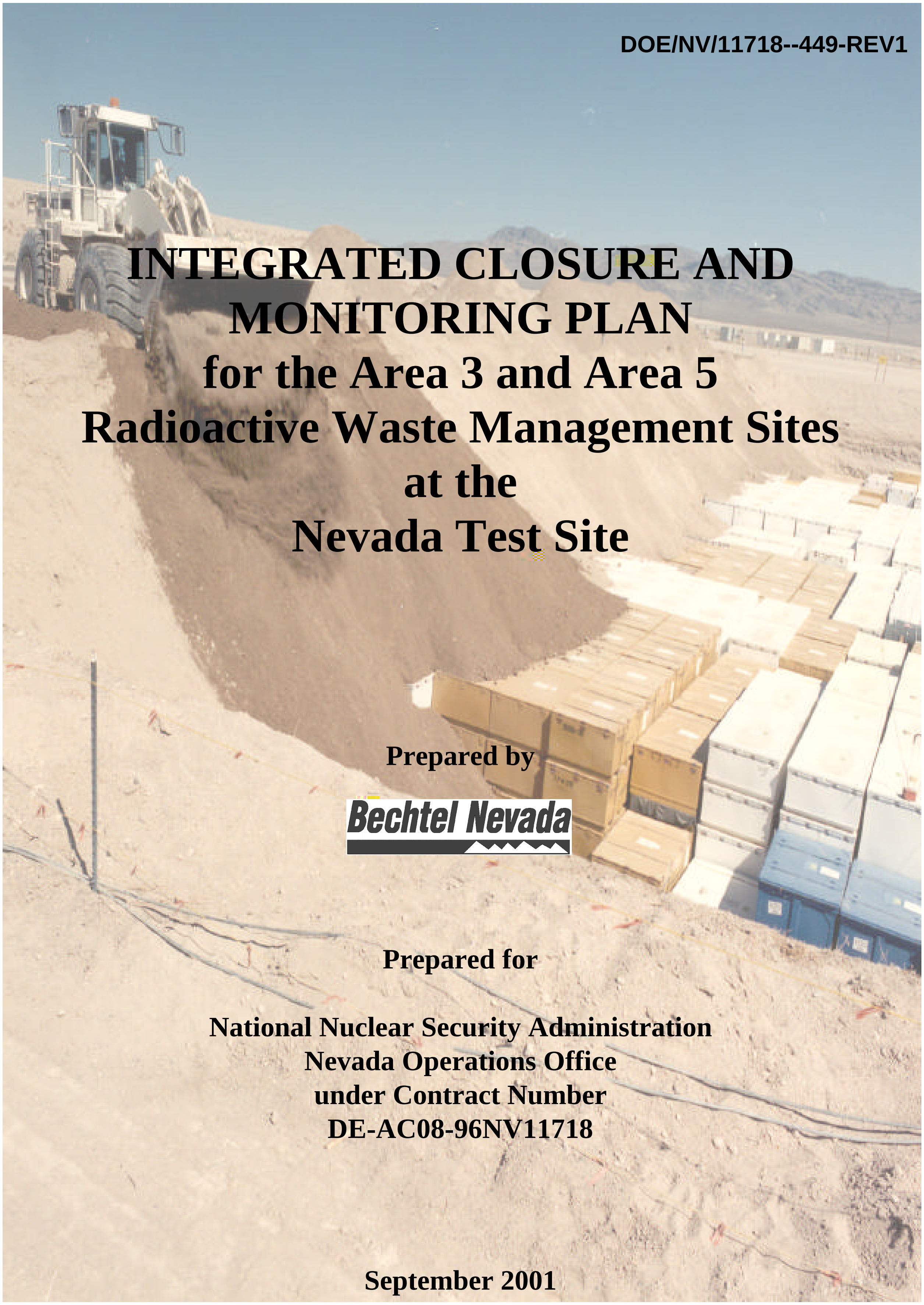

DOE/NV/11718--449-REV1

INTEGRATED CLOSURE AND MONITORING PLAN for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site

Prepared by

Bechtel Nevada

Prepared for

National Nuclear Security Administration
Nevada Operations Office
under Contract Number
DE-AC08-96NV11718

September 2001

DISCLAIMER NOTICE

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for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site

Approved by: KA Carlson Date: 11/21/01

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ACRONYMS and ABBREVIATIONS

ASER	Annual Site Environmental Report
ASTD	Accelerated Site Technology Deployment
BEIDMS	Bechtel Environmental Integrated Data Management System
BN	Bechtel Nevada
CA	Composite Analysis
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
DAS	Disposal Authorization Statement
DOE/HQ	U.S. Department of Energy/Headquarters
DOE/NV	U.S. Department of Energy/Nevada Operations Office
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ERD	Environmental Restoration Division (NNSA/NV)
ETS	Environmental Technical Services (BN)
FFACO	Federal Facilities Agreement and Consent Order
FY	fiscal year
GCD	Greater Confinement Disposal
HDP	Heat Dissipation Probe
HWSU	Hazardous Waste Storage Unit
ICMP	Integrated Closure and Monitoring Plan
IHI	Inadvertent Human Intrusion
LLW	Low-Level Waste
LTSM	Long-Term Surveillance and Maintenance
MLLW	Mixed Low-Level Waste
MTRU	Mixed Transuranic (waste)
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NNSA/NV	National Nuclear Security Administration Nevada Operations Office
NTS	Nevada Test Site
OP	Organization Procedure
PA	Performance Assessment
PET	Potential Evapotranspiration
QAASP	Quality Assurance, Analysis, and Sampling Plan
RCRA	Resource Conservation and Recovery Act
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
SME	Subject Matter Expert
TDR	Time-Domain Reflectometry
TLD	Thermoluminescent Dosimeter
TRU	Transuranic

Acronyms and Abbreviations

WAC	Waste Acceptance Criteria
WEF	Waste Examination Facility
WIPP	Waste Isolation Pilot Plant
WMD	Waste Management Division (NNSA/NV)

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EXECUTIVE SUMMARY

Bechtel Nevada (BN) manages two low-level Radioactive Waste Management Sites (RWMSs) (one site is in Area 3 and the other is in Area 5) at the Nevada Test Site (NTS) for the U.S. Department of Energy's (DOE's) National Nuclear Security Administration Nevada Operations Office (NNSA/NV). The current DOE Order governing management of radioactive waste is 435.1. Associated with DOE Order 435.1 is a Manual (DOE M 435.1-1) and Guidance (DOE G 435.1-1). The Manual and Guidance specify that preliminary closure and monitoring plans for a low-level waste (LLW) management facility be developed and initially submitted with the Performance Assessment (PA) and Composite Analysis (CA) for that facility. The Manual and Guidance, and the Disposal Authorization Statement (DAS) issued for the Area 3 RWMS further specify that the preliminary closure and monitoring plans be updated within one year following issuance of a DAS. This Integrated Closure and Monitoring Plan (ICMP) fulfills both requirements. Additional updates will be conducted every third year hereafter.

This document is an integrated plan for closing and monitoring both RWMSs, and is based on guidance issued in 1999 by the DOE for developing closure plans. The plan does not follow the format suggested by the DOE guidance in order to better accommodate differences between the two RWMSs, especially in terms of operations and site characteristics. The modification reduces redundancy and provides a smoother progression of the discussion. The closure and monitoring plans were integrated because much of the information that would be included in individual plans is the same, and integration provides efficient presentation and program management.

The ICMP identifies the regulatory requirements, describes the disposal sites and the physical environment where they are located, and defines the approach and schedule for both closing and monitoring the sites.

Over the next several decades, most waste disposal units at both the Area 3 and Area 5 RWMSs are anticipated to be closed. Closure of the Area 3 and Area 5 RWMSs will proceed through three phases: operational closure, final closure, and institutional control. Many waste disposal units at the Area 5 RWMS are operationally closed and final closure has been placed on one unit at the Area 3 RWMS (U-3ax/bl).

Because performance objectives of the PAs for the RWMSs are easily met, even with only an operational closure cover, the NNSA/NV has considerable flexibility in designing final closure covers. The basic closure cover design for all of the various units will be of the vegetated monolayer-evapotranspirative type. In some cases, such as when considering long-lived or high-activity radionuclides, or where burrowing by animals or intrusion of roots might be problematic, the basic design may require modest modification to ensure long-term containment. Such modifications will be dealt with on a case-by-case basis.

Waste disposed at the Area 3 and Area 5 RWMSs can be categorized based on security requirements, waste type, and disposal configuration. The criteria defining the categories of disposed waste, along with the spatial distribution of waste units at each of the RWMSs, provide logical groups of waste units when considering the activities, interactions, and documentation required to support closure. Such grouping of disposal units will allow key differences that might require different interactions or engineering to be adequately addressed in final closure documentation.

Disposal units that contain only LLW or that contain LLW and transuranic waste will be closed in accordance with regulations imposed by NNSA/NV in the process of self-regulation. A Corrective Action Unit (CAU) of "retired mixed waste cells" (citing from the Resource Conservation and Recovery Act [RCRA] Permit NEV HW009) is proposed based on evaluation of waste receipt records. The "retired mixed waste cells" are within a group of waste disposal units that were opened, and generally operationally closed prior to January 1987, when P03U was opened for disposal of waste with hazardous constituents. The CAU will be closed in concert with the Nevada Division of Environmental Protection (NDEP) in accordance with RCRA and regulations imposed by NNSA/NV in the process of self-regulation.

Closure activities for waste disposal units in the 92-acre site, an expansion area north of the Area 5 RWMS, and the Area 3 RWMS follow a systematic process consisting of ten steps, itemized below:

- a preliminary assessment,
- initial planning,
- drafting of a characterization plan,
- implementation of the characterization plan,
- drafting of a characterization report,
- drafting of a closure plan,
- implementation of closure,
- drafting of a closure report,
- acknowledgment of completion, and
- postclosure monitoring and maintenance (if required according to the closure plan).

The first two steps, preliminary assessment and initial planing, determine the depth to which each remaining activity or document have to be conducted or developed. Results of investigations conducted prior to the interim measure discussed above for the 92-acre site, and results of previous site characterization studies and ongoing measures of water balance at the 92-acre site and elsewhere, are believed to be sufficient that initial closure activities for the 92-acre site will be minimal. A closure plan for the 92-acre site is scheduled for fiscal year (FY) 2009, followed by closure construction and a closure report in FY 2010. Responsibilities for closure and monitoring of the 92-acre site are shared between the NNSA/NV Waste Management Division (WMD) and the Environmental Restoration Division (ERD). Determination of geotechnical parameters of operational closure covers, a topographic survey, updates of the ICMP, and all activities related to closure of the 92-acre site will be conducted by the WMD prior to FY 2008. Formal closure activities between FY 2008 and FY 2010, and monitoring related specifically to disposal units composing the CAU, will be conducted by the ERD. Closure activities for waste disposal units in the expansion area and the Area 3 RWMS are scheduled over the time frame of FY 2019 through 2021.

Active institutional controls, such as control of access, cover maintenance, and monitoring, will continue for 100 years (unless specified otherwise) following final closure; and passive institutional controls, such as markers, records, or archives, and government ownership regulations regarding land and resource use, will continue thereafter. Management of the RWMSs in both Area 3 and Area 5 is planned to be eventually transferred to another agency or group within NNSA/NV that is expected to have long-term responsibilities at the NTS. Under this NTS Landlord, waste disposal operations may continue in selected disposal units. The Landlord will also oversee and conduct institutional control activities.

Monitoring at the Area 3 and Area 5 RWMSs is required under a variety of regulatory drivers, including federal regulations and DOE Orders. Monitoring data are used to demonstrate compliance with regulatory drivers and performance objectives presented in the PAs, confirm assumptions about flux rates through upward and downward pathways, confirm assumptions about soil water contents and potentials, confirm conceptual models, provide input to PA maintenance, and evaluate radiation doses to the general public. Monitoring is also conducted to ensure the integrity of waste covers. In addition, the monitoring program is designed to sufficiently forewarn of any need for mitigative actions, and to record the utility of any mitigative actions.

This ICMP describes the programs for monitoring direct radiation fields, air, vadose zone, biota, groundwater, meteorology, and subsidence during the operational closure period (current), and final closure/active institutional control periods. Monitoring Data Quality Objectives are defined in the NTS Routine Radiological Environmental Monitoring Plan.

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1.0 INTRODUCTION

Bechtel Nevada (BN) manages two low-level Radioactive Waste Management Sites (RWMSs) at the Nevada Test Site (NTS) for the U.S. Department of Energy's (DOE's) National Nuclear Security Administration, Nevada Operations Office (NNSA/NV). The current DOE Order governing management of radioactive waste is 435.1. Associated with U.S. Department of Energy (DOE) Order 435.1 is a Manual (DOE M 435.1-1), and Guidance (DOE G 435.1-1). The Manual and Guidance specify that preliminary closure and monitoring plans for a low-level waste (LLW) management facility be developed and initially submitted with the Performance Assessment (PA) and Composite Analysis (CA) for that facility. Development of these plans is also a condition of the Disposal Authorization Statements (DASs) issued for the Area 3 and the Area 5 RWMSs.

This document is an integrated plan for closing and monitoring both RWMSs, and is based on recent guidance for developing closure plans issued by the DOE (DOE, 1999a). The plan does not follow the format suggested by the DOE guidance in order to better accommodate differences between the two RWMSs, especially in terms of operations and site characteristics. The modification reduces redundancy and provides a smoother progression of the discussion. A cross-walk between the contents of the plan and the DOE guidance is given in Appendix A. Closure and monitoring were integrated because monitoring measures the degree to which the operational and closed disposal facilities are meeting performance objectives of the PAs. The performance objectives are intended to ensure protection of workers, the public, and the environment from radiological exposure associated with the RWMSs now and in the future. Further, much of the information that would be included in the individual plans is the same, and integration provides efficient presentation.

Over the next several decades, most waste disposal units at both the Area 3 and Area 5 RWMSs are anticipated to be closed. This Integrated Closure and Monitoring Plan (ICMP) identifies the regulatory requirements, describes the disposal sites and the physical environment in which they are located, and defines the approach and schedule for both closing and monitoring the sites. The Plan presents overview information that can be referenced as necessary in final closure plans.

1.1 Performance Assessment and Composite Analysis

Performance Assessments provide the NNSA/NV with reasonable expectation that disposal of LLW will meet radiological performance objectives for long-term protection of the public and environment as established in DOE M 435.1-1. Composite Analyses are planning tools used by the NNSA/NV to ensure that the combined effect of all sources of residual radioactive material that could contribute to the dose calculated from disposal facilities will not compromise requirements for future radiological protection of the public and environment. The PA and CA for a disposal facility are reviewed and updated as described in the Maintenance Plan for the PA and CA. The process of review and revision ensures that the analyses intended to ensure protection of the public and environment are conducted with the best data available at the time. Monitoring during operation of a facility, closure of that facility,

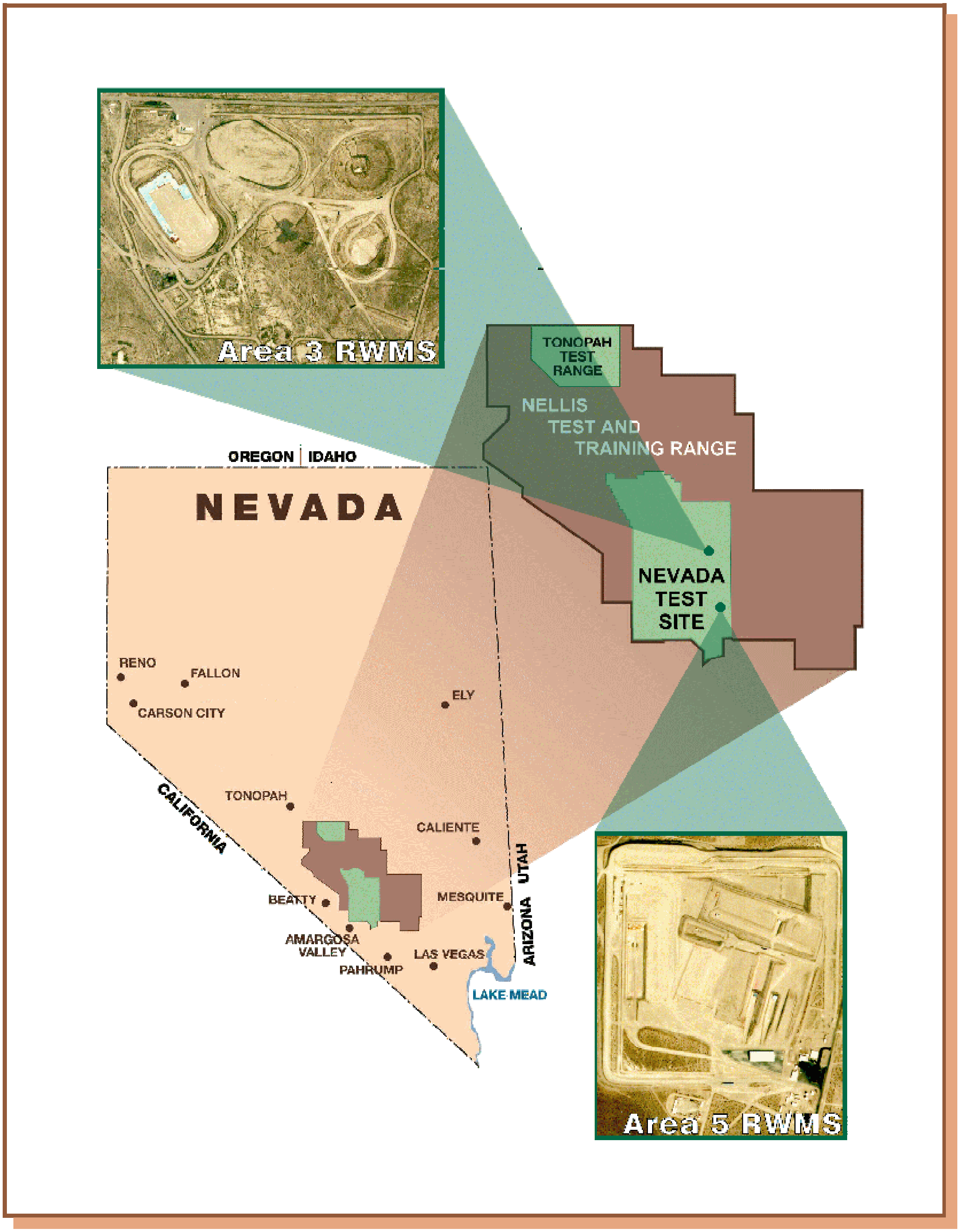

Figure 1 Location map of the Area 3 and Area 5 Radioactive Waste Management Sites

and monitoring after closure are inextricably tied to the PA and CA. The PA and CA provide information useful to determine the what, when, and where to monitor, and on the best method of closure to realize radiological protection of the public and environment. Conversely, results obtained through monitoring are part of the data needed to revise the PA and CA. Documents linked to the PA and CA and to this Integrated Closure and Monitoring Plan include the Auditable Safety Analysis (BN, 2000a), the NTS Waste Acceptance Criteria (NTSWAC) (NNSA, 2000), and the Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 1998a).

A PA and CA have been completed for both the Area 3 and Area 5 RWMSs (Shott *et al*., 1997; 1998, 1995; BN, 2000b). The combined PA and CA (under one cover) for the Area 3 RWMS was reviewed by DOE Headquarters (HQ) in 1999 and a conditional DAS was issued in October 1999. A revised PA/CA document addressing the DAS issues was prepared and submitted to DOE/HQ for review in 2000. The PA (under separate cover) for the Area 5 RWMS was reviewed and approved with conditions by DOE/HQ in 1996. A DAS was issued with conditions for the Area 5 RWMS in fiscal year (FY) 2001 following the review of the CA. A PA has been completed for the transuranic (TRU) waste in four Greater Confinement Disposal (GCD) boreholes (Cochran *et al*., 2001). The PA was reviewed by DOE/HQ in FY 2001 and is expected to be completed in early FY 2002.

In the PAs of the Area 3 and Area 5 RWMSs (Shott *et al*., 1997; 1998, 1995), the closure cover was assumed to consist of native alluvium, with its thickness corresponding to the thickness of the operational cover. The hydrogeologic properties of the cover material were based on results of field and laboratory tests. The assessments were done under closure conditions that were assumed to be more adverse than would likely occur. In the Area 3 RWMS PA/CA, a simple case was assumed where the closure cover subsides, but remains above grade. In the Area 5 RWMS PA, as a base case, the closure cover was assumed to not subside; as a worst case, the closure cover was assumed to thin, crack, and subside below grade. Performance objectives and results of the Area 3 and Area 5 RWMS PAs are shown in Table 1. Both the Area 3 and Area 5 RWMSs meet performance objectives by a wide margin. The dose from all interacting sources to a member of the public is calculated in the Area 3 and Area 5 RWMSs to be 2 mrem/yr and 7 mrem/yr, respectively. The CA performance objective is 100 mrem/yr.

The conceptual closure approach consists of ensuring that the performance of the actual cover at least meets that modeled in the PAs. The actual cover will be of the vegetated monolayer-evapotranspirative (ET) type, with the monolayer comprising native alluvium properly screened to exclude cobbles coarser than about 9 centimeters (cm) (3.5 inches [in]). Throughout a period of active institutional control, the cover will be maintained at its proper thickness by infilling subsided areas and cracks. Performance of the cover will be monitored at a frequency and for a period to be determined based on observed trends in monitoring data.

Table 1 Performance objectives and results of the Area 3 and Area 5 RWMS Performance Assessments

Performance Objective	Area 3 RWMS (Base Case) 1,000-year (yr) analysis; maximum values unless specified otherwise	Area 5 RWMS (Base Case); 10,000-yr analysis; maximum values unless specified otherwise	Area 5 RWMS (Subsided Case); 10,000-yr analysis; maximum values unless specified otherwise
MEMBER OF PUBLIC			
25 mrem/yr, all paths	0.0009 mrem/yr; 0.00004 mrem/yr (mean)	0.6 mrem/yr	0.8 mrem/yr
10 mrem/yr, airborne emissions excluding radon	0.0004 mrem/yr; 0.00003 mrem/yr (mean)	0.2 mrem/yr	0.2 mrem/yr
Average annual ^{222}Ra flux < 20 pCi/m^2/s	0.1 pCi/m^2/s; 0.02 pCi/m^2/s (mean)	6 pCi/m^2/s	10 pCi/m^2/s
Protect Groundwater Resources	No Release (mean)	No Release	See Below
• ^{226}Ra + ^{228}Ra < 5 pCi/L	Not Applicable[1]	Not Applicable[1]	0.3 pCi/L
• Gross alpha < 15 pCi/L	Not Applicable[1]	Not Applicable[1]	9 pCi/L
• Man-made beta-gamma emitters < 4 mrem/yr	Not Applicable[1]	Not Applicable[1]	1 mrem/yr
INADVERTENT HUMAN INTRUDER			
500 mrem Acute	< 0.04 mrem (mean)	0.2 mrem drilling, shallow land burial; 22 mrem drilling, Pit P06C	Not Assessed[2]
100 mrem/yr Chronic	0.04 mrem/yr (mean)	157 mrem/yr agricultural, shallow land burial[3]; Not applicable (too deep), agricultural, Pit P06C; 0.7 mrem/yr postdrilling, shallow land burial; 177 mrem/yr postdrilling, Pit P06C[4]	Not Assessed[2]

[1]Under the Base Case, there is not a groundwater pathway.
[2]Results would be the same as the Base Case.
[3]Requires monolayer-ET closure cover to be a minimum of 4 meters (m) (13 feet [ft]) thick to comply.
[4]Requires an inventory limit of 174 Ci in Pit P06C to comply.

1.2 Assumptions

Assumptions related to closure and monitoring of the Area 3 and Area 5 RWMSs are given in the life-cycle baselines of the Waste Management Division (WMD) and Environmental Restoration Division (ERD). Pertinent programmatic, scheduling, and funding assumptions from the Waste Management baseline are reproduced below, in addition to assumptions that relate more to the approach and responsibility for closure and monitoring described herein.

1.2.1 Assumptions Related to Closure

- Closure of legacy mixed low-level waste (MLLW) cells at the Area 5 RWMS (disposal units subject to conditions of Title 40 Code of Federal Regulations (CFR) 265.310, Resource Conservation and Recovery Act [RCRA] Permit NEV HW009, and DOE Order 435.1) will be included in the NNSA/NV ER baseline.
- Closure of disposal units not subject to conditions of Title 40 CFR 265.310 and RCRA Permit NEV HW009 will be included in the NNSA/NV WM LLW project baseline.
- The ICMP will address closure of all units in the Area 3 and Area 5 RWMSs, including disposed LLW (asbestos, hydrocarbon-impacted, and regular LLW), disposed MLLW, and indefinitely stored classified materials.
- The closure plan for MLLW disposal units will incorporate conditions of Title 40 CFR 265.310, RCRA Permit NEV HW009, DOE Order 435.1, the Area 5 RWMS DAS, and other applicable regulations as appropriate.
- The interim measure of adding soil to operational closure covers leading to final closure activities for the Area 5 RWMS 92-acre site will occur between FY 2002 and FY 2007.
- An engineered barrier will be a part of the final closure of GCD boreholes that contain TRU waste.
- Activities related to final closure of the Area 5 RWMS 92-acre site will occur from FY 2008 through FY 2010.
- The Characterization Report developed in FY 2008 for the Area 5 RWMS 92-acre site will be approved by the NDEP and NNSA/NV, and will lead to development of a closure plan.
- Closure construction at the Area 5 RWMS 92-acre site will be completed in FY 2010.
- Activities related to final closure of the Area 5 RWMS 92-acre site will be under the technical direction of ERD.
- The Nevada Division of Environmental Protection (NDEP) will not have oversight for closure activities between FY 2019 and FY 2021 (no mixed waste).
- Final closure activities for the Area 5 RWMS expansion area and the Area 3 RWMS will occur between FY 2019 and FY 2021.
- The characterization reports developed in FY 2019 for the Area 5 RWMS expansion area and the Area 3 RWMS will be approved by NNSA/NV and lead to development of closure plans.
- Closure construction at the Area 5 RWMS expansion area and at the Area 3 RWMS will be completed in FY 2021.

1.2.2 Assumptions Related to Monitoring

- Environmental monitoring will continue through FY 2021 in accordance with the ICMP; after FY 2021, environmental monitoring will continue under Long-Term Surveillance and Maintenance (LTSM).

- No waiver from RCRA groundwater monitoring requirements will be obtained, and monitoring of the Area 5 pilot wells will be required.
- Post-closure monitoring of the Area 5 RWMS will commence in FY 2011 and continue through FY 2021 in accordance with RCRA regulations.

1.2.3 Assumptions Related to Long-Term Surveillance and Maintenance

- Active institutional control of the Area 5 RWMS 92-acre site will start after final closure in FY 2010 and continue for a period of 110 years (through FY 2121).
- Active institutional control of the Area 5 RWMS expansion area and the Area 3 RWMS will start after final closure in FY 2021 and continue for a period of 100 years (through FY 2121).
- Passive institutional control of closed sites will start after active institutional control and continue indefinitely.

2.0 REGULATORY REQUIREMENTS

The Area 3 and Area 5 RWMSs are primarily LLW disposal sites. The Area 3 RWMS includes LLW and MLLW, whereas the Area 5 RWMS includes LLW and MLLW, and small amounts of TRU waste and mixed TRU (MTRU) waste. Low-level waste and TRU waste are also stored at the Area 5 RWMS. Waste with only a radioactive component is self regulated by the DOE. The radioactive component of mixed waste is self regulated by the DOE, whereas the hazardous component of mixed waste is regulated by RCRA under the authority of the U.S. Environmental Protection Agency (EPA). The NDEP has been granted the authority by the EPA to administer RCRA in Nevada. Nevada Administrative Code (NAC) 444.8632 incorporates the federal RCRA requirements by reference (Nevada Environmental Commission [NEC], 1987).

2.1 Closure Requirements

The following excerpts from the DOE Orders and other regulations for closure provide the basis for the Closure Program.

2.1.1 DOE Order 435.1

The DOE Order governing management of radioactive waste is 435.1. Associated with the Order are a Manual (DOE M 435.1-1), Guidance (DOE G 435.1-1), and a DOE/NV Manual (DOE NV M 435.1-1). The DOE NV Manual provides the requirements, roles, and responsibilities to establish the DOE/NV Radioactive Waste Management Program in accordance with the Order. The DOE Manual and Guidance list the following requirements related to closure of LLW disposal cells.

- *Chapter IV, Q (Closure) (1). A preliminary closure plan shall be developed and submitted to DOE/HQ for review with the Performance Assessment and Composite Analysis. The closure plan shall be updated within one year following issuance of the Disposal Authorization Statement to incorporate conditions specified in the Disposal Authorization Statement.*

- *Q (1)(a). Closure plans shall be updated as required during the operational life of the facility.*

- *Q (1)(b). Closure plans shall include a description of how the disposal facility will be closed to achieve long-term stability and minimize the need for active maintenance following closure and to ensure compliance with the requirements of DOE O 5400.5, "Radiation Protection of the Public and the Environment" (or 10 CFR 834, when promulgated).*

- *Q (1)(c). Closure plans shall include the total expected inventory of wastes to be disposed of at the facility over the operational life of the facility.*

- *Q (2). Closure of a disposal facility shall occur within a five-year period after it is filled to capacity, or after the facility is otherwise determined to be no longer needed.*

- *Q (2)(a). Prior to facility closure, the final inventory of the low-level waste disposed in the facility shall be prepared and incorporated into the PA and CA which shall be updated to support closure of the facility.*

- *Q (2)(b). A final closure plan shall be prepared based on the inventory of waste disposed in the facility and the updated PA and CA prepared in support of the facility closure.*

- *Q (2)(c). Institutional control shall continue until the facility can be released pursuant to DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (or 10 CFR 834, when promulgated).*

- *Q (2)(d). The location and use of the facility shall be filed with the local authorities responsible for land use and zoning.*

2.1.2 Title 40 CFR 265

Performance objectives related to closure of a waste disposal cell containing only LLW (*Table 1*) are similar in principle to those specified in the RCRA Subpart N, Title 40 CFR 265.310(a) for waste disposal cells containing MLLW:

At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:

- *Provide long-term minimization of migration of liquids through the closed landfill,*
- *Function with minimum maintenance,*
- *Promote drainage and minimize erosion or abrasion of the cover,*
- *Accommodate settling and subsidence so that the cover's integrity is maintained, and*
- *Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.*

In addition to the above requirements, Title 40 CFR 265.310(b) specifies that:

After final closure, the owner or operator must comply with all post-closure requirements contained in 265.117 through 265.120, including maintenance and monitoring throughout the post-closure care period. The owner or operator must:

- *Maintain the integrity and effectiveness of the final cover, including making repairs to the cover as necessary to correct the effects of settling, subsidence, erosion, or other events;*
- *Maintain and monitor the leak detection system in accordance with Title 40 CFR 264.301(c)(3)(iv) and (4) of this Chapter and 265.304(b), and comply with all other applicable leak detection system requirements of this part;*
- *Maintain and monitor the groundwater monitoring system and comply with all other applicable requirements of Subpart F of this part;*
- *Prevent run-on and runoff from eroding or otherwise damaging the final cover;* and
- *Protect and maintain surveyed benchmarks used in complying with Title 40 CFR 265.309.*

2.1.3 Title 40 CFR 191

Small amounts of TRU and MTRU wastes are disposed in Greater Confinement Disposal (GCD) boreholes and one shallow disposal unit at the Area 5 RWMS. According to DOE M 435.1-1, TRU waste is to be disposed in accordance with Title 40 CFR 191. With respect to the limited amounts of these wastes, the NNSA/NV will assess the applicability of Title 40 CFR 191 to closure through the process of self regulation.

A compliance assessment document for TRU waste disposed in GCD boreholes, including a PA with respect to the requirements of Title 40 CFR 191, has been completed by Sandia National Laboratories (SNL) (Cochran *et al*., 2001). Title 40 CFR 191 includes both quantitative requirements and qualitative "assurance" requirements that must be met to demonstrate adequate protection of human health and the environment. The three quantitative requirements pertain to containment, individual protection, and groundwater protection. The six assurance requirements are imposed to provide additional confidence that the containment requirements will be met: (1) active institutional controls, (2) passive institutional controls, (3) monitoring, (4) engineered and natural barriers, (5) siting to avoid resources, and (6) future removal of waste. According to definitions in Title 40 CFR 191 for active and passive institutional controls, the assurance requirement of monitoring is considered to be an active control, and barriers are considered to be a passive control.

Comparison of the assurance requirements associated with Title 40 CFR 191 with closure and monitoring requirements of DOE O 435.1 and DOE M 435.1-1 (Appendix B) indicates that measures taken to satisfy requirements of Title 40 CFR 191 will meet or exceed requirements of the radioactive waste management Orders. An assessment of the assurance requirements for TRU waste in the GCD boreholes is described in the GCD document (Brosseau, 2001). Closure and monitoring requirements of RCRA are also generally satisfied by these measures; specific requirements for closure and monitoring may be imposed by the NDEP for cells containing MTRU waste. These requirements are negotiated with the NDEP when drafting the specific closure plans.

2.1.4 NAC 444.743

Pit P07U is a permitted Class III asbestiform low-level solid waste disposal cell at the Area 5 RWMS.

- *NAC 444.743. Final cover or closure; postclosure. A Class III site must comply with requirements set forth in NAC 444.6891 to 444.6894, inclusive, concerning closure and postclosure.*

- *NAC 444.6891. Requirements for design and construction of system for final cover. 1. the owner or operator of a Class I site shall install a system for a final cover which is designed to minimize infiltration and erosion. Except as otherwise provided in Subsection 2, the system must be designed and constructed to:*

- *(a) Have a permeability that is less than or equal to the permeability of any system for a bottom liner or natural subsoils present, or have a permeability no greater than 1×10^{-5} centimeters per second, whichever is less;*

- *(b) Minimize infiltration through the closed municipal solid waste landfill unit by the use of an infiltration layer which contains at least 18 inches of earthen material; and*

- *(c) Minimize erosion of the final cover by the use of an erosion layer which contains at least 6 inches of earthen material which is capable of sustaining the growth of native plants.*

2.2 Monitoring Requirements

The following excerpts from the DOE Orders and other regulations for monitoring provide the basis for the Monitoring Program.

2.2.1 DOE Order 435.1

The DOE M 435.1-1 and DOE G 435.1-1 associated with DOE Order 435.1 (DOE O 435.1) provide requirements for air monitoring (including radon), vadose zone, meteorology, biota, direct radiation monitoring, and subsidence monitoring.

- *Chapter IV, P (1) (a). Dose to representative members of the public shall not exceed 25 mrem (0.25 mSv) in a year total effective dose equivalent from all exposure pathways, excluding the dose from radon and its progeny in air.*

- *P (1) (b). Dose to representative members of the public via the air pathway shall not exceed 10 mrem (0.10 mSv) in a year total effective dose equivalent, excluding the dose from radon and its progeny.*

- *P (1) (c). Release of radon shall be less than an average flux of 20 pCi/m^2/s (0.74 Bq/m^2/s) at the surface of the disposal facility. Alternatively, a limit of 0.5 pCi/1 (0.0185 Bq/l) of air may be applied at the boundary of the facility.*

- *R (3) (a). The site-specific performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.*

- *R (3) (b). The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance.*

- *R (3) (c). The environmental monitoring programs shall be capable of detecting changing trends in performance to allow application of any necessary corrective action prior to exceeding the performance objectives in this Chapter.*

2.2.2 DOE Order 5400.1

DOE Order 5400.1 and Guidance Document DOE/EH-0173T (DOE, 1991) provide requirements for air monitoring (including radon), groundwater, vadose zone, meteorology, biota, and direct radiation monitoring.

- *Chapter IV, 5b. (1). Environmental surveillance shall be designed to satisfy one or more of the following program objectives:*

- *5b (1)(a) Verify compliance with applicable environmental laws and regulations;*

- *5b (1)(b) Verify compliance with environmental commitments made in Environmental Impact Statements, Environmental Assessments, Safety Analysis Reports, or other official DOE documents;*

- *5b (1)(c) Characterize and define trends in the physical, chemical and biological condition of environmental media;*

- *5b (1)(d) Establish baselines of environmental quality;*

- *5b (1)(e) Provide a continuing assessment of pollution abatement programs;*

- *5b (1)(f) Identify and quantify new or existing environmental quality problems.*

2.2.3 Title 40 CFR 61

Title 40 CFR 61 provides requirements for radiological air monitoring (including radon) and direct radiation monitoring.

- *Subpart H, National Emission Standards for Emission of Radionuclides Other Than Radon from Department of Energy Facilities, Section 61.92 Standard. Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.*

- *Subpart Q, National Emission Standards for Radon Emissions from Department of Energy Facilities, Section 61.192 Standard. No source at a Department of Energy facility shall emit more than 20 pCi/m2/s of radon-222 as an average for the entire source, into the air. This requirement will be part of any Federal Facilities Agreement reached between Environmental Protection Agency and Department of Energy.*

To date, neither the Area 3 or the Area 5 RWMSs contain 11.e.(2) waste, so Subpart Q does not apply. However, Subpart Q is included in anticipation of receiving 11.e.(2) waste in the future.

2.2.4 Title 40 CFR 264

The Area 5 groundwater monitoring program is guided in part by the following sections of Title 40 CFR 264, Subpart F, unless as specified in the "Outline of a Comprehensive Groundwater Monitoring Program" (BN, 1998b), and the Annual Groundwater Monitoring Data Report (e.g., BN, 2001a) in agreement between NNSA/NV and NDEP:

- 264.97, General groundwater monitoring requirements;
- 264.98, Detection monitoring program;
- 264.99, Compliance monitoring program;
- 264.100, Corrective action program;
- 264.101, Corrective action for solid waste management units.

2.2.5 Title 40 CFR 265

The Area 5 groundwater monitoring program is driven in part by the following sections of Title 40 CFR 265, Subpart F, unless as specified in the "Outline of a Comprehensive Groundwater Monitoring Program" (BN, 1998b), and the Annual Groundwater Monitoring Data Report (e.g., BN, 2001a) in agreement between NNSA/NV and NDEP:

- 265.90, Applicability;
- 265.91, Groundwater monitoring system;
- 265.92, Sampling and analysis;
- 265.93, Preparation, evaluation, and response;
- 265.94, Record keeping and reporting.

2.2.6 Title 40 CFR 191

Title 40 CFR 191 provides the following general monitoring requirement:

- Section 191.14 Assurance Requirements, (b) *Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.*

3.0 SITE DESCRIPTION

3.1 Geography

The NTS, located in Nye County, Nevada, 104 kilometers (km) (65 miles [mi]) northwest of Las Vegas, comprises approximately 3,561 square km (km^2) (1,375 square mi [mi^2]) of land reserved to the jurisdiction of the DOE under four land withdrawals (DOE, 1996). The primary use of the NTS between 1952 and 1992 was testing of nuclear weapons. Since 1992, subcritical experiments and other defense-related and nondefense-related activities have been and continue to be conducted at the NTS. Mercury, in the southeast corner of the NTS, is the primary support facility for the NTS. Other, smaller communities, including Amargosa Valley, Lathrop Wells, and Indian Springs, are also present within a few tens of kilometers (tens of miles) of the NTS, along the U.S. Highway 95 corridor (*Figure 1*). The primary valleys on the NTS are Yucca Flat, Frenchman Flat, and Jackass Flats. Yucca Flat is in the northeast part of the NTS, Frenchman Flat is in the southeast part of the NTS, and Jackass Flats is in the southwest part of the NTS.

Yucca Flat is an elongated, sediment-filled basin that trends roughly north-south; the long axis is approximately 27 km (17 mi) and the short axis is approximately 16 km (10 mi). Yucca Flat is bounded by Quartzite Ridge and Rainier Mesa on the north, the Halfpint Range on the east, the Massachusetts Mountains and Control Point Hills on the south, and Mine Mountain and the Eleana

Range on the west. The Yucca Flat basin slopes from the north at an elevation of approximately 1,402 m (4,600 ft) to the south toward Yucca Playa, the lowest part of the basin at an elevation of approximately 1,189 m (3,900 ft). Yucca Flat was one of several primary nuclear test areas and is marked essentially the length of the valley with craters (Figure 2).

Frenchman Flat is a roughly circular basin bounded by the Massachusetts Mountains on the north, the Buried Hills and Ranger Mountains on the east and southeast, Mount Salyer on the west, and Mercury Ridge and Red Mountain on the south (Figure 3). Elevations range between 1,600 m (5,250 ft) in the surrounding mountains to 939 m (3,080 ft) at Frenchman Playa in the center of the basin. Frenchman Flat was one of several primary nuclear test areas. Atmospheric tests were conducted on the playa and a limited number of underground tests were conducted in the northern part of the basin.

3.2 Demography

3.2.1 Population Distribution

On the basis of a 1994 survey, 90 percent of the NTS workforce resided in Clark County, 7 percent resided in Nye County, and the remaining 3 percent resided in other counties or states (DOE, 1996). Although a more recent survey is not available, current percentages are likely similar to those of the 1994 survey. A population survey conducted in 1999 showed the population of Clark County to be 1.32 million, with the overwhelming majority, approximately 96 percent, of residents living in the Las Vegas Valley (Metropolitan Research Association [MRA], 2000).

According to estimates prepared by the Nye County Department of Planning, the population of Nye County at the end of 1999 was 38,442. Pahrump, located approximately 64 km (40 mi) from the NTS, is the largest and most rapidly growing community in Nye County. At the end of 1999, the population of Pahrump (at 28,709) accounted for approximately 75 percent of the Nye County population.

Amargosa Valley, located 3.2 km (2 mi) south of the southwestern corner of the NTS, is the nearest rural population center to the NTS. According to estimates prepared by the Nye County Department of Planning, the population of Amargosa Valley at the end of 1999 was 1,445. Other small rural population centers near the NTS are Beatty and Indian Springs. Steady, modest growth for each of these population centers is projected (DOE, 1996).

The population of the Las Vegas Valley and the rural centers is driven primarily by opportunities or resources, or both. Las Vegas offers primarily employment associated with the gaming and construction industries, and has become a preferred retirement center. Amargosa Valley offers ranching and agriculture. Pahrump is a preferred retirement center and continues to serve as a bedroom community for Las Vegas and the NTS. The population of Beatty is largely supported by the mining industry. The population of Indian Springs is largely supported by the military.

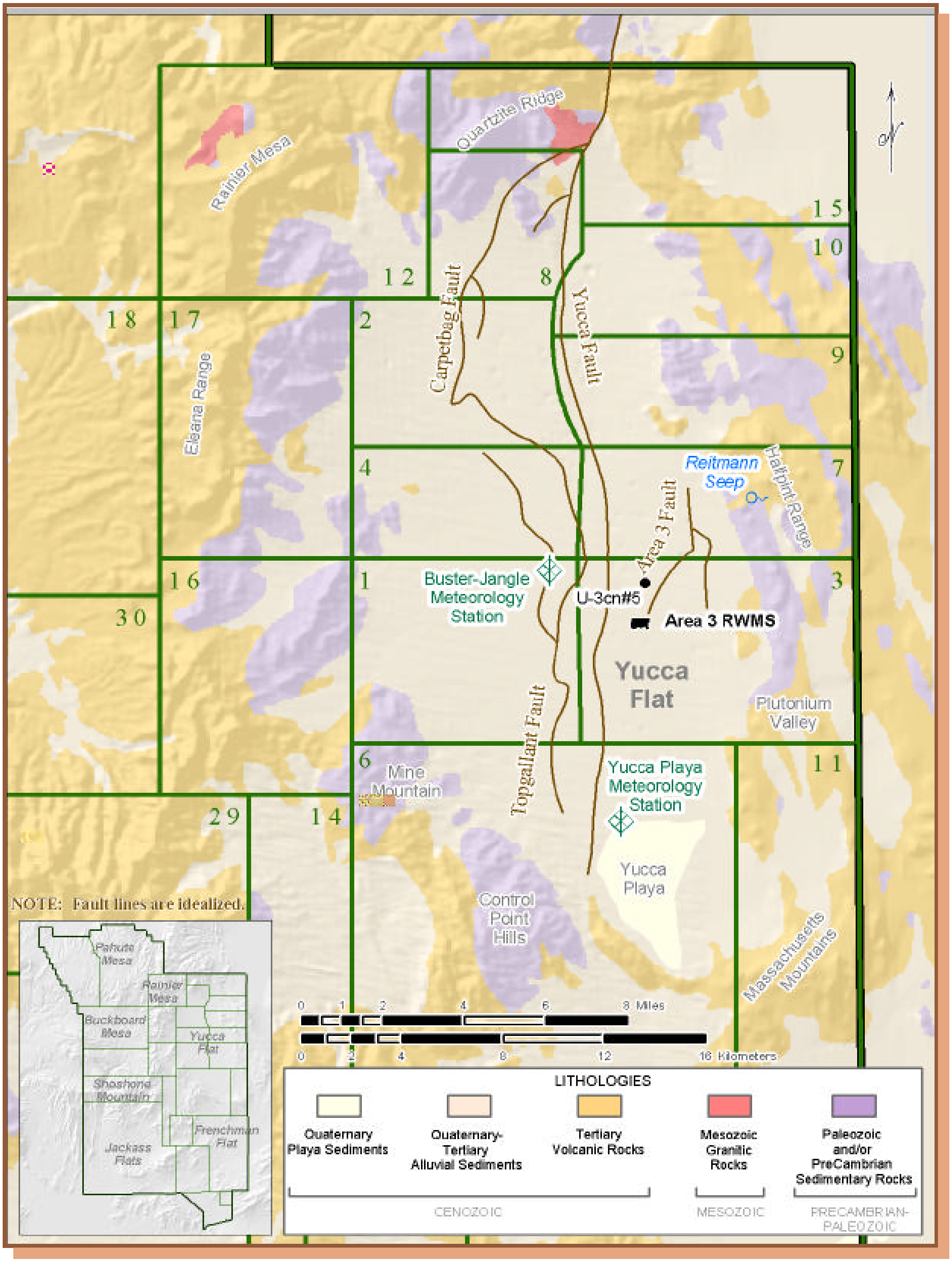

Figure 2 Map of Yucca Flat

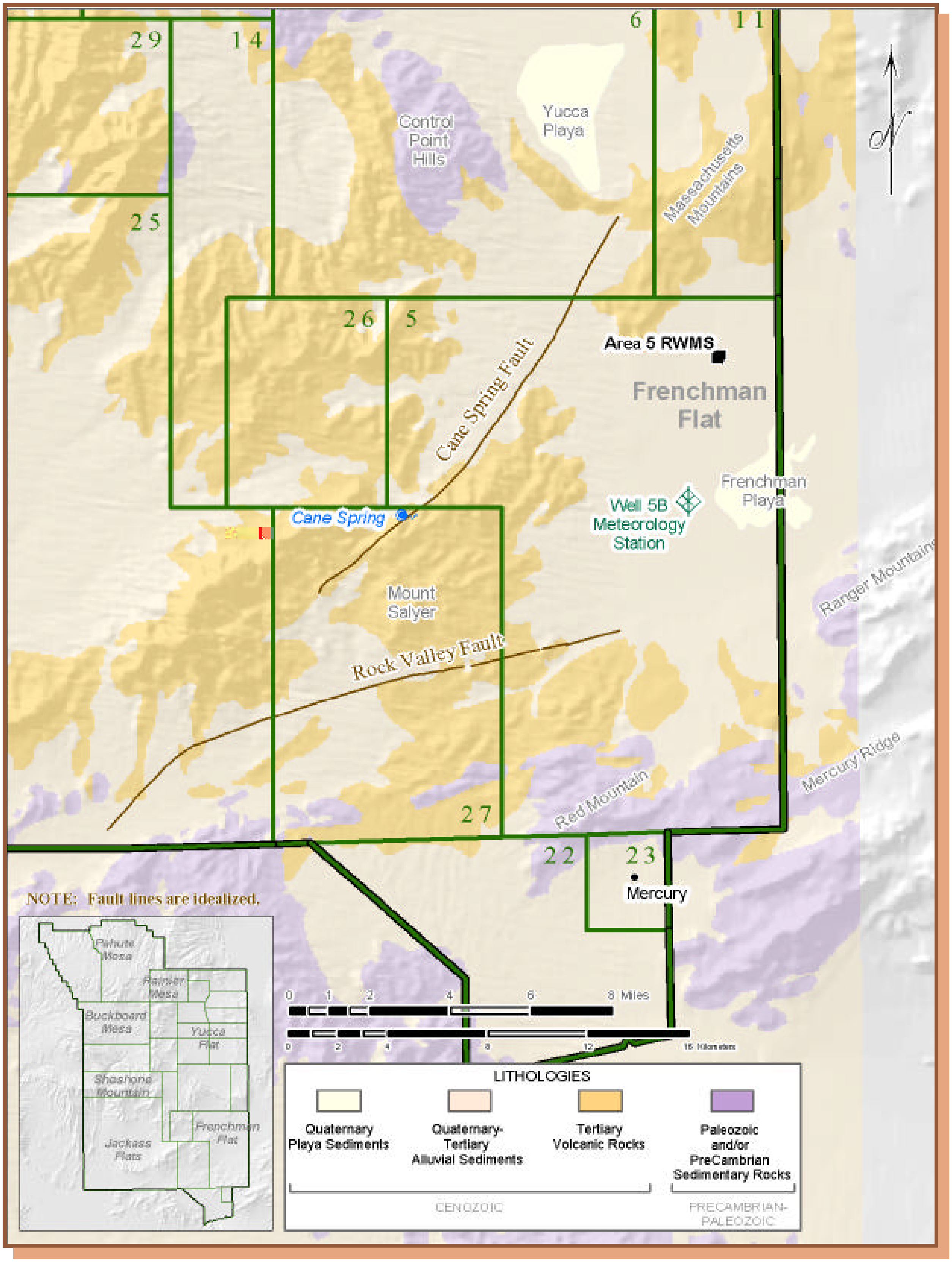

Figure 3 Map of Frenchman Flat

Aside from changes in population resulting from variances in primary supporting industries, the populations of rural communities near the NTS would likely respond to changes in activities at the NTS and surrounding land. The NTS is currently and for the foreseeable future withdrawn from all forms of appropriation. Uses of the NTS will continue to be governed by land resource constraints. Constraints at the NTS include weapons testing, radioactive waste management, contaminated areas, and ecological sensitivity. Current uses of the NTS will likely continue for the foreseeable future.

3.2.2 Uses of Adjacent Land

Native Americans were the first to use the lands now within the NTS. The Shoshone lived at springs in the northern NTS and the Paiutes lived at springs in the southern NTS. Later, early settlers established cattle ranches and wild horse capture operations at local springs (Reno and Pippin, 1985). Mining operations have occurred on the NTS at the Oak Spring District, Mine Mountain District, and Wahmonie District (Reno and Pippin, 1985). In 1928, Cane Spring supported the 1,500-person mining community of Wahmonie (Allred *et al*., 1963).

Ranching and mining remain important land uses in southern Nevada. Recreational activities and irrigation-based agriculture have become important land uses in southern Nevada. Provided that the NTS remains withdrawn from all forms of appropriation, these activities will likely not have a significant impact on the NTS. Three-fourths of the land immediately adjacent to the NTS is controlled by the U.S. Air Force. The remaining fourth is managed by the U.S. Bureau of Land Management. This federal use and management of the land further buffer the NTS from external influence.

3.3 Meteorology

Detailed discussions on meteorology and climatology specific to the Area 3 and Area 5 RWMSs are presented in the PAs (Shott *et al*., 1997; 1998, 1995) and the annual monitoring report (BN, 2001b) for those sites. Those discussions are summarized below.

3.3.1 Precipitation

The NTS is between the northern boundary of the Mojave Desert and the southern limits of the Great Basin Desert. This “Transitional Desert” is considered to be typical of either the Dry Mid-latitude or Dry Subtropical climatic zones. The climate is characterized by low precipitation, a large diurnal temperature range, a large evaporation rate, and moderate to strong winds.

Most precipitation in the Transitional Desert occurs in winter and summer. Winter precipitation is generally associated with transitory low-pressure systems originating from the west and occurring as uniform storms over large areas. Summer precipitation is generally associated with convective storms originating from the south or southwest and occurring as intense local storms. The average annual precipitation ranges between 7.6 and 25.4 cm (3 and 10 in), depending on elevation. Lower values of this range are typical in valleys, whereas higher values are typical in the surrounding mountains. The average annual precipitation in Yucca Flat is 16.3 cm (6.4 in), based on a 36-yr record between 1961 and 1996 at the Buster-Jangle meteorology station, which is located approximately 4.8 km (3 mi) northwest of the Area 3 RWMS at an elevation of 1,218 m (4,060 ft) (Shott *et al*., 1997). The average annual precipitation in Frenchman Flat is 12.7 cm (5.0 in) based on a 30-yr record between 1963 and 1993 at Well 5B in Area 5 (Shott *et al*., 1995). Well 5B is approximately 4.8 km (3 mi) southwest of the Area 5 RWMS, at an elevation of 927 m (3,090 ft).

3.3.2 Temperature

Average daily temperatures at the NTS range between 2^{o} Celsius (C) (35^{o} Fahrenheit [F]) in January to 24^{o}C (75^{o}F) in August. Large daily fluctuations are common on the valley floors. At Yucca Playa, over a 16-yr period between 1962 and 1978, the daily maximum air temperatures ranged from 0^{o}C (32^{o}F) in winter to 40^{o}C (104^{o}F) in summer. The daily minimum air temperatures ranged from -15^{o}C (5^{o}F) in winter to 25^{o}C (77^{o}F) in summer. The Yucca Playa meteorology station is approximately 11.2 km (7 mi) south of the Area 3 RWMS. The elevation at the meteorology station is 1,174 m (3,912 ft) (Shott *et al*., 1997). At the Area 5 RWMS, the daily maximum temperature ranged from 12^{o}C (54^{o}F) in winter to 36^{o}C (97^{o}F) in summer. The daily minimum air temperatures ranged from -12^{o}C (10^{o}F) in winter to 17^{o}C (63^{o}F) in summer (Magnuson *et al*., 1992). The Area 5 RWMS is at an elevation of about 960 m (3,200 ft).

3.3.3 Potential Evapotranspiration

Potential evapotranspiration (PET) at the NTS is high because of the large incident solar radiation and wind. PET is evapotranspiration at a potential, or energy-limiting rate; it is calculated using any of a number of available equations. The average annual PET calculated using the Penman equation (Doorenbos and Pruitt, 1977) and data collected from the Area 3 and Area 5 RWMS meteorology stations, is 163 cm (64 in) and 157 cm (62 in), respectively. PET is slightly higher in Area 3 than in Area 5 because Area 3 has greater wind speeds than Area 5. Average annual precipitation at Area 3 and Area 5 is 165 millimeters (mm) (6.5 in) and 127 mm (5.0 in), respectively. The greater the ratio between PET and precipitation, the greater is the evaporative demand in a given environment. This average ratio at Area 3 and Area 5 is 9.8 and 12.4, respectively. These rates are indicative of extremely evaporative conditions.

3.3.4 Wind

Wind speed and direction were recorded at the Yucca Playa meteorology station between 1962 and 1978, and at the Well 5B meteorology station between 1983 and 1993. Winds are primarily southerly during the summer months and northerly during the winter months. Wind speeds tend to be greater in the spring than in the fall. At the Yucca Playa station, the average annual wind speed was 3.2 m per second (m/s) (7.2 mi per hour [mph]); the maximum wind speed exceeded 27 m/s (60 mph). In 1999, average daily wind speed recorded at the Area 3 RWMS meteorology station at a height of 3 m (10 ft) above ground level was 3.0 m/s (6.7 mph), and the maximum wind speed recorded was 21.6 m/s (48 mph) (BN, 2001b). In 1999, average daily wind speed recorded at the Area 5 RWMS meteorology station at a height of 3 m (10 ft) above ground level was 2.5 m/s (5.6 mph), and the maximum wind speed recorded was 16.7 m/s (37 mph) (BN, 2001b).

3.4 Ecology

Detailed descriptions of plant and animal species and communities near the Area 3 and Area 5 RWMSs are presented in the PAs for those sites (Shott *et al*., 1997; 1998, 1995).

3.4.1 Vegetation

The Transitional Desert includes vegetation associations of both the Mojave Desert and the Great Basin Desert. Communities of the Mojave Desert occur over the southern third of the NTS, on bajadas and mountain ranges at elevations below about 1,200 m (4,000 ft). They are limited to areas with mean annual minimum temperatures greater than -2^{o}C (28^{o}F) and mean annual precipitation less than 18.3 cm (7.2 in) (O'Farrell and Emery, 1976). Mojave Desert communities can have highly variable floristic compositions, but all are dominated by creosote bush and variable co-dominant shrubs. Shrub coverage varies from 7 to 23 percent for Mojave Desert communities on the NTS (Beatley, 1976). Plant communities near the Area 5 RWMS are dominated by creosote bush (Ostler *et al.*, 2000).

Plant communities in Yucca Flat are dominantly Transitional Desert communities, although a few Mojave Desert assemblages are present. Plant communities near the Area 3 RWMS are similar to the desertthorn-hopsage or saltbush-winterfat assemblages (Winkel *et al*., 1995), and include desertthorn, Mormon tea, winterfat, fourwing saltbush, and littleleaf horsebrush (Hunter, 1992; Winkel *et al*., 1995; Ostler, *et al*., 2000).

3.4.2 Plant Rooting

Rooting depths of Mojave Desert or Transitional Desert plants at the NTS are concentrated near the surface, likely an adaptation to maximize capture of infiltration (Winkel *et al*., 1995; Hansen and Ostler, 2001). Wallace and Romney (1972) described root systems of several plants excavated from a wash in Rock Valley on the NTS. Creosote bush roots reached 168 cm (66 in) below surface, desertthorn roots reached 122 cm (48 in) below surface, Mormon tea roots reached 91 cm (36 in) below surface, and winterfat roots reached 64 cm (25 in) below surface. Wallace *et al*. (1980) excavated root systems of several Mojave Desert species at the NTS. The roots were distributed in the top 51 cm (20 in), except for fourwing saltbush and shadscale; less than 2 percent of the roots of these two species were found below 51 cm (20 in). Wirth *et al*. (1999) compiled rooting depths of various plant species found on the NTS. The depth of rooting is closely tied to soil characteristics, a relationship that can advantageously be applied to the design of closure covers.

3.4.3 Animal Burrowing

Ants and termites are the most numerous burrowing insects on the NTS (O'Farrell and Emery, 1976). Both small and large burrowing mammals are present in the areas of the RWMSs. Rodents are the most common of the mammalian species on the NTS (Allred *et al*., 1963). The depth of plant rooting is closely tied to soil characteristics. The depth of burrowing is closely tied to soil conditions and plant rooting depths (see Section 3.4.2).

3.5 Geology

Detailed descriptions of the geology of Yucca Flat and Frenchman Flat are in the PAs for the RWMSs in those areas (Shott *et al.*, 1997; 1998, 1995).

3.5.1 Regional Geology

A sequence of rocks at the NTS composed of Proterozoic and Paleozoic, primarily marine, sedimentary rocks; locally intrusive Cretaceous granitic rocks; Miocene volcanic rocks; and post-volcanic sand and gravel would be approximately 10,500 m (35,000 ft) thick if stacked at one location according to age (Frizzell and Shulters, 1990). The geometry of these rocks is complex. The Proterozoic and Paleozoic rocks were significantly deformed in Late Mesozoic time (approximately 70 million yrs ago). At that time, older rocks were thrust eastward tens of kilometers (tens of miles) over younger rocks, in some places resulting in repetition of the sequence of rocks (Orkild, 1983). In mid-Tertiary (Miocene) to Quaternary time, the Proterozoic and Paleozoic rocks and the overlying Miocene volcanic rocks were deformed by large-scale extensional block faulting, which is largely responsible for the present Basin and Range topography in Nevada. The extensional faulting is thought to have occurred in two phases across the NTS. The initial phase, about 16 to 14 million yrs ago, consisted of high-angle northwest- and northeast-trending normal faults, including detachment faults (Cole *et al.*, 1989). A second phase, younger than 11 million yrs ago, consisted of steeply dipping north-to-south-trending normalfaults. This later phase is responsible for the basin-forming faults presently obvious in Yucca Flat (Dockery-Ander, 1984).

3.5.2 Yucca Flat Geology

The geologic structure of Yucca Flat is typical of intermontaine basins throughout the Basin and Range Province of Nevada and adjoining states. The surrounding mountain ranges consist primarily of Tertiary volcanic rocks and underlying Paleozoic sedimentary rocks (*Figure 2*). These ranges bound rotated and downdropped blocks in the basin. Erosion of the mountain ranges has resulted in deposition of a significant thickness of alluvium in the basin. The topography of the prealluvial surface and ongoing structural activity during deposition of the alluvium influence the present thickness of the alluvium. The thickness of alluvium in southern Yucca Flat ranges between 30 and 690 m (100 and 2,300 ft) (Drellack, 1994). At the Area 3 RWMS, alluvium is approximately 300 m (1,000 ft) thick. Extensive stratigraphic data have been collected from boreholes in Yucca Flat (Drellack and Thompson, 1990). Borehole U-3cn#5 is the closest of the deep boreholes drilled in Yucca Flat to the Area 3 RWMS (*Figure 2*). The stratigraphy of this borehole is approximately 279 m (930 ft) of alluvium, underlain by 567 m (1,891 ft) of various tuffs (846 m [2,821 ft] deep), underlain by carbonate rocks. The borehole extended 63 m (209 ft) into the carbonate rocks, reaching a total depth of 909 m (3,030 ft).

Principal basin-forming faults in Yucca Flat are the Yucca Fault and the Carpetbag Fault (*Figure 2*). Both faults are east-dipping, moderately high-angle normal faults. The Yucca Fault trends north-south through the east-central part of the valley. The Carpetbag Fault trends north-south through the western part of the valley. Toward the south, the Carpetbag Fault steps eastward where it is called the

Topgallant Fault. Knauss (1981) brackets the last natural movement along the Carpetbag fault between 93,000 and 37,000 yrs ago, and along the Yucca Fault at less than 35,000 yrs ago. Both faults have experienced movement associated with underground nuclear testing.

The Area 3 RWMS is on a structural block bounded on the west by the Yucca Fault and on the east by a west-dipping fault known as the Area 3 Fault (*Figure 2*). The Area 3 Fault is a wishbone-shaped fault system in Area 3 and southern Area 7 (a north-south trace defined by nuclear-testing-induced fractures and a pretesting lineament at the north end, and a curved east branch defined by a pretesting lineament that was cracked along its entire length by nuclear testing). The east branch lineament is manifested as a scarp in three locations. The northernmost of the three scarps offsets a Late Pleistocene- or early Holocene-aged surface, providing a maximum age for movement on that part of the fault. The trace of the west branch of the Area 3 Fault crosses the eastern side of the Area 3 RWMS. Continuity of beds exposed in a trench dug across the trace of the fault within the RWMS shows no major vertical displacement since at least early Holocene time (7,000 to 10,000 yrs), and probably since the Middle Pleistocene (several hundreds of thousands of years). Minor vertical fractures with minimal extent were present. The lack of major displacement within this time frame suggests that disposal operations and closure covers will not be impacted by the Area 3 Fault within the foreseeable future (BN, 1998c).

3.5.3 Frenchman Flat Geology

The mountain ranges surrounding Frenchman Flat consist primarily of Tertiary volcanic rocks and underlying Paleozoic sedimentary rocks (*Figure 3*). These ranges bound rotated and downdropped blocks in the basin. Erosion of the mountain ranges has resulted in deposition of a significant thickness of alluvium. The stratigraphy of rocks within Frenchman Flat to intermediate depths is known to a reasonable degree based on boreholes drilled for water wells and underground nuclear testing. Alluvium in Frenchman Flat ranges between 0 and 900 m (0 and 3,000 ft); alluvium directly below the Area 5 RWMS is estimated to be between 354 and 453 m (1,180 and 1,510 ft) thick (Shott *et al*., 1995). Basalt flows with numerical ages of 8.6 and 8.4 million yrs are interbedded in the alluvium in the northern part of Frenchman Flat, approximately 270 m (900 ft) below the ground surface (Well ER-53 log [unpublished]). These flows tend to separate alluvium with a predominant percentage of Tertiary-aged tuff from underlying alluvium with a predominant percentage of Paleozoic-aged sediments (Snyder *et al*., 1994). This suggests that the source of alluvium in northern Frenchman Flat changed from being predominantly from the northeast to being predominantly from the north about 8.5 million yrs ago. The alluvium is underlain by interbedded Tertiary ash-flow and ash-fall tuff estimated to be over 540 m (1,800 ft) thick. On the basis of gravity data, the upper surface of the underlying carbonate rocks is about 1,320 m (4,400 ft) below the surface at the Area 5 RWMS, and perhaps as deep as 1,470 m (4,900 ft) near the center of the basin. A well recently drilled in northern Frenchman Flat as part of the Underground Test Area (UGTA) Program showed the top of the carbonate rocks to be 1,426 m (4,678 ft) below surface approximately 3.2 km (2 mi) northeast of the RWMS.

Principal basin-forming faults in Frenchman Flat are the Cane Spring Fault and the Rock Valley Fault (*Figure 3*). The Cane Spring Fault is a left-lateral, strike-slip fault that trends southwest to northeast in the northern part of Frenchman Flat, 6.4 km (4 mi) northwest of the RWMS. The Rock Valley Fault is a left-lateral, strike-slip fault with a minor dip-slip component (down to the north) that trends southwest to northeast in the southern part of Frenchman Flat, about 8.8 km (5.5 mi) south of the RWMS. Both of these faults are active and responsible for earthquakes within the recent past.

3.6 Hydrology

Detailed discussion of the surface water and groundwater hydrology of both Yucca Flat and Frenchman Flat are in the PAs for the Area 3 and Area 5 RWMSs (Shott *et al*., 1997; 1998, 1995) and in other technical documents prepared as part of the characterization of these sites (cited below).

3.6.1 Surface Water

No permanent surface water is present within Yucca Flat, with the exceptions of small artificial impoundments and five springs that issue from perched aquifers recharged from infiltration through fractures in the surrounding mountains. Most water that issues from these springs travels only a short distance before evaporating or infiltrating into the ground. Reitman Seep, located 6.4 km (4 mi) northeast of the Area 3 RWMS, is the closest spring to the site.

Alluvial fans within Yucca Flat are cut by numerous arroyos (dry washes) that drain storm runoff to the playa. Water that accumulates on the playa typically evaporates or infiltrates, or both, within days to several weeks, but sometimes more than one month. Yucca Playa is approximately 8 km (5 mi) south of the Area 3 RWMS.

No permanent surface water is present within Frenchman Flat, with the exception of small artificial impoundments and Cane Spring, which issues from a perched aquifer recharged from infiltration through fractures in the nearby mountains. Cane Spring is approximately 14.4 km (9 mi) southwest of the Area 5 RWMS. Alluvial fans within Frenchman Flat are cut by numerous arroyos that drain storm runoff to the playa. Water that accumulates on the playa typically evaporates or infiltrates, or both, within a short period of time. Frenchman Playa is approximately 6.4 km (4 mi) southeast of the Area 5 RWMS.

3.6.2 Vadose Zone

Climate and vegetation strongly control the movement of water in the upper 2 m (6 ft) of the alluvium. The magnitude and direction of both liquid and vapor fluxes vary seasonally and often daily. Except for periods following precipitation events, water contents in this near-surface region are low. Below the near-surface region is a region where relatively steady upward movement of water is occurring. In this region of slow upward water movement, stable isotope compositions of soil pore water show that evaporation is the dominant process (Tyler *et al*., 1996). This region extends to depths from approximately 3 to 49 m (10 to 160 ft) in Area 3, and from approximately 3 to 40 m (10 to 130 ft) in Area 5. Below this region, water potential measurements indicate the existence of a static region, which begins between approximately 49 to 119 m (160 and 390 ft) in Area 3, and between approximately 40 to 90 m (131 and 295 ft) in Area 5 (Shott *et al*., 1997; 1998, 1995). In this static region, essentially no vertical liquid flow is currently occurring. Below this static region, flow is steady and downward due to gravity. Stable isotope compositions of pore water from these depths indicate that infiltration into this region must have occurred under cooler, past climate conditions (Tyler *et al*., 1996). If contaminants were to migrate below the currently static region, movement to the groundwater would be extremely slow due to the low water content of the alluvium. Conservative estimates of the travel time from beneath the static region to the groundwater in Area 5 are in excess of 50,000 yrs (Shott *et al*., 1995). Conservative estimates of travel times from just beneath the root zone to groundwater in Area 3 are in excess of 500,000 yrs, assuming zero upward flux (Levitt *et al*., 1998).

Based on the results of extensive research, field studies, modeling data, and monitoring data, which are summarized in the Area 3 and Area 5 RWMS PAs (Shott *et al*., 1997; 1998, 1995) and in Levitt *et al*. (1998), there is no areally distributed groundwater recharge under current climatic conditions at the RWMSs. Recent studies indicate that under bare-soil conditions such as those found at the operational waste cell covers, some drainage may occur through the waste covers into the waste zone. This drainage is estimated to be about 1 percent of the annual rainfall at Area 5, and 10 percent of annual rainfall at Area 3, based on conservative modeling results (Levitt *et al*., 1999). In addition, monitoring data from a bare-soil weighing lysimeter located in Area 5 indicate that soil water contents at depths of 1 to 2 m (3 to 7 ft) are slowly increasing. It is unclear if water contents are approaching equilibrium values or increasing until drainage occurs through the bottom of the lysimeter. Drainage through the waste covers should not be confused with groundwater recharge because the covers will ultimately become partially vegetated, eliminating the downward pathway. Deep drainage and potential groundwater recharge appear to be occurring primarily along mountain fronts, but also in isolated valley locations at the NTS where soil permeabilities are high and vegetation is sparse.

3.6.3 Groundwater

The NTS is located within the Death Valley groundwater flow system, one of the major hydrologic subdivisions of the southern Great Basin. The Death Valley groundwater flow system covers an area of about 40,920 km^2 (15,800 mi^2). This flow system consists primarily of volcanic rock in the west and carbonate rock in the east and is estimated to transmit more than 8.6 million cubic meters (m^3) (70,000 acre-ft) of groundwater annually. Most of this flow moves through a thick sequence of Paleozoic carbonate rock extending throughout the subsurface of central and southeastern Nevada and is sometimes referred to as the “central carbonate corridor.” The divisions of different groundwater flow systems within the NTS are based on the concept of groundwater subbasins, defined as the area that contributes water to a major surface discharge. Three principal groundwater subbasins have been identified within the NTS region as the Ash Meadows, Oasis Valley, and Alkali Flat-Furnace Creek Ranch subbasins. Yucca Flat and Frenchman Flat lie within the Ash Meadows Subbasin (Laczniak *et al*., 1996).

The Ash Meadows subbasin covers an area of about 10,360 km^2 (4,000 mi^2). Precipitation is believed to recharge the subbasin along its northern boundary at the Belted, Reveille, Timpahute, and Pahranagat Ranges, along its eastern boundary at the Sheep Range, and along its southern boundary at the Spring Mountains. Recharge is also suspected to occur within the subbasin at higher elevations of the Spotted, Pintwater, and Desert Ranges. Groundwater primarily flows through the lower carbonate-rock aquifer and discharges along a line of springs in Ash Meadows. Groundwater flow rates through the Ash Meadows subbasin are highly variable, where estimates range from less than 0.3 to more than 300 m/day (0.1 to 100 ft/day), depending on the unit. In general, the regional carbonate-rock aquifer is believed to transmit water at the fastest rate, whereas the basement and Eleana confining units transmit water at the slowest rate, and volcanic and valley-fill aquifers and confining units transmit water at intermediate rates (Laczniak *et al*., 1996).

The lower carbonate-rock aquifer within the Ash Meadows subbasin is the only subsurface pathway by which groundwater leaves Yucca Flat and Frenchman Flat basins. Groundwater flows south from Yucca Flat into Frenchman Flat and then southwest toward downgradient areas (primarily Ash Meadows). Water levels within the lower carbonate-rock aquifer indicate that the gradient is nearly flat (less than 0.2 m/km [1 ft/mi]) between Yucca Flat and Frenchman Flat and down to the discharge area at Ash Meadows. This flat gradient is an indication of a high degree of hydraulic continuity within the aquifer, which is probably a result of a high fracture (secondary) permeability (Laczniak *et al*., 1996).

The hydrogeologic units overlying the lower carbonate-rock aquifer are thought to consist of alluvium overlying tuff (aquifer and confining units). The alluvium unit is variably cemented and consists of moderately sorted deposits of gravel and sand having high interstitial porosity and permeability. The tuff aquifer is a welded tuff and is characterized by high fracture permeability. The tuff confining unit is characterized as a bedded, nonwelded tuff that has been altered to zeolite minerals as a result of postvolcanic reactions with groundwater, resulting in decreased rock permeability. The Eleana confining unit is present only in the western part of Yucca Flat and does not occur beneath the Area 3 or Area 5 RWMSs.

At the Area 3 RWMS, there is a lack of deep drillhole data to identify depths of geologic units. Based on data from surrounding boreholes, alluvial deposits are believed to be approximately 305 to 457 m (1,000 to 1,500 ft) thick. These deposits are underlain by a tuff aquifer approximately 152 m (500 ft) thick, which in turn is underlain by a tuff confining unit approximately 305 m (1,000 ft) thick. Beneath the tuff confining unit is the carbonate-rock aquifer at a depth of approximately 914 m (3,000 ft). The water table occurs in the tuff units approximately 488 m (1,600 ft) below the ground surface (Shott *et al*., 1997).

At the Area 5 RWMS, an alluvial aquifer is believed to extend beneath all of the active portion of the facility. Three pilot wells surround the Area 5 RWMS (Figure 4), and the water table occurs in the alluvial aquifer at two of the three wells. The minimum thickness of the vadose zone beneath the Area 5 RWMS is 236 m (773 ft) at UE5PW-1. At UE5PW-3, the water table occurs in tuff at a depth of 272 m (891 ft), and the alluvium-tuff contact occurs at a depth of 180 m (591 ft) (Shott *et al*., 1995).

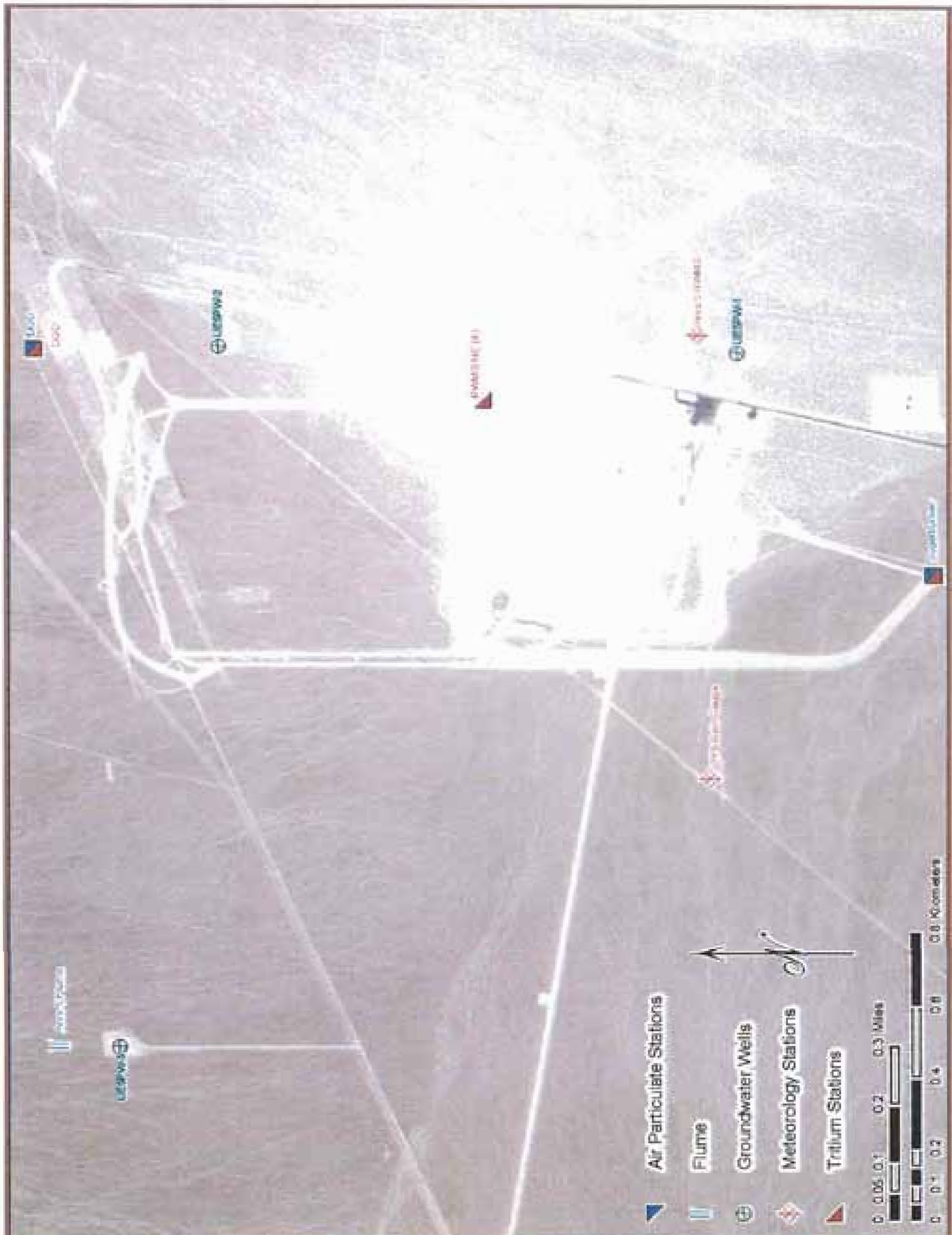

Figure 4 Locations of three pilot wells surrounding the Area 5 Radioactive Waste Management Site

Beneath the Area 5 RWMS, a 360- to 460-m- (1,180- to 1,510-ft)-thick alluvial unit is assumed to be underlain by approximately 549 m (1,800 ft) of tuff aquitard. The lower-carbonate aquifer lies beneath the tuff aquitard (Shott *et al*., 1995). A new well (ER-5-3#2) drilled northeast of the RWMS (near UE5PW-2) showed the alluvium to be 628 m (2,060 ft) thick. Underlying tuff is 798 m (2,618 ft) thick and contacts dolomite (a carbonate rock) at 1,426 m (4,678 ft) below the ground surface. The water table of this location is 283 m (927 ft) below the ground surface.

3.6.4 Groundwater Chemistry

Three types of groundwater chemistry facies dominate the region: (I) a calcium-magnesium bicarbonate (Ca-Mg-HCO_3) facies within the carbonate units, (II) a sodium and potassium bicarbonate (Na-K-HCO_3) facies derived from groundwater in volcanic rocks, and (III) a mixed facies containing components from both (I) and (II). The Na-K-HCO_3 facies (II) is found within the lava-flow aquifer and tuff-aquitard units. The facies also is seen in portions of the valley-fill aquifer, where a major portion of the alluvial-fill material has been derived from the erosion of volcanic units. The Ca-Mg-HCO_3 composition (I) is found within the Paleozoic carbonate units, such as the lower-carbonate aquifer and in the valley-fill aquifers that are composed of carbonate detritus. Most of the calcium and magnesium present is from the dissolution of limestone and dolomite ($CaCO_3$ and $CaMg(CO_3)_2$) mineralization in the unit as it conducts flow. Water of the mixed facies (III) contains portions of both the Na-K and Ca-Mg ions groups (Chapman, 1994; Winograd and Thordarson, 1975).

3.7 Alluvium Geochemistry

The geochemistry of the native alluvium affects the transport of radionuclides by affecting their solubility and sorption characteristics. The alluvium is dominated by quartz, feldspar, and cristobalite, with calcite, gypsum, and minor amounts of clays and zeolites. Measured pH values range between 7 and 9, indicating neutral to alkaline conditions (Cochran *et al*., 2001). The presence of clays and zeolites in an alkaline environment generally inhibit the mobility of the radionuclides. The geochemical environment of the closure cover is anticipated to be largely determined by the geochemistry of the constituent alluvium.

3.8 Natural Hazards

3.8.1 Seismicity

Seismic hazard studies conducted at the NTS (Campbell, 1980; Battis, 1978; Rogers *et al*., 1977; and Hannon and McKague, 1975) agree that the predicted maximum Richter magnitude for an earthquake is between 5.8 and 7.0, with a peak acceleration between 0.7 and 0.9 g. The predicted maximum magnitude earthquake (and the associated peak acceleration) has a return period between 12,700 and 15,000 yrs (Metcalf, 1983). The seismic studies show a 0.54 probability of an earthquake with a Richter magnitude greater than 6.8 within the next 10,000 yrs.

Earthquakes with magnitudes between 4.3 and 4.5 occurred in Frenchman Flat in 1971 and 1973 (Case *et al*., 1984) and in 1999. The 1973 and 1999 earthquakes were associated with the Rock Valley Fault, whereas the 1971 earthquake was associated with the Cane Spring Fault. The focus of this latter earthquake was in the Massachusetts Mountains which separate Yucca Flat and Frenchman Flat. No damage was reported from any of these earthquakes. Because of the absence of layers that could be disrupted by movement, the monolayer-ET design anticipated for closure covers at both RWMSs is intrinsically not prone to significant damage from earthquakes.

3.8.2 Volcanism

The risk of volcanism in the NTS region is indicated by the potential for either future silicic or future basaltic volcanism. Silicic volcanism is characterized by large-volume, explosive eruptions; whereas basaltic volcanism is characterized by cinder cones and lava flows of limited extent. The hazard for silicic volcanism is considered to be negligible because (1) within the last 20 to 10 million yrs, there has been a significant decrease and, in most areas, a cessation of silicic volcanism within the central and southern parts of the Great Basin; (2) silicic volcanism has been absent in the NTS region for the past 8.5 million yrs; and (3) Quaternary (less than 10,000 yrs) silicic volcanism is restricted to the eastern and western margins of the Great Basin (Crowe *et al*., 1983). A transition from predomi-antly silicic volcanism to basaltic volcanism occurred approximately 10 million yrs ago.

Late- and post-Miocene basaltic volcanism in the NTS region is divided into two episodes: (1) large-volume basaltic centers that are spatially and temporally associated with the waning phase of silicic volcanism; and (2) small-volume, spatially scattered basalt centers that postdate silicic volcanism (Crowe, 1990). The latter episode of volcanism is subdivided into two cycles: late Miocene basalt centers in the east and north-center of the NTS, and Pliocene and Quaternary basalt centers primarily in the southwest part of the NTS region. The youngest basaltic volcanic center in the NTS region is the 70,000-yr-old basalt of Lathrop Wells. The youngest basalt within Yucca Flat, at 8.4 million yrs, is between 226 and 308 m (740 and 1,010 ft) deep in borehole UE-1h, 1.6 km (1 mi) southwest of the Area 3 RWMS. The youngest basalt within Frenchman Flat, at 7.4 million yrs, is exposed at the surface in Nye Canyon, approximately 21 km (13 mi) northeast of the Area 5 RWMS.

The greatest hazard of future basaltic volcanism in the NTS region is within zones of Pliocene and Quaternary volcanism (Crowe *et al*., 1998a). The Area 3 and Area 5 RWMSs are outside and a considerable distance from all Pliocene and Quaternary volcanic zones. Based on studies at Yucca Mountain, Crowe *et al*. (1998a) calculated the probability of magmatic disruption of an equivalent area outside a volcanic zone to be 3E-09, or 3E-06 over a 1,000-yr compliance period. This probability is sufficiently low that basaltic volcanism can be dismissed as a credible event for the RWMSs.

3.8.3 Flooding

Schmeltzer *et al*. (1993) identified three watersheds that could contribute water to the Area 5 RWMS: Barren Wash, Massachusetts Mountains – Halfpint Range, and Scarp Canyon. The total area of these watersheds is approximately 360 km^2 (140 mi^2). A flood hazard assessment for the Area 5 RWMS based on these watersheds shows that only the southwest corner of the Area 5 RWMS is within a 100-yr flood hazard zone. This zone is defined by the Federal Emergency Management Agency (FEMA) to have a 0.01 (1 percent) probability that a flood with a depth of flow greater than 0.3 m (1 ft) could occur within any given year. The southwest corner of the RWMS has the potential for flooding from both alluvial-fan flow on the Barren Wash fan and shallow concentrated flow on the Massachusetts Mountains – Halfpint Range fan. Other parts of the Area 5 RWMS are within an area referred to as Zone X, where sheetflow resulting from a 100-yr, 6-hr precipitation event is anticipated to be less than 0.3 m (1 ft) deep. Recent studies, and a documented 25-yr, 24-hr precipitation event at the NTS, suggest that actual depths of flow and flow velocities may be considerably less than modeled because of water lost into the ground during transmission (French and Curtis, 1999). The currently active part of the Area 5 RWMS is now protected from a 25-yr, 24-hr flood event via a channel and berm system.

A flood hazard assessment for the Area 3 RWMS considered the entire watershed of Yucca Flat, but focused on a 94-km^2 (36-mi^2) drainage area east of the Area 3 RWMS that has the greatest potential to impact the site. The assessment determined that the Area 3 RWMS is not within a FEMA-designated 100-yr, 6-hr flood hazard zone (Miller, 1996).

3.9 Natural Resources

Exploration and exploitation of natural resources near the RWMSs potentially could have an impact on closure and monitoring over both the near and long terms. A natural resource is economically viable if it is available in sufficient quality and quantity, and a demand for the resource exists. Four potentially viable resources are identified for the NTS: sand and gravel, minerals, hydrocarbons, and water.

Both the Area 3 and Area 5 RWMSs are located on alluvial fans composed primarily of sand and gravel. Most sand and gravel is used for road base, building pads, and other fill structures. Construction of closure covers may require a relatively large volume of sand and gravel, presumably derived from within or near the RWMSs. Exploitation of sand and gravel from near the RWMSs for other than local use is unlikely because the gravels are composed largely of silicic volcanic rocks, which tend not to be durable. Additionally, good quality sand and gravel are generally available elsewhere.

Four mining districts are present on the NTS: Calico Hills, Oak Spring, Mine Mountain, and Wahmonie. Of these four districts, Calico Hills is considered to be sufficiently distant from Yucca Flat and Frenchman Flat to not significantly impact the RWMS if the district should be developed. Oak Spring district is in northern Yucca Flat, Mine Mountain district is in southwestern Yucca Flat, and Wahmonie district is in southern Frenchman Flat. The Oak Spring district is considered to have moderate potential for tungsten, and silver may be present (SAIC/DRI, 1991). Although economic deposits of silver and gold were extracted from Mine Mountain and Wahmonie districts, the current economic potential for these districts is uncertain (Richard-Haggard, 1983; Gustafson *et al*., 1993). Overall, especially considering that DOE anticipates institutional controls over the NTS for the foreseeable future, the probability of mineral exploration and exploitation that would impact the RWMSs is low.

The potential for oil and natural gas in southern Nye County is thought to be low (Garside *et al*., 1988; Castor, *et al*., 1990). Trexler *et al*. (1996), however, suggest a "cautiously optimistic view of the hydrocarbon potential" for the NTS and surrounding area based on the occurrence of thrust plates that provide potential reservoir space, and a favorable thermal history. Studies in southern Nye County and the NTS do not indicate the presence of coal, tar sand, or oil shale (Gustafson *et al*., 1993).

Groundwater under the NTS is generally acceptable for drinking water, and industrial and agricultural uses (Chapman, 1994). Industrial and agricultural uses are currently precluded because of land use and institutional controls over the NTS into the foreseeable future. Human consumption of water has the greatest probability for impacting the RWMSs. Such impact is likely not to occur in the near term because (1) current demand is low, (2) the cost of extracting water from below Yucca Flat and Frenchman Flat is high, and (3) water is available from other sources.

4.0 AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE DESCRIPTION

4.1 Waste Disposal Facility and Location

The Area 3 RWMS is approximately 45 km (28 mi) northwest of Mercury in the east-central part of Yucca Flat, in the northeast part of the NTS (*Figure 2*). The Area 3 RWMS covers 48 hectares (ha) (120 acres [ac]) and is comprised of seven subsidence craters (U-3ax, U-3bl, U-3ah, U-3at, U-3bh, U-3az, and U-3bg) that formed as a result of underground nuclear-device tests in the early 1960s (Figure 5). The area between craters U-3ax and U-3bl was excavated to form one large disposal unit (U-3ax/bl); the area between craters U-3ah and U-3at was also excavated to form another large disposal unit (U-3ah/at). Waste unit U-3ax/bl is operationally closed; waste units U-3ah/at and U-3bh are active; and the remaining craters, although currently undeveloped, are available for disposal of waste if required. The RWMS boundary is marked by a wire fence. Access to the RWMS is through a gate on the north side of the facility, adjacent to structures that house office space and access control. The craters and infrastructure associated with disposal operations within the fence boundary have largely disturbed natural conditions. This is also true, but to a lesser extent, beyond the fence boundary. Infrastructure, and radiologically controlled areas resulting from nearby aboveground nuclear tests, are present around the RWMS.

Both packaged and unpackaged, bulk LLW is disposed in craters that resulted from underground testing of nuclear devices during the 1960s. Mixed waste is not currently disposed at the Area 3 RWMS; however, some mixed waste was disposed in U-3ax/bl in the past.

4.2 Historical Development and Use of the Facility

The first documented disposal at the Area 3 RWMS[1] was in U-3ax crater on July 30, 1968 (REECo, 1968); debris and soil contaminated by atmospheric nuclear-device tests in the 1950s and early 1960s were collected and placed in the bottom of the crater (REECo, 1980). In 1984, when the bottom of U-3ax crater was level with the bottom of adjacent U-3bl crater, the area between the craters was excavated and disposal of contaminated debris and soil continued in the enlarged disposal cell. In 1985, cargo containers were disposed in the excavated area between the two craters and, in 1987, various sized containers were disposed in the upper part of U-3bl. An operational cover, nominally about 1.5 m (5 ft) thick (BN, 1999a), was placed over U-3ax/bl after disposal operations stopped in 1987. A final closure cover was placed over U-3ax/bl in 2001. About 80 percent of the waste disposed in U-3ax/bl is contaminated debris and soil, and about half of this waste is soil. Mixed LLW from other DOE facilities was also disposed in U-3ax/bl (Elletson and Johnejack, 1995). Consequently, U-3ax/bl is regulated as a mixed-waste landfill under RCRA and was closed in accordance with RCRA and DOE requirements.

Disposal of contaminated debris and soil from continued cleanup of atmospheric nuclear test areas was moved to U-3at crater in 1988. Two tiers of unpackaged waste were placed in the crater over a period of approximately one year. As at U-3ax/bl, the area between crater U-3at and adjacent crater U-3ah was then excavated to expand the volume for waste disposal. The resulting waste disposal cell is designated U-3ah/at. From 1989 to present, four additional tiers of waste in cargo containers, primarily from off-site generators, have been disposed in U-3ah/at. Soft-sided packages of plutonium-contaminated soil from cleanup of safety shots at the Tonopah Test Range north of the NTS have also been disposed in U-3ah/at since 1997. The disposal cell has sufficient remaining volume for at least one tier of waste and perhaps two, depending on the configuration of the final closure cover.

Unpackaged bulk waste and plutonium-contaminated soil and other waste in soft-sided packages and have been disposed in disposal cell U-3bh since 1997 and will continue to be disposed over the next several years. Disposed waste soil is covered with uncontaminated soil to ensure that contamination is not inadvertently spread.

4.3 Disposal Operations

Waste to be disposed at the Area 3 RWMS is transported there on trucks. On arrival, manifests are checked and trucks are inspected both visually and with instrumentation to ensure that there is no leakage of contaminated materials from the containers. When cleared, the containers are off-loaded and placed in one of the disposal configurations described above, depending on whether the waste is in cargo containers, soft-sided packages, or is unpackaged.

4.4 Ancillary Facilities

The only structures at the Area 3 RWMS are an office trailer and a change trailer that are manned only during disposal operations. All other functions are supported by facilities at the Area 5 RWMS.

[1]The Area 3 RWMS was formally established in 1978 with the advent of the NTS Waste Management Program.

4.5 Waste Characteristics

4.5.1 Waste Containers

Waste is generally delivered to the Area 3 RWMS in cargo containers, metal boxes that measure approximately 6 m (20 ft) long, 2.4 m (8 ft) wide, and 2.4 m (8 ft) high; one end of the container has doors that swing outward for access, or are loaded from the top. These containers are off-loaded and disposed without opening. Waste is also delivered to the RWMS in soft-sided packages. These containers are also off-loaded and disposed without opening.

4.5.2 Treatment or Processing Prior to Disposal

Treatment or processing of waste is conducted by the waste generator prior to shipment to the RWMS for disposal. Generators desiring to ship waste to the NTS must have their waste certification program and waste stream(s) approved by NNSA/NV. A waste stream is described on a waste profile. In addition to a description of the waste, a waste profile includes a description of the waste generation process(es), and an estimate of the low and high activity concentration of significant radionuclides. Approval to ship is granted on a waste-stream-specific basis once a generator's certification program has been approved. Waste shipped to the NTS for disposal must meet the NTSWAC (NNSA, 2000). Information on characterization of radiological waste is reported to the site operator, generally electronically, for entry into the site inventory at the time of shipment.

4.5.3 Types and Quantities of Waste at the Facility

Waste inventories for the various disposal units at the Area 3 RWMS are presented in the PA and CA for the Area 3 RWMS (Shott *et al*., 1997). The estimated inventories at closure for the Area 3 RWMS are summarized in Table 2. Only isotopes with an inventory of greater than 1 curie are shown. The inventory at closure in U-3ah/at is projected to be approximately 700 curies of activity in 0.26 million m^3 (9.4 million ft^3) of packaged waste (the inventory of U-3bh is included with the inventory of U-3ah/at). The inventory in U-3ax/bl at operational closure was approximately 6,700 curies of activity in 0.22 million m^3 (8.0 million ft^3) of primarily unpackaged, bulk waste.

5.0 AREA 5 RADIOACTIVE WASTE MANAGEMENT SITE DESCRIPTION

5.1 Waste Disposal Facility and Location

The Area 5 RWMS is approximately 22 km (14 mi) north of Mercury in the northern part of Frenchman Flat (*Figure 3*). The Area 5 RWMS covers 293 ha (732 ac) and is bounded by a buffer zone 300 m (1,000 ft) wide. Thirty-seven hectares (92 ac) in the southeast corner of the RWMS are actively used for disposal and storage of wastes (Figure 6). Packaged LLW and MLLW generated within Nevada under the purview of NNSA/NV are currently disposed in excavated disposal units, with exceptions, are typically between 180 and 210 m (600 and 700 ft) long, 12 and 18 m (40 and 60 ft) wide, and 6 and 9 m (20 and 30 ft) deep. The practice has been to designate an excavation as

Figure 5 Orthophotograph of the Area 3 Radioactive Waste Management Site

Table 2 Estimated inventories in the waste disposal units at the Area 3 RWMS at closure (the Area 3 RWMS PA/CA assumes closure in FY 2010). Only isotopes with an inventory greater than 1 curie are shown. Isotopes are presented in decreasing inventory. Data from Shott *et al*., 1997.

Radionuclide	U-3ah/at and U-3bh Estimated Inventory at Closure (Ci)	Radionuclide	U-3ax/bl Estimated Inventory at Closure (Ci)
hydrogen 3	480	hydrogen 3	6,000
plutonium 241	71	cesium 137	320
plutonium 239	51	strontium 90	260
cesium 137	26	cobalt 60	20
strontium 90	20	krypton 85	19
plutonium 240	12	plutonium 241	16
uranium 238	11	samarium 151	11
uranium 234	10	europium 152	9.4
americium 241	8.2	europium 154	7.1
plutonium 238	3	plutonium 239	4.4
krypton 85	1.2	plutonium 238	1.7
samarium 151	1.1	plutonium 240	1.1
		americium 241	1.1
Total	**695**	**Total**	**6,671**

either a “trench” or “pit,” the difference being that a truck could be turned around in a pit. (This equates to greater than 30 m [100 ft] wide for a pit and less than 30 m [100 ft] wide for a trench.) Trench designations are prefixed with a “T,” whereas pit designations are prefixed with a “P.” The designations are suffixed with either a “U” or “C” to indicate “unclassified” or “classified” waste, respectively. Currently, 7 of 23 disposal units are open for disposal of wastes; the others have been operationally closed with a cover of native alluvium approximately 2.4 m (8 ft) thick. (Trenches T04C and T04C-1 are herein considered to be discrete, resulting in 23 disposal units at the RWMS rather than 22 disposal units as is sometimes referenced.) Pit 8 is being constructed in the area north of the currently active 92-acres. This new disposal area is termed the “expansion area.”

Greater Confinement Disposal boreholes were used in the past to dispose waste that was considered unsuitable for shallow land disposal because of its high activity or potential for migration. Thirteen such boreholes were drilled. A GCD borehole is typically 3 m (10 ft) in diameter and 36 m (120 ft) deep and unlined except for the top 3 m (10 ft), which are cased with corrugated steel culvert. Waste was

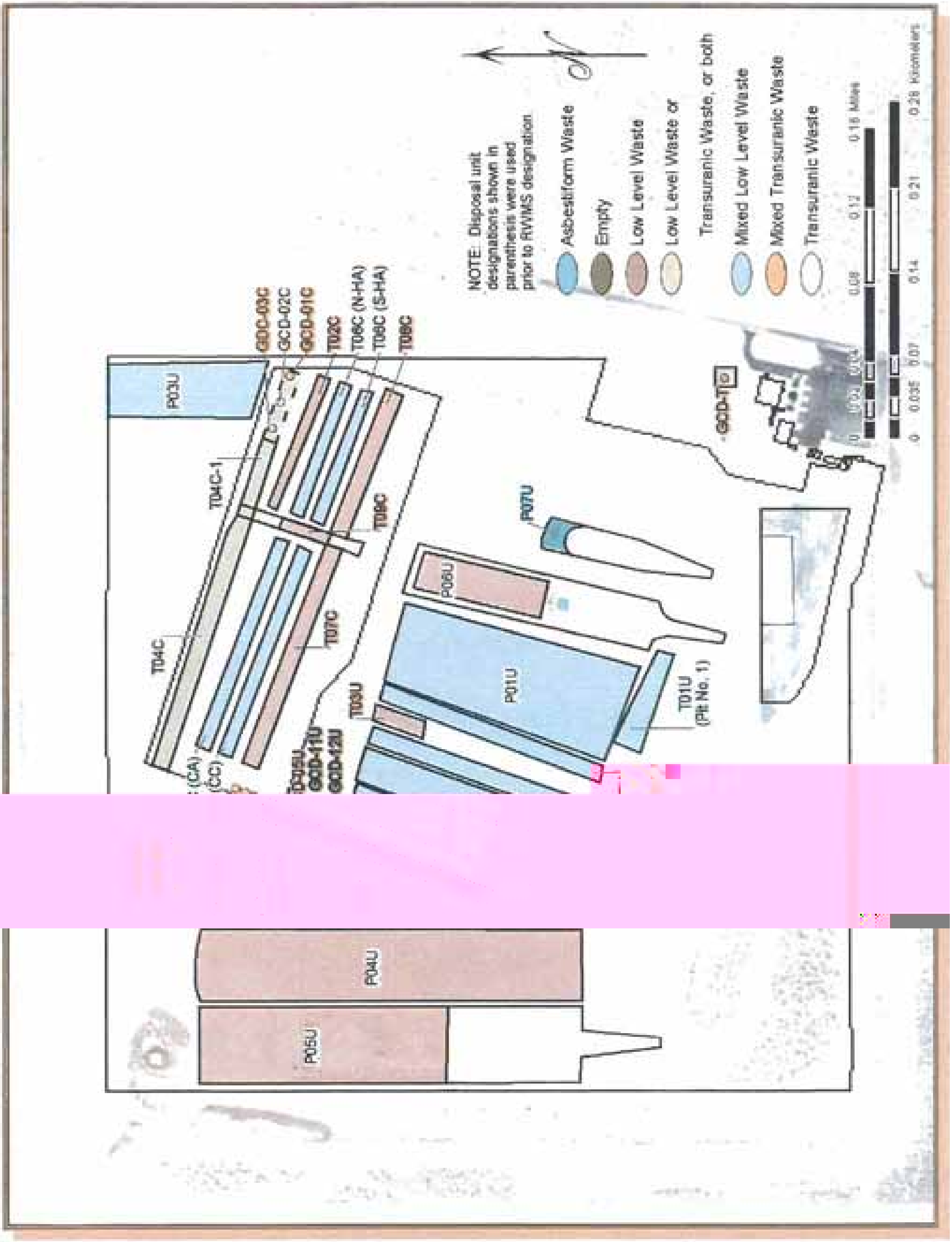

Figure 6 Orthophotograph of the Area 5 Radioactive Waste Management Site

remotely placed in the GCD borehole from the bottom to a depth of 21 m (70 ft) below surface and backfilled with native alluvium. Transuranic waste currently stored at the Area 5 RWMS on an asphalt pad is destined to be disposed at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

5.2 Historical Development and Use of the Facility

Disposal of radioactive waste at the Area 5 RWMS[1] started in 1961 and, through 1978, eight disposal units were filled primarily with on-site-generated waste and operationally closed. The Area 5 RWMS began disposing greater amounts of waste from off-site generators in 1978. Between 1978 and September 26, 1988 (the latter date being when DOE Order 5820.2A, "Radioactive Waste Management" [now replaced with DOE O 435.1] was promulgated), two pits (P01U and P02U) and one trench (T07U) were filled and operationally closed. Five pits (P03U, P04U, P05U, P06U, and P07U) and six trenches (T03U, T02C, T04C, T07C, T08C, and T09C) have been active since promulgation of DOE Order 5820.2A; one pit (P04U) and three trenches (T03U, T02C, and T04C) are now operationally closed, leaving seven currently active (P03U, P05U, P06U, P07U, T07C, T08C, and T09C). Most of the MLLW at the Area 5 RWMS was disposed before 1992; however, Pit P03U has accepted small amounts of MLLW generated on site since that time. Between 1983 and 1989, 9 of 13 GCD boreholes were used for disposal of high-specific activity LLW (waste similar to Greater-than-Class C) and TRU and MTRU wastes. Seven boreholes have been filled and operationally closed with backfill of native alluvium, two boreholes have received waste and remain open, and four boreholes are empty. Two GCD boreholes were active after promulgation of DOE Order 5820.2A.

5.3 Disposal Operations

Waste to be disposed at the Area 5 RWMS is transported there on trucks. On arrival, manifests are checked and trucks are inspected both visually and with instrumentation to ensure that there is no leakage of contaminated materials from the containers. When cleared, the containers are off-loaded and disposed in the appropriate active pit or trench, depending on waste type or classification, or both. Trucks are released only after being surveyed for contamination. Once disposed, waste is covered with approximately 2.4 m (8 ft) of screened native alluvium. Four "unclassified" pits (P03U, P05U, P06U, and P07U), and three "classified" trenches (T07C, T08C, and T09C) are currently open for receipt of waste.

Pit P03U is designated for disposal of MLLW under RCRA interim status; however, only a small amount of NTS-generated mixed waste has been disposed there since 1992. Pit P05U is open for receipt of LLW. Pit P06U has been deepened for disposal of thorium waste, and Pit P07U is open for receipt of radioactive asbestiform waste. Pit P08U in the expansion area will be opened for disposal of LLW.

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[1]The Area 5 RWMS was formally established in 1978 with the advent of the NTS Waste Management Program. This disposal site was previously termed "Suger Bunker."

Greater Confinement Disposal is not anticipated to be used as a waste disposal option in the future.

5.4 Ancillary Facilities

The Area 5 RWMS includes several equipment storage yards and five permanent and nine semipermanent structures that are used for offices, laboratories, storage, utilities, and routine operations. Ancillary to the Area 5 RWMS are a Waste Examination Facility (WEF) and several support structures. The WEF exists to characterize TRU waste stored at the Area 5 RWMS. Neighboring the RWMS are a Hazardous Waste Storage Unit (HWSU) and several administrative support structures. Hazardous wastes are managed at the HWSU until they are shipped off site for disposal.

5.5 Waste Characteristics

5.5.1 Waste Containers

Containers disposed at the Area 5 RWMS are categorized as boxes, drums, or nonstandard. Cardboard, octagonal "tri-wall" boxes were commonly used prior to the mid-1980s. These cardboard boxes were 0.6 or 1.2 m (2 or 4 ft) high and banded to wooden pallets with steel strapping. Waste was contained in plastic bags inside the cardboard boxes. These boxes were stacked as close to each other as the underlying pallet allowed and were susceptible to crushing if stacked too high. Plywood boxes came into wide use thereafter and range in size from 0.6 m (2 ft) high, 1.2 m (4 ft) wide, and 2.4 m (8 ft) long to 1.2 m (4 ft) high, 1.2 m (4 ft) wide, and 2.4 m (8 ft) long. Runners are typically attached to the bottom of the box to facilitate handling with a forklift. Steel boxes became popular in the 1990s. These boxes have standard sizes similar to those of plywood boxes. Steel runners or slots for handling with a forklift are typically part of the box design. Both the cardboard and steel boxes are stacked as close to each other as practicable; typically, several inches separate adjacent boxes.

Steel drums in various sizes have been used for disposal at the Area 5 RWMS. Standard 209-liter (L) (55-gallon [gal]) drums and 315-L (83-gal) overpack drums are common; less commonly used are six-drum overpack containers. Drums are stacked either vertically on pallets, horizontally in a square array, or horizontally in a nested array. Containers other than standard-sized boxes and drums are nonstandard. Many nonstandard containers have been disposed and include unusual shapes or non-standard-sized boxes or drums. Nonstandard containers are typically stacked to make best use of available pit volume.

5.5.2 Treatment or Processing Prior to Disposal

See Section 4.5.2.

5.5.3 Types and Quantities of Waste at the Facility

Wastes have been disposed at the Area 5 RWMS since 1960 and, for the purpose of developing the CA (BN, 2000b), operations were assumed to continue through 2028. The inventory of radioactive materials disposed at the Area 5 RWMS from 1960 through September 1988 was obtained from two databases that cover this period (1960 to 1978 and 1978 to 1992). These databases are known to have considerable uncertainty. The inventory anticipated to be disposed between September 1988 through 2028 was estimated in the Area 5 PA (Shott *et al*., 1998, 1995). The Area 5 RWMS PA is based on shipments of waste received between 1989 and 1993 (the last year that complete records were available for development of the PA); the probable inventory for the period between 1993 and 2028 is projected in the PA. The estimated inventories of radionuclides in pits and trenches at the Area 5 RWMS at closure (assumed in the PA and CA to be FY 2028) are summarized in Table 3. The estimated inventories of radionuclides in GCD are summarized in Table 4.

Table 3 Estimated inventories of radionuclides in all waste disposal units at the Area 5 RWMS at closure (FY 2028). Only isotopes with an inventory greater than 1 curie are shown. Isotopes are presented in decreasing inventory.

Radionuclide	Estimated Inventory at Closure (Ci)	Radionuclide	Estimated Inventory at Closure (Ci)
hydrogen 3	2400000	krypton 85	51
cesium 137	150000	radium 226	44
strontium 90	90000	lead 210	31
uranium 238	8100	carbon 14	24
uranium 234	4000	thorium 232	11
plutonium 239	900	radium 228	9.2
plutonium 238	830	thorium 228	9.0
plutonium 241	820	neptunium 237	6.2
technetium 99	540	argon 39	3.8
uranium 235	240	thorium 230	3.7
americium 241	210	uranium 233	1.3
plutonium 240	210	potassium 40	1.1
uranium 236	62	**Total**	**2,656,107**

Table 4 Estimated current inventories of radionuclides in GCD at the Area 5 RWMS. Only isotopes with an inventory of greater than 1 curie are shown.

Radionuclide	Estimated Inventory at Closure (Ci)	Radionuclide	Estimated Inventory at Closure (Ci)
hydrogen 3	2800000	americium 241	76
strontium 90	420000	plutonium 240	31
cesium 137	19000	actinium 227	8.0
cobalt 60	3300	plutonium 238	6.3
plutonium 241	630	uranium 234	3.4
plutonium 239	320	uranium 238	2.5
radium 226	99	**Total**	**3,243,476**

6.0 CLOSURE APPROACH

Closure of the Area 3 and Area 5 RWMSs will proceed through three phases: operational closure, final closure, and institutional control. Many waste disposal units at the Area 5 RWMS are operationally closed and one unit, U-3ax/bl, at the Area 3 RWMS, is finally closed. Over the latter part of the next decade, all waste disposal units at the Area 5 RWMS are anticipated to be closed. Waste disposal units at the Area 3 RWMS, units in the Area 5 RWMS expansion area, and possibly Pit P03U in the Area 5 RWMS 92-acre site will remain open for future waste disposal. Final closure of these units is anticipated in the FY 2019 through 2021 time frame. Operational maintenance and monitoring will transition to postclosure maintenance and monitoring immediately after closure of the disposal units, and extend through the period of active institutional control. Any future release of the site will be in accordance with the *NTS Resource Management Plan* (DOE, 1998) and annual summaries, and with DOE Order 5400.5, "Radiation Protection of the Public and Environment"; or, for mixed-waste units, in accordance with conditions negotiated with the NDEP.

6.1 Closure Cover Design

Because performance objectives of the PAs are easily met, even with only an operational closure cover, the NNSA/NV has considerable flexibility in designing the final closure covers. An approach will be taken for both closure and monitoring that emphasizes simplicity of design and maintenance. The basic closure cover design for all of the various units will be of the vegetated monolayer-ET type (Figure 7). A vegetated monolayer-ET closure cover was deployed in FY 2000 at the Central Nevada Test Area north of the NTS, and early in FY 2001 on U-3ax/bl at the Area 3 RWMS (DOE, 2000a). In some cases, such as when considering long-lived or high-activity radionuclides, or where burrowing by termites or intrusion of roots might be problematic, the basic design may require modest modification to ensure long-term containment. Such modifications will be dealt with on a case-by-case basis. An instrumented drainage lysimeter facility near the Area 5 RWMS and a similar facility constructed in 2001 at the Area 3 RWMS will collect data over at least the next several years that are useful to optimize the design of the closure covers for specific units (see Section 7.4.3.2).

A monolayer-ET closure cover was selected as the preferred alternative design to a multilayered RCRA closure cover and other alternative designs only after a comprehensive evaluation of many alternatives. Evaluation of alternative designs included review of relevant literature, research on water balance in vegetated and unvegetated weighing lysimeters in Area 5 of the NTS, hydrogeologic modeling, site visits to closure cover test facilities at SNL and LANL), NNSA/NV-sponsored workshops, and a conference on vadose zone monitoring. The various forums included representatives from industry, academia, and government, including SNL and LANL, and provided the opportunity to discuss closure and monitoring of waste disposal units. Multiple lines of evidence suggest that a monolayer-ET design will cost considerably less than a multilayer RCRA design, be much easier to install and maintain and, in an arid environment, perform according to performance criteria over long periods of time even under conditions of subsidence. The monolayer-ET cover and natural conditions

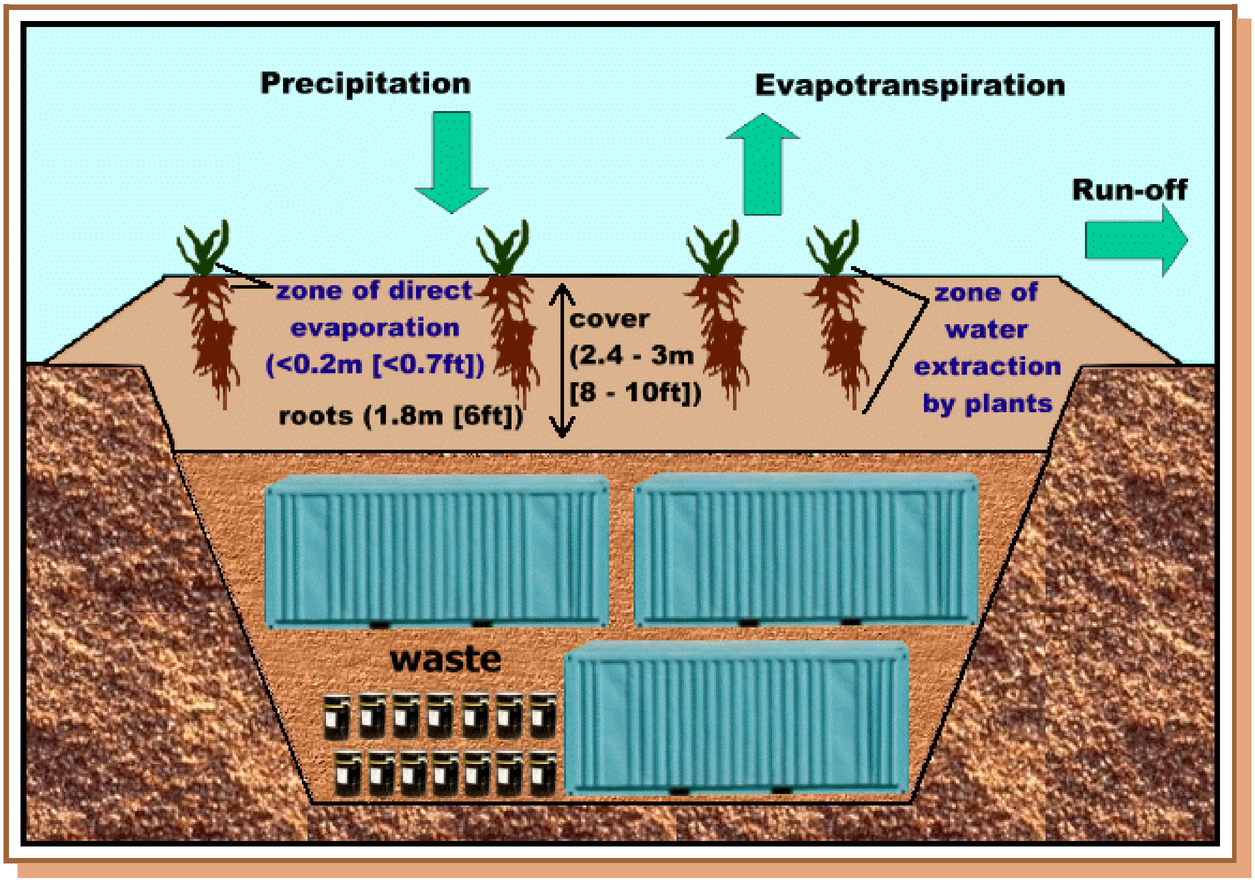

Figure 7 Diagram of a monolayer-ET closure cover.

at the NTS will integrate and operate as a system. Natural conditions that optimize the system are extemely low precipitation and high evapotranspiration; large depth to groundwater; and negligible recharge to groundwater.

6.1.1 Water Infiltration

Measurement and modeling of water balance in test monolayer-ET covers at the Area 5 RWMS and at National Laboratories in arid regions of the United States show that the design will minimize infiltration of water (Levitt *et al*., 1999; Dwyer, 1998).

Water balance studies conducted at the Area 5 RWMS have shown that a monolayer-ET closure cover is most effective when vegetated (Levitt *et al*., 1999). Under the current climatic regime, any water that infiltrates into the soil is quickly extracted by evaporation and uptake by plant roots, even with a relatively low density of plant cover. Closure covers constructed over waste units at both the Area 3 and Area 5 RWMSs will be planted with species native to the area. Shallow-rooted, invasive plant species will also be allowed to vegetate the closure covers. Over the long term, a plant assemblage that will survive the ambient range of environmental conditions is anticipated to become established. Plants will also serve to maintain stability of the closure covers. The cover will have adequate slope to safely carry any precipitation runoff without significant erosion.

6.1.2 Disposal Unit Cover Integrity

Design of any closure cover will have to consider the potential for plant root intrusion into disposed waste, a potential pathway for release of radionuclides. Cover designs will also have to consider the potential for animals burrowing into the closure cover or, less likely, into disposed waste. Burrowing by animals could degrade cover integrity, alter hydraulic properties of the cover, or transport radionuclides to the accessible environment (Hankonson *et al*., 1992). Mobile fauna could disperse contamination to distant sites, and animals could introduce contamination into trophic pathways, eventually leading to humans that consume wild game (O'Farrell and Gilbert, 1975). Design alternatives to mitigate these conditions will be included in closure plans specific to individual disposal units or groups of units.

6.1.3 Structural Stability

The structural stability of the closure cover would be affected by differential subsidence that would occur intermittently following infilling of void space around containers, and degradation and collapse of disposed waste containers. Values of parameters affecting subsidence such as volume of void space, as well as estimates of subsidence, are described in Shott *et al*. (1998, 1995), Barker (1997), and Obi *et al*. (1996). During a period of active institutional control, any subsidence that might occur would be immediately mitigated by filling and grading the subsided spots with native alluvium, thus ensuring structural stability at all times. Any major damage to vegetation on the closure cover from maintenance activities will be corrected by replanting. Part of the total expected subsidence may have taken place by the end of the active institutional control period. The monolayer-ET cover design will intrinsically be structurally stable in that it does not include layers which, if displaced, would render the cover ineffective. The cover, however, will have to be of adequate thickness to accommodate some, but perhaps not all, subsidence over time. The cover itself is expected to erode; depressions will fill with sediment eroded from surrounding areas of the cover. The design of the closure cover will include proper surface and side slopes, and perhaps limited armoring, to permit drainage but not channelized erosion.

6.1.4 Inadvertent Intruder Barrier

The monolayer-ET closure cover design does not include a barrier against inadvertent human intrusion (IHI). The thickness of the cover provides partial protection, but the greatest reliance is placed on a small probability of this occurrence, and on institutional control. The probability of IHI was the subject of an investigation of site-specific scenarios for inadvertent human intrusion into waste disposed at the Area 3 and Area 5 RWMSs. The intrusion scenarios focused on drilling for water in both Yucca Flat and Frenchman Flat, driven by an individual homesteader scenario and several community settlement scenarios (Black *et al*., 2001). A panel of Subject Matter Experts (SMEs) convened to elicit the probability of IHI into a waste unit considered the effectiveness of management controls on reducing the probability of intrusion. Management controls, which include institutional control, site knowledge, placards and markers, and surface and subsurface barriers, were thought by the panel to be effective only for the first few centuries; some controls were considered to be more effective than others. For example, surface barriers could effectively control siting of a drill rig over a waste unit; whereas subsurface barriers and placards and markers were much less likely to control drilling. Remoteness and harsh environmental conditions of both Yucca Flat and Frenchman Flat, and the presence of playas and subsidence craters, were thought by the panel to be the most important factors affecting the probability of drilling, and thus intrusion. One of several community scenarios, a community settlement that develops from an industrial-technological complex in a nearby, yet more accessible valley, and has commuter homesteaders living in Frenchman Flat, yielded the greatest probability of inadvertent intrusion; that is, about 10 percent.

Institutional control is discussed in Section 6.4.

6.2 Operational Closure

6.2.1 Area 3 Radioactive Waste Management Site

At both the Area 3 and Area 5 RWMSs, disposed waste is covered by placing screened native alluvium over the top of the waste. (Prior to 1995 the alluvium was not screened to remove cobbles and larger rocks.) A primary difference in approach to operational closure between the two sites is that waste at the Area 3 RWMS is disposed in tiers. Tiers are necessary to keep the height of stacked waste packages relatively low to ensure safety to workers. Depending on the disposal unit, a tier may consist of unpackaged bulk waste (U-3ax/bl), waste soil in soft-sided packages (U-3bh), or packaged waste (U-3ah/at). As a tier of waste is placed from one side of the unit toward the other side, the waste is progressively covered with 0.9 m (3 ft) of screened native alluvium. (Soft-sided packages are covered with 0.3 m [1 ft] of alluvium.) Each tier, when complete, extends over the entire floor of the disposal unit. With the exception of U-3ax/bl, whether disposal units at the Area 3 RWMS will be operationally closed above grade or at grade has yet to be determined. If closed above grade, alternating tiers of waste and alluvium will be brought to within 1.2 m (4 ft) of grade, and an operational cover will be placed as at the Area 5 RWMS. If closed at grade, the alternating tiers of waste and alluvium will be brought to within approximately 2.4 m (8 ft) of grade, and an operational cover will be placed. Design of the final closure cover for U-3bh and U-3ah/at will be established in a site-specific closure plan.

Disposal unit U-3ax/bl is the only unit at the Area 3 RWMS to have been filled and operationally and finally closed; the other two active disposal units are partially filled. Before final closure, the operational cover on U-3ax/bl was less than 1 m (3 ft) above grade. Until recently, little was known of the construction of the operational cover because at the time of closure, a recognized closure program was not in place. A ground-penetrating radar survey of the cover conducted in November 1999 showed the top 1.2 m (4 ft) to be homogeneous, and the interval between 1.2 and 3 m (4 and 10 ft) to be slightly heterogeneous but relatively free of disposed waste (DOE, 2000a). Test pits dug in November 1999 to 1.5 m (5 ft) below the surface of the operational cover, and probing of the cover to 2.7 m (9 ft) below the surface conducted prior to the radar survey, corroborate results of the radar survey. Most dry densities of samples collected from the test pits ranged approximately between 1.5 and 1.9 kilograms (kg)/m^3 (90 and 110 pounds [lbs]/ft^3) and calculated permeabilities of samples ranged approximately between 1.00E-3 and 1.00E-6 cm/s (4.00E-4 and 4.00E-7 in/s), with the mean permeability being approximately 1.00E-5 cm/s (4.00E-6 in/s) (DOE, 2000a). Because the method of placing the operational cover is generally the same between units and between the two RWMSs, these ranges of values for density and permeability may be generally representative of all the operational closure covers. Determination of density and permeability on operationally closed disposal units will be part of the final closure process.

6.2.2 Area 5 Radioactive Waste Management Site

Native alluvium excavated to form trenches at the Area 5 RWMS is typically stockpiled for later use in operational closure. Packaged waste is disposed starting at the upgradient end of a disposal unit and progresses toward the open end. Packages are stacked in the disposal unit to approximately 1.2 m (4 ft) below grade. An alphanumeric grid system laid out along the perimeter of the disposal unit is used for tracking the location of disposed waste. Aluminum tubes used later for neutron monitoring of soil moisture are placed at intervals between waste containers during stacking. The neutron monitoring tubes extend to the bottom of the disposal unit. Within a short time after disposal, stockpiled alluvium is screened to remove rocks larger than 9 cm (3.5 in) and then placed from the top of the unopen end of the disposal unit over the stacked packages. Final operational closures include placement of soil over the waste to a total thickness of about 2.4 m (8 ft), so that about 1.2 m (4 ft) of alluvium stand above grade. The front end of the waste is not covered with soil so that additional waste can be easily stacked. The alluvium is not put over the waste packages in lifts and is compacted by placement of the alluvium and from heavy equipment running over the total thickness of alluvium. After a disposal unit is completely filled, the operational cover is graded to provide a smooth surface. Maintenance of the cover includes filling of fissures and depressions resulting from compaction and piping of alluvium between waste packages, and compaction of the surface with a roller and regrading. Operational closure covers are not vegetated because of the need for continued maintenance activities.

Two weighing lysimeters installed near the Area 5 RWMS, one vegetated and the other bare, serve as analogs for the operational closure covers. Data collected over the past five years show that alluvium in the unvegetated lysimeter stores more water than similar alluvium in the vegetated lysimeter and, over a period of approximately five years, could have slight infiltration through the thickness of the soil column (approximately 1.8 m [6 ft]). Water that infiltrates into the vegetated lysimeter, however, is quickly removed by evapotranspiration. To date, no water has drained through the bottom of either lysimeter. Modeling conducted for final closure of disposal unit U-3ax/bl shows that water is effectively removed from the soil column with as little as 20 percent vegetation cover (DOE, 2000a). Several instrumented drainage lysimeters have also been installed at the Area 3 RWMS.

6.3 Final Closure

Waste disposed at the Area 3 and Area 5 RWMSs can be categorized based on security requirements, waste type, and disposal configuration (Table 5). Several GCD boreholes contain no waste; these have been designated to the appropriate category based on intended use in terms of classification. The criteria defining the categories of disposed waste, along with the spatial distribution of waste cells at each of the RWMSs, provide logical groups of waste cells when considering the activities, interactions, and documentation required to support closure. Such grouping of disposal units will allow key differences that might require different interactions or engineering to be adequately addressed in final closure documentation. Disposal units that contain only LLW, or that contain LLW and TRU waste, will be closed in accordance with regulations imposed by NNSA/NV in the process of self-regulation.

The Area 5 RWMS Atlas maintained by the management and operations contractor shows several operationally closed LLW disposal units within the 92-acre site that may contain hazardous constituents. Because the basis for this determination is unknown, review of paper records of waste received from 1961 through 1976, and of electronic records of waste received from 1977 through 1988 was conducted to verify to the extent possible which disposal units contain hazardous constituents regulated under the RCRA. At the time of disposal, these wastes were not regulated or defined as mixed waste. A Corrective Action Unit (CAU) of "retired mixed waste cells" (citing from the RCRA Permit NEV HW009) is proposed based on this evaluation. The "retired mixed waste cells" are within a group of waste disposal units that were opened, and generally operationally closed prior to January 1987, when P03U was opened for disposal of waste with hazardous constituents. The CAU will be closed in concert with the NDEP in accordance with RCRA and regulations imposed by NNSA/NV in the process of self-regulation (*Table 5*).

Over the period of FY 2002 through FY 2007, as an interim measure leading to final closure activities between FY 2008 and FY 2010, native soil will be added to cells composing the CAU and to all other operationally closed cells within the 92-acre site. The addition of native soil is comparable to the approach taken to close U-3ax/bl (CAU 110) at the Area 3 RWMS in FY 2001. Prior to this interim measure, a survey of existing topography will be conducted and certain geotechnical parameters of the operational covers will be determined.

Closure activities for waste disposal units in the 92-acre site, an expansion area north of the Area 5 RWMS, and the Area 3 RWMS follow a systematic process consisting of ten steps summarized below. These steps were followed for closure of U-3ax/bl (CAU 110). The first two steps, preliminary assessment and initial planning, determine the depth to which each remaining activity or document have to be conducted or developed. Results of investigations conducted prior to the interim measure discussed above for the 92-acre site, and results of previous site characterization studies an ongoing measures of water balance at the 92-acre site and elsewhere, are believed to be sufficient that initial closure activities for the 92-acre site will be minimal. A closure plan for the 92-acre site is scheduled for FY 2009, followed by closure construction and a closure report in FY 2010. Responsibilities for closure and monitoring of the 92-acre site are shared between the NNSA/NV WMD and the ERD.

Table 5 Categories of disposal cells at the Area 3 and Area 5 RWMSs based on security requirements, waste type, and disposal configuration. Disposal units that contain mixed waste compose CAU 111 and require involvement of the NDEP in the closure activities.

Category	Cells	Security Requirements	Waste Type	Disposal Configuration
1	T07U, T03U, P06U (thorium), P04U, P05U	"Unclassified"	LLW	Shallow Land Disposal
2	T02C, T07C, T08C, T09C	"Classified"		
3	T01U, T02U, T04U, T06U, P01U, P02U, P03U, P07U (asbestiform)	"Unclassified"	MLLW	
4	T01C, T03C, T04C-1, T05C, T06C	"Classified"		
5	T04C		MLLW/ TRU	
6	GCDT, GCD-05U, GCD-06U, GCD-09U (empty,) GCD-10U, GCD-11U (empty), GCD-12U (empty)	"Unclassified"	LLW	Greater Confinement Disposal
7	GCD-07C (probable solvents [F001-F005]), GCD-08C (empty)	"Classified"	MLLW	
8	GCD-02C		TRU	
9	GCD-01C (LiD [D003]), GCD-03C (melted high explosive); GCD-04C (LiH [D003]; probable solvents [F001-F005])		MTRU	
10	U-3bh, U-3ah/at	"Unclassified"	LLW	Shallow Land, Crater Disposal
11	U-3ax/bl		MLLW	

Activities related to closure of the 92-acre site prior to FY 2008 will be conducted by the WMD. Formal closure activities between FY 2008 and FY 2010, and monitoring related specifically to disposal units composing the CAU, will be conducted by the ERD.

Closure activities for waste disposal units in an expansion area north of the Area 5 RWMS 92-acre site and for the Area 3 RWMS are scheduled over the time frame of FY 2019 through 2021.

(1) Preliminary Assessment
Data regarding the disposal units to be closed and the surrounding area are gathered, compiled, and summarized in a report. Data may be acquired through on-site inspection; interviews; and review of literature, data bases, historical records, manifests, waste profiles, maps, engineering drawings, photographs, and other media.

(2) Initial Planning
On the basis of the preliminary assessment conduct initial planning to include as necessary stating the problem, defining the boundaries of the investigation, developing or refining a conceptual model, identifying data requirements, identifying the approach to acquiring required data, and identifying the approach to using acquired data. For closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the Federal Facility Agreement and Consent Order (FFACO) (1996), the NDEP is involved in the planning process and approves the results of planning.

(3) Characterization Plan
On the basis of initial planning, develop a plan for acquiring the required data. The characterization plan should include a field plan, sampling and analysis plan, a health and safety plan, and any other subplans that are required to acquire the data. For closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the FFACO (1996), the NDEP reviews and approves the characterization plan.

(4) Implement Characterization Plan
The various activities identified in the characterization plan are conducted in this step of the closure process.

(5) Characterization Report
Results of implementing the characterization plan are presented in a characterization report. For closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the FFACO (1996), the NDEP reviews and approves the characterization report.

(6) Closure Plan
A plan for closing the disposal units is developed based on results presented in the characterization report. The closure plan provides a summary description of the disposal facility and the physical setting, regulatory basis, the relationship of closure activities to other programs, assumptions, and the technical approach to closure. Closure planning for disposal units with mixed waste will follow the outline provided in Appendix D, *RCRA Closure/Monitoring Requirements for Interim Status TSD* [Treatment, Storage, and Disposal] *MLLW Disposal Facilities*, and include as necessary, engineering drawings (e.g., grading, sections, drainage); specifications for materials and placement of materials (e.g., permeability, lift height, compaction, moisture content); specifications of decommissioning and decontamination of ancillary facilities; procedures for radiological decontamination of equipment for release; specifications for final survey; specifications for emplacement of permanent facility location markers; construction quality control plan; records management plan; construction schedule for final closure; site conditions following final closure; and postclosure maintenance and monitoring. Closure planning for disposal units with only LLW will include similar information as necessary to be technically sound. For closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the FFACO (1996), the NDEP reviews and approves the closure plan.

(7) Implement Closure Plan (Construction)
Construction of the closure cover based on the closure plan is conducted in this step of the closure process.

(8) Closure Report
A closure report is developed following construction of the closure cover. This report discusses the construction process and the as-built conditions of the closure cover. For closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the FFACO (1996), the NDEP reviews and approves the closure report.

(9) Acknowledge Completion
On the basis of the closure report, an acknowledgment of completion is presented based on information in the closure report. The NDEP presents the acknowledgment for closure of disposal units regulated under RCRA or an NDEP-issued permit, or identified in the FFACO (1996). The NNSA/NV presents the acknowledgment for closure of all other disposal units.

(10) Postclosure Monitoring and Maintenance
Following completion, postclosure monitoring and maintenance of the final closure cover is conducted as specified in the closure plan specific to that closure.

6.4 Institutional Control

Various definitions exist for institutional control. DOE G 435.1-1 defines active institutional control to be a period ". . . when access is controlled, monitoring is performed, and custodial maintenance is performed." The EPA, in Title 40 CFR 191, differentiates between active institutional control and passive institutional control. Active institutional control is "(1) Controlling access to a disposal site by any means other than passive institutional control, (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance." Passive institutional control is "(1) Permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land and resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system." Installation of engineered barriers to control access to a site or disposal unit is another form of passive institutional control. Such barriers will be part of the final closure of GCD boreholes that contain TRU waste (Cochran *et al*., 2001).

DOE Orders and federal regulations relevant to closure and monitoring of the Area 3 and Area 5 RWMSs provide varying guidance regarding institutional control over these sites. DOE M 435.1-1 specifies that institutional control be continued until the facility can be released pursuant to DOE Order 5400.5 (DOE O 5400.5), "Radiation Protection of the Public and Environment." DOE G 435.1-1 assumes the period of institutional control to be 100 yrs but adds, consistent with the manual, that after institutional control, ". . . release of a closed disposal facility to unrestricted uses cannot occur until the requirements of DOE O 5400.5 . . . are met." DOE O 5400.5 generally specifies that property may be released for unrestricted use when the effective dose equivalent that could be received by an individual from all pathways associated with that property does not exceed 100 mrem/yr.

Active institutional controls for both the Area 3 and Area 5 RWMSs will be consistent, where appropriate, with in-place or anticipated provisions for the entire NTS and surrounding federal lands (DOE, 2000b,c; 1996). The NNSA/NV program for active institutional control will include:

(1) Agreements and discussions with the Nellis Air Force Range (also known as the Nellis Test and Training Range), the U.S. Bureau of Land Management, the U.S. Fish and Wildlife Service, and the NDEP regarding long-term ownership and control of the lands including and surrounding the NTS. The NNSA/NV will arrange for provisions that will assure long-term land ownership, stewardship, funding, and control of unauthorized activities where agreements with the above agencies are not possible or forthcoming.

(2) Analysis of existing and potential activities on the NTS lands with the goal of showing how implemented institutional controls will control or prevent unauthorized activities. Existing activities that could continue include scientific research, production of groundwater, excavation for sand and gravel, construction, and serving as corridors for utilities and transportation. Potential activities include ranching, farming, hunting, exploration for hydrocarbons, mining, and illegal or hostile activities such as vandalism, sabotage, and theft.

(3) Commitment to establish and retain the controls for as long as the DOE and the federal government remain viable public entities and are able to maintain ownership and control of the site; that is "in perpetuity" (DOE, 2000b,c).

(4) Maintenance operations, remedial actions, and decommissioning steps necessary to establish the proper postclosure condition for the site.

(5) Monitoring of parameters related to performance of waste disposal systems (BN, 1998a,b,d).

(6) Implementation of specific controls: (a) fences and signs, (b) facility guarding roadways, and patrols, (c) land-use control and permits, (d) land reclamation, (e) inspection and maintenance, and (f) reporting of activities and incidents that impact access control and security, and any corrective actions.

Most of the above institutional controls are currently ongoing for the NTS or RWMSs, or both. Action (3) above indicates commitment to establish and retain the controls for as long as the DOE and the federal government remain viable public entities and are able to maintain ownership and control of the site; that is, "in perpetuity." The "in perpetuity" commitment warrants separation of controls for the NTS from controls specific to the RWMSs. Subject matter experts gathered to elicit the probability of IHI into a closed waste disposal site in both Frenchman Flat (Area 5 RWMS) and Yucca Flat (Area 3

RWMS) concluded that institutional control will likely not survive in perpetuity. They suggested a maximum duration of 2,000 years, with 90 percent probability that control will be lost within 1,000 years, and 50 percent probability that control will be lost within 250 years. The probability of institutional control lasting at least 50 years was suggested by the SMEs to be 90 percent (Black *et al*., 2001). The probability of active institutional control lasting 100 years then falls at the high end of a range from 50 to 90 percent. In accordance with DOE Orders and federal regulations, the period generally specified for active institutional control over a closed waste disposal site is 100 yrs. Beyond 100 yrs of active institutional controls, passive institutional controls at the disposal sites, such as those defined under Title 40 CFR 191, and institutional controls in place for the NTS are assumed to be sufficient for the RWMSs.

Dates for closure, monitoring, and long-term surveillance and maintenance of the Areas 3 and 5 RWMSs are presented in Section 1.2, Assumptions. Other dates for closure have been used in various related documents (e.g., Shott *et al*., 1998, 1995, 1997; Cochran *et al*., 2001), based on programmatic assumptions valid at the time of their development. Both RWMSs will remain open, albeit disposal operations will be considerably reduced for an undetermined period of time. Although many of the institutional controls are currently ongoing and will remain ongoing, active institutional controls shall start the first day of FY 2011 for waste disposal units closed at that time. Within several decades, much of the environmental restoration and waste management activities at the NTS will be concluded or proceeding at a reduced or maintenance level. The expected level of activities does not justify continuation of the current organization responsible for environmental restoration and waste management beyond FY 2021. Therefore, the continuing work and responsibility for the associated infrastructure are assumed to be transferred to another agency or group within NNSA/NV that is expecting long-term responsibilities at the NTS. This agency or group is referred to as the NTS Landlord. After transference of the RWMSs to the NTS Landlord, the schedule for closing waste disposal units, and the start of active institutional controls specific to those units, will be determined by the Landlord.

6.5 Unrestricted Release of the Site

Public access to the NTS is currently restricted and will continue to be restricted as long as the NTS has an active national security mission. An active national security mission is assumed into the foreseeable future. If the NTS national security mission ends, the release of NTS land for public access will be constrained by historical contamination from atmospheric nuclear testing, underground nuclear testing, nuclear rocket testing, and radioactive waste disposal. Remediation and closure of historically contaminated sites on the NTS is regulated by the FFACO (1996) between the NNSA/NV, the state of Nevada, and the U.S. Department of Defense. The FFACO defines a RCRA-like process for remediation and closure of CAUs and requires the state of Nevada to review and approve all corrective actions. Release of land for public access is also subject to the requirements of DOE Order 5400.5.

The NNSA/NV has implemented the UGTA Program and the Soils Program to close the UGTAs and contaminated soil sites under the FFACO (1996). The remediation option for UGTA closures, which is accepted by the state, is identification of areas within the NTS where public access or groundwater use will be restricted in perpetuity. The dose to a future member of the public who may have access to lands in Frenchman Flat and Yucca Flat has been evaluated in the CAs for the Area 3 and Area 5 RWMSs. Composite Analyses considered all sources of residual radioactive material, assuming that the Soils Sites may not be cleaned up and restricted areas that will be identified by the UGTA program would be in effect, and showed that cumulative dose to a member of the public who resides in Frenchman Flat or Yucca Flat will be below the CA dose limit of 100 mrem/yr and dose constraint of 30 mrem/yr. Current CAs do not show the extent of the restricted areas: the restricted areas will be incorporated into the CAs under the PA Maintenance Plan when the UGTA Program completes the necessary site characterization and modeling and the boundaries of the restricted areas are agreed between the state of Nevada and the NNSA/NV. Tentatively, the Frenchman Flat UGTA CAU boundaries will be established in about 2004; and the Yucca Flat boundaries in 2008.

7.0 MONITORING APPROACH

7.1 Introduction

Monitoring at the Area 3 and Area 5 RWMSs is required under a variety of regulatory drivers including federal regulations and DOE Orders. Monitoring data are used, in part, to:

- Demonstrate compliance with regulatory drivers;
- Confirm PA conceptual models;
- Confirm PA assumptions about soil water contents;
- Confirm PA assumptions about flux rates through upward and downward pathways;
- Verify the PA performance objective results;
- Provide input to the PA maintenance plan; and
- Evaluate radiation doses to the general public.

Monitoring is also conducted to ensure the integrity of covers over water disposal units. In addition, the monitoring program is designed to sufficiently forewarn management and regulators of any need for mitigative actions, and to record the utility of any mitigative actions.

Monitoring data are required for input to PA maintenance. The maintenance guide for DOE LLW disposal facility PAs and CAs (DOE, 1999b) states the review of results of monitoring and research and development results consist of several activities including:

- Comparing facility monitoring results with expected performance and determining consistency with conceptual models;
- Evaluating monitoring results for consistency with CA and conceptual models;

- Evaluating other monitoring activities for significant results;
- Evaluating research and development results to determine impacts on PA results and conclusions and consistency with conceptual models;
- Evaluating research and development results to determine impacts on CA results and conclusions;
- Determining if better methodologies or technologies are available; and
- Evaluating the results of special studies.

Review of monitoring data for routine PA and CA maintenance is an iterative process that will ultimately dictate which monitoring data should continue to be collected, and which monitoring data are no longer required.

This ICMP describes the program for monitoring direct radiation, air, vadose zone, biota, groundwater, meteorology, and subsidence at the Area 3 and Area 5 RWMSs during the operational closure period (current), and final closure/active institutional control periods.

At present, direct radiation is continuously monitored at five locations at the Area 3 RWMS and ten locations at the Area 5 RWMS. Air monitoring for radionuclides other than radon is conducted at several locations at each RWMS using air samplers, whereas radon is passively monitored at six locations at each RWMS, and at several background locations. Radon flux through waste covers is monitored annually at various locations at each RWMS and at background locations. Vadose zone monitoring for soil water content and soil water potential is conducted continuously in waste covers, beneath waste units, and at lysimeter facilities. Surface water runoff is monitored at flumes, and at the floor of a nuclear subsidence crater. Tritium in soil gas moisture is monitored annually in a deep borehole at the Area 5 RWMS (GCD-05U), which contains a large tritium source. Biota are monitored annually for tritium. Groundwater is monitored semiannually at three wells surrounding the Area 5 RWMS for radioactive and nonradioactive constituents. In addition, meteorology parameters are continuously monitored at both RWMSs, and monitoring of waste cover subsidence is conducted monthly at both RWMSs. A summary of current monitoring activities at the RWMSs is shown in Table 6.

The approach to monitoring in this document references many other documents for details of various components of the section. Particularly relevant are (1) the RREMP (BN, 1998a) for the decision-based approach to identify key monitoring data that must be collected, and (2) specific monitoring Organization Procedures (OPs) required to maintain consistency and comparability of data from year to year.

7.2 Quality Assurance, Analysis, and Sampling Plans

The Quality Assurance, Analysis, and Sampling Plans (QAASPs) specify the sampling, analytical, and quality assurance and quality control procedures for obtaining technically defensible data of acceptable quality to satisfy the project objectives. The QAASP includes guidance for data verification, data

Table 6 Monitoring Activities at the Area 3 and Area 5 Radioactive Waste Management Sites

Monitoring Element	Area 3 RWMS	Area 5 RWMS
Direct Radiation Monitoring	Five thermoluminescent dosimeters (TLDs)	10 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	• Six stations with E-PERMs (Electret-Passive Environmental Radon Monitors) • Radon flux measurements from waste covers (various locations)	• Six stations with E-PERMS • Radon flux measurements from waste covers (various locations)
Meteorology Monitoring	• air temperature at two heights • relative humidity at two heights • wind speed at two heights • wind direction at two heights • barometric pressure • solar radiation • net radiation • soil heat flux • 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 • net radiation • soil heat flux • precipitation
Vadose Zone Monitoring	• neutron logging for soil water content • measurements of soil water content and water potential in waste disposal unit covers • drainage lysimeter for water balance since 2001 • runoff monitoring at a flume and in a nuclear subsidence crater	• neutron logging for soil water content • measurements of soil water content and water potential in waste disposal unit covers • measurements of soil water content in waste disposal unit floors • two weighing lysimeters (vegetated and bare) for water balance since 1994
Soil Gas Moisture Monitoring for Tritium		• soil gas moisture sampling for tritium at nine sampling ports at depths from 21 to 36 m (70 to 120 ft) at GCD-05U • runoff monitoring at a flume
Biota Monitoring	Sampling vegetation for tritium	Sampling vegetation for tritium

Table 6 (continued)

Monitoring Element	Area 3 RWMS	Area 5 RWMS
Groundwater Monitoring	None	Three wells sampled semiannually for RCRA constituents; biennially for RREMP constituents
Subsidence Monitoring	Routine inspections of operational covers for subsidence features such as cracks, depressions, ponding, and erosion	Routine inspections of operational covers for subsidence features such as cracks, depressions, ponding, and erosion

validation, and data quality assessment. Detailed QAASPs for air, water, biota, and direct radiation media can be found in Appendices A through D of the RREMP (BN, 1998a).

A vadose zone monitoring QAASP specific to the RWMSs has recently been developed and will be incorporated into the RREMP during its next revision, by the end of Calendar Year 2001.

7.3 Routine Radiological Environmental Monitoring Plan

The RREMP (BN, 1998a) brings together sitewide environmental surveillance; site-specific effluent monitoring; and operational monitoring conducted by various missions, programs, and projects on the NTS. The plan provides an approach to identifying and conducting routine radiological monitoring at the NTS, based on integrated technical, scientific, and regulatory compliance data needs. The RREMP uses a decision-based approach to identify the environmental data that must be collected and provides QAASPs which ensure that defensible data are generated. The approach is based on a modification of the EPA's Data Quality Objective (DQO) process (EPA, 1994), a seven-step process that calls for identification of the decisions that data collection activities must support, and uses a logical structure to develop the plan for data collection and analysis. The detailed steps of the process for each media are presented in Appendix E of the RREMP. During the design process, existing and historical site information and regulatory requirements were reviewed. A summary of the site characteristics, transport and exposure pathways, regulatory requirements, and historical data were evaluated for each medium in the preparation of the RREMP to support the monitoring designs.

7.4 Monitoring During Operational Closure

Based on applicable regulatory drivers and data needs, monitoring during operational closure includes environmental monitoring of direct radiation, air, vadose zone, biota, and groundwater. Additional monitoring includes meteorology monitoring, and subsidence monitoring of operational waste covers.

7.4.1 Direct Radiation Monitoring

The objective of direct radiation monitoring is to assess the state of the RWMSs' external radiation environment, detect changes in that environment, and measure gamma radiation levels at the RWMSs and at background locations away from the RWMSs. Direct radiation monitoring is conducted to comply with DOE Orders 5400.1, 5400.5, and 435.1, and the guidance document for DOE Order 5400.1. Direct radiation monitoring is conducted using TLDs deployed at locations throughout the RWMSs. Five TLDs are deployed at the Area 3 RWMS, and ten TLDs are deployed at the Area 5 RWMS. Siting of the TLDs was based on a DQO process and described in Appendix D of the RREMP (BN, 1998a).

Figures 8 and 9 show TLD locations at the RWMSs. Annual direct radiation monitoring data are reported in the Annual Site Environmental Report (ASER) (BN, 2001c).

Details of the RWMS direct radiation monitoring activities can be found in the RREMP Organization Procedure OP-2154.111, "Environmental Dosimetry."

7.4.2 Air Monitoring

The regulatory drivers for the RWMS air monitoring network include Title 40 CFR 61, Subpart H; DOE Order 5400.1; DOE Order 5400.5; and guidance document to DOE 5400.1 (DOE, 1991). Details of the DQOs, sampling strategy, field operations, analytical design, analytes, and methods, and quality control checks are described in Appendix A of the RREMP (BN, 1998a). Air particulate samples are collected at the RWMSs using continuously operated low-volume air samplers and are analyzed for gross alpha radiation, gross beta radiation, gamma radiation, americium, and plutonium concentrations in air. Atmospheric moisture is collected and analyzed for tritium. Tritium is a volatile radionuclide and is therefore a conservative indicator of waste disposal unit performance.

Air particulate samples are collected at air sampling stations at four locations at the Area 3 RWMS, and two locations at the Area 5 RWMS. Tritium in atmospheric moisture is collected at the Area 5 RWMS at three locations. Atmospheric moisture is not collected at the Area 3 RWMS because of the small tritium inventory, and because of the inability to uniquely define the source of tritium in atmospheric moisture (atmospheric tests were conducted close to the Area 3 RWMS and continue to be a tritium source). *Figures 4, 8,* and *9* show locations of air samplers at the RWMSs.

Siting of the air samplers was based on the RREMP DQO process. Important siting decision factors included wind patterns and historic analytical data. In Area 3, wind direction is generally northerly or southerly. Therefore, air sampling stations are sited at locations north and south of each of the active disposal units, U-3ah/at, and U-3bh. In Area 5, air sampling stations (air particulate and tritium samplers) are sited to the north and south of the RWMS. In addition, there is a tritium sampler at the northeast corner of the Area 5 RWMS.

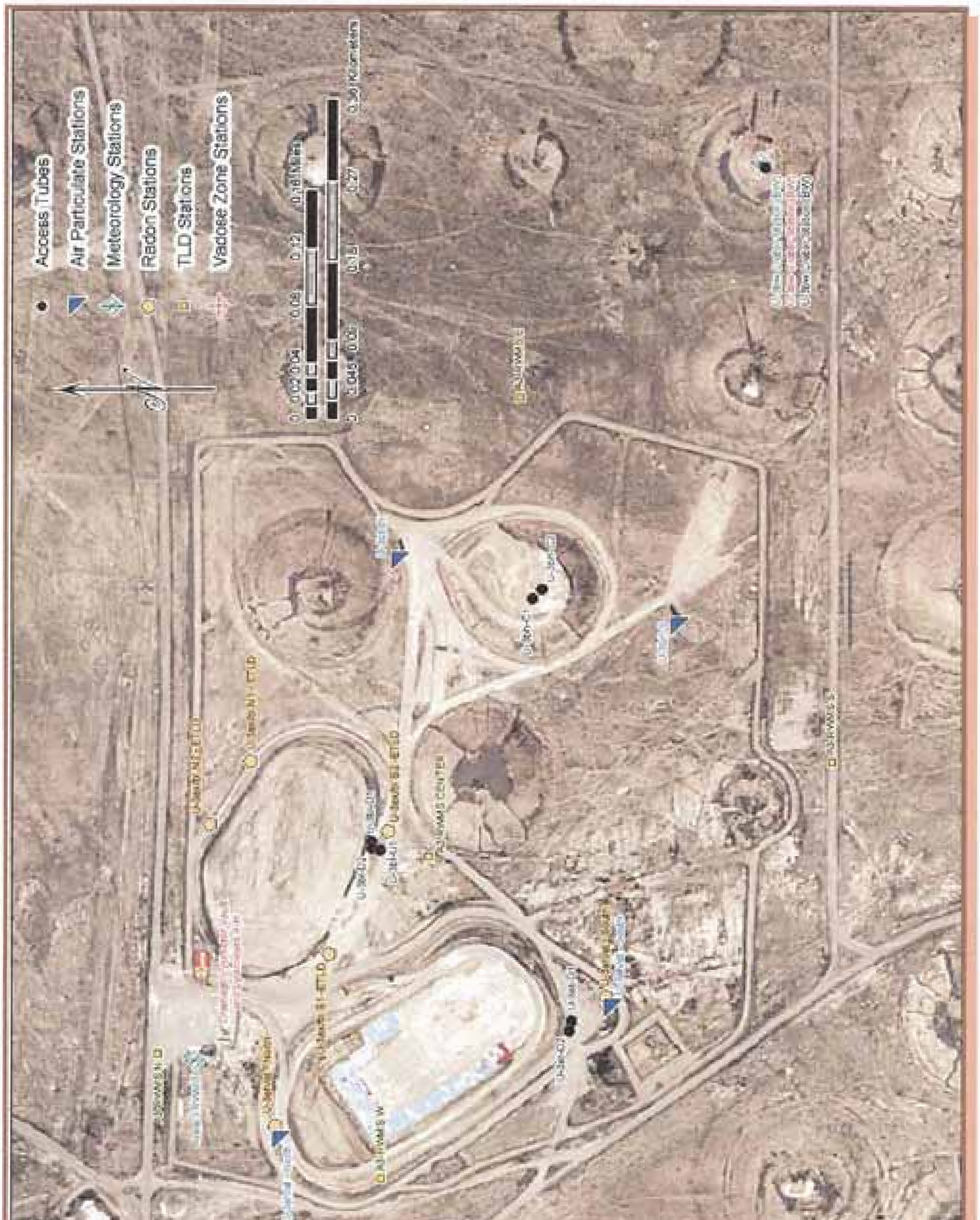

Figure 8 Monitoring stations at the Area 3 Radioactive Waste Management Site

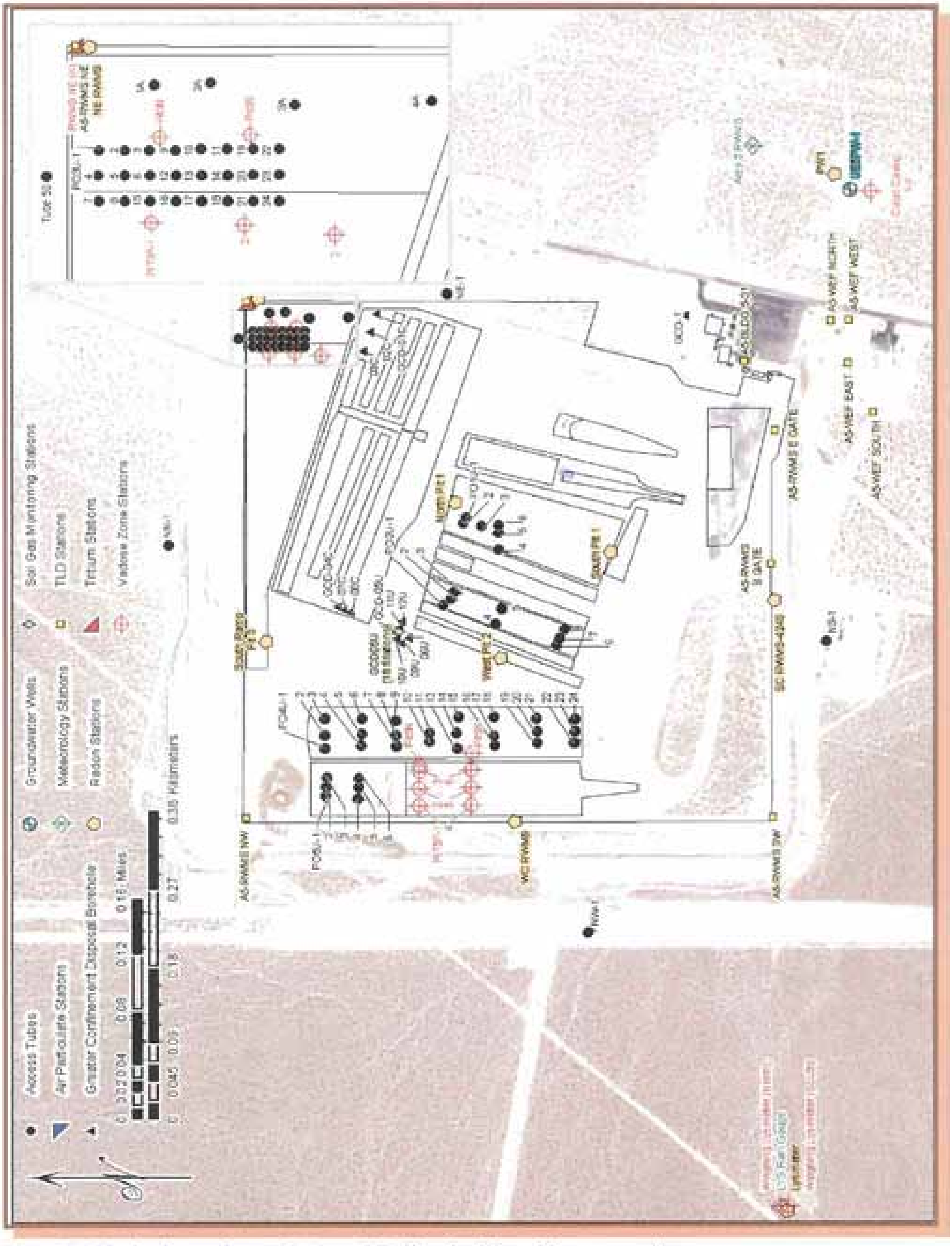

Figure 9 Monitoring stations at the Area 5 Radioactive Waste Management Site

Annual air monitoring data are reported in the ASER (e.g., BN, 2001c), and the National Emissions Standard for Hazardous Air Pollutants (NESHAP) report (e.g., BN, 2001d). Annual radon monitoring data are reported in the Annual Waste Management Monitoring Report (e.g., BN, 2001b).

Details of the RWMS air monitoring activities are in the RREMP Organization Procedures OP-2154.101, "Sampling for Airborne Particulates"; OP-2154.102, "Tritiated Water Vapor Sampling"; and OP-2154.115, "Radon Monitoring Using the E-PERM System."

7.4.2.1 *Radon Monitoring*

Radon concentrations in air at the RWMSs are monitored continuously using E-PERMs (Electret-Passive Environmental Radon Monitors), which are read quarterly to determine if radon concentrations in air at the RWMSs are within a DOE O 435.1 performance objective of 0.5 pCi/L above background at the boundary of the facility. E-PERMs are passive radon monitoring devices in which an electrostatically charged plate is discharged by radon-222. There are six radon monitoring stations located within each RWMS, and at several background locations. *Figures 8* and *9* show locations of radon monitoring stations at the RWMSs.

Beginning in 2001, radon concentrations in air at the RWMSs have also been measured using Alpha Tracts. This new methodology will continue to be evaluated, and if deemed to be more reliable than E-PERMS, Alpha Tracts may become the standard method for measurement of radon concentrations in air at the RWMSs.

Measurements of radon flux through operational waste covers are conducted at various locations every year using E-PERMs to determine if the fluxes are within a performance objective of 20 pCi/m^2/s given in the Area 3 and Area 5 PAs and DOE O 435.1. Radon flux monitoring is conducted on the cover of U-3ax/bl because it is the only closed unit at the Area 3 RWMS. Intensive radon flux monitoring is conducted at one or two waste disposal units per year. For example in FY 2001, intensive radon flux monitoring was conducted on the operational cover of Pit P01U at the Area 5 RWMS.

7.4.3 Vadose Zone Monitoring

Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs to:

- Demonstrate compliance with DOE 5400.1 and 435.1;
- Confirm PA assumptions regarding the hydrologic conceptual model including soil water contents, and upward and downward flux rates;
- Provide added assurance to PA conclusions regarding facility performance;
- Test the PA performance objective of protecting groundwater resources;
- Demonstrate negligible infiltration of precipitation into zones of buried waste;
- Detect changing trends in performance;
- Establish baseline levels for long term monitoring; and
- Comply with NDEP negotiated requirements at Area 3, U-3ax/bl.

Compliance at the RWMSs is achieved by demonstrating that PA assumptions are valid, and that there is negligible infiltration of precipitation into zones of buried waste.

Vadose zone monitoring is conducted by measuring all the water balance components at several locations to account for some spatial variability, and to apply that water balance to an entire RWMS using a concept of surrogate sampling. This type of vadose zone monitoring is not leak detection; it is performance monitoring.

Water balance measurements activities include:

- Meteorological monitoring to measure precipitation (the driving force for downward flow), and to calculate potential evapotranspiration (PET) (the driving force for upward flow);
- Lysimeters (weighing and drainage) to measure infiltration, soil water redistribution, bare-soil evaporation, evapotranspiration, and deep drainage;
- Neutron logging through access tubes to measure infiltration, soil water redistribution, and to monitor specific locations of interest (in some locations to depths of hundreds of feet);
- Automated vadose zone monitoring systems with *in situ* sensors (time domain reflectometry [TDR] probes, and heat dissipation [HD] probes) to measure soil water content and soil water potential over a large spatial area, but usually to a limited depth;
- Surface water runoff monitoring at flumes and at the floor of a nuclear subsidence crater; and
- Soil-gas sampling for tritium to confirm PA assumptions and transport coefficients.

This strategy provides an accurate estimate of the RWMS water balance including any drainage through the RWMS waste covers, and therefore, potential recharge. Based on these data, as well as other work (Tyler *et al*., 1996), there is essentially no recharge to the groundwater under current conditions at the RWMSs, and all precipitation is effectively returned to the atmosphere by plant transpiration and soil evaporation.

A technical design process for development of a detailed QAASP for vadose zone monitoring at the RWMSs, including guidance for action levels and corrective actions and styled after the EPA DQO process (EPA, 1994), will be included in the next revision of the RREMP. The current vadose zone monitoring program is designed based on a strong understanding of the vadose zone system from the results of extensive vadose zone characterization studies (BN, 1998d; Blout *et al*., 1995; REECo, 1994, 1993a,b; Schmeltzer *et al*., 1996; Shott *et al*., 1998, 1995, 1997; Tyler *et al*., 1996), and modeling studies (Crowe *et al*., 1998b; Levitt *et al*., 1999). In addition, the vadose zone monitoring program is designed in part from the results of an Alternative Evaluation Study on vadose zone monitoring (BN, 1998e) using an organized team approach, and in part from successful vadose zone monitoring field experience.

Annual vadose zone monitoring data are reported in an annual monitoring report (e.g., BN, [2001b]). Details of the RWMS vadose zone monitoring activities can be found in the RWMS vadose zone monitoring Organization Procedure OP-2154.113, “Instructions for Datalogger Monitoring Stations”; OP-2154.114, “Neutron Moisture Logging”; and OP-2154.117, “Soil Gas Sampling at GCD-05U.”

7.4.3.1 *Area 5 Weighing Lysimeter Facility*

Two weighing lysimeters were installed about 400 m (1,312 ft) southwest of the Area 5 RWMS. 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. Each of the weighing lysimeters is instrumented with TDR probes to measure volumetric soil water content at depths ranging from 10 to 170 cm (4 to 67 in). The TDR probes are connected to automated datalogger systems that provide daily profiles of soil water content. The sensitive scale (loadcell) is also connected to a datalogger which provides extremely accurate measurements of weight changes. For details of the weighing lysimeters, refer to Levitt *et al*. (1996).

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 depths of infiltration, soil-water redistrubution, 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 PAs, including confirmation of no downward pathway. In addition, this facility provides data for calibration and verification of flow models, important tools for prediction of radio-nuclide transport. This facility has also provided data to justify and evaluate the performance of other NTS closure covers (DOE, 2000a,d).

Operation of the Area 5 weighing lysimeter facility will continue to be an important component of the RWMS vadose zone monitoring program by providing detailed water balance data analogous to the water balance of waste covers at the Area 5 RWMS. *Figures 4* and *9* show the location of the Area 5 weighing lysimeter facility.

The Area 5 weighing lysimeter facility is managed by BN Environmental Technical Services (ETS), and any future activities at this site will be managed and coordinated by ETS. For more information on this facility, refer to Levitt *et al.* (1996).

7.4.3.2 *Area 3 Drainage Lysimeter Facility*

A drainage lysimeter facility was constructed adjacent to the northwest corner of the waste disposal unit U-3ax/bl at the Area 3 RWMS. The facility consists of eight drainage lysimeters. Each lysimeter is instrumented with soil water content and soil water potential sensors at eight depths. Each lysimeter is 3-m (10-ft) in diameter, 2.4-m (8-ft) deep, and has a sealed bottom that enables direct measurement of drainage. Construction of the facility was funded by the Accelerated Site Technology Deployment (ASTD) program under the U.S. DOE, Office of Science and Technology (OST). The objective of the facility is to collect data to reduce the uncertainty associated with the performance of monolayer ET waste covers in arid regions. This uncertainty includes waste cover surface treatment such as vegetation type and density, and mulching types. Therefore, the surface treatment of the lysimeters is being addressed as follows: two lysimeters were left bare (A and B); two were allowed to revegetate with invader species (C and D); two were revegetated with native species (E and F) identically to the revegetation of U-3ax/bl; and two are reserved for future investigations (G and H), but currently treated like lysimeters C and D.

The lysimeter facility was constructed between October 2000 and January 2001. Data collection of daily water content and water potential measurements began in February 2001. To date, all 128 sensors in the facility are working properly, and no drainage has been measured from any lysimeter.

Data from this facility will address the uncertainty in surface treatment of the monolayer waste covers, such as determining which vegetation and/or mulching scenario is most effective at removing moisture from waste disposal unit covers. In addition, data from this facility, and data from the U-3ax/bl waste cover monitoring system, will help assess the performance of future monolayer-ET covers at the Area 3 RWMS. *Figure 8* shows the location of the Area 3 drainage lysimeter facility.

The Area 3 drainage lysimeter facility is managed by BN ETS, and any future activities at this site will be managed and coordinated by ETS. For more information of this facility, refer to Dixon *et al.* (2000), and Levitt and Fitzmaurice (2001).

7.4.3.3 *Automated Vadose Zone Monitoring Systems*

Installation of automated vadose zone monitoring systems was initiated in 1998 with water content sensors (TDR probes) and temperature sensors buried 1.2 m (4 ft) beneath the open pit floors of Pit P03U and Pit P05U at the Area 5 RWMS. In 1999, TDR probes were installed in the operational cover of Pit P03U at two locations (*Figure 9*), at depths ranging from 10 to 180 cm (4 to 71 in). In 2000, TDR probes and temperature sensors were installed in the operational covers of Pits P04U and P05U at depths ranging from 15 to 180 cm (6 to 71 in), and HDPs were installed in the operational cover of Pit P05U at those same depths. These sensors are connected to dataloggers that automatically collect and store data, which are downloaded by telephone links (at some locations) for immediate analysis. The datalogger station for the Pit P03U floor sensors is currently located in Pit P03U. This station will either be discontinued or moved (and some sensor cables may need to be lengthened), if enough waste arrives in Pit P03U to warrant the move.

Time domain reflectometry probes were installed at four locations and eight depths in the U-3ax/bl waste cover in 2000, as described in the closure plan for U-3ax/bl (DOE, 2000a), and the closure report for U-3ax/bl (NNSA, 2001). Vadose zone performance monitoring of the waste cover at U-3ax/bl is required by NDEP for closure of U-3ax/bl, as described in a letter from NDEP to DOE/NV, dated February 22, 2000. Vadose zone monitoring of the U-3ax/bl waste cover is currently administered and conducted by BN ERD. All other vadose zone monitoring at the RWMSs is currently administrated and conducted by BN ETS.

Installation of a vadose zone monitoring system in a waste cover at the Area 3 RWMS other than U-3ax/bl is unlikely to occur for several years because no other disposal units will be full for several years. Once the U-3bh disposal unit is full, its waste cover may be instrumented with a vadose zone monitoring system. Installation of automated vadose zone monitoring systems at the Area 3 and Area 5 RWMSs will then be complete, although upgrades of system components may be required.

Heat dissipation probes were also installed in the floor of subsidence crater U-3bw to a depth of 4 m (13 ft) in December 1998 in order to monitor depths of infiltration following rainfall, and enhanced runoff caused by the geometry of a 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 nuclear subsidence crater used for waste disposal at the Area 3 RWMS. These data are required to understand the hydrologic system of a nuclear subsidence crater for waste disposal in Area 3. Refer to *Figure 8* for the location of U-3bw. Time-domain reflectometry and other types of automated vadose zone monitoring systems have been implemented at many other study sites with varying degrees of success. Some sites in which TDR or other vadose zone technologies have been used include Beatty, Nevada (Andraski, 1997), Phoenix, Arizona (Young *et al*., 1999), Albuquerque, New Mexico (Dwyer, 2001; Goering, 1999), Hanford, Washington (DOE, 1999c), and the Savannah River Site (Burns, 1999).

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. However, their ceramic porous material is also not expected to corrode for decades. An additional consideration is that as new and improved vadose zone monitoring sensors and technologies become available, they should be implemented for redundancy or replacement of current systems, wherever appropriate.

7.4.3.4 *Neutron Logging*

Neutron logging is currently conducted at selected neutron access tubes at the Area 3 and Area 5 RWMSs to provide profiles of soil water content with depth and time. After complete installation of automated vadose zone monitoring systems at the RWMSs, use of neutron logging for vadose zone monitoring at the RWMSs may not be necessary, so it may be discontinued. The decision to discontinue neutron logging will be technically defensible, based on a DQO process. Use of limited neutron logging may be useful to supplement automated vadose zone systems where access tubes remain accessible. No neutron access tubes are anticipated to remain in the covers. *Figures 8* and *9* show locations of all neutron logging access tubes at the RWMSs.

At the Area 3 RWMS, deep vadose zone monitoring by neutron logging is currently conducted in cased boreholes angled under the U-3ah/at and U-3ax/bl disposal units, and in cased boreholes drilled directly into the floor of the U-3bh disposal unit. These boreholes are designated U-3at-D1, U-3at-D2, U-3bh-C1, U-3bh-C2, U-3bl-D1, U-3bl-D2, and U-3bl-U1.

At the Area 5 RWMS, neutron logging is currently conducted in access tubes penetrating the 2.4-m- (8-ft)-thick operational covers. Neutron access tubes for routine monitoring were selected based on data history, tube integrity, and to provide a representative area of wide spatial coverage. Area 5

RWMS access tubes provide data on the near-surface water balance, but Area 3 RWMS access tubes provide data only on changes in water contents at depth greater than about 3 m (10 ft) due to the presence of thick surface casings and cement structures that cannot be logged with accuracy.

7.4.3.5 *Surface Water Runoff Monitoring*

Design of structures and closure covers that can best accommodate run-on from precipitation events over long periods of time must rely on historical precipitation and discharge data. Precipitation data have been collected at various locations around the NTS for several decades. However, until recently, the locations of data collection were not proximal to middle reaches of watersheds that potentially collect and discharge waters to the vicinities of facilities. To collect preciptation and discharge data relevant to performance assessment and eventual design activities, two each of precipitation gauges and flumes have been installed in watershed channels near the Area 3 and Area 5 RWMSs. One precipitation gauge and flume is located in a watershed channel east of the Area 3 RWMS and the other is located in a watershed channel northwest of the Area 5 RWMS. Refer to Figures 10 and *4* for the locations of the Area 3 and Area 5 flumes, respectively. The flume in Area 3 was installed in FY 1999 and the flume in Area 5 was installed in FY 2000. The intent is to collect precipitation and discharge data at these locations through FY 2007, afterwhich, activities associated with final closure of the currently active, 92-acre part of the Area 5 RWMS will be initiated.

7.4.3.6 *Soil Gas Moisture Monitoring for Tritium*

Tritium monitoring of moisture in soil gas is conducted to evaluate the upward pathway for radionuclide transport. Tritium is a volatile radionuclide and therefore provides a conservative measure of the performance of the waste site and its ability to isolate buried waste.

Tritium monitoring of moisture in soil gas is conducted by sampling at GCD-05U, a GCD unit with a large tritium inventory (2.2 million Ci at time of disposal) located near the center of the RWMS, which is instrumented with a string of nine gas sampling ports buried at depths of 21 to 37 m (70 to 120 ft). Tritium sampling at GCD-05U provides a measure of tritium migration from waste packages with time because of degradation of waste containers and natural transport processes. Tritium sampling at GCD-05U has been conducted every year since 1990, providing an important data set for analyzing tritium migration from the Area 5 RWMS. *Figure 9* shows the location of GCD-05U at the Area 5 RWMS.

Soil gas sampling ports are also located in various locations at the Area 5 RWMS including several locations beneath pits P03U and P05U. The ports are not currently monitored, but if required, they may be monitored in the future to augment current studies of tritium migration.

7.4.4 Biota Monitoring

There are no formal DOE dose limits for terrestrial biota. Dose limits for terrestrial biota are proposed in Title 10 CFR 834, which has not yet been promulgated. However, a DOE memorandum dated April 21, 2000, regarding guidance for preparation of the ASER (e.g., BN, 2001c) recommends demonstration for DOE and stakeholders that DOE site activities are meeting the internationally recommended dose limits for terrestrial biota. These dose limits recommend that the absorbed dose to

Figure 10 Locations of flumes at the Area 3 Radioactive Waste Management Site

terrestrial plants will not exceed 1 rad per day (10 milliGray [mGy] per day) from exposure to radiation or radioactive material, and that the absorbed dose to terrestrial animals will not exceed 0.1 rad per day (1 mGy per day) from exposure to radiation or radioactive material. These dose limits will be incorporated into the next revision of the RREMP, as required. The RREMP (BN, 1998a) currently evaluates dose by uptake of wild game consumed by off-site residents.

At the RWMSs, biota monitoring consists of sampling vegetation for tritium. If tritium concentrations in vegetation are exceedingly high, other wild game are sampled. Vegetation sampling may be limited year to year, depending on rainfall and waste cover operations during operational closure. Vegetation from on and near waste covers, as well as vegetation from control areas far from waste covers, are sampled in mid-summer each year and analyzed for tritium. Timing of the sampling is important because vegetation is forced to remove soil water from greater depths (closer to waste) as surface soils dry out in summer. Plant water is extracted from the vegetation samples by room temperature vacuum distillation and analyzed by liquid scintillation for tritium. Animals (and soil from animal burrows) will be monitored for tritium if warranted by increasing tritium trends in vegetation, or if animal burrows on or near waste covers are observed in significant numbers.

Slightly elevated tritium concentrations in air and vegetation at the Area 5 RWMS indicate that there is an upward pathway for tritium migration primarily because of the combined effects of diffusion and plant transpiration processes. Therefore, this pathway should continue to be monitored.

Annual biota monitoring data are reported in BN (2001b). Details of the RWMS biota monitoring activities can be found in the RWMS biota monitoring Organization Procedure OP-2154.112, "Biota Sampling for Small Animals and Vegetation."

7.4.5 Groundwater Monitoring

Groundwater monitoring is not currently conducted at the Area 3 RWMS. Mixed waste disposal unit U-3ax/bl requires groundwater monitoring under Title 40 CFR 264 or 265. However, a groundwater monitoring waiver has been approved by NDEP which waives the requirements of groundwater monitoring under Title 40 CFR 264 or 265 at the Area 3 RWMS.

Groundwater monitoring is conducted at the three pilot wells surrounding the Area 5 RWMS (*Figure 4*) as required by Title 40 CFR 264 or 265. These wells were originally drilled in 1993 as characterization wells for determination of physical and chemical properties of drill core, for determination of chemical properties of groundwater in the uppermost aquifer, and for determination of depths to the uppermost aquifer. In a letter from DOE/NV to NDEP dated December 12, 1993, DOE/NV requested that the pilot wells be accepted as RCRA monitoring wells. In a letter from NDEP to DOE/NV, dated February 24, 1994, NDEP stated that the pilot wells appear to meet the applicable design, construction, and development criteria for RCRA groundwater monitoring wells. A revised groundwater monitoring program outline was submitted to NDEP on March 1, 1998 (BN, 1998b). On March 31, 1998, NDEP transmitted a letter to DOE stating concurrence with the sampling frequency, indicator parameters, and investigation levels submitted in the groundwater monitoring outline.

Groundwater from pilot wells are sampled semiannually for the following parameters (BN, 1998b):

Indicators of Contamination:
- pH
- specific conductance
- total organic carbon
- total organic halogen
- tritium

General Water Chemistry Parameters:
- total Ca, Fe, Mg, Mn, K, Na, SiO_2
- total SO_4, Cl, F
- alkalinity

Investigation levels for these indicators of contamination can be found in BN (1998b). Details of pilot well construction can be found in BN (2001a).

Additional groundwater monitoring requirements were driven by DOE Orders and, independent of EPA requirements, were determined through a DQO-driven process and are detailed in the RREMP (BN, 1998a). Groundwater monitoring analytes identified in the RREMP include:

- tritium,
- gross alpha,
- gross beta,
- gamma spectroscopy, and
- plutonium 238, and plutonium 239+240.

The groundwater monitoring frequency identified in the RREMP is biennial.

All groundwater sampling data from the Area 5 RWMS pilot wells to date indicate that the groundwater in the uppermost aquifer is unaffected by RWMS or NNSA weapons testing activities. Tritium concentrations in the groundwater beneath the Area 5 RWMS have never exceeded the method detection limit (MDL) for enriched tritium analysis (approximately 15 pCi per liter). Groundwater elevation data indicate that the water table beneath the Area 5 RWMS is nearly flat, with groundwater flowing in a northeastern direction at a horizontal velocity of approximately 23 cm (9 in) per year (BN, 2001a).

Groundwater monitoring data are presented in detail in the annual groundwater monitoring data report (e.g., BN, 2001a). Details of the Area 5 RWMS groundwater monitoring activities can be found in the Area 5 RWMS groundwater monitoring Organization Procedures OP-2151.214, “Instructions for Area 5 RWMS Groundwater Well Preparation and Groundwater Sampling”; and OP-2154-103, "Preparing and Sampling Routine Radiological Environmental Monitoring Plan (RREMP) Groundwater Wells."

7.4.6 Meteorology Monitoring

A meteorology monitoring program is maintained by operating one two-level meteorology tower at each RWMS. In addition to fulfilling basic regulatory requirements for meteorology monitoring in DOE Order 5400.1, the RWMS meteorology monitoring program is designed to include measurements of components of the surface energy balance for calculation of PET using the Penman equation (Doorenbos and Pruitt, 1997). PET calculations are an important component of the water balance estimates of the RWMSs.

Meteorological parameters monitored at the RWMSs include:

- Air temperature at two heights
- Relative humidity at two heights
- Wind speed at two heights
- Wind direction at two heights
- Barometric pressure
- Solar radiation
- Net radiation
- Soil heat flux
- Precipitation

Figures 8 and *9* show locations of meteorology monitoring stations at the Area 3 and Area 5 RWMSs. Annual meteorology monitoring data are reported in BN (2001b). Details of the RWMS meteorology monitoring activities can be found in the RWMS meteorology monitoring Organization Procedure OP-2154.113, "Instructions for Datalogger Monitoring Stations."

7.4.7 Subsidence Monitoring

Subsidence monitoring consists of routine inspections of operational and final waste covers for subsidence features such as cracks and depressions, ponding, and erosion. When such features are observed, their locations are recorded using a Global Positioning System unit and digital camera, and operations personnel are informed to take corrective action.

U-3ax/bl is the only disposal unit at the Area 3 RWMS that is finally closed. Subsidence monitoring of U-3ax/bl is currently conducted as required by agreement with NDEP (by BN ER division).

At the Area 3 RWMS, subsidence monitoring is conducted monthly at disposal units U-3bh and U-3ah/at where waste is buried to ensure that waste remains covered.

At the Area 5 RWMS, subsidence monitoring is conducted monthly at all operationally closed disposal units and at partially buried open disposal units.

Details of the RWMS subsidence monitoring activities can be found in the RWMS subsidence monitoring Organization Procedure OP-2154.116, "Subsidence Monitoring at the Radioactive Waste Management Sites." The effectiveness of subsidence monitoring will be periodically evaluated.

7.5 Monitoring During Final Closure and Active Institutional Control

Monitoring activities during the final closure and active institutional control periods of the RWMSs are expected to be reduced and limited to:

- Air monitoring for radon-222 and atmospheric tritium;
- Tritium monitoring of moisture in soil gas at GCD-05U;
- Vadose zone monitoring of waste covers, waste disposal unit floors, and lysimeter facilities;
- Groundwater monitoring;
- Biota monitoring for tritium; and
- Subsidence monitoring.

The decision to continue or terminate any monitoring activities will be based on a routine decision-based approach to identify environmental monitoring data that must continue to be collected during the final closure and active institutional control periods.

Air monitoring for radionuclides (other than for radon and atmospheric tritium) will be discontinued during final closure and the institutional control period because the primary mechanism for transport of airborne radionuclides other than radon and tritium is from open pits in which waste is directly exposed to the atmosphere. Once waste is buried, air monitoring for radionuclides other than radon and tritium is not required. Radon concentrations in air and radon flux from waste units will continue to be monitored during the final closure and active institutional control period because radon concentration limits are specific performance objectives. Tritium in atmospheric moisture will continue to be monitored during final closure and active institutional control period because tritium is an important indicator of waste disposal unit performance.

Groundwater monitoring for compliance with Title 40 CFR 264 or 265 will be discontinued if a groundwater monitoring waiver is requested from, and approved by, NDEP. However, groundwater monitoring may continue at the Area 5 RWMS pilot wells under the RREMP program.

7.6 Monitoring During Passive Institutional Control

No monitoring will be conducted during the passive institutional control period.

7.7 Data Management

All RWMS monitoring data are archived in BN's data management system, Bechtel Environmental Integrated Data Management System (BEIDMS). BEIDMS is an Oracle™-based relational database management system developed by BN for the comprehensive management and processing of environmental data. This database management system has been licensed and tailored to support both small and large environmental projects at BN. BEIDMS will ensure consistency and promote advanced planning, while providing a central repository for all unclassified environmental data.

7.8 Data Evaluation and Data Reporting

Evaluation of all monitoring data is conducted once per year, at minimum, and conclusions of those evaluations are incorporated into one or all of the applicable annual data reports including the ASER (e.g., BN, 2001c); the NESHAP report (e.g., BN, 2001d; the Annual Groundwater Monitoring Report (e.g., BN, 2001a; and the Annual Waste Management Data Report (e.g., BN, 2001b.

The BN OPs required for preparation of the NESHAP report and ASER include:

- OP-2154.108, "Development of the Annual National Emission Standards for Hazardous Air Pollutants (NESHAP) Report for the NTS and Offsite Dose Assessment"
- OP-2154.109, "Investigation of Facilities for National Emissions Standards for Hazardous Air Pollutants (NESHAP) Compliance"
- OP-2154.110, "Preparation of the Annual Site Environmental Report (ASER)"

7.9 Organization Procedures for RWMS Monitoring Activities

The OPs required for routine monitoring of the RWMSs include:

- OP-2151.214, "Instructions for Area 5 RWMS Groundwater Well Preparation and Groundwater Sampling"
- OP-2154.101, "Sampling for Airborne Particulates"
- OP-2154.102, "Tritiated Water Vapor Sampling"
- OP-2154.103, "Preparing and Sampling Routine Radiological Environmental Monitoring Plan (RREMP) Groundwater Wells"
- OP-2154.111, "Environmental Dosimetry"
- OP-2154.112, "Biota Sampling for Small Animals and Vegetation"
- OP-2154.113, "Instructions for Datalogger Monitoring Stations"
- OP-2154.114, "Neutron Moisture Logging"
- OP-2154.115, "Radon Monitoring Using the E-PERM System"
- OP-2154.116, "Subsidence Monitoring at the Radioactive Waste Management Sites"
- OP-2154.117, "Soil Gas Sampling at GCD-05U."

8.0 SCHEDULE

Activities associated with final closure of the Area 5 RWMS 92-acre site are scheduled to start in FY 2008 and be completed in FY 2010. Activities associated with final closure of the Area 5 expansion area north of the 92-acre site and the Area 3 RWMS are scheduled to start in FY 2019 and be completed in FY 2021. Monitoring and maintenance specified for active institutional control will start after closure and continue for the assumed time periods, or for mixed waste, also in accordance with conditions negotiated with the NDEP (see Section 1.2).

9.0 PLAN MAINTENANCE

U.S. DOE M 435.1-1 and G 435.1-1 specify that preliminary closure and monitoring plans for a LLW management facility be developed and initially submitted with the PA and CA for that facility. The Manual and Guidance further specify that the preliminary closure and monitoring plans be updated within one year following issuance of a DAS. Additional updates of the closure plan are specified during and after operation of the facility. A final update of the closure plan is specified to be completed prior to conduct of final closure activities. The Manual and Guidance do not specify an update of the monitoring plan beyond that conducted one year following issuance of a DAS. Review of the RREMP is conducted annually and updates are conducted every second year based on DOE O 5400.1 and consensus that this frequency is appropriate for capturing: (1) changes in related policy, operating plans, performance assessment, or facility design; (2) unexpected events that affect monitoring needs and requirements; (3) results of research and development; and (4) analysis of new monitoring and other data. This precedence of updating the documents will be continued for the PA Maintenance Plan (BN, 2000c and this Integrated Closure and Monitoring Plan. The intent of periodically updating the various related documents is to realize the primary objective of ensuring that workers, the public, and the environment are safe during and after waste disposal operations.

The Manual and Guidance associated with DOE O 435.1 specify that the preliminary closure and monitoring plans be updated within one year following issuance of a DAS. A DAS for the Area 3 RWMS was issued by DOE/HQ on October 20, 1999. However, because of the difference in timing of the approval of the DASs for the Area 3 RWMS and the Area 5 RWMS, this Integrated Closure and Monitoring Plan is submitted in lieu of the update. The next update is scheduled for FY 2004. Subsequent updates are scheduled every third year through FY 2019.

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Appendix A

Cross-Walk Between Closure Plan Guidance and the Integrated Closure and Monitoring Plan

CROSS-WALK BETWEEN CLOSURE PLAN GUIDANCE AND THE INTEGRATED CLOSURE AND MONITORING PLAN

The outline below is based on the U.S. Department of Energy (DOE) Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Closure Plans, dated November 10, 1999. Because this Integrated Closure and Monitoring Plan is a reference document and includes both closure and monitoring activities, the format does not conform exactly with the DOE guidance. Referenced sections are those in this Integrated Closure and Monitoring Plan that most closely correspond to guidance outline. The format and contents of the Integrated Closure and Monitoring Plan follow this information.

Guidance	**Corresponding Section(s)**
EXECUTIVE SUMMARY	Executive Summary
INTRODUCTION	1.0
Facility Description	4.1, 4.2, 4.3, 4.4, 5.1, 5.2, 5.3, 5.4
Closure and Monitoring Approach	6.0, 7.0
Closure and Monitoring Schedule	6.3, 8.0
Related Activities	1.1, 7.0, 9.0
Assumptions	1.2
DISPOSAL FACILITY CHARACTERISTICS	3.0, 4.0, 5.0
Site Characteristics	
Geography and Demography	3.1, 3.2
Disposal Site Location	4.1, 5.1
Disposal Site Description	4.1, 4.2, 4.3, 4.4, 5.1, 5.2, 5.3, 5.4
Population Distribution	3.2.1
Uses of Adjacent Land	3.2.2
Meteorology and Climatology	3.3
Ecology	3.4
Geology	3.5
Regional and Site-Specific Geology/Topography	3.5.1, 3.5.2, 3.5.3
Seismology	3.8.1
Hydrology	3.6
Surface Water	3.6.1
Groundwater	3.6.2, 3.6.3, 3.6.4
Geochemistry	3.7
Natural Resources	3.9

Guidance	**Corresponding Section(s)**
Facility Characteristics	6.1
Water Infiltration	6.1.1
Disposal Unit Cover Integrity	6.1.2
Structural Stability	6.1.3
Inadvertent Intruder Barrier	6.1.4
Waste Characteristics	4.5, 5.5
Waste Types	4.5.3, 5.5.3
Source Term	4.5.3, 5.5.3
TECHNICAL APPROACH TO CLOSURE AND MONITORING	
Performance Objectives	1.1
All-Pathways Dose	1.1
Air-Pathway Dose	1.1
Radon Flux	1.1
Other Requirements	1.1
Detailed Closure Activities	6.0
Operational/Interim Closure	6.2
Final Closure	6.3
Institutional Control	6.4
Unrestricted Release of Site	6.5
Monitoring Activities	7.0
Operational/Interim Closure	7.4
Final Closure/Institutional Care	7.5, 7.6
SCHEDULE	8.0
REFERENCES	10.0
APPENDICES	Appendices A, B, C

This outline is provided to show that more sections are in the Plan than are specified in the guidance. It serves as a quick reference so the reader does not have to go to the Table of Contents to find the Section Titles when reading the previous few pages.

INTEGRATED CLOSURE AND MONITORING PLAN

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Appendix B

Comparison of the Assurance Requirements Associated with Title 40 CFR 191 with Closure and Monitoring Requirements of DOE Order 435.1/Manual 435.1-1

40 CFR 191	DOE Order 435.1/Manual 435.1-1
ACTIVE INSTITUTIONAL CONTROLS	
§191.14(a) Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.	Acceptable definition found in legislation, regulation, other DOE Directives, or in the DOE Glossary. Term discussed further in guidance
MONITORING	
§191.14(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.	**M.IV.R.(3)** Disposal Facilities. A preliminary monitoring plan for a low-level waste disposal facility shall be prepared and submitted to Headquarters for review with the performance assessment and composite analysis. The monitoring plan shall be updated within one year following issuance of the disposal authorization statement to incorporate and implement conditions specified in the disposal authorization statement. (a) The site-specific performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored. --- **M.IV.P.(4)** Performance Assessment and Composite Analysis Maintenance (a) Performance assessments and composite analyses shall be reviewed and revised when changes in waste forms or containers, radionuclide inventories, facility design and operations, closure concepts, or the improved understanding of the performance of the waste disposal facility in combination with the features of the site on which it is located alter the conclusions or the conceptual model(s) of the existing performance assessment or composite analysis.

40 CFR 191	DOE Order 435.1/Manual 435.1-1
MONITORING (continued)	
§191.14(b) (Continued)	Disposal Facilities (Continued) **M.IV.Q.(2)(c)** Institutional control measures shall be integrated into land use and stewardship plans and programs, and shall continue until the facility can be released pursuant to DOE 5400.5, *Radiation Protection of the Public and the Environment.*
	M.I.1.E.(7) Environmental Monitoring. Radioactive waste management facilities, operations, and activities shall meet the environmental monitoring requirements of DOE 5400.1, *General Environmental Protection Program;* and DOE 5400.5, *Radiation Protection of the Public and Environment.*
	M.IV.R.(3)(b) The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance.
	M.IV.R.(3)(a) The site-specific performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.
	M.IV.R.(3) Disposal Facilities (c) The environmental monitoring programs shall be capable of detecting changing trends in performance to allow application of any necessary corrective action prior to exceeding the performance objectives in this chapter.

40 CFR 191	DOE Order 435.1/Manual 435.1-1
MONITORING (continued)	
§191.14(b) (Continued)	**M.I.1.E.(7)** Environmental Monitoring. Radioactive waste management facilities, operations, and activities shall meet the environmental monitoring requirements of DOE 5400.1, *General Environmental Protection Program;* and DOE 5400.5, *Radiation Protection of the Public and Environment.*
PASSIVE INSTITUTIONAL CONTROLS	
§191.14(c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location.	**M.IV.P.(6)(b)** Permanent identification markers for disposal excavations and monitoring wells shall be emplaced. **M.I.1.E.(14)** Records Management. Radioactive waste management facilities, operations, and activities shall develop and maintain a record-keeping system, as required by DOE O 200.1, *Information Management Program;* and DOE O 414.1, *Quality Assurance.* Records shall be established and maintained for radioactive waste generated, treated, stored, transported, or disposed. To the extent possible, records prepared in response to other requirements may be used to satisfy the documentation requirements of this Manual. Additional records may be required to satisfy the regulations applicable to the hazardous waste components of mixed waste.
ENGINEERED AND NATURAL BARRIERS	
§191.14(d) Disposal systems shall use different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included.	None, term not used in DOE O 435.1 or DOE M 435.1-1. **M.IV.P.(6)** Disposal Facility Operations. The disposal facility design and operations must be consistent with the disposal facility closure plan and lead to disposal facility closure that provides a reasonable expectation that performance objectives will be met. Low-level waste shall be disposed in such a manner that achieves the performance objectives stated in this Chapter, consistent with the disposal facility radiological performance assessment.

40 CFR 191	DOE Order 435.1/Manual 435.1-1
ENGINEERED AND NATURAL BARRIERS (continued)	
§191.14(d) (continued)	**M.IV.O.** Treatment. Low-level waste treatment to provide more stable waste forms and to improve the long-term performance of a low-level waste disposal facility shall be implemented as necessary to meet the performance objectives of the disposal facility.
SITING TO AVOID RESOURCES	
§191.14(e) Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive ecosystems. Such places shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future.	**M.IV.M.(1)** Site Evaluation. Proposed locations for low-level waste facilities shall be evaluated to identify relevant features that should be avoided or must be considered in facility design and analyses. (a) Each site proposed for a new low-level waste facility or expansion of an existing low-level waste facility shall be evaluated considering environmental characteristics, geotechnical characteristics, and human activities, including for a low-level waste disposal facility, the capability of the site to demonstrate, at a minimum, whether it is: **M.I.1.D** Analysis of Environmental Impacts. Existing and proposed radioactive waste management facilities, operations, and activities shall meet the requirements of 10 CFR Part 1021, *National Environmental Policy Act Implementing Procedures* , and DOE O 451.1A, *National Environmental Policy Act Compliance Program.* All reasonable alternatives shall be considered, as appropriate. Nothing in this Order is meant to restrict consideration of alternatives to proposed actions.
FUTURE REMOVAL OF WASTE	
§191.14(f) Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal.	

Appendix C

RCRA Closure and Monitoring Plan Requirements for Interim Status, MLLW Treatment, Storage, and Disposal Facilities

**RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)
CLOSURE AND MONITORING PLAN REQUIREMENTS FOR
INTERIM STATUS, MIXED LOW-LEVEL WASTE (MLLW)
TREATMENT, STORAGE, AND DISPOSAL (TSD) FACILITIES**

Title 40 Code of Federal Regulations (CFR) 265.110 Applicability
Title 40 CFR 265.111 Closure Performance Standards

The owner or operator must close the facility in a manner that:
(a) Minimizes the need for further maintenance, and
(b) Controls, minimizes or eliminates to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere, and
(c) Complies with the closure requirements of this subpart, including but not limited to requirements of Title 40 CFR 265.310...

Title 40 CFR 265.112 Closure Plan; Amendment of Plan
- 40 CFR 265.112(a) Written Plan
- 40 CFR 265.112(b) Content of Plan
- 40 CFR 265.112(c) Amendment of Plan
- 40 CFR 265.112(d) Notification of Partial Closure and Final Closure
- 40 CFR 265.112(e) Removal of Wastes and Decontamination or Dismantling of Equipment

Title 40 CFR 265.113 Closure; Time Allowed for Closure
- 40 CFR 265.113(a)
- 40 CFR 265.113(b)
- 40 CFR 265.113(c)
- 40 CFR 265.113(d)
- 40 CFR 265.113(e)

Title 40 CFR 265.114 Disposal or Decontamination of Equipment, Structures, Soils
Title 40 CFR 265.115 Certification of Closure
Title 40 CFR 265.116 Survey Plat
Title 40 CFR 265.117 Post-Closure Care and Use of Property
- 40 CFR 265.117(a)
- 40 CFR 265.117(b)
- 40 CFR 265.117(c)
- 40 CFR 265.117(d)

Title 40 CFR 265.118 Post-Closure Plan
- 40 CFR 265.118(a)
- 40 CFR 265.118(b)
- 40 CFR 265.118(c)
- 40 CFR 265.118(d)

Post-Closure Notices
Title 40 CFR 204.120 Certification of Completion of Post-Closure Care
Title 40 CFR 265.310 Closure and Post-Closure Care

Title 40 CFR 265.310(a) At final closure of the landfill or upon closure of any unit, the owner or operator must cover the landfill or unit with a final cover designed and constructed to:

(1) Provide long-term minimization of migration of liquids through the closed landfill;
(2) Function with minimum maintenance;
(3) Promote drainage and minimize erosion or abrasion of the cover;

(4) Accommodate settling and subsidence so that the cover's integrity is maintained; and
(5) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

Title 40 CFR 265.310(b) After final closure, the owner or operator must comply with all post-closure requirements contained in 265.117 through 265.120 including maintenance and monitoring throughout the post-closure period. The owner or operator must:

(1) Maintain the integrity and effectiveness of the final cover, including making repairs to the cover as necessary to correct the effects of settling, subsidence, erosion, or other events;
(2) Maintain and monitor the leak detection system in accordance with 264.301(c)(3)(iv) and (4) of this chapter and 265.304(b), and comply with all other applicable leak detection system requirements of this part;
(3) Maintain and monitor the ground-water monitoring system and comply with all other applicable requirements of Subpart F of this part;
(4) Prevent run-on and run-off from eroding or otherwise damaging the final cover; and
(5) Protect and maintain surveyed benchmarks used in complying with 265.309.

Title 40 CFR 265: Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Subpart F - Groundwater Monitoring

Title 40 CFR 264: RCRA Monitoring Requirements for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Subpart F - Releases From Solid Waste Management Units