U.S. DEPARTMENT OF ENERGY

Evaluation of Potential Opportunities to Classify Certain Defense Nuclear Waste from Reprocessing as Other than High-Level Radioactive Waste

Report to Congress
December 2020

United States Department of Energy
Washington, DC 20585

Message from the Secretary

The Department of Energy (DOE or Department) is providing this Report pursuant to Section 3139 of the National Defense Authorization Act for Fiscal Year 2018. While the Report reflects DOE's best efforts given existing data, the Report is necessarily preliminary in nature and is intended to serve informational purposes only. In issuing the Report, DOE is not proposing or taking any specific actions – nor is DOE committing to propose or take any specific actions – with respect to the inventory of reprocessing wastes that the Department manages. Rather, the Report identifies potential opportunities for DOE to reduce risk to public health and the environment while completing its cleanup mission more efficiently and effectively. DOE would conduct further data gathering, analysis, and engagement with stakeholders before taking action on any of these potential opportunities.

The Nuclear Waste Policy Act of 1982, as amended, made DOE responsible for the United States spent nuclear fuel and high-level radioactive waste, and DOE remains committed to fulfilling the Federal Government's legal and moral obligations to properly manage and dispose of that material. The Fiscal Year 2021 Budget does not provide funding to advance the Yucca Mountain Project. The Budget supports the development of a durable, predictable yet flexible plan that addresses more efficiently storing waste temporarily in the near term, followed by permanent disposal, and the Administration will establish an interagency working group to develop this plan in consultation with States.

DOE looks forward to continued engagement with Congress and other stakeholders on the issues and information covered in the Report.

This Report is being provided to the following members of Congress:

- **The Honorable James Inhofe**
  Chairman, Senate Armed Services Committee

- **The Honorable Jack Reed**
  Ranking Member, Senate Armed Services Committee

- **The Honorable Adam Smith**
  Chairman, House Armed Services Committee

- **The Honorable Mac Thornberry**
  Ranking Member, House Armed Services Committee

- **The Honorable Frank Pallone, Jr.**
  Chairman, House Energy and Commerce Committee

- **The Honorable Greg Walden**
  Ranking Member, House Energy and Commerce Committee

- **The Honorable Lisa Murkowski**
  Chairman, Senate Energy and Natural Resources Committee

- **The Honorable Joe Manchin**
  Ranking Member, Senate Energy and Natural Resources Committee

If you have any questions, please contact me or Mr. Shawn Affolter, Deputy Assistant Secretary for Senate Affairs, or Mr. Christopher Morris, Deputy Assistant Secretary for House Affairs, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Dan Brouillette

Executive Summary

In Section 3139 of the National Defense Authorization Act for Fiscal Year 2018, Public Law 115-91, Congress directed the Department of Energy (DOE or the Department) to "conduct an evaluation of the feasibility, costs, and cost savings of classifying" certain waste resulting from the reprocessing of spent nuclear fuel that was generated from the United States' nuclear defense program (reprocessing waste) "as other than high-level radioactive waste (HLW) without decreasing environmental, health, or public safety requirements." *See* Section 3139(a). In other words, Congress directed DOE to evaluate whether certain reprocessing waste that the Department is currently managing as HLW may be properly classified and safely disposed of as a lower level of radioactive waste. Section 3139 refers to any such reprocessing waste that may be properly classified as a lower level of radioactive waste as "covered defense nuclear waste." *See* Section 3139 (e)(2). While HLW requires disposal in a deep geologic repository that does not currently exist, lower levels of radioactive waste can be safely disposed of in near-surface or intermediate-depth disposal facilities.

HLW is a statutory term defined in the Atomic Energy Act of 1954, as amended, and the Nuclear Waste Policy Act of 1982, as amended. After Section 3139 was enacted, and while DOE was in the process of drafting this Report, DOE issued its interpretation of the statutory term HLW (HLW Interpretation). The DOE HLW Interpretation, which was informed by public review and comment, was published in the June 10, 2019, Federal Register Notice*, Supplemental Notice Concerning U.S. Department of Energy Interpretation of High-Level Radioactive Waste* (84 FR 26835) (Supplemental Notice). As explained in the Supplemental Notice, DOE interprets the statutory term such that some reprocessing wastes may be classified as not HLW (non-HLW) and may be disposed of in accordance with their radiological characteristics.

Section 3139 requires DOE to evaluate the circumstances under which it would be appropriate to classify certain reprocessing waste as non-HLW. DOE undertook a similar analysis when developing its HLW Interpretation and concluded that the statutory term HLW is properly interpreted such that certain reprocessing wastes are appropriately classified as non-HLW where the radiological characteristics of the waste in combination with the disposal facility requirements for safe disposal demonstrate that disposal of the waste in a near-surface or intermediate-depth disposal facility would be fully protective of human health and the environment. Accordingly, it is appropriate for DOE to conduct its evaluation pursuant to Section 3139 using its HLW Interpretation as an analytical basis for determining reprocessing wastes that may be covered defense nuclear waste appropriate for classification and disposal as non-HLW.

Although DOE is responding to Section 3139 using the HLW Interpretation as an analytical basis for the evaluation, this Report is not – and should not be viewed as – a proposal for implementing the HLW Interpretation. Rather, this Report was produced in the normal course of DOE responsibilities to manage its reprocessing waste inventories, which includes responding to requests from Congress. Furthermore, the conclusions in this Report are necessarily preliminary in nature. They are based on existing data that would need to be verified before serving as the basis for any proposed action, and, as discussed further in the Report, there are numerous other steps that would need to occur before the HLW Interpretation could be implemented for a specific waste stream at a specific site. Accordingly, this Report's usage of the HLW Interpretation, undertaken as a means to respond to the Congressional direction in Section 3139, is intended to serve informational purposes only.

Section 3139 specifies that covered defense nuclear waste consists of two types of reprocessing waste. The first type is reprocessing waste that contains more than 100 nanocuries per gram of alpha-emitting transuranic (TRU) isotopes with half-lives greater than 20 years. *See* Section 3139(e)(2)(A). This waste has the same radiological characteristics as TRU waste suitable for disposal in the Waste Isolation Pilot Plant (WIPP). The second type is reprocessing waste that may be classified, managed, treated, and disposed of, regardless of origin or previous classification, as non-HLW. *See* Section 3139(e)(2)(B). The Report provides DOE preliminary conclusions regarding potential opportunities to classify both types of reprocessing waste as a lower level of radioactive waste, and safely dispose of such waste at a near-surface disposal facility, an intermediate-depth disposal facility, or – in the case of waste with the same radiological characteristics as TRU waste – WIPP, regardless of origin or previous classification.

This Report specifically evaluates the inventory of reprocessing waste that is in storage or planned to be produced at the Savannah River Site (SRS) in South Carolina, the Idaho National Laboratory (INL) in Idaho, and the Hanford Site (Hanford) in Washington. Based on this evaluation, and assuming full compliance with other legal obligations, the Report concludes that there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139. Classifying these reprocessing wastes as non-HLW could enable DOE to begin disposition of such waste earlier, reduce costs, and lower the risk to workers, the public, and the environment.

Potential benefits could be realized due to the following factors:

- Reduction of activities, including level of treatment, stabilization, storage, construction of facilities, and use of first-of-a-kind technologies, hence reducing program and project risk.
- Reduction of disposal costs by implementing disposition paths based on the radiological risk characteristics of the final waste form.
- Initiation of many cleanup projects earlier and completion of them sooner.

Those potential benefits could include the following[1]:

- Early batches (batches 1-4) of vitrified waste from SRS, which were lower in radionuclide content, are candidates for other disposal sites, saving approximately $3 billion to $4 billion with potential for an additional $1.2 billion if batches 5-7 were also candidates by

[1] The estimated cost savings for SRS, INL, and Hanford are in escalated dollars. Tables 5-7 show SRS and INL cost savings in constant dollars.

eliminating the need for additional on-site storage capability and reducing off-site transportation and disposal costs.

- Reprocessing wastes in solid, granular form at INL (sodium-bearing waste and calcine) may be suitable for disposal in near-surface, intermediate-depth, or WIPP without requiring further, expensive treatment and reducing off-site transportation and disposal costs. Alternative disposition of granular wastes could potentially save $12 billion to $15 billion.
- Hanford West Area tank wastes present the best opportunity to realize potential savings of $73 billion to $210 billion by treating low-activity waste by grouting, which would make the waste a candidate for other disposal sites, thus avoiding the production of thousands of canisters of vitrified waste, and decreasing the tank waste mission by at least a decade.

As a demonstration of the HLW Interpretation, DOE conducted National Environmental Policy Act analysis, issued a Finding of No Significant Impact and disposed of 8 gallons of stabilized (grouted) Defense Waste Processing Facility recycle wastewater from SRS at a commercial low-level radioactive waste facility outside of South Carolina.

Evaluation of Potential Opportunities to Classify Certain Defense Nuclear Waste from Reprocessing as Other than High-Level Radioactive Waste

Table of Contents

Executive Summary iv

I. Legislative Language 1

II. Introduction 2

III. Locations and Quantities of Eligible Waste 9

IV. Potential Opportunities 14

V. Conclusions 27

Appendix A—What is a Performance Assessment? 30

Appendix B—Disposal Facilities 31

Appendix C—Cost Estimate Assumptions 36

I. Legislative Language

This Report responds to Section 3139 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2018 (Public Law 115-91), (NDAA FY 2018) which reads:

SEC. 3139. EVALUATION OF CLASSIFICATION OF CERTAIN DEFENSE NUCLEAR WASTE.

(a) EVALUATION.—The Secretary of Energy shall conduct an evaluation of the feasibility, costs, and cost savings of classifying covered defense nuclear waste as other than high-level radioactive waste, without decreasing environmental, health, or public safety requirements.

(b) MATTERS INCLUDED.—In conducting the evaluation under subsection (a), the Secretary shall consider—

(1) the estimated quantities and locations of covered defense nuclear waste;
(2) the potential disposal paths for such waste;
(3) the estimated disposal timeline for such waste;
(4) the estimated costs for disposal of such waste, and potential cost savings;
(5) the potential effect on existing consent orders, permits, and agreements;
(6) the basis by which the Secretary would make a decision on reclassification of such waste; and
(7) any such other matters relating to defense nuclear waste or other reprocessing waste that the Secretary determines appropriate.

(c) REPORT.—Not later than February 1, 2018, the Secretary shall submit to the appropriate congressional committees a report on the evaluation under subsection (a), including a description of—

(1) the consideration by the Secretary of the matters under subsection (b);
(2) any actions the Secretary has taken or plans to take to change the processes, rules, regulations, orders, or directives, relating to defense nuclear waste, as appropriate;
(3) any recommendations for legislative action the Secretary determines appropriate; and
(4) the assessment of the Secretary regarding the benefits and risks of the actions and recommendations of the Secretary under paragraphs (1) and (2).

(d) DIFFERENTIATION OF WASTE.—In conducting the evaluation under subsection (a) and preparing the report required by subsection (c), the Secretary shall distinguish between covered nuclear waste described in subparagraph (A) of subsection (e)(2) and covered nuclear waste described in subparagraph (B) of that subsection.

(e) DEFINITIONS.—In this section:

(1) APPROPRIATE CONGRESSIONAL COMMITTEES.—The term ''appropriate congressional committees'' means the following:

(A) The congressional defense committees.
(B) The Committee on Energy and Commerce of the House of Representatives.
(C) The Committee on Energy and Natural Resources of the Senate.

(2) COVERED DEFENSE NUCLEAR WASTE.—The term ''covered defense nuclear waste'' means radioactive waste that resulted from the reprocessing of spent nuclear fuel that was generated from atomic energy defense activities and that—

(A) contains more than 100 nCi/g of alpha-emitting transuranic isotopes with half-lives greater than 20 years; or
(B) may be classified, managed, treated, and disposed of, regardless of origin or previous classification, as other than high-level radioactive waste.

II. Introduction

Purpose and Scope

This Report has been prepared to respond to Section 3139 of NDAA FY 2018 by evaluating potential opportunities to reduce risk to public health and the environment by classifying certain waste resulting from the reprocessing of spent nuclear fuel (SNF) that was generated from the United States' nuclear defense program (reprocessing waste) as not high-level radioactive waste (non-HLW), including the associated costs and costs savings. Section 3139 refers to reprocessing waste that may be properly classified and safely disposed of as a lower level of radioactive waste as "covered defense nuclear waste." *See* Section 3139(e)(2).

To conduct this evaluation, this Report:

(1) utilizes the Department of Energy's (DOE or Department) interpretation of the statutory term HLW (HLW Interpretation) as an analytical basis for assessing whether there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139. The HLW Interpretation is based on the Nuclear Regulatory Commission's (NRC) current regulatory approach for classification and disposal of low-level radioactive waste (LLW) and is further explained in the Federal Register Notice, *Supplemental Notice Concerning U.S. Department of Energy Interpretation of High-Level Radioactive Waste* (84 FR 26835) (Supplemental Notice);

(2) utilizes available information on the location, amounts, current status, and expected disposal schedules and pathways of reprocessing waste at the Savannah River Site (SRS) in South Carolina, the Idaho National Laboratory (INL) in Idaho, and the Hanford Site (Hanford) in Washington; and

(3) considers the potential impacts and benefits of utilizing alternative disposal pathways for disposal of covered defense nuclear waste as non-HLW.

As explained in the Supplemental Notice, DOE interprets the statutory term HLW such that some reprocessing wastes may be classified as non-HLW and may be disposed of in accordance with their radiological characteristics. As the Supplemental Notice further explains, the HLW Interpretation did not change or revise any current policies, legal requirements, or agreements with respect to HLW. Decisions about whether and how the HLW Interpretation will apply to existing wastes and whether such wastes may be managed as non-HLW will be the subject of subsequent actions that will be implemented, if at all, on a site-specific basis with appropriate public engagement and full compliance with other legal obligations, such as compliance with the National Environmental Policy Act (NEPA) and applicable agreements.[2]

[2] DOE has completed one such action involving a waste stream at SRS, which is explained in the Federal Register Notice, *Environmental Assessment for the Commercial Disposal of Defense Waste Processing Facility Recycle*

Although DOE is responding to Section 3139 using the HLW Interpretation, this Report is not – and should not be viewed as – a proposal for implementing the HLW Interpretation. Rather, this Report was produced in the normal course of DOE responsibilities to manage its reprocessing waste inventories, which includes responding to requests from Congress. This Report's usage of the HLW Interpretation, undertaken as a means to respond to the Congressional direction in Section 3139, is intended to serve informational purposes only.

This Report concludes that, assuming full compliance with other legal obligations, there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139. Classifying these reprocessing wastes as non-HLW has the potential to realize significant benefits in terms of reducing risk, complexity, and costs for management and accelerating schedules for disposition of reprocessing waste, while fully protecting human health and the environment.

While this Report identifies potential opportunities for DOE to reduce risk to public health and the environment while completing its cleanup mission more efficiently, the conclusions in the Report are necessarily preliminary in nature. They are based on existing data that would need to be verified before serving as the basis of any proposed action, and, as discussed further in the Report, there are numerous other steps that would need to occur before any action is taken for a specific waste stream at a specific site. Among other things, DOE would conduct further data gathering, analysis, and engagement with stakeholders before taking action on any of these potential opportunities.

Statutory Framework - Definition of HLW

The Nuclear Waste Policy Act, as amended,[3] (NWPA), and the Atomic Energy Act of 1954,[4] as amended, (AEA) define HLW as follows:

> (A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and
> (B) other highly radioactive material that the [Nuclear Regulatory] Commission, consistent with existing law, determines by rule requires permanent isolation.[5]

Clause A of this definition is both source-based ("resulting from the reprocessing of SNF") and risk-based ("highly radioactive" and "fission products in sufficient concentrations"). In other words, waste is HLW if it is "highly radioactive" and either (1) the liquid waste produced directly

Wastewater from the Savannah River Site (84 FR 26847). At this time DOE has not proposed to evaluate any other waste at any other site for disposal as non-HLW under the HLW Interpretation.
[3] 42 U.S.C. 10101 *et seq*.
[4] 42 U.S.C. 2011, *et seq.*
[5] NWPA § 2(12).

in reprocessing, or (2) any solid material derived from such liquid waste that contains fission products in sufficient concentrations.

International Context

International waste classification systems are based on radiological risk. The International Atomic Energy Agency (IAEA) establishes guidance for each of its member states (the United States is a member state) to assist in classifying radioactive waste. The IAEA uses several approaches, most notably radioactivity concentration, to distinguish HLW from other waste types. The IAEA defines HLW as waste "that contains such large concentrations of both short- and long-lived radionuclides that, compared to intermediate-level waste, a greater degree of containment and isolation from the environment is needed to ensure long-term safety."[6] Such HLW typically has levels of activity in the range of 10,000 to 1,000,000 terabecquerels per cubic meter (m^3)[7] (about 270 to 27,000 curies per liter[8]). This activity level is significantly above the activity level for much of the reprocessing waste that DOE manages today as HLW, based solely on its source (reprocessing), as well as much of all of the waste classified as LLW or transuranic (TRU) waste.

NRC's LLW Regulatory Framework and TRU Waste

NRC has developed extensive regulations concerning the near-surface land disposal of LLW that provide useful information on which types of waste can be disposed of in a near-surface or an intermediate-depth disposal facility (in other words, do not require permanent isolation in a geological repository).

NRC's regulations at 10 Code of Federal Regulations (CFR) Part 61.55 identify classes of LLW - Class A, B, or C - for which near-surface disposal is safe for public health and the environment. Waste that exceeds the Class C tables in 10 CFR 61.55 also may be safely disposed in a near-surface or intermediate-depth disposal facility under certain conditions. This waste classification regime is based on the concentration levels of a combination of specified short-lived and long-lived radionuclides in a waste stream, with Class C LLW having the highest concentration levels. In accordance with NRC regulations, 10 CFR 61.55(a)(2)(iv) and 10 CFR 61.58, waste that exceeds the Class C levels is evaluated on a case-specific basis to determine whether it requires disposal in a deep geologic repository, or whether an alternative disposal facility can be demonstrated to provide safe disposal.

TRU waste is defined, with certain exceptions, as waste from the United States' nuclear defense program "containing more than 100 nanocuries of alpha emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years" in the Waste Isolation Pilot Plant (WIPP) Land

[6] International Atomic Energy Agency, "Classification of Radioactive Waste", General Safety Guide No. GSG-1, 2009, pg. 14.
[7] Ibid, pg. 15.
[8] This Report refers to radioactivity concentration in units of curies per liter of waste. Another common measurement is curies per cubic meter, which equals 1/1,000th of a curie per liter.

Withdrawal Act (LWA), Public Law 102-579, as amended by Public Law 104-201. The only currently available disposal path for TRU waste generated by United States' nuclear defense activities is WIPP.

HLW Interpretation

This Report uses the HLW Interpretation as an analytical basis to evaluate whether there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139, including the potential impacts and benefits from disposal of such waste at land disposal facilities (near-surface or intermediate-depth) or at WIPP, subject to the statutory limitations in the LWA on the amounts and the activity level of material that can be disposed of at WIPP.[9, 10]

DOE's HLW Interpretation could enable certain reprocessing waste to be classified as non-HLW and disposed of based on its radiological characteristics that determine risk. As explained in the *Supplemental Notice Concerning U.S. Department of Energy Interpretation of High-Level Radioactive Waste* (84 FR 26835), DOE interprets the AEA and NWPA definition of HLW to provide that a reprocessing waste may be determined to be non-HLW if it meets either of the following criteria.

(I) does not exceed concentration limits for Class C low-level radioactive waste as set out in section 61.55 of title 10, Code of Federal Regulations, and meets the performance objectives of a disposal facility; or

(II) does not require disposal in a deep geologic repository and meets the performance objectives of a disposal facility as demonstrated through a performance assessment conducted in accordance with applicable requirements.

Under Criterion I, reprocessing waste that does not exceed Class C limits and meets the performance objectives of a disposal facility is non-HLW because it could be classified as LLW under NRC's current waste classification system in 10 CFR 61.55. Such LLW can be, and routinely is, safely disposed in near-surface facilities that are proven to be protective of human health and the environment. This Criterion could include any waste that falls within Section 3139(e)(2)(B).[11]

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[9] WIPP LWA section 7(a).

[10] A WIPP Hazardous Waste Facility Permit modification would be necessary for any tank waste to be disposed of at WIPP. *See* WIPP Hazardous Waste Facility Permit, Table C-4, Waste Tanks Subject to Exclusion (https://wipp.energy.gov/Library/Information_Repository_A/Searchable_Permit_NWP_Manager_Change_Sep_16_2019.pdf)

[11] Section 3139(e)(2)(B) includes reprocessing waste that "… may be classified, managed, treated, and disposed of, regardless of origin or previous classification, as other than high-level radioactive waste."

Under Criterion II, reprocessing waste that exceeds NRC's Class C limits (because, for example, it contains more than 100 nanocuries per gram (nCi/g) of alpha-emitting TRU isotopes with half-lives greater than 20 years), is non-HLW if technical analysis of the radiological characteristics of the waste demonstrates that it does not require disposal in a deep geologic repository and meets the performance objectives of a disposal facility. That is, the analysis must show that a given waste does not require deep geologic disposal and can be safely disposed of considering the physical characteristics of a specific disposal facility and a method of disposal compliant with that facility's performance objectives. Appendix A provides information on performance assessments used to demonstrate compliance with performance objectives. This Criterion could include any wastes defined under section 3139(e)(2)(A).[12] In addition to alternative disposal in a near-surface facility, this report also evaluates alternative disposal of wastes defined under section 3139(e)(2)(A) at WIPP because, although WIPP is a geologic repository, it is an existing facility specifically designed to safely dispose of waste exceeding 100 nCi/g of TRU isotopes. All TRU waste generated from atomic energy defense activities to be disposed of at WIPP must comply with the WIPP LWA, the WIPP Hazardous Waste Facility Permit, the WIPP waste acceptance criteria (WAC), and other applicable requirements. Currently, any reprocessing waste that may be determined to be non-HLW could not be disposed of at WIPP because the WIPP Hazardous Waste Facility Permit specifically prohibits tank waste from disposal at WIPP.

The Criteria are based on NRC's current regulatory approach for classifying and disposing of LLW.[13] Waste meeting either Criterion could be classified based on its radiological content and disposed of in accordance with: the disposal facility WAC; allowable radionuclide content; waste form and packaging; and required waste generator certifications and approvals.

Reprocessing waste that is classified as either LLW or TRU potentially could be disposed of much sooner than HLW because LLW and TRU waste disposal facilities currently exist. Earlier disposal would result in significant benefits to DOE and the public without decreasing environmental, health, or public safety requirements, including: (1) avoided HLW storage and treatment costs; (2) advancement of long-term health and safety by eliminating the need for active human control and maintenance of HLW at various DOE sites; and (3) progress toward meeting tank closure and other requirements at DOE sites that store tank waste. Disposal facilities are summarized in Appendix B.

[12] Section 3139(e)(2)(A) includes reprocessing waste that "…contains more than 100 nCi/g of alpha-emitting transuranic isotopes with half-lives greater than 20 years." Criterion 2 could also apply to wastes that may contain less than 100 nCi/g of TRU but have concentrations greater than NRC's Class C limits due instead to fission and/or activation products.

[13] The NRC is in the process of amending 10 CFR Part 61 to become more risk-based, to allow for site-specific technical evaluations and site-specific criteria for accepting LLW. Its July 2019 draft Regulatory Basis proposes to allow some wastes with concentrations exceeding Class C limits (i.e., up to 10,000 nCi/g of TRU elements) to be disposed in near-surface facilities.

General Requirements for All Waste Disposition

If reprocessing waste is classified as non-HLW, a path forward for its disposition can be developed. There are a number of general technical, regulatory and programmatic steps required, including, but not limited to:

- Confirming disposal facilities.
- Evaluating disposal facility WAC and impacts on performance objectives of potential disposal facilities (the licensee or permittee for the disposal facility may also be required to obtain appropriate regulatory authorizations to accept waste).
- Preparing NEPA analyses and documentation.
- Preparing or revising necessary permits, and appropriate approvals from Federal, State, and local regulators and authorities (including coordination with, and approval by, the Agreement State).
- Coordinating with stakeholders.
- Preparing Resource Conservation and Recovery Act (RCRA) or Comprehensive Environmental Response, Compensation, and Liability Act documentation, if needed, to retrieve, treat, package, characterize, and certify the wastes for disposal.
- Modifying affected contracts, if necessary.
- Initiating project planning and execution activities in accordance with DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, as appropriate.
- Developing waste loading, packaging, and transportation cask systems as needed to remove the waste from the site and deliver it to the disposal facility.

Additional Requirements for LLW Disposition

For waste that could potentially be classified as LLW, including LLW with characteristics greater than NRC's Class C limits, the following additional steps would be considered for emplacement in a LLW disposal facility:

1. Low-activity waste (LAW) at Hanford must be vitrified (or solidified using an equivalent technology) if it is to be disposed on-site at the Integrated Disposal Facility (IDF).[14] No decision has been made on technology to treat the supplemental LAW.
2. The low-activity fraction of SRS tank waste must be decontaminated to remove certain radionuclides before being added to grout and disposed in on-site saltstone disposal units.[15]

[14] *See* Tank Waste Remediation System, Hanford Site, Richland, WA, February 26, 1997 (62 FR 8693). https://www.energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EIS-0189-ROD-1997.pdf
[15] *See* Liquid Waste System Plan Revision 21. SRR-LWP-2009-00001, January 2019 (https://www.energy.gov/sites/prod/files/2019/05/f62/SRS-Liquid-Waste-System-Plan-January-2019-0.pdf)

3. For disposal of non-HLW reprocessing waste at an off-site disposal facility, if the waste exceeds current WAC limits, the site permit or license would need to be amended to incorporate disposal of qualifying waste.[16]
4. Under current NRC regulations, disposal of waste that exceeds Class C limits, when disposed in a commercially licensed facility, must be approved by NRC (or the appropriate Agreement State if delegated by NRC) on a case-by-case basis.[17]

Additional Requirements for TRU Waste

For waste that could potentially be classified as TRU waste to be emplaced in WIPP, the following additional steps would be considered for emplacement:

1. Make a formal determination that the waste meets the TRU waste definition in the WIPP LWA and that the TRU waste was generated by atomic energy defense activities.[18]
2. Assess impact on other WIPP LWA requirements.
3. Include the waste form and volume in the DOE *Annual Transuranic Waste Inventory Report* and incorporate the waste in the WIPP recertification performance assessment that is reviewed by the U.S. Environmental Protection Agency (EPA).[19]
4. Approval by the New Mexico Environment Department (NMED) of a permit modification to the WIPP Hazardous Waste Facility Permit to allow tank waste to be disposed at WIPP.[20]
5. After receipt of permit modification to authorize additional panels, mine additional disposal area to accommodate the TRU waste form, as needed.[21]
6. If new panels are necessary at WIPP, additional panels would need to be permitted by NMED and the EPA would need to approve the change. DOE would need to submit a planned change request to the EPA and the Agency would need to determine whether it

[16] 10 CFR 61
[17] 10 CFR 61.55(a)(2)(iv).
[18] *See* Sections 2(18) and 2(19), Public Law 102-579, 106 Stat. 4777, 1992 (as amended by Public Law 104-201, 1996) (http://www.wipp.energy.gov/library/CRA/BaselineTool/Documents/Regulatory%20Tools/10%20WIPPLWA1996.pdf).
[19] TRU Waste Inventory Data Update Guidance and Instructions-2018
[20] *See* WIPP Hazardous Waste Permit, Table C-4, Waste Tanks Subject to Exclusion (https://wipp.energy.gov/Library/Information_Repository_A/Searchable_Permit_NWP_Manager_Change_Sep_16_2019.pdf)
[21] This report analyzes an estimated 10,312 m^3 of tank waste for alternative disposal at WIPP, based on the assumption that the final waste form would contain more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years. The 10,312 m^3 of tank waste analyzed for alternative disposal at WIPP would exceed the remote-handled (RH) TRU waste volumetric limit of 7,083 m^3 defined by the Consultation and Cooperation Agreement between DOE and the State of New Mexico. The WIPP LWA RH TRU waste limits of 23 curies per liter and 5,100 total curies would also need to be considered for disposal at WIPP. The additional disposal capacity that would be needed for RH tank waste would depend on a number of factors, such as thermal loading and emplacement configuration. *See* https://wipp.energy.gov/waste-panels-and-capacity.asp.

would be an administrative change or require a rulemaking per the requirements of 40 CFR Part 194.[22]

III. Locations and Quantities of Eligible Waste

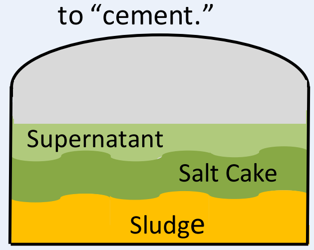
Historically, SNF reprocessing for atomic energy defense activities took place at DOE facilities (SRS, INL, and Hanford). In addition, a commercial reprocessing facility was operated in West Valley, New York.

The most utilized reprocessing technology is known as "aqueous reprocessing" in which SNF is dissolved in acid. The text box describes the general characteristics of tank wastes resulting from aqueous reprocessing. Different sites have implemented various tank waste strategies with the primary objective to ensure the waste is safely managed until it can be transformed into a final waste form for disposal. It should be noted that projections of reprocessing waste inventories discussed in this Report are best estimates. Numbers of canisters projected, volumes of waste projected, and associated costs in the following Tables have been rounded.

Tank Waste Characteristics

After useful products are extracted from the SNF-acid solution, waste is transferred to tanks and neutralized. Over time, gravity causes the highly dissolved solids to settle and form into three basic layers:

- Supernatant is liquid with a high level of dissolved solids.
- Saltcake is a layer below supernatant that is high in salts. Saltcake can be mobilized by adding liquid (water or supernatant) to re-dissolve the solids.
- Sludge is the concentrated layer of solids settled to the bottom of the tank. With time, the sludge layer develops a consistency ranging from "peanut butter" to "cement."



SRS Tank Waste

SRS reprocessing liquid waste is stored in underground tanks. The high-activity portion of this waste is transferred from the tanks, treated as needed, and immobilized into a glass waste form at the Defense Waste Processing Facility (DWPF), which has operated since 1996. The low-activity portion is transferred from the tanks, treated as needed, and is stabilized in grout and disposed on-site in saltstone vaults.

[22] 61 FR 5224-5245, Feb. 9, 1996. 40 CFR Part 194 Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations and the 40 CFR Part 194 Compliance Criteria.

Table 1 details the present and planned form of waste glass produced and planned for production. The SRS waste glass canisters are stored on-site pending disposal.

Table 1. Existing Volumes of Immobilized and Tank Waste and Estimated Canisters

Present Form	Final HLW Waste Form	Quantity (m^3)	Canisters	Status
Waste Glass	Canistered Waste Glass	3,600	4,190	Canisters are stored in one of two Glass Waste Storage Buildings
Tank Waste	Canistered Waste Glass	3,500	4,000 (estimate)	About 135-175 canisters produced annually will be placed into storage

Canisters from DWPF are stored in glass waste storage buildings, where canisters are placed below grade in individual vaults, as shown in the image below.

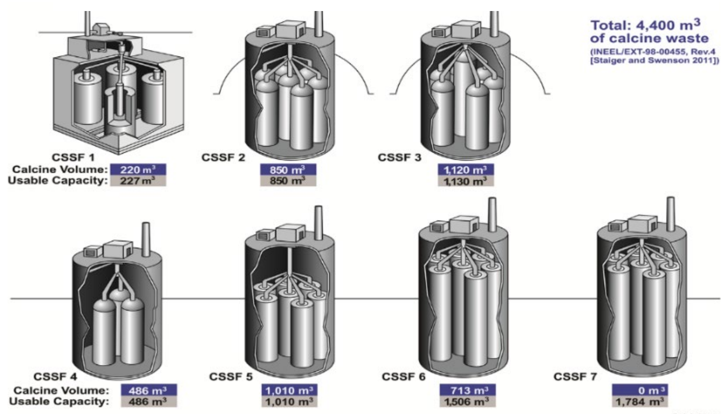
Treatment of tank waste will also generate secondary waste streams, such as ion exchange filters, wastewater, and contaminated equipment. The secondary waste includes recycle wastewater generated as part of DWPF operations. The recycle wastewater is a combination of several diluted liquid waste streams consisting of condensates from the pretreatment and vitrification processes, off-gases from the melter, process samples, sample line flushes, sump flushes, and cleaning solutions from the decontamination and filter dissolution processes. The DWPF recycle wastewater is currently managed as HLW. The DWPF recycle wastewater is transferred to the 2H evaporator system to separate the concentrates (evaporator bottoms) from the condensates (overheads). The concentrates are stored in the tank farm, and the condensates are routed to the Effluent Treatment Project (ETP) facility for further processing prior to release to a permitted outfall. To support acceleration of tank closure, which include completion of Salt Waste Processing Facility and DWPF mission, DOE is evaluating potential alternative treatment and disposal method for the approximately 380,000 gallons of DWPF recycle wastewater. As a demonstration, DOE conducted NEPA analysis, issued a Finding of No Significant Impact and disposed of 8 gallons of stabilized (grouted) DWPF recycle wastewater from SRS H-Area Tank Farm at a commercial LLW facility outside of South Carolina.

INL Calcine

DOE conducted SNF reprocessing activities at the INL Chemical Processing Plant (now known as the Idaho Nuclear Technology and Engineering Center [INTEC]) from 1952 until 1992. The resulting liquid waste, referred to as first-cycle solvent extraction waste, was stored in tanks at the Tank Farm Facility (TFF), shown in the aerial photograph. In order to close the tank farm, DOE removed the liquid wastes from most of the tanks and used a process called calcination to solidify the wastes. This solidification was completed in 1998. Calcine is currently stored in the Calcine Solids Storage Facility (CSSF).

Liquid waste generated at INTEC contained a small amount of RCRA-listed hazardous wastes, as well as toxicity characteristic metals, and is considered a mixed waste. The waste was treated by a high-temperature fluidized bed process and converted to a dry, granular solid waste form called calcine. About 4,400 m^3 of calcine was produced.

Figure 1. Binsets at INTEC containing calcine waste



The CSSF is comprised of seven, stainless steel-lined, underground "binsets" (one of which is empty). Six binsets contain a homogenous mixture of calcined waste with similar radiological characteristics. The total number of canisters that will be produced for off-site disposal of calcine is dependent upon the final form selected. Table 2 summarizes the location and quantities of calcine waste based on the current stabilization approach of hot isostatic pressing (HIP).

Table 2. Volumes of Calcine in each Binset and Estimated HIP Canisters

Binset No.	Volume (m^3)	Projected Canisters (#)
Binset 1	220	327
Binset 2	850	1,256
Binset 3	1,120	1,654
Binset 4	486	718
Binset 5	1,010	1,492
Binset 6	713	1,053
TOTALS	**4,400**	**6,500**

The disposition path for calcine is disposal in a HLW repository as a HIP[23] waste form. The HIP process results in a monolithic glass/ceramic solid by introducing an engineered additive to the calcine, placing it into small cans, and putting the cans into a machine that presses the cans under high temperature and pressure. The HIP cans would be placed into larger canisters and stored until a geologic repository is available for disposal.

INL Sodium-Bearing Waste

The TFF also stores other wastes generated at the site in separate tanks. These wastes, referred to as sodium-bearing waste (SBW), include second- and third-cycle reprocessing wastes (material not directly produced from the reprocessing of SNF), decontamination waste, laboratory waste, and waste from other INTEC operations.

INL SBW consists of the liquids and solids remaining in the INTEC TFF. SBW is a mixture of wastes derived from the following sources:

- Decontamination solutions from past SNF reprocessing maintenance activities.
- Tank heel solids (the hard-packed sludge at the bottom of most waste tanks).
- Liquid wastes from ongoing INTEC maintenance and closure activities.
- Remaining second- and third-cycle SNF reprocessing extraction wastes.
- Trace contamination from first-cycle SNF reprocessing extraction waste, primarily from tank heels.

SBW is mixed waste, containing both a hazardous waste component including RCRA-listed wastes, and a radioactive waste component, generated as a by-product of SNF reprocessing at INTEC. Approximately 850,000 gallons of SBW are stored in three underground tanks at INTEC. Fluidized-bed steam reforming at the Integrated Waste Treatment Unit is the treatment method for the SBW.[24] SBW will be converted to a dry, solid carbonate and aluminate mineral. The resulting granular solids and fine powdered waste will be packaged in stainless steel, cylindrical canisters approximately 3 meters (10 feet) long and 0.66 meters (2 feet) in diameter. The current estimate is that there will be approximately 690 canisters of SBW. The current planned disposition path for SBW is disposal as either HLW or disposal in WIPP as RH TRU waste assuming a non-HLW determination, permit modification approval for WIPP to accept reprocessing waste, and fulfilment of other applicable requirements. Table 3 provides estimated quantities of SBW.

[23] Based on the Record of Decision for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement (DOE/EIS-0287), September 2002, and Federal Facilities Compliance Act Site Treatment Plan.
[24] The Integrated Waste Treatment Unit is currently undergoing simulant and start-up testing to define operational boundaries and permit conditions in preparation for radiological operations.

Table 3. Volumes of Sodium-Bearing Waste by Tank and Estimated Canisters

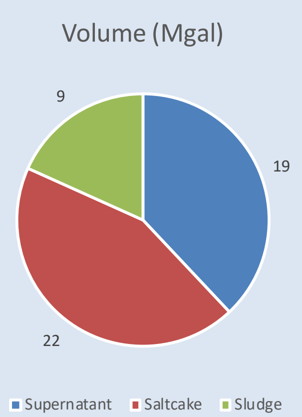
Tank ID	Volume (m³)	Projected Canisters (#)
WM-187	1,080	230
WM-188	1,070	230
WM-189	1,060	230
TOTALS	**3,210**	**690**

Hanford Tank Waste

Forty years of plutonium production at the Hanford Site has yielded a challenging nuclear waste legacy - approximately 56 million gallons of wastes are stored in 177 underground tanks (11 tank farms in East Area and 7 tank farms in West Area) located on Hanford's Central Plateau.

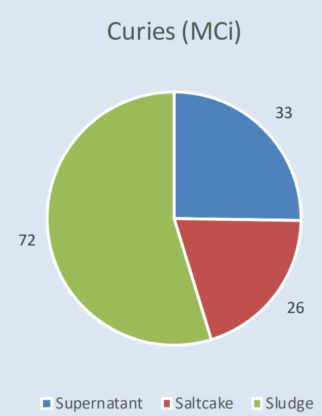
The waste is currently stored in single-shell and double-shell tanks. The reprocessing waste at Hanford is mixed waste, containing both a radioactive waste component and a hazardous waste component, including RCRA-listed wastes. Figure 2 shows that supernatant and saltcake represent the largest volume of the waste in the tanks, yet contribute the lowest levels of radioactivity.

Figure 2. Hanford Tank Waste Quantities and Characteristics



All Tanks*	Volume (Mgal)	Curies (MCi)
Supernatant	19	33
Saltcake	22	26
Sludge	9	72
TOTAL	50	131

* Excluding 11 TRU Tanks (B-201, B-202, B-203, B-204, T-104, T-110, T-111, T-201, T-202, T-203, T-204)



Treatment and immobilization of Hanford tank waste has not yet begun, although construction of facilities for vitrification is progressing.[25] The current planned disposition path for some of the tank waste is the Waste Treatment and Immobilization Plant (WTP) consisting primarily of a pretreatment (PT) facility, a HLW facility, and a LAW facility. As envisioned at project initiation, the PT facility would receive, pretreat, and separate liquid waste received from the tank farms,

[25] In the 1970s, however, a large fraction of cesium-137 and strontium-90 were removed from waste tanks at Hanford to reduce the temperature of the waste inside the tanks.

and then the pretreated waste would be sent to the HLW or LAW facility for vitrification. In order to begin treatment of LAW expeditiously, the Department is implementing a direct-feed LAW approach (DFLAW) that would utilize a tank-side cesium removal capability and/or LAW PT system to pretreat waste and then feed the waste to the LAW facility for vitrification. The vitrified LAW would be stored in canisters and would be disposed on-site in the IDF in the 200 Area of Hanford. Pursuant to the Consent Decree in *State of Washington v. U.S. Department of Energy,* [2:08- CV-05085-RMP] (Amended Consent Decree), LAW facility hot commissioning completion is required by December 31, 2023. The LAW facility is not designed to immobilize all of the low-activity tank waste.[26]

The quantities of both LAW and HLW glass are listed in Table 4.

Table 4. Quantities of Projected Waste

Waste Type	Volume (m^3)	Quantity
HLW Glass	9,150	7,800 canisters
LAW Glass	118,000	51,700 canisters
Supplemental Glass	97,300	42,300 canisters
Potential TRU Waste	1,700	8,400 drums

Note: The final waste form for supplemental LAW has not been determined. The table assumes all LAW is vitrified.
Source: Office of River Protection Project simulation modeling and analysis.

IV. Potential Opportunities

Situational Analysis

The following factors indicate that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139 and classifying such wastes as non-HLW could reduce risk to public health and the environment while enabling DOE to complete its cleanup mission more efficiently and effectively:

- The only option for permanent disposal of reprocessing waste that is classified as HLW is permanent isolation in a geologic repository.
- The WIPP LWA expressly prohibits HLW disposal at WIPP.[27]
- LLW is essentially defined, in relevant part, as radioactive waste that is not SNF, HLW, certain by-product material, or TRU waste, which limits what LLW facilities can accept.

[26] The portions of the Hanford Federal Facility Agreement and Consent Order related to the treatment and disposal of radioactive tank wastes is largely based on the operation of the WTP, which was conceived to treat the high activity waste and approximately 40 percent of the low-activity waste currently stored at Hanford. The Department has not identified a preferred alternative, and as a result, has not selected a technology for the treatment and disposition of the remaining approximate 60 percent of the low-activity tank waste (generally referred to as "supplemental treatment" or "supplemental LAW").
[27] WIPP LWA, sec. 12.

In addition, there has been widespread recognition that the current approach to managing and disposing of reprocessing wastes has shortcomings, and that alternative strategies should be explored and developed.

Summary of Benefits

Based on the evaluation in this Report, there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139. Classifying these reprocessing wastes as non-HLW could enable the Department to achieve significant benefits in safety, risk reduction, and lower complexity in waste treatment, stabilization, and disposal actions. Shortened mission schedules and large cost savings and cost avoidances could be realized by allowing waste that has been managed as HLW to be classified and disposed of as LLW or TRU waste, as appropriate. Hanford, INL, and SRS could reduce the time that untreated radioactive waste is stored on-site, furthering DOE's commitment to state and local communities to move radioactive material out of the generator state. In all cases, the final waste form would have to meet all WAC for the disposal site. Also, regardless of the disposition path for LLW, TRU waste, and HLW, it is the Department's intent to ensure that potential benefits would be achieved without decreasing protection of the public, workers, and the environment.

Some opportunities assessed in this Report assume future availability of disposal pathways that are currently not authorized, e.g., permit and facility modifications would be necessary.[28] Requirements for any existing or future disposal facility to accept reprocessing waste classified as non-HLW are discussed in Section II of this Report. For simplicity, this section will refer generically to "alternative disposal facilities" which could apply to one or more of the above facilities being able in the future to accept lower-risk reprocessing wastes.

Potential Opportunities

This section summarizes the potential opportunities for DOE to reduce risk to public health and the environment while completing its cleanup mission more efficiently and effectively. Some of the waste streams are currently in final form and no further treatment or stabilization would be required. Other waste streams would require treatment or stabilization to obtain a final waste form or require additional actions (e.g., retrieval from tanks). Treatment is generally focused on removing certain radionuclides that have the potential to impact stabilization of a given waste, the ability to efficiently transport the waste to a disposal facility, and/or the ability of the final waste form to meet the disposal facility's WAC. Finally, some waste streams have not seen any significant treatment or stabilization and could require substantial preparation to attain final waste forms for disposition.

[28] For example, a WIPP permit modification would be necessary for any tank waste to be disposed of at WIPP, and RCRA permit modifications may be required for retrieval of waste from Hanford tanks.

As discussed below, each site could potentially benefit from determining that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139 and classifying such waste as non-HLW. Potential benefits could be realized due to the following:

- Reduction of activities, level and complexity of treatment, stabilization, storage, construction of facilities, and use of first-of-a-kind technologies, thereby reducing program and project risk. These include:
  - At SRS, treatment and stabilization approaches would not change. However, removing canisters from storage sooner would avoid the need for additional on-site storage and reduce the cost and time of active security, surveillance, and maintenance.
  - At SRS, alternate treatment and disposal of DWPF recycle wastewater could support acceleration of tank closure.
  - At INL, the potential to dispose of calcine without further treatment could eliminate the need to develop and operate a first-of-a-kind technology, the HIP process, if the robust nature of the features of an alternative disposal site eliminate the need for it. This may result in a significant savings and would reduce the time and cost of on-site storage.
  - At Hanford, large potential benefits could be realized by reducing the higher-complexity facilities and activities and utilizing lower-complexity facilities and activities. In particular, maximizing the use of low-temperature, low-risk, grout facilities, which are well understood and have a considerable base of operating experience, to stabilize some or all of the supplemental LAW – which the LAW facility is not designed to vitrify – could have significant operational benefits while reducing risk to public health and the environment.
- Selecting and implementing disposition paths based on the radiological risk characteristics of the final waste form could contribute to savings. Thousands of canisters otherwise destined for a HLW repository could be dispositioned elsewhere or rendered unnecessary to produce. Waste forms with lower radioactivity and TRU concentrations could be produced and disposed of in near-surface or intermediate-depth facilities, or WIPP. Disposition of canisters as non-HLW could save several hundred thousand dollars for each canister not emplaced in a HLW repository.

Cost Savings Estimation Approach

The Congressional reporting requirement for this Report requests DOE evaluation of, among other things, cost savings. It is important to understand that cost savings presented in this section are “rough-order-of-magnitude” (ROM) estimates, with large ranges of possible cost savings due to the numerous uncertainties at this stage of the life-cycle.

The estimation process generally begins with a definition of the work scope to be performed and the expected duration of each activity. Unit costs for equipment, parts, etc. and labor costs for the appropriate skill mixes for the work scope are documented by subject matter experts and cost estimators. Uncertainties (e.g., risks that could arise during the project's execution) are reflected as cost ranges based on accepted methods to estimate project contingencies.

These are generally considered Class 4 or Class 5 estimates with uncertainty ranges from -30 to +50 percent over the most-likely "point" (single value) cost estimate.[29] For this Report, DOE uses the "point" estimates for simplicity.

This Report develops scenarios that DOE believes could potentially be feasible to implement consistent with the potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste.

This Report also estimates a separate set of costs reflecting the off-site transportation and disposal costs for the three types of disposal facilities considered: geologic disposal in a HLW repository, disposal in a TRU disposal facility, and disposal in a near-surface or intermediate-depth disposal facility. Estimates for this component of off-site disposition costs are based on available data. Costs were converted into unit costs (e.g., cost per canister or cost per cubic meter) to allow a parametric approach to estimate off-site disposition costs based on the volume of waste to be disposed at the different types of disposal facilities. With the exception of WIPP, all shipments to these facilities assumed shipment by rail, which is generally less expensive than shipment by truck but is also fully protective of human health and the environment.

Despite the uncertainties implicit in ROM cost savings estimates, the preliminary conclusion appears valid – a change in classification of reprocessing wastes could potentially save taxpayers many billions of dollars, accelerate mission completion, and maintain the level of public safety necessary to safely isolate these defense nuclear wastes.

Waste Inventory Assumptions

The cost estimates and comparisons presented in this Report are dependent on estimated stored and projected waste volumes (before and after treatment), radionuclide concentrations, assumed packaging for the final waste form, and a number of other factors. Although the waste inventory estimates are based on available data and reasonable assumptions, there are inherent uncertainties in forecasting final waste form volumes and radionuclide concentrations for reprocessing waste that has not been retrieved, treated and/or packaged for disposal. Therefore, the estimates and underlying assumptions are subject to change, e.g., as

[29] As explained in DOE's Cost Estimating Guide (DOE Guide 413.3-21A), cost estimates can be classified based on their maturity level of project definition deliverables, end usage of estimate, estimating methodology, and the effort and time needed to prepare the estimate. Five cost estimate classes are established, where Class 1 estimates are the closest to full project definition and maturity and Class 5 estimates have the lowest maturity level of project definition. Typically, as a project evolves, it becomes more definitive. Determination of cost estimate classifications helps ensure that the cost estimate quality is appropriately considered. Classifications may also help determine the appropriate application of contingency, escalation, use of direct/indirect costs (as determined by cost estimate techniques), etc.

characterization data is validated with current sampling data, progress of tank closure and waste disposition activities, conduct of NEPA analysis and documentation, etc. Each waste stream would be properly characterized to ensure safe management and compliance with the waste acceptance requirements for the treatment, storage, or disposal facility receiving the waste.

SRS Tank Waste

As the SRS liquid waste system is constructed and most facilities are currently operational, there are limited options to modify any future waste streams from DWPF or the Saltstone Disposal Facility that create the waste glass and low-activity grout for off-site and on-site disposal, respectively. However, significant savings in cost and schedule could potentially still be achieved for some of the early macrobatches (MB) of waste glass. Figures 3 and 4 comparatively show the radioactivity (curies per liter) and TRU content (nCi/g), respectively, of the final waste forms. Some MB could be classified as non-HLW if it can be demonstrated that their emplacement in an appropriate disposal facility (e.g., intermediate-depth) would meet the facility's performance objectives. Based on existing data, it is possible that some or all of the canisters produced in batches 1 through 4 could be considered for emplacement in an alternative disposal facility. Canisters that do not meet a particular disposal facility's WAC could be eligible for disposal in more protective facilities. Any canisters that remain within the definition of HLW, however, would need to remain in on-site storage until a HLW repository is available.

Figure 3. Radioactivity (Curies/liter)

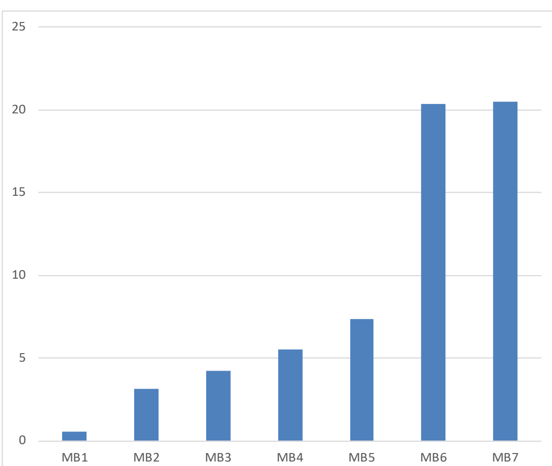
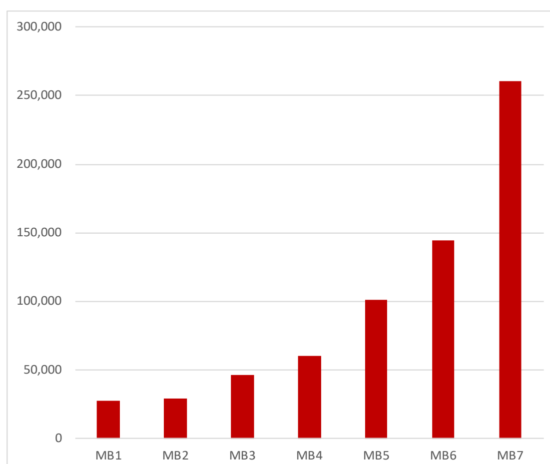


Figure 4. TRU Content (nCi/g)



With the possibility that some of the canisters may not require deep geologic disposal, a portion of the projected inventory of waste glass could be shipped and disposed of off-site at an earlier date. Schedule advantages would be realized as WIPP and LLW facilities are currently operating.

If enough glass canisters could be disposed of in this way before 2029, SRS would avoid the need for additional on-site storage. Furthermore, the difference in disposal costs between a HLW repository and existing disposal facilities for TRU waste and LLW is significant as the cost of siting, characterization, and construction, and initial facility licensing have already been incurred for non-HLW waste forms.

Table 5 summarizes potential cost and schedule savings from this opportunity. The highlighted cost savings reflect the most promising opportunities for the first four MB; namely, that they be considered for emplacement in a potential intermediate-depth facility or emplacement at WIPP (after a permit modification to allow disposal required for both cases). If at least 1,300 canisters could be shipped off-site prior to 2029, additional on-site storage could be avoided, and the time needed for security, surveillance, and maintenance of any waste planned for that facility could be reduced.

Table 5. Comparison of Cost and Schedule for SRS Waste Glass Disposition Alternatives (millions of FY2019 constant dollars[30])

Waste Stream	Disposition Alternative	Storage (additional GWSB)	Transport & Disposal	Cost Savings (comp. to Reference)[30]	Potential Schedule Impacts
MB 1-4	Intermediate-depth facility	-	$160	$2,400	Enables removal of up to 2,311 canisters
	WIPP	-	$900	$1,700	
	HLW Repository (reference)	$60	$2,500	-	
MB 5-7	WIPP	-	$320	$590	Removes an additional 831 canisters earlier
	HLW Repository (reference)	0	$910	-	

-Note: MB=Macrobatch
-Values reported to two significant figures. Due to rounding, costs savings totals may not correspond with the sum and difference of the separate figures

Key cost savings drivers in Table 5 involve:

- Avoidance of third canister storage facility construction due to early disposition of canisters (i.e., removal of at least 1,300 canisters by 2029).
- Lower cost of transportation and disposal in an alternative, existing facility versus a future HLW repository: potential intermediate-depth disposal facility ($70,000/canister) or WIPP ($390,000/canister) relative to an HLW repository ($1,100,000/canister).[31]

[30] The estimated cost savings in escalated dollars are $4.1 billion for MB 1-4 intermediate-depth facility; $3.0 billion for MB-1-4 WIPP; and $1.2 billion for MB 5-7 WIPP.

[31] The analysis assumes that the SRS canisters are RH waste and would be shipped to the alternative disposal facility in a shielded transport cask (e.g., RH-72B cask). For alternative disposal at WIPP, depending on heat

The intermediate-depth facility disposition alternative assumes the facility receives a license amendment from NRC or the Agreement State[32] to accept the canisters. The WIPP alternative assumes NMED approves a permit modification to the WIPP Hazardous Waste Facility Permit to allow tank waste to be disposed at WIPP and that NMED and the EPA approve any needed new waste panels.

Another opportunity is the alternate treatment and disposal method for some of the SRS DWPF recycle wastewater. The DWPF recycle wastewater is currently managed as HLW. This waste stream is currently being transferred to the 2H evaporator system to separate the concentrates (evaporator bottoms) from the condensates (overheads). The concentrates are stored in the tank farm, and the condensates are routed to the ETP facility for further processing prior to release to a permitted outfall. To allow for SRS tank closure, approximately 380,000 gallons of DWPF recycle wastewater need to be diverted outside of the tank farm; however, a specific treatment and disposition path has not been selected. As a demonstration of a potential alternative treatment and disposal at the end of the liquid waste mission life at SRS, DOE disposed of 8 gallons of stabilized (grouted) DWPF recycle wastewater from the SRS H-Area Tank Farm at a commercial LLW facility outside of South Carolina.

INL SBW

Based on preliminary data, the TRU concentration of SBW may be less than 3,000 nCi/g and the specific activity may be less than 0.35 curies per liter. Additionally, the fission product concentrations of SBW, both long- and short-lived, may be well below NRC's Class C concentration limits. As a result, SBW could potentially be demonstrated to not require disposal as HLW and instead be dispositioned in an alternative disposal facility.

Table 6 summarizes potential cost and schedule savings from this opportunity. Removal of SBW from INL could be achieved much sooner than if SBW were required to be emplaced in a HLW repository.

generation and other considerations, the waste could be emplaced either in horizontal boreholes into the disposal room walls or in shielded containers on the disposal room floor similar to contact-handled (CH) waste. WIPP space and associated costs would depend on the type of emplacement (e.g., shielded canisters could require less space and be more cost effective than horizontal boreholes).

[32] An Agreement State is a State that has assumed a portion of NRC's regulatory authority over certain radioactive materials, under Section 274 of the AEA. Any such disposition would be in coordination with, and approval by, the Agreement State.

Table 6. Comparison of Cost and Schedule for-INL SBW Disposition Alternatives (millions of FY 2019 constant dollars[33])

Waste Stream	Disposition Alternative	Treatment, Packaging, & Storage	Transport & Disposal	Cost Savings (comp. to Reference)[33]	Estimated Schedule Impacts
SBW	Near-surface or intermediate-depth facility	-	$48	$710	Removes SBW once facility can accept
	WIPP	-	$270	$490	
	HLW Repository (reference)	-	$760	-	-

-Note: SBW is assumed to be steam reformed and placed into canisters in all cases.
-Values reported to two significant figures. Due to rounding, cost savings totals may not correspond with the sum and difference of the separate figures.

The key cost savings driver in Table 6 involves:

- Lower cost of transportation and disposal in an alternative, existing facility versus a future HLW repository.[34]

The near-surface or intermediate-depth disposition alternative assumes the facility would receive a license amendment from NRC or the Agreement State to accept the canisters. The WIPP alternative assumes NMED would approve a permit modification to the WIPP Hazardous Waste Facility Permit to allow tank waste to be disposed at WIPP.

INL Calcine

Although INL has removed its reprocessing waste from the original liquid waste tanks, 4,400 m^3 of calcine must still be retrieved, potentially stabilized into a HIP waste form, and packaged for off-site disposal. It is possible that an alternative disposal option could avoid the need for costly treatment of the calcine using HIP, a first-of-a-kind technology.

The figures below provide comparisons of important radiological characteristics of the six binsets. Figure 5 compares the radioactivity, in curies per liter, and Figure 6 compares the TRU concentration, in nCi/g, for each binset. This allows some insights into disposition strategies.

[33] The estimated cost savings in escalated dollars are $1.2 billion for near-surface or intermediate-depth facility and $890 million for WIPP.
[34] For INL SBW and calcine, the analysis assumes that the waste is RH and would be shipped to the alternative disposal facility in a shielded transportation cask (e.g., RH-72B cask). For alternative disposal at WIPP, depending on heat generation and other considerations, the waste could be emplaced either in horizontal boreholes into the disposal room walls or in shielded containers on the disposal room floor similar to CH waste. WIPP space and associated costs would depend on the type of emplacement (e.g., shielded canisters could require less space and be more cost effective than horizontal boreholes).

Figure 5. Radioactivity (curies/liter)

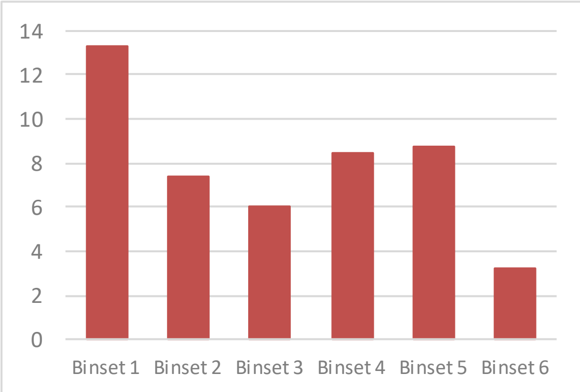
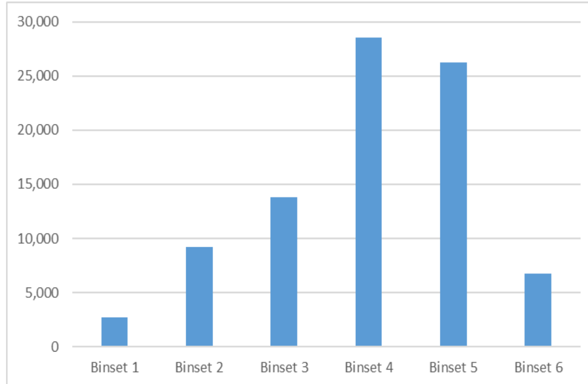


Figure 6. TRU Content (nCi/g)



Based on existing data, the radioactivity concentration of all binsets may be less than 14,000 curies per m^3 (14 curies per liter). TRU concentrations may range from about 2,600 to 28,000 nCi/g and could be the lowest among the two defense sites (SRS and INL) that have completed or are in the process of removing waste from the tanks. Hence it is possible that much of this waste form could be classified as non-HLW and suitable for disposal in an alternative disposal facility. Depending on a specific disposal facility's WAC and license, there may not be a need to further treat the calcine (e.g., the first-of-a-kind technology HIP process may not be required). There may still be a need, however, to treat calcine to address potential RCRA characteristics.

Table 7 summarizes potential cost and schedule savings from this opportunity. There are three alternative scenarios envisioned: all calcine disposed in a near-surface or intermediate-depth disposal facility, split disposal of selective binsets between near-surface/intermediate-depth disposal facility and WIPP (based on TRU concentrations), or all calcine disposed in WIPP. The highlighted cost savings reflect the most promising potential opportunities for calcine; namely, that the 3 binsets (1, 2, and 6) with the lowest TRU concentrated calcine could be emplaced in a LLW facility (once it is approved for disposal) and the 3 binsets (3, 4, and 5) with the highest TRU concentrated calcine could be emplaced in WIPP.

Table 7. Comparison of Cost and Schedule for INL Calcine Disposition Alternatives (millions of FY 2019 constant dollars[35])

Waste Stream	Disposition Alternative	Treatment, Packaging, & Storage	Transport & Disposal	Cost Savings (comp. to Reference)[35]	Estimated Schedule Impacts
All bins	Near-surface or intermediate-depth facility	$740	$360	$8,200	Calcine may be road-ready by 2035 Settlement Agreement milestone
3 bins	Near-surface or intermediate-depth facility	$740	$150	$7,200	
3 bins	WIPP		$1,300		
All bins	WIPP	$740	$2,100	$6,500	
All bins	HLW Repository (reference)	$2,200	$7,100	-	-

-Note: Bins=Binsets
-Calcine is assumed to need further treatment (HIP) only for disposal in a HLW repository. It is assumed to not need further treatment if disposed in an alternative facility.
-Values reported to two significant figures. Due to rounding, cost savings totals may not correspond with the sum and difference of the separate figures.

The key cost savings drivers in Table 7 involve:

- Elimination of HIP treatment process for the near-surface or intermediate-depth and WIPP disposition alternatives, which employ direct disposal of calcine.
- Lower cost of transportation and disposal in an alternative, existing facility versus a future HLW repository: near-surface facility based on lower unit costs for alternative disposition and lower number of canisters produced under direct disposal assumption.

The near-surface or intermediate-depth disposition alternative assumes the facility would receive a license amendment from NRC or the Agreement State[33] to accept the canisters. The WIPP alternative assumes NMED would approve a permit modification to the WIPP Hazardous Waste Facility Permit to allow tank waste to be disposed at WIPP.

Hanford Tank Waste

The WTP LAW vitrification facility is not designed to support treatment of all LAW within the anticipated operating life of the plant, and a supplemental treatment method will be necessary for the remaining LAW (supplemental LAW). The Hanford West LAW disposition path is not yet defined, so off-site shipment of waste is an option, e.g., disposition of appropriate Hanford tank

[35] The estimated cost savings in escalated dollars are $14 billion for near-surface or intermediate depth facility (All bins); $12 billion for near-surface or intermediate-depth facility (3 bins) and WIPP (3 bins); and $11 billion for WIPP (All bins).

waste could be achieved using the Tank-Side Cesium Removal system, if needed, to remove cesium (e.g., to meet transportation requirements) at tank-side. This type of approach, coupled with appropriate treatment and stabilization technologies, could be used for off-site disposition of LAW in West Area in a waste form different than a borosilicate glass matrix.

The requirement that certain LAW from Hanford tanks be vitrified (or use an equivalent technology) to be disposed on-site at IDF makes Hanford the only tank waste site that plans to vitrify LAW tank waste. The most common method worldwide to stabilize LLW is grout. Other sites such as the West Valley Demonstration Project (WVDP) have used grout and disposed of LLW at an off-site disposal facility. Hanford has evaluated grouting the supplemental LAW and has proposed a reference grout mixture specific to site conditions called cast stone; it is expected that other solidification approaches and methods that meet the WAC and underlying performance objectives of the disposal facility would be safe and technically acceptable. Based on existing data, it is possible that most Hanford tank waste could be made into a compliant LLW form and meet disposal requirements for near-surface facilities today.

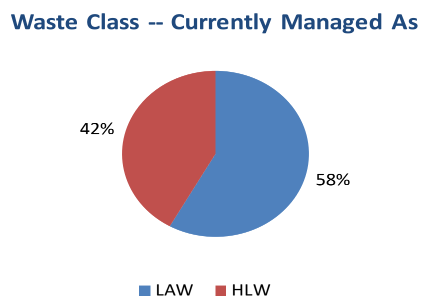
As shown in Figure 7, based on existing data and the assumptions in this evaluation, it is possible that almost 80+% of all Hanford tank wastes could be classified as Class C LLW or lower (assuming current waste characterization data is accurate).[36] In this Figure, "Current Form" refers to the waste as it resides in tanks; "Grout Form" refers to that portion of reprocessing waste that can be made into a Class C (or less) LLW form for disposal.

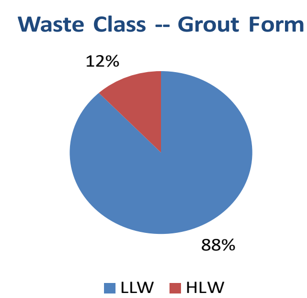
[36] Grout is a proven safe and effective technology that continues to be used by DOE and other national and international parties to stabilize radioactive wastes, including certain tank wastes, for disposal. Use of stabilization agents for this purpose is consistent with the NRC's Concentration Averaging and Encapsulation Branch Technical Position, which allows mixing of nonradioactive constituents with radioactive waste (e.g., solidification, encapsulation, or additives used in thermal processing) provided the mixing has a purpose other than reducing the waste classification, such as waste stabilization or process control.

Figure 7: Hanford Waste Classification

	West	East	Total*
Tanks	79	87	166
Volume (m3)	71,500	118,000	190,000
Activity (MCi)	37	94	131
Currently Managed As			
LAW	17,000	93,100	110,000
HLW	54,500	24,700	79,200
	71,500	118,000	189,000
Waste Class after Grouting (in tank volume)			
LLW	59,000	108,000	167,000
HLW	12,400	10,200	22,600
	71,400	118,000	190,000

* Values exclude 11 TRU Tanks (B-201,B-202,B-203,B-204,T-104,T-110,T-111, T-201,T202,T-203,T204)





-Numbers reported to three significant figures. Total values may not add due to rounding.

In considering wastes projected under the reference case and alternative case for West Area only, Figure 8 compares the final waste form volumes of glass and grout likely to be produced. The alternative case attempts to minimize or eliminate the amount of vitrified LAW canisters planned for supplemental LAW and increase the amount of grouted LLW produced.

Figure 8. Reference Case Compared with the Grout Opportunity (West Area only)

	HLW Glass (m^3)	LAW Glass (m^3)	Grout (m^3)
Reference Case	9,150	216,000	0
Grout West Area	6,750	137,000	371,000

This approach is consistent with the Government Accountability Office (GAO) recommendation (GAO-17-306, May 2017)[37] in that Congress should authorize DOE to classify Hanford's supplemental LAW based on risk and encourage DOE to develop alternative treatment methods for this waste stream. A panel of experts convened by the National Academy of Sciences on behalf of the GAO concluded that both vitrification and grout could likewise effectively treat Hanford's supplemental LAW based on knowledge from more recent studies:

[37] https://www.gao.gov/products/GAO-17-306

> "Experts at GAO's meeting stated that developing updated information on the performance of treating Hanford's supplemental LAW with other methods, such as grout, may enable DOE to consider waste treatment approaches that accelerate DOE's tank waste treatment mission, thereby potentially reducing risks and lifecycle treatment costs" (GAO-17-306, May 2017).

The benefits of reducing cost and schedule are shown in Table 8. The cost savings reflect the difference between the alternative case and two cost estimates of the reference case. The lower of the two estimates (Low Reference Case) is a baseline case of current planned tank waste disposition using Office of River Protection simulation and modeling analysis. The higher of the two estimates (High Reference Case) factors in additional contingency to reflect risks and uncertainties.

Table 8. Comparison of Cost and Schedule for Hanford Tank Waste Disposition Alternatives (millions of escalated dollars)

Waste Stream	Disposition Alternative	Treatment, Packaging, & Storage	Transport & Disposal	Cost Savings (comp. to Reference)	Estimated Schedule Impacts
Low Reference Case					
Tank Waste	West Area Grout with near-surface disposal[1]	$160,000	$24,000	$73,000	Approximately 8 years reduction in estimated duration of operations
	Reference (all vitrification)[2]	$240,000	$20,000	-	-
High Reference Case					
Tank Waste	West Area Grout with near-surface disposal[1]	$340,000	$24,000	$210,000	Approximately 14 years reduction in estimated duration of operations
	Reference (all vitrification)[2]	$560,000	$20,000	-	-

Values reported to two significant figures. Due to rounding, cost savings totals may not correspond with the sum and difference of the separate figures.

[1]In the West Area Grout Alternative approximately 80% of the West tank farm inventory after grouting could be disposed of in a commercial LLW near-surface facility as Class C or less. The remaining 20% of the West tank farm inventory and the entire East tank farm inventory would require vitrification at the WTP and disposal in the Hanford IDF (low-activity fraction) and a HLW repository (high activity fraction).

[2]In the Reference case the entire East and West tank farm inventories would require vitrification at the WTP and disposal in the Hanford IDF (low-activity fraction) and a HLW repository (high activity fraction).

The cost savings shown in Table 8 are ROM estimates primarily driven by:

- Reduction in the estimated number of HLW canisters produced in the 200 West Area Grout Case.
- Reduction in the number of years of operation for the tank waste treatment systems.

- Elimination of the need for supplemental LAW treatment capability/operations.

Further savings could be realized by exploring lower cost alternatives to the planned 7-mile cross-site transfer line; and extension of the risk-based approach to the East Area tank farms.

The West Area grout alternative assumes the grouted tank waste does not exceed concentration limits for Class C LLW and meets the performance objectives for the disposal facility and other applicable WAC. Grouting does not have certain technical risks of high-temperature vitrification, so it can generally be completed sooner at lower cost, and with less secondary wastes. In addition, more LAW grout means that less waste glass would be produced at the LAW facility. The trade-off is that it takes more grout to stabilize a fixed volume of waste than LAW glass. In addition, if less pretreatment of LAW grout is assumed, then there could be less HLW glass produced because more radionuclides could be stabilized in grout.

Such an approach for reducing HLW and LAW glass would need to consider four key factors in addition to existing legal obligations. First, only vitrified LAW glass may presently be disposed on-site. Second, DOE is nearing the date that DFLAW will be operational. DOE is not changing the plan for DFLAW operations. Third, the other facilities at WTP are in various stages of construction and are located to treat the higher radioactivity in East Area tanks. And finally, separate treatment and stabilization in West Area can avoid the need for replacing and/or repairing the seven-mile cross-site transfer line between East and West Areas.

As noted above, only the alternative of using grout in West Area is considered in this analysis. But even with the added cost of shipping grouted waste to an off-site LLW disposal facility, DOE could save significant billions and reduce the cleanup mission by at least a decade.

Other Potential Opportunities

There are a number of other wastes and actions whose disposition path could be evaluated for risk-informed solutions resulting in additional potential cost savings and/or cost avoidance. Such an evaluation could identify other potential opportunities for the Department to reduce risk to public health and the environment while completing its cleanup mission more efficiently and effectively across the sites. Other potential opportunities that may warrant further evaluation include WVDP vitrified canisters, cesium and strontium capsules at Hanford, SRS failed melters, INL electrometallurgical treatment waste, and ion-exchange columns/cartridges used in waste treatment (e.g., cesium removal).

V. Conclusions

The Report concludes that, assuming full compliance with other legal obligations, there are potential opportunities to determine that certain reprocessing wastes are covered defense nuclear waste within the meaning of Section 3139 of NDAA FY 2018. Classifying these reprocessing wastes as non-HLW could potentially realize cost and schedule savings while reducing risk to public health and the environment. Another potential benefit could be following through on long-standing commitments to local and State stakeholders to accelerate the disposition of reprocessing waste and remove many of the barriers presently in place that are keeping these wastes on-site for the foreseeable future.

While this Report identifies potential opportunities for DOE to reduce risk to public health and the environment while completing its cleanup mission more efficiently, the conclusions in the Report are necessarily preliminary in nature. They are based on preliminary existing data that would need to be verified before serving as the basis of any proposed action, and, as discussed further in the Report, there are numerous other steps that would need to occur before any action is taken for a specific waste stream at a specific site. This Report, in Section II under the heading *"General Requirements for All Waste Disposition,"* summarizes the activities that would be needed to implement alternative approaches to disposition reprocessing wastes. Among other activities, successful implementation would require a demonstration that such disposal meets the WAC and any other applicable requirements for that disposal facility and that all necessary approvals had been obtained.[38]

A key requirement of this Report was to evaluate potential cost savings of classifying covered defense nuclear waste as non-HLW. The parametric and scaling approaches utilized in this Report to estimate ROM cost and schedule impacts cannot substitute for the detailed analysis needed to understand all potential operational and capital asset impacts. Despite the uncertainties implicit in ROM cost savings estimates, the preliminary conclusion appears valid – a change in classification of reprocessing wastes could save taxpayers potentially many billions of dollars, accelerate mission completion, and maintain the level of public safety necessary to safely isolate these defense nuclear wastes.

Cost Impacts

There is limited ability to impact treatment of tank waste at SRS. However, there are still potential benefits from consideration of alternate disposition sites based on applying the approach in this Report to treated tank waste from all sites[39]:

- Early batches of vitrified waste from SRS have sufficiently low radionuclide content to be candidates for alternative disposal, i.e., not in a HLW repository, potentially saving approximately $3 billion to $4 billion by eliminating the need to build additional storage capacity and reducing off-site transportation and disposal costs.
- INL calcine waste could also be a key candidate for alternative disposition without HIP treatment, potentially saving approximately $11 billion to $14 billion through avoidance of high-risk treatment and reduced cost of near-term off-site transportation and

[38] In this regard, it should be noted that the disposal of reprocessing waste or tank waste at certain facilities (e.g., WIPP) is currently prohibited regardless of whether such waste is HLW or not.
[39] The estimated cost savings for SRS, INL, and Hanford are in escalated dollars. Tables 5-7 also show the SRS and INL cost savings in constant dollars.

disposal; INL SBW could be a promising candidate to classify as non-HLW with potential cost savings of approximately $890 million to $1.2 billion.

- There could be potentially significant opportunities for cost savings of approximately $73 billion to $210 billion at Hanford, as none of the tank wastes have been treated to date.

Schedule Impacts

The most significant potential benefits are those that could allow for accelerated site closures or area closures within a site, as these would represent the completion of one or more site missions. The schedule impacts noted in this Report, which were based on ROM parametric and scaling methods, could accrue to the Hanford Site for early completion of the tank waste treatment mission with an opportunity to finish years earlier than currently planned. By employing the approach in this Report, it is possible that the mission could finish a decade or more earlier than the reference case, at a potential savings of billions of dollars in Federal appropriations.

The availability of a HLW repository is a key consideration when assessing schedule impacts. The date of availability of a HLW repository would likely have an impact on the schedule that reprocessing wastes remain at generator sites.

Appendix A—What is a Performance Assessment?

In the context of disposal of radioactive waste, a performance assessment[40] is a quantitative evaluation of potential releases of radioactivity from a disposal facility into the environment, and assessment of the resultant radiological doses. The term performance assessment can refer to the process, model, or collection of models used to estimate future doses to human receptors. Typically, a performance assessment is conducted to demonstrate whether a disposal facility has met its performance objectives. In general, a performance assessment considers the following factors:

- Selected scenario: specific features and processes at the disposal facility and in the surrounding area, such as the location of the potential release, location and general characteristics of the receptors, and applicable transport pathways through which radionuclides might reach the environment and pose a threat to the selected receptor groups.
- Performance of the cask or other engineered barrier system used to dispose of the waste, limit the influx of water, and reduce the release of radionuclides.
- Release and migration of radionuclides through the engineered barrier system and geosphere (those deep-underground portions of the disposal facility where human contact is generally not assumed to occur).
- Radiological dose(s) to the human receptor(s).

Because it is not possible for computer models to precisely replicate all conditions of a realistic disposal facility, the Department of Energy and the Nuclear Regulatory Commission (NRC) use abstraction to simplify the information to be considered in a performance assessment. The degree of abstraction normally reflects the need to improve reliability and reduce uncertainty, balanced with other practical considerations (such as making the model and its results easy for people to understand). Nonetheless, it is important for the model to be sufficiently detailed to ensure that it yields valid results for the performance assessment.

Also, while traditional deterministic methods have been sufficient to ensure adequate safety, performance assessments can be more explicitly quantified through probabilistic approaches. In particular, a probabilistic performance assessment considers the risk triplet: "What can go wrong?" "How likely is it?" and "What are the consequences?" Use of performance assessment tools and methodologies aids in applying a risk-informed and performance-based approach to decision-making.

[40] Adapted from NRC's public website: https://www.nrc.gov/about-nrc/regulatory/performance-assessment.html

Appendix B—Disposal Facilities

Commercial Low-Level Waste Disposal Sites

Low-level radioactive waste (LLW) disposal occurs at commercially operated LLW disposal facilities that must be licensed by either Nuclear Regulatory Commission (NRC) or Agreement States. The facilities must be designed, constructed, and operated to meet safety standards and performance objectives. The operator of the facility must also extensively characterize the site on which the facility is located and analyze how the facility will perform for thousands of years into the future.

Licensing Requirements for Land Disposal of Radioactive Waste (10 Code of Federal Regulations (CFR) Part 61)[41] provides stringent requirements to ensure that land disposal of commercial LLW is managed and disposed of in a manner that is protective of worker and public health and safety, and the environment. These NRC licensing requirements place a heavy emphasis on performance assessments as part of NRC or Agreement State licensing. The disposal facilities operate within established and documented operating bases. This approved safe operating envelope requires a documented safety analysis, specific waste acceptance criteria (WAC), and an approved disposal facility performance assessment that ensures compliance with the NRC's or the applicable Agreement State's performance objectives.

Commercial LLW disposal facilities are designed, constructed, and operated under licenses issued by either NRC or an Agreement State, pursuant to Section 274 of the Atomic Energy Act, based on NRC health and safety regulations governing waste disposal quantities, forms, and activity levels (10 CFR Part 61). These regulations establish the procedures, criteria, and terms and conditions for the issuance of licenses for land disposal of LLW. Compliance with four performance objectives, including protection of an inadvertent intruder who intrudes into the waste disposal site after site closure and when institutional controls may no longer be in effect, must be demonstrated by the licensee. In addition, 10 CFR Part 61.55 addresses the classes of LLW. The Low-Level Radioactive Waste Policy Act of 1980, as amended and replaced in 1985, by the Low-Level Radioactive Waste Policy Amendment Act[42], gives the states the responsibility for the disposal of LLW generated within their borders (except for certain waste generated

[41] NRC is currently in the process of amending 10 CFR Part 61. The original rule was issued in 1982. A final rule has not been promulgated as of the time of issuance of this Report.

[42] P.L. 109-58, 42 USC 2021b, *et seq*. That Act amended and replaced the Low-Level Radioactive Policy Act of 1980, P.L. 96-573.

by the Federal Government). The Act authorizes the states to enter into compacts that allow them to dispose of waste at a common disposal facility.

The commercial LLW disposal sites frequently used by the Department of Energy (DOE) are Waste Control Specialists LLC (WCS) and Energy*Solutions* facilities, as described below.

Waste Control Specialists LLC, TX

WCS, near Andrews, Texas: accepts Class A, B, and C LLW from generators within the Texas Compact (Texas and Vermont). LLW from generators outside the Texas Compact is accepted for disposal by approval of the Compact. At this site, WCS also operates the Federal Waste Facility, which accepts certain DOE LLW and mixed low-level radioactive waste (MLLW).

Energy*Solutions*, Clive UT

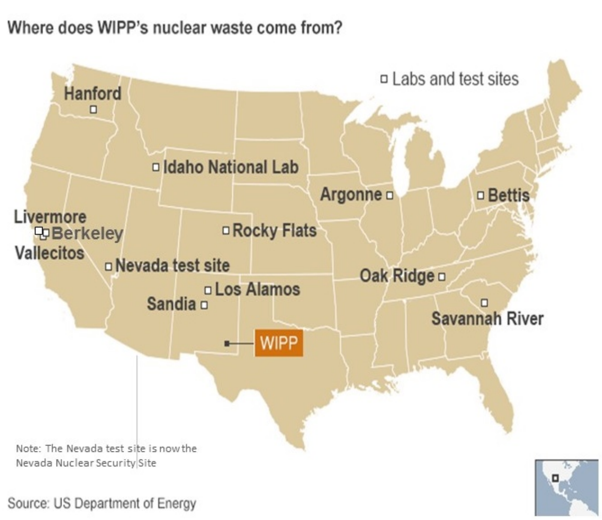
Energy*Solutions* operates a LLW disposal facility, the Clive Disposal Facility, which is licensed by the State of Utah. The Clive Disposal Facility receives Class A LLW and MLLW for disposal from a wide variety of generators, both commercial and federal government.

DOE LLW Disposal Sites

Currently, six DOE sites are operating one or more LLW disposal facilities: the Hanford site, the Idaho National Laboratory (INL), the Nevada National Security Site (NNSS), the Los Alamos National Laboratory, the Oak Ridge Reservation, and the Savannah River Site. Also, the Portsmouth site is near operation. Oak Ridge is designing another LLW disposal facility because the current one is nearing capacity. INL has a remote-handled LLW disposal facility for Office of Nuclear Energy and Naval Nuclear Propulsion Program wastes.

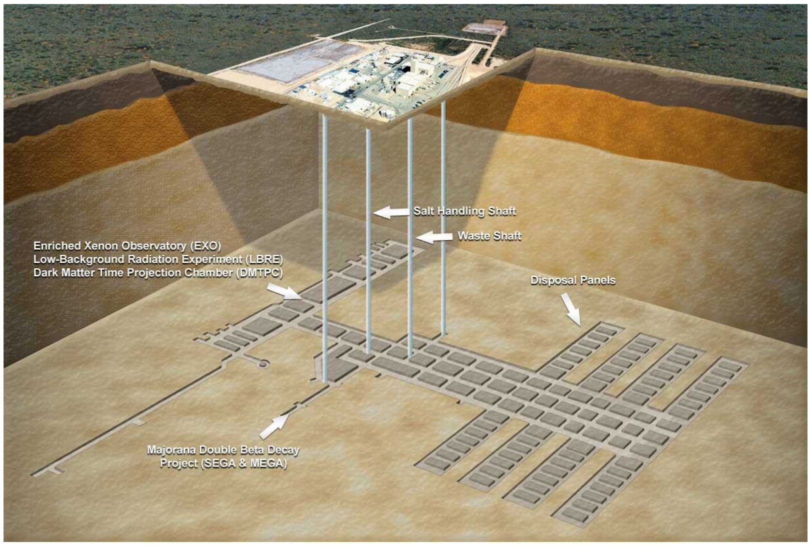
All DOE LLW facilities operate under requirements established by DOE Order 435.1, *Radioactive Waste Management* and DOE Manual 435.1-1, *Radioactive Waste Management Manual*. DOE Manual 435.1-1 establishes the performance assessment (and a composite analysis to address combined sources of radioactivity at DOE sites) as the primary basis for disposal authorizations, and the corresponding performance objectives and performance measures for LLW are generally equivalent to those of NRC. Only one of DOE LLW facilities is presently accepting waste from other DOE sites. The NNSS LLW disposal facility, which includes two disposal cells (one in Area 3 and one in Area 5), is authorized to accept MLLW.

Waste Isolation Pilot Plant (WIPP), NM



WIPP is the only operating geologic repository in the U.S. built to safely and permanently dispose of transuranic (TRU) waste generated by atomic energy defense activities. WIPP began operations on March 26, 1999, after more than 20 years of scientific study, public input, and regulatory review. WIPP is located in southeastern New Mexico, about 80 kilometers from Carlsbad. The repository consists of disposal rooms mined 655 meters underground in a 600-meter thick salt formation. This formation has been stable for more than 200 million years. Approximately 97,745 cubic meters (m^3) of defense-generated TRU waste was emplaced as of April 2020.[43] The disposal limit, as defined in the WIPP Land Withdrawal Act (LWA), is 175,500 m^3.

[43] Of this emplaced waste value, 69,176 m^3 is reported separately by DOE relative to the WIPP LWA volume of record. Information on the most recent WIPP disposal volumes can be found at: https://wipp.energy.gov/shipment-information.asp

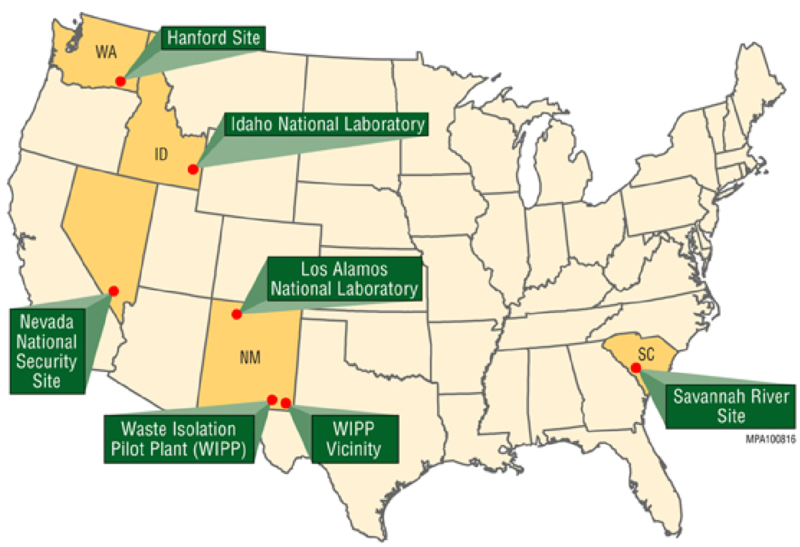


The WIPP WAC does not allow disposal of high-level radioactive waste and spent nuclear fuel, specific tank wastes, nor any TRU waste that was not generated by atomic energy defense activities, consistent with exclusions in the WIPP LWA. WIPP is authorized for disposal of mixed waste.

The WIPP WAC contains technical and performance criteria that would likely be applicable to any waste form considered for disposal at WIPP, including the radiologically based criterion limiting radioactivity concentration of waste forms to 23 curies per liter.

Federal Disposal Facility for Greater Than Class-C (GTCC) LLW

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (as amended) assigns the Federal Government responsibility for disposal of GTCC LLW. GTCC LLW is LLW generated by NRC or Agreement State licensees that has radionuclide concentrations that exceed the concentration limits for disposal as Class C LLW in 10 CFR 61.55.



In the *Final Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste* (DOE/EIS-0375) (Final EIS) issued in February 2016, DOE analyzed disposal of GTCC LLW and "GTCC-like waste," which consists of DOE owned or generated LLW or non-defense TRU waste with characteristics similar to GTCC LLW and has no identified disposal path ("GTCC-like waste" is a term DOE used for purposes of the Final EIS and is not a waste classification). The Final EIS evaluated five alternatives, including four alternative types of disposal, as well as a No Action Alternative. It also considered alternative sites for the various disposal methods. The preferred alternative for the disposal of GTCC LLW and GTCC-like waste identified in the Final EIS is land disposal at generic commercial facilities and/or disposal in the WIPP geologic repository.

DOE submitted a Report to Congress on GTCC LLW disposal alternatives and related implementation considerations, as required by section 631 of the Energy Policy Act, 2005, in November 2017. The Report noted that waste emplacement operations at WIPP are not expected to increase until the 2021 timeframe, and therefore DOE is primarily considering disposal at generic commercial facilities at this time. DOE has not yet made a final decision about which disposal alternative(s) to implement.

Appendix C—Cost Estimate Assumptions

The rough order of magnitude (ROM)[44] cost estimates discussed in this Report are divided into two basic components:

- Front-End: The scope, cost, and schedules developed by each of the sites with tank waste, consistent with current planning assumptions, through front-end disposition of tank waste (i.e., the end of the liquid waste cleanup mission).
- Back-End: Off-site transportation and disposal costs are normalized to estimate a "per-canister" or "per-volume" cost for dispositioning a given waste off-site. Parametric costs (dollars per canister or volume) were developed for all potential disposal facilities considered in this Report; namely, a high-level radioactive waste (HLW) repository, the Waste Isolation Pilot Plant (WIPP) for defense transuranic (TRU) waste and federal and/or commercial near-surface disposal facilities.

Front-end costs incurred at Office of Environmental Management sites to prepare wastes into a final waste form for transportation and disposal generally include the following scope:

- Treatment – activities to mobilize non-liquid waste streams, stabilize liquid wastes, and remove radionuclides if needed. For example, adding water to saltcake allows it to be pumped to an ion exchange column to remove cesium.
- Immobilization or stabilization – activities to solidify waste streams into a form suitable for transportation and disposal. For example, incorporating waste into a solid matrix, such as glass, ceramic, or grout.
- Storage – activities to safely hold a waste on-site until the facilities become available to disposition it off-site. Storage buildings and storage pads are examples of facilities to hold wastes until further actions are needed to disposition them.
- Packaging – removing wastes from storage, placing it into disposable canisters, preparing it for packaging into transportation casks, loading it into the casks, and placing the loaded casks onto transportation conveyances.

Back-end costs would generally be lower on a unit basis as the complexity of the disposal facility is reduced. For example, it is generally expected that costs to dispose of HLW would be greater than for TRU waste, which would also be greater than for low-level radioactive waste (LLW). Some of this advantage for facilities other-than-HLW repositories is due to the existence of disposal facilities for defense TRU waste and LLW. The cost of siting, characterization, and

[44] The Government Accountability Office (GAO) describes a "rough-order-of-magnitude" cost assessment as: Developed when a quick estimate is needed and few details are available. Usually based on historical ratio information, it is typically developed to support what-if analyses and can be developed for a particular phase or portion of an estimate to the entire cost estimate, depending on available data. It is helpful for examining differences in high-level alternatives to see which are the most feasible. Because it is developed from limited data and in a short time, a rough order of magnitude analysis should never be considered a budget-quality cost estimate. *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP, March 2009.

construction, and initial facility licensing have already been incurred for other waste forms (e.g., WIPP development funds prior to operations were expended to provide a disposal capability for existing defense TRU waste), and these cost components are not included in the unit cost estimates for reprocessing waste disposal. With the exception of WIPP, all transportation costs to disposal sites assume shipment by rail, which is generally less expensive than by truck.

For the Hanford West Area tank waste, ROM cost savings are based on the amount of Hanford tank waste meeting Nuclear Regulatory Commission Class C limits in the grout form, the cost of treating and grouting the waste, then shipping it off-site for disposal. The grouting estimate is based on production of cast stone, a durable cementitious grout. No dilution is assumed beyond the minimum needed for grout production.