Office of Enterprise Assessments
Lessons Learned from Assessments of Low-Level Radioactive Waste Management and Disposal Practices at U.S. Department of Energy Facilities

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Office of Nuclear Safety and Environmental Assessments
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Acronyms

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EA	Office of Enterprise Assessments
EM	Office of Environmental Management
LFRG	Low-Level Waste Disposal Facility Federal Review Group
SME	Subject Matter Expert
WAC	Waste Acceptance Criteria

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) Office of Environment, Safety and Health Assessments, within the independent Office of Enterprise Assessments (EA), conducted assessments at five DOE nuclear sites between 2015 and 2017, as part of a DOE complex-wide evaluation of low-level radioactive waste management practices. The facilities are managed under the direction of the Office of Environmental Management (EM) and the National Nuclear Security Administration. The individual EA assessment results were analyzed to provide this lessons-learned report, which focuses on issues that affect multiple facilities and identifies areas of strengths and weaknesses with the goal of promoting organizational learning and improving performance.

The assessed facilities were operated in a manner that protects the health and safety of the workers, the environment, and members of the public. The performance assessments developed by the contractors for each disposal facility indicate that the projected doses to future members of the public and inadvertent intruders throughout the 1,000-year evaluation period will be significantly better than the performance objectives established by the Department.

EM is reviewing the current DOE radioactive waste management program directives that were first issued in 1999, with minor administrative changes since that time. The current directives include many prescriptive requirements that are not easily or practically implemented in the field. They also include obsolete references to other directives or interfaces with other regulatory requirements, thereby leaving some incongruities.

This lessons-learned report identifies recommendations for consideration by DOE Office of Environmental Management policy makers and line management for all low-level waste disposal activities in the DOE complex. Recommendations are: EM should consider additional guidance for composite analysis to enhance its use as a land planning and resource allocation tool; EM should evaluate the adequacy of existing guidance for waste form stabilization as it relates to long-term active maintenance to address subsidence; DOE site offices should consider conducting periodic, technical re-baseline reviews of the underlying assumptions and modeling used in the performance assessments; and DOE contractors should consider improvement actions for these lessons learned as applicable to their specific waste operations.

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Enterprise Assessments (EA) carries out the Department's independent oversight program, which is designed to enhance DOE safety and security programs by performing independent assessments of the adequacy of DOE policy and requirements and the effectiveness of DOE and contractor line management in safety, security, and other critical functions. The program is described in and governed by DOE Order 227.1A, *Independent Oversight Program*, as well as a comprehensive set of internal protocols and criteria and review approach documents.

The EA Office of Nuclear Safety and Environmental Assessments conducted five independent assessments as part of a DOE complex-wide set of targeted assessments of low-level radioactive waste management practices, including disposal facility operations and waste generator and processor operations. These assessments, performed between May 2015 and December 2017, evaluated performance related to these facilities. EA also assessed how well the associated contractors, local DOE offices, and DOE Headquarters program offices implemented the requirements of DOE Order 435.1, Change 1, *Radioactive Waste Management*, and the additional invoked requirements of DOE Manual 435.1-1, *Radioactive Waste Management Manual*. Observations concerning implementation are intended for consideration during the DOE Office of Environmental Management's (EM) planned updates of these directives.

1.1 Background

EA conducts the Department's independent oversight activities, which are designed to provide the Secretary and Deputy Secretary of Energy, Under Secretaries of Energy, other DOE managers, senior contractor managers, Congress, and other stakeholders with an independent evaluation of the performance and risk management in safety, security, and other critical functions as directed by the Secretary of Energy.

DOE Order 435.1, by reference to DOE Manual 435.1-1, assigns responsibility to the Assistant Secretary for Environment, Safety and Health to conduct independent appraisals and audits of DOE waste management programs (DOE Manual 435.1-1, Section I.2.C); those responsibilities now reside with EA as a result of organizational changes subsequent to the promulgation of these directives. DOE Manual 435.1-1 includes prescriptive requirements for managing radioactive waste. The DOE Office of Environmental Management (EM) is currently evaluating both documents for revision. EM issued technical standard DOE-STD-5002-2017, *Disposal Authorization Statement and Tank Closure Documentation*, dated July 20, 2017, with updated guidance in preparation for updating DOE Order 435.1.

1.2 Requirements and Guidance

EA's radioactive waste management assessments were based on the requirements of DOE Order 435.1, which provides the high-level regulatory requirements and responsibilities for radioactive waste management. The order invokes DOE Manual 435.1-1 as a primary requirements document intended to protect against exposures to radioactive and hazardous wastes, and addresses the short-term hazards for current workers, members of the public, and the environment, as well as the long-term hazards to future

potential receptors. DOE Guide 435.1-1, *Implementation Guide for Use with DOE M 435.1-1,* provides additional information, along with acceptable methods and approaches for meeting the requirements of DOE Manual 435.1-1. These directives include requirements for high-level wastes, transuranic wastes, and low-level wastes. The five EA assessments analyzed here focused principally on low-level wastes, which are addressed primarily in Chapter IV (Low-Level Waste Requirements) of the manual.

1.3 Scope and Methodology

This report analyzes EA's overall observations and conclusions from five independent assessments of field implementation of low-level radioactive waste management and disposal practices. EA supplemented these observations with review of data in the DOE Occurrence Reporting and Processing System to determine whether the themes that EA identified during these assessments were consistent with other data from around the DOE complex. This report also describes EA's observations of DOE line oversight and evaluations of the effectiveness of current DOE policy and directives as implemented in the field. Finally, this report identifies recommendations pertaining to contractors' field implementation of low-level radioactive waste management practices, DOE site office and Headquarters line management oversight practices, and DOE policy and directives initiatives.

Table 1 lists the facilities and associated contractors, program offices, and field elements that EA assessed within the timeframe of this report.

The evaluation criteria for the targeted assessments were based on applicable sections of DOE Manual 435.1-1. The objectives, criteria, and lines of inquiry for these assessments were drawn from the following sections of EA Criteria and Review Approach Document 31-11, *Low-Level Radioactive Waste Management*:

- 4.1 Radioactive Waste Management Planning and Generic Safety Requirements
- 4.2 Radioactive Waste Identification, Characterization, and Monitoring
- 4.7 Waste Disposal
  - 4.7.1 Disposal Facility Siting and Approval
  - 4.7.2 Disposal Facility Design and Operations
  - 4.7.3 Facility Closure and Post-Closure Surveillance and Maintenance.

The remainder of this report is organized into the following sections:

- Section 2 provides an overall analysis of the results of the radioactive waste management assessments.
- Section 3 describes recommendations for consideration as potential improvements at all sites that handle radioactive wastes.
- Appendix A provides supplemental information on the organization and team members contributing to the assessment.
- Appendix B lists the EA reports used as source documents for this lessons-learned report.

The assessments that provided the basis for this report were conducted at eight facilities on the five sites listed in the table below:

Table 1. Sites, Facilities, and Contractors Assessed

Assessment Site	Facilities Assessed	Contractor	DOE Headquarters Program Office	DOE Field Element
Portsmouth Gaseous Diffusion Plant	Buildings X-326, X-705, X-744G, X-700, X-720, X-847	Fluor-B&W Portsmouth, LLC	Office of Environmental Management	Portsmouth/Paducah Project Office
Savannah River Site	Saltstone Disposal Facility	Savannah River Remediation	Office of Environmental Management	Savannah River Operations Office
Savannah River Site	Area E Low Level Waste Facility	Savannah River Nuclear Solutions, LLC	Office of Environmental Management	Savannah River Operations Office
Nevada National Security Site	Area 3 Radioactive Waste Management Facilities	National Security Technologies, LLC and Navarro, Inc. *	National Nuclear Security Administration	Nevada Field Office
Nevada National Security Site	Area 5 Radioactive Waste Management Facilities	National Security Technologies, LLC and Navarro, Inc. *	National Nuclear Security Administration	Nevada Field Office
Idaho Site	Idaho CERCLA ** Disposal Facility And the Radioactive Waste Management Complex Active Low-Level Waste Disposal Facility	Fluor Idaho, LLC	Office of Environmental Management	Idaho Operations Office
Idaho Site	Remote Handled Low-Level Waste Disposal Facility	Fluor Idaho, LLC	Office of Environmental Management	Idaho Operations Office
Hanford Site	Environmental Restoration Disposal Facility and 200 East and West Low Level Burial Grounds	CH2M-Hill Plateau Remediation Company	Office of Environmental Management	Richland Operations Office

* Subsequent to the EA review, Mission Support and Test Services, LLC replaced National Security Technologies, LLC as the prime contractor in December 2017

** CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

2.0 OVERALL ASSESSMENT

2.1 General Low-Level Radioactive Waste Management Requirements

DOE Order 435.1 and the associated DOE Manual 435.1-1 outline strategic planning and evaluation requirements for radioactive waste management. These requirements include: life cycle management from generation to disposal; evaluation of environmental impact and conformance with Federal, state, and local environmental regulations; siting and operations of facilities to ensure protection of workers, the public, and the environment; and measurement and analysis of performance indicators.

EM, through the Assistant Secretary for Environmental Management, is responsible for directives management and updates of DOE Order 435.1, DOE Manual 435.1-1, and the associated guide. The current DOE radioactive waste management program directives were first issued in 1999, with minor administrative changes since that time. They include many prescriptive requirements that are not easily or practically implemented in the field. They also include obsolete references to other directives or interfaces with other regulatory requirements, thereby leaving some incongruities. EM policy makers have recognized the need to update the existing directives and guidance. EM recently issued a new technical standard, DOE-STD-5002-2017 *Disposal Authorization Statement and Tank Closure Documentation*, as an initial step toward addressing inconsistencies in the current guidance. Additional work is under way to understand all the challenges, clarify the expectations, and revise the directives.

Strengths:

- The DOE order and manual establish performance objectives that require keeping the doses and risks from current operations, as well as the projected doses and risks to future members of the public and the environment, within accepted safe limits. All assessed disposal facilities satisfied these performance objectives and operated in a manner that protects the current workers, the public, and the environment from undue hazards.
- The assessed sites had effectively implemented the common cross-cutting functional areas required by DOE Manual 435.1-1 (e.g., training and qualification of personnel, quality assurance, integrated safety management, emergency preparedness, and records management) through application of existing site wide institutional programs governing these areas to ensure the protection of workers.
- All observed sites effectively used software and/or web-based waste characterization and tracking systems to manage the vast amounts of data needed to manage waste operations.
- All assessed disposal facilities had implemented environmental monitoring programs and provided annual summary reports, including analysis of the performance indicators.

Weaknesses:

- While records management and data tracking systems are used effectively for ongoing operations at all assessed sites, some facilities' records archiving protocols reference the National Archives and Records Administration Records Schedule Guidelines for records retention. Implementation of these guidelines at some sites allows many operational records to be designated for destruction after 75 years. However, required post-closure active monitoring and maintenance periods for the disposal facilities extend for 100 years or longer. Destroying records before the end of the active monitoring and maintenance period could adversely affect maintenance or remediation decisions in the later portion of that period.
- The current directives include references that are obsolete or unclear with respect to overlapping expectations, responsibilities, and authorities, such as those related to the Comprehensive Environmental Response, Compensation, and Liability Act.

2.2 Work Planning and Control and Worker Safety

DOE Manual 435.1-1 incorporates by reference the worker safety and health requirements of DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, which was superseded by DOE Order 440.1B Chg. 2, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*; 10 CFR Part 835, *Occupational Radiation Protection*; and DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (archived).

EA observed application of work planning and control processes at all of the assessed facilities. The most prevalent worker safety hazards associated with waste disposal activities are non-radiological hazards related to industrial safety, including use of heavy equipment, forklifts, cranes, and hoists, as well as rugged terrain. The most common radiological hazards for routine operations at disposal facilities and post-packaging generator facilities result from external radiation fields, which are adequately addressed in the routine radiological work permits and controls implemented at the assessed sites.

Strengths:

- At all assessed facilities, routine industrial hazards associated with normal handling of radioactive waste packages were properly analyzed and controlled through use of site level work planning and control processes.
- All assessed facilities effectively communicated and implemented industrial and radiological controls for routine and expected conditions for most observed activities.
- All observed waste handling activities were monitored and well supported by active radiation control technician coverage.

Weaknesses:

- For three of the assessed facilities, overly-broad standing radiological work permits covered a wide range of operating conditions, potentially resulting in confusion regarding the applicable control sets. In some cases, detection, monitoring, and response plans for off-normal conditions were not tailored to the hazards or specific source terms. These weaknesses could delay the recognition of hazards during unexpected off-normal conditions, such as a leaking or breached waste container, and could increase the risks to workers.
- For three of the assessed disposal facilities, the observed practices for monitoring and clearance of personnel and equipment following waste operations were not sufficiently implemented to ensure detection and control of potential contamination, uptakes, or off-normal conditions.

2.3 Support Facility, Generator Processing, and Disposal Cell Design and Operations

DOE Manual 435.1-1 identifies specific siting and design criteria for waste disposal facilities. These include waste confinement, ventilation as necessary to prevent buildup of gases to potential flammable or explosive concentrations or pressures, stability to minimize the need for long-term active maintenance, and control of rain water runoff during and after waste disposal. Additional criteria are provided for generator facilities engaged in processing, packaging, storing, and general handling or transportation of wastes. Requirements address monitoring, containment, inspection, and inventory management, as well as limitations on the length of time for storage prior to transfer.

Strengths:

- The assessed active disposal facilities were appropriately sited and designed for placement and long-term isolation of the received wastes. Many included CERCLA-compliant engineered liner systems and water management leachate collection and processing systems.
- Many of the assessed facilities, such as Nevada National Security Site, were sited such that the natural environment (e.g., limited precipitation, distance to surface or groundwater, and soil types) enhances the long-term performance of the facility.
- Most assessed facilities had appropriately designed, installed, and operated environmental monitoring systems. The Hanford Site has a site wide groundwater monitoring process that is well integrated to address all of the various regulatory compliance and performance assessment needs. In addition, the Savannah River Site Saltstone facility's sample analysis practices comprehensively address the significant analytes and potential dose contributors that impact the performance assessment.

Weaknesses:

- Waste generator facilities that transition from operational missions to the processes of decontamination and decommissioning often do not have installed containment, ventilation, fire suppression, and radiological monitoring systems engineered for new mission activities, such as dismantling of previously-sealed process equipment, and inspection, volume reduction, stabilization, and repackaging of legacy wastes. In some cases, the absence of these systems/equipment has resulted in localized facility and personnel contamination and increases risks to the collocated workers and the environment.
- Some waste generator facilities do not have installed systems or equipment to safely compact or remove/fill void space and stabilize wastes shipped for disposal. Disposal facilities do not have installed capabilities to assess the level of void space or long-term waste form stability to ensure conformance to the waste acceptance criteria (WAC) and directive requirements. Un-stabilized waste contributes to long-term subsidence challenges and diminishes the long-term stability of the disposal facilities.
- Only two of the assessed disposal facilities had installed capabilities for radiological clearance of personnel or equipment following operations in the disposal areas, resulting in dependence on less-reliable field frisking and counting capabilities.

2.4 Waste Characterization and WAC Certification and Verification

DOE Manual 435.1-1 requires low-level waste to be characterized using direct or indirect methods and the characterization to be documented in sufficient detail to ensure safe management and compliance with the waste acceptance requirements of the facility receiving the waste. The characterization is to address physical and chemical characteristics, radionuclide activities and concentrations, and any other information needed to maintain disposal facility performance. Further, the manual requires generators of waste to certify that the waste conforms to the disposal facility's WAC prior to shipment. Additionally, the receiving facility is required to authorize the shipment and evaluate the waste for acceptance to confirm that technical and administrative requirements have been met.

Strengths:

- The assessed disposal facilities had all implemented effective review and acceptance processes to ensure that proposed waste stream profiles from the generators conform to the disposal facility's WAC.
- All the assessed waste generators had established policies, procedures, and practices to characterize wastes streams, visually inspect waste containers during packaging, and perform quality assurance on package assay measurements to ensure waste profile conformance and support WAC certification prior to shipment to the disposal facilities.

- All assessed disposal facilities had established processes to audit generator characterization and WAC certification processes. Some of these audit practices were well developed, staffed and supported by knowledgeable and experienced subject matter expert (SME) auditors, and observed to be thorough and effective.
- All assessed sites made effective use of software and/or web-based waste characterization and tracking systems. Waste management programs inherently have a significant need for information technology support to manage the vast amounts of data generated by waste operations. Records management systems are needed to track and evaluate many parameters, such as waste stream identification, waste packaging, physical contents, weights, radionuclide content, disposal facility WAC, and location. These electronic tools are used effectively to track all waste through the characterization, storage, processing treatment, shipment, and disposal processes.

Weaknesses:

- Three generator waste characterization procedures exhibited vulnerabilities in measurements for specific analytes and in application of specific dose-to-curie modeling methods. These shortcomings could allow the activities or isotopic compositions of the wastes to exceed WAC limitations. Specifically, some relied on historical knowledge scaling factors or geometric modeling that were subject to uncertainties, potentially resulting in underestimation of the activity of certain isotopes in the waste.
- Two disposal facility-managed generator audit processes lacked sufficiently documented performance-based evaluations to effectively verify the adequacy of the generator's characterization and WAC certification practices.

2.5 Performance Assessments, Composite Analysis, and Environmental Monitoring Plans

EA assessed the long-term projections of doses to the public and the environment for facilities at four DOE sites. The projected total effective dose equivalents to a member of the public over the 1000 year evaluation period were significantly lower than the performance objective of 25 millirem in any year. The relevant elements required by DOE Manual 435.1-1 that contribute to the outcome of those projections include performance assessments, the composite analysis, and environmental monitoring, as well as closure plans (see Section 2.6). The annual reports on current environmental monitoring results and disposal cell inventories are integral to validating the adequacy of the projected performance modeling calculations and the planned and engineered closure designs.

Performance Assessments

DOE Manual 435.1-1 defines the performance assessment as "an analysis of a radioactive waste disposal facility conducted to demonstrate there is a reasonable expectation that performance objectives established for the long-term protection of the public and the environment will not be exceeded following closure of the facility." The manual further describes the specific dose objectives, receptor locations for points of compliance, evaluation periods for the performance, acceptable dose conversion factors, and institutional control periods for preventing inadvertent intrusion into the disposal site. The manual also requires maintenance of the performance assessments, along with annual summaries evaluating the continued adequacy of the performance assessments. The manual requires the maintenance plan to include the conduct of research, field studies, and monitoring needed to address uncertainties or gaps in existing data.

Strengths:

- Each of the performance assessments for the assessed disposal sites indicates that the performance objectives will be satisfied and that the projected dose to the receptors over the 1,000-year evaluation period mandated by DOE Manual 435.1-1 will be significantly lower than the dose limits.
- All assessed facilities have appropriately provided annual summaries for review by the Low-Level Waste Disposal Facility Federal Review Group (LFRG). All reviewed summaries indicated the continued adequacy of the basic determinations of the performance assessments, projecting doses well below the limits of performance objectives throughout the evaluation period of 1,000 years.
- Most of the assessed facilities have implemented significant testing and evaluation practices as part of the performance assessment maintenance plans to validate and inform the assumptions and modeling parameters used in the performance assessments. The Idaho Site in particular uses an annual one-to-one comparison of environmental monitoring trending data with the near term modeling projections to help validate the model assumptions and conclusions.

Weaknesses:

- Some of the older performance assessments need revision and updating. Some were based on computational modeling systems, parameters, and assumptions that were appropriate when they were developed. Since then, further monitoring results, testing performed as part of the maintenance plans, and enhanced modeling tool development (both for waste constituent transport in the environment and for uptake pathway dose modeling) indicate that these older assessments need updating to provide more accurate and supportable projections of long-term facility performance and ensure that the modeling continues to be consistent with the results of the environmental monitoring programs.

Composite Analysis

DOE Manual 435.1-1 defines the composite analysis as "an analysis that accounts for all sources of radioactive material that may contribute to the long-term dose projected to a hypothetical member of the public from an active or planned low-level waste disposal facility. The analysis is a planning tool intended to provide a reasonable expectation that current low-level waste disposal activities will not result in the need for future corrective or remedial actions to ensure protection of the public and the environment." While the composite analysis uses the same 1,000-year evaluation period as the performance assessment, unlike the performance assessment it does not specify a receptor evaluation location or address inadvertent intruder doses, since the location of the superposition of various interacting residual source terms may vary. Instead, the composite analysis is used to evaluate projected doses to a hypothetical future member of the public and serves as a planning tool to assist in remediation and land use decisions, considering the potential influence and superposition of other residual site source terms that could interact with the source terms from the disposal facilities.

Strengths:

- All assessed sites had developed composite analyses that adequately evaluated projected doses to the hypothetical representative members of the public to be significantly below the performance objectives throughout the evaluation periods.
- Most assessed sites effectively used the composite analysis as a planning tool to drive remediation activities and decisions for future site land release and institutional boundary controls.
- One site was actively involved in methodically planning updates to the composite analysis based on revised remediation decisions, new characterization of residual source terms and migration paths, and updated transport modeling capabilities.

- All sites effectively used the CAs to evaluate boundaries and assure long term DOE control of property for the safety of the public.

Weaknesses:

- EA identified no common weaknesses in this area among the DOE facilities in this report.

Environmental Monitoring

DOE Manual 435.1-1 requires that all disposal facilities have a monitoring program with the following attributes:

- The site-specific performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.
- 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 that may affect long-term performance.
- 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.

Strengths:

- Most assessed disposal facilities had adequately implemented environmental monitoring programs. For most facilities, the performance assessments indicated that groundwater was the most significant transportation pathway for receptor dose. Therefore, the primary emphasis was on sampling groundwater surrounding the facilities.
- All assessed facilities incorporated monitoring information in the annual summary reports certifying the continued adequacy of the performance assessments.
- Most assessed facilities analyzed the samples for a complete range of important isotopes and chemical analytes based on the source terms and constituents of the wastes. The Savannah River Site Saltstone facility implements a comprehensive facility environmental monitoring system that incorporates a wide range of analytes and analysis processes.
- Most assessed sites effectively analyzed the data and compared trends to modeling projections to inform and validate the assumptions and parameters used in the performance assessment. The Savannah River Site Saltstone facility performs a variety of bench-level waste matrix tests and soil column tests to validate the parameters and assumptions used in modeling. Similarly, the Nevada National Security Site facilities conduct a variety of tests on water transpiration rates and plant coverage systems to study the model parameters for long-term performance.
- The Hanford Site efficiently integrated the facility monitoring/sampling and analysis programs with plume pump and treat remediation/measurement systems, ensuring an integrated site wide monitoring, analysis, and modeling program.

Weaknesses:

- Environmental monitoring at some facilities was not sufficient to support evaluation of the performance of the disposal cells. These included inadequate sample locations to cover the plume distribution pathways and inadequate selection of analytes to evaluate the potential source term migration. For example:
  - Lysimeters are used at many facilities for localized sampling near the disposal cell liners; however, the collection range does not provide adequate coverage to satisfy all the monitoring program requirements without additional sampling points, which were not available or used at some facilities. As an example, one facility used limited placement of lysimeter sampling locations in an effort to separate the disposal facility signals from the signals from known residual plumes from other nearby pre-existing facilities. However, this

approach limited coverage of the facility, reducing the ability of sampling to detect potential leakage from the trenches in downgradient locations.

- Two of the assessed facilities limited the monitoring sample analysis only to tritium on the assumption that it would be the most mobile of the isotopes. However, in one case tritium was not a significant constituent of the source term and dose from many of the disposed-of waste packages, so it did not provide a sufficient indication to evaluate releases and detect changing trends in facility performance. In another facility, which is located in a dry environment, the evapotranspiration model for tritium migration was not analogous to the transportation mode for other pertinent non-evaporating isotopes, so it provided only part of the analysis necessary to validate facility performance and inform the modeling parameters.
- Use of deep well sampling as the sole means of performance monitoring at some locations was also identified as a weakness, since modeling indicated that most precipitation would evaporate before it reached the water table in the area of those disposal facilities. In that and similar arid environments, isotopes that do not evaporate would migrate in localized wetting fronts with each precipitation event, but no monitoring capability was in place to evaluate that potential migration. Additionally, active monitoring was not performed to validate modeling assumptions regarding the moisture density or water motion in the intervening levels above deep well aquifers.

2.6 Closure Plans and Disposal Facility Long-Term Stability

A fundamental concept in managing long-term waste disposal is to minimize the potential for and slow the processes by which the waste material will migrate into areas that are accessible to humans or animal life in a manner or concentration that could pose a biological risk or cause harm. One way to achieve this goal is to ensure that the disposal facilities and migration barriers maintain structural integrity and stability long after the waste is placed for final disposal. DOE Manual 435.1-1, Chapter IV contains multiple requirements intended to ensure long-term stability of the disposal cells to minimize the costs of active long-term maintenance or the need for future remediation, thus protecting the long-term integrity of migration barriers and minimizing the influx of water that serves as the primary means for migration.

Strengths:

- Four of the assessed facilities use containment structures and component or package grouting to ensure the long-term structural stability of the disposal cells and minimize or delay the potential for subsidence or animal and plant penetration into the waste matrix. These facilities include some vault areas of the Savannah River Site E Area, the Savannah River Site Saltstone disposal units, the remote-handled low-level radioactive waste vaults at the Idaho Site Radioactive Waste Management Complex, and component and package grouting at the Hanford Environmental Restoration Disposal Facility.
- Many of the assessed facilities incorporate synthetic liners and engineered drainage systems to minimize exposure of the wastes to water.
- Many of the assessed facilities are sited in locations with minimal annual precipitation and significant distances between the waste trenches and groundwater aquifers, minimizing the potential media for migration of the wastes.
- Some facilities are located in alluvial areas where natural processes will continue to add soils as coverage over any subsidence or degradation in the caps.

Weaknesses:

- Due to the immediate hazards, the lack of engineered processing capabilities at the generator facilities, and potential costs, some wastes have been packaged, shipped, and accepted for disposal with significant void space. Over time, these components and packages will corrode and lose structural integrity. In three active disposal facilities, analysis indicated that those conditions

would result in significant subsidence and a need for long-term maintenance, repair, or remediation of the disposal cell closure caps. Sites with such analyzed conditions plan to delay application of the final closure cap until near the end of the monitoring and institutional control periods. Some analyses indicated that the subsidence process would continue well after the established institutional control and active monitoring periods. Additionally, legacy disposal cells at one site are currently exhibiting subsidence due to past disposal of un-stabilized high void space wastes and are restricted from vehicular or pedestrian traffic. Additional remediation will be required. Performance degradation and migration of wastes due to un-remediated subsidence and ponding have been well documented at other waste industry disposal facilities.

2.7 DOE Oversight

DOE Order 435.1, which invokes DOE Manual 435.1-1 as the primary requirements document, provides specific requirements for DOE oversight of radioactive waste management, in addition to the more general oversight requirements of DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*.

DOE Manual 435.1-1 delegates responsibilities for issuance of Disposal Authorization Statements and for review and approval of performance assessments, composite analyses, and appropriate CERCLA documentation to the EM Deputy Assistant Secretaries for Waste Management and Environmental Restoration. To assist with those responsibilities and the review of the annual summaries, the Deputy Assistant Secretaries rely on the LFRG as an advisory panel consisting of EM Headquarters Federal SMEs and site office representatives. While some aspects of radioactive waste management basis reviews and daily operational oversight are delegated to the field elements, substantial aspects of disposal facility review and approval are assigned to EM Headquarters management and implemented through the LFRG's review, advice, and recommendations.

Strengths:

- The LFRG has updated the execution plan and improved scheduling and participation in LFRG oversight assessments and annual summary reviews. LFRG leadership currently consists of two co-chairs, one from the EM Office of Regulatory Compliance (EM-4.31) and one from the EM Office of Waste Management (EM-4.22). In recent years, there have been significant leadership and personnel changes and reorganizations within the LFRG. The current leadership, with the support of their management, have rejuvenated active LFRG review and oversight activities.
- All assessed sites with disposal facilities appropriately generated, reviewed, and submitted the annual summaries to the LFRG in a timely manner and were responsive to and supportive of LFRG reviews. The LFRG recently initiated improvements in the review process and modified the format of the annual summaries to be consistent with the newly issued technical standard, DOE-STD-5002-2017, to ensure consistency in the review process.
- All assessed site offices had knowledgeable, experienced, and engaged radioactive waste management SMEs who typically serve as the site representatives to the LFRG.
- All assessed disposal facilities had Facility Representatives engaged with daily facility oversight, including waste disposal activities. Some sites were aware of the need for succession planning and engaged in training of junior staff.

Weaknesses:

- A comprehensive DOE-wide analysis has not been performed comparing the near-term local waste generator project costs and hazards for void space elimination to the long-term disposal site or DOE complex-wide liabilities for disposal cell subsidence. Some project-specific waste generation and packaging practices include un-stabilized wastes with significant void space or compressibility. In many cases, further waste stabilization and void space elimination is not

considered to be practical or technically justifiable based on near-term hazards or project costs at the waste generator facilities. On a case-by-case basis, many of the disposal facilities accept these generator waste profiles. However, high void space and waste compressibility are known to contribute to a long-term need for disposal facility maintenance, and delay cap and closure activities. These challenges are recognized in the DOE reviewed and approved disposal facility performance assessments. Several sections of DOE Manual 435.1-1 reference the need for long-term stability and prompt closure of the disposal facilities. For example, DOE Manual 435.1-1 Section VI G, *Waste Acceptance*, (1)(d)1 states "Low-level waste must contribute to and not detract from achieving long-term stability of the facility, minimizing the need for long-term active maintenance, minimizing subsidence, and minimizing contact of water with waste. Void spaces within the waste and, if containers are used, between the waste and its container shall be reduced to the extent practical." Disposal of high void space and compressible waste streams has been determined to be most practical based on near-term hazards or project costs at the waste generator facilities without evaluation and comparison to long term costs and hazards at the disposal facilities.

3.0 RECOMMENDATIONS

The recommendations presented below are based on lessons learned during the EA assessments and related analyses of low-level radioactive waste management discussed in this report. While the underlying issues do not necessarily apply to all the assessed sites, the recommendations provide additional insights into potential improvements at all sites that handle radioactive wastes. Consequently, DOE organizations should evaluate the applicability of the following recommendations to their operations and consider using them as appropriate to improve contractor oversight and low-level radioactive waste management.

DOE Office of Environmental Management

- Continue with efforts to review and update the current directives.
- Consider clarifying the intent of the composite analysis requirement with respect to plausible loss of institutional boundary controls over time and the potential for onsite receptor locations impacted by superposition of multiple source terms.
- Consider providing formalized guidance for acceptable composite analysis points of compliance and appropriate sensitivity analyses on composite analysis assumptions concerning site boundary control to enhance the utility of the composite analysis as a land use planning and resource allocation tool.
- Consider performing an evaluation of the risks, hazards, and costs to current and future workers, members of the public, and the environment for pre-disposal stabilization and void space reduction in comparison to the risks, hazards, and costs of long-term maintenance and remediation at the disposal facilities. The evaluation should consider DOE complex-wide long-term liabilities in contrast to local immediate project costs. Based on the results of that evaluation, consider modifying DOE Manual 435.1-1 requirements and guidance for waste form stabilization.

Site Offices

- As applicable to the risks of the waste operations being conducted and in coordination with LFRG technical teams, consider conducting periodic, technical re-baseline reviews of the underlying assumptions and modeling used in the performance assessments to ensure that the modeling assumptions and parameters continue to be supported and are validated by the available monitoring data. This enhanced effort could be integrated with the current annual summary report processes.

Contractors

- Site offices should encourage contractors to consider improvement actions as applicable to the risks of the waste operations being conducted for each of the following lessons-learned areas (see the individual reports identified in Appendix B as needed for further detail):
  - To tailor controls to hazards for higher source-term packages, consider incorporating package source term-specific emergency hazard evaluations into work planning and control processes to ensure an adequate means of detecting and responding to off-normal conditions or breaches that could result in release of dispersible powders or aerosols or other contaminants from the waste containers.
  - For higher source-term radiological conditions, consider implementing additional radiological controls for contamination during trench work and for clearance of equipment and personnel leaving the waste placement or waste handling areas to ensure detection of off-normal conditions, such as a container breach, and to prevent migration of material out of the facility.
  - At waste generators and facilities undergoing decontamination and decommissioning where facility engineered safety systems and hazard controls have been dismantled and previously-sealed process systems are being opened, and based on the potential for radiological contamination, consider establishing areas and/or acquiring equipment for localized engineering controls in support of waste inspection, waste form stabilization, and packaging. Such control systems include confinement, filtered ventilation, safety and health monitoring, and fire suppression.
  - Consider ensuring that records documenting waste disposal are retained throughout the institutional control and post-closure monitoring periods (longer than 75 years). Records documenting the physical, chemical, and radiological characteristics of the waste and the certification of that information may be needed to assist activities throughout the entirety of these periods.
  - Consider reviewing the environmental monitoring programs and performance assessment models to ensure that the placement of sampling locations and the measured analytes are effective for evaluating facility performance; validating or testing assumptions and parameters in the performance assessment models; and ensuring that monitoring results are consistent with the model predictions.

Appendix A
Supplemental Information

Office of Enterprise Assessments Management

William A. Eckroade, Acting Director, Office of Enterprise Assessments
Thomas R. Staker, Director, Office of Environment, Safety and Health Assessments
William E. Miller, Deputy Director, Office of Environment, Safety and Health Assessments
C.E. (Gene) Carpenter, Jr., Director, Office of Nuclear Safety and Environmental Assessments
Kevin G. Kilp, Director, Office of Worker Safety and Health Assessments
Gerald M. McAteer, Director, Office of Emergency Management Assessments

Quality Review Board

John S. Boulden III
Steven C. Simonson
Michael A. Kilpatrick

Office of Enterprise Assessments Report Contributors

Preparer
Timothy F. Mengers

Additional Contributors
Aleem E. Boatright
Ronald G. Bostic
Joseph Lischinsky
Thomas G. Naymik
Rosemary B. Reeves
Jeff Snook
Mario A. Vigliani

Appendix B
Source Documents

Office of Enterprise Assessments Review of Radioactive Waste Management at the Portsmouth Gaseous Diffusion Plant – December 2015

Office of Enterprise Assessments Assessment of Savannah River Site Radioactive Waste Disposal Facilities – September 2016

Office of Enterprise Assessments Assessment of Low-Level Radioactive Waste Management and Disposal at the Idaho Site – January 2017

Office of Enterprise Assessments Assessment of Nevada National Security Site Radioactive Waste Disposal Facilities – January 2017

Office of Enterprise Assessments Assessment of Low-Level Radioactive Waste Disposal Practices at the Hanford Site – February 2018