also planned. Updated estimates of the upward liquid water flux for Area 3 and radon diffusion coefficient are expected in FY 2005.

CONTENTS

CONTENTS
(continued)

List of Tables

List of Figures

ACRONYMS and ABBREVIATIONS

ASER	Annual Site Environmental Report
BN	Bechtel Nevada
CA	composite analysis
CADD	Corrective Action Decision Document
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
Ci	Curie
Ci/m^3	Curies per cubic meter
cm	centimeter
DAS	Disposal Authorization Statement
DNSC	Defense National Stockpile Center
DOE	U.S. Department of Energy
DOE/HQ	U.S. Department of Energy/Headquarters
ET	evapotranspiration
FCP	Fernald Closure Project
FEHM	Finite-Element Heat and Mass-Transfer
ft	foot
ft^3	cubic feet
FY	fiscal year
GCD	Greater Confinement Disposal
HDP	heat dissipation probe
ICMP	Integrated Closure and Monitoring Plan
in.	inch
ISC	Industrial Source Complex
µCi	microCurie
pCi	picoCurie
LLNL	Lawrence Livermore National Laboratory
LFRG	Low-Level Waste Disposal Facility Federal Review Group

ACRONYMS and ABBREVIATIONS (continued)

m	meter
m^2	square meters
m^3	cubic meters
mm	millimeter
mrem/yr	millirem per year
NDEP	Nevada Division of Environmental Protection
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NNSA/NSO	U.S. Department of Energy National Nuclear Security Administration Nevada Site Office
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
PA	performance assessment
pCi/(m^2 s)	picoCurie per square meter per second
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RWMS	Radioactive Waste Management Site
SLB	shallow land burial
SOF	Sum of Fractions
SRS	Savannah River Site
TDR	time-domain reflectometry
TEDE	total effective dose equivalent
TLD	thermoluminescent dosimeter
UGTA	Underground Test Area

1.0 INTRODUCTION

This report summarizes the results of an annual review of conditions affecting the operation of the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) and a determination of the continuing adequacy of the Area 3 Performance Assessment/Composite Analysis (PA/CA) and the Area 5 Performance Assessment (PA) and Composite Analysis (CA) (Shott et al., 1998, 2000; Bechtel Nevada [BN], 2001a) and supporting addenda (BN, 2001b; 2001c). The Maintenance Plan for the Performance Assessments PAs and CAs (BN, 2000) and the Disposal Authorization Statements (DASs) for the Area 3 and 5 RWMSs (U.S. Department of Energy [DOE], 2000a; 2002) require preparation of an annual summary and a determination of the continuing adequacy of the PAs and CAs. The annual summary report is submitted to DOE Headquarters (DOE/HQ).

The annual summary report for fiscal year (FY) 2003 found that operating conditions at the Area 3 RWMS and Area 5 RWMS were still within the scope of the DASs and that the PAs and CAs were still adequate (BN, 2004a). The estimate of the waste inventory increased at both disposal sites relative to the PA inventories. Quantitative analysis of the Area 5 RWMS inventory using the Area 5 RWMS v2.101 GoldSim® model indicated that all performance objectives were met. Revision of the PAs was judged to be unnecessary. No significant changes for the CAs were noted.

Following the annual report format in the DOE PA/CA Maintenance Guide (DOE, 1999b), this report presents the annual summary for the PAs in Section 2.0 and the CAs in Section 3.0. The annual summary for the PAs includes the following:

- Section 2.1 summarizes changes in waste disposal operations.
- Section 2.1.5 provides an evaluation of the new estimates of the closure inventories derived from the actual disposals through FY 2004.
- Section 2.2 summarizes the results of the monitoring conducted under the National Nuclear Security Administration Nevada Site Office's (NNSA/NSO's) *Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site* (BN, 2001b), and the research and development (R&D) activities.
- Section 2.4 is a summary of changes in facility design, operation, or expected future conditions; monitoring and R&D activities; and the maintenance program.
- Section 2.5 discusses the recommended changes in disposal facility design and operations, monitoring and R&D activities, and the maintenance program.

Similarly, the annual summary for the CAs (presented in Section 3.0) includes the following:

- Section 3.1 presents the assessment of the adequacy of the CAs, with a summary of the relevant factors reviewed in FY 2004.

- Section 3.2 presents an assessment of the relevant site activities at the Nevada Test Site (NTS) that would impact the sources of residual radioactive material considered in the CAs.
- Section 3.3 summarizes the monitoring and R&D results that were reviewed in FY 2004.
- Section 3.4 presents a summary of changes in relevant site programs (including monitoring, R&D, and the maintenance program) that occurred since the CAs were prepared.
- Section 3.5 summarizes the recommended changes to these programs.

1.1 Tracking of Minor Issues

Tracking and resolution of all minor or secondary issues identified in the Low-Level Waste Disposal Facility Federal Review Group (LFRG) review reports for the Area 3 and Area 5 RWMS PAs and CAs continued in FY 2004. Table 1 lists the minor issues that are being tracked and resolved through the maintenance program. The resolution pathway for each issue is included in the third column of Table 1.

Table 1. Minor Issues Identified in the LFRG Reports for the Area 3 and Area 5 RWMS PAs and CAs

Identified Issue	Source Document for Issue	Resolution Pathway
An engineered barrier will be added and the assurance requirements of U.S. Environmental Protection Agency Title 40 Code of Federal Regulations (CFR) 191 must be met for the Greater Confinement Disposal (GCD) boreholes.	GCD PA	An engineered barrier will be added and the assurance requirements will be met at the time of closure of the Area 5 RWMS, as stated in the Integrated Closure and Monitoring Plan (ICMP) (BN, 2001d).
Inconsistencies between conceptual models for the Area 5 RWMS PA and CA, the Area 3 RWMS PA and CA, and the GCD PA	Area 5 RWMS PA; Area 5 RWMS CA; Area 3 RWMS PA/CA; GCD PA	The development of probabilistic performance assessment models using the GoldSim software system will integrate past PAs and eliminate inconsistencies; this work will be described in annual summary reports.
Conduct site monitoring and site characterization studies, as required, to increase confidence in the results of the PAs.	Area 3 RWMS PA/CA	Monitoring programs at both Area 5 and Area 3 RWMSs are ongoing; data will be incorporated through Bayesian updating in the probabilistic models and combined with value of information studies; impact on the uncertainty and confidence in results will be presented in annual summary reports.
The maintenance program must include periodic assessment of changes in potentially interacting sources (underground test areas [UGTA], industrial sites) and impacts on the CAs	Area 5 RWMS CA; Area 3 RWMS PA/CA	Changes in potentially interacting sources will be evaluated through the maintenance and results presented in the annual summary reports.

Table 1. Minor Issues Identified in the LFRG Review Reports for the Area 3 and Area 5 RWMS` PAs and CAs (continued)

Identified Issue	Source Document for Issue	Resolution Pathway
The maintenance program must include periodic assessment of changes in land-use restrictions and impacts on the CAs.	Area 5 RWMS CA; Area 3 RWMS PA/CA	Changes in land-use restrictions will be reviewed through the maintenance program and results presented in the annual summary reports.
Monitoring systems need to be deployed and data gathered and evaluated to distinguish between interacting sources at the Area 3 RWMS.	Area 3 RWMS PA/CA	The monitoring systems deployed at the disposal facilities are described in the ICMP (BN, 2001d); monitoring results will be evaluated and presented in the annual summary reports.

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2.0 PERFORMANCE ASSESSMENT

2.1 Waste Disposal Operations

Performance assessment maintenance requires an annual review of waste operations including waste forms and waste containers disposed, facility design, waste acceptance criteria, closure design, and waste inventory. Current operations are compared with the assumptions and conceptual models of the PAs to assess the continuing validity of the PA and compliance with DAS conditions. Differences in waste inventory, facility design, and closure design between the PAs and current conditions are noted and described below. The impacts of these changes for the Area 5 RWMS PA are summarized in Section 2.1.5.

2.1.1 Waste Form and Containers

The Area 3 and Area 5 RWMS PAs do not explicitly model the performance of waste forms and containers. Radionuclides are assumed to be fully available for release and transport at closure. These assumptions remain valid for the majority of waste disposed through FY 2004. However in FY 2004, several new waste streams were proposed for disposal that contained significant quantities of radium-226 (Ra-226) and had the potential to increase radon-222 (Rn-222) emissions. The modeling of the release and transport of Rn-222 within these waste forms is based on the specific properties of each waste form. Details of the assumptions made are described below in Section 2.1.3.1. A small volume of one of these waste streams was disposed at the Area 5 RWMS in FY 2004.

2.1.2 Facility Design and Operations

The PAs use assumptions about disposal unit volume, area, and depth of burial that may affect performance. Historical information on these parameters remains unchanged, although uncertainty in some of the values exists. Changes resulting from the operation of new disposal units are described below.

No new disposal units were opened at the Area 3 RWMS in FY 2004 and assumptions concerning disposal unit volume, area, and depth of burial remain unchanged. Operational changes that have increased the Area 3 RWMS inventory in recent years, including the disposal of drummed wastes and thorium waste at the Area 3 RWMS, continued in FY 2004.

At the Area 5 RWMS, five new disposal cells were opened and three cells received waste in FY 2004. A new shallow land burial unit (Pit 11 [P11U]) was opened west of the low-level waste management unit. Pit 11 is a long, narrow (256 × 8 meters [m] (840 × 26 feet [ft])) trench used for disposal of waste with high gamma exposure rates. Pit 11 is excavated to a depth of 4.4 m (14 ft) and is expected to have a closure cover 4 m (13 ft) thick. A new classified disposal unit (Pit 12 [P12C]) was excavated in FY 2004, but did not receive any waste. Pits 13 (P13U), 14 (P14U), and 15 (P15U) are deeper units north of the low-level management unit excavated for disposal of wastes with a potential to generate Rn-222 gas. These deeper units are excavated to a depth of 7.6 m (25 ft) and can accommodate a cover thickness greater than 8 m (26 ft). The greater cover thickness was planned to reduce Rn-222 flux density at the ground surface to the DOE Order 435.1 (2001) limit of 20 picoCuries per meter per second (pCi/[m^2 s]). In FY 2004, Pit 13 began receiving the Defense National Stockpile Center (DNSC) thorium nitrate waste stream, a waste requiring a greater cover thickness to attenuate Rn-222 flux. Pit 14 received low-level waste acceptable of disposal below a 4-m (13-ft) cover. Pit 15 did not receive waste in FY 2004. The greater depth of Pits 13, 14, and 15 will allow closure covers greater than the 4-m (13-ft) cover assumed for shallow land burial (SLB) units in the PA.

2.1.3 Waste Receipts

The Area 3 and Area 5 RWMS PAs analyzed waste inventories that were estimated as the sum of past disposals and estimated future disposals. The estimate of closure inventory will change over time if estimates or records of past disposals are revised or if forecasts of future waste change. Approximately half of the inventory expected at closure will be disposed in the future. Consequently, closure inventory uncertainty is dominated by uncertainty in future disposals. Experience has shown that future inventory estimates will change, perhaps significantly, over time as new generators are approved, new waste streams are approved, or wastes are sent to other alternative disposal sites. Occasionally, estimates of past disposals may change as disposal records are reviewed, database records revised, and assumptions used to revise historical records change.

2.1.3.1 *New or Revised Waste Streams*

Each new or revised waste stream is evaluated by the Radiological Waste Acceptance Program for its potential impacts on the PA and conformance with Waste Acceptance Criteria. Some waste streams because of their potential to alter PA assumptions or conceptual models require a special analysis for acceptance. In FY 2004, five waste streams required a special analysis. These were the Fernald Closure Project (FCP) silo 1 and 2 waste stream, the FCP silo 3 waste stream, the DNSC thorium nitrate waste stream, the Savannah River Site (SRS) treated depleted uranyl nitrate residues, and the Lawrence Livermore National Laboratory (LLNL) research-derived waste.

The FCP silo materials are 11e.(2) by-product materials produced by the processing of high-grade uranium ore concentrates. The FCP silo material consists of two waste streams, the silo 1 and 2 waste stream and the silo 3 waste stream. The silo 1 and 2 waste stream consists of 38,900 cubic meters (m^3) (1.4E6 cubic feet [ft^3]) of Portland cement solidified waste in carbon steel tanks. The silo 3 waste stream consists of 4,600 m^3 (1.6E5 ft^3) of calcined uranium ore processing residues packaged in soft-sided packages. The silo wastes were evaluated by special analysis because they required a thicker cover to attenuate Rn-222 emissions. The special analysis was performed with the Area 5 RWMS GoldSim model making waste stream-specific assumptions regarding the release and transport of Rn-222 in the waste form. The radon emanation coefficient distribution for each waste form was estimated from generator measurements that indicated a slightly lower emanation coefficient for these wastes compared to other low-level wastes. The Rn-222 effective diffusion coefficient distribution for the silo 1 and 2 grout waste form was estimated from literature values of the diffusion coefficient in concrete. The steel waste containers were not assumed to retard radionuclide release. The Area 5 RWMS GoldSim model was used to determine the cover thickness to reduce the Rn-222 flux density to 20 pCi/(m^2 s) and to confirm that all other performance objectives were met. The FCP silo wastes were accepted for disposal with the condition that the closure cover be at least 8.4 m (27 ft) thick to reduce Rn-222 flux. The state of Nevada is opposed to disposal of this waste at the NTS. Although the silo wastes have been accepted for disposal at the NTS, the DOE/HQ is continuing to explore other disposal options for this waste. The FCP silo waste special analysis is documented in BN, 2004b.

The DNSC thorium nitrate waste consists of 1,700 m^3 (6E4 ft^3) of thorium nitrate and is similar to other thorium waste disposed in Pit 6. The DNSC thorium nitrate also will generate Rn-222 gas and was evaluated by special analysis using the Area 5 RWMS GoldSim model to determine the cover thickness required to reduce the Rn-222 flux density to 20 pCi/(m^2 s). The waste stream was approved for disposal with the condition of a closure cover at least 7.9 m (26 ft) thick. Disposal of the DNSC thorium nitrate began during FY 2004 in Pit 13 (P13U) at the Area 5 RWMS.

The SRS treated depleted uranyl nitrate residues are cement-stabilized uranyl nitrate solutions from nuclear target processing. The high Ra-226 concentration and significant volume of this waste stream (1,500 m^3 [5.3E4 ft^3]) required a special analysis to assess the impact of on-site Rn-222 emissions. The SRS treated depleted uranyl nitrate residues were accepted for disposal with the conditions that (1) the waste be disposed at the Area 3 RWMS and (2) the total inventory of thorium-230 (Th-230) and Ra-226 in each disposal unit (i.e., U-3ah/at or U3bh) shall not exceed 9.2 Curies (Ci). This inventory limit will ensure that the Rn-222 flux density will remain below the performance objective. Disposal of the SRS treated depleted uranyl nitrate residues at the Area 3 RWMS began in FY 2004.

The LLNL research-derived waste is a complex and diverse waste stream consisting of more than 50 radionuclides with highly variable concentrations. The majority of individual waste packages are expected to contain only a few radionuclides at a small fraction of the upper limit concentration reported by the generator. A special analysis was performed with the Area 5 RWMS GoldSim model to assess the potential to comply with the performance objectives. The analysis provided a reasonable expectation of compliance when the waste stream was averaged over the volume of waste at the Area 5 RWMS. The waste stream was approved for disposal without conditions.

2.1.3.2 *FY 2004 Closure Inventory Estimate for the Area 3 Radioactive Waste Management Site*

The Area 3 RWMS PA evaluated an estimated closure inventory for two disposal units, U-3ah/at and U-3bh. The inventory was estimated by summing past disposals from FY 1989 through FY 1996, revisions for unreported and underreported radionuclides, and estimated future disposals. Radionuclide activity was not decayed or ingrown during disposal operations. Future disposals were estimated by projecting past disposals into the future and including inventories of NTS plutonium (Pu)-contaminated soils designated for cleanup and disposal. Disposal was assumed to continue until FY 2013 when U-3ah/at and U-3bh were projected to be filled. The PA inventory was calculated as a deterministic sum without radioactive decay or ingrowth. The deterministic sum was assumed to be the mode of a triangularly distributed inventory. The lower and upper limits of the distribution were assumed to be 0.1 and 10 times the mode, respectively. The FY 1996 PA inventory is summarized in columns 2 and 3 of Table 2.

Table 2. Comparison of the Area 3 RWMS PA Inventory and Current FY 2004 Inventory Estimate for Waste Disposed After September 26, 1988. Both inventories are estimated at closure and include past disposals and estimates of future disposals. All data are for the U-3ah/at and U-3bh disposal units combined. Current FY 2004 inventory estimates are calculated from 500 Monte Carlo realizations.

Nuclide	FY 1996 PA Inventory (Ci)	FY 1996 PA Inventory (Ci/m^3)	Current FY 2004 Inventory Estimate			Ratio of Current Inventory Concentration to PA Inventory Concentration	Geometric Mean of the Sum of Fractions
			Geometric Mean (Ci)	Geometric Mean (Ci/m^3)	Geometric Standard Deviation		
H-3	5.6E+02	1.5E-03	9.9E+05	2.1E+00	2.1	1.4E+03	1.9E-05
C-14	1.6E-02	4.3E-08	4.1E+00	8.5E-06	2.0	2.0E+02	1.8E-03
Al-26	7.0E-07	1.8E-12	1.5E-07	3.2E-13	3.9	1.8E-01	NL
Cl-36	4.2E-03	1.1E-08	3.2E-03	6.7E-09	2.3	6.1E-01	3.3E-08
Ar-39	1.7E-02	4.6E-08	8.8E-03	1.8E-08	3.0	4.0E-01	NL
Ar-42	D	D	4.7E-02	9.8E-08	2.0	NA	NL
K-40	4.7E-03	1.2E-08	8.0E-02	1.7E-07	2.2	1.4E+01	NL
Ca-41	4.0E-02	1.1E-07	1.1E-02	2.3E-08	3.4	2.1E-01	NL
Ti-44	D	D	1.1E+00	2.3E-06	2.0	NA	NL
Ni-59	7.4E-04	1.9E-09	4.3E-03	8.9E-09	2.4	4.7E+00	6.4E-11
Ni-63	9.7E-02	2.6E-07	8.0E+00	1.7E-05	2.3	6.5E+01	3.7E-08
Co-60	7.6E-05	2.0E-10	7.3E-01	1.5E-06	2.0	7.6E+03	NL
Se-79	D	D	3.4E-05	7.1E-11	2.9	NA	NL
Kr-85	1.4E+00	3.7E-06	5.4E-01	1.1E-06	2.9	3.0E-01	NL
Sr-90	2.3E+01	6.2E-05	1.8E+04	3.8E-02	3.1	6.1E+02	1.9E-03
Zr-93	1.1E-03	2.8E-09	5.2E-04	1.1E-09	2.9	3.9E-01	5.0E-12
Nb-93m	8.0E-02	2.1E-07	2.3E-02	4.9E-08	3.4	2.3E-01	NL
Nb-94	3.7E-03	9.7E-09	1.1E-02	2.3E-08	2.2	2.4E+00	NL
Tc-99	1.8E-02	4.8E-08	8.9E+01	1.9E-04	2.2	3.9E+03	9.1E-05
Pd-107	3.7E-05	9.7E-11	1.7E-05	3.5E-11	2.9	3.6E-01	1.8E-14
Cd-113m	1.3E-02	3.3E-08	5.4E-01	1.1E-06	3.1	3.4E+01	NL
Sn-121m	7.3E-02	1.9E-07	3.6E-02	7.6E-08	3.0	4.0E-01	NL
Sn-126	9.8E-04	2.6E-09	2.9E-03	6.1E-09	2.4	2.4E+00	5.9E-07
I-129	2.3E-05	6.0E-11	3.0E-02	6.4E-08	2.2	1.1E+03	1.1E-06
Cs-135	8.2E-04	2.1E-09	3.9E-04	8.2E-10	2.9	3.9E-01	1.9E-11
Cs-137	3.0E+01	7.9E-05	1.0E+04	2.1E-02	2.2	2.7E+02	3.2E-03
Ba-133	D	D	7.7E-01	1.6E-06	2.1	NA	NL
Sm-151	1.2E+00	3.2E-06	5.6E-01	1.2E-06	2.9	3.7E-01	6.2E-11
Eu-150	1.4E-03	3.8E-09	1.5E-03	3.2E-09	3.9	8.3E-01	NL
Eu-152	7.4E-01	2.0E-06	1.0E+00	2.2E-06	2.1	1.1E+00	2.3E-09
Eu-154	4.6E-01	1.2E-06	1.6E-01	3.3E-07	2.6	2.8E-01	1.8E-12
Gd-152	P	P	2.5E-14	5.3E-20	2.0	NA	NL
Ho-166m	2.3E-07	6.0E-13	1.0E-07	2.1E-13	3.1	3.5E-01	NL
Pb-210	4.7E-04	1.2E-09	3.2E+00	6.7E-06	2.5	5.6E+03	3.1E-08
Bi-210m	D	D	9.9E-05	2.1E-10	2.9	NA	NL

Table 2. Comparison of the Area 3 RWMS PA Inventory and Current FY Inventory Estimate for Waste Disposed After September 26, 1988 (continued)

Nuclide	FY 1996 PA Inventory (Ci)	FY 1996 PA Inventory (Ci/m^3)	Current FY 2004 Inventory Estimate			Ratio of Current Inventory Concentration to PA Inventory Concentration	Geometric Mean of the Sum of Fractions
			Geometric Mean (Ci)	Geometric Mean (Ci/m^3)	Geometric Standard Deviation		
Ra-226	1.2E-03	3.2E-09	1.2E+00	2.4E-06	2.3	7.6E+02	3.6E-03
Ra-228	8.1E-03	2.1E-08	6.5E+00	1.4E-05	2.6	6.5E+02	NL
Ac-227	1.7E-05	4.5E-11	1.5E-01	3.1E-07	2.9	6.9E+03	2.1E-08
Th-228	1.2E-02	3.2E-08	8.5E+00	1.8E-05	2.2	5.6E+02	NL
Th-229	4.4E-04	1.2E-09	1.4E-03	2.9E-09	2.1	2.4E+00	3.6E-08
Th-230	1.5E-03	3.9E-09	6.3E+00	1.3E-05	2.2	3.4E+03	7.1E-03
Th-232	1.3E-02	3.3E-08	1.0E+01	2.1E-05	2.7	6.4E+02	1.6E-03
Pa-231	8.4E-05	2.2E-10	1.1E-02	2.3E-08	2.1	1.1E+02	8.3E-07
U-232	6.3E-03	1.6E-08	2.2E+00	4.6E-06	2.8	2.9E+02	3.1E-05
U-233	4.5E-01	1.2E-06	1.3E+00	2.7E-06	2.3	2.3E+00	4.7E-06
U-234	1.2E+01	3.2E-05	3.3E+02	7.0E-04	2.2	2.2E+01	1.9E-03
U-235	3.6E-01	9.5E-07	1.4E+01	3.0E-05	2.0	3.1E+01	1.2E-04
U-236	1.4E-02	3.7E-08	1.6E+01	3.3E-05	2.6	9.0E+02	1.7E-05
U-238	1.3E+01	3.4E-05	4.6E+02	9.6E-04	2.0	2.8E+01	7.8E-04
Np-237	4.6E-04	1.2E-09	7.6E-01	1.6E-06	2.2	1.3E+03	1.2E-04
Pu-236	C	C	2.7E-07	5.7E-13	3.4	NA	2.0E-13
Pu-238	3.1E+00	8.2E-06	8.3E+00	1.8E-05	2.2	2.1E+00	7.7E-06
Pu-239	5.2E+01	1.4E-04	1.1E+02	2.4E-04	2.0	1.7E+00	5.0E-04
Pu-240	1.1E+01	2.8E-05	2.4E+01	5.1E-05	1.9	1.8E+00	1.0E-04
Pu-241	5.4E+01	1.4E-04	9.7E+01	2.0E-04	2.0	1.5E+00	1.9E-05
Pu-242	1.0E-03	2.6E-09	4.3E-03	9.0E-09	2.0	3.5E+00	1.8E-08
Pu-244	D	D	3.2E-11	6.8E-17	2.9	NA	NL
Am-241	8.5E+00	2.2E-05	2.0E+01	4.3E-05	1.9	2.0E+00	1.1E-04
Am-242m	D	D	1.2E-02	2.5E-08	2.4	NA	NL
Am-243	6.4E-05	1.7E-10	7.6E-03	1.6E-08	2.4	9.4E+01	1.4E-07
Cm-242	C	C	9.9E-03	2.1E-08	2.4	NA	1.2E-27
Cm-243	D	D	5.2E-05	1.1E-10	2.9	NA	NL
Cm-244	3.3E-02	8.6E-08	4.1E-01	8.7E-07	2.1	1.0E+01	5.4E-09
Cm-245	D	D	3.8E-03	8.0E-09	2.4	NA	NL
Cm-246	D	D	6.2E-04	1.3E-09	2.3	NA	NL
Cm-247	D	D	1.1E-13	2.3E-19	2.8	NA	NL
Cm-248	D	D	2.6E-22	5.4E-28	2.9	NA	5.9E-27
Cf-249	D	D	1.6E-07	3.4E-13	2.4	NA	NL
Cf-250	D	D	9.9E-08	2.1E-13	3.0	NA	NL
Cf-251	D	D	2.6E-07	5.4E-13	2.9	NA	NL
Total	**7.7E+02**	**2.0E-03**	**1.0E+06**	**2.2E+00**			**2.3E-02**

C – Included for completeness; short-lived nuclide that decays to long-lived parent.
D – Disposed since preparation of the PA.
P – Long-lived progeny of disposed nuclide.
NL – No waste concentration limit.
NA – Not available; nuclide not evaluated in Area 3 RWMS PA.

The current FY 2004 Area 3 RWMS inventory was prepared using the Area 3 Inventory v2.005 GoldSim model. The model sums the inventory of wastes disposed in U-3ah/at and U-3bh from FY 1989 through FY 2004, revisions to the inventory, and the estimated inventory of future waste to be disposed by closure in FY 2013. Radioactive decay and ingrowth during disposal operations are calculated. Revisions estimate the activity of individual nuclides assumed to be present in radionuclide mixtures such as mixed fission products, depleted uranium, enriched uranium, and weapons-grade plutonium. Future inventory is estimated as the product of future volume estimated by waste generators and the mean concentration of waste disposed from FY 1989 through FY 2004. Except for updating of FY 2004 disposal data, no major changes were implemented in the Area 3 Inventory model in the past year.

The Area 3 Inventory v2.005 GoldSim model is a probabilistic model. Most parameters, including annual disposal rates, revision scaling factors, future volume, and future concentrations, are stochastic parameters. Monte Carlo simulation is used where stochastic inputs are randomly sampled once each model realization and the closure inventory is estimated as a distribution. The inventory geometric mean and standard deviation appear in Table 2.

The volume of waste disposed at the Area 3 RWMS increased again in FY 2004 and continued to exceed the forecast disposal rate (Figure 1). However, the arithmetic mean volume estimate for closure increased only slightly from 4.6E5 m^3 (1.6E7 ft^3) in FY 2003 to 4.8E5 m^3 (1.7E7 ft^3) in FY 2004. The current estimate is greater than the 3.8E5 m^3 (1.3E7 ft^3) estimated in the PA.

The recent trend of increasing inventory at the Area 3 RWMS continued in FY 2004 (Figure 2). The geometric mean inventory at closure increased from 1.4E5 Ci in FY 2003 to 1.0E6 Ci in FY 2004 (Table 2). The current inventory is significantly greater than the 7.7E2 Ci assumed in the PA. Inventory has risen in recent years with the addition of new generators and operational changes allowing disposal of drummed waste. Even with the recent increases, the concentration of waste at the Area 3 RWMS is still less than at the Area 5 RWMS. Acceptance of the SRS depleted uranium uranyl nitrate waste stream was conditional on maintaining the inventory of Ra-226 and Th-230 in each disposal unit below 9.2 Ci. The geometric mean closure activity of Ra-226 and Th-230 at the Area 3 RWMS was 7.5 Ci, indicating that this condition was met in FY 2004.

The sum of fractions (SOFs) is the sum over all radionuclides of the ratio of waste concentration to the waste concentration limit. A SOFs equal to 1 indicates performance equal to the performance objective. The Area 3 RWMS SOFs has been increasing rapidly since FY 1999, but remains relatively low at approximately 0.02 (Figure 3). A SOFs of 0.02 indicates that the waste concentration is still only 2 percent of that allowed by the PA. The main contributors to the SOFs are Th-230, Ra-226, uranium-234 (U-234), thorium-232 (Th-232), cesium-137 (Cs-137), strontium-90 (Sr-90), and carbon-14 (C-14). The low SOFs indicates that current inventory complies with all performance objectives.

The seventh column of Table 2 shows the ratio of the FY 2004 inventory estimate to the PA estimate. A value of 1.0 indicates no difference between the FY 1996 PA inventory and the current inventory estimate, values greater than 1 show an expected increase, and values less than 1 indicate an expected decrease. The geometric mean activity concentration of

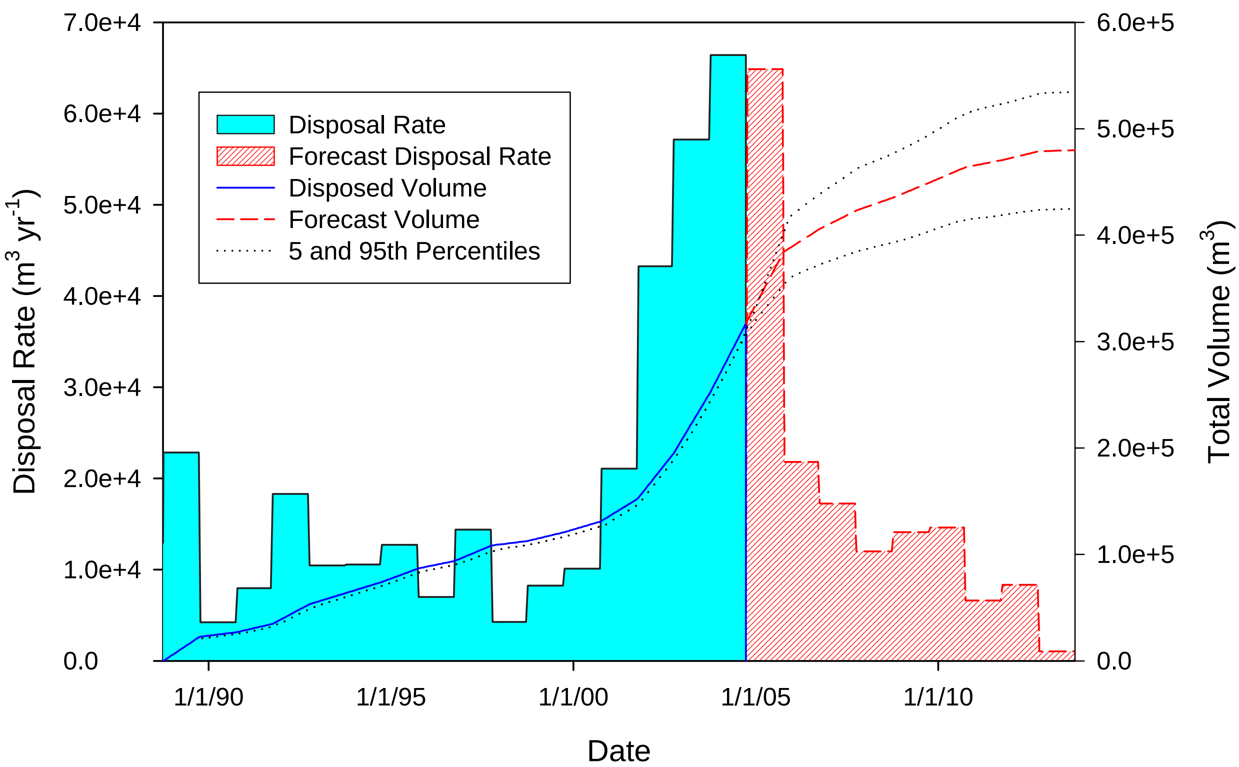

Figure 1. **Volume Disposed per Year and the Arithmetic Mean of Cumulative Volume for the Area 3 RWMS**

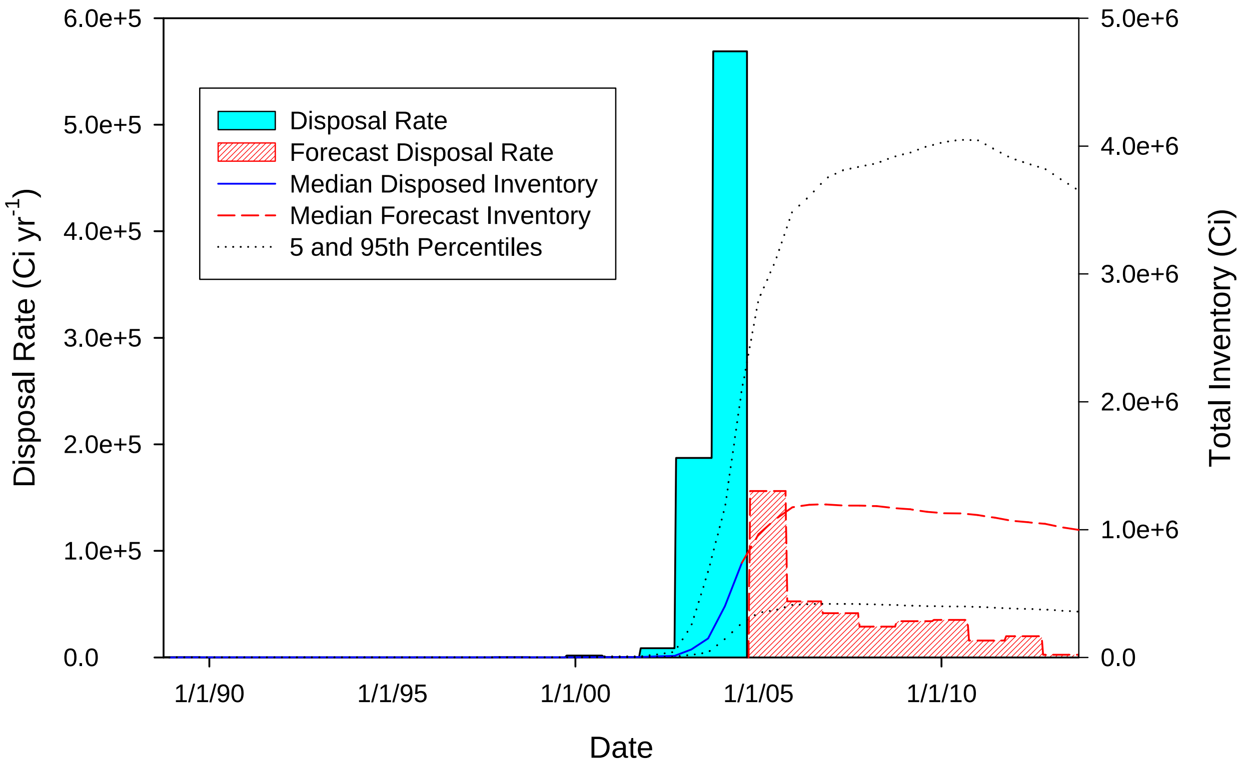

Figure 2. Activity Annual Disposal Rate and Median Inventory for the Area 3 RWMS

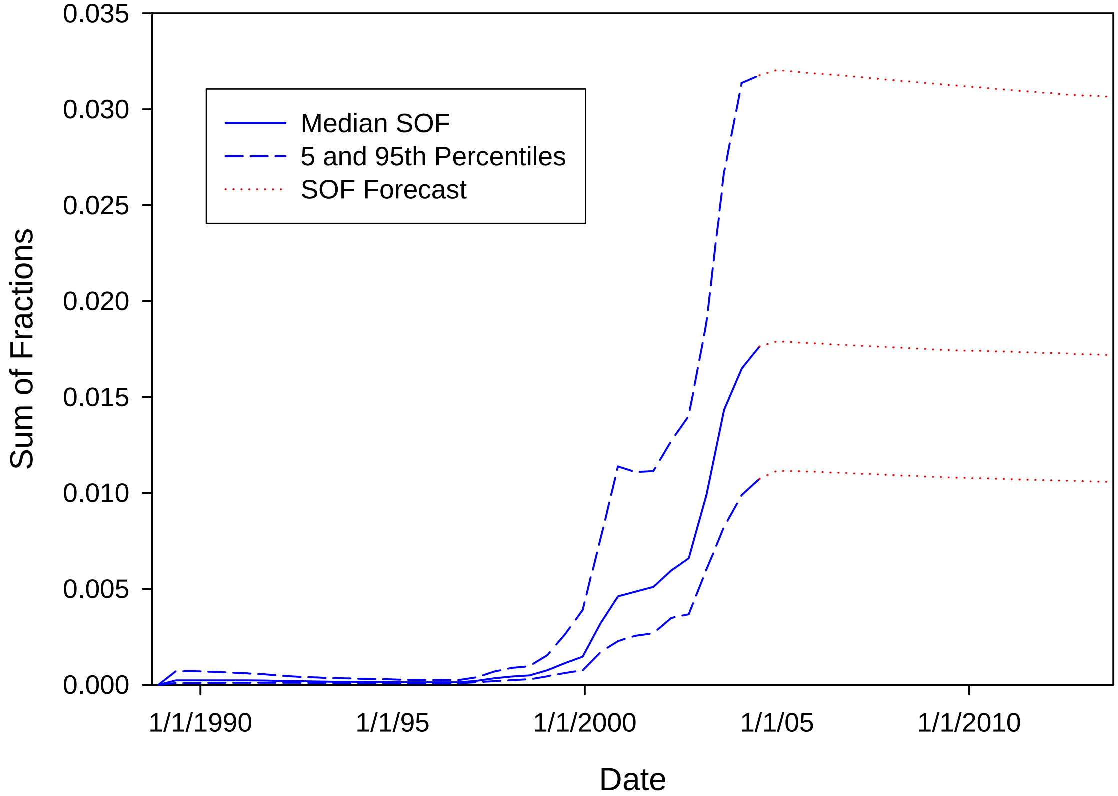

Figure 3. Median Sum of Fractions for U-3ah/at and U-3bh at the Area 3 RWMS

26 radionuclides has increased to greater than 10 times the PA concentration, indicating that the current concentration has increased beyond the 99th percentile of the PA estimate. No new radionuclides were received at the Area 3 RWMS in FY 2004. Overall, 15 long-lived radionuclides not considered in the PA have been disposed at the Area 3 RWMS. The inventories of these radionuclides are less than approximately 1 Ci and unlikely to impact performance.

2.1.3.3 *FY 2004 Closure Inventory Estimate for the Area 5 Radioactive Waste Management Site*

The Area 5 RWMS PA evaluated an estimated inventory for the SLB disposal units and Pit 6 (P06U), a deeper cell used for disposal of thorium waste. These inventories at closure were estimated by summing past disposals through FY 1993, revisions for unreported and under-reported radionuclides, and estimates of future disposals. The calculations did not include radioactive decay during the operational period. Waste disposed in the future was assumed to have the composition of waste disposed from FY 1989 through FY 1993. Disposal was assumed to continue until FY 2028. The PA inventory was estimated by summing past disposals, revisions, and future estimates deterministically. The resulting inventory sums were assumed to be the median of a lognormally distributed inventory with the 95th percentile equal to 10 times the median.

The FY 2004 estimate of the Area 5 RWMS closure inventory was prepared using the Area 5 Inventory v2.011 GoldSim model. The model sums past disposals, revisions, and future inventory estimates probabilistically. Radioactive decay and ingrowth during the operational period are explicitly included in the model. Inventories are calculated for the SLB disposal units with a 4-m (13-ft) cover and for two deep cells, Pit 6 (P06U) and Pit 13 (P13U).

The Area 5 Inventory model underwent major revision in FY 2004. The pre-1993 waste management database has been reviewed and revised since preparation of the Area 5 PA. All inventory data sources, including the pre-1993 databases were queried and the new query results input into the model. The volume and activity results from the new database queries are significantly different from past results, but believed to be more accurate and complete.

Changes were made to several of the inventory revision calculations. Pre-1993 database records are incomplete. Missing volume is estimated by comparing the physical volume of the disposal trenches and the volume of waste recorded in database records. Pre-1993 volume and activity is increased proportionally to account for the difference between physical volume and database records. In FY 2004, the volume correction factor was modified to reflect current FY 2004 estimates of the physical volume of the pre-1993 disposal units and current database query results. The mixed fission product scaling factors were revised to reflect recently declassified data on the inventory and inventory uncertainty of NTS UGTAs. The calculation of scaling factors for uranium isotopes in depleted and enriched uranium was revised to use an empirical relationship between uranium-235 (U-235) enrichment and uranium specific activity for the gaseous diffusion process. The fraction of enriched uranium inferred to be low enrichment is now randomly selected from a distribution based on historical data. These changes moderately increase the inventory of radionuclides disposed before FY 1989.

The inventory disposed in each future fiscal year was previously calculated as the product of the waste generator estimate of volume in the given year and an estimate of radionuclide concentration based on the mean concentration of past disposals. The volume for each future fiscal year was a normally distributed variable with the mean equal to the generator estimate. The future concentration was a lognormally distributed variable with geometric mean equal to the geometric mean concentration of all post-1988 years. The concentration was constant in all future years. The treatment of future volume in the new model is unchanged. However, the radionuclide concentration in each future year is now selected randomly from a discrete distribution of annual concentrations observed between FY 1989 and FY 2004. The effect of these changes for common radionuclides (e.g., those disposed every year) is to slightly reduce the mean and uncertainty of future inventory. Some reduction in the future inventory is expected each year as the number of remaining years until closure decreases. The uncertainty in future inventory significantly increases for those radionuclides whose annual concentration has been zero in many past years.

The Area 5 Inventory model is a probabilistic model. Most model parameters including annual disposal rates, revision scaling factors, future waste volumes, and future waste concentrations are stochastic parameters. In past models, input distributions were sampled once for each realization (i.e., parameters were constant over time). The current model samples distributions at the beginning of every fiscal year, allowing all model parameters to vary with each new fiscal year. The geometric mean and standard deviation of the inventory appear in Table 3.

The volume of waste disposed at the Area 5 RWMS continued to increase in FY 2004 (Figure 4). The arithmetic mean volume estimate increased only slightly from 3.8E5 to 3.9E5 m^3 (1.3E7 to 1.4E7 ft^3). Disposal volumes have been increasing in recent years and are expected to increase for one more year as many DOE sites complete environmental cleanup activities. Overall, the Area 5 RWMS volume forecast has changed little from the PA assumption of 3.7E5 m^3 (1.3E7 ft^3).

The geometric mean closure inventory estimate has decreased slightly from last year to 1.6E6 Ci (Figure 5). The FY 2004 inventory is still greater than the PA inventory which was 3.2E5 Ci. The seventh column in Table 3 shows the ratio of the current inventory estimate to the PA estimate. The ratio is greater than 1.0 for most radionuclides, indicating that the expected waste concentration has increased since preparation of the PA. A ratio greater than 10 indicates that the current estimate is greater than the 95th percentile value assumed in the PA. The inventory of 27 long-lived nuclides currently exceeds the PA 95th percentile inventory. The ratio has increased for most important radionuclides since last year’s annual review. Especially large increases are noted for the PA important radionuclides chlorine-36 (Cl-36), Sr-90, technetium-99 (Tc-99), iodine-129 (I-129), and Cs-137.

The last column in Table 3 shows the estimated SOFs at closure. The median SOFs has varied between 0.03 and 0.08 since preparation of the PA (Figure 6). The current estimate of 0.06 indicates that the expected concentration at closure would be about 6 percent of the amount permitted under the performance objectives. This indicates that the current FY 2004 inventory is expected to meet all PA performance objectives.

Three long-lived radionuclides, promethium-146 (Pm-146), samarium-146 (Sm-146), and curium-247 (Cm-247), not previously disposed, were received in FY 2004. Since preparation of the Area 5 RWMS PA, 15 radionuclides not included in the PA have been disposed at the Area 5 RWMS. The closure inventory of all are well below 1 Ci and unlikely to have any significant impact on performance.

Pit 6 Inventory

The lower cell of Pit 6 (P06U) was excavated to greater depth to contain thorium waste and was operational from FY 1992 until it was closed in FY 2002. The FY 2004 Pit 6 inventory has changed slightly from the FY 2003 inventory due to the new database query results and differences in how uncertainty is propagated in the current inventory model (Table 4). The actual inventory in FY 2004 is significantly less than that assumed in the PA.

Table 3. Comparison of the Area 5 RWMS PA Inventory and Current FY 2004 Inventory Estimate for Waste Disposed After September 26, 1988, in the SLB Disposal Units. Both inventories are estimated at closure and include past disposals and future disposals. Current inventory estimate is calculated from 500 Monte Carlo realizations.

			Current FY 2004 Inventory Estimate				
Nuclide	FY 1993 PA Inventory (Ci)	FY 1993 PA Inventory (Ci/m^3)	Geometric Mean (Ci)	Geometric Mean (Ci/m^3)	Geometric Standard Deviation	Ratio of Current Concentration to PA Concentration	Geometric Mean of the Sum of Fractions
H-3	3.18E+05	8.64E-01	1.6E+06	4.0E+00	1.6	4.7E+00	2.7E-05
C-14	4.12	1.12E-05	3.6E+00	9.2E-06	1.8	8.3E-01	1.5E-03
Al-26	A	A	9.0E-07	2.3E-12	2.7	NA	NL
Cl-36	1.54E-07	4.18E-13	5.7E-03	1.4E-08	2.5	3.4E+04	4.8E-08
Ar-39	A	A	2.5E-02	6.3E-08	2.5	NA	NL
K-40	D	D	2.4E-01	6.1E-07	1.8	NA	NL
Ca-41	D	D	3.9E-02	9.8E-08	2.6	NA	NL
Ni-59	2.34E-05	6.36E-11	9.4E-03	2.4E-08	1.8	3.8E+02	1.1E-10
Ni-63	3.73	1.01E-05	2.6E+00	6.5E-06	1.6	6.5E-01	9.7E-09
Co-60	0.207	5.68E-07	1.1E+01	2.7E-05	2.7	4.7E+01	NL
Kr-85	0.0265	7.18E-08	3.2E-02	8.1E-08	2.1	1.1E+00	NL
Sr-90	4.89	1.33E-05	8.6E+02	2.2E-03	2.4	1.6E+02	5.4E-05
Zr-93	3.74E-05	1.02E-10	1.4E-04	3.6E-10	2.4	3.5E+00	9.5E-13
Nb-93m	3.74E-05	1.02E-10	2.3E-02	5.9E-08	2.7	5.8E+02	NL
Nb-94	D	D	3.1E-02	8.0E-08	2.6	NA	0.0E+00
Tc-99	29	7.88E-05	4.6E+03	1.2E-02	2.3	1.5E+02	3.9E-03
Pd-107	1.09E-05	2.96E-11	5.9E-06	1.5E-11	2.5	5.0E-01	4.2E-15
Ag-108m	D	D	1.4E-04	3.5E-10	2.2	NA	NL
Cd-113m	A	A	2.2E-02	5.7E-08	2.6	NA	NL
Sn-121m	A	A	3.4E-01	8.7E-07	2.6	NA	NL
Sn-126	1.29E-05	3.50E-11	6.8E-05	1.7E-10	2.3	4.9E+00	1.1E-08
I-129	3.28E-06	8.91E-12	4.1E-02	1.0E-07	1.7	1.2E+04	1.3E-06
Cs-135	5.07E-05	1.38E-10	1.1E-04	2.7E-10	2.4	2.0E+00	3.6E-12
Cs-137	5.07E+00	1.38E-05	2.1E+04	5.3E-02	2.3	3.8E+03	5.7E-03
Ba-133	1.47E-04	3.99E-10	7.7E-02	2.0E-07	2.4	4.9E+02	NL
Pm-145	D	D	4.9E-06	1.2E-11	2.7	NA	NL
Pm-146	D	D	1.1E-06	2.9E-12	2.3	NA	NL
Sm-146	D	D	3.2E-13	8.2E-19	2.4	NA	NL
Sm-151	1.41E-01	3.83E-07	1.4E-01	3.5E-07	2.5	9.0E-01	1.1E-11
Eu-150	A	A	4.9E-02	1.2E-07	3.0	NA	NL
Eu-152	6.94E-08	1.89E-13	2.8E-01	7.1E-07	2.1	3.8E+06	5.5E-10
Eu-154	7.72E-03	2.10E-08	8.0E-02	2.0E-07	2.0	9.6E+00	6.2E-13
Gd-148	D	D	2.8E-07	7.2E-13	1.9	NA	NL
Gd-152	*negligible*	*negligible*	4.8E-14	1.2E-19	2.3	NA	NL
Ho-166m	A	A	1.2E-03	3.1E-09	2.6	NA	NL
Pb-210	0.0368	1.00E-07	2.0E+00	5.0E-06	1.5	5.0E+01	1.4E-08
Bi-207	1.07E-08	2.90E-14	1.9E-06	4.8E-12	2.3	1.6E+02	1.6E-12

Table 3. Comparison of the Area 5 RWMS PA Inventory and Current FY 2004 Inventory Estimate for Waste Disposed After September 26, 1988, in the SLB Disposal Units (continued)

Nuclide	FY 1993 PA Inventory (Ci)	FY 1993 PA Inventory (Ci/m^3)	Current FY 2004 Inventory Estimate			Ratio of Current Concentration to PA Concentration	Geometric Mean of the Sum of Fractions
			Geometric Mean (Ci)	Geometric Mean (Ci/m^3)	Geometric Standard Deviation		
Ra-226	0.0906	2.46E-07	2.5E+00	6.2E-06	1.6	2.5E+01	6.4E-03
Ra-228	1.46	3.98E-06	2.1E+01	5.2E-05	1.7	1.3E+01	NL
Ac-227	0.106	1.88E-07	1.0E-01	2.6E-07	1.4	1.4E+00	9.5E-09
Th-228	1.42	3.86E-06	2.3E+01	5.9E-05	1.6	1.5E+01	NL
Th-229	2.29E-06	6.22E-12	2.2E-02	5.7E-08	1.9	9.1E+03	5.1E-07
Th-230	0.606	1.65E-06	1.2E+01	3.0E-05	1.7	1.8E+01	1.2E-02
Th-232	1.89	5.13E-06	2.2E+01	5.5E-05	1.7	1.1E+01	2.5E-03
Pa-231	0.0613	1.66E-07	1.3E-01	3.4E-07	1.4	2.0E+00	8.9E-06
U-232	0.098	2.66E-07	2.3E+00	5.8E-06	2.3	2.2E+01	2.3E-05
U-233	1.28E-03	3.48E-09	9.6E+00	2.4E-05	1.9	7.0E+03	2.9E-05
U-234	534	1.45E-03	2.7E+03	6.9E-03	1.4	4.8E+00	1.3E-02
U-235	30.3	8.22E-05	1.2E+02	3.0E-04	1.3	3.7E+00	9.3E-04
U-236	0.858	2.33E-06	7.9E+01	2.0E-04	1.5	8.6E+01	6.2E-05
U-238	1.02E+03	2.76E-03	4.9E+03	1.2E-02	1.3	4.5E+00	7.8E-03
Np-237	7.91E-03	2.15E-08	1.6E+00	4.1E-06	1.4	1.9E+02	2.2E-04
Pu-236	C	C	1.2E-10	2.9E-16	9.6	NA	4.7E-17
Pu-238	127	3.45E-04	1.0E+02	2.5E-04	1.4	7.4E-01	7.9E-05
Pu-239	118	3.21E-04	1.4E+02	3.5E-04	1.4	1.1E+00	5.6E-04
Pu-240	24.7	6.72E-05	3.2E+01	8.1E-05	1.4	1.2E+00	1.3E-04
Pu-241	127	3.45E-04	8.8E+01	2.2E-04	1.3	6.4E-01	1.6E-05
Pu-242	2.34E-03	6.35E-09	1.8E+01	4.6E-05	2.3	7.3E+03	7.1E-05
Pu-244	*negligible*	*negligible*	2.2E-08	5.5E-14	2.6	NA	NL
Am-241	18.7	5.09E-05	3.1E+01	8.0E-05	1.3	1.6E+00	1.6E-04
Am-242m	D	D	5.1E-02	1.3E-07	1.7	NA	NL
Am-243	8.56E-04	2.33E-09	1.1E-02	2.8E-08	1.9	1.2E+01	1.5E-07
Cm-242	C	C	4.2E-02	1.1E-07	1.7	NA	NL
Cm-243	D	D	9.5E-04	2.4E-09	1.7	NA	NL
Cm-244	0.623	1.69E-06	6.8E+00	1.7E-05	2.3	1.0E+01	7.9E-08
Cm-245	D	D	8.4E-03	2.1E-08	2.1	NA	NL
Cm-246	D	D	1.3E-03	3.4E-09	2.2	NA	NL
Cm-247	D	D	2.2E-10	5.5E-16	1.9	NA	NL
Cm-248	6.74E-10	1.83E-15	6.9E-08	1.7E-13	1.9	9.5E+01	1.0E-12
Cf-249	D	D	8.9E-05	2.3E-10	1.8	NA	NL
Cf-251	D	D	2.0E-04	5.1E-10	1.9	NA	NL
Cf-252	C	C	7.9E-05	2.0E-10	3.0	NA	NL
Total	**3.2E+05**	**0.87**	**1.6E+06**	**4.1E+00**			**5.5E-02**

A – Assumed to be present in mixed fission products.
C – Included for completeness; short-lived nuclide that decays to long-lived parents.
D – Disposed since preparation of the PA.
NL – No waste concentration limit.
NA – Not available; nuclide not evaluated in Area 5 RWMS PA.
Negligible - Inventory less than 1E-12 Ci.

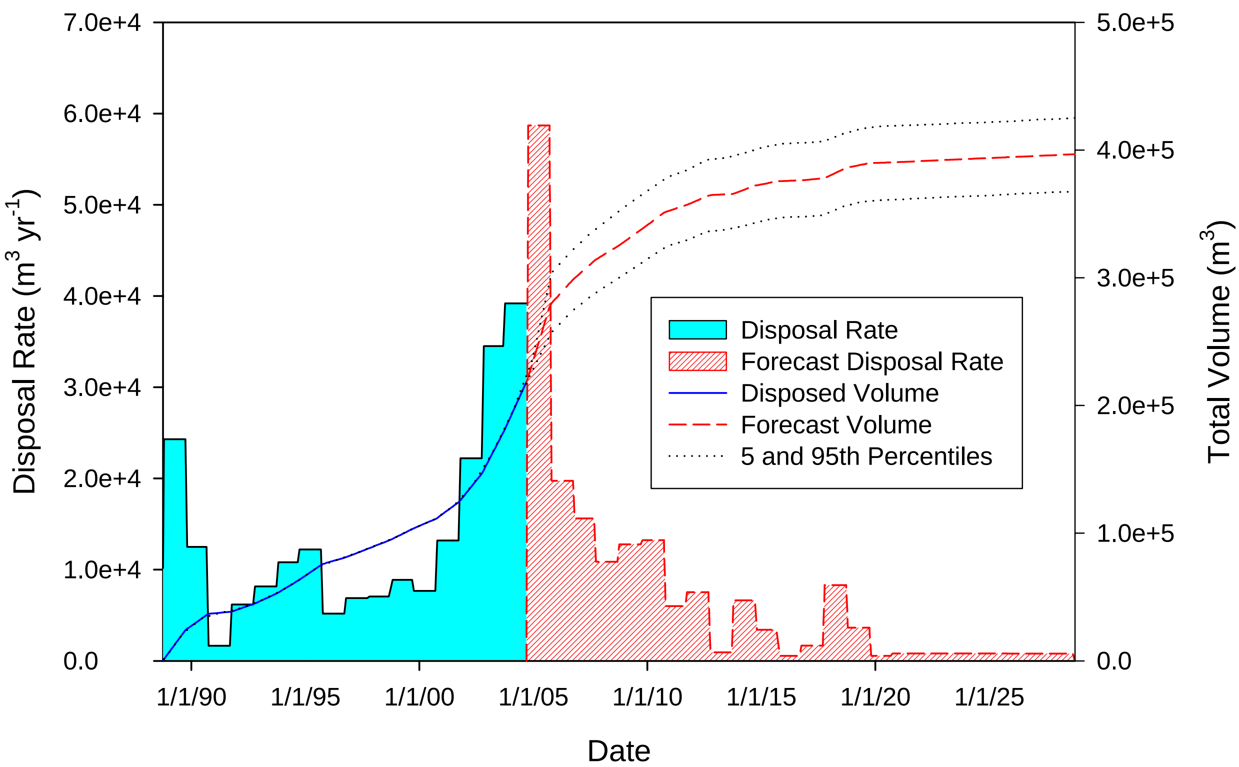

Figure 4. Volume Disposed per Year and the Arithmetic Mean of Cumulative Volume for the Area 5 RWMS SLB Disposal Units

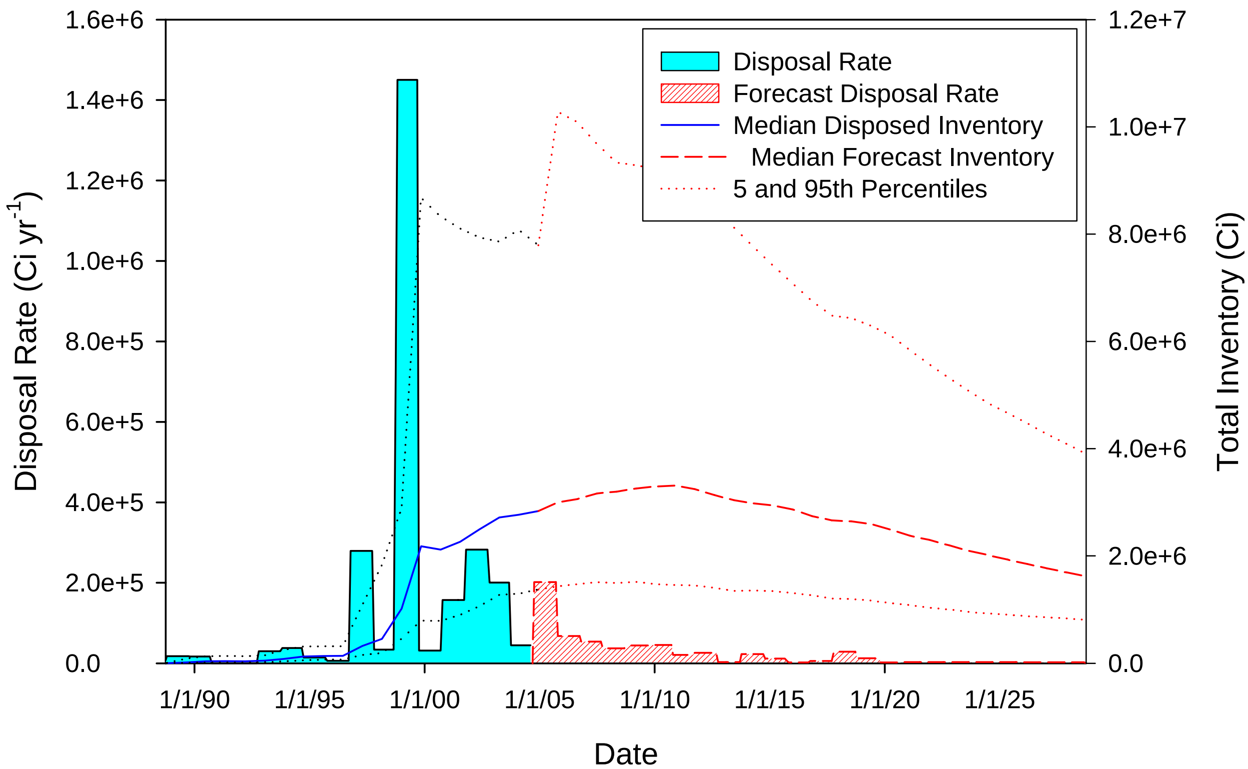

Figure 5. Activity Annual Disposal Rate and Median Inventory for the Area 5 RWMS SLB Disposal Units

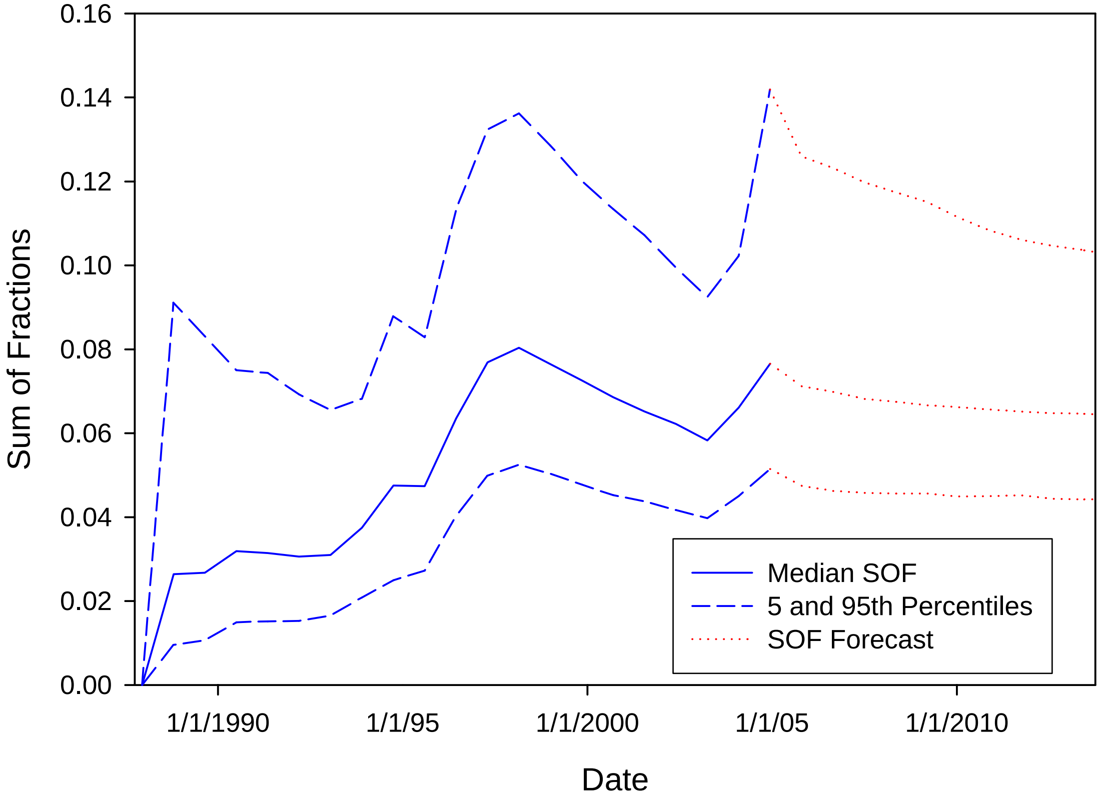

Figure 6. Median Sum of Fractions for the SLB Disposal Units at the Area 5 RWMS

Table 4. Comparison of the Area 5 RWMS PA Inventory and the Current FY 2004 Inventory Estimate for the Lower Cell of Pit 6 (P06U). Current inventory estimate is calculated from 500 Monte Carlo realizations.

Nuclide	FY 1993 PA Inventory (Ci)	FY 1993 PA Inventory (Ci/m^3)	FY 2004 Inventory			Ratio of Actual FY 2004 Concentration to PA Concentration
			Geometric Mean (Ci)	Geometric Mean (Ci/m^3)	Geometric Standard Deviation	
Sr-90	D	D	5.1E-04	1.0E-07	2.6	NA
Tc-99	D	D	2.6E-02	5.2E-06	2.6	NA
Pb-210	6.9E-01	1.2E-04	1.8E-01	3.6E-05	1.6	2.9E-01
Ra-226	1.2E+00	2.2E-04	5.1E-01	1.0E-04	1.7	4.7E-01
Ra-228	2.8E+02	5.0E-02	1.6E+02	3.1E-02	1.6	6.4E-01
Ac-227	D	D	6.5E-05	1.3E-08	1.9	NA
Th-228	2.8E+02	5.0E-02	1.6E+02	3.1E-02	1.6	6.3E-01
Th-229	D	D	1.3E-01	2.6E-05	2.1	NA
Th-230	4.3E+01	7.7E-03	3.9E+01	7.9E-03	1.7	1.0E+00
Th-232	2.8E+02	5.0E-02	1.6E+02	3.2E-02	1.6	6.5E-01
Pa-231	D	D	1.7E-04	3.5E-08	1.9	NA
U-233	D	D	4.9E+01	9.9E-03	2.1	NA
U-234	D	D	4.8E+00	9.6E-04	1.9	NA
U-235	D	D	2.6E-01	5.1E-05	2.0	NA
U-236	D	D	5.0E-03	9.9E-07	2.1	NA
U-238	D	D	6.0E+00	1.2E-03	1.9	NA
Np-237	D	D	2.3E-05	4.6E-09	2.5	NA
Pu-238	D	D	3.8E-01	7.7E-05	2.0	NA
Pu-239	D	D	9.3E-05	1.9E-08	2.1	NA
Pu-241	D	D	2.9E-01	5.9E-05	2.1	NA
Am-241	D	D	2.7E-02	5.5E-06	2.1	NA
Total	**8.8E+02**	**1.6E-01**	**5.8E+02**	**1.1E-01**		**7.3E-01**

D – Disposed since preparation of the PA.
NA – Not available; nuclide not evaluated in Area 5 RWMS PA.

Pit 13 Inventory

Pit 13 (P13U) was excavated to a depth of 7.6 m (25 ft) below grade to contain Ra-226-bearing waste. The greater depth will allow installation of a thicker cover for attenuation of Rn-222 flux. In FY 2004, a small volume of DNSC thorium nitrate waste was placed in Pit 13. The DNSC thorium nitrate is being disposed in a single 2.4-m (8-ft) layer, allowing a 7.9-m (26-ft) closure cover. To date, the DNSC thorium waste is the only waste stream specifically designated for disposal in Pit 13. The FY 2004 inventory assumes that the entire DNSC thorium nitrate waste stream will be disposed in Pit 13 (Table 5). The Pit 13 inventory is likely to change in future years as new wastes are identified for disposal in this unit.

Table 5. FY 2004 Estimate of the Pit 13 (P13U) Inventory

	Current FY 2004 Inventory Estimate		
Nuclide	**Geometric Mean (Ci)**	**Geometric Mean (Ci/m^3)**	**Geometric Standard Deviation**
Pb-210	1.0E+00	8.8E-05	1.7
Ra-226	2.2E+00	1.9E-04	1.7
Ra-228	1.4E+02	1.2E-02	1.1
Th-228	1.3E+02	1.2E-02	1.1
Th-230	3.4E+01	3.0E-03	2.4
Th-232	1.5E+02	1.3E-02	1.1
Total	**4.6E+02**	**3.9E-02**	

2.1.4 Closure

The Area 3 RWMS PA/CA assumes that the disposal units will be closed with a vegetated monolayer cover of native alluvium. The cover is assumed to be 3 m (10 ft) thick after subsidence. This was a conservative assumption consistent with closure plans for U-3ax/bl.

The Area 5 RWMS PA assumes that the site will be closed with a 2.4-m (8-ft) vegetated monolayer cover. This was a conservative assumption consistent with the operational covers that were installed when the PA was prepared. After 100 years of active institutional control, the integrity of the cover is assumed to degrade by erosion and subsidence. The Area 5 RWMS v3.0mod GoldSim model for the Area 5 RWMS assumes that a 4-m- (13-ft)-thick closure cover, consistent with the Area 5 RWMS DAS requirements, will be installed.

Closure plans remain unchanged since publication of the ICMP (BN, 2001d). The PA and CA assumptions continue to be consistent with or more conservative than closure plans. The current closure plan is to use monolayer evapotranspiration (ET) closure covers. Closure cover thickness will be delineated in specific closure plans for each disposal unit. A revised ICMP is expected in FY 2005.

2.1.5 Impact of FY 2004 Inventory Changes on the Area 5 Radioactive Waste Management Site PA Results

The current FY 2004 Area 5 RWMS inventory was analyzed using the Area 5 RWMS v3.0mod GoldSim model to assess the continuing validity of PA conclusions. The geometric mean inventory and standard deviation data listed in Tables 3 through 5 were entered into the inventory elements for the SLB units, Pit 6, and Pit 13, respectively. The disposal unit area, disposal unit volume, and waste volumes were updated with FY 2004 data. All SLB disposal units were assumed to be closed with a 4-m- (13-ft)-thick cover. The model was run assuming an approximately 250-year median period of institutional control and a 1,000-year compliance period. The results for the FY 2004 inventory are compared with a control case using the FY 1993 PA inventory.

The results for the FY 2004 SLB inventory indicate that there is reasonable expectation of compliance with the performance objectives (Table 6). The mean for the atmospheric pathway for all scenarios is less than the 10 millirem per year (mrem/yr) limit. The mean for the all-pathways compliance scenarios, the transient occupancy and open rangeland scenario, are less than the 25 mrem/yr performance objective. The resident farmer scenario is a low probability scenario analyzed to evaluate the impact of agricultural pathways. The mean for the resident farmer scenario, 0.35 mrem/yr, indicates that there is a reasonable expectation of compliance even in the unlikely event that a future resident is engaged in agriculture at the site. The resident farmer total effective dose equivalent (TEDE) is mostly attributable to ingestion of Tc-99 in food produced on site. The mean Rn-222 flux density is less than the 20 pCi/(m^2 s) performance objective. The mean of the probability weighted intruder TEDE is less than the 100 millirem (mrem) performance objective for the postdrilling and intruder-agriculture scenario. The 95th percentile of all scenarios is less than the performance objective, indicating that there is a high probability of compliance.

Table 6. Comparison of Area 5 RWMS v3.0mod GoldSim Model Results for the FY 1993 PA Inventory Estimate and the Current FY 2004 Inventory Estimate. Results are the maximum result occurring from the end of institutional control to 1,000 years after closure, except for radon flux density which is the maximum from 0 to 1,000 years after closure. All results are for a 4-m (13-ft) closure cover. Results are calculated from 2,000 Monte Carlo realizations.

Performance Objective/Scenario	Limit	1993 PA Inventory Estimate		FY 2004 Inventory Estimate	
		Mean	95th Percentile	Mean	95th Percentile
Air Pathway/Transient Occupancy (mrem/yr)	10	5.3E-5	1.5E-4	8.2E-5	1.9E-4
Air Pathway/Resident Farmer (mrem/yr)	10	2.0E-4	5.8E-4	3.1E-4	7.1E-4
Air Pathway/Open Rangeland – Cane Springs (mrem/yr)	10	1.1E-8	3.3E-8	1.8E-8	4.2E-8
All Pathways/Transient Occupancy (mrem/yr)	25	6.0E-2	1.7E-1	9.2E-2	2.0E-1
All Pathways/Resident Farmer (mrem/yr)	25	1.4E-1	4.1E-1	3.5E-1	7.1E-1
All Pathways/Open Rangeland (mrem/yr)	25	2.5E-6	8.4E-6	1.1E-5	2.7E-5
Radon Flux Density (pCi/[m^2 s])	20	3.8E-1	1.0E0	5.8E-1	1.2E0
Chronic Intruder/Agriculture (mrem) SLB	100	2.5E-1†	8.7E-1†	4.0E0†	1.9E1†
Chronic Intruder/Postdrilling SLB	100	1.7E-1‡	4.8E-1‡	2.8E-1‡	7.9E-1‡

† - Results weighted with 0.076 scenario probability
‡ - Results weighted with 0.11 scenario probability

The results for the FY 2004 Pit 6 inventory indicate that there is a reasonable expectation of compliance with the performance objectives (Table 7). The probability weighted mean intruder TEDEs are less than the 100 mrem performance objective for both intrusion scenarios. The 95th percentiles for both scenarios are less than the performance objective, indicating a high expectation of compliance.

Table 7. Comparison of Area 5 RWMS v3.0mod GoldSim Model Results for Pit 6 Using the FY 1993 PA Inventory and the Current FY 2004 Inventory Estimate. Results are the maximum result occurring from the end of institutional control to 1,000 years after closure. Results are calculated from 2,000 Monte Carlo realizations.

Performance Objective/Scenario	Limit	1993 PA Inventory Estimate		FY 2004 Inventory Estimate	
		Mean	95th Percentile	Mean	95th Percentile
Radon Flux Density (pCi/[m^2 s])	20	3.0E-1	9.4e-1	7.5E-1	1.6E0
Chronic Intruder/Agriculture (mrem)	100	1.6E-1†	5.1E-1†	8.6E0†	3.8E1†
Chronic Intruder/Postdrilling (mrem)	100	3.3E0§	1.2E0§	5.1E-1§	1.1E0§

† - Results weighted with 0.076 scenario probability.
§ - Results weighted with 0.009 scenario probability.

The results for the FY 2004 Pit 13 inventory indicate that there is a reasonable expectation that current inventory projection meets all performance objectives (Table 8). The 95th percentiles of all performance objectives are less than the performance objective, indicating that there is a high probability of compliance.

Table 8. Summary of Area 5 RWMS v3.0mod GoldSim Model Results for Pit 13 Using the FY 2004 Inventory Estimate. Results are the maximum result occurring from the end of institutional control to 1,000 years after closure. Results are calculated from 2,000 Monte Carlo realizations.

Performance Objective/Scenario	Limit	1993 PA Inventory Estimate		FY 2004 Inventory Estimate	
		Mean	95th Percentile	Mean	95th Percentile
Radon Flux Density (pCi/[m^2 s])	20	NA	NA	2.7E0	8.5E0
Chronic Intruder/Agriculture (mrem)	100	NA	NA	1.0E1	3.4E1
Chronic Intruder/Postdrilling (mrem)	100	NA	NA	2.4E1	3.5E1

NA – Inventory not evaluated in PA.

The largest differences between the FY 1993 PA inventory and the FY 2004 inventory are seen for the scenarios that include agricultural pathways. The increases for agricultural scenarios are due to the disposal of a large Tc-99 inventory in FY 2004. The Tc-99 is initially transported by liquid diffusion to soil at the base of the cover below the no-flux boundary. Once Tc-99 contamination is transported to the cover, it is available for transport to surface soils by plants and burrowing animals. The TEDEs in the intruder-agriculture scenarios for the SLB disposal units and Pit 6 increase because the intruder excavates contaminated cover soil directly. Higher TEDEs are estimated for agricultural scenarios, the resident farmer scenario and the intruder-agriculture scenario for the SLB disposal units and Pit 6, due to ingestion of Tc-99 in agricultural products produced on site. Scenarios without agricultural pathways are unaffected by the Tc-99 release. The postdrilling intruder scenario, which does include agricultural scenarios, is not strongly affected by the Tc-99 inventory because radionuclide release is dominated by the drilling event which selects all radionuclides equally.

2.2 Monitoring and Research and Development Results

2.2.1 Monitoring

Monitoring activities at the Area 3 and 5 RWMSs and at the NTS provide the data necessary to support PA and CA maintenance. The *Nevada Test Site Routine Radiological Environmental Monitoring Plan* (BN, 2003) is the basis for all NTS-wide environmental surveillance, site-specific effluent monitoring, and operational monitoring conducted by various missions, programs, and projects on the NTS. The ICMP (BN, 2001d) describes the specific monitoring programs for the waste disposal facilities at the NTS. The program for the RWMSs includes the following monitoring elements:

- Direct Radiation Monitoring
- Air Monitoring
- Radon Monitoring
- Groundwater Detection Monitoring (Area 5 RWMS only)
- Vadose Zone Monitoring
- Meteorology Monitoring
- Biota Monitoring
- Subsidence Monitoring

The following four reports, published annually, contain the monitoring results:

- *Annual Site Environmental Report (ASER)* (e.g., BN, 2004c)
- *National Emissions Standard for Hazardous Air Pollutants (NESHAP) Report* (e.g., BN, 2004d)
- *Annual Waste Management Monitoring Report* (e.g., BN, 2004e)
- *Annual Area 5 Groundwater Monitoring Report* (e.g., BN, 2004f)

The monitoring activities are summarized in Table 9.

2.2.1.1 *Area 3 Radioactive Waste Management Site*

Of particular importance to PA maintenance are the data collected from the automated vadose zone monitoring systems at the Area 3 RWMS. These data are collected to:

- Demonstrate compliance with DOE Orders 5400.1 and 435.1.
- Confirm PA conceptual model and assumptions including soil water contents and upward and downward flux rates.
- Provide added assurance to PA conclusions regarding facility performance.

Table 9. Monitoring Activities at the Area 3 and Area 5 RWMSs

Monitoring Element	Area 3 RWMS	Area 5 RWMS
Direct Radiation Monitoring	Nine thermoluminescent dosimeters (TLDs)	11 TLDs
Air Monitoring	Air particulate samples collected at four locations	Air particulates sampled at two locations; atmospheric moisture sampling for tritium at three locations
Radon Monitoring	• Radon flux measurements from waste covers (various locations)	• Radon flux measurements from waste covers (various locations)
Meteorology Monitoring	• Air temperature at 3 and 10 m (10 and 33 ft) • Relative humidity at two heights • Wind speed at two heights • Wind direction at two heights • Barometric pressure • Solar radiation • Precipitation	• Air temperature at two heights • Relative humidity at two heights • Wind speed at two heights • Wind direction at two heights • Barometric pressure • Solar radiation • Precipitation
Vadose Zone Monitoring	• Measurements of soil water content in waste disposal unit cover • Eight drainage lysimeters for water balance since 2001 • Runoff flow rate monitoring at a flume and in a nuclear subsidence crater	• Measurements of soil water content and water potential in waste disposal unit covers • Measurements of soil water content in waste disposal unit floor • Two weighing lysimeters (vegetated and bare) for water balance since 1994 • Runoff monitoring at a flume
Soil Gas Moisture Monitoring for Tritium	None	• Soil gas moisture sampling for tritium at nine sampling ports at depths from 3 to 36 m (10 to 120 ft) at GCD-05U
Biota Monitoring	Sampling vegetation for tritium	Sampling vegetation for tritium
Groundwater Monitoring	None	Resource Conservation and Recovery Act (RCRA) detection monitoring at three wells
Subsidence Monitoring	Routine inspection of operational covers	Routine inspection of operational covers

- Test the PA performance objective of protecting groundwater resources by demonstrating negligible infiltration of precipitation into waste zones.

- Detect changing trends in performance.

- Establish baseline levels for long-term monitoring.

- Comply with the Nevada Division of Environmental Protection (NDEP) negotiated requirements for the closure of U-3ax/bl.

Three locations in Area 3 are instrumented with vadose zone monitoring sensors: (1) the closure cover of U-3ax/bl, (2) subsidence crater U-3bw, and (3) the drainage lysimeter facility constructed in January 2001 (Figure 7). The mixed-waste disposal unit U-3ax/bl was closed under the RCRA, subject to NDEP oversight. NNSA/NSO obtained a groundwater monitoring waiver from NDEP, which waives the requirements of groundwater monitoring under Title 40 CFR 264 or 265 at the Area 3 RWMS. Instead of groundwater monitoring, monitoring of soil-water content using time-domain reflectometry (TDR) in the U-3ax/bl closure cover was negotiated. TDR is a widely used and established technology.

Figure 7. Monitoring Stations at the Area 3 RWMS

TDR probes were installed at four locations and eight depths in the U-3ax/bl cover in 2001, as described in the closure plan (DOE, 2000b) and closure report (NNSA/NSO, 2001). The Area 3 RWMS drainage lysimeter facility, funded by the Accelerated Site Technology Deployment program under the DOE Office of Science and Technology, evaluates the performance of the monolayer-ET covers in arid regions. The facility consists of eight drainage lysimeters. Each lysimeter is 3 m (10 ft) in diameter and 2.4 m (8 ft) deep, with a sealed bottom that allows direct measurement of drainage. TDR probes for water content and heat dissipation probes (HDPs) for water potential monitoring are installed throughout each lysimeter's profile.

The lysimeters are designed to evaluate landfill cover performance in response to differing surface treatments. Two of the lysimeters have bare covers, two are vegetated with native species, and four are vegetated with invader species. Beginning October 2003, the south row of lysimeters (surface treatments include: one bare cover cell, one native vegetation cell, and two invader vegetation species cells) have been irrigated to effectively produce a three times background precipitation treatment. This design will be used to evaluate the performance of monolayer-ET covers under enhanced precipitation conditions.

HDPs were installed in the floor of the empty subsidence crater U-3bw to a depth of 4 m (13 ft) in December 1998, although the two deepest sensors (2.5 and 4 m [8.2 and 13 ft]) have since failed. The sensors were installed to monitor depths of infiltration following rainfall and enhanced runoff collection due to the increased catchment area of the subsidence crater. In addition, a 3-m (10-ft) meteorology tower and a neutron logging access tube were installed at the floor of U-3bw to collect a variety of data to characterize the dynamic water balance of a typical subsidence crater used for waste disposal at the Area 3 RWMS.

The expected life span of these automated vadose zone monitoring systems is unknown. With routine maintenance of datalogger systems at the ground surface, and occasional replacement of failed components, these systems should last for decades because TDR probes are not expected to corrode for decades. The expected life span of HDPs is unknown, although several probes have failed during current monitoring studies. New and improved vadose zone monitoring sensors and technologies will be considered and implemented as they become available.

2.2.1.2 Area 5 Radioactive Waste Management Site

Two weighing lysimeters were installed about 400 m (1,312 ft) southwest of the Area 5 RWMS in 1994. The lysimeters consist of soil tanks with a volume of 16 m^3 (565 ft^3) mounted on a sensitive scale. The top of the soil tank is flush with the ground surface, and access to the side of the soil tank is provided through an underground entry. One lysimeter was revegetated with native shrubs, whereas the other was kept bare to simulate a nonvegetated waste cover. The Area 5 RWMS lysimeters are currently instrumented with TDRs and HDPs at depths ranging from 15 to 180 centimeters (cm) (6 to 70 inches [in.]). The sensitive scale (loadcell) is also connected to a datalogger which provides extremely accurate measurements of weight changes.

The Area 5 RWMS weighing lysimeter facility has been in continuous operation since March 1994, providing detailed measurements of the surface water balance components including soil-water redistribution, evapotranspiration, bare-soil evaporation, total soil water storage, and drainage. This facility is considered to be a cornerstone of support for assumptions made in the Area 3 and Area 5 RWMS PAs, including confirmation of no downward pathway. In addition, this facility provides data for calibration and verification of flow models, important tools for modeling of radionuclide transport. This facility has also provided data to justify and evaluate the performance of other NTS closure covers (DOE, 2000b).

Installation of automated vadose zone monitoring systems was initiated in 1998 at the Area 5 RWMS with water content sensors (TDR probes) and temperature sensors buried 1.2 m (4 ft) beneath the open pit floors of Pit 3 (P03U) and Pit 5 (P05U). In 1999, TDR probes were installed in the operational cover of Pit 3 (P03U) at two locations (Figure 8), at depths ranging

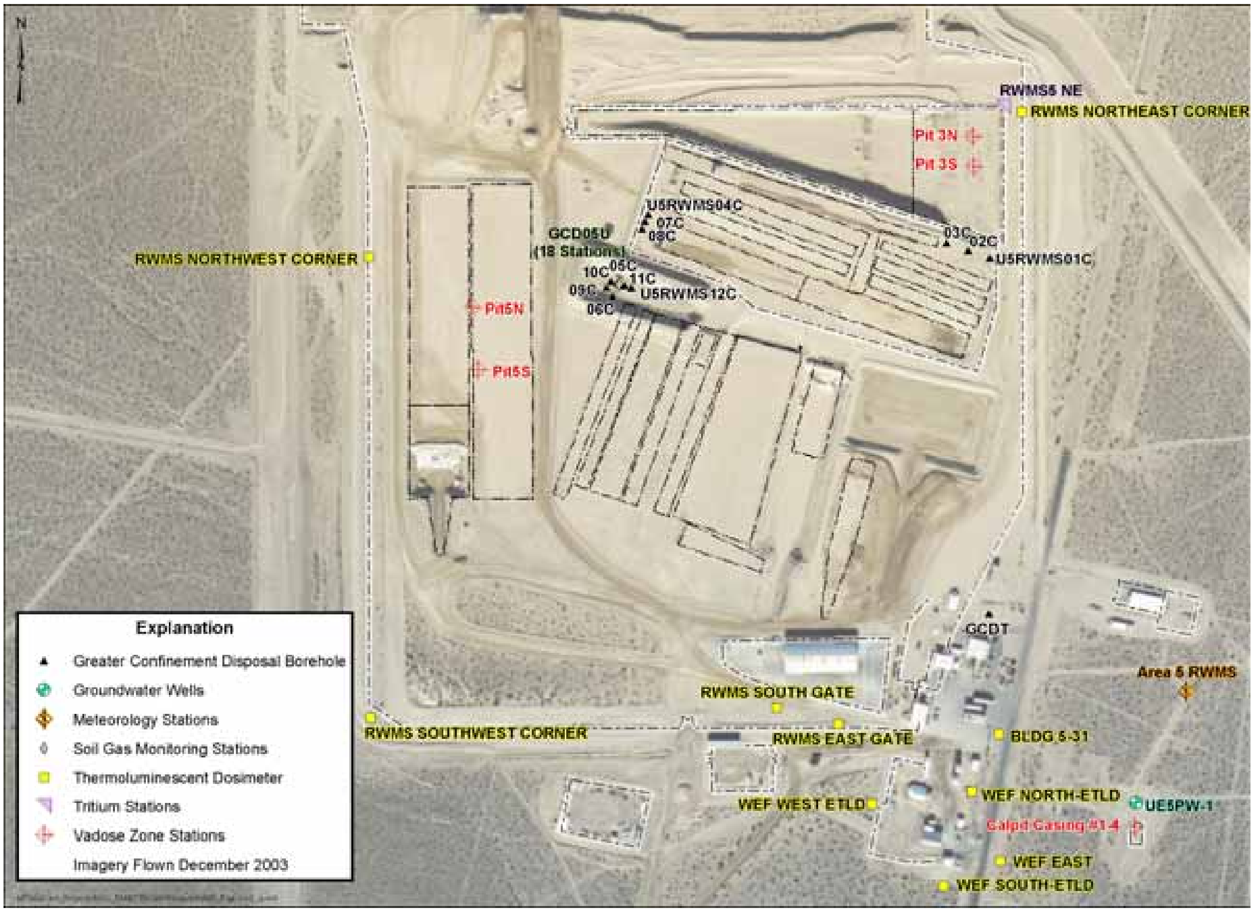

Figure 8. Monitoring Stations at the Area 5 RWMS

from 10 to 180 cm (4 to 71 in.). In 2000, TDR probes and temperature sensors were installed in the operational covers of Pits 4 (P04U) and 5 (P05U) at depths ranging from 15 to 180 cm (6 to 71 in.), and HDPs were installed in the operational cover of Pit 5 (P05U) at those same depths. Installation of additional HDPs at locations instrumented with only TDR is scheduled for FY 2005.

Sensors are connected to dataloggers that automatically collect and store data, which are downloaded by telephone links or wireless phone. The datalogger station for the Pit 3 (P03U) floor sensors was discontinued in January 2002 to accommodate waste disposal operations.

2.2.1.3 *Monitoring Results for 2003*

The 2003 calendar year review of the monitoring data indicates that the assumptions, conceptual models, and conclusions of the PAs are consistent with monitoring results. Vadose zone monitoring results indicate that rainwater falling on the Area 3 and Area 5 RWMSs and adjacent lysimeter sites infiltrated approximately 0.6 m (2 ft) into the alluvium before being returned to the atmosphere by evapotranspiration.

Rainfall at Area 5 for 2003 was slightly above the long-term average totaling 154 illimeters (mm) (6.1 in.) while Area 3 received slightly less than average precipitation totaling 150 m (5.9 in.). Potential evapotranspiration was estimated to be 1,700 mm (67 in.) and 1,800 mm (71 in.) in 2003 for Areas 3 and 5, respectively.

Drainage from the bottom of the Area 5 weighing lysimeters, in operation since 1994, still has not occurred. Soil-water storage in the bare-soil lysimeter continues to be greater than the vegetated lysimeter and drainage may eventually occur from the bottom of the bare-soil lysimeter (Levitt et al., 1999; Nichols, 1987).

The exposure rates at the RWMSs appear to be lower inside, or at the boundary, compared with that outside the RWMSs' perimeters. This is likely due to the presence of radionuclides released from historical testing distributed throughout the area around the RWMSs and clean soil used inside the RWMSs to cap waste pits (BN, 2004c).

Airborne tritium is slightly elevated at the northeast sampling points at the Area 5 RWMS, but is less than any level of concern for the public. Biota monitoring was not conducted in 2003.

Air particulate monitoring results at the Area 3 RWMS indicate that elevated levels of plutonium-239 plus plutonium-240 (Pu-239+240) are present. These levels, however, are consistent with airborne Pu-239+240 detected in nearby soil contamination areas created by nuclear weapons tests. The airborne Pu is most likely resuspended from contaminated soil sites throughout Yucca Flat. The mean result for 2003 (9.0E-17 Ci/m^3) is less than any level of concern for the public. The monitoring results are less than the CA model result of 2E-16 Ci/m^3 for resuspension of Pu from contaminated soil sites in Yucca Flat.

Radon-222 flux density was measured at numerous grid points on Pit 1 (P01U) within the Area 5 RWMS and on U-3ax/bl within the Area 3 RWMS. All results were similar to background and significantly less than the 20 pCi/(m^2 s) performance objective limit for radon flux density.

Groundwater detection monitoring at three wells at the Area 5 RWMS continues to support PA assumptions and models (Figure 9). No groundwater contaminants have been detected in the uppermost aquifer.

Subsidence has been formally monitored since 2000. Subsidence occurs most commonly in recently filled disposal units. Subsidence events are most common along the edges of trenches, where thick soil backfill may not be completely compacted. Subsided areas are repaired.

2.2.2 Research and Development

The PA/CA Maintenance Plan calls for annual reviews of R&D activities relevant to the PA. Results of both on-site and off-site R&D activities (e.g., those performed at other DOE sites, the National Laboratories, the Desert Research Institute, and academic institutions) provide the data necessary to manage uncertainty in conceptual models, mathematical models, model parameters, and evaluation scenarios of the PA and to assure continuing adequacy of the PA.

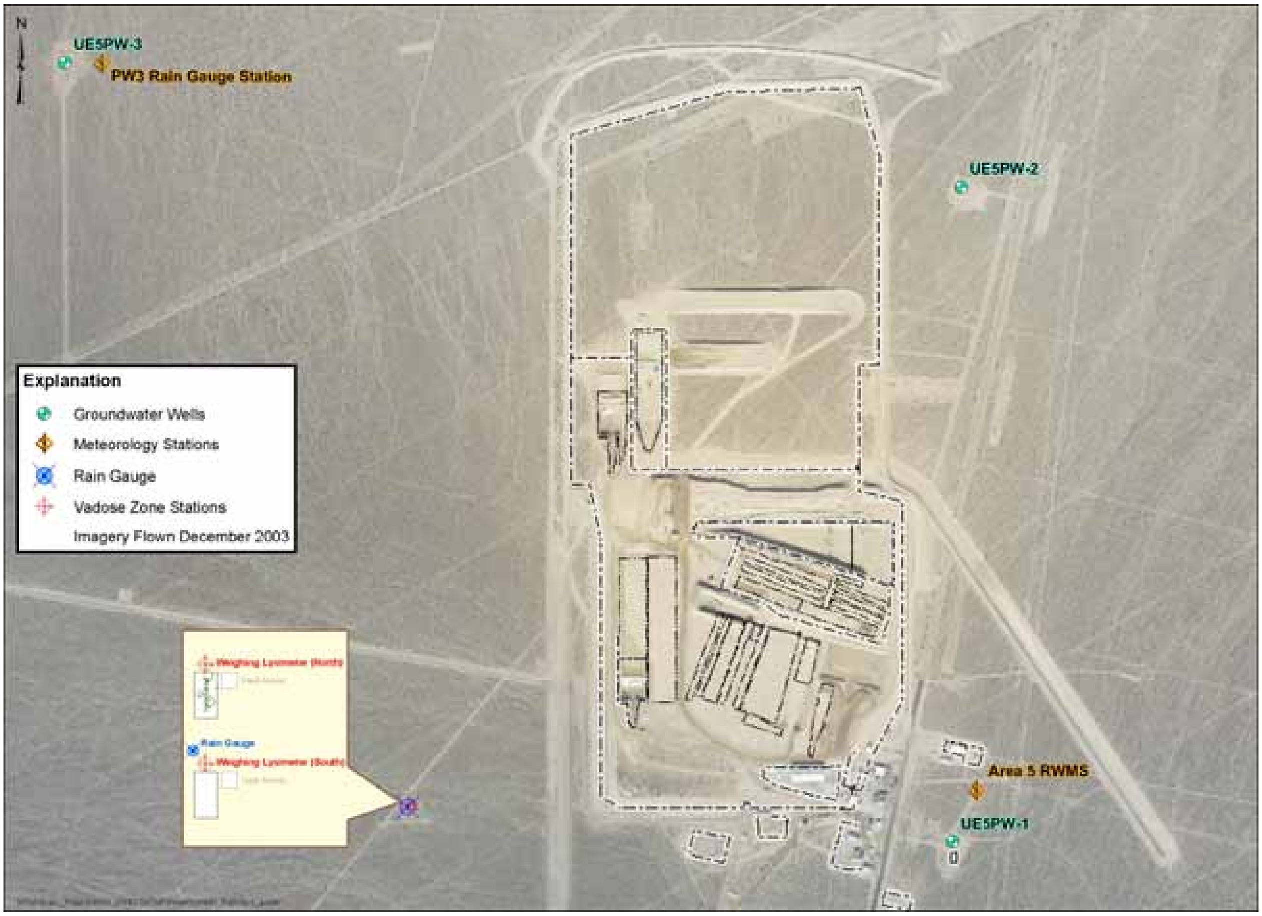

Figure 9. Location of the Area 5 RWMS Pilot Wells and Weighing Lysimeters Facility

The DASs require NNSA/NSO to address all secondary issues (e.g., consistency of models and parameters between the Area 3 and 5 RWMSs) noted during the PA/CA reviews as part of the maintenance program. R&D is the mechanism for NNSA/NSO to address these issues and manage uncertainty. R&D funded by the Technology Development Division of Environmental Management at NNSA/NSO (which annually compiles R&D needs of various projects, prioritizes these needs, and selects the activities for funding) will also aid the PA maintenance program needs.

2.2.2.1 *FY 2004 Research and Development Activities*

The major R&D efforts undertaken in FY 2004 were the continuation of the development of the Area 5 RWMS GoldSim model and the development of GoldSim inventory models for the Area 3 and Area 5 RWMSs. The impacts of model development, inventory changes, and the change of the compliance period from the 10,000-year to the 1,000-year period adopted in DOE Order 435.1 on the expected performance of the Area 5 RWMS are summarized in Section 2.1.5. Other significant activities were the evaluation of new waste streams considered for disposal at the NTS, the evaluation of the upward liquid water flux for the Area 3 RWMS, continuation of the field work characterizing biotic activity near the Area 5 and Area 3 RWMSs, and radon laboratory diffusion experiments using soil samples from Area 5 RWMS. These are summarized below.

Area 5 Radioactive Waste Management Site GoldSim Model Development

The development of the Area 5 RWMS GoldSim model continued in FY 2004 using the GoldSim platform (GoldSim Technology Group, 2004). The model development included continuous updating of model algorithms and parameters values and further streamlining model structure and solution algorithms for faster model execution, and model documentation.

Version 3.0mod of the model was evaluated for suitability for use in decision making. The model has been tested and reviewed through iterative stages of model development and was found to be acceptable for specific programmatic uses based on the following:

- Benchmarking of Area 5 RWMS GoldSim model version 1.0 against the LFRG accepted PA results for the Area 5 RWMS (Shott *et al*., 1998)

- Multiple stages of detailed examination of model results, multivariate analyses of model output, and sensitivity analyses of model output

- Maintenance of a model change log through multiple stages of development

- A comparison of the radon flux results for v2.301 with results obtained using Nuclear Regulatory Commission (NRC) Regulatory Guide 3.64 methods (NRC, 1989; Rogers and Nielson, 1991).

All evaluations summarized in this report were based on v3.0mod of the model. The modeling work continued through the end of the fiscal year, resulting in Version 3.0mod of the Area 5 GoldSim model. The major model improvements implemented in FY 2004 includes the following:

- Reconfiguring the model structure for efficiency and addition of new modules for future disposal cells of variable geometry and closure cap requirements

- Updating disposal geometry input parameters using revised data from disposal operations

- Restructuring the model to couple the animal and plant transport of radionuclides with other processes

- Updating the inventories and separating the total closure inventory into pre-1988, post-1988, and future forecasted inventory categories so that model could be used to evaluate performance under current as well as future closure conditions

- Updating animal and plant transport parameters with field data

- Implementing the capability to use waste-specific radon emanation factors

- Updating the air dispersion model with recently obtained meteorological data from Frenchman Flat

Modeling of Upward Liquid Water Flux

An evaluation of the upward liquid flux rate for the Area 3 RWMS was undertaken in FY 2004 using the Finite-Element Heat and Mass-Transfer (FEHM) code from Los Alamos National Laboratory (Zyvoloski et al., 1997). The modeling methodology was the same as that used for the Area 5 RWMS flux estimates made in FY 2003. Advective and diffusive liquid and vapor fluxes were modeled under non-isothermal conditions. The FEHM model was coupled with the PEST parameter estimation software to obtain optimized parameter estimates, parameter uncertainty estimates, and correlations in the parameter estimate uncertainties. Then, 1,000 Monte Carlo simulations using the parameter correlation matrices were conducted to generate ranges of liquid and vapor fluxes at all locations in the vertical profile of the model. A draft report was submitted for review and the final report is expected in FY 2005.

Tritium Transport Modeling

Modeling of tritium diffusive transport from GCD borehole 5 at the Area 5 RWMS using the FEHM code was attempted but failed to provide an estimate of a site-specific diffusion coefficient for tritium. It was expected that by calibrating the diffusion model to the long-term measurements of tritium concentrations at various depths in the borehole, the tritium diffusion coefficient could be estimated. The high uncertainty of the tritium source term, however, did not allow a reliable estimate.

Field Characterization of Biotic Activity

Field characterization of biological activity at the Area 5 and Area 3 RWMSs continued in FY 2004. The primary focus of field biology activities was to characterize the nesting geometry of deep-burrowing ant species in Area 5 and Area 3 RWMSs. These ant species include *Pogonomyrmex rugosus* (both RWMSs), *Messor pergandei* (Area 5 RWMS only), and *Myrmecocystus mexicanus* (Area 3 RWMS only). Three field trips for a total duration of five weeks were conducted to excavate the entirety of 19 *P. rugosus* nests (10 in Area 5 and 9 in Area 3), 13 *M. pergandei* nests, and 8 *M. mexicanus* nests. Excavations were conducted to investigate the maximum burrowing depth, nest volume, and three-dimensional structure of chambers and galleries. With a better understanding of nesting geometry, as well as burrowing intensity by depth, improvements can be made in GoldSim modeling of pedoturbation of soils by ants. Perennial grass productivity was measured by collecting the living aboveground tissues of perennial grasses at eight quadrats. These tissues will be weighed for dry weight in order to calculate net annual primary production at the Area 3 and 5 RWMSs.

Rn-222 Effective Diffusion Coefficient

Radon-222 diffusion modeling is extremely sensitive to the effective diffusion coefficient. The Area 3 and Area 5 RWMS PAs have used predictive models published in the literature to estimate this parameter. In FY 2004, soil sample were collected from soil borrow used to construct closure covers at the Area 5 RWMS. The samples were sent to the laboratory for measurement of Rn-222 effective diffusion coefficient at representative water contents and compaction. In FY 2005, the measurement results will be compared to the currently assumed values and a new predictive model for Area 5 soil will be developed if necessary.

2.2.2.2 *Current Research and Development Activities*

The current R&D activities include the following:

- Continuing development of the Area 5 GoldSim model: model development in FY 2005 will include updating of parameter distributions as more information or data become available, development of site-specific receptor scenarios, inclusion of the CA terms, and introduction of decision analysis components so that the model can be used to support future disposal, closure, and monitoring decisions, as well as institutional control decisions. Version 3.1 of the Area 5 GoldSim model will focus on inclusion of site-specific receptor scenarios and updating of parameters. Version 4 is expected to include the CA terms, and the decision analysis components are planned for Version 5. Updating of parameter distributions can be anticipated from two ongoing research activities: field activities that are being continued to improve distributions of biotic parameters, and radon experiments that are aimed at reducing uncertainty in the radon model. The ongoing monitoring program can also support updating of some model parameters.

- Quality assurance: Version 3.1 of the Area 5 GoldSim model, as well as the subsequent versions, will be validated following quality assurance procedures developed by Neptune and Company, the main developer of the PA codes.

- Performing sensitivity analyses for the Area 5 RWMS PA GoldSim model: Uncertainty and sensitivity analysis will be performed on the Area 5 GoldSim model for each new version. The sensitivity analysis results have been used to determine which components of the model require further attention. For example, the biotic components continue to be important, and the recent addition of radon emanation has uncovered the need to further refine this parameter. In all sensitivity analyses to date, the inventory remains as the major source of uncertainty.

- Further evaluation of the impact of the changes on the Area 5 RWMS PA results.

- Development of an Area 3 RWMS GoldSim model: The Area 3 RWMS GoldSim model is planned for development after completion of Version 4 of the Area 5 RWMS GoldSim model. Version 4 of the Area 5 RWMS model will serve as the basis for the Area 3 RWMS model. The anticipated differences between the Area 3 and Area 5 models have already been documented and investigated. Important differences include different climatic conditions, soil types, geologic structure, disposal unit design, and inventories. Decision analysis components will be added in conjunction with Version 5 of the Area 5 RWMS GoldSim model.

- Performing sensitivity analyses for the Area 3 RWMS GoldSim model.

- Evaluation of the impact of Area 3 RWMS GoldSim model changes on PA results.

- Revision of inventory estimates using the GoldSim inventory models for FY 2005 disposals.

- Continuation of field characterization of biotic processes.

- Laboratory measurements of the radon effective diffusion coefficient in Area 5 cover materials.

- Modeling of upward liquid water flux modeling for the RWMSs: The Area RWMS 3 upward flux report will be finalized to include reviewer comments and suggestions.

2.2.2.3 *FY 2006 Research and Development Activities*

Activities beyond FY 2005 will focus on:

- Updating the model as more data or information become available

- Using the model to support future disposal, closure, monitoring and research decisions

- Using sensitivity analysis to simplify the Area 5 GoldSim model

- Abstracting the model into a less complex form so that decision analysis and prediction can be performed in near-real time

- Evaluating new and revised waste streams as they are proposed

The development of the GoldSim models and their integration into a decision analysis framework will continue in FY 2006. The decision module will be constructed either in the GoldSim model itself or as a separate post-processing module that will process the model-generated data.

The GoldSim models will continue to be used to evaluate PA results using revised closure inventories that include current disposals. Based on the results of the sensitivity analyses undertaken in FY 2005, new studies will be undertaken in FY 2006 to reduce the uncertainty of sensitive model parameters. The field activities started in FY 2005 will continue in FY 2006 as discussed previously.

2.2.2.4 *Research and Development Activities beyond FY 2006*

The long-term goal of the maintenance program is to reduce uncertainty in exposure scenarios (member of public and inadvertent human intrusion), conceptual models, mathematical models, and model parameters. Reduction of uncertainty and associated improvement of the PA model will be accomplished through special studies. In addition, future R&D activities include the development of new waste concentration limits, evaluation of waste forms and containers (both engineering and geochemical properties) for disposal, the refinement of closure cover designs, and evaluation of institutional control and land-use options for optimizing disposal operations.

2.3 Summary of Changes

In FY 2004, changes in site inventories, the Area 5 RWMS disposal facility design, the Area 5 RWMS PA model, and site characterization data were noted. Updated closure inventories were estimated that indicate a large increase in the inventory of Tc-99 at the Area 5 RWMS. The Area 3 RWMS inventory has increased significantly since preparation of the PA, but still remains less than that of the Area 5 RWMS. Deeper disposal units were developed at the Area 5 RWMS for disposal of Ra-226 bearing wastes. One of the deeper disposal units, Pit 13, began to receive a thorium waste stream similar to other thorium waste disposed in the past. Development of the Area 5 RWMS GoldSim model continued in FY 2004 with release of v3.0mod. New site characterization data were developed in FY 2004 including new estimates of the upward liquid water flux at the Area 3 RWMS and additional biotic characterization data. The need to update model parameters based on these new data will be assessed in FY 2005 when data reports are finalized. Monitoring results continue to support PA assumptions and conceptual models.

2.4 Recommended Changes

A number of significant changes have occurred since preparation of the Area 5 RWMS PA including:

- Development of the probabilistic Area 5 RWMS GoldSim model

- Preparation of a revised closure inventory with 27 long-lived radionuclides that exceed the 95th percentile of the PA inventory

- Reduction of the compliance period from 10,000 years to 1,000 years

Analysis of the current inventory data with the Area 5 RWMS v3.0mod GoldSim model indicates that there is still a reasonable expectation of compliance with all performance objectives. Nevertheless, the significance of the changes that have occurred since preparation of the Area 5 RWMS PA suggests that a revision of the PA and an updating of PA results are appropriate at this time. A revised Area 5 RWMS PA is scheduled for completion in FY 2005.

The most significant change occurring at the Area 3 RWMS is the increasing inventory. The Area 3 RWMS inventory and inventory concentration are still less than the Area 5 RWMS inventory. Quantitative evaluation of the inventory changes should be performed in FY 2005 when a probabilistic Area 3 RWMS PA model is available.

3.0 COMPOSITE ANALYSIS

3.1 Assessment of the Adequacy of the Composite Analysis

The reviews of the Area 3 and Area 5 RWMS inventories, environmental restoration activities at the NTS—those impacting the sources of residual radioactive materials considered in the CAs, the results of the monitoring and R&D activities, and land-use planning—show that the assumptions in the CAs have not changed. Therefore, the results of the CAs remain valid, and revision of the CAs is not necessary at this time.

Of particular importance are the conservative assumptions made in the CAs about institutional control and future land use. Although NNSA/NSO has been considering controlling the NTS boundaries in perpetuity, the CAs assume that, after an institutional control period of 250 years, the public will have access to lands within 100 m (330 ft) of the disposal sites. Therefore, dose scenarios evaluated in the CAs provide conservative bounding estimates of future performance.

3.2 Source Terms

In addition to the PA inventories, the CAs evaluated the pre-1988 inventory of the RWMSs and other sources of residual radioactive materials from the ER sites that interact with the RWMSs. The ER sources considered in the CAs remain unchanged. There has been no deletion of the sources of residual radionuclides considered in the CAs. There have been no new sources identified, and there has been no new information that would reduce the uncertainty of the sources considered in the CAs. The review results for the RWMSs and ER sources are summarized below.

3.2.1 Radioactive Waste Management Sites

There have been no significant changes to the pre-1988 waste inventories evaluated in the CAs. The U-3ax/bl disposal unit was operationally closed in 1987, and a final closure cover was placed in FY 2001. No additional data on this unit's inventory have become available. Therefore, the inventory estimated in the CA is assumed to still be valid. The Area 5 Inventory GoldSim model underwent major revision in FY 2004. The estimate of the pre-1988 inventory has changed slightly relative to the CA inventory due to changes in database records, changes in scaling factors for mixed fission products, and inclusion of radioactive decay during the operational period in the model. The most significant inventory changes are due to the inclusion of radioactive decay in the model. Inventory changes due to radioactive decay are unlikely to impact CA results because the short-lived nuclides affected by decay have little impact on CA results. Therefore, the pre-1988 waste contribution to the CA dose is not expected to be significantly different. The closure inventories of the disposal cells for the PAs have been reevaluated considering new estimates of future disposals. However, these changes are judged not to impact the results of the CAs.

3.2.1.1 *Closure*

The Area 3 RWMS PA/CA assumes that the site will be closed with a vegetated monolayer cover of native alluvium (Shott et al., 2000). The cover is assumed to be 3 m (10 ft) thick after subsidence.

The U-3ax/bl disposal unit was closed in FY 2001 with the installation of a monolayer alluvium cover. The existing 2.7-m (8.9-ft) operational cover was supplemented with an additional 0.3 m (1 ft) of soil and sloped to promote drainage off the cover. The installed cover is generally consistent with the CA assumption of a 3-m (10-ft) monolayer cover.

The Area 5 RWMS CA makes similar, but slightly less conservative assumptions (BN, 2001a). The CA assumes that the cover is maintained for 100 years and public access is restricted for 250 years. The cover is assumed to be a monolayer alluvium cover, 2 to 6 m (6 to 20 ft) thick.

The ICMP remains consistent with the PA assumptions for the U-3ah/at and U-3bh units at the Area 3 RMWS and the units in the Area 5 RWMS (BN, 2001b). The current plan is to construct monolayer-ET closure covers. Closure cover thickness will be specified in the specific closure plan for the disposal unit. Current closure plans remain consistent with PA and CA assumptions.

3.2.2 Underground Testing Areas

The CAs for the Area 3 and Area 5 RWMSs assumed that land-use controls can control exposure of the public to groundwater contamination from UGTAs on the NTS. There are still no plans to release lands within either Yucca Flat or Frenchman Flat where the Area 3 and Area 5 RWMSs are located, respectively. The results of the flow and transport model that will aid in determining the 1,000-year groundwater contaminant boundaries for Yucca Flat are not expected until FY 2020. The Area 3 RWMS CA assumptions are still consistent with current plans for the Yucca Flat CAU.

Site characterization studies are underway to estimate the extent of groundwater contamination from the Frenchman Flat UGTA. The results of the radionuclide transport model are expected by FY 2009. Land-use controls are still likely to be adequate to control exposure of the public to contaminated groundwater in Frenchman Flat. Therefore, the Area 5 RWMS CA is still consistent with the plan to manage the Frenchman Flat UGTA.

3.2.3 Soil Sites

The CAs assume that the NTS Soil Sites will not be remediated. No Soil Sites have been characterized or remediated since completion of the CAs. The closure of Soil Sites is currently awaiting a regulatory determination of appropriate cleanup levels. Therefore, the results of the CAs remain valid and provide a conservative bounding estimate of site performance.

3.2.4 Industrial Sites

The CAs assume that the impact of the Industrial Sites is insignificant compared with the Soil Sites. No Industrial Sites have been characterized or remediated that impact interacting sources in Frenchman Flat or Yucca Flat since preparation of the CAs. Therefore, the CA assumptions remain unchanged.

3.3 Monitoring and Research and Development Results

3.3.1 Monitoring

The monitoring activities discussed in Section 2.2.1 also pertain to the CAs. As discussed in Section 2.2.1, the results of environmental monitoring across the NTS are reported annually in the ASER and NESHAP reports (BN, 2004c, 2004d). Plutonium-239+240 are the only man-made radionuclides routinely detected at the Area 3 RWMS at slightly elevated levels, the sources being the former atmospheric testing sites throughout Yucca Flat, including ground zeros in the immediate vicinity of the RWMS. The mean result for 2003 was 1.9 E-16 Ci/m^3. This is consistent with previous results and the CA model estimated Pu-239+240 concentration of 2E-16 Ci/m^3. Results of the CA resuspension and dispersion models for plutonium are consistent with environmental monitoring results.

3.3.2 Research and Development

There have been no R&D activities in FY 2004 whose results might impact the CA results and conclusions. The discussions of the R&D activities in Section 2.2.2 for PAs are also pertinent for CAs.

The release and transport of radionuclides from the disposal sites and resuspension of radionuclides from the surface soils into the atmosphere are modeled for the CA using the same models developed in the PA. In the CAs, the Industrial Source Complex (ISC) model was used to evaluate the spatial distribution of the concentration of radionuclides in the atmosphere as a result of resuspension of radionuclides from the disposal units, as well as all other pertinent radionuclide sources. The ISC model was also used to evaluate the deposition of airborne radionuclides on the ground. Aside from updating the ISC model results (air concentration source strength ratios) with recent meteorological data from Frenchman Flat, no further revisions were performed.

3.4 Summary of Changes

There have been no changes in FY 2004 that affect the conclusions of the CAs, as indicated by reviews of the disposal unit closure inventories, estimated inventories of the ER sources of residual radionuclides, the progress of the ER cleanup projects, land-use planning, and the results of the monitoring and R&D activities. Therefore, the results of the CAs remain unchanged.

Although differences in individual radionuclides are observed between the CA inventories and the new estimates, they are judged not to impact the results of the CAs.

3.5 Recommended Changes

There are no recommended changes to the ER programs that could affect the CAs. Likewise, there are no recommended changes to the monitoring and R&D activities. There have been no significant changes that would impact CA results and conclusions. Therefore, the Area 3 and Area 5 RWMS CAs are assumed to still be adequate and revision is not required at this time.

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