DOE/NV/25946--305

Assurance Requirements Compliance for the Greater Confinement Disposal Boreholes, Area 5 Radioactive Waste Management Site, Nevada Test Site

Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by

Denise Wieland[1], Vefa Yucel[1], Lloyd Desotell[1],
Greg Shott[1], Bruce Crowe[2],
Susan Krenzien[3], and Gary Pyles[4]

November 2007

[1]National Security Technologies, LLC
[2]Stoller-Navarro Joint Venture/Battelle Memorial Institute
[3]Navarro Research and Engineering, Inc.
[4]U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office

DOE/NV/25946--305

Assurance Requirements Compliance for the Greater Confinement Disposal Boreholes, Area 5 Radioactive Waste Management Site, Nevada Test Site

Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by

Denise Wieland[1], Vefa Yucel[1], Lloyd Desotell[1],
Greg Shott[1], Bruce Crowe[2],
Susan Krenzien[3], and Gary Pyles[4]

November 2007

[1]National Security Technologies, LLC
[2]Stoller-Navarro Joint Venture/Battelle Memorial Institute
[3]Navarro Research and Engineering, Inc.
[4]U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office

This Page Intentionally Left Blank

CONTENTS

List of Figures

List of Tables

ACRONYMS and ABBREVIATIONS

BLM	Bureau of Land Management
BN	Bechtel Nevada
CA	Composite Analysis
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE/HQ	U.S. Department of Energy Headquarters
EIS	Environmental Impact Statement
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
ET	evapotranspirative; evapotranspiration
FFACO	*Federal Facility Agreement and Consent Order*
ft	feet
GCD	Greater Confinement Disposal
HDP	heat dissipation probe
ICMP	Integrated Closure and Monitoring Plan
LLMWU	low-level mixed waste unit
m	meter(s)
MTRU	mixed transuranic
NSTec	National Security Technologies, LLC
NDEP	Nevada Division of Environmental Protection
NNSA	National Nuclear Security Administration
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NTS	Nevada Test Site
PA	Performance Assessment
PIC	passive institutional control
RCRA	Resource Conservation and Recovery Act
RWMS	Radioactive Waste Management Site
SME	Subject Matter Expert
TDR	time-domain reflectometer

ACRONYMS and ABBREVIATIONS (continued)

TFRG	Transuranic Waste Disposal Federal Review Group
TRU	transuranic
UGTA	Underground Test Area
USGS	U.S. Geological Survey

1.0 PURPOSE

This paper addresses deficiencies identified with the Performance Assessment (PA) for Greater Confinement Disposal (GCD) Boreholes compliance with the Title 40 Code of Federal Regulations (CFR) Part 191.14, "Assurance Requirements" (CFR, 1985). The Transuranic Waste Disposal Federal Review Group (TFRG), and U.S. Department of Energy Headquarters (DOE/HQ), need to concur that the assurance requirements have been met at the time of closure of the Area 5 Radioactive Waste Management Site (RWMS).

2.0 BACKGROUND

The GCD Boreholes are located within the southeast quadrant (the 92-Acre Area) of the Area 5 RWMS of the Nevada Test Site (NTS). Four of the GCD boreholes contain mixed transuranic (MTRU) and transuranic (TRU) classified material.

The MTRU and TRU disposal units must meet the regulatory requirements of Title 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," under DOE self-regulation as specified in DOE Order 435.1. The §191.14 Assurance Requirements provide increased confidence that long-term compliance with the containment requirements in §191.13 will be achieved. The PAs for TRU waste disposal facilities must show that the containment requirements are likely to be met for 10,000 years. Overlapping measures mitigate potential inadvertent disturbance of the waste and reduce potential exposures and releases to the environment.

Sandia National Laboratories prepared a "Performance Assessment for the GCD TRU Boreholes" (Cochran et al., 2001). In 2002, the TFRG determined that *Volume 4: Application of the Assurance Requirements, Version 1.1, July 21, 2000*, did not meet 40 CFR 191.14 assurance requirements for: institutional controls; a monitoring program; markers, records, and other passive institutional controls; an engineered barrier system; information to support the claim that there are no economically useful minerals in the area; and removal of waste. The U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) committed to resolve these issues during the closure planning process for the Area 5 RWMS (Colarusso et al., 2003) and that the TFRG would review closure and post-closure documents to determine compliance with the 1993 version of Title 40 CFR 191 (Fiore and Berube, 2002). The 1993 version has more restrictive individual protection requirements and groundwater protection standards than the 1985 version, and it uses dosimetric standards consistent with U.S. radiation exposure regulations.

This paper provides the general strategy for meeting the assurance requirements. Detailed compliance measures will be incorporated into the Closure and Post-Closure Care Plan for the GCD boreholes.

The design for the final cover for the disposal units in the 92-Acre Area and a draft of the Closure Plan are in development. Approval of the assurance requirements compliance strategy by TFRG and DOE/HQ will help NNSA/NSO maintain the PA/Composite Analysis (CA) revision and closure schedule, as the results of the PAs must be incorporated into the final closure plans.

3.0 OVERVIEW

There are six assurance requirements topics to be addressed:

- Passive institutional controls (PICs)
- Active institutional controls
- Monitoring plan
- Economic resource assessment
- TRU waste retrieval plan
- Engineered and natural barriers to isolate the waste

Passive institutional controls, active institutional controls, and monitoring are interrelated components of post-closure care planning. Some of the details of these provisions may be refined further during post-closure care plan development. The distinction between passive and active institutional controls varies by institution, regulatory agency, and publication. U.S> Environmental Protection Agency (EPA) regulatory definitions are used here. The institutional control strategy outlined in this paper is consistent with the *Federal Facility Agreement and Consent Order* (FFACO) between the state of Nevada, U.S. Department of Energy (DOE), and U.S. Department of Defense (DoD) (FFACO, 1996) Underground Test Area (UGTA) Corrective Action Unit (CAU) approach. The FFACO is a multi-agency agreement detailing how certain corrective action sites in Nevada will be investigated and remediated.

The Area 5 RWMS is located far from significant economic resources that may attract human intrusions, important water supplies, and sensitive and unique habitats. This paper identifies some of the detailed economic resource assessments and waste retrieval plans that have been prepared for the Area 5 RWMS. A few key points of the economic resource assessments are summarized.

Since 1992, the NNSA/NSO has maintained a waste retrieval plan in accordance with 40 CFR 191. The latest update was prepared in 2007 (DOE, 2007).

The strategy for meeting the engineered barrier assurance requirement assumes the best choice is the most cost-effective barrier that complies with the regulation. The effectiveness of the site setting as a natural barrier has been detailed in the PAs and CAs for the Area 5 RWMS. National Security Technologies, LLC (NSTec), and the NNSA/NSO, recently evaluated engineered barrier options for Trench T04C, a shallow trench containing low level waste and TRU, which is within approximately 150 meters (m) (492 feet [ft]) of the GCD borings containing TRU. The results of the special assessment and modeling are expected to be available for DOE/HQ review by the end of fiscal year 2007. Because the site conditions are similar, some of the findings from the T04C assessment are applicable to the GCD boreholes. Recent evolution of the institutional control strategy may result in further optimization of the closure cover design, which may impact the final engineered barrier compliance choice.

4.0 PASSIVE INSTITUTIONAL CONTROLS

40 CFR 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.

In 40 CFR 191.12, “Definitions” a PIC is defined as “(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." Physical barriers and conditions that control access to a site or disposal unit are also sometimes identified as another form of PIC. Inspection and maintenance of passive structures and markers is an active control.

Many of the PICs are meant to remain in place beyond the active institutional control period. These controls may reduce, but not eliminate, the likelihood of inadvertent human intrusion. Performance evaluations may take credit for PICs. However, the GCD PA took no credit for PICs in deterring intrusion into the boreholes. The following PICs are being considered for the GCD facility:

- Boundary monuments and signs
- Records distributed to national and international archives
- Records submitted to record centers locally, nationally, and internationally
- Government control and land-use restrictions
- Other means of communication in references, books, maps, and atlases
- Natural and engineered barriers.

NNSA/NSO has reviewed land-use restrictions and institutional control policies across environmental protection programs to improve consistency in assessment of human intrusion and public exposure scenarios. PICs can be implemented at closure and/or during the active institutional control period.

4.1 Monuments and Signs

Monuments will be selected, sited, and installed with consideration of maximizing potential endurance.

Many of the operationally closed landfill cells in the 92-Acre Area are currently marked by concrete monuments. Some monuments are labeled with plates. Many of the monuments are likely to be buried or disturbed in the course of constructing the final cover over the 92-Acre Area. In addition to the final closure monuments, these buried monuments may also serve to warn future inadvertent excavators in the far future. Inadvertent encounters with monuments and markers of the surrounding shallow landfill cells may discourage deeper excavation.

Signs provide short-term protection. The 92-Acre Area must meet posting requirements under several different regulations, programs, and permits (e.g., the Nevada Division of Environmental Protection [NDEP] solid waste permit for the asbestos landfill cell, future FFACO use restriction area for the CAU 111 shallow mixed waste trenches, *NV/YMP Radiological Control Manual* [Bechtel Nevada (BN), 2004]) posting requirements for underground radioactive material areas, etc.). Passive controls in the Closure Plans will be accepted and approved by the various posting compliance entities.

After construction of the final cover, in lieu of posting signs to warn of unit-specific hazards, the entire 92-Acre Area will be use-restricted, fenced, and posted on the boundary fence with signs every 30.5 m (100 ft). The warning notices will indicate there is buried hazardous, radioactive, TRU, and asbestos waste, and provide contact information. Such signs will be effective during the active institutional control period. After active institutional control ends, and routine sign maintenance ends, the signs are not likely to remain intact and legible for more than a few years because of weather damage. Other monuments will provide longer-term indications of the extent of the buried waste area.

4.2 Public Records

Information on the 92-Acre Area, including the GCD boreholes, will be recorded in various public records maintained by several agencies and institutions. Because the existence and location of the Area 5 RWMS will be documented in several different formats in multiple locations, the 92-Acre Area should be easy to locate well into the future.

Some of the public records will include:

- A Survey Plat of the closed 92-Acre Area, including the location and dimensions of regulated disposal units, will be submitted to NDEP prior to or with the Certification of Closure.

- The FFACO use-restriction to be implemented for the adjacent CAU 111 mixed waste trenches will be recorded in the FFACO database and NTS Facility Information Management System database.

More records will be detailed in the closure plans.

4.3 Government Regulation of Land and Resource Use

Government ownership, stewardship, and land-use controls are addressed in the active institutional controls section because they are most relevant to the period of active control.

4.4 Control Effectiveness

In Black et al. (2000), subject matter experts (SMEs) considered the long-term effectiveness of PICs to control intrusion. Two distinct forms of controls were evaluated: the ability to maintain site knowledge through oral or archival records, and the ability of placards and markers placed around the site to ward off potential inadvertent intruders and, hence, deter intrusion.

The SMEs expected that site knowledge could be maintained indefinitely through formal means such as universities, libraries, local culture, oral history, and government agencies. However, access to that knowledge was expected to decline as the time between major events at the NTS and the present increases. The site knowledge resources were expected to be viable sources for many years after loss of active institutional control, provided institutional control was not lost through involuntary or abrupt means. The SMEs agreed that there is a 50 percent chance that site knowledge will be lost within 100 years after the loss of institutional controls and a 95 percent chance within 500 years. The SMEs also evaluated the potential for placards and markers to effectively reduce the chance of future inadvertent human intrusion into the subsurface disposal units. The primary factors identified by the SMEs for the potential effectiveness of placards and markers were their durability and interpretability over time. The SMEs were uncertain about the ability for placards and markers to endure for 10,000 years, citing the potential for weathering or erosion, and vandalism, such as defacing, or theft.

5.0 ACTIVE INSTITUTIONAL CONTROLS

40 CFR 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.

In 40 CFR 191, the EPA defines an active institutional control as "(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."

Institutional controls are active measures taken at the DOE sites to limit radiation exposure to the public. Active institutional controls include physical security programs that restrict public access to the sites; ensuring that radioactive materials and radiologically contaminated areas are properly identified, posted, and controlled; and administrative programs that ensure compliance with DOE orders and external agreements with other federal and state agencies and stakeholders. For the purpose of this discussion, the monitoring plan will be presented as a separate assurance item.

Active institutional controls for the Area 5 RWMS include:

- Access controls and site security provided through government control of the NTS, and federal land use and environmental stewardship policies.

- Provisions for inspections and maintenance of passive institutional controls, landfill cover, and an environmental monitoring system to be included in the post-closure care plan.

- Provisions for detecting and responding to releases, which will also be included in the post-closure care plan for the 92-Acre Area.

- The monitoring strategy is summarized in the post-closure care plan and adjusted as needed through the PA/CA maintenance process. For the purpose of this discussion, the monitoring plan strategy will be presented as a separate assurance requirement item.

- FFACO UGTA land-use restrictions. (See Appendix VI, Corrective Action Strategy, Rev. 1, December 7, 2000, in the January 2007 version of the FFACO [FFACO, 1996]).

The following sections outline the active institutional control strategy with respect to the PA, federal land-use policy, long-term stewardship, access and security programs, DOE Orders and interagency agreements, post-closure inspection and maintenance provisions, and post-closure emergency response plans. A brief assessment of the potential long-term effectiveness of active institutional controls is included. Institutional controls at the NTS are anticipated to endure longer than the 100 years assumed in the GCD PAs.

5.1 GCD Performance Assessment Institutional Control Assumptions

The GCD PA modeling was performed with a 100-year institutional control period. It was assumed that during this period, there would be no intrusion into the waste and that no member of the public would be allowed near the facility because active institutional controls would be in place and effective in the Area 5 RWMS. The PA assumed the "drilling" and "first homesteader member of the public" scenarios would take place in the first year after the 100-year institutional control period following the closure of the facility. In addition, the PA took no credit for the PICs. The GCD PA results for the 40 CFR 191 containment and individual protection requirements are far below the regulatory limits. The following provides the assurance that active institutional controls will be in place for at least 100 years, post-closure.

5.2 Land Ownership and Land Use

Figure 1 shows land ownership in the NTS region. Most of southern Nevada is federally controlled. The NTS occupies public lands that are administered by the U.S. Department of Interior, Bureau of Land Management (BLM). Public access to the NTS area has been restricted since the 1940s, when the land was part of a bombing and gunnery range under the jurisdiction of Nellis Air Force Base. In the 1950s, the U.S. established the area as the primary continental location for U.S. nuclear testing. In the 1950s and 1960s, the U.S. Atomic Energy Commission withdrew the land that now comprises the NTS under four Public Land Orders.

DOE currently has jurisdiction of the NTS through withdrawals under public land laws, including mining and mineral leasing laws through the Public Land Orders, and a memorandum of understanding (DOE, 2006).

The NTS Environmental Impact Statement (EIS) (DOE, 1996a) and the *Nevada Test Site Resource Management Plan* (DOE, 1998c) state that a primary mission of the NTS is to ". . . preserve the capability to resume underground nuclear testing . . . and accomplish stockpile stewardship and national security missions." Therefore, it is expected that public access will be restricted as long as the NTS is an operational Defense Program facility.

In 1983, the BLM reviewed the four land withdrawals comprising the NTS. The BLM concluded that the lands were still being used for the purposes withdrawn, but recognizing the potential end of testing, recommended another review in 100 years (DOE, 2006). Although the agency with jurisdiction over NTS land may change, federal responsibility for the NTS is expected to continue in perpetuity. There are currently no plans to remove institutional controls placed on lands within the NTS boundary.

The EIS (DOE, 1996a) defined NTS land uses for planning purposes. The Area 5 RWMS is a designated "Waste Management Site" and is managed through a comprehensive waste management program in accordance with pertinent DOE orders, DOE policies, federal regulations, and laws. Closure requirements are designed to help protect future users of the property from exposure to the contaminants in the waste.

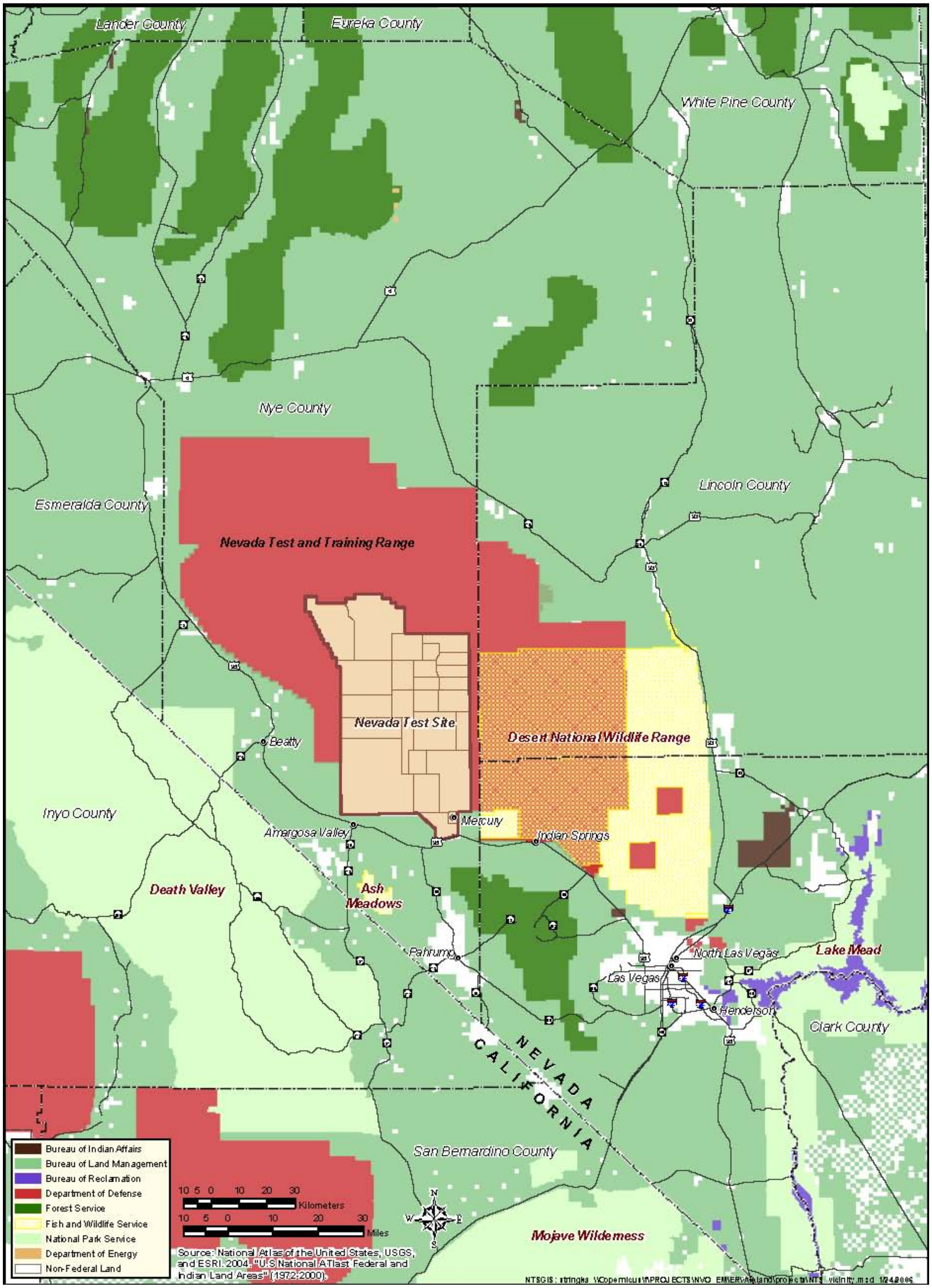

Figure 1. Land Ownership

The Area 5 RWMS is within a Restricted Use Zone defined in local directives. Activities within a Restricted Use Zone must, among other criteria, be ". . . compatible with NTS natural and manmade resources . . ." and there must be a ". . . compelling need (such as security, restricted access, remote location, physical characteristics) that drives the project to be located within the security boundary of the NTS" (DOE, 1998c).

Some of the processes and permits pertinent to land use at the Area 5 RWMS and to ensuring waste containment during the period of active control include:

- FFACO land-use restrictions for the UGTA CAU 98 and CAU 111 FFACO sites
- NTS excavation permits
- NTS radiological work permits
- Nevada groundwater well permits
- National Environmental Protection Act checklist reviews and compliance for planned NTS activities

5.3 Long-Term Stewardship

The U.S. government's commitment to the long-term environmental stewardship of the NTS while accomplishing agency missions has been stated in many planning and policy documents:

- DOE Policy P 430.1, "Land and Facility Use Planning" (DOE, 1996b)
- *Accelerating Cleanup: Paths to Closure* (DOE, 1998a)
- *Accelerating Cleanup: Paths to Closure, Nevada Operations Office* (DOE, 1998b)
- *From Cleanup to Stewardship* (DOE, 1999)
- *Nevada Test Site Resource Management Plan* (DOE, 1998c)
- *Performance Management Plan* (DOE, 2002)
- *Nevada Test Site, Environmental Management, End State Vision* (DOE, 2006)

DOE policy is to manage its ". . . land and facilities as valuable natural resources, with stewardship based on principles of ecosystem management and sustainable development . . . . The goal of NTS ecosystem management is to accomplish the DOE/NV[1] missions of national security, EM [Environmental Management], technology diversification, energy efficiency and renewable energy, and NTS stewardship while at the same time, sustaining the health and biological diversity of NTS ecosystems" (DOE, 1998c). Furthermore, "DOE will maintain a presence at the NTS to ensure reduced risks to human health and the environment. This long-term stewardship will include passive and active institutional controls, the degree of which will be determined through negotiations between DOE/NV, regulators, Tribal Nations, and stakeholders." (DOE, 1998b)

The NNSA/NSO and DOE contractors at the NTS must comply with DOE Order 450.1, "Environmental Protection Program" (DOE, 2003a). The principle objective of DOE Order 450.1 is "To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by Department of Energy (DOE) Operations and by which DOE cost effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations and DOE requirements." (DOE, 2003a)

[1] U.S. Department of Energy, Nevada Operations Office (prior to Nevada Site Office).

The NNSA/NSO *Performance Management Plan* (DOE, 2002) is compliant with DOE Policy P455.1, "Use of Risk-Based End States" (DOE, 2003b). Expected future land uses are a driver in selecting acceptable end-state conditions and cleanup goals for the NTS. NNSA/NSO EM's land management assumptions and framework for EM activities include:

> The NTS will remain under federal control in perpetuity as an NNSA test site, and the large buffer zone surrounding the NTS (the Nevada Test and Training Range) is assumed to remain under the control of the U.S. Air Force. There are no plans for transfer of any NTS lands to other agencies or public entities. Access will continue to be restricted to the NTS and the surrounding areas.
>
> For management purposes, NNSA/NSO EM activities have been established based on the source of contamination and type of waste requiring management. Environmental Restoration activities within the State of Nevada fall under the purview of a formal regulatory agreement, the *Federal Facility Agreement and Consent Order* (FFACO); Environmental Restoration activities outside the State of Nevada fall under the purview of each affected State's regulatory framework but are planned and negotiated with the State using the FFACO Corrective Action Strategy framework for applicable activities. Waste Management activities are governed by the *Federal Facility Compliance Act and Consent Order* and the *Mutual Consent Agreement*. A Joint Low-Level Waste Oversight Agreement is in place to allow State of Nevada representatives to participate in review and approval processes associated with waste receipt and disposal operations. (DOE, 2002)

The *Nevada Test Site, Environmental Management, End State Vision* (DOE, 2006) addresses contaminated sites controlled by NNSA/NSO EM. Long-term federal stewardship of the NTS underlies the end-state vision. "The long-term end state vision of the NTS is to restore the environment to an extent that will allow the maximum continuation of the national security mission conducted by the NNSA/NSO, the national laboratories and contractors." (DOE, 2006)

DOE criteria for free release of land may result in an extended federal environmental stewardship role. Because of past activities, including both atmospheric and underground nuclear weapon tests, some land within the NTS boundary cannot be released for unrestricted use without remediation. It may not be cost-effective to remediate residual contamination from underground nuclear testing and long-term land-use restrictions may be required.

DOE (1998b) projects long-term federal stewardship: "Institutional control of the NTS is assumed in perpetuity at the existing boundaries." If DOE ceases to exist, it is assumed that ". . . another federal agency will become the landlord . . . as institutional control of the site is considered an obligation of the federal government and one that is expected to be maintained."

Although the PA for the GCD TRU boreholes assumes institutional control will last only 100 years in accordance with 40 CFR 191.14 (a), active federal stewardship of the NTS is expected to last longer than 100 years. Section 5.8 addresses active institutional control effectiveness in more detail.

5.4 Access Control and Security Programs

Because of its past and anticipated missions of operational readiness and nuclear weapons testing, the DOE and the U.S. government have committed to oversight and management of the

NTS for the foreseeable future. The following are the controls in place limiting access to the NTS, described in the *Nevada Test Site Resource Management Plan* (DOE, 1998c):

> The NTS is surrounded by government-controlled buffer zones and protected by Security Police officers, mobile patrols, and highly trained emergency response teams. Sensitive areas within the NTS use chain-link fencing, protective alarms, closed-circuit television, and secure communications systems. The Nye County Sheriff's Department provides civil law enforcement.
>
> The NTS is a controlled-access area with road access beginning at the Security Station on Mercury Highway, 5 miles (mi) from the U.S. Highway 95 Mercury turnoff. Although a security clearance is not required for entry, access is not allowed without proper identification and an identification badge [and an appropriate reason for access]. Personnel are issued dosimetry badges if entering areas where they might be exposed to radiation levels above background. Security areas within the NTS have stringent personnel controls, requiring the appropriate security clearance and an operational need before access is allowed.
>
> The entire perimeter of the NTS is not fenced, but it is posted as a restricted area; access is prohibited except at designated entrances. Beyond the perimeter, the BLM and Nellis Air Force Range [now Nevada Test and Training Range] provide buffer zones. Barricades and/or Security Stations control the few roads that access NTS boundaries. Perimeter barricades are checked by security force patrols. (DOE, 1998c).
>
> Inactive facilities and areas that are known to be contaminated and require access control are fenced and posted with warning signs. In remote areas where personnel rarely perform work activities, appropriate posting at the perimeter boundary as well as access roads to the contaminated area may be substituted instead of fencing. Further program enhancement is accomplished by following the Integrated Safety Management guiding principles and core functions. (DOE, 1998c)

5.5 Federal Orders and Interagency Agreements

The NNSA/NSO has programs to ensure compliance with DOE Order 5400.5, "Radiation Protection of the Public and the Environment" that limits annual exposure of the public to 100 millirem in a year (DOE, 1990). DOE Order 5400.5 also contains conditions and requirements for unrestricted release of land. Because some of the residual contamination from past nuclear tests is likely to be closed in place and will persist for many years, portions of the NTS, such as Yucca Flat and Frenchman Flat, may not meet unrestricted release requirements. Therefore, use restrictions may preclude new rural development, mining permits, groundwater wells, and other intrusive uses even after DoD and DOE activities cease.

The NNSA/NSO entered into the FFACO in May 1996. This agreement specifies a process for the identification, remediation, and closure of CAUs on the NTS. The FFACO land-use restrictions for CAUs near the Area 5 RWMS are part of the active institutional control strategy for the Area 5 RWMS. Anticipated FFACO land-use restrictions in Frenchman Flat have implications for future public access to the area for drilling water wells, and for the Area 5 RWMS PA and CA scenario evaluations.

The UGTA CAUs are identified as Restricted Use Zones in local directives (NNSA/NSO, 2006). The following section provides an overview of the UGTA program strategy.

The corrective action strategy for UGTA is based on a corrective action process where boundaries are identified for each CAU that encompass geographic areas containing groundwater that may be unsafe for domestic and municipal use. Each UGTA CAU will be evaluated through data collection, evaluation, and numerical modeling leading to predictions of the maximum extent of groundwater flow and contaminant transport from underground testing of nuclear weapons. The vertical and horizontal extent of contaminant migration will be predicted for each CAU. The contaminant boundary will be used to negotiate a compliance boundary between the NNSA/NSO and the NDEP. With establishment of a regulatory compliance boundary, remedial actions will be evaluated and a five-year monitoring plan will be developed to assess adequacy of CAU surveillance. If the monitoring plan is found acceptable, a closure plan for the CAU will be developed, followed by a long-term closure monitoring program.

It is expected that protection from UGTA contamination regarding human health and the environment will be based on controlled access to areas of contamination (areas within the UGTA FFACO compliance boundary). As part of the FFACO process, land-use restriction forms and maps are approved by the NDEP and become official records for documenting sites with remaining contamination after closure. The NNSA/NSO, the BLM, and the U.S. Air Force will maintain use-restriction records as long as the land is under their jurisdiction and will give notice of such restrictions to any successor organizations.

Current results are inconclusive regarding whether the Area 5 will be included in the contaminant and compliance boundaries associated with a cluster of underground tests in northern Frenchman Flat based on the distribution of UGTA contamination. The model boundaries are expected to be close to the Area 5 site and the Assistant Manager for EM of the NNSA/NSO has administratively agreed that the facility will be included within the contaminant and compliance boundaries for the Frenchman Flat CAU.

The land-use restrictions will prohibit public access to contaminated groundwater within the NDEP compliance-negotiated boundaries for 1,000 years. Land-use restrictions eliminate groundwater drilling as a release pathway and effectively eliminate the “resident homebuilder” and the “water drilling inadvertent human intrusion” scenarios from consideration in the PA/CA for the Area 5 RWMS.

5.6 Inspections and Maintenance

Anticipated inspection and maintenance provisions were outlined in the *Integrated Closure and Monitoring Plan* (ICMP) (BN, 2005). The final inspection and maintenance strategy will be presented in the post-closure care plans for the Area 5 RWMS. Inspection and maintenance requirements for the 92-Acre Area will require compliance with the Resource Conservation and Recovery Act (RCRA) requirements for the closure of the Pit 3 Mixed Waste Disposal Unit. The following is extracted primarily from the ICMP.

The inspection program has requirements for environmental monitoring equipment, fire protection systems, safety and emergency equipment, security devices, and operating or structural equipment that are critical to prevent, detect, or respond to human health or environmental hazards. Records will be used by RWMS personnel to ensure that inspections are conducted according to established schedules.

Inspections will be performed during the institutional control closure period and will consist of visual observations of closure cover integrity, fencing, and boundary monuments. The inspection schedule will be determined at closure. Inspections and associated repairs will ensure the continuing protection of human health and the environment.

Post-closure inspection and maintenance will be minimized to the extent possible by the design of the disposal unit and closure cover system, and the additional site security measures. Post-closure inspections will include:

- General facility inspection
- Boundary monument inspection
- Warning sign inspection
- Cover inspection
- Run-on/runoff inspection

During each inspection, any changes in the condition of the closure cover, vegetation, or fenced area will be documented (40 CFR 265.310[b][1]). Specific changes noted on the current condition of the cover include, but are not limited to, trash and debris within the fenced compound, animal burrows or nesting activity, and erosion of the cover.

Maintenance activities will be based on inspection results. Custodial maintenance or repair actions may include repairing fences, replacing warning signs; reestablishing the location control monuments, removing unwanted vegetation, and reconstructing slopes, cover, or embankments.

All repair work to the cover will ensure that the integrity of the cover and design “as built” is maintained. For RCRA-regulated disposal units, if cover repair requires modifications of the closure cover design, NNSA/NSO will present a formal design modification request to the NDEP prior to making the design modification.

Closure and post-closure monitoring documentation will be maintained in the Area 5 RWMS files and at the NNSA/NSO Technical Library in North Las Vegas.

5.7 Emergency Response

Except for extraordinary events, the site access restrictions, closure cover design, post-closure inspections, and preventive maintenance are expected to mitigate the need for emergency release response during the active control period. NTS environmental surveillance and site-specific monitoring programs are designed to detect conditions indicating a potential containment breach. After detection, further investigation may be necessary to confirm site conditions and to assess the scope and nature of the problem. The type and level of response will depend on the scope and nature of the problem and the hazards that must be addressed to implement the response safely. The response may include several phases of activity, including quick containment measures and longer-term construction projects. The NTS has on-site capacity to address many types of emergencies rapidly and is likely to maintain such capacity while active DoD and DOE operations remain.

5.8 Control Effectiveness

NNSA/NSO evaluated the effectiveness and probable duration of long-term institutional controls in Frenchman Flat by convening a panel of independent SMEs (Black et al., 2000). The SMEs unanimously agreed that institutional control would not last for 10,000 years (the elicitation's target compliance period) because no human institution, government, or political civilization has lasted for this length of time. Instead, the SMEs focused on the time frame in which institutional control might be lost. The consensus was that institutional control would be lost within 1,000 years (90 percent probability), that institutional control has a reasonable chance of lasting about 250 years (50 percent chance), and that it was very likely to last at least 50 years (90 percent chance). The SMEs also suggested that 2,000 years is the longest period of time for which institutional control could reasonably be expected to last. The SMEs considered a time frame of 100 to 500 years for institutional control because they expected that it would take this long for sociopolitical will to erode sufficiently for institutional control to cease.

6.0 MONITORING PLAN

40 CFR 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.

An integrated closure and monitoring plan has been developed for the Area 5 RWMS (BN, 2005). This plan addresses monitoring requirements for the multiple regulations applicable to the RWMS, including 40 CFR 191.14(b).

The Area 5 RWMS monitoring system consists of a combination of direct monitoring of radionuclides released from the disposal system, as well as monitoring transport mechanisms, which could lead to the release of radionuclides to the accessible environment. The monitoring system consists of the following elements:

- Vadose zone monitoring
- Groundwater detection monitoring
- Radon monitoring
- Meteorology monitoring
- Biota monitoring
- Subsidence monitoring
- Air monitoring
- Soil gas at GCD-05U

Current monitoring locations are shown in Figures 2 and 3. GCD-specific monitoring will be described in the post-closure care plan.

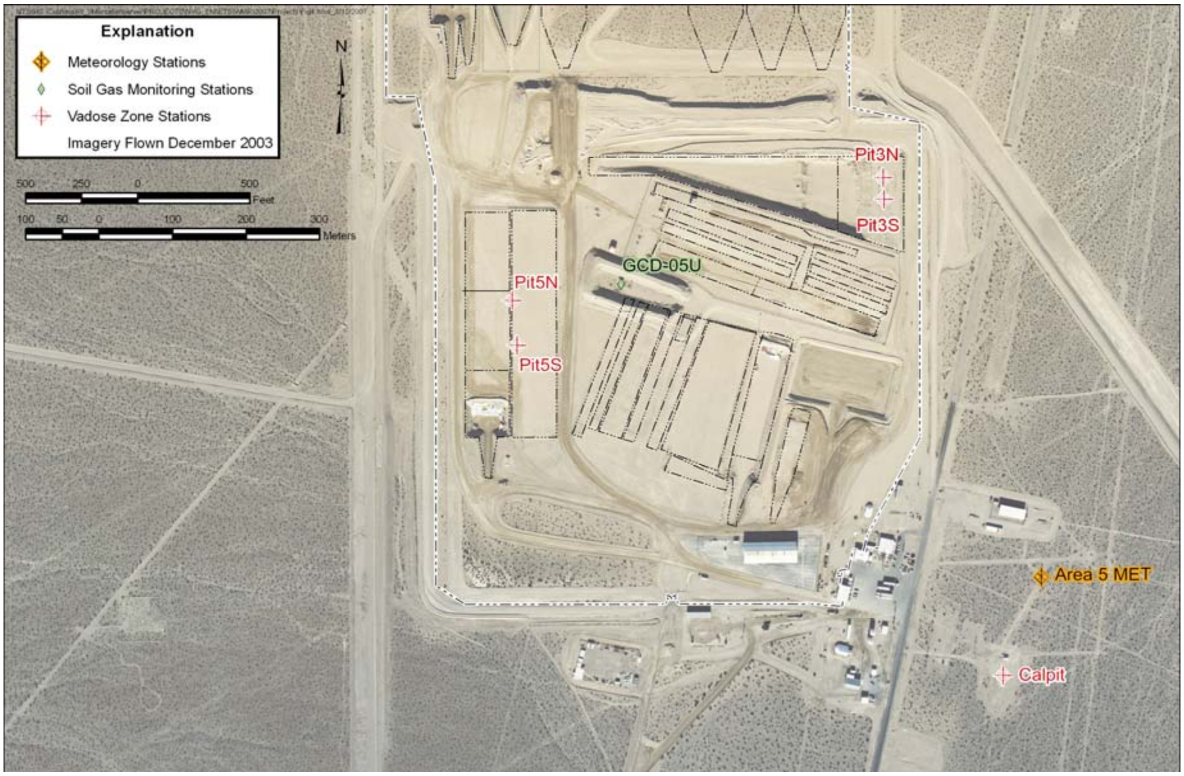

Figure 2. Meteorology, Soil Gas, and Vadose Zone Monitoring Stations at the Area 5 RWMS

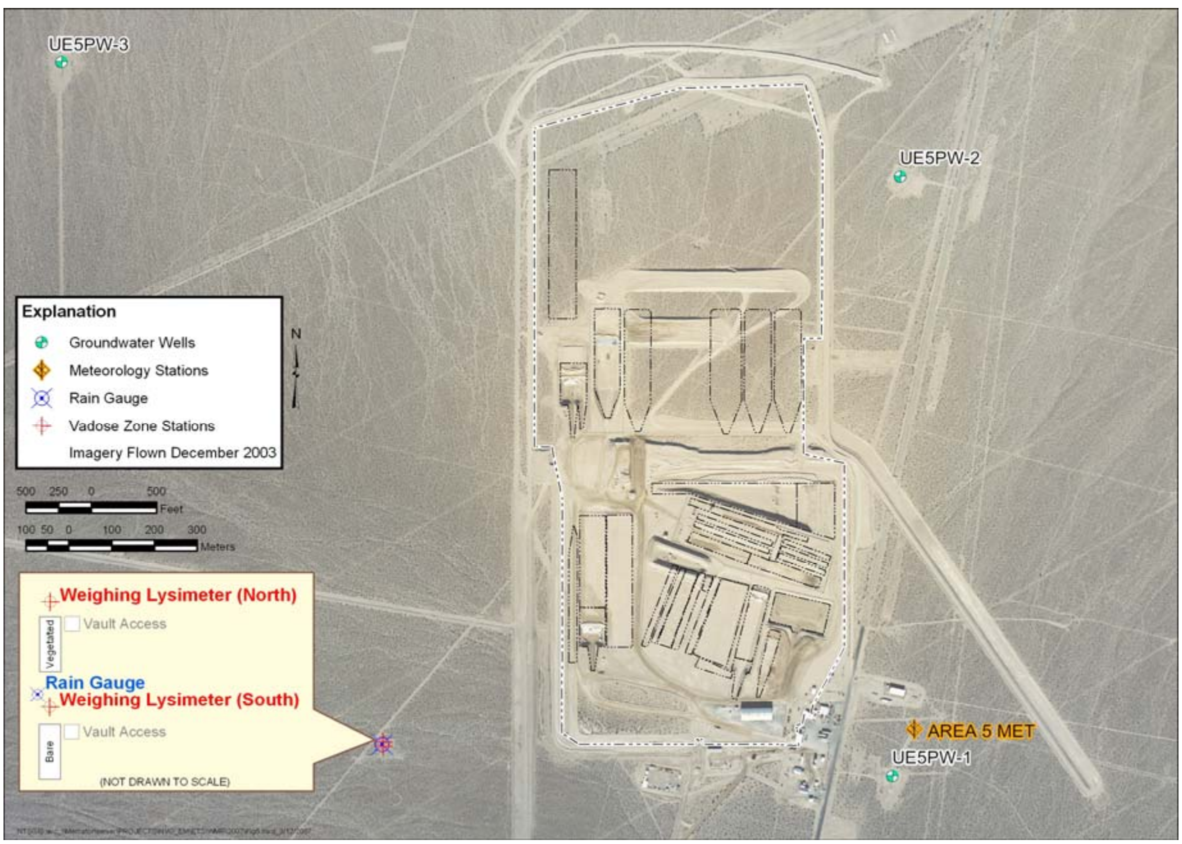

Figure 3. Groundwater Wells, Weighing Lysimeters, Rain Gauge, and Other Monitoring Stations Near the Area 5 RWMS

The same monolayer-evapotranspirative (ET) cover design using native alluvium and native vegetation will be used to close all waste cells within Area 5. Additionally, extensive characterization and monitoring data indicate little spatial variability in the cover and geologic materials (NSTec, 2006; Shott et al., 1998). These factors, coupled with the relatively small areal extent of the RWMS, support the position that cover performance monitoring conducted within Area 5 is generally applicable to all the Area 5 RWMS regulated waste cells.

6.1 Vadose Zone Monitoring

Vadose zone monitoring is conducted to confirm the key assumption of no downward pathway, to detect changes in system performance, and to establish baseline data for long-term monitoring. The vadose monitoring system consists of weighing lysimeters and instrumented operational covers. Two precision weighing lysimeters have been in continuous operation since March 1994. One lysimeter is vegetated with native plant species at the approximate density of the surrounding desert, and the other lysimeter is kept bare to simulate operational covers. The lysimeters are capable of measuring changes in storage of ± 800 grams or ± 0.1 millimeter of water. Additionally, both lysimeter soil columns are instrumented with time domain reflectometers (TDRs) for volumetric water content and heat dissipation probes (HDP) for matric potential and soil temperature measurements.

Three operational covers and one pit floor are instrumented with TDR probes. Sensors are installed throughout the cover profile to a depth of 180 centimeters. HDP arrays are also installed in two of the operational covers. Vadose zone sensors are typically read once a day.

6.2 Groundwater Monitoring

Since 1993, groundwater monitoring has been conducted for a suite of radiologic and chemical constituents at the three wells surrounding the Area 5 RWMS. The wells have been sampled semiannually for RCRA compliance and biennially as part of the sitewide groundwater monitoring program. Water table elevation measurements taken at the three wells surrounding the RWMS, as well as neighboring wells, indicate the uppermost aquifer is approximately 235 m 771 (ft) below ground surface and is essentially flat, with very low rates of groundwater flow.

6.3 Meteorology Monitoring

Detailed meteorological data are collected at the Area 5 RWMS. Measurements include precipitation, air temperature, relative humidity, wind speed and direction, barometric pressure, and incoming solar radiation. Hourly data are recorded. These basic meteorological parameters are required to quantify the exchange of water and heat between the soil and atmosphere. Meteorological measurements are taken to (1) confirm that the RWMS is sited in an arid environment, (2) use as input for process level models, and (3) refine PA/CA parameter distributions.

6.4 Subsidence Monitoring

Subsidence has been formally monitored since 2000. Subsidence occurs most commonly in recently filled disposal units, especially along the edges where soil backfill may not be completely compacted. Subsidence monitoring ensures that subsidence features are repaired to maintain the integrity of the closure cover.

6.5 Air Monitoring

Air particulate samples are collected weekly at two stations surrounding the Area 5 RWMS using glass fiber filters. Air particulate samples are screened for gross alpha and gross beta activity weekly. Monthly composites are analyzed by gamma spectroscopy for gamma-emitting radioactivity and by radiochemical analyses for americium and plutonium.

Atmospheric moisture is collected and analyzed for tritium at two stations. Tritium samples are collected over a two-week period. Tritium acts a conservative tracer and therefore is an excellent indicator of volatile radionuclide migration from waste cells.

6.6 Soil Gas Monitoring

Soil gas sampling for tritium has been conducted annually at the GCD-05U borehole since 1990. GCD-05U has a large tritium inventory (~ 2.2 million curies at time of disposal). GCD-05U has the same approximate geometry and is located near the 40 CFR 191-regulated GCD boreholes (GCD-01C, -02C, -03C, and -04C). GCD-05U therefore is a direct performance analog for the 40 CFR 191-regulated units and provides data to evaluate the movement of volatile radionuclides in a GCD configuration.

6.7 Biota Monitoring

Vegetation growing on and around waste disposal units is periodically sampled. Vegetation sampling provides a direct measure of radionuclide transport through plant uptake. Because of its high mobility, tritium is the primary target analyte, although other radionuclides are often included in the analysis suite. Small burrowing animals also are collected periodically and analyzed for radionuclides.

6.8 Radon Flux

Although significant radon flux is not predicted in the GCD TRU PA, radon flux measurements taken at other locations within Area 5 provide supporting data for volatile radionuclide transport calculations applicable to GCD.

6.9 Post-Closure Monitoring

Monitoring data will be evaluated and compared against PA model assumptions to confirm that conceptual and parameter assumptions are not changing on an annual basis. Included in these evaluations will be recommendations for changes in frequency or addition/deletion of monitored parameters.

7.0 ECONOMIC RESOURCE ASSESSMENT

40 CFR 191(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.

Several assessments show that the Area 5 RWMS was not sited near any significant economic mineral deposits, viable petroleum or natural gas deposits, valuable geologic formations, or irreplaceable sensitive water supplies. The Area 5 RWMS is located on an alluvial fan, in an arid, remote, alluvium-filled basin, with deep groundwater. Such alluvial deposits are common and widely distributed in the southern Great Basin. Biological studies show the Area 5 RWMS is not located near unique or sensitive ecosystems.

The NTS continues to be used by the DOE and DoD for a variety of testing and training purposes, and federal institutional control of the site is expected to continue to protect the Area 5 RWMS from intrusive development for many decades.

7.1 Previous Studies

NSTec (2007) identified potentially exploitable resources near the Area 5 RWMS that could lead to inadvertent human intrusion after active institutional control ends. Sand and gravel, minerals, petroleum, and water were considered. Quality, quantity, availability of better sources, transport costs, and limited local demand are likely to limit commercial extraction of geologic economic resources in the NTS region.

NSTec (2007) also reviewed Desert Research Institute's examination of rural land-use potential (Case et al., 1984; Richard-Haggard, 1983) and concluded that "Alternative land uses such as agriculture, grazing, and hunting do not appear to be potential causes for inadvertent human intrusion."

Shott et al. (1998) also reviewed references to evaluate the potential for the development of geologic resources and agriculture in the region of the Area 5 RWMS. Detailed information is presented in Chapter 2.6, Land Use (Shott et al., 1998).

Although these assessments were quite thorough, NSTec briefly reviewed some of the recent U.S. Geological Survey (USGS) and Nevada Bureau of Mines publications available to confirm that no new economic mineral resources have been identified near Frenchman Flat.

A few points from these economic resource studies are summarized below to demonstrate that the assurance requirement for siting the waste cells away from significant economic resources has been fulfilled and that the potential risk of future intrusions into the waste areas for development of such resources is very low.

7.2 Sand and Gravel Resources

Although there are sands and gravels in the upper alluvium at the Area 5 RWMS, the quality of the material is poor and the location is far from the most likely sources of demand for roadways, building pads, and other fill structures. Samples of alluvium from excavations in the Area 5 RWMS indicate the shallow gravels are composed predominantly of clastic fragments derived from the erosion of pyroclastic volcanic rocks. The alluvium deposits with significant percentages of reworked pyroclastic volcanic rocks are too friable to be suitable for many typical commercial uses. Current existing population centers (e.g., Alamo, Beatty, and Pahrump) and major highways (e.g., U.S. 95) are far from the Area 5 RWMS. If development were to occur in the Frenchman Flat region in the future, gravel resources are more likely to be extracted from the south side of the basin where the material may be higher quality because carbonate rocks are more prevalent (NSTec 2007).

7.3 Mineral Resources

NSTec (2007) reviewed the literature and concluded that the Area 5 RWMS has "a very low mineral potential." There is no record of historic mining activities within Frenchman Flat. Four mining districts have been identified on the NTS: Calico Hills, Wahmonie, Mine Mountain, and

Oak Spring. The nearest recorded mineral deposits are 23 kilometers (14 miles) northwest of the Area 5 RWMS in the Mine Mountain Mining District.

The economic mineral potential of these districts was summarized by Shott et al. (2000). Silver may be present in the Oak Spring District. Potentially economic mineral deposits may remain in the Wahmonie District. Commercial tungsten mining occurred in the Oak Spring District in the 1950s and early 1960s. The NTS is considered to have a moderate potential for tungsten skarn deposits (Science Applications International Corporation/Desert Research Institute, 1991; in Shott et al., 2000). Molybdenum is associated with these deposits.

Although there are natural zeolites in some of the volcanic tuffs underlying Frenchman Flat, the likelihood of the vicinity of the Area 5 RWMS being mined for zeolites is very low. Only 1 of the 10 companies that mined natural zeolites in the U.S. in 2005 was located in Nevada, and the U.S. produced less than 3 percent of the world production in 2005. The main domestic uses for natural zeolites are for animal feed, water purification, and pet litter (Virta, 2006). There are alternative materials for these products. Many commercial industrial applications use synthesized zeolites for their purity and unique characteristics. Most U.S. foreign trade in zeolites is in synthetic zeolite products (Virta, 2006).

Projections for growth in demand and production of natural zeolites in the U.S. are modest. New products and markets, such as lightweight aggregate for specialty concrete products are in development. Based on recent trends, the USGS predicts U.S. production and sales of natural zeolites will increase by at least 4- to 5-percent per year for the next 2 to 3 years (Virta, 2006).

However, natural zeolite resources are not unique to the Frenchman Flat area. There are existing operations in the U.S. extracting higher quality and more accessible material. Should a local market for zeolites ever develop within the NTS (unlikely), the mid-fan location of the Area 5 RWMS is less likely to be a viable source than volcanic tuffs in alkaline lake deposits.

7.4 Petroleum Resources

Petroleum exploration in Nevada has been very limited. Petroleum had been produced from wells in Railroad Valley, approximately 148 km (92 miles) north of the Area 5 RWMS, and in Blackburn Field in Eureka County, over 241.4 km (150 miles) north of the Area 5 RWMS. The potential for oil and natural gas is rated low for southern Nye County according to two Nevada Bureau of Mines and Geology Reports (Garside et al., 1988; Castor et al., 1990). Drilled prior to 1992, four oil and gas exploration holes within 64.3 km (40 miles) of the Area 5 RWMS ranged in depth from 447 m (1,468 ft) to 1,702 m (5,583 ft) and were dry holes.

7.5 Groundwater and Surface Water Supplies

Pilot wells at the Area 5 RWMS indicate depth to groundwater is about 235 m (772 ft) at Ue5PW-1 and 257 m (842 ft) at Ue5PW-2 (BN, 2003). The water quality monitoring results from the pilot wells indicate that the groundwater is good quality in the immediate vicinity of the Area 5 RWMS. These wells tap the uppermost alluvial aquifer, which is not regionally extensive and is locally impacted by radionuclides in the vicinity of some nuclear tests that were conducted below or near the water table. Many Corrective Action Sites have been identified in Frenchman Flat. It is anticipated that the Area 5 RWMS will fall within the boundary of a use restriction area to be established for the UGTA Frenchman Flat CAU.

NSTec (2007) identifies at least three potential uses for groundwater from the aquifer (agricultural irrigation, commercial geothermal energy development, and human consumption), assuming the aquifer is accessible and there was a sufficient quantity of water.

Future residents (if any) are likely to locate near surface water resources. The nearest spring is Cane Spring, about 9 miles southwest of the Area 5 RWMS.

7.6 Important Habitats

Unique and sensitive areas of the NTS have been identified through biological studies. The Area 5 RWMS is not within an area of the NTS identified as "important habitat," based on high species diversity, uniqueness, pristineness, or sensitive habitat that would be slow to recover from disturbances (DOE, 1998c). The vegetative community of the Area 5 RWMS is classified as creosote bush/white bursage, a common community within the Mojave Desert.

Large portions of the NTS are within the range of the Western burrowing owl, a bird protected by the state of Nevada. There is no evidence that the Area 5 RWMS operations have affected the owls, which often reside in culverts and abandoned conduit pipe. The Area 5 RWMS is also within the range of the desert tortoise, a threatened species protected under the *Endangered Species Act*, but in an area of relative scarcity. Activities within the tortoise habitat of the NTS are conducted in accordance with a U.S. Fish and Wildlife Biological Opinion, which includes provisions for surveys, relocations, and mitigation. The *Nevada Test Site Resource Management Plan* (DOE, 1998c) and annual Nevada Test Site Environmental Reports provide further information on monitoring and protection programs for flora, fauna, water supplies, and other critical resources of the NTS.

7.7 Agriculture and Range

Site conditions do not appear to be favorable for intensive agriculture or ranching. Shott et al. (1998) summarized information on agricultural productivity and agricultural use in southern Nevada. The arid climate, soils, and topography limit productivity. Most agriculture in southern Nevada is for animal feed crops and pasture.

There are irrigable soils in Frenchman Flat, but the soils have poor water-retention characteristics. It is technically feasible to produce hay crops such as alfalfa, but demand for irrigable land is low, and only 5 percent of the irrigable land in Nevada is in use (Richard-Haggard, 1983). The cost of infrastructure and power to extract deep irrigation water is a factor in agricultural demand. Southern Nevada farming tends to be located near surface water or shallow groundwater supplies.

Shott et al. (1998) cites several evaluations of grazing potential at the NTS. The general picture is that cattle graze selectively on preferred plants. Only a few of the species of plants in Mojave Desert plant communities are suitable for forage. Populations and productivity of these forage shrubs and annual grasses are such that only very low densities of cattle could be supported by the plant communities of Frenchman Flat. Comparison of the average animal unit month for BLM grazing permits issued in Nevada to the estimated capacity of the Frenchman Flat area suggests the Frenchman Flat area is less productive than average BLM-controlled Nevada rangeland. Accessibility and cost of water is also a factor in range use. The meager forage and deep groundwater of the Area 5 RWMS area may be less attractive to future ranchers than more productive areas near springs.

8.0 TRU WASTE RETRIEVAL PLAN

40 CFR 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.

All of the TRU material in the GCD boreholes is solid material packed in containers. According to Chu and Bernard (1991), the nuclear weapon accident residues in GCD-1C, GCD-2C, and GCD-3C were packaged in metal boxes, metal barrels, and plywood boxes coated with fiberglass. Probertite was backfilled around the packages. The Rocky Flats Plant material in GCD-4C was packed in fiberboard containers packed in plastic bags, placed in a rigid drum liner, packed in 55-gallon metal drums. Material from Lawrence Livermore National Laboratory in GCD-4C was packed in boxes. These packages are 21 m (70 ft) to 36 m (120 feet) below ground surface and covered by at least 21 m (70 ft) of backfill.

The GCD disposal system does not preclude removal of the waste packages. Although it would be expensive to safely excavate and remove the buried TRU waste at the Area 5 RWMS, it is technically feasible. The NNSA/NSO has maintained a GCD waste retrieval plan since 1992, with the most recent update completed in 2007 (DOE, 2007). The current removal plan assumes that contingency costs will be built into the work scope and cost estimate in the event that packages are breached in the excavation and grappling process.

9.0 ENGINEERED AND NATURAL BARRIERS TO ISOLATE THE WASTE

40 CFR 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.

In 40 CFR 191.12, the EPA defines the accessible environment as "(1) The atmosphere, (2) land surfaces, (3) surface waters, (4) oceans, and (5) all of the lithosphere that is beyond the controlled area." The EPA defines a barrier as "any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment. For example, a barrier may be a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides."

DOE performance objectives in DOE Order 435.1 include a provision for an exposure limit for inadvertent intruders. Avoidance of intrusions expands the barrier concept to include structures and conditions that might help prevent inadvertent human intrusion. The lack of significant economically exploitable natural resources in the region, the cost of drilling and pumping from deep wells, and land-use restrictions that prohibit public access to groundwater within compliance boundaries to be established for the UGTA Frenchman Flat CAU, will help mitigate the risk of inadvertent human intrusions for water drilling and residential agriculture during the 1,000 year compliance period.

Because the waste packages in the GCD boreholes are buried 21.3 m (70 ft) below ground surface, the risk of inadvertently digging into the waste is low. The waste is also below the rooting depth of native plants and the digging depth of native insects and mammals.

The Area 5 RWMS is situated in a remote alluvial basin in the Mojave Desert. The site conditions, including the thick, dry, sandy vadose zone separating the waste cells from the local aquifer; the thick volcanic aquitard further separating the waste deposits from the deep regional carbonate aquifer; and the arid climate provide an effective natural containment barrier. The rooting depths of native plants are relatively shallow and efficiently draw infiltrating water from the soil. The proposed final monolayer-ET cover takes advantage of these site conditions.

PA and CA models for the Area 5 RWMS included the effects of erosion, bioturbation, a cooler and wetter climate, and other factors in evaluating the effectiveness of containment. Transport models demonstrated there is insufficient vertical transport for contaminants to migrate from the GCD borehole waste containers to groundwater. The median travel time for water to reach groundwater under current conditions has been estimated to be 51,000 years (Shott et al., 1998).

Some types of engineered barriers could further reduce the risk of drilling and digging, and some types of barriers could also reduce infiltration of storm water and intrusions by burrowing animals and insects in near-surface cover fill, which would also help the performance of the containment system. However, because initial calculations and model results demonstrate that the natural contaminant barrier and proposed cover are sufficient to meet DOE performance objectives, any engineered barrier component would be an extra measure of protection. Furthermore, the incorporation of any additional engineered barrier features must be integrated with the cover design to ensure that the effectiveness of the cover and adjacent landfill cell covers is not significantly compromised.

Final consideration of alternative engineered barriers will be based on identification of the transport pathways with maximum release potential, as determined through the PA. These assessments require optimization of the closure-cover design. Current model results show extremely limited to no releases associated with the TRU inventory in the GCD boreholes. It is unlikely that added barriers will provide cost-effective reduction in releases. Therefore, the design of an engineered barrier would be to primarily address the procedural aspects of the barrier requirements of 40 CFR 191.

The regulations do not identify the criteria or process for engineered barrier selection and do not require technical analysis. For the Waste Isolation Pilot Plant, EPA proposed that DOE select barriers using cost-benefit analysis (EPA, 1995). Therefore, one approach is to assume that the best engineered barrier for closure of the GCD boreholes is the most cost-effective barrier that complies with 40 CFR 191.

Cost effectiveness of several engineered barrier alternatives was recently evaluated for shallow trench T04C (Shott et al., 2007). T04C is within 150 m (492 ft) of the GCD boreholes and has similar environmental and site conditions. Barriers that prevent or substantially delay upward transport and release of radionuclides to land surface by gaseous diffusion, liquid diffusion, liquid advection, bioturbation, and human intrusion were ranked for cost-effectiveness using an analytical hierarchy process and a multicriteria decisional analysis method. The performance of alternatives was evaluated against a 2.6-m (8.5-ft) operational cover without additional intrusion barriers using the 90^{th} and 99.9^{th} percentile of the normalized cumulative release and the member of public total effective dose equivalent at 10,000 years. The most likely exposure scenario was assumed to be a member of the public residing at the site boundary who commutes to work elsewhere and does not grow food at the residence. Hydrologic performance and reliability were other benefit criteria.

An increase in cover thickness from a 2.6-m (8.5-ft) operational cover to a 4-m (13-ft) final cover was included in several scenarios, for consistency with the current Disposal Authorization Statement. Cover thickness was the most important factor affecting cumulative release at the

90th percentile. At the 99.9th percentile, cover thickness was important for cumulative release but a highly effective intruder barrier seemed to add benefit if the cover is at least 4-m (13-ft) thick.

Cost factors included cost of construction, materials, and maintenance; worker safety; and compatibility with the cover plans for surrounding closure units. For T04C, the best cost-benefit ratio was obtained for the 4-m (13-ft) monolayer-ET cover. The second most cost-effective barrier was the 4-m (13-ft) monolayer-ET cover combined with a boulder mound surface intruder barrier. However all alternatives including a thinner monolayer-ET cover appear to meet the requirements of DOE Order 435.1 and 40 CFR 191.

Extrapolating from the T04C special analysis, the relative merits of barrier alternatives can be qualitatively evaluated for the GCD boreholes. Most of the waste containers in the GCD boreholes are already buried under 21.3 m (70 ft) of native alluvium. It is assumed that the incremental benefits of a thicker final cover are small compared to the performance of the existing 21.3 m (70 ft) of cover. The base case is a monolayer-ET cover, at least 1.3 m (4.25 ft) above the ground elevation, integrated with the existing operational cover on the low-level mixed waste unit (LLMWU). Table 1 qualitatively describes the relative benefits and costs of several barrier alternatives.

Table 1. Engineered Barriers Comparison

Alternative	Engineered Barrier Description (all barriers are above the 21.3-m (70 ft) native fill operational cover)	Relative Cost	Human Intrusion Reduction Benefit
1	Monolayer ET Cover (Contiguous with LLMWU Cover)	Lowest	Lowest
2	Asphalt Barrier (asphalt geotextile or geosynthetic clay liner above asphalt concrete layer)	Moderately high	Negligible
3	Capillary Break Layer	Moderate	Negligible
4	1.1 m (3.6 ft) Revegetation Layer over 9-m (30-ft) Waste Rubber Tire Layer	High	Fair
5	1.1 m (3.6 ft) Revegetation Layer over 9-m (30-ft) Bailing Wire Layer	High	Fair
6	1.1 m (3.6 ft) Revegetation Layer over 1.5 m (5 ft) Reinforced Concrete Layer	Highest	Good
7	Boulder Field on Monolayer Cover Contiguous with LLMWU ET Cover	Low	Good
8	3-m (10 ft) Boulder Wall Surrounding GCD Units on Monolayer ET Cover Contiguous with LLMWU ET Cover	Low	Good
9	Boulder Mounds on GCD Units on Monolayer Cover Contiguous with LLMWU ET Cover	Low	Best

This assessment assumes cumulative release is far more sensitive to human intrusions (e.g., drilling boreholes) than movement of radionuclides by bioturbation and water/vapor transport. Comparison of the cost of constructing and maintaining a barrier compared to the increased human-intrusion prevention benefits suggest a boulder mound over each GCD borehole may cost effectively marginally reduce the risk of drilling into the GCD wastes. The risk reduction is above and beyond the significant risk-reduction benefits of the remote site location, the lack of economically exploitable natural resources, the significant cost to develop groundwater, and institutional controls after closure of the GCD units.

The strategy for meeting the engineered barrier assurance requirement is being evaluated by NNSA/NSO in the context of the design and optimization of the closure cover. The details of any proposed engineered barrier will be incorporated in the Closure Plan for the GCD boreholes.

10.0 CONCLUSIONS

The measures outlined above fulfill five of the assurance requirements of 40 CFR 191.14 with respect to the GCD boreholes containing TRU:

- Passive institutional controls
- Active institutional controls
- Monitoring plan
- Economic resource assessment
- TRU waste retrieval plan

The effectiveness of the natural containment barriers was previously demonstrated through the PA process. The strategy for meeting the engineered barrier assurance requirement is being evaluated by NNSA/NSO in the context of the design and optimization of the closure cover. The incorporation of any additional engineered barrier features must be integrated with the cover design. PA/CA and special analysis data suggest a monolayer ET cover integrated with the final cover of the LLMWU will meet the assurance requirements for an engineered barrier. An additional surface structure such as a boulder mound may be considered for marginal intrusion prevention benefits, but is not necessary in order to comply with the assurance requirements.

11.0 REFERENCES

Bechtel Nevada, 2003. *Nevada Test Site, 2002 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site*. DOE/NV/11718--776. Las Vegas, NV. February 2003.

———, 2004. *NV/YMP Radiological Control Manual*. *Revision 5.* DOE/NV/11718--079 REV 5. Las Vegas, NV. November 2004.

———, 2005. *Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site*. DOE/NV/11718--449-REV 2. Las Vegas, NV. June 2005.

Black, P., K. Black, M. Hooten, L. Mathai, and D. Neptune, 2000. *Assessing the Probability of Inadvertent Human Intrusion at Nevada Test Site Radioactive Waste Management Sites*, Draft Final Report for DOE. Neptune and Company, Inc. March 2000.

BN, See Bechtel Nevada.

Case, C., J. Davis, R. French, and S. Raker, 1984. *Site Characterization in Connection with the Low-Level Defense Waste Management Site in Area 5 of the Nevada Test Site, Nye County, Nevada, Final Report.* Desert Research Institute, Publication No. 45034. Las Vegas, NV.

Castor, S. B., S. C. Feldman, and J. V. Tingley, 1990. *Mineral Evaluation of the Yucca Mountain Addition, Nye County, Nevada*. Nevada Bureau of Mines and Geology. Open File Report 90-4. Reno, NV.

Chu, Margaret S. Y. and E. A. Bernard, 1991. *Waste Inventory and Preliminary Source Term Model for the Greater Confinement Disposal Site at the Nevada Test Site*. Sandia National Laboratories, SAND91-0170. Albuquerque, NM, and Livermore, CA.

Cochran, J. R., W. E. Beyeller, D. A. Brosseau, L. H. Brush, T. J. Brown, B. Crowe, S. H. Conrad, P. A. Davis, T. Ehrhorn, T. Feeny, B. Fodelman, D. P. Gallegos, R. Haaker, E. Kalinina, L. L. Price, D. P. Thomas, and S. Wirth, 2001. *Compliance Assessment Document for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site*, Volume 2: Performance Assessment. Sandia National Laboratories Report. SAND2001-2977. September 2001.

CFRs, see Code of Federal Regulations

Code of Federal Regulations. Title 40, Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes." 2002

Code of Federal Regulations, Title 40 CFR Part 191: Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes; Final Rule." 1985.

Colarusso, A., B. Crowe, and J. Cochran, 2003. "Completion of the Transuranic Greater Confinement Disposal Borehole Performance Assessment for the Nevada Test Site." Presented at Waste Management WM'03 Conference, February 23-27, 2003, Tucson, AZ. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office; Los Alamos National Laboratory; and Sandia National Laboratories. February 2003.

DOE, see U.S. Department of Energy.

Federal Facility Agreement and Consent Order, 1996 (as amended) . Agreed to by the State of Nevada, U.S. Department of Energy, and U.S. Department of Defense, 1996. *Federal Facility Agreement and Consent Order*. May 10, 1996. Available at: http://empcs.nv.doe.gov/emis2/fa/pg/FFACO.pdf.[Accessed [Accessed April 12, 2007]

FFACO, see *Federal Facility Agreement and Consent Order.*

Fiore, J. J., and R. P. Berube, 2002. Memorandum from U.S. Department of Energy to C. P. Getz, NNSA/NSO Environmental Management. Subject: Compliance Assessment for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site. February 5, 2002.

Garside, I. J., R. H. Hess, K. L. Fleming, and B. S Weimer, 1988. *Oil and Gas Developments in Nevada*. Bulletin 104: Nevada Bureau of Mines and Geology, Reno NV.

National Security Technologies, LLC, 2006. *Nevada Test Site 2005 Waste Management Monitoring Report, Area 3 and Area 5 Radioactive Waste Management Sites*. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, DOE/NV/11718--1241, DOE/NV/25946--198. Las Vegas, NV. August 2006.

———, 2007. *Summary of Natural Resources that Potentially Influence Human Intrusion at the Area 5 Radioactive Waste Management Site, DOE/Nevada Test Site, Nye County, Nevada*. Raytheon Services Nevada, DOE/NV/25946--198. Las Vegas NV. June 2007.

NNSA/NSO, see U.S Department of Energy, National Nuclear Security Administration Nevada Site Office

NSTec, See National Security Technologies, LLC

Richard-Haggard, K., 1983. *Economic Potential of Alternative Land and Natural Resources Uses at the Nevada Test Site, Nye County, Nevada.* Desert Research Institute. Publication No. 45030. Las Vegas, NV.

SAIC, see Science Applications International Corporation.

Science Applications International Corporation/Desert Research Institute, 1991. Special Nevada Report, U.S. Air Force, Tactical Weapons Center, Office of Public Affairs, Nellis Air Force Base, Las Vegas, Nevada. September, 1991.

Shott, G. J., L. E. Barker, S. E. Rawlinson, M. J. Sully, and B. A. Moore, 1998. *Performance Assessment for the Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada (Rev. 2.1)*. Bechtel Nevada, DOE/NV/11718--176. Las Vegas, NV. January 1998.

Shott, G. J., V. Yucel, M. J. Sully, L. E. Barker, S. E. Rawlinson, and B. S. Moore, 2000. *Performance Assessment/Composite Analysis for the Area 3 RWMS at the NTS, Nye County, Nevada*, Revision 2.1. Bechtel Nevada, DOE/NV--491-REV 2.1. Las Vegas, NV. October 2000.

Shott, G. J., V. Yucel, and L. Desotell. 2007. Special Analysis of Transuranic Waste in Trench T04C at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye county, Nevada. National Security Technologies, LLC, DOE/NV/25946-283. Las Vegas, NV. September 2007.

———, 1996a. *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada*. DOE/EIS 0243. U.S. Department of Energy, Nevada Operations Office, Las Vegas, NV. August 1996.

U.S. Department of Energy, 1990. DOE Order 5400.5, "Radiation Protection of the Public and the Environment." Office of Environment, Safety and Health, Washington, D.C. February 1990.

———, 1996b. *Compliance Certification Application for the Waste Isolation Pilot Plant*. Submitted by U.S. Department of Energy to the U.S. Environmental Protection Agency, October 29, 1996.

———, 1996c. DOE P 430.1, "Land and Facility Use Planning." U.S. Department of Energy, Washington, D.C. July 9, 1996.

———, 1998a. *Accelerating Cleanup: Paths to Closure.*. U.S. Department of Energy, Office of Environmental Management, DOE/EM-0362. Washington, D.C. June 1998.

———, 1998b. *Accelerating Cleanup: Paths to Closure*. U.S. Department of Energy, Nevada Operations Office,DOE/NV-586. Las Vegas, NV. December 1998.

———, 1998c. *Nevada Test Site Resource Management Plan*. U.S. Department of Energy, Nevada Operations Office, DOE/NV--518. Las Vegas, NV. December 1998.

———, 1999b. *From Cleanup to Stewardship*, a Companion Report to *Accelerating Cleanup: Paths to Closure*. DOE/EM--0466. October 1999.

——— 2002. *Performance Management Plan*. U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office. Las Vegas, Nevada. August 2002.

———, 2003a. DOE Order 450.1, "Environmental Protection Program." U.S. Department of Energy, Washington, D.C. January 15, 2003.

———, 2003b. DOE Policy P 455.1, "Use of Risk-Based End States." U.S. Department of Energy, Washington, D.C. July 15, 2003.

———, 2006. *Nevada Test Site Environmental Management End State Vision*. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. DOE/NV--958. Las Vegas, NV. January 2006.

———, 2006. "Project Screening and Siting Approval Process." U.S Department of Energy, National Nuclear Security Administration Nevada Site Office. NNSA/NSO Local Directive NSO M412.X-2. Las Vegas, NV. May 16, 2006.

———, 2007. *Plan For Retrieval of Radioactive Packages from Trenches and Greater Confinement Disposal Boreholes at the Nevada Test Site Area 5 Radioactive Waste Management Site*. Revision 1. U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. DOE/NV--1190-REV1. Las Vegas, NV. February 2007.

Virta, Robert L., 2006. *2005 Minerals Yearbook, Zeolites*. U.S. Geological Survey. June 2006.