TASK 3.3: CONSOLIDATED REPORT – APPLICABILITY OF EXHUMATION WORKING GROUP FINDINGS TO WVDP AND WNYNSC

Revision 1

WEST VALLEY DEMONSTRATION PROJECT AND
WESTERN NEW YORK NUCLEAR SERVICE CENTER

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Task 3.3: Consolidated Report – Applicability of Exhumation Working Group Findings to WVDP and WNYNSC

Revision 1

TABLE OF CONTENTS

Page

Contents

Exhibits

Tables

Acronyms and Abbreviations

°C	degrees Celsius
1.2E10	scientific notation for 1.2×10^{10}
ALARA	as low as reasonably achievable
Am	americium
ARP	accelerated retrieval project
AWRS	advanced waste retrieval system
Ba	barium
C	carbon
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CF	cubic feet (also ft^3)
CFR	*Code of Federal Regulations*
CHBWV	CH2MHill/Babcock & Wilcox West Valley Joint Venture
Ci	curie
Ci/m^3	curies per cubic meter
cm	centimeter
CMF	Container Management Facility
Co	cobalt
Cs	cesium
CSEE	confined sluicing end effector
CWF	Compact Waste Facility
CY	cubic yards
DCGL	derived concentration guideline level
DEIS	Draft Environmental Impact Statement (DOE and NYSERDA, 1996)
DOE	United States Department of Energy
ECS	Enviro Compliance Solutions, Inc.
EPRI	Electric Power Research Institute
EXWG	Exhumation Working Group
FEIS	Final Environmental Impact Statement (DOE and NYSERDA, 2010)
ft	feet
ft^3	cubic feet (also CF)
FWF	Federal Waste Disposal Facility
g/cm^3	grams per cubic centimeter
gal	gallon
gpd	gallons per day
gpm	gallons per minute
GPU	General Public Utilities
GSEE	gunite scarifying end effector
GTCC	greater than Class C
HEPA	high efficiency particulate air
HLW	high-level waste

Acronyms and Abbreviations (cont.)

I	iodine
IIF	internals indexing fixture
in.	inch/inches
in./min.	inches per minute
INEL or INL	Idaho National Engineering Laboratory
IX	ion exchange
kg	kilograms
lbs	pounds
LLW	low-level waste
LLW2	liquid low-level waste water
LLWTF	Low-Level Waste Treatment Facility
LSA	low-specific activity
LTF	leachate treatment facility
LWS	lightweight scarifier
m	meter(s)
m^3	cubic meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mCi	millicuries
MeV	mega-electron volt
MLLW	mixed low-level waste
mm	millimeter
mR/hr	milliroentgens per hour
mrem/hr	millirem per hour
MSEE	modular shielded environmental enclosure
NDA	NRC-Licensed Disposal Area
NFS	Nuclear Fuels Services, Inc.
Ni	nickel
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission (also USNRC)
NTF	North Tank Farm
NYSERDA	New York State Energy Research and Development Authority
ORNL	Oak Ridge National Laboratory
PC	performance category
pCi	picocuries
pCi/L	picocuries per liter
PCRV	pre-stressed concrete reactor vessel
PDM	powered dexterous manipulator
PPE	personal protective equipment
psi	pounds per square inch

Acronyms and Abbreviations (cont.)

Pu	plutonium
PUREX	Plutonium Uranium Redox Extraction
R/hr	roentgen per hour
RHWF	remote handled waste facility
Ra	radium
RCRA	Resource Conservation and Recovery Act
RCS	retrieval confinement structure
rem/yr	rem per year
ROD	Record of Decision
SDA	State-Licensed Disposal Area
SEIS	Supplemental Environmental Impact Statement
SME	Subject Matter Expert
Sr	strontium
SREE	silo retrieval end effector
SRS	Savannah River Site
SST	single shell tank
STF	South Tank Farm
STS	supernatant treatment system
SWSA	solid waste storage area
Tc	technetium
THOREX	Thorium Extraction
TMI	Three Mile Island
TRU	transuranic waste
TSCA	Toxic Substances Control Act
TWI	The Welding Institute
U	uranium
uCi	microcuries
URS	URS Corporation
VPU	vertical pipe unit
WCS	Waste Control Specialists
WES	weather enclosure structure
WIPP	Waste Isolation Pilot Plant
WIR	waste incidental to reprocessing
WMA	waste management area
WSMS	Washington Safety Management Solutions LLC
WNYNSC	Western New York Nuclear Service Center
WTF	Waste Tank Farm
WTFWPF	WTF Waste Processing Facility
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Company, Inc.

Executive Summary

A. Purpose and Overview

The West Valley Exhumation Working Group (EXWG) has completed exhumation-related studies under the Enviro Compliance Solutions, Inc. (ECS) contract to perform Phase 1 Studies at the West Valley Demonstration Project (WVDP) and the Western New York Nuclear Service Center (WNYNSC). The objectives of the collective Phase 1 exhumation studies were to enable improved scoping of alternatives for waste exhumation at the WVDP and WNYNSC, to evaluate and potentially reduce the associated uncertainty in related analyses, and to assist the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA) (collectively, the Agencies) in reaching consensus on waste exhumation alternatives that may eventually be selected for final analysis as part of the Phase 2 decision process.

Study 3, one of three areas of study conducted by the EXWG, involved the identification and evaluation of exhumation methods applied at other sites and their potential applicability to waste exhumation at West Valley to supplement those proposed in the Final Environmental Impact Statement (FEIS) (DOE and NYSERDA, 2010). The purpose of Task 3.3, as reported herein, was to consolidate the findings of Study 3 and the overall EXWG's Phase 1 studies into an evaluation of exhumation-related methods and technologies as they apply to specific categories of exhumation scenarios for the State-Licensed Disposal Area (SDA), the U.S. Nuclear Regulatory Commission (NRC)-Licensed Disposal Area (NDA), and the Waste Tank Farm (WTF). In particular, the following processes associated with waste exhumation activities were evaluated and are reported in the identified sections of this document:

- Leachate Management and Treatment (Section III)
- Protective Measures (Section IV)
- Waste Exhumation (Section V)
- Waste Processing (Section VI)
- Interim Waste Storage (Section VII)
- High Level Waste Tanks – All Processes (Section VIII)

One area of focus for the EXWG's work was the study of options for selective waste exhumation to supplement the "Sitewide Removal Alternative" and the "Sitewide Close-in-Place Alternative" addressed in the FEIS (DOE and NYSERDA, 2010). Of particular interest was the evaluation of whether any methods or technologies other than those proposed for the Sitewide Removal Alternative in the FEIS (referred to herein as the FEIS base case) could achieve the project objectives at lower cost without jeopardizing worker and community safety. The latter evaluation was performed with recognition that the FEIS base case was developed to address the full range of waste conditions that could be encountered under the Sitewide Removal Alternative. As such, the FEIS base case represents the most comprehensive, protective, and costly of the options for most processes evaluated. On the other hand, many of the options developed under Study 3, though less costly, are limited in their applicability only to certain selective removal scenarios.

The findings and conclusions of the EXWG's work are presented in this report both for Study 3 alone and for the overall scope of Phase 1 work performed by the EXWG. The Study 3 summary (Section IX) focuses on the comparative evaluation of methods and approaches for each of the exhumation-related processes listed above. The overall work of the EXWG is addressed in Section X within the framework of seven topical questions previously prepared by DOE and NYSERDA to help focus the EXWG on those areas for which further study would facilitate interagency consensus related to exhumation alternatives. Because the Task 3.3 evaluation relies on information gained from other studies previously conducted by the EXWG, the report initially summarizes these related studies and then refers back to them at appropriate points within the various evaluation sections.

B. Study 3: Findings and Conclusions

As mentioned above, the FEIS base case represents the most comprehensive, protective, and costly of almost all options due to its development as a Sitewide Removal Alternative. Based on the findings of Study 3, and as summarized in this section, some options do exist to provide a comparable level of protection at lower cost while retaining applicability across all waste classes under the Sitewide Removal Alternative. Even greater cost savings could be achieved by using other optional methods, but with the limitation that these methods would not apply to high exposure rate conditions.

1. Leachate Management and Treatment

FEIS Base Case: Centralized Treatment Plant for SDA, NDA, and Other Non-WTF Leachate

Option 1: Addition of Portland Cement to Leachate to Form Stabilized Grout

Option 2: Evaporation of Leachate

Summary Discussion: The general conclusion reached by the EXWG is that the FEIS base case is a viable option for the Sitewide Removal Alternative, due primarily to its multiple treatment processes and applicability to the full range of radiological and chemical constituents in the various influent streams. However, based on precedent applications at other sites, both grouting and evaporation are also considered to be capable of treating the constituents in the leachate that would be extracted from the SDA, NDA, and other sources. All three methods can treat the expected volume and flow rate of leachate requiring treatment, with evaporation and grouting more scalable than the centralized treatment plant proposed under the FEIS base case.

The evaporation option, and to a lesser extent the leachate grouting option under low leachate volumes, would provide for significantly lower cost treatment under certain selective removal alternatives. Evaporation would be favored over grouting unless the leachate volume is low due to the complications and high cost of grout disposal. Tritium is most effectively treated under the grouting option. Evaporation would release tritium to the atmosphere without additional treatment, but a release has not been shown to be a public health concern under precedent projects. The issue of tritium treatment remains unresolved under the FEIS base case, as discussed in Section III.

2. Protective Measures

FEIS Base Case: Fixed Outer Enclosure and Modular Inner Enclosure

Option 1: Modular Outer and Inner Enclosures

Option 2: Single Modular Enclosure

***Summary Discussion**:* The proposed use of rigid outer enclosures that would span entire waste disposal areas with modular inner enclosures over individual excavation areas is a prime example of the FEIS base case representing the most comprehensive, protective, and costly of the available options. No precedent project has required this level of robust protection under conditions generally similar to those expected at West Valley. A viable, less costly option used at other sites appears to be available in the form of modular tension-membrane enclosures (Option 1), with improved design technology since the issuance of the FEIS in 2010. The preference for Option 1 would increase under a selective exhumation scenario that targets long-lived radionuclide removal while avoiding trenches of high gamma activity. Consideration of a single enclosure (Option 2) would be feasible only if a selective exhumation scenario would not involve exposure to high doses from short-lived radionuclides, or if the project was delayed until the short-lived radionuclides decayed before removal.

3. Waste Exhumation: SDA and NDA Trenches and NDA Special Holes

FEIS Base Case: Remotely-Operated Crane with Z Mast Attachments

Option 1: Manually-Operated Equipment within Trench

Option 2: Manually-Operated Equipment from Outside of Trench

Summary Discussion: The most significant difference in the options is a move away from remote exhumation using a crane system (FEIS base case) to the use of manually-operated earth-moving equipment (Options 1 and 2). The FEIS base case is the most versatile approach to protect workers across the full range of waste types from the SDA and NDA. Nevertheless, because about 96% of the SDA waste (exclusive of Trench 6) and most, if not all, of the waste in the NDA trenches and Special Holes does not exceed the 50 millirem per hour (mrem/hr) criterion cited in the FEIS for remote operation, the other options should be considered for more extensive application at the NDA and SDA. Both Option 1 and Option 2 represent approaches used at other DOE sites, with further analysis required to determine which of the two approaches would be most applicable for the SDA and NDA given their respective advantages and limitations cited in Section V and summarized in Section IX (Exhibit IX-3).

4. Waste Exhumation: NDA Deep Holes

FEIS Base Case: Remotely-Operated Crane with Z Mast Attachments

Option 1: Waste Grouting and Coring

Summary Discussion: Only one precedent project – the removal of Vertical Pipe Units (VPUs) at DOE's Hanford Reservation – was identified that involved waste removal from units similar to the NDA Deep Holes. Among the various removal methods either considered or actually employed for the VPU project, only one option was considered to be sufficiently applicable to the NDA Deep Holes to be carried through to the Study 3 evaluation. This method involved the in-situ grouting of the waste prior to extracting the grouted mass, versus the FEIS base case under which the waste would be directly extracted using end effectors on the Z mast of a remotely-operated crane. At this point of study, and with a lack of detailed cost information to differentiate the two options, there is nothing that would favor one approach over the other. Both the FEIS base case and Option 1 involve remote operations to protect against worker exposure, while each carries a degree of technical and performance uncertainty. Additional studies, including possibly pilot studies in a non-waste area of the site, would likely be required to determine both the relative applicability of the two methods and their respective costs.

5. Waste Processing

FEIS Base Case: Central Container Management (Waste Processing) Facility (CMF)

Option 1: Localized Waste Processing Facility within Each Exhumation Area

Option 2: Sitewide Waste Processing Facility (Including WTF Waste)

Summary Discussion: The primary difference among the three waste processing options is the degree of consolidation of the operations. The FEIS base case represents a hybrid case between the full separation of waste processing by waste area (Option 1) and the full consolidation of waste processing operations, including WTF waste (Option 2). For reasons cited in Section VI, all three waste processing options are judged to be of comparable cost due to the underlying need to implement the full suite of process technologies regardless of the degree of operational separation. As such, there is no overriding reason to move away from the FEIS base case unless a selective exhumation scenario does not require the full suite of process technologies.

6. Interim Waste Storage

FEIS Base Case: Central Storage within Container Management Facility (CMF)

Option 1: Stand-Alone Interim Storage Area

Option 2: Off-Site Waste Storage and Disposal

Summary Discussion: Only orphan waste with no currently available option for permanent off-site disposal is planned for interim storage at the CMF. This would include Class B and Class C low-level radioactive waste that does not qualify for disposal at a DOE facility, greater than Class C (GTCC) waste, and transuranic waste (TRU). Shifting to a segregated storage facility for orphan waste (Option 1) is highly comparable to the FEIS base case and provides no significant advantage in either applicability or cost other than possibly providing additional flexibility in design as the Phase 2 decision process progresses.

Option 2 is quite different and would take advantage of the availability of an off-site facility (Waste Control Specialists [WCS] in Texas) that was licensed for the disposal of Class B and Class C waste subsequent to the issuance of the FEIS. Use of this facility would allow for the immediate transfer of Class B and Class C waste from West Valley, thus reducing the size requirement for the planned on-site storage facility. On-site storage at the CMF would still be required, albeit at a smaller scale, because the WCS facility cannot accept either the TRU or GTCC waste under its license. The use of the WCS facility by West Valley carries a level of uncertainty because New York is a non-Compact state and there will be a need for continued approval by the Texas Compact Commission to accept the waste and to provide the necessary disposal capacity.

Low specific activity (LSA) and Class A wastes, as well as any mixed waste, represent an estimated 99% of the waste and impacted soil expected to be generated at West Valley. These wastes are assumed under the FEIS base case to be shipped directly to off-site disposal facilities. The possibility exists, however, that the availability of off-site disposal capacity will not keep up with the rate of soil/waste production at West Valley. To address this possibility, the EXWG evaluated a temporary on-site low-level waste (LLW) storage facility that would be separate from the CMF. This facility would be similar to those successfully implemented at several other DOE sites.

7. HLW Tanks: Overall Approach to Tank Waste Removal

FEIS Base Case: Removal Following Tank Roof Removal within WTF Waste Processing Facility

Option 1: Removal of Waste “Through the Risers”

Option 2: Partial Grouting of Bottom of Tanks before Removal

Option 3: Full Grouting of Tanks before Removal

Option 4: Filling Tanks with Water before Removal

Summary Discussion: The five options for the removal of the HLW tanks are best defined as overall approaches that are broadly correlated to how worker protection would be achieved. The comparison of these five options was an exception to the approach used for other exhumation processes because full removal of similar tanks has no precedent at other sites to confirm applicability or to establish comparative costs, and many of the individual technologies have not been applied under conditions similar to those at the WTF. Rather than establishing a prioritization of options, the comparison of the five approaches was limited to the primary advantages and disadvantages/limitations of each option to support the Phase 2 decision process.

Based on the information available at this time, it can be generally concluded that any of the options, when compared to the FEIS base case, represents a trade-off between cost and performance uncertainty, exposure risk, and technical limitations. All options except for the partial grouting option (Option 2) have technical applicability as demonstrated on precedent projects with some level of similarity with the WTF tanks. These options are worth further consideration in the Phase 2 decision process as a balance against the exceptionally high cost of the FEIS base case.

8. HLW Tanks: Individual Technologies

Topic 1: Removal of Tank Contents

Topic 2: Removal of STS Equipment

Topic 3: Removal of Tank Shells

Topic 4: WTF Waste Processing

Summary Discussion: Beyond the comparison of overall approaches to tank removal, the EXWG also addressed individual technologies for four distinct aspects of removing either the tank contents or the tank shells, as listed above. Work on the development of technologies and systems that could be applicable to the HLW tanks has been underway for some time at other DOE sites, universities, and private companies. Considerable uncertainty remains as to which individual technology will eventually be selected for use for the HLW tanks (i.e., the FEIS did not propose a specific system for removal of the sludge/zeolite in the tanks, stating only that such systems exist or were in the development stage, and that an appropriate system would be selected during the detailed design phase). The eventual decision on specific technologies will almost certainly be influenced by the overall approach selected for tank removal, and some degree of technology development and refinement will still be needed regardless of the technologies selected.

C. EXWG Phase 1 Studies: Summary and Conclusions

Throughout the EXWG's work, the Agencies maintained a focus on how any proposed work or study findings contribute to the resolution of seven topical questions posed to the EXWG at the beginning of their work in order to facilitate interagency consensus related to exhumation alternatives. Responses to these questions provide a convenient framework to summarize the consolidated work of the EXWG.

1. Question 1: Selective Removal Alternatives

Question: Can the long-lived inventory in the SDA, NDA, and WTF be somehow selectively removed to reduce the time that these facilities will pose a hazard? If so, at what cost?

Response: Based on the analyses performed for the SDA and NDA under Task 1.3, selective removal of long-lived radionuclides is a viable option that warrants consideration. Various selective removal scenarios for the SDA and NDA were evaluated under Task 1.3, with the results indicating that high percentages of the activity associated with certain targeted radionuclides can be removed through the selective exhumation of comparatively small volumes of the buried waste due to differences in waste disposal patterns. How the move to specific categories of selective exhumation scenarios could affect exhumation-related methods and approaches is addressed in Sections III-VII of this report.

For the WTF, much of the waste is contained within the sludge/zeolite at the bottom of the tanks or within the "bathtub ring" on the sidewall of Tank 8D-2. Therefore, the location of each of these potentially removable items is already well known, and it would not be of value to target specific radionuclides or to determine what percentage of a particular radionuclide would be selectively removed under various scenarios.

2. Question 2: Mining of Waste from Surrounding Soil

Question: If the long-lived inventory cannot be selectively removed from the disposal areas, can the waste be "mined" out of the SDA and NDA while leaving a majority of the surrounding soil in place? If so, at what cost?

Response: The direct answer to this question is that it is not practical to mine waste and leave the narrow (4-foot to 10-foot wide) soil zone that separates the waste trenches in place. The deeper soil zone is in contact with saturated waste and is, therefore, expected to be radiologically impacted. The shallower soil might also require removal in order to slope the sidewalls of the excavation areas for stability, or to establish a lower-elevation platform for removal operations depending on what approach is used for waste exhumation of the trenches. Therefore, it can be assumed that the soil zone between the trenches, as well as any impacted soil adjacent to the outermost trenches and below the trenches, will be removed along with the waste. The FEIS indicates that clean soil from the upper zone above and between trenches can be stockpiled and reused as temporary backfill during trench exhumation.

3. Question 3: Selective Tank Removal

Question: If the long-lived inventory cannot be selectively removed from the tanks, could portions of the tanks be removed while leaving surrounding tank material, or just the vaults, in place? If so, at what cost?

Response: Removal of only the tank contents is a credible approach worthy of consideration to target long-term risk reduction, but complete content removal is likely not achievable without removal of the tank shells due to technology limitations, as discussed in Section VIII. Precedent projects at other sites have targeted only content removal from tanks, but those projects with the highest degree of similarity to the West Valley tanks have not achieved complete removal. Removal of the tank shells separate from the vaults is unprecedented, yet there are viable approaches worth consideration to achieve full removal of both the tank contents and the tank shells.

4. Question 4: Protective Enclosures

Question: Are the robust facilities shown in the FEIS for conducting tank and disposal area removals necessary, or can removals be done using less robust, yet still protective methods, at lower cost?

Response: Required enclosures are highly dependent on a number of factors that will vary with the removal scenario, including the specific waste unit(s) being excavated, the waste type and container, the size of the excavation zone, and the timing of the project as a result of radioactive decay of the short-lived radionuclides. The protective enclosures documented for site-wide removal in the FEIS represent the most robust and costly of the available options. Less robust options have been successfully employed on several precedent projects at other sites, and should be considered for the SDA and NDA, particularly under selective removal scenarios.

5. Question 5: Impacts of Radioactive Decay

Question: Would answers to any of the above questions change if we waited for 30, 60, 90, or 120 years before undertaking the action? For example, could the action go from a remote action to a contact-handled action?

Response: Radioactive decay of the waste inventory over the time periods of interest was evaluated under Task 1.2, with the potential effects on dose under various removal scenarios evaluated as part of Task 1.3. As would be expected, the decay of the short-lived radionuclides in the SDA and NDA would eventually result in dose rates to workers below 2.5 mrem/hr, and allow for contact handling of waste well before a 120-year timeframe. An exception is the NDA Deep Holes, which would likely require remote operations for waste removal even beyond a 120-year timeframe. As developed in this report, there are a number of optional methods that would provide a lower-cost approach than the FEIS base case under low activity conditions. As such, it can be concluded that waiting for the decay of the short-lived radionuclides could significantly lower the cost of waste removal for the SDA and portions of the NDA.

For the WTF, the Task 1.2 report showed that about 500 years would be necessary to allow for “hands on” work to proceed. Therefore, for purposes of this study, only remote operations are considered to be applicable for the HLW tanks.

6. Question 6: Reduction in Uncertainty

Question: With respect to each of these questions, what are the uncertainties associated with estimations of changes in source term and cost given currently available information? Would additional studies likely better quantify and/or reduce these uncertainties? If so, what are these additional studies?

Response: Given that a focus of the Phase I Studies was selective removal as a new alternative that had not been previously addressed in the FEIS, the critical uncertainty in source term was determined to be the reliability of the published waste inventories and the level of confidence that one should have in making decisions regarding selective waste removal based on those inventories. Initial plans to statistically analyze inventory reliability through new field studies as part of Study 2 proved to be infeasible. However, the results of a follow-on geophysics prove-out study provided evidence of general agreement between the geophysical results and the inventory of waste forms in several of the most important trench segments, thus increasing the level of confidence without providing quantification of the uncertainty.

There remains a level of uncertainty as to the applicability and performance of the methods and technologies evaluated in this report under the specific conditions at West

Valley, and additional studies will likely be required prior to full-scale application. Nevertheless, the potential application of the methods and technologies based on precedent projects is sufficiently supported by the information contained in Sections III-VIII to retain the methods and technologies in the Phase 2 decision process.

7. Question 7: Pilot Studies

Question: Are there exhumation uncertainties or data needs that can be addressed only through a pilot exhumation? Would such a pilot exhumation action be feasible and reasonable considering health and safety, worker exposure, waste generation, and cost? Given these considerations, what would be the costs/benefits of a pilot exhumation?

Response: There remains a level of uncertainty regarding inventory reliability that most likely can only be addressed through a pilot exhumation. The cost/benefit aspect of a pilot-scale exhumation may not, however, justify such a study when compared to continued reliance on the published inventories (as somewhat verified by the geophysics study). A pilot study would necessarily require construction of all process elements required for the prototype work, and therefore the cost and required time for such a study will be exceptionally high both in total and per unit volume of waste/activity removed. It must also be recognized that the non-homogeneous nature of the SDA wastes, and to a lesser degree the NDA wastes, would limit the value of any pilot study. That is, a technique shown to be effective at one location may not be applicable 10 or 20 feet down a trench where the waste form and type changes.

The concept of a pilot study could make practical sense if the study takes the form of a selective removal as the first phase of a larger exhumation program. In this case, the pilot study would be used more to refine the exhumation approach than to reduce uncertainty in support of the Phase 2 decision process. Another option would be to perform pilot studies for evaluating the applicability of individual technologies once the technologies are preliminarily selected as part of a broader alternative in the FEIS. These studies would be best performed in clean areas of the site rather than within waste units in order to negate the need for high-cost support operations such as leachate treatment, protective enclosures, and waste processing facilities.

I. Introduction and Background

A. Purpose

The EXWG has completed exhumation-related studies under the ECS contract to perform Phase 1 Studies at the WVDP and the WNYNSC (collectively, the West Valley site). The objectives of the collective Phase 1 exhumation studies were to enable improved scoping of alternatives for waste exhumation at the WVDP and WNYNSC, to evaluate and potentially reduce the associated uncertainty in related analyses, and to assist DOE and NYSERDA (collectively, the Agencies) in reaching consensus on waste exhumation alternatives that may eventually be selected for final analysis as part of the Phase 2 decision process.

Study 3, one of three areas of study conducted by the EXWG, involved the identification and evaluation of exhumation methods applied at other sites and their potential applicability to waste exhumation at West Valley to supplement those proposed in the FEIS (DOE and NYSERDA, 2010). The purpose of Task 3.3, as reported herein, was to consolidate the findings of the EXWG's Phase 1 studies into an evaluation of exhumation-related methods and technologies as they apply to specific categories of exhumation scenarios for the SDA, NDA, and WTF. In particular, a series of potentially applicable methods and technologies for leachate treatment, waste exhumation, waste processing, and interim waste storage are evaluated in this report, including measures to protect workers from radiation exposure during project execution. Because the Task 3.3 evaluation relies on information gained from a number of other studies previously conducted by the EXWG, the report initially summarizes these related studies and references back to them at appropriate points within the evaluation.

The findings and conclusions of the EXWG's work are presented both for Study 3 alone and for the overall scope of Phase 1 work performed by the EXWG. The Study 3 summary focuses on the comparative evaluation of methods and approaches for the exhumation-related processes identified above. The overall work of the EXWG is addressed within the framework of seven topical questions previously prepared by DOE and NYSERDA to help focus the EXWG on those areas for which further study would facilitate interagency consensus related to exhumation alternatives.

B. Scope of Work Performed

The EXWG concentrated its studies on two former waste disposal areas at the West Valley site – the SDA and the NDA – and the WTF. The work performed by the EXWG was guided by a 2015 Study Plan prepared by the EXWG (ECS, 2015), as approved by DOE and NYSERDA. Most elements of the Study Plan were carried out as proposed, whereas some tasks were modified over time based on progressive study findings. The three primary studies completed by the EXWG are described in the following sections.

1. Study 1: Waste Inventory – Analysis and Application

Purpose: One area of focus for the EXWG's work was the study of options for selective waste exhumation to supplement the "Sitewide Removal Alternative" and the "Sitewide

Leave-in-Place Alternative" addressed in the FEIS (DOE and NYSERDA, 2010). The need to consider selective exhumation scenarios placed increased importance on an evaluation of the previously reported waste inventories in the SDA, NDA, and WTF. In response, Study 1 was planned to justify the selection of a particular published waste inventory for use in the Phase 1 studies, to update the selected inventory to account for radioactive decay, and to use the compiled inventory to support an evaluation of various selective exhumation scenarios.

Scope: Study 1 was broken into three tasks corresponding directly to the three study objectives cited above. These included:

- ***Task 1.1:*** A comparative evaluation of all previously published inventory estimates was performed toward the objective of selecting, with technical justification, which published waste inventories would be used by the EXWG for the Phase 1 studies.
- ***Task 1.2:*** The radionuclide inventories for the NDA, SDA, and WTF selected in Task 1.1 were updated to account for radiological decay and build-up since the time of inventory development, and to correct for any waste processing that occurred at the WTF subsequent to inventory development.
- ***Task 1.3:*** The updated waste inventories were evaluated in order to recommend specific locations and volumes of waste materials that should be preferentially exhumed for various target radionuclides in order to support pending decisions by the Agencies related to selective waste exhumation scenarios.

Each task was performed as planned, with a comprehensive Technical Memorandum produced upon completion of each task.

Findings and Conclusions:

- ***Task 1.1***: Based on a comparison of waste inventories in Task 1.1 (ECS, 2016a), it was concluded that the waste inventory presented in URS (2002) provided the best estimate of the SDA inventory for use in the Phase 1 studies, with the exception of the Sr-90 activity. The Sr-90 activity inventory was subsequently revised to specifically include waste shipments from a Martin Marietta facility that had been inadvertently omitted from the URS (2002) inventory. For the NDA, the inventory comparison supported the use of the URS (2000) inventory estimate. Specific concerns previously expressed regarding the NDA plutonium inventory were resolved as part of Task 1.1. For the WTF, it was recommended that the West Valley Nuclear Services Company, Inc. (WVNS) inventory (WVNS, 2005) be used for Tanks 8D-1 and 8D-2, whereas the CH2MHill/Babcock & Wilcox West Valley Joint Venture (CHBWV) inventory (CHBWV, 2012) was recommended for Tank 8D-4.
- ***Task 1.2***: In Task 1.2, the Bateman equation was used to decay each of the selected inventories from the base year of the inventory to a new base year of 2020, as well as to the years 2050, 2080, 2110, and 2140. The latter four years were selected to correspond to approximately four half-lives of Cesium-137 (Cs-137), which

represents the source of highest radiological activity in the short term. In order to maintain consistency with the level of detail presented in the original inventories, the decay calculations were performed by radionuclide for each 50-foot segment of each trench in the SDA, each trench and disposal hole in the NDA, and each tank in the WTF. The results were presented in the Task 1.2 Technical Memorandum (ECS, 2016b) as a series of tables and graphs. The Technical Memorandum also included critical discussions of observations of particular importance to later Phase 1 studies and Phase 2 decision-making.

- ***Task 1.3***: The following three categories of selective exhumation scenarios for the SDA and NDA were analyzed in Task 1.3: exhumation of the 'long-lived' radionuclides; exhumation of GTCC waste; and exhumation of the waste disposal areas most prone to erosion or slope failure. The EXWG also analyzed a trench by trench exhumation scenario for the SDA. Each scenario was defined by an exhumation target (e.g., radiological activity) and an exhumation standard (e.g., 100% of GTCC waste, 75% of all I-129 activity, 90% of transuranic activity, etc.). Consideration was also given to the level of reduction that would be achieved for any co-located higher-activity, short-lived radionuclides upon removal of the long-lived radionuclides specifically targeted under a given exhumation scenario.

  The results for each case were shown in three ways in the Task 1.3 Technical Memorandum (ECS, 2017) – a plot of the percentage of the exhumation target removed as a function of the percentage of total waste volume removed; a table showing the waste volume that would have to be removed to achieve certain exhumation standards; and a color-coded graphic showing an optimized progression of waste units to be exhumed to achieve various exhumation standards for a given target. For most scenarios, particularly for the SDA, it was shown that a high percentage of the targeted radionuclide or group of radionuclides could be removed by exhuming a much smaller percentage of the buried waste.

2. Study 2: Correlation Study – Waste Inventories vs. Field Study Results

Purpose: Although Study 1 generated valuable information from the published inventories, the reliability of the Study 1 results remains dependent on how well the disposal records from which the inventories were derived match what is actually buried in each waste unit. The original purpose of Study 2 was to determine the degree of correlation between the published SDA/NDA inventories and the results of a statistically-designed field investigation of the trench contents. The statistical correlation was intended to provide a quantitative measure of the level of confidence that one would have in predicting the approximate location of specific types of wastes or radionuclides based on the inventories in support of selective exhumation planning. Over time, the scope of Study 2 was modified to include a wider range of tasks and objectives, as discussed in the following paragraphs.

Scope: As with Study 1, three tasks were initially proposed to meet the objectives of Study 2. Task 2.1 was a preparatory step to the field investigation that included: (1) a review of previous radiological surveys to determine their potential value to the planning of the field studies; (2) MicroShield modeling to help determine the positioning of planned boreholes to be used for the downhole measurement of gamma activity from targeted waste disposal areas; and (3) general planning of the overall field program from a statistical standpoint. The scopes of work for Tasks 2.2 and 2.3 were to be the implementation of the field investigation and the statistical evaluation of the data and related reporting, respectively. However, the planned work under Tasks 2.2 and 2.3 had to be aborted after the MicroShield modeling results showed that shielding by the waste forms would prohibit the collection of any meaningful radiation data at distances of more than a few feet from the activity source.

A contingent plan was then initiated for Task 2.2 that involved the use of advanced surface geophysical methods to provide a qualitative line of evidence as to the reliability of the waste form inventory. This would be accomplished by demonstrating a correlation of geophysical anomalies at locations where the published inventories would indicate the presence of distinguishable waste forms (e.g., trench segments with a high density of metal waste or large concrete casks). The original plan was to test various geophysical methods in a prove-out study across a section of the SDA before planning and executing a full-scale study of the SDA and NDA. However, the results of the prove-out study were sufficiently conclusive to qualitatively confirm the reliability of the waste form inventory in those sections of the trenches surveyed. The full-scale geophysical study was, therefore, postponed given funding and scheduling limitations under the ECS contract.

A number of other miscellaneous paper studies were also performed under Study 2 to address certain aspects of the seven topical questions, as for example an evaluation of protective measures based on the worker dose estimates derived in Task 1.3. No reports were issued for these latter studies given their overlap with the Study 3 work; rather, the results have been incorporated into this Task 3.3 Consolidated Report of the EXWG's Phase 1 work.

Findings and Conclusions: The only report generated out of Study 2 was a Technical Memorandum for the geophysical prove-out study (TerranearPMC and ECS, 2017). Based on an interpretative comparison of the geophysical results with the reported waste inventories, a qualitative correlation was observed between the geophysical results and the waste form inventories at the spatial scale of interest – a 50-foot trench segment. Specific examples across the segments of Trenches 1, 3, 4, and 5 selected for the prove-out study included:

- In Trench 1, the geophysical results revealed a high density of drums and other metallic waste containers in the northern portion of the trench segment that compares well with the inventory records. The results then showed a lesser density of metal as one moves south, consistent with the inventory records that indicate a shift to concrete casks as the dominant waste form in the southern portion of the trench segment.

- In Trench 3, the results of the geophysics study across the segment were highly consistent with the characteristics of the reported waste shipments. A single large shipment of metal bins with dry waste from Argonne National Laboratory that was reported to begin in the segment of interest and extend more than 100 feet to the south was evident by the higher level of metallic waste noted near the southern end of the trench segment. The geophysical results from the remainder of the trench segment were consistent with the reported large number of small shipments of various types of metallic and non-metallic waste containers.
- In Trench 4, the single disposal record that was available inhibited the interpretation of geophysical results at a scale less than the full length of the trench segment. Nevertheless, the geophysical results generally revealed large quantities of drums and concrete casks across the Trench 4 segment, which are consistent with the waste forms reported in the one available disposal record.
- In Trench 5, the geophysical results were very consistent with the reported large inventory of drums and other metal containers reported to be disposed within the north and south segments of the prove-out study footprint. On the other hand, the level of metal detection decreased in the middle portion of the trench segment where less metallic waste was disposed according to the inventory records.

While the prove-out study results were consistent with disposal records in terms of waste forms, the geophysical techniques were not able to confirm the reliability of the estimated radionuclide inventory of the SDA. The study also found that Trenches 4 and 5 may be located 6-18 feet west of the locations previously shown on plan views of the SDA.

3. Study 3: Review of Precedent Projects – Application to West Valley

Purpose: The primary purpose of Study 3 was to apply the experiences in exhuming or treating waste disposal areas and tanks at other DOE, commercial, and international sites to help determine: (1) the state-of-practice in exhumation and treatment technologies; (2) methods employed for worker, public, and environmental protection; (3) lessons learned; and (4) what uncertainties were important and how they were addressed. When supplemented by the direct experience of the EXWG Subject Matter Experts (SMEs) on similar projects, these findings were used in Task 3.3 to formulate, at a conceptual level, a number of the most appropriate methods for waste exhumation and/or treatment at the SDA, NDA, and WTF.

Scope: Four tasks were originally proposed under Study 3. Task 3.1 involved a detailed review of precedent waste exhumation projects at seven targeted radiological waste disposal sites expected to have the highest degree of similarity with West Valley. Other sites where conditions were similar to West Valley in only one or a few key areas (e.g., hazardous waste sites that involved exhuming waste under saturated conditions) were reviewed in Task 3.2. Task 3.3 was originally set up for the SMEs to jointly evaluate the applicability of the Tasks 3.1 and 3.2 findings to West Valley, with Task 3.4 reserved for the final report of findings. However, as the work progressed under Tasks 3.1 and 3.2, a decision was made to prepare interim reports of findings upon completion of the corresponding research. As a result of the preparation of these interim reports, as well as for budgetary and schedule reasons, Tasks 3.3 and 3.4 were eventually consolidated into Task 3.3. This Consolidated Report, as prepared under Task 3.3, is the final work product of Study 3 and the EXWG's Phase I studies.

Findings and Conclusions: While fundamental differences exist between the targeted sites and West Valley, several approaches successfully implemented at other sites were determined to be applicable to the West Valley waste units. These are addressed in Sections III – VIII of this report in accordance with the report organization presented below.

C. Report Organization

This *Consolidated Report – Applicability of Exhumation Working Group Findings to WVDP and WNYNSC* is organized generally around the major process components of a waste removal alternative, whether it be full or selective exhumation. As shown in Exhibit I-1, two 'overview' sections are first presented (Sections I and II). The main body of the report then progresses through the exhumation process, from the pre-removal need to provide leachate treatment (Section III) and protective enclosures (Section IV) to the exhumation of the waste (Section V), and finally to waste processing (Section VI) and waste storage (Section VII). Due to its somewhat unique and independent processes, removal of the HLW tanks is addressed in a separate section (Section VIII). Exhibit I-1 also distinguishes between those processes that must be evaluated within the framework of the broader waste exhumation project, and those that are more specific to a given type of waste unit. Each section is described further below.

- ***Section I:*** This introductory section has highlighted the overall purpose and scope of the EXWG's Phase 1 studies, including Task 3.3 being reported herein, and has set the stage for the evaluation of methods and technologies in later sections of the report.
- ***Section II:*** Section II provides an overview of the FEIS base case and the general categories of selective exhumation scenarios that establish the framework for evaluation in Task 3.3. The specific methods and technologies that were selected for evaluation are also identified in Section II.
- ***Sections III-IV and Sections VI-VII:*** In these four sections, various methods and technologies potentially applicable to those processes that are common across the SDA and NDA are evaluated. In each case, the approach proposed in the FEIS is first introduced as a base case against which the optional approaches are compared. Each optional approach is then presented, including a description of the approach, a discussion of any precedent projects that utilized that approach, an evaluation of its applicability and limitations for use at West Valley, and finally a summary of any cost information that is available. Each section is closed out by a comparative evaluation of the optional approaches to the FEIS base case.

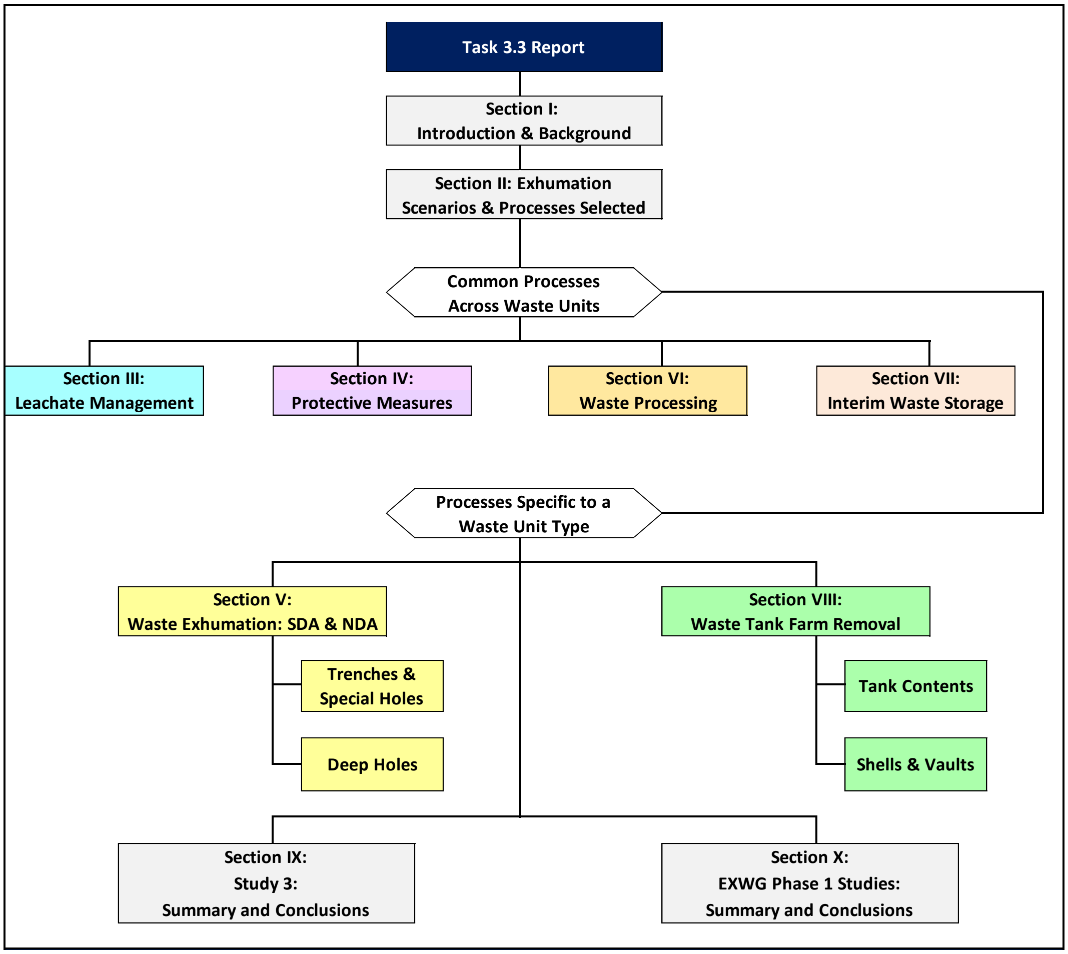

Exhibit I-1: Report Organization

- ***Section V:*** Section V is organized similar to Sections III-IV and VI-VII, with the exception that two different sets of exhumation approaches are addressed within this section. One set of approaches deals with the SDA trenches and the NDA trenches and Special Holes due to their similarity, with a second set of approaches evaluated for the NDA Deep Holes.
- ***Section VIII:*** Section VIII addresses the tank removal scenarios and processes for the WTF, which are different and independent from those considered for the SDA and NDA. All aspects of the tank removal process are presented in detail in Section VIII, with the information throughout this section exclusive to the HLW tanks. The section differentiates between removal of the tank contents, tank shells, and tank vaults due to differences in the corresponding methods and technologies.
- ***Section IX:*** Section IX provides a summary of the Study 3 report contents and the primary conclusions reached by the EXWG regarding methods and technologies related to the waste exhumation process. The section includes a discussion of the methods and technologies most applicable to selective removal scenarios that were not addressed in the FEIS, as well as potential changes to the methods and technologies proposed for the Sitewide Removal Alternative in the FEIS to reduce costs without jeopardizing worker and community safety.

- ***Section X:*** Throughout the EXWG's work, the Agencies have maintained a focus on how any proposed work or study findings contribute to the resolution of seven topical questions in order to facilitate interagency consensus related to exhumation alternatives. In Section X, the seven topical questions are used as the framework for a final discussion of the EXWG's overall Phase 1 work and findings. Responses are provided to each of the seven questions based on the consolidated work of the EXWG.

II. Exhumation Scenarios and Process Options Evaluated

A. Exhumation Scenarios

As indicated above, the primary objective of Task 3.3 was to evaluate exhumation-related methods and technologies as they apply to the SDA, NDA, and WTF. This objective is best met by being able to evaluate the methods and technologies against specific selective exhumation scenarios, which is complicated by the continuum of possible scenarios that could be selected by the Agencies for evaluation in the pending Supplemental Environmental Impact Statement (SEIS). To address this uncertainty for purposes of this report, a number of general selective exhumation scenarios were formulated for analysis based primarily on the findings of Task 1.3, as shown in Exhibit II-1.

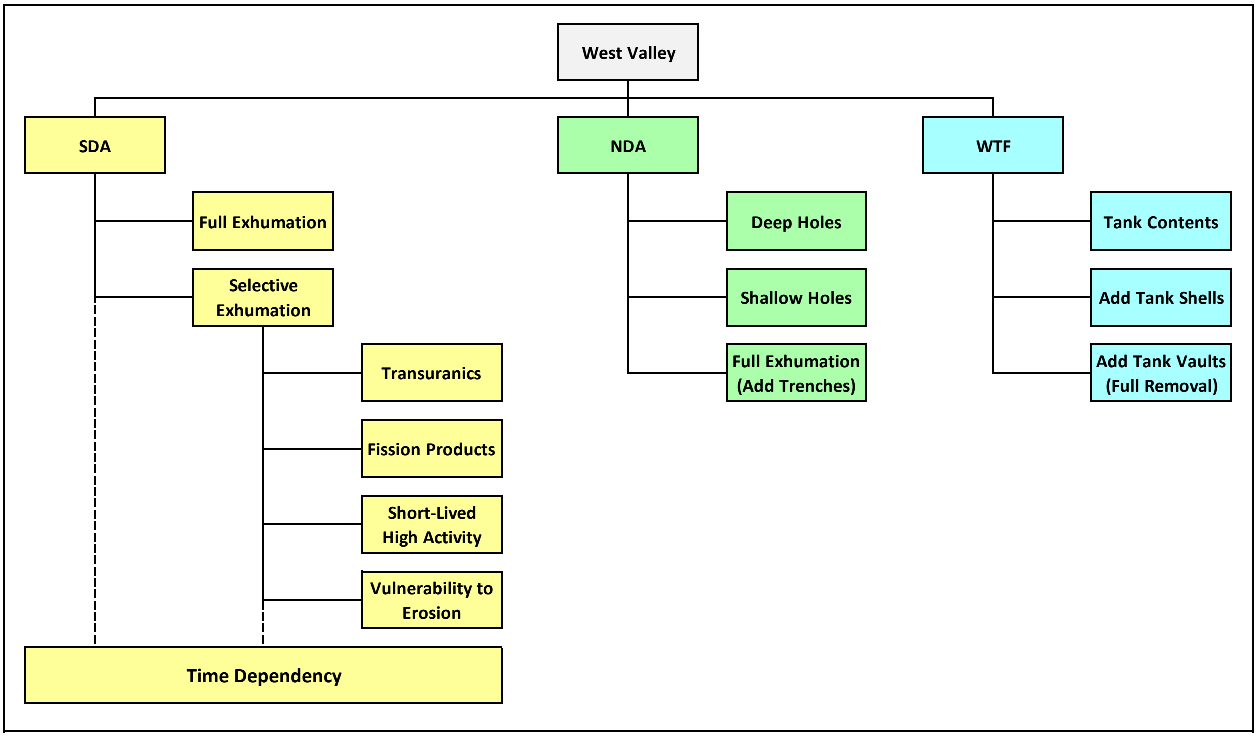

Exhibit II- 1: General Selective Exhumation Scenarios for Evaluation

With reference to Exhibit II-1, the selected scenarios represent a cross-section of the range of selective exhumation scenarios in terms of waste types, radionuclide targets, doses to workers, and spatial scales. These selective exhumation scenarios are in addition to the Sitewide Removal Alternative, as presented in the FEIS, which establishes the base case against which other scenarios are compared. Variations of these scenarios may eventually be selected by the Agencies for future evaluation in the SEIS, but the comparative applicability of the various methods and technologies reported herein should remain valid across the foreseeable range of scenarios eventually selected.

1. State-Licensed Disposal Area Scenarios

Facility Description: The SDA is approximately 15 acres in size and consists of 14 waste disposal trenches (Exhibit II-2). The SDA North Disposal Area includes Trenches 1 through 7, whereas the South Disposal Area includes Trenches 8 through 14. All trenches except Trenches 6 and 7 are of trapezoidal shape, with top and bottom widths of about 35 feet and 20 feet, respectively, and a depth of about 20 feet. These trenches were used to dispose of solid wastes having contact surface readings less than 200 milli-roentgens per hour (mR/hr). Trench 6 is a series of 19 special-purpose holes used to dispose of wastes having contact surface readings of more than 200 mR/hr. These holes are 2 to 6 feet wide, 4 to 12 feet long, and 8 to 12 feet deep. The wastes disposed in these holes consist primarily of irradiated reactor parts. Trench 7 consists of a concrete slab with wastes placed on top of the slab and concrete poured over the wastes to encase them. Trench 7 also contained waste with contact dose rates in excess of 200 mR/hr in sealed metallic containers that had not been solidified in concrete.

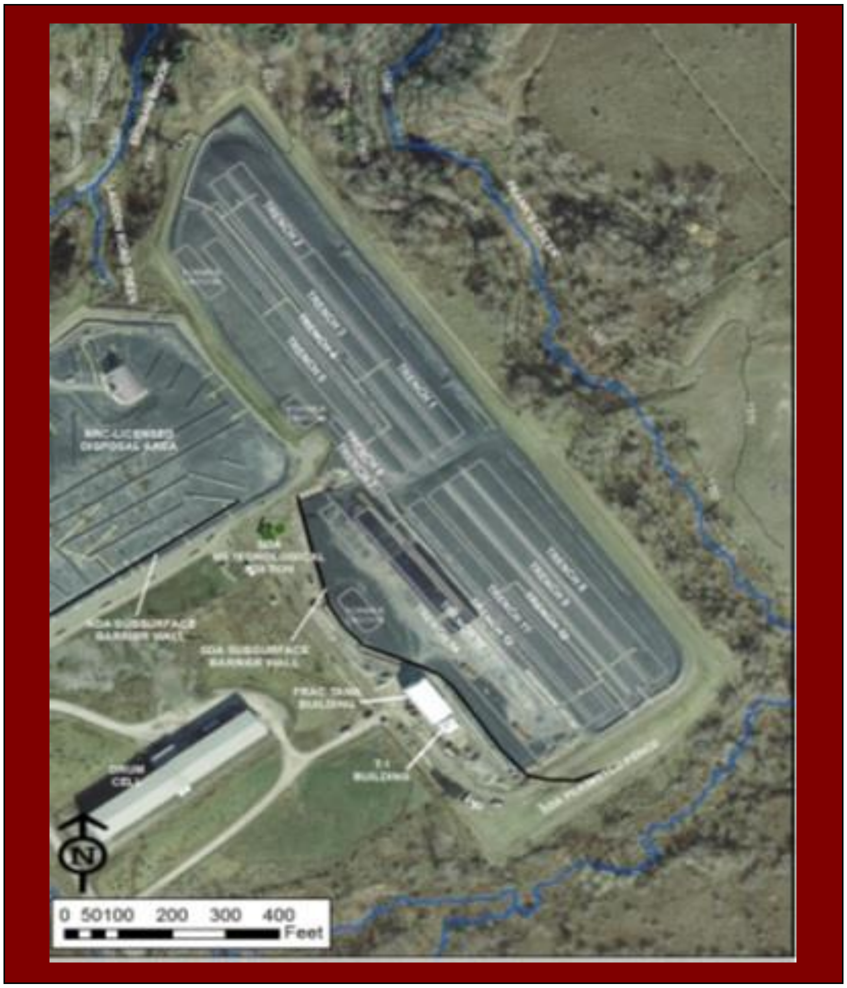

Exhibit II- 2: State Licensed Disposal Area

From 1963 to 1975, low-level radioactive wastes were received at the SDA for burial from the following six types of sources:

- Nuclear power plants
- Institutional and educational facilities and hospitals
- Federal government facilities
- Industrial, pharmaceutical manufacturing, and industrial research facilities
- Nuclear Fuel Services operations at West Valley
- Waste disposal and decontamination companies

The wastes were disposed in their original shipping containers, which included 5-gallon, 30-gallon, and 55-gallon steel drums; wooden crates; cardboard boxes; fiber drums; and plastic bags. Exhibit II-3 is an example of an open SDA trench with waste disposed in 55-gallon metal drums and large wooden boxes.

Exhibit II-3: SDA Waste Disposal - Open Trench Photo

In September 1992, NYSERDA installed a soil-bentonite subsurface barrier wall along the western side of Trench 14 to divert groundwater flow away from the south trenches. In June 1993, the project was completed with the installation of a geomembrane cover extending from the centerline of Trench 12 across Trenches 13, 14, and the barrier wall. In 1995, NYSERDA expanded the use of geomembrane covers at the SDA with the installation of a cover over the remaining trenches. As part of this project, NYSERDA also installed a storm water management system.

FEIS Base Case - Full Exhumation: Under the Sitewide Removal Alternative presented in the FEIS, the waste in the SDA trenches would be exhumed, processed, characterized, repackaged, and either temporarily stored on site or transported to suitable off-site disposal facilities. In addition, the geomembrane cover and the Mixed Waste Storage Facility would be removed. All contaminated soil, sediment, and groundwater in the area would also be removed until derived concentration guideline levels (DCGLs) supporting unrestricted release are met. The individual methods and technologies to achieve full exhumation of the SDA trenches, as presented in the FEIS, are addressed as the base case in Sections III-VII.

Selective Removal Scenarios: As shown in Exhibit II-1, four general categories of selective exhumation scenarios that effectively represent the full range of potential scenarios for the SDA were evaluated in Task 1.3. Two of the four scenarios target the exhumation of a certain category of radionuclides – long-lived radionuclides and GTCC waste. A third scenario evaluated how the trenches would be prioritized for removal if the objective was to reduce total activity at the SDA regardless of the type of waste removed. The removal of those trenches most susceptible to erosion made up the fourth scenario. For purposes of this study, each would typically be associated with exhuming one or more segments of a trench, a single trench, or a limited number of trenches depending on the removal target, and would involve the same process technologies depending on the waste activity and the level of exposure risk.

2. NRC-Licensed Disposal Area Scenarios

Facility Description: The NDA is approximately 8 acres in size and is divisible into the following three areas: the Nuclear Fuel Services (NFS) disposal area, which is comprised of Special Holes and Deep Holes; the WVDP disposal trenches and caissons; and the remaining area occupied by the WVDP NDA Interceptor Trench and the associated liquid pretreatment system. A plan view of the NDA that shows the spatial distribution of the various types of disposal units is provided in Exhibit II-4.

- ***NFS Deep Holes:*** A total of about 6,600 CF of leached cladding from reprocessed fuel, also known as hulls, and non-fuel bearing fuel assembly hardware were disposed in approximately 100 deep disposal holes located in the eastern portion of the NDA. Many of these Deep Holes are 2.7 feet x 6.5 feet in size and 50-70 feet deep. Generally, the hulls are in 30-gallon steel drums, with three drums laid side by side and vertically stacked in the Deep Holes. Three of the 30-gallon drums contain irradiated non-reprocessed New Production Reactor fuel with damaged cladding. These three drums are enclosed in concrete at the bottom of Deep Hole 48.
- ***NFS Special Holes:*** Approximately 136 NFS Special Holes are located in the northern and western portions of the NDA. The Special Holes are, in essence, small trenches about 12 feet wide, 20 to 30 feet deep, and of varying length depending on both the quantity of waste requiring disposal during each disposal event and the dimensions of large waste items, such as failed equipment. Wastes other than leached hulls or related spent nuclear fuel debris were disposed in several types of containers in the NFS Special Holes, including steel drums, wooden crates, and cardboard boxes.

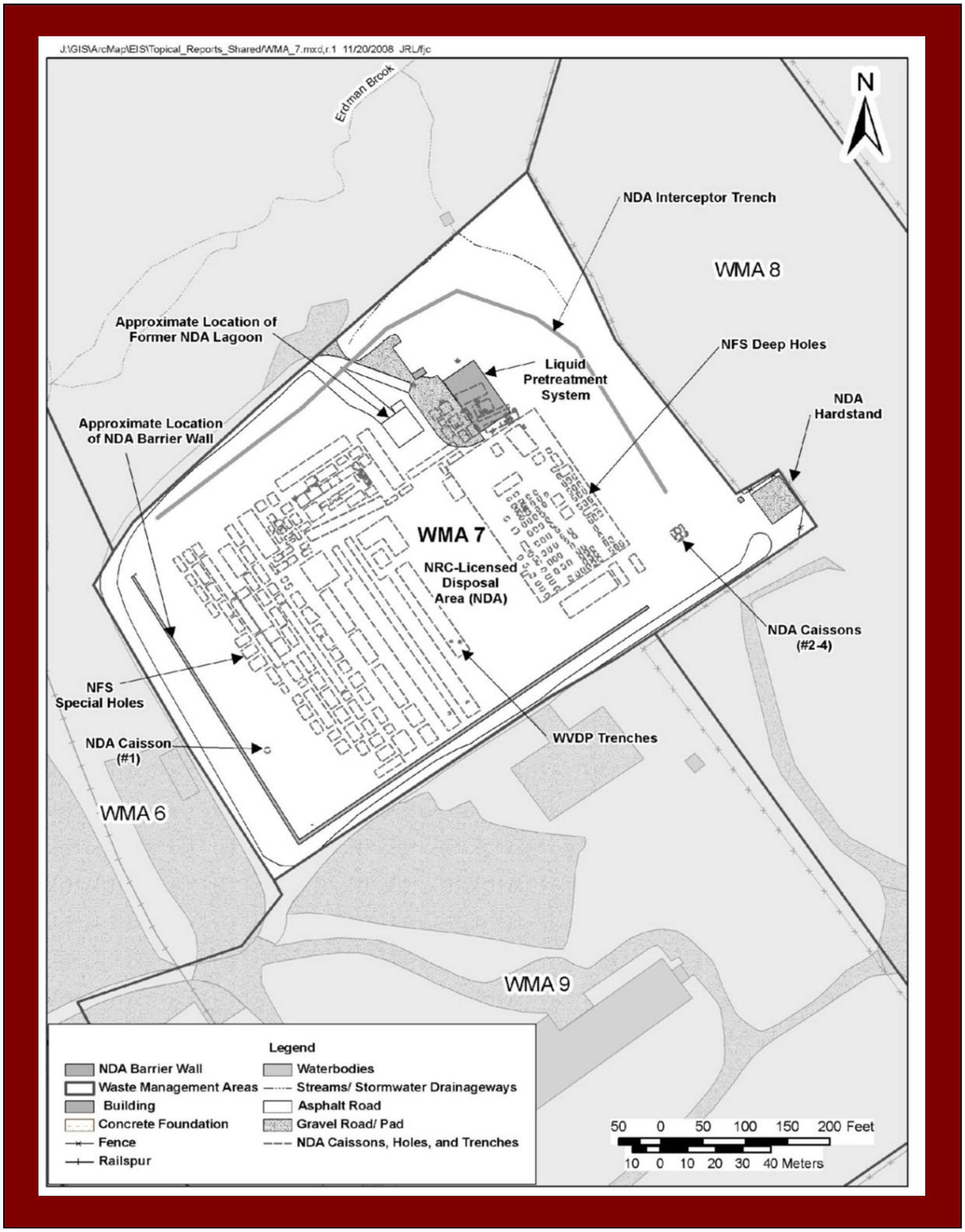

Exhibit II- 4: NRC Licensed Disposal Area

- ***WVDP Trenches:*** Twelve WVDP trenches located in the NDA contain approximately 200,000 CF of low-level radioactive waste resulting from decontamination activities at West Valley. Most of these wastes are located interior to the U-shaped disposal area. The WVDP trenches are typically about 30 feet deep and 15 feet wide. The lengths vary from 30 to 250 feet.

- ***WVDP Caissons:*** Four steel-lined concrete caissons (cylindrical concrete vaults), 7 feet in diameter and 60 feet deep, were constructed near the eastern and southern corners of the NDA. WVDP disposal records indicate that approximately 823 CF of waste in drums were placed in Caisson 1. No disposal records exist to indicate that any waste was placed in the other three caissons. The caissons are plugged with concrete for shielding and are covered with a plastic cap to prevent rainwater infiltration.

As part of the deactivation phase in 2008, infiltration and leachate control measures were implemented at the NDA. This work involved the installation of an upgradient slurry/barrier wall along the southwest and southeast boundaries of the NDA, as well as a groundwater interceptor trench along the northwest and northeast NDA boundaries. A geomembrane cover similar to that installed over the SDA was also installed over the NDA during the deactivation phase.

FEIS Base Case - Full Exhumation: The Sitewide Removal Alternative closure approach for the NDA would include exhumation of all buried wastes in the Deep Holes, Special Holes, trenches, and caissons. The existing liquid pretreatment system and the NDA Interceptor Trench would also be removed, as would the geomembrane cover, the buried leachate transfer line, the former lagoon, and the remaining concrete slabs and gravel pads. All contaminated soil, sediment, and groundwater in the area would be remediated to levels supporting unrestricted release.

Selective Removal Scenarios: As shown in Exhibit II-1, the primary selective exhumation scenarios developed by the EXWG for the NDA are simply the Deep Holes and the Special Holes without the more detailed breakout of individual radionuclide groupings such as those shown for the SDA. The reason is that the findings of Task 1.3 indicate that the activity profile of the NDA waste across either the Deep Holes or the Special Holes is nearly identical, and that the NDA Deep Holes and Special Holes each represent approximately 50% of the total activity in the NDA. The former finding implies that there is little advantage in targeting an individual radionuclide or group of radionuclides for removal; that is, removing one radionuclide or grouping will concomitantly remove an equivalent activity of the others.

Variations in activity do exist from hole to hole, however, even though the waste profiles are similar, which allows for a prioritization of certain Deep Holes and/or Special Holes under a selective removal scenario. As a result, those holes with the highest activity would be targeted for removal first. With an equal distribution of total activity across the Deep Holes and Special Holes, a fundamental question to be answered as part of the Phase 2 decision process is whether it is better to prioritize selective removal of the Deep Holes or the Special Holes, or a combination thereof. Advantages of exhuming the Deep Holes when compared to the Special Holes are the smaller number of holes within a smaller geographic footprint, and a lower soil and waste volume for processing and disposal. Disadvantages are the greater dose rate, the greater depth, and thus the higher unit cost of exhumation.

One argument for prioritizing the Special Holes is the fact that the Deep Holes represent less exposure risk if left in place due to the greater depth of burial. An added advantage of removing the Special Holes is that some of these holes are located in an area of the NDA that is most susceptible to erosion. However, the holes within the area of erosion concern have comparatively less activity and, therefore, a very low removal efficiency rating for exhumation.

A related consideration is the cost-benefit trade-off between removing holes in close proximity to each other (including Special Holes in close proximity to Deep Holes) versus targeting holes of highest activity that may be spread across the entire footprint of the Deep Holes or Special Holes. From a technology standpoint, this boils down to options to remove individual holes (the exact location of which may not be known) versus options to remove larger areas containing multiple adjacent holes. These issues are discussed further Section V, but fundamentally do not affect the evaluation of those alternate waste exhumation options presented herein. Any related decisions will be made by DOE and NYSERDA as part of the Phase 2 decommissioning process.

3. Waste Tank Farm

Facility Description: The WTF area is shown in Exhibit II-5. For this study, the primary components of interest are the four underground HLW storage tanks: 8D-1, 8D-2, 8D-3, and 8D-4. During reprocessing, HLW from the main plant was sent to Tanks 8D-2 and 8D-4. Tank 8D-4 held acidic Thorium Extraction (THOREX) waste produced during Campaign 11, while neutralized Plutonium Uranium Redox Extraction (PUREX) waste from the other campaigns was held in Tank 8D-2. Tank 8D-1 was modified by the WVDP to house the Supernatant Treatment System (STS) components, including ion exchange (IX) columns that contained zeolite and other resins to treat the Tank 8D-2 supernatant and sludge wash solutions. Spent resins from the IX columns were dumped to the bottom of Tank 8D-1 during STS operation, and IX columns filled with spent resin remain suspended in Tank 8D-1. Tank 8D-3 was mostly kept as a spare to Tank 8D-4.

Much of the high-level waste that had been stored in the tanks was removed and vitrified into borosilicate glass in the WVDP Vitrification Facility during the five-year period from 1996 to 2001. In particular, about 98% and >99.9% of the Cs-137 and strontium (Sr)-90 activity, respectively, was removed from the tanks and vitrified. Essentially all the WTF waste is currently contained within the sludge/zeolite at the bottom of the tanks, the ‘bathtub ring’ on the sidewall of Tank 8D-2, and the Tank 8D-1 IX columns.

FEIS Base Case - Full Removal: The Sitewide Removal Alternative for the WTF calls for the removal of all facilities associated with Waste Management Area 3. For purposes of this study, this includes the removal of the contents and shells of Tanks 8D-1, 8D-2, 8D-3, and 8D-4, as well as their associated vaults. All contaminated soil and groundwater would also be remediated to levels supporting unrestricted release.

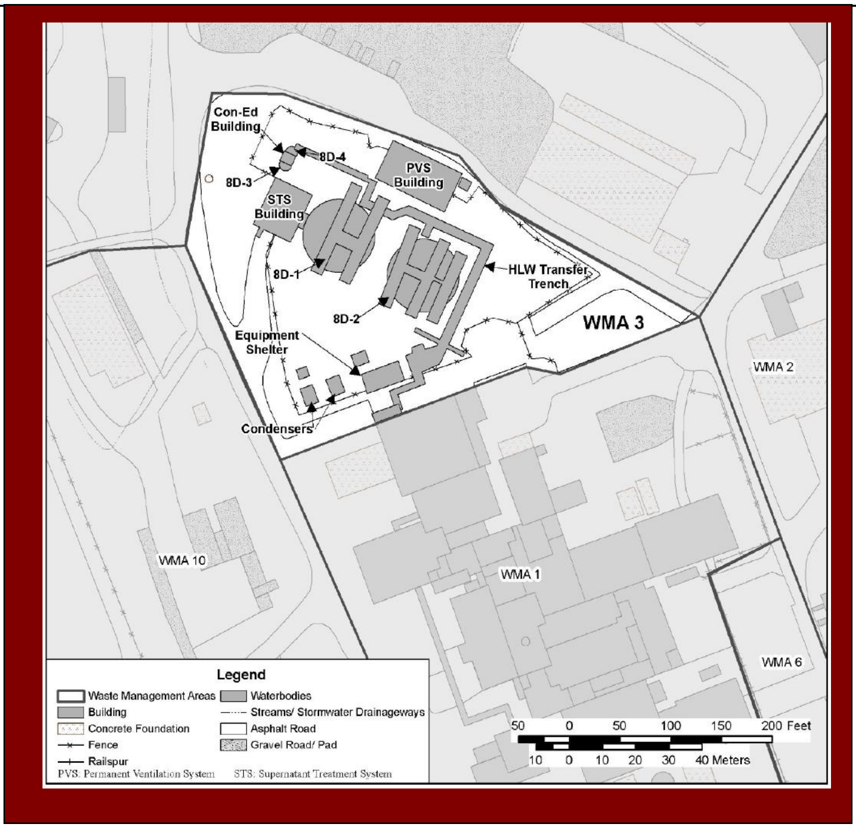

Exhibit II- 5: Waste Tank Farm

Selective Removal Scenarios: As indicated in Exhibit II-1, the selective removal scenarios for the WTF are progressive, starting with the removal of the tank contents only as a source removal scenario for long-term risk reduction. Achieving 100% activity removal under this scenario is unlikely, however, due to limitations of currently available technologies to remotely remove the encrusted 'bathtub' ring materials or the materials located within the complex grid of baffles on the bottom of the tanks. The next scenario in the progression would involve a combination of approaches and technologies that integrates the removal of the tank contents along with the tank shells to achieve a complete source removal scenario. The addition of the tank vaults, which is equivalent to the FEIS base case described above, completes the progression of removal scenarios for the WTF. Additional information on these tank removal scenarios is provided in Section VIII, which addresses the WTF independent of the other sections that focus primarily on the SDA and NDA.

B. Exhumation Processes

The methods and technologies evaluated in Task 3.3 for each waste exhumation process combine certain methods and technologies previously evaluated in the West Valley Draft EIS (DEIS) (DOE and NYSERDA, 1996) and the 2010 FEIS with the findings of Tasks 3.1 and 3.2 and the personal experience of the EXWG SMEs. These methods and technologies are shown in Exhibit II-6, which also identifies the section of this report where the corresponding evaluations are found. As previously discussed in Section I.C, the four processes listed across the middle of Exhibit II-6 support exhumation work at multiple waste units and must be evaluated within the framework of the broader waste exhumation project. The two major categories of processes shown along the bottom of Exhibit II-6 are more specific to a given type of waste unit or grouping of waste units.

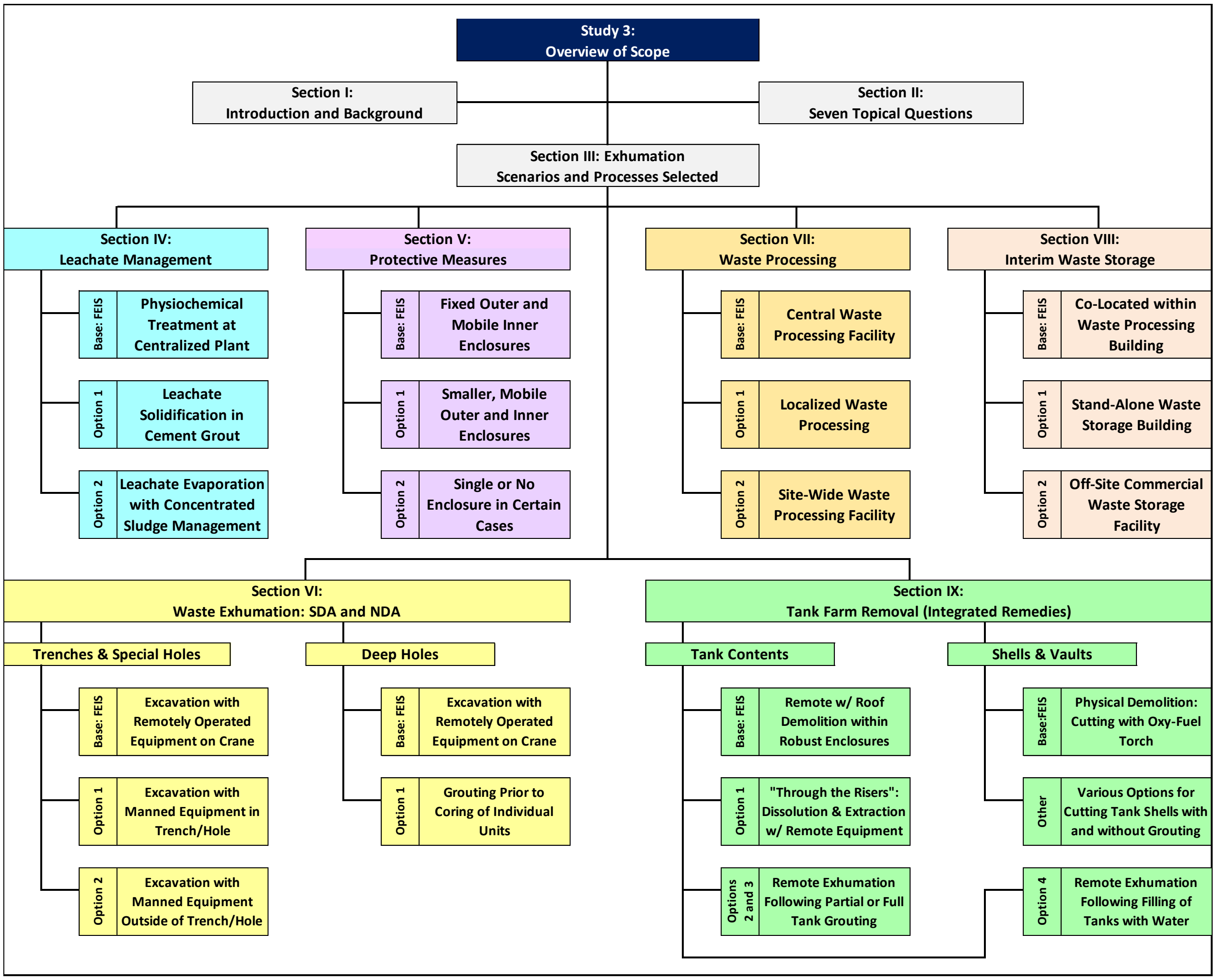

Exhibit II- 6: Methods and Technologies Considered within Framework of Report Organization

In each case, the method or technology proposed in the FEIS is listed first and provides a baseline against which a number of optional methods and technologies are compared. Within the scope analyzed in this study, the FEIS base case represents the most robust and usually the most costly approach to meeting the project objectives, which is at least partially explained by its development within the framework of the full scope of the Sitewide Removal Alternative. A primary purpose of Task 3.3 is to determine if any optional method or technology could improve upon the FEIS approach from a cost-effectiveness standpoint while maintaining the safety of workers and the community, particularly considering the introduction of selective exhumation scenarios that may not demand the same waste treatment, processing, and protection requirements as those of the Sitewide Removal Alternative.

III. Leachate Management and Treatment

A. Summary of Need

The SDA and NDA trenches, as well as the NDA Deep Holes and Special Holes, were excavated into unweathered, low permeability Lavery Till. As a result, a "bath tub" condition exists within the trenches and holes, and water entering the waste units tends to be retained within the more permeable waste materials and backfilled soil. The trapped water is impacted over time due to contact with the contiguous waste materials, forming the so-called "leachate."

The dynamics of water exchange within the SDA and NDA trenches was significantly altered by the installation of impermeable covers, groundwater cutoff walls, collection trenches, and storm water runoff controls over the years. Annual measurements of leachate levels in all but two of the SDA trenches have exhibited a very gradual steady decline since 2006, with observed declines in leachate levels of six inches or less over the 11-year monitoring record (NYSERDA 2016). An approximate six-inch increase has been observed in Trench 1 over the same period, whereas a reversal from a declining trend to an increasing trend occurred in Trench 14 in approximately 2010 and is continuing.

1. Leachate Volumes

It is expected that exhumation of the SDA and NDA trenches and NDA Special Holes will be most effectively performed if the leachate is pumped out prior to initiation of the work, and then managed to retain a "no freely draining pore water" condition during removal operations. The need to extract the leachate prior to waste exhumation in turn requires that leachate treatment be provided. The process technologies discussed in this section represent applicable approaches to leachate treatment at the West Valley Site.

Based on 2015 water level measurements (NYSERDA, 2016) and NYSERDA's estimates of the elevation of the bottom of the trenches, the depth of leachate in the SDA trenches was calculated to range from 0.0 feet in Trenches 3 and 4 to 6.8 feet in Trench 14, with an average depth of 2.5 feet across the 14 trenches. The trench-by-trench values are provided in Table III-1.

Due to uncertainty as to the depth of the trenches and the sloping nature of the trench bottoms to promote drainage, the leachate depths reported in Table III-1 are not exact. They are, however, of sufficient accuracy for purposes of this evaluation of applicable technologies. Based on an assumed average void space (porosity) of 0.3 for the waste materials and backfilled soil, an estimated 1,000,000 gallons of leachate are currently contained in the SDA trenches that would require removal and treatment if all trenches are exhumed (Table III-1). The planned use of sheet piling and protective enclosures is expected to limit water infiltration into the trenches during the period of exhumation.

Trench	Length (Ft)	Width (Ft)	Trench Bottom Elevation (Ft amsl)	March 2015 Leachate Elevation (Ft amsl)	Depth of Leahate (Ft)	Leachate Volume (Gallons)	Time to Remove at 1,000 gpd (Days)	Volume of Grout if Solidified (CY)
1	351	25	1363.7	1365.76	2.06	40,564	41	519
2	351	25	1357.0	1361.03	4.03	79,355	79	1,016
3	698	25	1361.2	1360.40	0.00	0	0	0
4	675	25	1362.8	1362.71	0.00	0	0	0
5	600	25	1359.8	1363.18	3.38	113,771	114	1,456
8	564	25	1360.7	1361.39	0.69	21,832	22	279
9	561	25	1359.2	1360.54	1.34	42,173	42	540
10S	277	25	1357.7	1360.73	3.03	47,085	47	603
10N	277	25	1361.1	1361.63	0.53	8,236	8	105
11	554	25	1358.6	1360.34	1.74	54,078	54	692
12	554	25	1358.2	1361.10	2.90	90,130	90	1,154
13	610	25	1357.5	1363.54	6.04	206,695	207	2,646
14	659	25	1359.2	1366.01	6.81	251,765	252	3,223
N/A	50	25			2.50	7,023	7	90
TOTAL						**955,684**	**956**	**12,233**

Table III-1: Summary of SDA Leachate Volume by Trench

Information on leachate levels in the NDA trenches and holes is lacking. An engineering document prepared in support of the FEIS (URS, 2008a) reports NDA leachate volumes in the range of 1,000,000 gallons, and thus similar to the SDA leachate volume shown in Table III-1. For comparison purposes, an estimated 50,000 gallons of water were removed from NDA Special Holes 10 and 11 over the duration of a 1986 exhumation project to address a release of a mixture of n-dodecane and tributyl phosphate from buried tanks (Blickwedehl et al, 1987). If extrapolated over the entire NDA, this quantity of water would be far in excess of the 1,000,000-gallon estimate. However, the amount of water in Special Holes 10 and 11 at the start of exhumation and the degree of groundwater infiltration during the 1986 tank exhumation were abnormally high due to site conditions at the time, including the fact that the impermeable cover had not yet been installed over the NDA. It would not be appropriate to assume that a comparable volume of leachate would have to be managed during future waste exhumation at the NDA.

2. Regulatory Framework

A primary regulatory concern in relation to leachate treatment is the high level of tritium in the leachate and its final disposition to meet surface water discharge or air emission standards. The concentration of tritium in each trench is quite different. To develop a representative value for purposes of this evaluation, a weighted average tritium concentration was computed based on the volume of leachate in each trench (from Table III-1 above) and the average concentration reported for the corresponding trench in the 1994 Final RFI Report. (The 1994 values are the most recent tritium measurements available until the results of recent leachate sampling by NYSERDA are published.) The resulting weighted average concentration, when corrected for decay to 2020, is 9.2E+07 pCi/L. At the assumed dewatering rate of 1,000 gals/day, this would represent a loading of 0.35 Ci/day (128 Ci/yr) to surface water and/or air if no tritium is removed during treatment.

There is no effluent limit for tritium under the WVDP State Pollutant Discharge Elimination System (SPDES) permit for discharges to surface water. DOE's most appropriate comparative limit is a "Derived Concentration Standard" of 1.9E+06 pCi/L, which is used as a reference value for the application of best available technology per DOE Order 458.1. The New York State water quality standard for Class A waters is 2.0E+04 pCi/L, which is the same as EPA's safe drinking water standard for tritium. Note that the latter two values are surface water and drinking water standards, respectively, and not discharge limits.

The most relevant criterion for air emissions would be DOE's Derived Concentration Standard for tritium in water vapor, with a value of 2.1E+07 uCi/mL (2.1E+07 pCi/m^3). The controlling Federal regulation is NESHAPs, the National Emission Standards for Hazardous Air Pollutants. NESHAPs pertains to the facility as a whole, and requires that emissions of radionuclides to the air must not cause any member of the public to receive an effective dose equivalent of more than 10 mrem in any year. WVDP has recently transitioned to an 'environmental measurement' approach to demonstrate compliance with NESPHAPs, which involves direct monitoring of radionuclide concentrations in ambient air at specified monitoring locations. As such, monitoring of tritium releases from a specific source will likely not be performed.

No specific emission standards for volatile organic compounds (VOCs) at the WVDP were identified. The VOC levels in the leachate are not expected to be a regulatory concern; nevertheless, low-cost treatment options (e.g., activated carbon units) are available if a need is eventually identified.

B. Potentially Applicable Technologies

1. FEIS Base Case: Central Treatment Plant

Description: The Leachate Treatment Facility (LTF) proposed in the FEIS would be constructed as a stand-alone facility near SDA Trench 14. The components of the LTF would be constructed inside of a building intended to provide appropriate shielding between the treatment components and the environment. The LTF would be capable of removing organic chemicals that might be present by biological degradation and adsorption, entrained solids by filtration, and dissolved radionuclides by ion exchange. The FEIS then has the treated water being transferred to the existing Low-Level Waste Treatment Facility (LLWTF) for final treatment and discharge although, as discussed below, the LLWTF is scheduled to be taken out of service as part of the Phase 1 decommissioning work.

The LTF would be operated on demand with a planned process flow rate of 1,000 gallons of leachate per day (gpd) on average. The principal components of the LTF are:

- *Raw (Untreated) Leachate Holding Tank* – A 9,000-gallon leachate holding tank would be installed in a shielded enclosure, separate from the treatment process and the treated leachate storage tanks. Leachate pumped from the holding tank would be filtered using mechanical filtration prior to introduction to the treatment train.
- *Bioreactor* – A bioreactor would be used to treat any organic chemicals in the leachate. The reactor would be operated on a batch basis and would employ aeration with agitation, settling, and decanting. The sludge from the bioreactor would be transferred to a sludge holding tank for processing, packaging, and disposal.
- *Ion Exchange Columns* – The IX columns would remove dissolved radionuclides from the leachate by employing inorganic ion exchange material for the selective removal of the principal radionuclides of concern, as determined from the results of leachate sampling being performed by NYSERDA in 2017.
- *Mechanical Filter* – Decanted leachate from the sludge holding tank would be passed through fine filters to remove entrained solids prior to introduction of the leachate into the activated carbon polisher beds, thereby preventing plugging of the beds.
- *Carbon Polishing Beds* – Activated carbon polishing beds would be used to remove any remaining organic material that was not removed by the bioreactor.
- *Treated Water Storage Tanks* – The effluent from the carbon beds would be directed to a series of treated water storage tanks. The treated leachate in these tanks would be sampled and analyzed before being directed either to the LLWTF lagoons for final treatment and permitted discharge, or back into the LTF for further treatment.
- *Off-Gas Treatment* – Off-gases from the bioreactor would be treated by: (1) mist elimination to remove entrained droplets; (2) heating to reduce the relative humidity for purposes of protecting downstream equipment; (3) high efficiency particulate air (HEPA) filtration to remove radiologically contaminated particulate matter; and (4) carbon adsorption to remove organic vapors. An off-gas blower would keep the process under negative pressure for contamination control.

Precedent Applications: The EXWG found no precedent project that used the FEIS-proposed LTF in a similar application. Nevertheless, the individual process technologies are well-established and have been successfully applied for the removal of solids, organics, and radionuclides on a number of projects. As such, it can be stated that the proposed LTF has been proven in precedent applications.

Summary of Applicability: As presented in the FEIS, the LTF and its individual process components are applicable for the treatment of the range of organic and radionuclide constituents in the SDA and NDA leachate except for tritium. The FEIS alternative does, however, have an allowance for transferring the treated water from the LTF to the LLWTF and lagoons in Waste Management Area 2 for final treatment and discharge, most notably for the dilution of tritium that would not be effectively removed by the LTF. By sending the LTF effluent to the LLWTF, and from there to the lagoons and then presumably to stream discharge, the discharge flow can be augmented in order to keep the tritium effluent concentration below the discharge standard.

Limitations on Use: The LTF represents a robust approach to leachate treatment that provides general applicability to a number of waste units under the full exhumation alternative. However, limitations would exist under expected site conditions. The first involves the planned removal of the LLWTF and lagoons as part of the Phase 1 decommissioning program. Because tritium is not removed by the LTF itself, consideration would have to be given to a contingency plan given that the facilities being planned for tritium dilution will likely no longer exist. An approximate 50-fold dilution of the tritium in the leachate (as estimated based on limited and dated data) would be required to meet the DOE Derived Concentration Standard.

In addition to its potential reliance on the LLWTF, the most significant limitations are the LTF’s lack of mobility, scalability, and flexibility. The fixed location at the SDA could require the transfer of highly contaminated liquid from multiple areas some distance away. The scalability factor is a limitation because uncertainty exists regarding how many and which trenches will eventually be removed and under what schedule and funding profile. The bioreactor in particular requires some level of consistent conditions to maintain the microorganism population.

Depending on which trenches or holes are eventually selected for removal, treatment process selection and design could be affected by the organics and radionuclides specific to the trenches being exhumed. Note in Table III-1, for example, the wide range of leachate volumes that would have to be removed and treated depending on the trenches selected for exhumation. The Task 1.3 Technical Memorandum further demonstrates the differences in radionuclide composition of the waste depending on the selective removal target. By adopting a centralized fixed-base facility, the necessary flexibility to accommodate a variety of “what if” conditions can only be achieved by a conservatively designed multi-process system such as the LTF, with a correspondingly high cost. This limitation is evident if a single trench is targeted for a pilot-scale exhumation in that the full-scale LTF may require construction to service the pilot study.

Cost Considerations: The following estimated costs for the LTF construction, operation, and closure were taken from the *Sitewide Removal Alternative Technical Report* (URS 2009), which was prepared in support of the FEIS:

- LTF Construction: $ 8,084,600
- LTF Operation: $77,669,600
- LTF Closure: $ 3,424,400
- **TOTAL: $89,178,600**

The costs shown above are reported by URS (URS 2009) to be in 2008 dollars, which indicates that inflation was not considered over the 60-year project duration used in the FEIS. Because more than 90% of the total cost is associated with the annual costs of future system operation, the total LTF cost would exceed $200 million in future dollars if a 3% annual inflation rate is accounted for.

2. Option 1: Solidification in Cement Grout

Description: Leachate treatment through solidification within a cement grout would involve the use of leachate as the water additive to Portland cement. Upon adequate mixing of the leachate with Portland cement in cement mixing trucks, the grout slurry would be discharged from the trucks into transport containers, where it would harden and trap the organics and radionuclides that were in the leachate. Based on a previous application at another site (see next section), the following process components would be included. Refinements to these components or to the overall system configuration would occur during final engineering and design.

1. *Leachate Retrieval System:* The leachate retrieval system would consist of submersible pumps to extract leachate from the existing sumps in the SDA trenches, as well as meter boxes and flexible double-contained piping to transport leachate to shielded, double-contained storage tanks. Leachate extraction from the NDA waste units would require system development and implementation, although certain of the removal schemes being considered (e.g., in-situ waste grouting of the Deep Holes prior to removal) may not require leachate removal.

2. *Leachate Storage Facility:* The leachate storage tanks would be located within a shielded storage and processing facility housed in a new or converted building. Each tank would be constructed of stainless steel and sized to provide a minimum of three days of leachate storage based on the operating capacity of the concrete batch plant. A centrifugal pump would be attached to each storage tank to provide leachate recirculation and transfer.

3. *Batch Plant:* Leachate would be transferred from the storage tanks to a batch plant where controlled quantities of Portland cement and leachate would be added to cement trucks to achieve a leachate/cement ratio of approximately 70% by weight. The batch plant would contain a dry cement silo, cement weighing hopper, and equipment to provide the proper mix of cement and leachate for pneumatic transfer

to the cement transit trucks. Mixing of the cement and leachate to form the grout would occur in the trucks.

4. *Grout Disposal:* The final disposal option for the grout would likely be direct transfer from the cement transit trucks to transport containers for curing and off-site disposal.

Precedent Applications: The most prominent example of a precedent application of leachate treatment by grouting is a recent leachate removal project at the Maxey Flats Disposal Site, an inactive commercial LLW disposal facility located in Fleming County, Kentucky. In this case, approximately 821,000 gallons of leachate were extracted from 201 trench sumps and solidified as grout. With reference back to Table III-1, this quantity of leachate is approximately 18% less than the total volume of leachate currently contained in the SDA trenches, but of the same order of magnitude. The main contaminants of concern in the Maxey Flats leachate were tritium (up to 1.2E+10 pCi/L), Sr-90 (up to 2.1E+06 pCi/L), plutonium (Pu)-238 (up to 3.2E+05 pCi/L), and uranium (U)-233 (up to 1.3E+05 pCi/L). Total activity disposed in the Maxey Flats bunkers was approximately 14,000 curies (Ci), almost all of which was due to the tritium in the leachate.

On average, 0.8 CY (160 gals) of grout were produced for every 100 gallons of liquid treated at Maxey Flats, a 160% volume increase. A total of 1,580,000 gallons of grout mixture made up of leachate, process water, bunker water, and cement were disposed as grout in pre-constructed on-site concrete bunkers divided into 112 separate 12 ft x 50 ft partitions. The disposal bunkers were designed to be permanent on-site disposal cells for the grout.

Summary of Applicability: Solidification via cement grouting is applicable and could provide a viable option for the treatment of leachate extracted from the SDA and NDA trenches, particularly under a selective removal scenario involving a lower volume of leachate. The last column in Table III-1 shows the volume of grout that would require disposal to treat the volume of leachate in each trench of the SDA based on the values experienced at Maxey Flats. The reported values are based on the aforementioned 160 gals of grout for every 100 gals of leachate treated, but also reflect an estimated 60% increase in the total volume of liquid treated to account for water used to clean out the cement trucks on a daily basis and other miscellaneous process water (as experienced at Maxey Flats).

When the trench-specific grout volumes in Table III-1 are cross-referenced to the trench segments identified in Task 1.3 as having the highest priority for exhumation, the following observations are made:

1. Most selective exhumation scenarios would allow the exhumation of greater than 80% of the targeted radionuclides while generating only about 2,500 CY of grout.

2. Trench 4, which would have the highest priority for exhumation under most selective exhumation scenarios, has little to no leachate that would require treatment.
3. Trenches 13 and 14, which account for about half of the leachate volume and produced grout associated with the SDA trenches, are not of high priority for exhumation for most selective exhumation targets.
4. Many selective exhumation scenarios would require only removal of certain trench segments rather than entire trenches. Using the average depth of leachate in the SDA trenches, the quantity of grout generated from a single 50-foot trench segment is only 90 CY.
5. Grouting may be particularly applicable for a pilot exhumation study due to the scaling of the leachate storage and transfer facilities that can be accommodated by the grouting approach.

From an activity standpoint, a compilation of data on SDA leachate quality from the 1994 RFI Report indicates that the SDA leachate would have significantly less activity than the leachate successfully treated with grout at Maxey Flats. As with Maxey Flats, more than 99% of the total activity in the SDA leachate is due to tritium. However, the maximum tritium activity in SDA leachate, when decayed to 2020, would be about 30 times less than the 1.2E+10 pCi/L Maxey Flats value. The average SDA tritium concentration would be about 130 times less than the Maxey Flats value. For other radionuclides, the maximum reported activities for the SDA were about the same as or up to an order of magnitude less than the corresponding Maxey Flats values.

The total activity in the SDA leachate at the time of RFI sampling in the late 1980's was approximately 2,000 Ci, compared to the 14,000 Ci value reported for Maxey Flats. Again, because it is driven by tritium that has a relatively short half-life of 12.3 years, the total activity in the SDA leachate today would be much lower. Comparable information on leachate quality is not available for the leachate from the NDA holes and trenches.

From a regulatory compliance standpoint, total measured airborne annual dose equivalents during remedial operations (1997-2003) at Maxey Flats, including the grout bunkers, was 1 mrem/yr compared to the NESHAPs limit of 10 mrem/yr. Tritium accounted for approximately 99 percent of the total dose, and the grout bunkers contributed approximately 97 percent of that dose. There was no indication from the literature that organics were a major concern at Maxey Flats. While a number of organic compounds were found during site leachate testing between 1977 and 1981, it was concluded that trench leachate would pass the ET toxicity test as 'non-toxic' for organics. The only major organics found in groundwater samples from around the Maxey Flats site were fuel-related constituents at low concentrations – benzene (5-96 ppb), toluene (6-9 ppb), and naphthalene (10 ppb).

Limitations on Use: A primary limitation on the use of leachate treatment through solidification at West Valley is the volume of radioactive waste generated as grout. As shown in Table III-1, the full exhumation alternative would generate approximately 12,200 CY of radiological grout from the SDA, and possibly that same volume from the NDA based on the limited information available. To put this volume of grout in perspective, 24,400 CY is equivalent to almost 25% of the total volume of waste in the SDA. The use of grouting for the full exhumation alternative would, therefore, be counter to the DOE/NYSERDA goal of waste minimization. The cost of disposal also becomes a major negative factor when dealing with such large volumes, as discussed in the next section. However, as discussed above, the volume of waste generated may not be a significant decision factor under many selective exhumation scenarios.

A second potential limitation of grouting is the risk that certain radionuclides or hazardous constituents would leach from the concrete matrix over time. However, grouting is a preferred method for stabilizing both hazardous metals and organics, and no component of the leachate would appear to negate the applicability of the grouting option. In general, the radiological and chemical make-up of the leachate is similar to the Maxey Flats leachate to which grouting was successfully applied. Bench-scale testing would, however, have to be performed on various leachate mixes from multiple trenches to more conclusively demonstrate that none of the site-specific contaminants would exceed the leaching standards. Secondary containment provided by the transport cask for off-site disposal would also protect against any release if leaching was to occur from the solidified concrete mass.

Cost Considerations: The reported construction cost of the leachate removal system, storage facility, and bunkers at Maxey Flats was approximately $11,323,000 in 2002 dollars. Leachate removal and disposal operations, which included characterization of the leachate in the storage tanks, cost approximately $15,125,000. Using the total cost of $26,448,000 for leachate removal and disposal operations, the cost per gallon of leachate extracted from the Maxey Flat trenches was approximately $32.00. This unit cost would place the cost of grouting (once inflated to 2008 at an inflation rate of 3%) at about 42% of the LTF cost; however, such a direct comparison is not appropriate unless the grout would be disposed in engineered on-site cells at West Valley such as was the case at Maxey Flats.

The costs for grout disposal at an appropriately licensed facility in Texas were used to evaluate the potential impacts of off-site disposal on project costs. The 2015 tipping fees for ‘routine’ and ‘shielded’ Class A LLW, as regulated by the Texas Commission on Environmental Quality, were $100/CF and $180/CF, respectively. These values do not include the costs of labor, materials, transportation, etc. NUREG-1307, Rev 16 (page 7) indicates that disposal fees make up only about 22% of the total LLW disposal cost. Using this factor along with the tipping fees given above, the total cost of grout disposal (24,400 CY) could be in the range of $300 - $500 million depending on the waste classification. At this rate, the disposal of 24,400 CY of grout from the treatment of SDA and NDA leachate would greatly exceed the cost of the LTF. This indicates that grouting with off-site disposal would not be cost-effective except possibly under a selective removal scenario with far less leachate to treat.

3. Option 2: Evaporation

Description: Leachate treatment by evaporation generally refers to the heating of the liquid stream to vaporize the fluid for volume reduction. The residual, higher activity evaporator concentrates would require further processing prior to disposal. Evaporation units range from small-scale portable units capable of treating up to 1 gallon per minute (gpm), to full-scale truck-mounted units with a typical flow capacity in the range of 50 gpm. Fixed-based industrial units of larger capacity are also available but would exceed the needs of this project. Vapor emission controls may also be required in conjunction with the evaporation unit, although vapor treatment was not required on similar precedent applications of evaporative treatment.

Incineration, which can be considered as a more robust form of thermal treatment, was also evaluated by the EXWG. It was concluded that incineration does not provide a sufficient operational advantage for the removal of radionuclides and metals to justify a much higher cost when compared to evaporation. Even though incineration would destroy volatile organics more fully than evaporation, the concentration of volatile organics is not expected to be high enough to warrant treatment. Even if found to be necessary, air emissions of volatile organics can be controlled by adding an activated carbon vapor unit to the evaporation process at a much lower cost than incineration.

Precedent Applications: Two precedent applications of evaporators for the treatment of radiologically-impacted water demonstrate the viability of this technology. The first is the Maxey Flats site, where an evaporator was operated from 1973 through 1986 as a means of managing large volumes of water infiltrating the disposal trenches prior to placement of an impermeable cover. The evaporator generally operated 24 hours per day over an average of approximately 250 days per year. The evaporator processed more than 6,000,000 gallons of leachate over 13 years (~1,850 gpd on average), leaving behind evaporator concentrates that were stored in on-site aboveground tanks. Evaporator concentrates were eventually disposed in one of the on-site trenches (US EPA, 1991). As discussed above, tritium accounted for most of the activity in the leachate, although long-lived radionuclides were also present.

A second application was the use of an evaporator to treat 2.3 million gallons of stored water contaminated during and after the near-meltdown at Three Mile Island. The evaporation process took nearly two years and was completed in August 1993. The evaporation process at TMI-2 was a multi-step process in which the bottoms from the primary evaporator were treated through a second evaporator unit to achieve further volume reduction. The bottoms from the second evaporator were then processed through a dryer to form solid ‘pellets’ for off-site disposal at a commercial facility.

Summary of Applicability: The successful application of evaporation on similar liquid waste streams at both Maxey Flats and Three-Mile Island without excessive worker or community exposure indicates that the technology is potentially applicable to the West Valley site. Nevertheless, bench-scale or pilot-scale testing of leachate from the SDA and NDA would be recommended to better establish the applicability of evaporation for the treatment of leachate at West Valley. To further demonstrate process applicability, the number of days of evaporative treatment that would be required to treat the leachate from each trench and for the SDA as a whole at a flow-through rate of 1,000 gpd is shown in the next-to-last column in Table III-1. As shown, the number of days is not excessive except for Trenches 13 and 14.

The 1,000 gpd flow rate was selected for three reasons: (1) it matches the treatment rate assumed in the FEIS for the LTF; (2) it is close to (about 50% lower than) the average flow rate successfully treated at Maxey Flats; and (3) it would be within the typical treatment capacity of a small mobile evaporator if operated 24 hours per day. By selecting 1,000 gpd as the basis of this analysis, the same number of days as shown in Table III-1 would be required under the LTF system proposed in the FEIS. Additional treatment time would be required for the NDA leachate and any other liquid waste stream generated as a result of Phase 2 decommissioning activities, but again the same total treatment time would apply under the LTF option. Higher flow rates could be achieved either by operating multiple mobile evaporators or by upgrading to a truck-mounted system. As such, system capacity does not appear to be a limitation on evaporator use.

Limitations on Use: Two potential challenges to evaporator use include the evaporative release of tritium to the atmosphere and the generation of a new waste stream in the form of concentrated sludge. While tritium release can be viewed as a community exposure risk, monitoring results from both Maxey Flats and Three-Mile Island indicated doses far below any established dose limit and within typical background dose levels. For example, during the use of on-site evaporators at Maxey Flats, the concentration of tritium in the air ranged from 240 pCi/m^3 to 3,000 pCi/m^3, which is orders of magnitude below DOE's Derived Concentration Standard of 2.1E+07 pCi/m3. At TMI-2, it was estimated that the maximum radiation exposure that a member of the public might have received from the entire evaporation process was less than one millirem (GPU 1995).

Either solidification or drying of the concentrated sludge would be required prior to storage. There are a number of available transportable LLW treatment systems that can solidify evaporator bottoms. However, because a rotary dryer is already planned as part of the Container Management Facility (CMF) at West Valley due to the likelihood of 'wet' waste being generated from the SDA and NDA (refer to Section VI), it is likely that the bottoms from the evaporator could be introduced into the incoming waste stream for final processing in the CMF. Therefore, the concentration of the radionuclides in the residual liquid and sludge is not a significant limitation in this case.

Cost Considerations: The only cost information found regarding the two precedent projects was a $4 - $6 million cost estimate to treat 2.3 million gallons of radiologically impacted water at Three-Mile Island using evaporation. This would convert to a cost of approximately $2.00 per gallon, which is more than an order of magnitude lower than the cost of the LTF and grouting options. The cost of small mobile evaporator units capable of treating 1,000 gpd is on the order of $100,000, which helps explain the significant cost reduction when compared to the high capital investment required for the LTF and grouting options.

C. Comparison of Options

Of primary interest to Study 3 is the determination of whether any options to the methods and technologies proposed for the Sitewide Removal Alternative in the FEIS could achieve the project objectives at lower cost without jeopardizing worker and community safety. In the case of leachate treatment, all three approaches are generally applicable for the treatment of leachate from the SDA and NDA, although high disposal costs limit the grouting option (Option 1) in terms of the quantity of leachate that can be feasibly treated when compared to the FEIS Base Case and Option 2. The two optional approaches retain more flexibility of operation when compared to the LTF proposed in the FEIS, a factor that increases in importance with the introduction of selective removal scenarios.

Tritium is best treated under the grouting option (Option 1) in that the tritium is bound up in the cement grout rather than being discharged to surface water or air. In comparing the two options that would involve tritium release to the environment, discharging tritium to the atmosphere through evaporation (Option 2) is considered preferable to discharging tritium in liquid discharges to surface waters under the FEIS base case. This is particularly true given the reported low concentrations of tritium in air during the use of evaporation at Maxey Flats and TMI-2. Whereas the LTF (FEIS Base Case) had a provision to further dilute the tritium in the LLWTF and lagoons before discharge, this provision would likely not be available given the plan to take the LLWTF and lagoon system off-line prior to SDA exhumation.

URS (2009) includes a table of waste volumes to be generated during implementation of the Sitewide Removal Alternative. In this table, the LTF is shown to be a primary source of mixed waste due to the presence of organic chemicals in SDA and NDA leachate. The LTF would remove organic chemicals by both biological degradation in a bioreactor and adsorption onto liquid-phase and vapor-phase activated carbon units. Both the sludge produced in the bioreactor and the spent carbon will require disposal as mixed waste. Therefore, in the case of the LTF, mixed waste is being generated by the contamination of treatment media by organic chemicals in the leachate. This would not be the case for the other two options. Under the grouting option, the organic chemicals would become bound in the grout and would not produce a secondary mixed waste stream. In the evaporation process, organic chemicals will either be volatilized or retained in the concentrated sludge, but again will not contribute additional volume to any mixed waste being produced unless it is eventually determined that the volatile emissions will require treatment with vapor-phase carbon.

The most significant drawback of the grouting option is the large volume of cemented grout that is produced and that will require permanent disposal as radioactive waste, a condition that decreases in importance if the grout is disposed on site or if the volume of leachate is significantly reduced under a selective exhumation scenario. The option of evaporation is expected to carry a lower total cost when compared to the LTF.

Although not expected, it is unknown at this point if any contaminant in the SDA or NDA leachate (or any other liquid waste stream) will not be adequately treated or will cause future concerns under the grouting or evaporation option. The similarity in radiological make-up of the SDA and Maxey Flats leachate would indicate that this is not a significant concern. Nevertheless, bench-scale testing of the leachate would be required to more firmly address this concern. Without confirmatory bench-scale testing, there would be more confidence that the multi-component makeup of the LTF will be able to address all constituents in the leachate and other liquid waste streams, but at higher cost.

IV. Protective Measures

A. Summary of Need

As part of Study 2, the EXWG evaluated the need for and types of protective measures to control both external and internal radiation exposures for the employees working to exhume the waste. Controls are also needed to limit the discharge of radioactive materials to the environment. The Study 2 evaluation was designed to differentiate the potential need for multiple types of protective measures, with a focus on the types of environmental enclosures required based on specific waste types, forms, and activities. A range of protective measures was evaluated for the types of needs identified for the SDA and NDA, either as those proposed in the FEIS or adopted at other sites, or variations or supplements to the methods used elsewhere. Specifically, the Study 2 evaluation considered the following elements:

- *Means to Reduce Direct Exposures* – Tasks 1.1 and 1.2 addressed the inventories of the SDA and NDA, and how those inventories would change over time as a result of radiological decay. Task 1.3 used that information to evaluate the potential dose to workers under a number of selective exhumation scenarios. Based on those studies, Cs-137 and cobalt (Co)-60 are present in the wastes in both the NDA and the SDA at levels that pose a potential for elevated external radiation exposures to workers. While shielding provides the most common engineering control for reducing direct exposure risk, administrative approaches such as increasing one’s distance from the waste package or decreasing the amount of time in close proximity to the source of radiation are also important considerations.

  The degree to which protection against external radiation exposure from Cs-137 and Co-60 is needed depends on the threshold dose rate set for contact-handled (vs. remote or shielded) operation, the specific waste units being exhumed, and when the exhumation would take place. The FEIS used a dose rate of 50 mrem/hr as the value above which remote/shielded operations would be required, whereas the EXWG used a value of 2.5 mrem/hr as the threshold value for evaluating enclosure and shielding requirements.[1] The following example of the benefit of waiting for Cs-137 and Co-60 decay before initiating

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[1] The 50 mrem/hr versus 2.5 mrem/hr threshold values represent different assumptions regarding worker exposure in relation to the ultimate standard of concern – the 10 Code of Federal Regulations (CFR) 835 annual dose limit of 5 rem/yr. The basis for the 50 mrem/hr value used in the FEIS is not known to the EXWG, but likely was selected to provide a factor of safety relative to the contact-handled waste criterion of 200 mrem/hr set by DOE under DOE Regulation N435.1, which accounts for a worker being exposed to dose rates up to the threshold value for only a small portion of a year. In other words, because a worker could be exposed to a 50 mrem/hr radiation field for only 100 hours per year before exceeding the 5 rem/yr limit, it is being assumed that the worker would be exposed to lower radiation fields for much of the time in order to extend their hours well beyond 100. This may not be the case, however, for waste exhumation at West Valley given that the project is expected to involve the same group of workers exposed to similar conditions and dose rates on a day-to-day basis over many years. For this case, the EXWG considered 2.5 mrem/hr to be a more appropriate threshold because an unshielded worker could be exposed to dose rates up to the threshold value over a full 2,000 person-hour year without exceeding the 5 rem/yr annual dose limit.

waste exhumation illustrates the importance of this difference in threshold values. Based on the results of Task 1.3 (ECS, 2017), 96% (136 of 141) of the 50-foot SDA trench segments (excluding Trench 6 as a special case) would not exceed the 50 mrem/hr dose limit as of 2020, and could be exhumed without the need for remote operations within special enclosures under the FEIS threshold. On the other hand, only 59% (83 of 141) of the trench segments would meet the 2.5 mrem/hr dose limit adopted by the EXWG. Therefore, to delay waste exhumation until 2080 would have little value under the 50 mrem/hr threshold, but the percentage of trench segments achieving the 2.5 mrem/hr threshold would increase significantly to over 80% by waiting until 2080.

For the NDA, Cs-137 is shown to dominate the source of potential exposure during waste exhumation throughout the time period of interest. Based on the Task 1.2 results, about 79% and 52% of the NDA waste would not require shielding in 2020 based on whole-body dose rate thresholds of 50 mrem/hr and 2.5 mrem/hr, respectively (ECS, 2016b, Exhibit IV-5). If one waited until 2080 to exhume the NDA waste, these percentages would increase to 85% and 76%, respectively. Therefore, there would be marginal benefit to delay NDA exhumation for 60 years. The benefit to be realized decreases beyond 2080 so that, even if one waited until 2140, more than 20% of the NDA would still require shielding relative to the 2.5 mrem/hr threshold (ECS, 2016b).

- *Means to Reduce Internal Exposures* – Internal exposures are reduced by minimizing the ingestion and inhalation pathways of exposure, with inhalation of airborne radioactive materials presenting the greatest risk of internal exposure during waste exhumation. The isotopes of principal concern for internal exposure at the SDA and NDA are the alpha emitting isotopes, including U-238, Pu-239, and americium (Am)-241. The primary method for reducing the potential for internal exposure is the use of containment enclosures equipped with a ventilation system to keep the enclosure at a negative pressure relative to the ambient environment and to filter the air through HEPA filters before discharge. Such enclosures are the primary protective measures addressed in this section.

  Employees working inside the enclosures will also be required to use personal protective equipment, including respiratory protection and disposable coveralls and gloves to limit exposure to the skin and to provide a means for effective decontamination. A control zone at the entrance/exit of the enclosure will provide a means to limit access, to provide radiation monitoring, and to accommodate decontamination of workers and equipment before exiting the enclosure. Remote handling techniques are also effective in reducing internal exposures, and are addressed in other sections of this report.

B. Potentially Applicable Protective Measures

1. FEIS Base Case: Fixed Outer Enclosure Building, Modular Inner Enclosure

Description - SDA: Under the Sitewide Removal Alternative in the FEIS, two outer structures would be constructed to support the exhumation of the SDA trenches (DOE and NYSERDA, 2010). The North SDA Environmental Enclosure would be constructed over Trenches 1 through 7, and would be approximately 760 feet long by 205 feet wide.

The South SDA Environmental Enclosure would cover Trenches 8 through 14, and would be about 710 feet long by 345 feet wide. Both structures would have an eave height of about 35 feet, high enough to allow use of heavy equipment and erection of additional confinement structures within the enclosures. Each environmental enclosure would include a ventilation system with HEPA filtration, a fire protection system, a heating system, electrical lighting, a closed-circuit television system, and a gantry crane system.

The conceptual SDA Environmental Enclosures would be tri-span, steel-framed buildings with 1-foot-thick reinforced concrete exterior walls for structural design purposes and a metal roof with gutters. The perimeter foundations would be placed outside the perimeter of known waste burials. Piles would be driven into the unweathered Lavery Till to a depth of approximately 30 feet in order to stabilize the foundation of each enclosure. Both structures would be designed to withstand natural hazards such as earthquakes, high winds, and snow loading.

Modular Shielded Environmental Enclosures (MSEEs) would also be built inside the SDA Environmental Enclosures. During the excavation and retrieval activities, the MSEEs would provide the primary means to reduce both direct and inhalation exposures to workers, as well as confinement for radiological and hazardous material releases that are expected. Each MSEE would be designed to accommodate remote excavation using cranes as well as waste retrieval and maintenance operations. Each would be of modular design, with individual modular panels locked together to provide an airtight enclosure. The enclosures would be maintained under negative pressure using a HEPA-filtered ventilation system, and would be equipped with a fire suppression system. The cranes would be installed on the inside of these enclosures, so no roof penetrations would be necessary.

Each MSEE would be configured to fit specific SDA trenches based on the perimeter of each trench, and would be reused for one or two additional trenches of similar size. For example, Trench 3, with a length of approximately 700 feet and a width of about 33 feet, would have a perimeter of almost 1,500 feet. Based on this perimeter, a total of 76 shielded wall panels (20 feet each) and 36 roof panels (20 feet by 40 feet) would be needed. This same enclosure would then be disassembled and rebuilt for Trenches 1 and 2. Overall, seven MSEEs are planned for use for the 14 SDA trenches.

Description – NDA: A single structure, called the NDA Environmental Enclosure, would be constructed over all Deep Holes, Special Holes, and WVDP Trenches 1 through 7 at the NDA. It would be designed as a Performance Category 3 structure (as defined by DOE Standard 1020-2002) and would involve substantial walls and roof to withstand design-basis natural hazards such as earthquakes, high winds, and snow loading.

The conceptual NDA Environmental Enclosure would be a single-span, steel-framed building with 1-foot-thick reinforced concrete exterior walls and a metal roof. The foundations would be placed outside the perimeter of known waste burials. A perimeter barrier wall and French drain would be installed to provide groundwater control during the project. The enclosure would be large enough to allow use of heavy equipment and erection of localized confinement structures within it. The ventilation air discharge would be HEPA-filtered to limit the release of airborne radionuclides to the atmosphere. Fire protection equipment, a heating system and insulation, electrical lighting, a closed-circuit television system, and a gantry crane system would also be included to support the work.

As with the SDA, MSEEs would also be installed inside the NDA Environmental Enclosure to control airborne emissions, shield against high-radiation fields, and permit exhumation of wastes from holes up to 55 feet deep. The MSEEs would be designed to allow remote control of excavation, retrieval, and maintenance operations. The wall panels of the modular structure would be approximately 10 feet wide and 20 feet high and would be constructed with a steel frame around the perimeter of the planned excavation. The roof panels would be approximately 10 feet wide and would come in three lengths – 10 feet, 20 feet, and 40 feet – suitable to cover holes or trenches of different size. Each MSEE would be used numerous times prior to being replaced. The conceptual design included in the Sitewide Removal Alternative calls for six structures, two of each size.

The NDA MSEEs would employ a Z-mast crane system operating from the outside of the enclosure. The crane mast would penetrate through a boot in the top of the modular enclosure. Supplemental shielding for external radiation exposure would be accomplished using a core of lead brick shielding (2 inches thick) installed from the bottom of the wall (ground level) to a height of 8 feet to provide shielding for the workers on the ground around the perimeter of the MSEE. The lead core would be held in place by steel sheeting on the inner and outer surfaces of the lead brick core. The roof panels would not be shielded. Several of the MSEEs would have apparatus attached for ventilation systems, shield window atriums, and glovebox panels or equipment and waste container passages. The NDA MSEEs would also be equipped with a soil handling workstation and a material handling workstation.

Precedent Applications: The use of dual enclosure systems with internal shielding to support the exhumation of radiological wastes has precedents at other DOE sites. However, the engineering design features being proposed under the FEIS base case are generally more robust than what have been used at other sites. These differences are addressed as part of the optional approaches in later sections.

Summary of Applicability: The system of protective measures presented in the FEIS provides for both the direct and internal exposure controls being sought, with the dual enclosure providing a level of redundancy for the protection of both workers and the community/environment. The fixed design of the outer enclosure is most applicable to the full removal alternative based on the assumed condition that all waste units across the footprint of the SDA and NDA would be exhumed within the fixed enclosures, with the modular enclosures providing a degree of mobility and flexibility at a more local level of a single waste unit.

Limitations on Use: There is nothing that would limit the use of the dual enclosure system presented in the FEIS, even under a selective exhumation scenario. The question in this case is one of cost, as reflected in the fourth of the seven topical questions posed by DOE and NYSERDA to the EXWG; that is, "… are the robust environmental enclosures presented in the FEIS necessary, or can removals be done using less robust, yet still protective methods, at lower cost?" Precedent projects at other sites would indicate that the FEIS base case is a highly conservative design and that more cost-effective options have had demonstrated success under similar conditions. This is addressed under Option 1 below.

Cost Considerations: An engineering cost estimate for the fixed outer environmental enclosures for the SDA and NDA was prepared in support of the FEIS (URS 2009). The estimated costs for the construction and demolition of the NDA and SDA enclosures are as follows:

NDA Environmental Enclosure – Construction	$ 41,014,500
NDA Environmental Enclosure – Demolition:	$ 77,225,500
South SDA Environmental Enclosure – Construction:	$ 76,028,300
South SDA Environmental Enclosure – Demolition:	$148,236,100
North SDA Environmental Enclosure – Construction:	$ 52,552,300
North SDA Environmental Enclosure – Demolition:	$109,629,600
Total Estimated Cost:	**$504,686,300**

In addition to the costs shown above, the estimated construction costs for the NDA and SDA MSEEs are $64,366,500 and $220,048,100, respectively (URS 2009, Table 3-18). These are not included in the above totals in order to allow for a more direct cost comparison with the modular outer enclosures that make up Option 1 (see next section). The costs of demolition for the MSEEs are not separately reported, but rather are incorporated into the estimated costs for SDA and NDA waste exhumation.

The high demolition costs for the outer enclosures can be attributed to the assumption that the enclosures would have to be processed and disposed as low-level radioactive waste. The reported costs are in 2008 dollars. Inflating those costs to the new base year of 2020 at an average annual inflation rate of 3% would result in a total estimated cost of approximately $700 million. Adding in the costs for the construction and eventual demolition and disposal of 13 MSEEs for the SDA and NDA would push the total cost of the environmental enclosures in 2020 dollars (with 3% inflation) to over $1.0 billion.

2. Option 1: Modular Outer and Inner Environmental Enclosures

Description: The first option to be evaluated is similar in concept to the FEIS base case in that dual environmental enclosures would be employed at both the SDA and NDA. Smaller inner enclosures would be erected over single trenches or localized groups of holes to provide a first line of worker protection, with larger outer enclosures serving primarily to control the external spread of contaminants through redundant air filtration and negative pressure systems, ingress/egress control, and personnel monitoring. Under this option, however, the major change would be the use of modular structures of varying size in place of the fixed NDA, SDA South, and SDA North Environmental Enclosures. For purposes of this discussion, a tension-membrane structure similar to those described in the next section will be presumed, although alternate designs could satisfy the intent of Option 1. The inner MSEEs are assumed to be generally the same under both the FEIS base case and Option 1, and thus are not addressed in this section.

Precedent Applications: The use of large modular structures for waste exhumation projects is common across the DOE complex. Three precedent applications of waste exhumation under large modular tension-membrane structures of different types are included in this and the next section. One project at Idaho National Engineering Laboratory (INEL or INL) involved both an outer membrane enclosure and an inner control structure, and is most appropriate for inclusion in this discussion of Option 1. A second precedent application at INL represents a hybrid situation in which there was no inner structure comparable to the MSEE, but instead various smaller structures (airlocks) were constructed within the main enclosure for special remote waste handling operations. This is the first project described in this section, even though it could be argued that the situation has more similarity to the use of a single enclosure being addressed as Option 2. The third precedent project was performed at Oak Ridge National Laboratory (ORNL) and employed only a modular tension-membrane structure without any interior control structure. This project is included in the Option 2 discussion in the next section.

1. ***Idaho National Laboratory Accelerated Retrieval Projects:*** A series of accelerated retrieval projects (ARPs) have been conducted at INL beginning in 2004 and continuing into 2017. Targeted waste for retrieval contained uranium and TRU radionuclides such as plutonium. Each ARP included a main environmental enclosure with several smaller structures (airlocks) attached for waste sorting and equipment maintenance. A total of eight main structures were built by 2014. Table IV-1 details the dimensions of each of the past and current ARP main structures. For comparison purposes, two of the ARP enclosures would typically be required to span the length of an SDA trench, with the enclosure width capable of spanning the width of multiple SDA trenches.

Enclosure		Width	Length	Height	Interior Clearance
		(Feet)	(Feet)	(Feet)	(Feet)
ARP I[a]		170	290	57	20
ARP II		170	242	57	20
ARP III		100	333	42	20

Enclosure		Width	Length	Height	Interior Clearance
		(Feet)	(Feet)	(Feet)	(Feet)
ARP IV		235	270	68	21
ARP V		165	410	52	20
ARP VI		170	195	58	21
ARP VII		135	243	57	21
ARP VIII (Two Segments)		200	250	55	26
		290	250	65	26
ARP IX (Future)		N/A	N/A	N/A	N/A

Table IV-1: ARP Environmental Enclosures (DOE, 2014)

All enclosures are commercially available, tension-membrane, temporary structures that provide weather protection for year-round waste retrieval (Exhibit IV-1). Rubb Inc., a Norwegian company with a subsidiary in the U.S., was the lead supplier of the enclosures for all ARPs. Each enclosure building is constructed using a pre-fabricated steel frame covered with two layers of polyvinyl chloride-impregnated fabric textile as an inner and outer membrane (DOE, 2010a). The textile contains compounds that make the membrane flame-resistant. The inner membrane can be repaired or replaced if damaged or if surface contamination occurs. The steel frame rests on either a cast-in-place foundation or a concrete-block foundation, or is supported by a pile and ballast system. As shown in Exhibit IV-2, individual structures can be connected to each other with a fabric vestibule with metal-framed doors or by covered access corridors (DOE, 2010b). This design feature provides flexibility to cover single waste units or groups of waste units.

Exhibit IV- 1: Typical Environmental Enclosure Used at INL

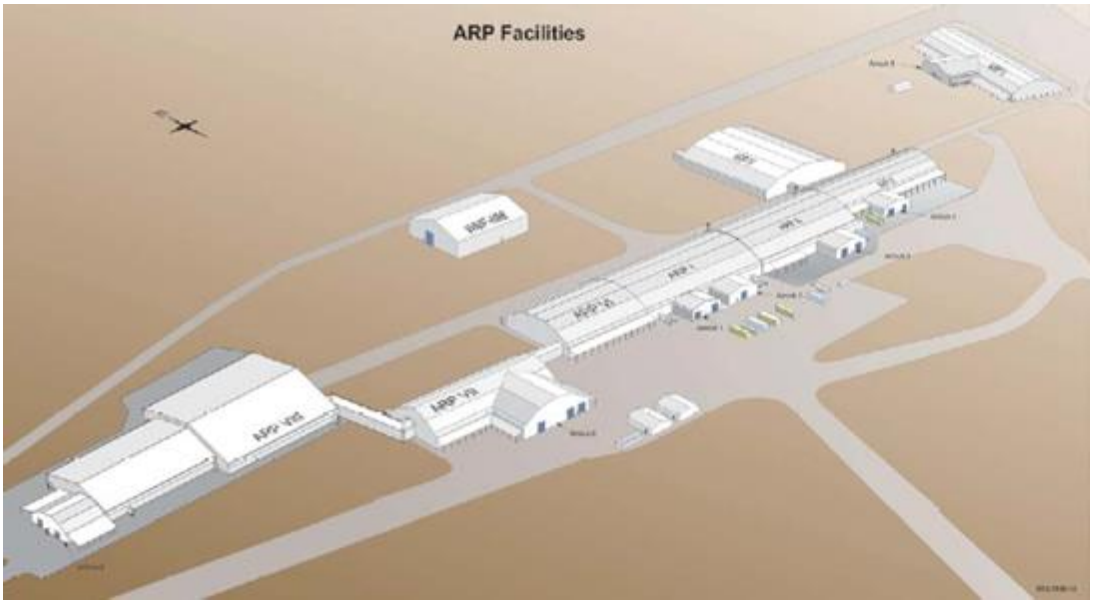


Exhibit IV- 2: Multiple Connected Environmental Enclosures

The enclosures are designed to withstand snow, seismic, and wind loads. A ventilation system keeps the enclosure at a negative pressure relative to the ambient environment. Heating systems in the main enclosure are designed to keep the interior temperature above freezing for protection of retrieval equipment.

Airlocks can be structurally attached to the main enclosure structure, with each airlock atmospherically separated from the main retrieval area to provide a buffer area for workers. Interior enclosures for special operations can be constructed within the airlocks while remaining structurally independent of the airlocks. For example, drum packaging stations were incorporated into an airlock at INL. These stations were modified gloveboxes designed to allow operators to examine and repackage the waste for eventual disposition as TRU or LLW. The walls and ceiling of these enclosures were lined with galvanized metal, including stainless steel in contamination areas.

2. ***INL Glovebox Demonstration Project at OU 7-10 (Pit 9):*** The exhumation of Pit 9 at INL generally involved the same type and quantity of radioactive materials as the SDA and NDA. OU 7-10, however, is a much smaller area that covered only those parts of Pit 9 that contained Rocky Flats TRU waste and INL LLW contained within 55-gal steel drums and plastic bags. Over 99 percent of the radioactivity within Pit 9 came from six TRU radionuclides: Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, and Am-241. Am-241 represented the principal gamma-producing isotope that posed a potential for direct radiation exposure (INEL, 2004). Although not representative of the SDA and NDA in size or isotopic makeup, the enclosure concept used at the smaller scale is conceptually representative of what could be used at West Valley to control and limit exposures to operating personnel and the environment. Under this enclosure option, it is assumed that multiple outer enclosures would be used at West Valley rather than enclosures spanning SDA North, SDA South, or the NDA as proposed under the FEIS base case.

   The selected alternative for the glovebox demonstration project consisted of an exterior weather enclosure structure (WES), an interior retrieval confinement structure (RCS), three packaging glovebox systems, and a facility floor structure (Exhibit IV-3). The WES was the outer enclosure constructed of a steel frame covered with a weather-treated tension fabric. The inner RCS was made of a stainless steel frame with glass-clad polycarbonate panels, and was sealed over the demonstration excavation area (INEL, 2004). The dig face was approximately 20 feet by 20 feet, the RCS was approximately 30 feet by 40 feet, and the WES was approximately 80 feet by 110 feet.

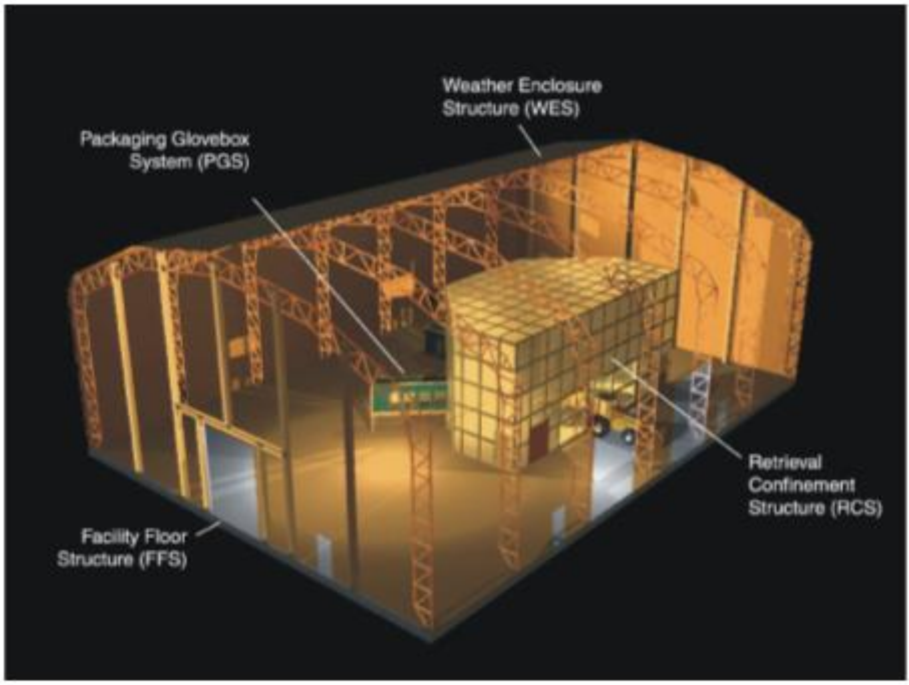


Exhibit IV- 3: Artist rendering showing a cutaway view of the project facility (INEL, 2004)

> During excavation operations, only the arm of the excavator protruded into the confinement area, while the operator and the rest of the excavator chassis remained outside the confinement structure. Workers wore PPE with respirators when working within the RCS, and dust suppression equipment was used to minimize fugitive dust generation.

Summary of Applicability: The widespread use of commercially available tension-membrane structures as a protective measure for radiological waste removal projects is evidence of their general applicability to the SDA and NDA. Under Option 1, it is being assumed that the internal modular enclosures will essentially be the same as those proposed for use in the FEIS base case. It is these enclosures that provide the primary source of protection against direct exposure to workers and internal exposure via airborne releases. The primary difference in the FEIS base case and Option 1 are the outer enclosures, moving from the robust fixed environmental enclosures of the base case to the use of modular tension-membrane structures under Option 1. The outer enclosures essentially provide secondary protection through the provision of redundant air filtration and negative pressure systems, ingress/egress control, and personnel monitoring. As such, the less robust system being proposed under Option 1 is applicable and appropriate to achieve the planned objectives.

The introduction of selective exhumation scenarios underscores the advantages of the modular outer enclosures when compared to the fixed structure of the FEIS base case that was developed specifically for use under the Sitewide Removal Alternative. The flexibility to enlarge or contract the enclosure through the use of connected modular structures is evident. In addition, depending on the targeted radionuclides, the level of necessary protection may vary and could be better accommodated with modular units.

Another potential area of cost savings between the FEIS base case and Option 1 would be the use of concrete rather than lead shielding. The applicability of concrete shielding is demonstrated by Exhibit IV-4, which shows the change in dose rates for a 55-gallon drum full of waste (with a density of 2.35 grams per cubic centimeter [g/cm^3]) as a function of concrete shielding thickness using concentrations of Co-60 and Cs-137 at levels defined by the USNRC and 10 CFR 61 (ECS, 2016b).

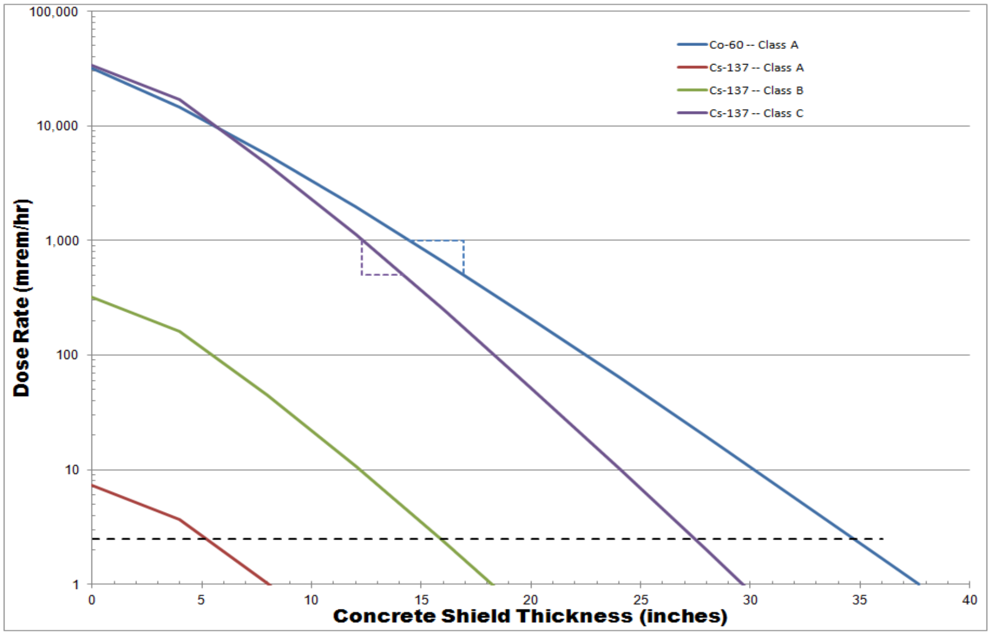


Exhibit IV- 4: Thickness of Concrete Shield to Achieve an Acceptable Dose Rate

The black dashed line in Exhibit IV-4 is a dose rate of 2.5 mrem/hr, which is equivalent to the 10 CFR 835 annual occupational dose limit of 5 rem assuming an annual exposure of 2,000 hours. The four color-coded curves show the change in dose rate as a function of the thickness of concrete shielding assuming starting points equivalent to the dose limits defining Class A waste for Co-60 and Class A, B, and C waste for Cs-137. For example, if one had waste for which the unshielded dose rate because of Cs-137 is at the Class B limit of 300 mrem/hr (green curve), a concrete shielding wall approximately 16 inches thick would be necessary and sufficient to reduce the dose to 2.5 mrem/hr. Even Class C waste could be adequately shielded with less than 3 feet of concrete. Higher dose rates would likely justify lead shielding at the workface.

Limitations on Use: The primary limitation on the use of modular structures would be if the waste being exhumed is of sufficient activity to require a more robust engineered structure. However, as discussed above, any special requirements could likely be satisfied by improvements to the smaller MSEEs such that the major cost savings of using a tension-membrane outer enclosure would not be compromised.

There would also be a concern that the severe weather conditions at West Valley could jeopardize the structural integrity of a membrane structure. While this is not considered to be a limitation based on continued improvements in structural design and the successful application of such structures at other DOE sites with severe wind and snow loads, further evaluation in conjunction with the manufacturer is warranted. Literature from the manufacturer reports that one of their enclosure buildings survived 90 MPH winds during a hurricane.

Cost Considerations: A direct comparison of costs between the FEIS base case and Option 1 is made difficult by the methods in which the estimated costs are reported. The closest comparative cost information is that reported for the waste retrieval project at INL that used the type of enclosure reported above for the ARPs. In this case, the costs are split into the following three categories: Procurement; Construction of Retrieval Enclosures; and Deactivation, Decontamination, and Decommissioning of Enclosures. The problem is that the “Procurement” value appears to be inclusive of all equipment and materials for the retrieval project, and the percent of that value attributable to the acquisition of the enclosures is unknown. As a result, the total cost (when pro-rated to the same acreage of coverage as the SDA and NDA enclosures) could range from $136 million (no procurement dollars assigned) to $488 million (100% of procurement dollars assigned). These estimated costs are also in 2008 dollars, and thus are directly comparable to the $491 million given above for the FEIS base case. Therefore, one can only conclude that the cost of the tension-membrane structure of Option 1 is likely less than the cost of the fixed structure proposed in the FEIS, and possibly by a significant amount.

A more direct comparison is possible if one only considers the demolition cost, which would not be influenced by the uncertainty in the procurement value. In this case, the INL value converts to $93.6 million when corrected for the SDA and NDA areas being enclosed. This value is comparable to the $335 million reported for the demolition of the SDA and NDA outer enclosures. Therefore, even if one assumes that the procurement and construction costs of the FEIS fixed enclosures and the Option 1 tension-membrane structures are relatively the same, Option 1 would result in a significant cost reduction due to a large difference in demolition costs, subject to the following qualifications:

1. The above cost extrapolation applies to a single tension-membrane structure being used across the entire area of the SDA and NDA retrieval, when in fact smaller units would likely be acquired and reused across the exhumation footprint under Option 1. The net effect on capital, maintenance, and disposal costs of multiple units, some of which would be reused, is difficult to determine.
2. The cost estimate for disposal of the FEIS enclosures assumed disposal as LLW. It is not certain if the INL costs are based on the same assumption. The description used in the INL cost estimate is “non-transuranic” waste, which would seem to indicate disposal of the enclosures as LLW as opposed to non-radioactive waste.

3. Option 2: Single Modular Environmental Enclosure

Description: Option 2 is similar to Option 1 except that only a single tension-membrane structure would be used with appropriate shielding and ventilation to protect against worker exposure and environmental releases. The use of a single structure is not unprecedented for radiological waste exhumation projects, and could find use either for selective exhumation scenarios or if the exhumation project is delayed until radiological decay limits the exposure risk. The SDA would likely be the primary candidate for use of a single environmental enclosure.

For purposes of this evaluation, the selection of a tension membrane structure as the single enclosure is based primarily on its use for the precedent project described below. A feasible variation to this type of structure would be a rigid-frame metal Butler building, as envisioned for use over some of the NDA trenches in the FEIS. What type of enclosure is eventually selected does not change the overall evaluation of this option, as the activity of the waste being exhumed is the dominant factor in whether a single enclosure (Option 2) would have potential applicability for waste exhumation at the SDA or NDA.

Precedent Application: A single environmental enclosure was used at ORNL for waste retrieval at Solid Waste Storage Area (SWSA) 5N, which was the designated location for the disposal of TRU waste generated at ORNL. The SWSA 5N area contained a group of 22 earthen burial trenches that were designated for retrievable storage of remote handled TRU waste. Prior to the initiation of retrieval operations, a temporary movable enclosure structure was constructed over the first trenches to be exhumed. A primary purpose of the structure was to prevent the release of radiological constituents to the ambient environment during retrieval operations. The structure also afforded worker protection by providing a weather enclosure with a ventilation system to provide clean airflow and to remove diesel exhaust from equipment. A leachate removal system was available to handle any water present during excavation.

As illustrated in Exhibit IV-5, the enclosure consisted of five separate sections that covered several trenches at once (Turner et al., 2005, Turner, 2006). As retrieval operations progressed, the structure was disassembled and moved to cover an adjacent set of trenches. Over the lifespan of the retrieval operations, the structure was moved three times (Bonilla et al., 2008). The enclosure was constructed with an outer and inner fabric skin that could be removed in sections or completely removed and replaced if the skin became contaminated. The primary enclosure was big enough to allow for the deployment of equipment (Exhibit IV-6). The size of the enclosure could accommodate a secondary enclosure in the event of high airborne contamination levels; however, none was employed for the project.

Exhibit IV- 5: Photo Showing Environmental Enclosure at SWSA 5N (Skinner et al., 2008)

Exhibit IV- 6: Interior of Enclosure Showing TRU Casks and Cask Transfer

Summary of Applicability: The TRU waste disposed at SWSA 5N in 1969 contained material with sufficient amounts of gamma exposure rates above 200 mR/hr or high neutron fluxes to warrant burial in shielded casks or boxes. Surface dose rates at the time of burial were estimated at 1 to 1,000 mrem/hr for 85% of the casks and boxes, with the remaining 15% between 1,000 and 5,000 mrem/hr. The effects of radiological decay on the dose rates at the time of exhumation are not known, but in and of themselves would not determine if a single enclosure would be sufficient for the exhumation of waste units at the SDA and NDA.

It is likely that the option of using a single environmental enclosure would be applicable only under those selective exhumation scenarios when the waste inventory for the targeted waste unit or group of waste units indicates low dose rates. The evaluation performed under Task 1.3 identified such selective exhumation scenarios, but whether these would be selected in the future remains uncertain. Additional trench segments could reach an acceptable condition with the decay of Cs-137 and Co-60 over time, but again this is not a decision known today.

Limitations on Use: The primary limitation in this case is the continuing uncertainty in the reported waste inventories and the guarded level of confidence that one would have in the calculated doses to warrant the selection and use of a single enclosure. Previous applications at other sites were under conditions where the waste types and waste forms were better known and, in fact, had been originally disposed under the pretext that the waste would be retrieved at some point in the future.

Cost Considerations: Based on the information reported in previous sections, the potential cost savings of moving to a single enclosure would likely be in the range of hundreds of million dollars. The cost to upgrade the single modular enclosures to meet a higher level of structural and protective design in lieu of an outer enclosure is expected to be far less than the currently projected cost of about $700 million in 2020 dollars for the fixed outer enclosures in the FEIS.

C. Comparison of Options

A comparison of the two optional approaches against the FEIS base case indicates that the three cases demonstrate a clear trade-off between the degree of protection provided and the associated cost. The FEIS base case and Option 1 differ primarily in the type of enclosures used for the outer of two sets of environmental enclosures. Based on precedent applications at other sites, both approaches would likely provide an acceptable level of worker and environmental protection through a dual system of enclosures, with the primary inner enclosure being essentially the same for both approaches and thus not a discriminator. The commercial availability of the tension-membrane enclosure of Option 1 is considered to be an advantage from a schedule standpoint, with the modular nature also providing design flexibility across the various trenches and holes being exhumed. Based on available information, the cost of the enclosures under Option 1 may be in the range of 50% of the cost of the FEIS rigid structures, which is significant given the nearly $700 million cost associated with the protective structures in the FEIS.

The trade-off of performance versus cost is even more pronounced for Option 2, which essentially eliminates the high cost of the outer enclosures while downgrading the range of conditions to which the enclosure would apply. Any future decision regarding a single structure would carry with it a degree of uncertainty and risk regarding the adequacy of the level of protection being provided given the wide range of wastes disposed in the SDA and NDA and questions as to the reliability of the published waste inventories.

The life expectancy of the various enclosures is also an important consideration given that the excavation of the NDA and SDA was projected to take 18 and 33 years, respectively, in the FEIS. The robust concrete structures in the FEIS base case are almost certain to last for such periods of time. As for the tension-membrane enclosures, information from the manufacturer (Rubb Group) is that the design life of the steel frame is 30+ years, whereas the design life of the fabric enclosure is 25-30 years. Damaged fabric can, however, be repaired in sections over time. A Rubb enclosure at a site in West Sayville, NY (on Long Island) has been operating for over 25 years. Rubb enclosures are also now being constructed as permanent airport hangars that would typically have a life-expectancy of at least 25 years.

V. Waste Exhumation

This section, which addresses methods for exhuming wastes from the various disposal units, is broken into two major subsections. Section V.A covers methods for the exhumation of waste from the SDA trenches, NDA trenches, and NDA Special Holes. As indicated in earlier sections, the NDA Special Holes are, in essence, small trenches with features similar enough to the primary SDA and NDA trenches to warrant their inclusion in the evaluation of optional methods for trench exhumation. Section V.B addresses the NDA Deep Holes, for which a different set of exhumation methods would apply due to their smaller size and greater depth when compared to the trenches and Special Holes.

A. Trenches and NDA Special Holes

1. Summary of Need

A method for removing waste from the SDA and NDA trenches, as well as the NDA Special Holes, will need to be implemented if the Phase 2 decision involves the full removal of the SDA and/or NDA, or the selective exhumation of just one or more trenches, trench segments, or Special Holes. The selection of a suitable exhumation approach needs to address:

- Support of excavation side walls
- Size, shape, and weight of waste packages
- Physical condition of the waste packages at the time of removal
- Sequence of and approach to exhumation
- Potential need for workers to enter trench
- Whether or not remote operations have to be employed
- Backfilling requirements

The waste that was disposed in the SDA trenches is reported to have been contained in a number of different waste packages. The most common type of waste package was 55-gallon steel drums, though 30- and 40-gallon drums were also used regularly, as were drums made of compressed fiber. Other types of waste packages included steel boxes, wooden boxes, and cardboard boxes, as well as concrete casks. Several large tanks up to 10,000 gallons in size were also disposed in the SDA trenches.

For purposes of this study, the condition of metal drums and boxes is assumed to range from relatively intact to completely corroded. The condition of the wooden crates is assumed to be degraded or crushed. It was assumed that all cardboard boxes are degraded to the point that they no longer provide structural support for the contents when uncovered. Concrete casks and tanks are assumed to be intact; however, any lift rings are assumed to be degraded, or at a minimum will need to be inspected before use.

As described in the FEIS, the primary objective of trench exhumation is to ensure that all waste materials, particularly high activity wastes, have been removed within the planned enclosure structures. The targeted material would be any waste or soil within the confines of the temporary sheet piling to be placed around each trench to a depth of 25 feet from the top of the trenches, corresponding to 5 feet below the approximate 20-foot thickness of the trenches.

The full exhumation process was also to extend beyond these limits to include the excavation of: (1) soil that overlies the trenches (including the clay cap); (2) the soil zone that separates the trenches throughout the depth of burial; and (3) potentially impacted soil extending laterally away from the outer trenches until soil conditions meet unrestricted use standards. The limits of excavation beyond the outer trench boundaries were not specified in the FEIS or the supporting engineering reports, and will depend on confirmatory testing. However, the estimated volume of soil reported in the FEIS appears to correspond to a distance of approximately 20 feet beyond the outer boundaries of the trenches.

2. Potentially Applicable Technologies – Trenches and Special Holes

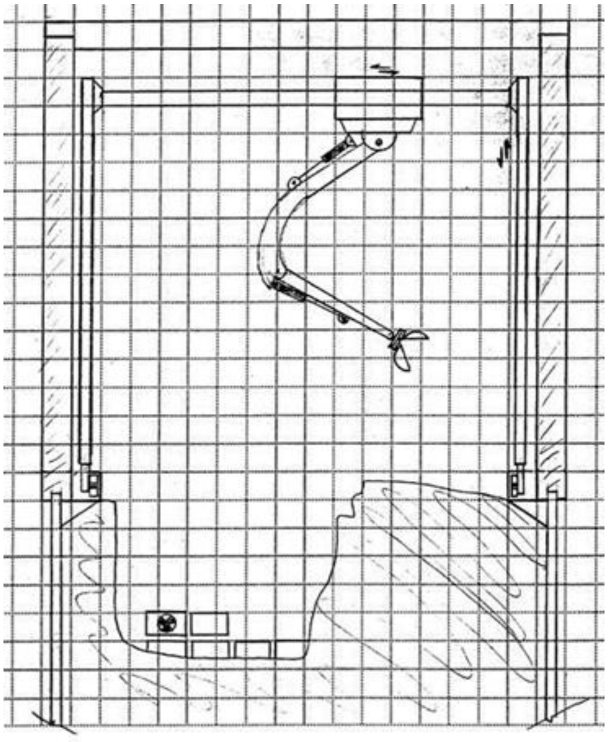
a) FEIS Base Case: Remotely Operated Equipment

Description: Due to the planned full removal of the trench disposal areas described above, it is expected that both high activity and low activity wastes will be exhumed from the trenches, whereas LSA soil would be removed from above, laterally adjacent to, and below the trenches. As addressed in Section IV, the removal of wastes from the SDA and NDA would be performed within fixed outer environmental enclosures that provide secondary containment and control of releases to the environment, and a series of MSEEs within the larger enclosures to provide primary protection against direct worker exposure and inhalation risk. The general approach presented in the FEIS would be to implement remote operations within the MSEEs and whenever radiation fields are detected in excess of 50 mrem/hr. Otherwise, excavation could be performed using manually-operated standard equipment that incorporates any necessary shielding.

Excavation of the SDA trenches would commence with the removal of the existing geomembrane cover and underlying soil cap using shielded standard dozers and excavators. Soil from the cap identified as potentially contaminated would be placed directly into waste containers for disposal as LSA waste. Soil that is not impacted will be stockpiled within the SDA Environmental Enclosures for later reuse as temporary trench backfill.

Excavation of the trenches would be performed next toward the objective of removing all high activity wastes and other waste materials within the temporary sheet piling in order to allow soil excavation to proceed using standard excavation equipment without the need for the MSEEs (i.e., using only the outer environmental enclosures). The loose soil commingled with waste would be removed using a remotely-operated vacuuming system. During vacuuming, the soil that is brought to the surface would be placed into 55-gallon drums. The filled containers would be remotely closed, wiped down, and removed from the MSEE through an airlock for transfer to the CMF.

The method proposed for exhumation of the waste from the SDA trenches under the FEIS base case is not well-described in either the FEIS or the supporting engineering reports. Rather, these documents describe the method as being similar to that proposed for the NDA. The referenced NDA section includes only a discussion of a remotely-operated crane system. However, the same documents propose the use of standard earth-moving equipment for the NDA Special Holes unless the 50 mrem/hr criterion is exceeded, thereby creating some uncertainty as to how the wastes from the SDA trenches are to be excavated. Further research by the EXWG found a sketch from 'URS Calculation: BUF-2004-194' that appears to confirm that a remotely-operated gantry crane outfitted with various end effectors is planned for excavating the SDA trenches (Exhibit V-1).



Only about 10% of the waste volume in the SDA is estimated to have contact exposure rates in excess of 50 mrem/hr. Therefore, the planned use of the remotely-operated crane appears to be in conflict with the plan to employ remote operations only when the 50 mrem/hr criterion is exceeded. One possible explanation for the decision is that the MSEEs may not provide enough space to operate earth-moving equipment in and out of the trenches. A second possible explanation is that the use of the crane keeps radiation exposures as low as reasonably achievable (ALARA), in that remote operations would be performed even when less intense radiation fields suitable for contact-handled operations are encountered.

Exhibit V- 1: Sketch of Crane Assembly to be Used for SDA Trench Excavation

Material brought to the surface would be placed into waste containers, such as B- 25 boxes, which would be closed and secured, decontaminated, and transferred to the CMF for further processing. After the waste has been removed from the trenches within the MSEEs, removal of the surrounding soil will be completed using standard excavation equipment. Since the higher activity wastes would have already been removed, the soil would be placed directly into waste containers and managed as LSA waste. The staged overburden soils removed to gain access to the buried wastes would be used as temporary trench backfill. Following a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Final Status Survey to verify that residual radioactivity levels do not exceed the established clean-up standards, the area would be backfilled with clean soil and graded, as necessary, to restore the approximate natural grade.

Under the FEIS base case, the excavation method for the NDA Special Holes is different than for the SDA trenches due to the lower expected activity of the waste. In general, excavation of the Special Holes would be performed using standard shielded excavation equipment. In cases where radiation fields in excess of 50 mrem/hr are detected, remote controlled excavation would be utilized. The existing geomembrane cover, as well as the upper layers of overburden and capping soils, would be excavated to an approximate depth of four feet. This soil would be managed as LSA waste with placement into lift liners and then into either intermodal type containers or directly into railcars.

Individual Special Holes or groups of Special Holes would be opened by excavating a vehicle access ramp at the end of the hole down to the floor level of the hole. Depending upon moisture content, the excavated soil would either be transported to the CMF to be dried and processed, or sampled and placed directly into lift liners in intermodal type containers or railcars. Waste containers, non-containerized loose waste, and waste materials commingled with soil that are excavated would be transported directly to the CMF for processing.

Items expected to be classified as GTCC that could not be adequately processed within the MSEE would be placed into appropriate containers, which would be closed, remotely wiped down, then transferred to the CMF. Large items would be segmented and placed into B25 boxes that would subsequently be closed, wiped down, and transferred to CMF for further processing.

Precedent Applications: The EXWG found no precedent project that used the FEIS-proposed method of remote excavation for exhuming material from waste trenches. While some of the individual process technologies are well-established and have been successfully applied for the removal of solids, organics, and radionuclides, a combined robotic excavation system on this scale has not been attempted before.

Summary of Applicability: The use of the MSEE coupled with a remote crane system could be effective in removing waste from the SDA trenches. However, since the exact types of end effectors have not yet been determined, extensive cold testing in a clean test area will be needed to prove any proposed technology.

The use of standard excavation equipment for the NDA Special Holes below 50 mrem/hr is similar to other radioactive waste excavation projects, several of which are described in the following sections.

Limitations on Use: For the SDA, neither the FEIS nor the supporting engineering reports provide exact details beyond the URS sketch on how waste packages would be removed and what particular attachments to the Z mast would be used. The likely long-term degradation of metal drums and wooden boxes means it will be difficult to remove intact individual waste packages using an excavator bucket. The prevention of airborne releases of radionuclides to workers may necessitate a less invasive end effector, such as a clamshell bucket. The use of a remotely-operated crane arm to remove concrete casks and large tanks for which the lift rings may not be intact or structurally sound also raises questions as to how the removal will actually be achieved.

The construction of the access ramps for the Special Holes could become difficult in areas where a number of holes are clustered together and there is little room to build a ramp. In addition, if material above 50 mrem/hr is discovered after excavation of a Special Hole has begun, it would be difficult to then install an MSEE over the excavated area to continue working.

Cost Considerations: Estimated costs related to the exhumation of wastes from the SDA and NDA are available in the *Sitewide Removal Alternative Technical Report* (URS 2009), which was prepared in support of the FEIS. These costs are available only at a high level, and for the NDA represent total costs with no breakdown between the Special Holes and trenches that are the subject of this section, and the Deep Holes that are addressed separately in the next section. The general categories of costs specifically cited as being related to waste exhumation are the following:

Excavation of SDA Waste:

• Materials:	$ 65,360,100
• Labor:	$ 422,976,500
• Waste Disposal:	$ 257,962,100
• Contingencies:	$ 308,134,000
• TOTAL COSTS:	**$ 1,054,432,700**

Excavation of NDA Waste (Including Deep Holes):

• Materials:	$ 30,848,600
• Labor:	$ 171,088,300
• Waste Disposal:	$ 176,563,200
• Contingencies:	$ 126,920,600
• TOTAL COSTS:	**$ 505,420,700**

Of the costs shown, the labor costs would be the most highly correlated to the methods used for exhuming the wastes from the trenches. Given that the labor costs also represent the largest single item of cost among those shown, the method of waste exhumation becomes an important cost consideration. The other categories of cost are generally independent of the exhumation method. The costs shown above are much lower than what was reported in the previous 2008 Technical Report (URS, 2008b). The primary reason is that the costs of the respective MSEEs were included in the waste excavation costs in the earlier report, but were broken out separately in the 2009 update. The construction costs of the MSEEs were provided in Section V.B.1 above.

b) Option 1: Manned Excavation Within Trench

Description: Option 1 considers the case under which waste exhumation from within the SDA trenches would be achieved through the use of conventional excavator equipment, similar to what is proposed for the NDA Special Holes under the FEIS base case. The excavation equipment, along with human operators and possibly workers on foot, would enter the uncovered trench to remove waste. This would only apply to those trenches or trench segments where exposure rates would be low enough to allow for manned operations, which was shown to be the case for certain trenches and for some selective exhumation scenarios in Task 1.3.

Precedent Applications: Two precedent applications of excavation within waste trenches demonstrate the viability of this method, including waste removal at the Hanford 300 Area and the ORNL SWSA 5N burial grounds.

Hanford 300 Area:

Eight burial grounds and two legacy landfills were excavated at the Hanford 300 Area, with an additional burial ground in the process of excavation. Conditions at these waste areas were similar to those at the SDA trenches, including:

- The burial areas contained unlined earthen trenches that were 300-600 feet long, 30-184 feet wide, and 16-25 feet deep. The two landfills were also unlined with dimensions of 340 feet long, 246 feet wide, and 10 feet deep. Over 750,000 tons of waste and contaminated soil were excavated across the 300 Area.
- The wastes disposed in the trenches consisted of process equipment, construction debris, laboratory waste, protective equipment, industrial equipment, and drummed waste (Haass et al., 2007). While the primary radionuclide of concern was uranium, quantities of fission products, plutonium, and other TRU wastes were also present.
- Waste packages included wooden crates, glass and plastic bottles, steel drums, steel boxes, and shielded drums. Non-containerized loose waste was also present.
- Waste was covered with a layer of soil backfill.

Excavation took place in open-air conditions, and no enclosure structure was used. Excavation equipment included various types of standard track hoe excavators, track loaders, front-loaders, and backhoes. Toothless buckets were used on most equipment to reduce the potential of puncturing waste drums. Metal sheering end effectors were used to cut up large pieces of buried metal pipe.

Excavator arms were fitted with an infrared thermometer and radiation meter mounted on the end of a metal pole along with a photoionization detector intake tube that ran the length of the excavator arm. A portable radiological assay using gamma ray spectroscopy helped to remotely identify the presence of uranium, plutonium, or thorium, and a portable isotopic neutron-spectroscope was used to remotely indicate the presence of zirconium or beryllium. A mobile drum-penetrating facility was also in place to contain and sample unvented drums for reactive wastes.

Exhumation began with the removal of surface vegetation and clean overburden soil, which was staged for use as backfill. Four excavation techniques were used for the waste-containing areas, as follows:

- <u>1 ft. Horizontal Lifts:</u> An exposed horizontal face of 1 ft. was radiologically and visually screened, followed by removal of large debris and anomalous material. The remaining material was removed and placed in a bulk waste material stockpile. This method was employed in areas known to contain quantities of drummed waste.
- <u>1 ft. Diagonal Lifts:</u> Heavy equipment was used to rake material down the sloped face of an excavation zone in 1 ft. lifts for visual inspection. Radiological surveys were conducted at the bottom of the sloped face. After debris and intact waste packages were removed, the remaining bulk material was excavated and stockpiled.
- <u>Bulk Excavating and Spreading:</u> This method exhumed the waste in 1 ft. layers using heavy equipment, and then spread the material on the ground outside of the waste excavation pit for inspection and sorting.
- <u>0.5 ft. Loader Lifts</u>: In areas with little to no visible debris or waste packages, visual and radiological screening of an excavation surface was performed followed by exhumation using a front-end loader instead of a trackhoe.

Originally, waste was transported from the dig face to a centralized stockpiling and sorting area. This practice was terminated after four workers became exposed to airborne plutonium from the combined waste staging stockpile. Stockpiling and sorting were subsequently conducted only within the excavation footprint to better monitor and control dust emissions.

Excavated drums were cradled in the excavator bucket and moved to the edge of the remediation area. All lead-lined drums were placed in 85-gal. or 110-gal. steel overpack drums using the excavator bucket. Excavated drums suspected of containing reactive material were first placed into larger steel overpack drums, then loaded onto a long-reach forklift equipped with a blast shield. The forklift transported the overpack drums to a non-destructive characterization area.

Bulk material was placed in reusable carbon steel open-top, hinged-gate roll-off containers, which were transported by haul truck to an on-site disposal cell. For soils containing hazardous material subject to the land ban, the waste was first mixed with grout (Portland cement) using an excavator bucket. The waste/grout mixture was then emptied into an on-site disposal cell using a bulldozer. Solid hazardous material was encapsulated and placed in an overpack waste package before on-site disposal.

Following the completion of waste removal, the excavated trench/pit was backfilled with either clean stockpiled soil or soil from a supplemental borrow pit. The backfilled trenches and pits were then graded and re-vegetated to improve topsoil stabilization and to limit erosion.

Oak Ridge Area 5N:

The Area 5N burial grounds contained 23 earthen unlined burial trenches designated for retrievable storage of remote-handled TRU waste. The unlined trenches were 40-200 feet long, 7-12 feet wide, and 10-16 feet deep. Waste packages were located 3-15 feet below ground surface. Topsoil was used as a cover and as infill between the waste packages. The waste containers were similar to what is found within the SDA trenches; however, the distribution of container types was quite different, with excavated waste consisting of 204 large concrete casks, 12 steel and/or wooden boxes, and three carbon steel drums (Skinner et al., 2008). In addition, approximately 530 CF of miscellaneous loose waste were excavated from the trenches. By comparison, most of the SDA waste is in 55-gallon drums. Total waste volume was estimated to be 12,360 CF (Billingsley et al., 2001). Total waste activity in the 23 trenches, as estimated in 1989, was 62,300 Ci.

Excavation activities were conducted under a movable weather enclosure, as described in Section IV. The following commercially-available excavation equipment was used during the course of the project: a Caterpillar 963 track loader, an all-terrain crane and a mobile crane, and a trackhoe, dump truck, and wheel loader. Work crews operated in groups of 10 for waste excavation and repackaging from the trenches.

Waste package excavation began by using the trackhoe affixed with a bucket to remove soil between waste trenches and surrounding each waste package, and to scrape loose soil from the sides of the cask. Once a cask was exposed and cleaned of any loose soil, a sling was positioned around the cask in a choker arrangement and attached to the all-terrain crane. The cask was lifted out of the trench by the crane and placed on the front of the track loader, which was fitted with a modified logging fork attachment. The cask was then transported to a loading area within the weather enclosure where it was placed in a lifting sling and lifted into a steel overpack lined with plastic.

Summary of Applicability: The applicability of using manually-operated dozers and excavators for the removal of waste from the SDA trenches hinges on two primary conditions, as follows:

1. Would the potential exposure rates allow for the approach, as opposed to the remotely-operated crane system proposed for the FEIS base case? As indicated above based on Task 1.3 results, while exposure rates exceeding 50 mrem/hr are expected in some SDA trenches, 96% of the 50-foot trench segments likely fall below this criterion. The findings reported for Task 1.3 also indicate that exposure rates less than 2.5 mrem/hr would be expected in almost 60% of the trench segments. In general, if a selective exhumation scenario is eventually selected for the SDA, the possibility exists that exposure rates would be low enough to accommodate the Option 1 approach.

2. Would the MSEE structures be large enough for the safe and unencumbered operation of earth-moving equipment? Because separate MSEEs are to be utilized for each trench, and thus would likely span only that trench, the necessary space may not be available. However, there is a likelihood that an MSEE would not be needed when exposure rates for a given trench are sufficiently low, and the operation could proceed within the SDA Environmental Enclosure alone. This is the approach being proposed in the FEIS for the NDA Special Holes. Under this condition, which again would likely be satisfied under certain selective exhumation scenarios, earth-moving equipment could be used.

Limitations on Use: When compared to conditions at Hanford and Oak Ridge, key differences with the SDA trenches are the variability of the SDA wastes and the lack of confirmatory data on the accuracy of the inventory records. Although there has been considerable work performed to extract detailed inventories from the waste disposal records, and the geophysical results correlated well with the inventory waste forms, there will always be a low-probability threat of an unexpected high level of exposure if a remote operation is not employed.

Additional risks include the potential need for the operator to abandon the protective shielding of the equipment (e.g., due to equipment breakdown) while in an area of elevated exposure, and the threat of trench collapse and engulfment of the operator by waste and soil. The former risk is somewhat mitigated by the normal progression of the operation that would allow for operator egress from the trench across previously excavated areas. Protection against the latter risk would be provided by the planned sheet piling that will encircle the trench and by sloping the working face of any waste areas being actively remediated. The sequence of trench removal would need to be evaluated and developed in conjunction with worker protection requirements.

Cost Considerations: The excavation costs reported in the Hanford 300 Area Record of Decision issued in 2013 were estimated to be $299,152,000 non-discounted, and $247,614,000 net present value (US EPA, 2013). If one assumes a typical average unit weight of excavated material (waste, soil, and debris) to be 1.3 tons/CY, the volume represented by the reported 750,000 tons of excavated material at Hanford would be approximately 16,000,000 CF. The excavation of the SDA would amount to about 2,300,000 CF of waste (ECS, 2016a) and 14,000,000 CF of LSA soil and debris (ECS, 2016c), which when totaled is nearly identical to the Hanford volume. Therefore, on a cost per unit volume basis, the Hanford project cost of about $300 million is shown to be much less than the estimated $1.05 billion cost for SDA trench removal (exclusive of the MSEE costs).

Although the above analysis provides a qualitative cost comparison for the two approaches, a direct comparison of the two cost values is difficult due to uncertainty in what is included in each estimate. One caveat to such a comparison of costs is that the Hanford waste is removed to a centralized stockpiling and sorting area, placed in reusable carbon steel containers as bulk waste, and transported by haul truck to an on-site disposal area. The resulting transportation and disposal costs would be much lower than the $257,962,100 estimated cost for the off-site disposal of SDA waste. Nevertheless, it is observed that the total reported cost for the Hanford excavation project is less than just the estimated labor cost for SDA trench excavation, which is exclusive of disposal costs.

c) Option 2: Excavation from Outside of Trench

Description: The second option, waste exhumation from outside the trench, was evaluated assuming that a conventional excavator operates from the crest of the trench sides parallel to the trench (i.e., the excavator would be positioned on the soil wedge that separates the trenches longitudinally). The trench walls would be supported during excavation through the use of sheet piles, as proposed in the FEIS.

A Caterpillar 325L excavator would be used to maximize the available reach to pick up material along the center line of the trench bottom. The maximum load that could be picked up will depend upon the position of the boom, but the Caterpillar 325L can lift up to 2.7 tons with the boom extended if parked with the tracks parallel to the trench edge. The sheet piling will need to be designed to support the total load of the excavator and waste packages, and any limitations will need to be determined once the weights of individual packages are estimated.

Precedent Applications: The most prominent example of a precedent application is the ongoing selective excavation of TRU waste at the Idaho Radioactive Waste Management Complex. In this case, the excavation activities span across 21 unlined pits and 58 unlined trenches, with the goal to excavate a minimum of 8,158 CY of waste from a combined area of 5.69 acres by 2028. Waste retrieval is targeted to only remove TRU waste and co-located waste impacted by organic solvents, with other low-level radioactive wastes returned to the trenches for permanent burial.

The INL trench dimensions and waste forms are similar to those of the SDA and NDA trenches and NDA Special Holes. The trenches are unlined and were constructed to the underlying basalt, with average dimensions of 900 feet long, 6 feet wide, and 13 feet deep. Pits are the same depth but much wider than the trenches, with varying lengths. All disposal areas were covered with a 4-foot to 9-foot layer of soil. Most waste was placed in 55-gallon steel drums. Additional waste packages included cardboard boxes, wooden boxes, metal garbage cans, and plastic bags. No sheet piling was used at INL, as groundwater control was not required and there was sufficient room between trenches to allow the sides of the excavations to be benched and sloped for stability.

Excavation activities were conducted under nine tension-membrane structures. The primary piece of excavation equipment used was a modified Gradall XL-5200. Gamma radiation and neutron detectors were mounted on the excavator arm to support waste identification. A puncture tool was also attached to the excavator arm to vent drums during excavation, along with a dust suppression spray system. The cab exterior was shielded to minimize exposure to operators. Cameras mounted on the cab exterior allowed for real-time remote observation by external waste identification specialists.

Exhibit V-2 provides a visual overview of the excavation process, which is being completed in pre-determined grids. The top 2 ft. of exposed soil is removed to form an initial trench. This layer is mostly rock and dirt placed over the waste, and is considered potentially contaminated. The removed soil is staged near the initial trench, and used for backfill following excavation of targeted waste. The waste zone of the initial trench is then excavated down to native soil, usually between 11 feet to 14 feet. An approximate 1:1 angle of repose is maintained during excavation of the trench.

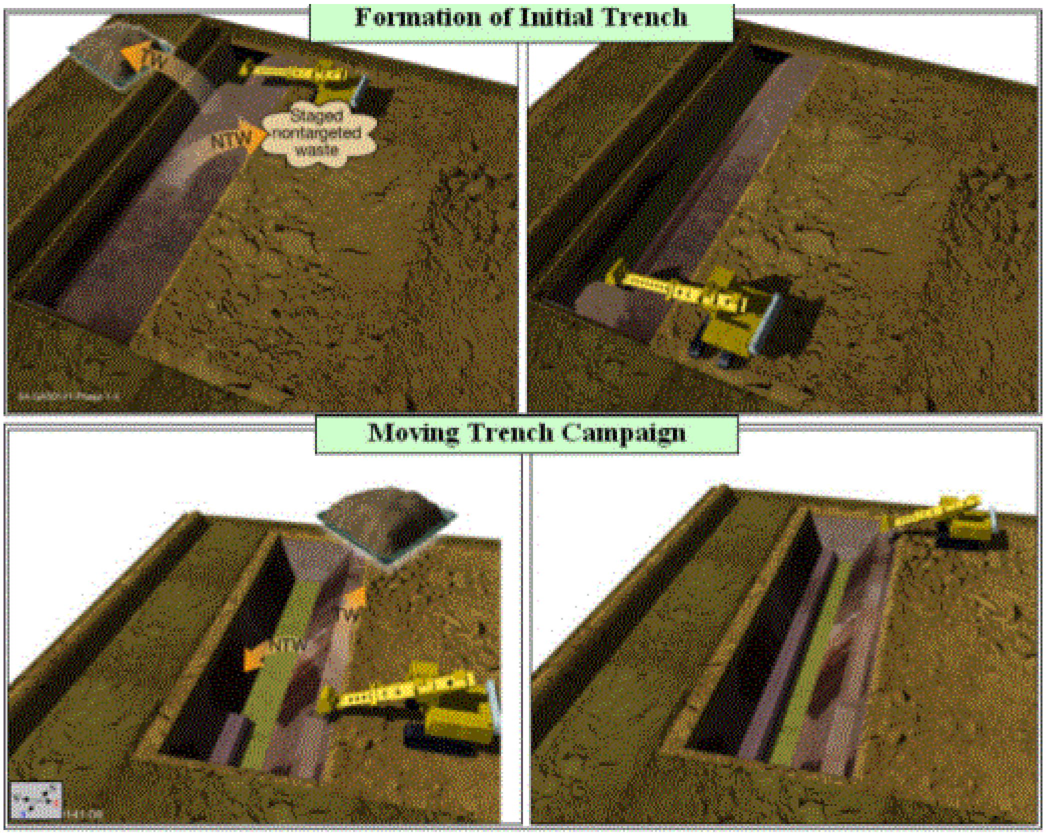


Exhibit V- 2: **Initial Trench and Moving Trench Waste Excavation Campaigns**

Waste is segregated as it is removed from the trench. Retrieval specialists trained to visibly identify the targeted waste streams based on appearance, packaging, content, and labeling work through closed-circuit television to distinguish the target waste being removed from the other waste that would be left in the trenches. This information is then passed on to the excavator operator by radio.

The excavator places targeted material into a lined metal tray, which is then transported by forklift (telehandler) to a sorting and processing station inside one of the airlocks. Waste determined as non-targeted is first containerized if loose, then transported by telehandler to a temporary staging area within the retrieval enclosure. Following completion of the initial trench, the excavator begins a second "moving trench" adjacent to the first trench. Non-targeted waste from the initial trench is retrieved from the staging area and placed within the void space of the initial trench excavation, and staged overburden soil is used to cover the non-targeted waste returned to the initial trench. The process is then repeated with a new adjacent moving trench.

Summary of Applicability: Option 2 is applicable to the SDA trenches and generally applicable to the NDA trenches and Special Holes subject to the same conditions as those discussed for Option 1 above. In this case, however, worker exposure is of less concern as work is not performed within the trenches. Some limitations do exist, however, as discussed below.

Limitations on Use: The full depth of excavation could reach 30 feet below existing ground surface. Stabilizing an ~30-ft deep excavation along the operating face presents a challenge due to the need to accommodate the combined weight of the excavator and exhumed waste. The proposed alternative is to use a sheet pile wall along the trench sidewall; however, the sheet piling would have to be of much higher strength than those proposed for side stabilization under the FEIS base case. The other commonly-used method of sloping the sidewalls of the trench may not be feasible in this case if the necessary cut back extends into the adjacent trench.

In addition, because of uncertainties in the exact location of the trench boundaries, the sheet piling would have to be conservatively located several feet from the expected trench boundary, further extending the necessary reach of the excavator and possibly exceeding that of the Caterpillar 325L. If excavator reach became an issue, it might be necessary to create a lower operating bench by removing the soil between the trenches down to the depth of the top of the trench prior to exhuming the waste.

Backfilling the trench segment would also be a challenge using the excavator along the side of the trench. Typically, soil is placed and compacted in lifts with a bulldozer, which would require a decision to enter the trench once the waste is removed. Under this scenario, either the trench would have to remain open until the entire trench is excavated, or the backfilling operation would have to occur within the trench when there is still an open face of waste materials at the point of active excavation. Either case represents a health and safety or exposure risk. The option would be to use remotely-operated equipment for the backfill and compaction operations, thus reducing the cost-effectiveness of Option 2, or to dump and spread the fill with the excavator and then compact the fill using dynamic compaction. The latter is typically only cost-effective where a large open area of soil needs to be compacted.

Cost Considerations: Through 2014 (the last year for which information is available), the actual costs for implementing the INL removal were reported to be $673,903,730. Given the 7,980 CY of waste retrieved through 2014, the total cost converts to an average unit cost of waste retrieval and disposal of $84,450/CY. While this unit cost would appear to be several times higher than the estimated cost for the FEIS base case, it must be recalled that the volume of waste reported for INL (7,980 CY) represents only the volume of targeted transuranic waste removed. The total volume of waste and impacted soil excavated from the waste units would be much larger, but this value is unknown so that a direct comparison with the FEIS base case is not possible.

3. Comparison of Options

A comparison of options for waste removal from the SDA and NDA trenches and Special Holes indicates that all three approaches are generally applicable for the excavation of most waste from the SDA and NDA trenches. The major limitation of Option 1 and Option 2 is that they would not apply to the small number of trench segments that exceed the exposure rate criterion of 50 mrem/hr established in the FEIS (refer, for example, to Exhibit II-14 of ECS, 2017). As such, the options would be most applicable for those selective removal scenarios that do not involve trenches of high potential exposure. Although it carries a higher cost, the FEIS base case that involves remote operations would be the only option that alone could meet all conditions under the Sitewide Removal Alternative. An approach using a combination of remotely operated and manned equipment may warrant consideration, however, even under the Sitewide Removal Alternative given that a high percentage of the trench segments and Special Holes satisfy the <50 mrem/hr criterion.

When compared to Option 2, Option 1 has a greater potential for worker exposure because the equipment operator will be in the trench. On the other hand, Option 2 carries more performance uncertainty due to the width and depth of the trenches compared to the effective reach of the excavator, as well as the limited extent of the soil zone that would serve as the operational platform. Option 1 would result in the highest rate of production and would accommodate the use of multiple types of equipment to better address differences in waste containers and forms. Both Option 1 and Option 2 retain more flexibility of operation when compared to the remote exhumation base case, a factor that increases in importance with the introduction of selective removal scenarios. Each optional approach is also expected to carry a much lower total cost when compared to the FEIS base case due to a higher rate of production.

B. NDA Deep Holes

1. Summary of Need

The NDA was operated by NFS for the disposal of solid radioactive waste materials from the nearby Main Plant Process Building exceeding 200 mrem/hr, as well as other materials for which disposal in the SDA was not permitted. A total of 3,081 containers containing 25,200 CF of waste are buried in approximately 100 Deep Holes at the NDA, with a total activity in 2000 of 220,000 Ci. The Deep Holes are approximately 55 feet in depth and about 3 feet wide by 7 feet long, except for one hole that is 6 feet by 10 feet and another that is 7 feet by 15 feet (URS, 2008a). The holes are spaced with at least 6 feet of undisturbed soil between them (Kelleher and Michael, 1973). The locations of the Deep Holes within the NDA are shown in Exhibit V-3.

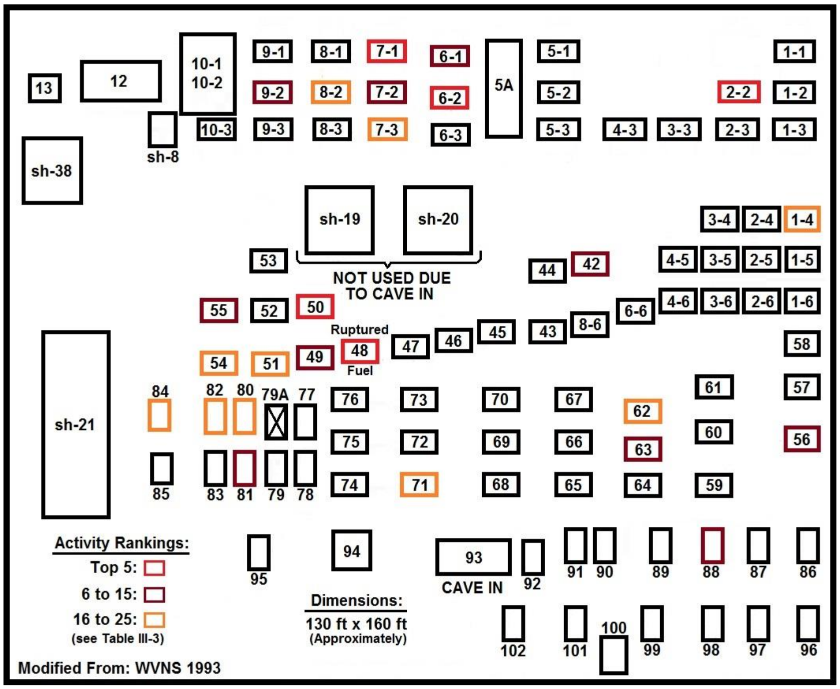


Exhibit V- 3: Location of NDA Deep Holes and Special Holes

About 6,660 CF of leached cladding from reprocessed fuel, known as hulls, were disposed in the Deep Holes at the NDA. Most of the hulls are reported to have been placed inside 30-gallon steel drums, which are laid three abreast in the holes (URS, 2008a). In addition to the predominant 30-gallon drums, waste was also disposed in the Deep Holes in 50-gallon drums and wooden crates, and some waste was encased in concrete (Kelleher and Michael, 1973). The average number of containers per Deep Hole is 31, with one hole containing as many as 128 drums. Placement of the drums was restricted to a height of at least four feet below the top of the weathered Lavery till, or about 8-10 feet below normal ground surface.

The singular nature of the Deep Holes in terms of their size, configuration, and contents, as compared to the NDA Special Holes and NDA and SDA trenches, requires a different set of exhumation methods than those evaluated in the preceding section. The methods specifically developed for the NDA Deep Holes are addressed in the following sections.

As indicated in Exhibit V-3, the Deep Holes are spread in an irregular configuration within an approximate 0.5-acre portion of the NDA. From an exhumation standpoint, this introduces two options to consider – removal of individual Deep Holes (the exact location of which may not be known), or removal of larger areas containing multiple adjacent Deep Holes. The options addressed in this section apply to the removal of individual Deep Holes, as each approach involves the extraction of waste using equipment with a limited lateral extension but capable of reaching depths exceeding 50 feet. The primary difference in moving to a multi-hole strategy would be the use of a single, larger MSEE across several holes and a potential revision to the sheet piling configuration for leachate control and hole stabilization. In some cases, a single crane system capable of lateral movement similar to that proposed for the SDA trenches could be used to span multiple Deep Holes using a single crane/enclosure set up, although the removal itself would still be sequential from hole to hole. Any type of mass excavation of the Deep Holes is limited by the 55-foot depth of the holes, the difficulty in stabilizing such a deep and large excavation, and the large volume of soil that would have to be concomitantly removed and disposed along with the waste contained in the Deep Holes.

2. Potentially Applicable Technologies

a) FEIS Base Case: Remotely Operated Equipment

Description: Removal of wastes from the NDA Deep Holes would be performed within two environmental enclosures – the NDA Environmental Enclosure that will cover most of the NDA to provide secondary containment against airborne discharges of radionuclides, and an MSEE to provide primary confinement for the radiological and hazardous material releases that are expected during waste retrieval from the Deep Holes. The NDA MSEE would be designed for remote control of excavation, retrieval, and maintenance operations. The modular design of the NDA MSEE would allow it to be configured over work areas of various size and used numerous times prior to being replaced.

For the Deep Holes, waste removal under the FEIS base case would be achieved using a remotely operated gantry crane equipped with various arm attachments. The gantry crane mast would penetrate through a boot in the top of the MSEE (Exhibit V-4), and would be operated from outside of the MSEE structure using remote video. The MSEE would also contain an internal chain hoist system capable of reaching to the bottom of the Deep Holes. The MSEE would be equipped with a shielded soil handling workstation and a shielded material handling workstation, and would include a soil vacuum system for the removal of loose soil from around or attached to the waste containers.

Prior to excavation of a Deep Hole and deployment of the MSEE, sheet piling would be driven around the hole to a depth of approximately 10 ft. below the base of the planned excavation. The sheet piling would provide structural support of the surrounding till during the excavation process. The existing geomembrane cover would be removed for disposal, and bulk soil that was backfilled over the waste would be excavated using an excavator bucket attachment on the gantry crane. Clean soil would be staged within the NDA Environmental Enclosure for later reuse as temporary backfill. Loose soil commingled with waste would be removed, whenever possible, by the vacuuming system. Soil brought to the surface during vacuuming would be placed into 55-gallon drums for testing and disposal.

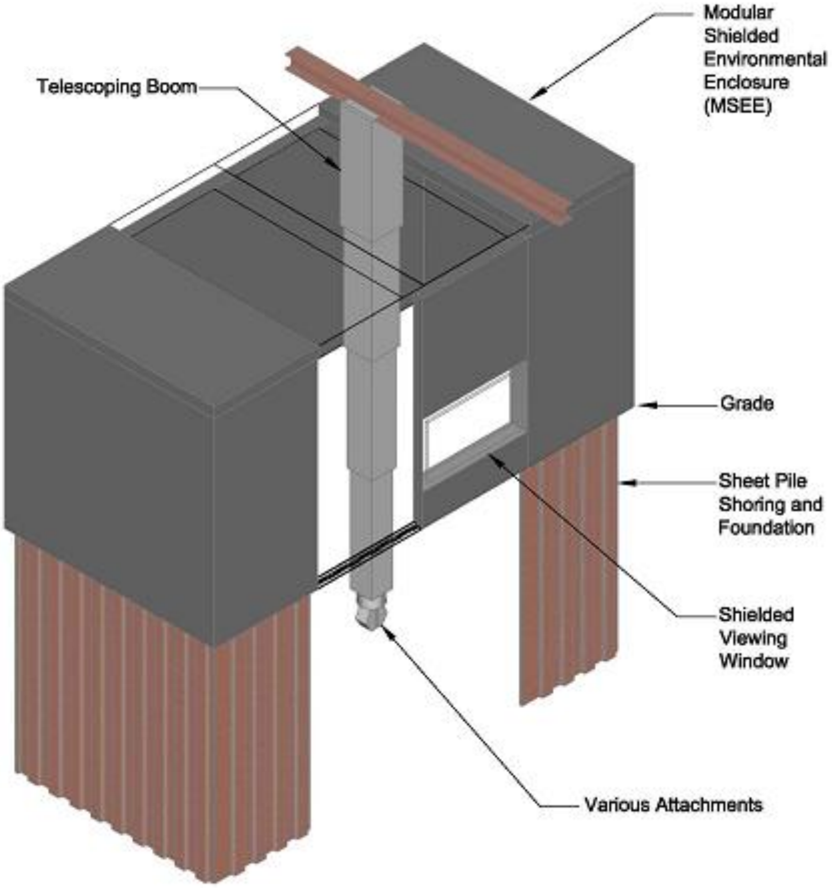


Exhibit V- 4: MSEE for the NDA Deep Holes – Perspective View (URS 2009)

A hydraulic hammer attachment would be used to break up any hard objects that may be present in the Deep Holes, such as the concrete placed over the spent fuel in Deep Hole 48. The crane and its various attachments would then be used to remove the waste from the Deep Holes. Because a large number of the drums are located in saturated soil, it is expected that the drums will not be structurally intact for removal. In this case, a clamshell bucket attachment might be used for bulk waste removal. Remote monitoring instruments on the crane arm will be used to preliminarily determine the waste activity level and the type of waste package into which the waste will be placed upon removal. Both drums and B-25 boxes will be used for waste transfer to the CMF for further waste testing, processing, and shipment or storage.

After the waste has been removed from the Deep Holes, Special Holes, and WVDP trenches, the entire burial area would be excavated to a depth below the bottoms of the disposal holes using standard excavation equipment. This excavation would encompass subsurface barriers installed to support remediation. The excavated soil would be placed into lift liners in intermodal type containers or in gondola railcars, sampled for waste characterization purposes, and then managed as LSA waste.

Precedent Applications: The EXWG found no precedent project that used the FEIS-proposed method of excavating material from a borehole in a similar application. In particular, the fundamental reliance on a variety of end effectors attached to the Z mast of a remotely-operated crane to remove waste from 55-ft. depths in a constrained 3 ft. x 7 ft. hole is without any known precedent.

Summary of Applicability: At a concept level, there is nothing that would rule out the MSEE and crane system as being applicable for excavating the Deep Holes. It is likely, however, that a prototype unit would need to be developed and proven on a clean test area, and the equipment modified based on lessons learned.

Limitations on Use: Neither the FEIS nor the supporting engineering reports provide details on how the waste drums would be removed and what particular attachments to the Z mast of the crane would be used. From a practical standpoint, the ability to remotely secure and remove intact drums when they are positioned side-by-side within a 3 ft. x 7 ft. Deep Hole would be questionable. This scenario is further complicated by the saturated nature of the surrounding soil and the likely long-term degradation of the drums. It may be found that the only option is to remove the waste in bulk using a clamshell bucket. This increases the risk of damaging any drums that may still be intact and exacerbating the release of radionuclides to adjacent soil and groundwater.

The sheet piles to support the excavation will need to be on the order of 65 ft. long. The NDA Environmental Enclosure has eave heights that are on the order of 35 ft. high. Full-length sheets will not be able to be driven; instead, sheet sections will need to be welded together during pile driving.

Cost Considerations: As indicated in Section V.A.2.a above, the cost information supporting the FEIS base case did not segregate the costs of exhuming waste from the Deep Holes from the costs of waste removal from the Special Holes and trenches. Consequently, the $818,807,900 total cost associated with NDA waste excavation and disposal remains the only value available. Nevertheless, because the number of Deep Holes and Special Holes is roughly the same, and the Deep Holes will represent a more costly effort on a ‘per hole’ basis due to the remote operations and greater depths, one can reasonably assume that considerably more than half of the estimated costs will be associated with the Deep Holes.

b) Option 1: Excavation Using Waste Grouting and Drilling

Description: Under Option 1, large-diameter augers capable of injecting grout into the porous waste and adjacent soil under pressure would be used to drill through each Deep Hole, break up any hard material, and inject a solidifying grout throughout the waste column. Exhumation of the solidified grout mixture (including the waste) from within the borehole would then be completed through a drill-out operation.

Precedent Applications: The primary example of a precedent application is the excavation of wastes from vertical pipe units (VPUs) at the Hanford 618-10 and 618-11 areas. Both burial grounds were used for the disposal of wastes from research activities related to fuel metallurgy and plutonium separation processes (Faulk et al, 2011; US Department of Energy, 2013). The 618-10 Area contained 94 cylindrical VPUs used for the disposal of higher activity wastes (some of which have already been removed), whereas the 618-11 Area contains 50 VPUs (Faulk and Little, 2010).

Each VPU is approximately 15 feet in length, 1.8 feet in diameter, and covered with several feet of soil (Dunhan, 2012). The most common type of VPU was constructed from five 55-gallon steel drums welded together with the tops and bottoms removed, thus forming an open pipe-like structure. Two other types of VPUs are the same length and design, but use either a corrugated metal tube or a solid steel pipe instead of welded drums (Mayers, 2014). As illustrated in Exhibit V-5, these open-bottom cylindrical forms were placed vertically in an excavated hole with a concrete floor pad. The VPUs stored high activity waste from hot-cells that was stabilized in gelatin and placed within aluminum paint cans and jars, which then dropped into the VPUs along with soil to fill the void space, and capped with a concrete plug before being backfilled with clean soil (Faulk and Little, 2010).

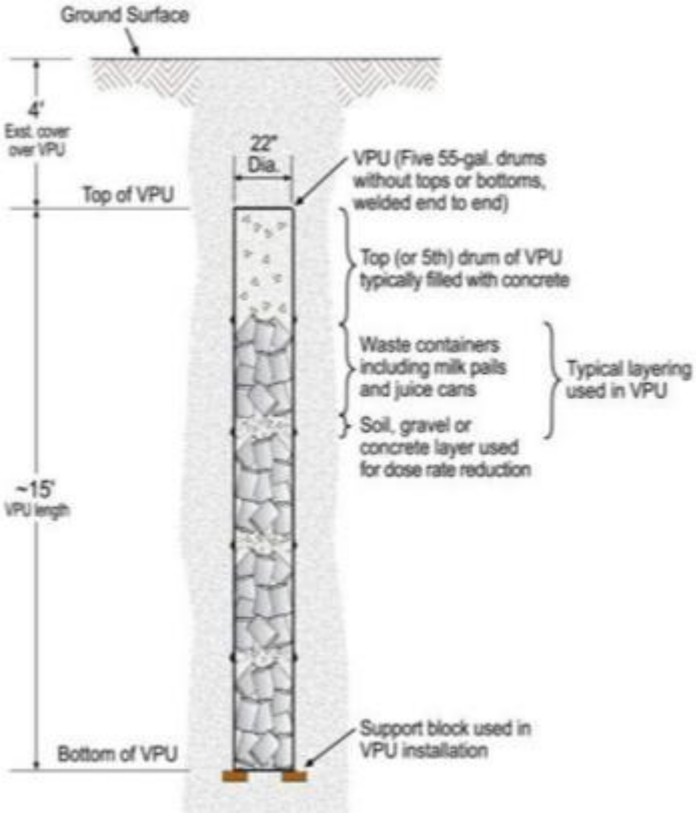


Exhibit V- 5: Sketch of a Typical Vertical Pipe Unit (Dunhan, 2012)

A geophysical survey was initially conducted to delineate the location of the VPUs. Following these geophysical surveys, intrusive characterization of the VPUs was conducted in 2009 and 2010 by installing four push probes around each VPU. A multi-detector probe (MDP) was used to provide in-situ characterization of the VPU waste and to identify VPU hot-spots. The MDP incorporated a gross gamma detector, a low-level gamma isotopic activity detector, a high-level gamma isotopic activity detector, a neutron detector, and a gamma probe. Dose rate information from the characterization study showed that approximately one-third of the VPUs contained waste with exposure rates less than 100 mrem/hr, one-third contained waste between 100 and 1,000 mrem/hr, and one-third contained waste between 1,000 and 9,000 mrem/hr. About 20 percent of the waste was estimated to be TRU. It was also determined that no contamination of the soil around and beneath the VPUs had occurred.

The first step in removing waste was to use a crane with a vibratory hammer to install a 4 ft diameter cylindrical steel over-casing extending the length of each VPU (Exhibits V-6a and V-6b) (Dunhan, 2012). This created an isolated working environment to prevent the lateral release of waste constituents. Next, a rock auger mounted on a deep foundation drill was used to drill into the material enclosed within the over-casing to destroy the waste containers and to mix the waste (Exhibit V-7) (Mayers, 2014). The auger tool was encased in an enclosure at ground surface to prevent any airborne contaminant release. During removal of the auger, waste samples were retrieved for characterization to support off-site disposal (Exhibit V-8). (It is noted that Exhibits V-6b through V-9 apply to the Hanford project and contain some information not pertinent to West Valley.)

Exhibit V- 6a: Over-Casing Being Driving into the VPUs (Charboneau, 2015)

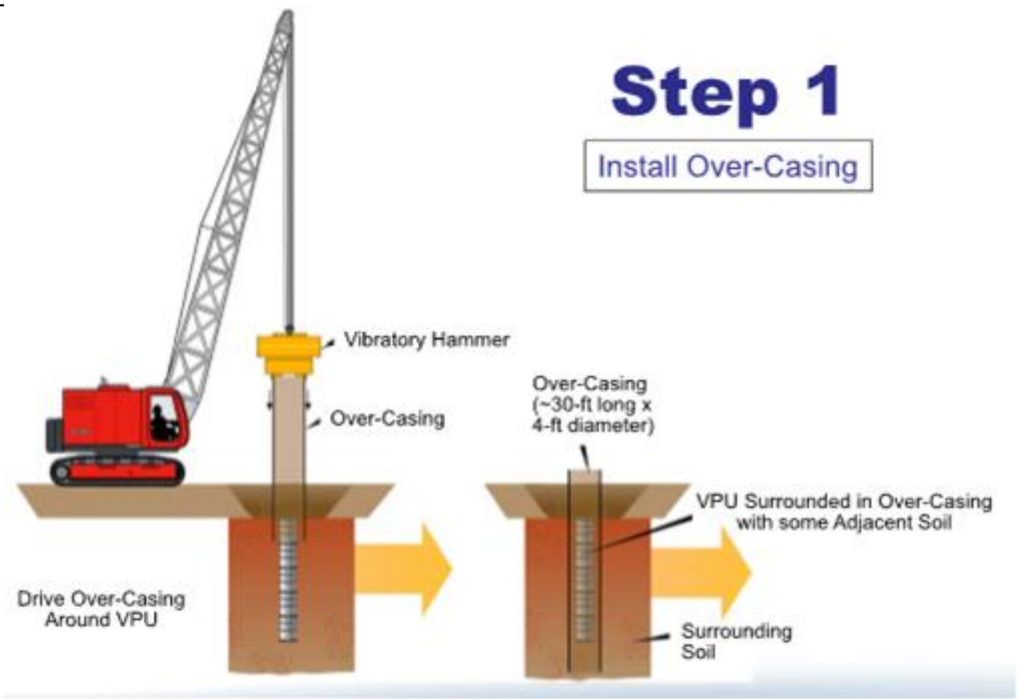


Exhibit V-6b: Installation of Over-Casing Around a Vertical Pipe Unit (Dunhan, 2012)

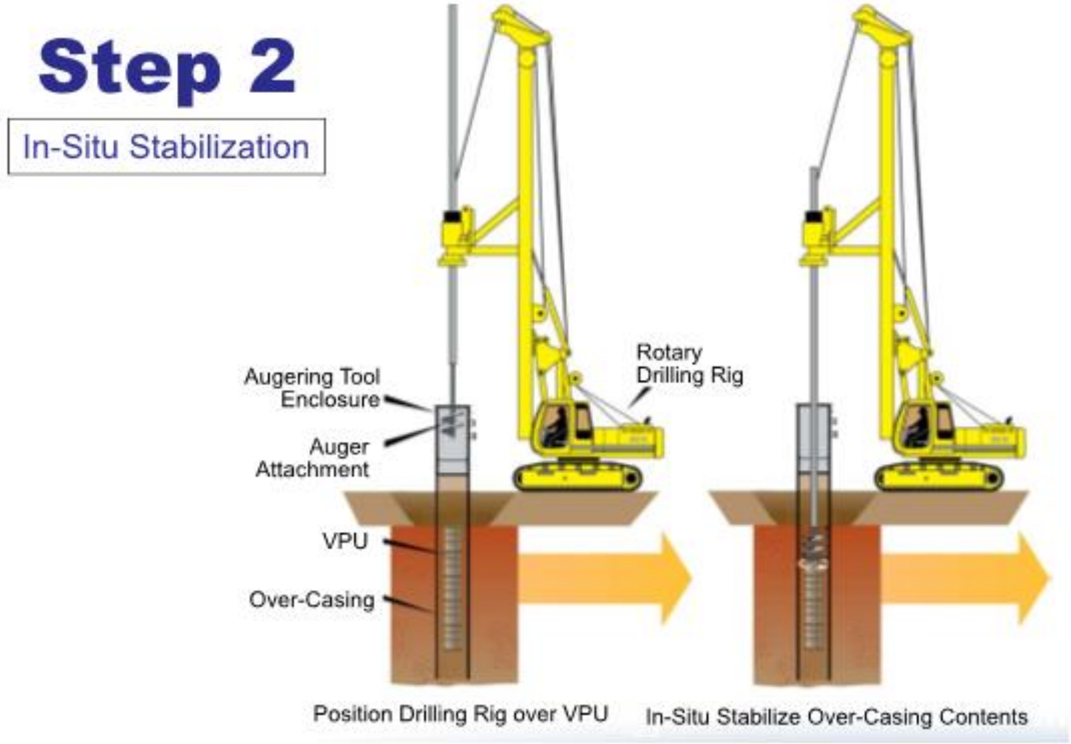


Exhibit V- 7: Augering of Material within a VPU (Dunhan, 2012)

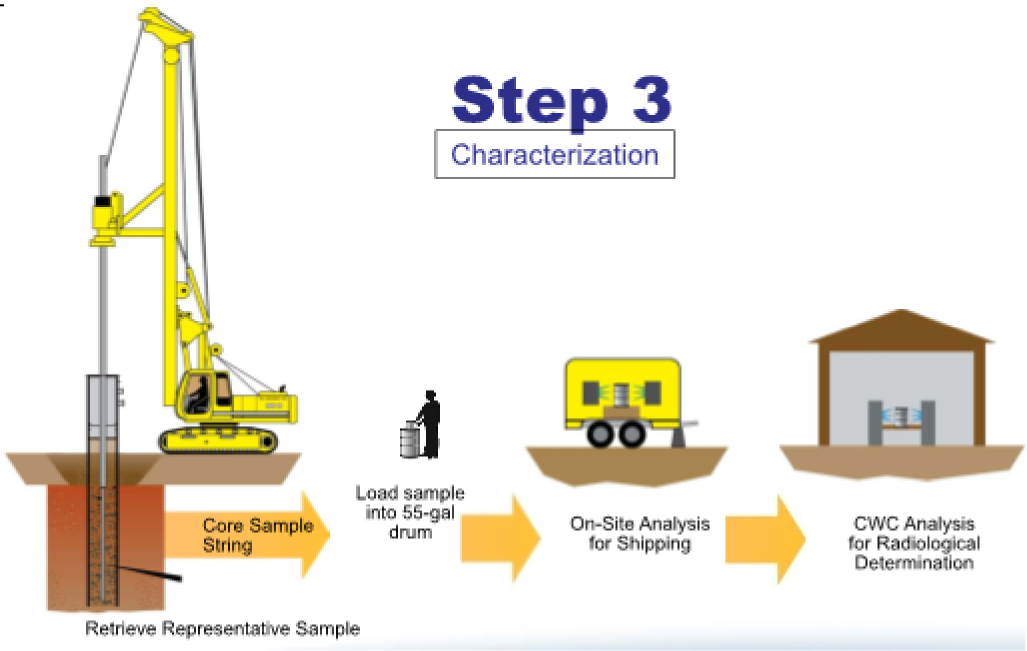


Exhibit V- 8: Sampling and Characterization of Material within a VPU (Dunhan, 2012)

Following characterization, one of three previously tested methods was used for retrieving wastes from the VPUs depending on the expected waste type. Due to the depth of the NDA Deep Holes, the method most applicable to the NDA Deep Holes is to inject grout into the augered waste and over-casing to stabilize the entire volume of waste material (Exhibit V-9), and then to use an augering device to extract the grout mixture from the borehole (Exhibit V-10).

A sealed retrieval enclosure containing HEPA filtration and negative pressure was employed to prevent waste release and to protect workers upon waste retrieval (Exhibit V-10). The grab tool at Hanford dropped waste onto a movable hopper, which then deposited the waste onto a conveyor for transfer to a waste drum. Grout was also added to the drums if waste stabilization was required for hazardous substances.

Summary of Applicability: The drilling technology at Hanford was equipped to cut through metal waste containers and steel drums, so it should be able to handle cutting through West Valley waste containers, particularly those that are expected to be deteriorated as a result of saturated soil conditions. The method was designed to safely exhume TRU and hazardous waste at Hanford, and should be able to extract the waste types found in the Deep Holes with few exceptions. The grout will provide shielding from the waste material, reduce the risk of reactivity events, stabilize the waste, and absorb leachate present within the grout matrix.

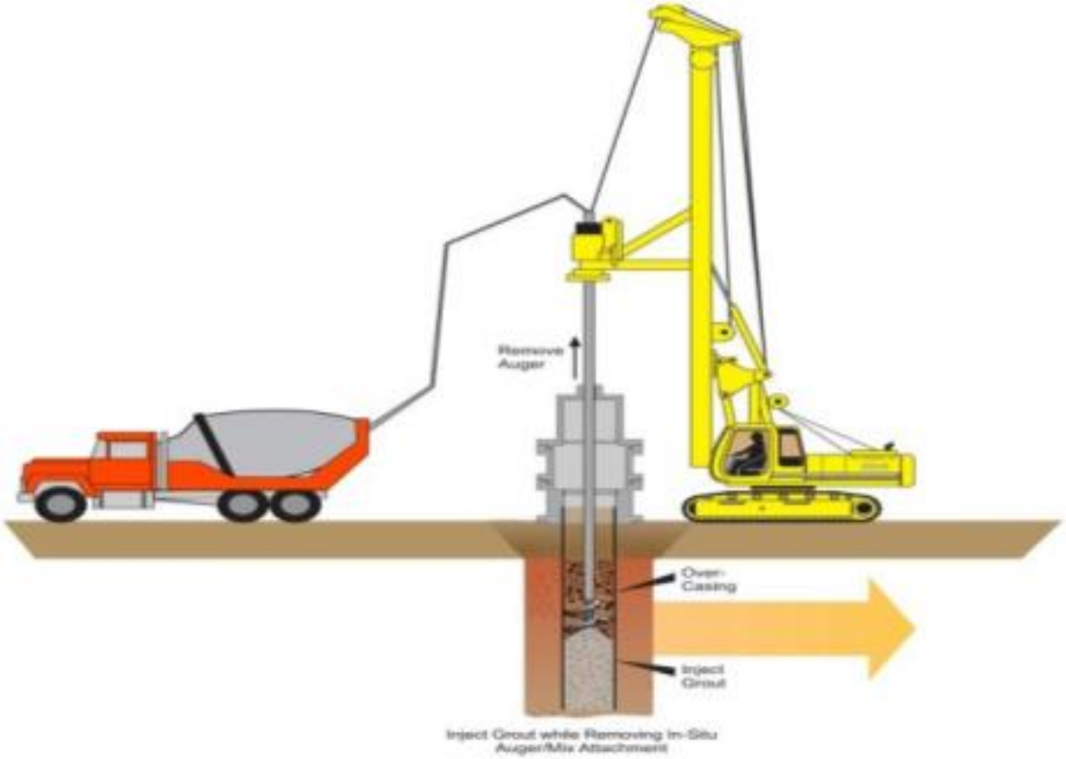


Exhibit V- 9: Injection of Grout into Augered Material and Over-Casing (Halliwell, 2012).

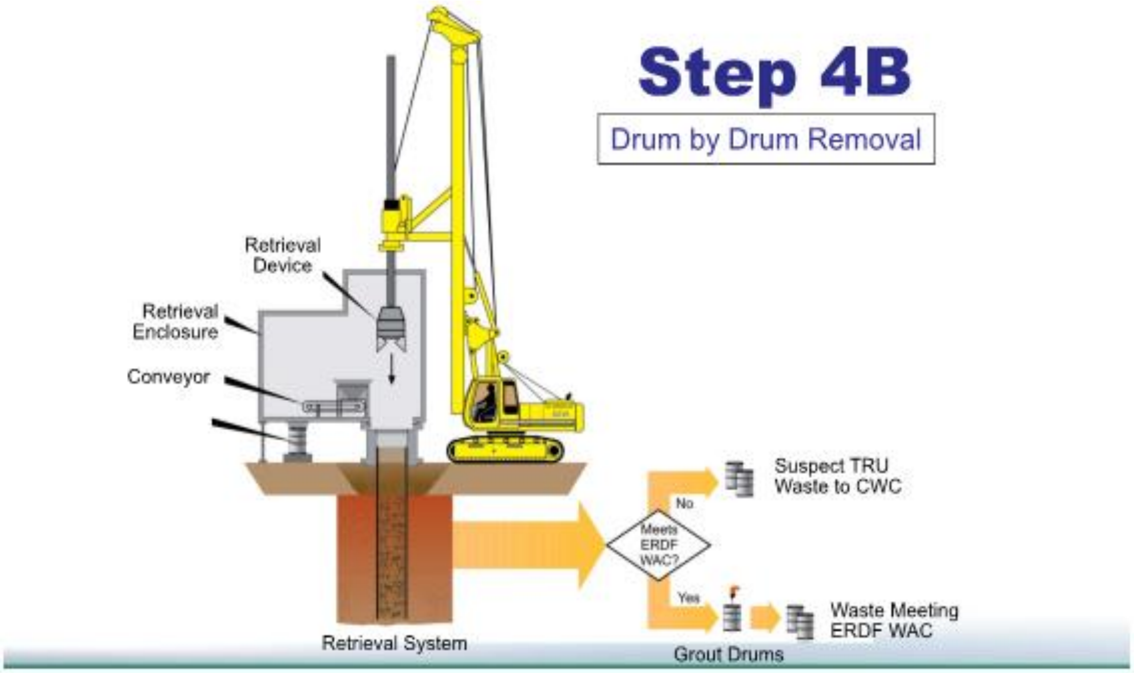


Exhibit V- 10: Surface Operations for Removal of Grouted Waste (Halliwell, 2012).

A pre-augering characterization study of the soil surrounding each Deep Hole using an MDP with gamma detection is recommended to preliminarily characterize the waste material in each Deep Hole prior to exhumation. The study results can be used to determine if the soil surrounding a Deep Hole is contaminated and the lateral limits of the planned excavation. The injection of grout into augered waste and/or the mixing of waste with grout raises some technical concerns when applied to the NDA Deep Holes, as discussed below, but these limitations would not necessarily eliminate the method from consideration.

Limitations on Use: The Deep Holes at West Valley are larger in diameter than the size of the over-casing designed for Hanford, which would require the fabrication of a larger over-casing and auger assembly. The waste at the NDA is also buried significantly deeper than the waste in the VPUs – up to 55 feet at West Valley versus 15 feet at Hanford. The presence of the Lavery Till throughout the waste zone will also make it more difficult to drive up to a 9-ft diameter casing around a Deep Hole to a depth of 55 feet. Therefore, a cutter head with teeth similar to those used for drilled shaft formations will likely be needed. The option of installing a sheet pile wall similar to that proposed under the FEIS base case, and then grouting the waste within the sheet pile wall, may be viable and should be retained for further evaluation.

The enclosure supporting the augering operation may also have to be higher under this option in order to accommodate the necessary overhead clearance. To offset this concern, the auger system would use drilled shaft construction equipment designed to operate in low ground clearance situations. Equipment selection would have to balance the required power rating to turn the augers against the available clearance. In the event that equipment meeting site conditions are not available, a unit may need to be specially fabricated. It should be noted that while drilled shaft equipment can be operated with a low overhead clearance, it is typically less efficient than operating without any clearance restrictions.

The concept of grouting and then removing all material within the 9-ft diameter casing would also require removal of a soil volume that would approximately double the volume of material to be managed as waste from each hole. The total quantity of the volume increase will depend on how many Deep Holes are exhumed. The large volume increase is mostly made up of in-situ soil within the annular space of the augered boring and not the cement being added to form the grout. Ideally, the volume of cement added will be enough only to fill the existing pore space (absorbing pore water to form the grout). Practically, this volume is exceeded so that several feet of ground heaving will likely occur. The heaving is expected to involve only the soil layer covering the waste in the Deep Holes and will not introduce an additional exposure risk.

Another potential limitation is that the Deep Holes at West Valley may not be as easily locatable due to the absence of metal casing that allowed the use of geophysics to locate the VPUs at Hanford. Based on the experience when removing two NDA Special Holes in 1986, accurately locating the Deep Holes may be difficult and it may be necessary to remove the cover soil before using geophysical techniques to locate the metallic drums buried in the Deep Holes.

Cost Considerations: The estimated excavation costs reported in the Hanford 300 Area ROD issued in 2013 were $299,152,000 non-discounted and $247,614,000 net present value (US EPA, 2013). However, these costs cover the entirety of the Hanford 300 Area cleanup, and there is no breakdown available for VPU removal at the 618-10 and 618-11 Areas. Therefore, there are no costs to compare against the FEIS costs, which as stated earlier are also not broken out to show only the cost of removing the NDA Deep Holes.

3. Comparison of Options

The approach taken at the Hanford 618-10 Area using an over-casing and mixing the waste with grout before excavation is generally comparable to the FEIS base case of remote retrieval in terms of applicability and worker exposure. The Hanford approach retains more flexibility of operation and could be applied to a wider range of waste streams when compared to the FEIS base case. This is because the Hanford approach grinds and mixes all waste before excavation while providing additional worker shielding by mixing the waste with grout and using a retrieval enclosure. However, this is at the expense of creating up to double the volume of waste compared to the FEIS base case. Without an appropriate break-out of cost information on either option, it is not possible to make a cost effectiveness comparison.

Both the FEIS base case and Option 1 carry technical challenges that could require testing in a clean environment prior to full-scale implementation at the NDA. In the case of the FEIS base case, there remains some uncertainty as to what end effectors would be most appropriate to remove tightly-spaced, degraded drums in a narrow, confined space more than 50 feet below ground. As for Option 1, there would be a need to modify the original over-casing design used at Hanford, as the Deep Holes are much deeper and larger in diameter.

VI. Waste Processing

A. Summary of Need

The potentially large volume of waste to be generated under the Phase 2 decommissioning program will come from different areas at the WVDP and will be highly varied in terms of the waste type; the size, material, and condition of the waste containers; the radiological make-up of the waste; and the activity level. In addition, even if dewatering is implemented prior to waste removal, at least a portion of the waste will be wet when exhumed and will require drying prior to processing. As such, there is a need to provide for remote waste handling, processing (drying, size reduction, sorting, compaction), packaging, and characterization of the solid wastes removed. Because the WTF will likely have its own waste processing facility (refer to Section VIII), the focus of this discussion is the need for post-exhumation management of the wastes generated from the NDA and SDA excavation projects. It is recognized that various other WVDP decommissioning projects may also contribute waste for processing at any facility set up for the NDA and SDA wastes.

In preparing the FEIS, one existing facility was considered as a potential candidate to house the waste processing operations – the Drum Cell. The Drum Cell was, however, determined to be inadequate in terms of size, and would require significant modification to upgrade what was then a 20-year old facility to support the required functions. Consequently, the need arose for a new facility or facilities to provide the necessary waste handling, processing, packaging, and characterization capabilities.

B. Potentially Applicable Approaches

1. FEIS Base Case: Central Container Management Facility (CMF)

Description: In the FEIS, waste exhumed from the SDA, NDA, and other areas was assumed to be processed in a newly constructed, centralized CMF. The CMF was to be constructed along the rail spur on the South Plateau for three primary reasons: (1) the greatest quantities of such wastes would come from the adjacent NDA and SDA; (2) the location would minimize the effort needed to ship waste containers by rail; and (3) the single location on the South Plateau would allow all facilities and operations to be removed from the North Plateau.

The CMF would be capable of receiving and handling wastes in an "as excavated" form or in a “packaged” form. The primary components of the waste processing area would include:

- *Rotary Waste D*ryer – A rotary drum dryer was selected for drying the mixture of buried wastes, soil, and waste packages expected from the NDA and SDA removal projects. It would be capable of accepting a wide variety of materials in any size smaller than the diameter of the rotary drum. The dryer would be operated at a slight vacuum for purposes of contamination control. The tumbling action of the dryer would break clods of soil and cause separation of the soil from any equipment, hardware and other debris.

- *Off-Gas Treatment System* – The off-gas treatment train from the rotary drum dryer would consist of a catalytic oxidizer for destruction of airborne organics; a heat exchanger for removal of heat energy from the off-gas; a quencher for temperature reduction; and a HEPA filters for particulate removal.
- *Dry Waste Processing Stations* – Numerous remotely-operated processing stations would be used to appropriately sort, size-reduce, and package the dry wastes. In general, each of these stations would include shield windows, master-slave manipulators, and power manipulators. The various types of processing stations planned for the CMF consist of:
  - *Shaker Station* – The primary item of equipment in the shaker station would be a shaker table designed to separate loose soil from waste hardware.
  - *Sorting Station* – Located in close proximity to the shaker station, the sorting station would be where an operator would begin sorting wastes based on physical makeup.
  - *Volume and Size Reduction Stations* – These stations would consist of various remotely-operated cutting equipment (saws and torches), shearing equipment, vises, and a super-compactor.
  - *Packaging Station* – Drumming and boxing of wastes would occur at the packaging station. This station would employ a bridge crane capable of lifting and moving filled waste containers and any processing equipment that needs to be decontaminated and transferred out for repair.
- *Decontamination Room* – The Decontamination Room would be located in an airlock that would allow for hand-wiping of packages containing contact-handled wastes, and for mechanical decontamination of packages containing remote-handled wastes. A remotely operated decontamination system, such as a carbon dioxide pellet system, would be provided.
- *Waste Characterization and Cask Loading Room* – This room would include an overhead crane, scales, nondestructive analytical equipment, and portable shielding. The nondestructive analytical equipment would include separate radiography stations for boxes and drums, a waste curie monitor that would employ scintillation detectors to measure beta/gamma activity, high-resolution gamma spectroscopic measurement systems employing high-purity germanium detectors for boxes and drums, and passive neutron measurement systems for boxes and drums.

The CMF would also have a storage area to provide for long-term storage of any orphan waste for which there is no currently approved disposal location. The interim storage aspect of the CMF is addressed separately in Section VII below.

Precedent Applications: The layout, process design, and equipment selection for the CMF were specific to the types of waste and waste containers expected to be generated from the NDA, SDA, and other areas of West Valley. While no precedent project was found that replicated this design, the individual processes are commonly used at DOE facilities and in commercial operations. The EXWG identified several variants of these processes used on precedent projects at DOE sites under Task 3.1. One exception is the Rotary Drum Dryer proposed for use as an integral part of the CMF, as the precedent projects involved only waste exhumation under dry conditions and did not have to accommodate a means for drying the waste prior to processing.

Summary of Applicability: As indicated above, the proposed CMF was conceptually designed specifically for the waste types and containers expected to be generated from the NDA and SDA, and is thus fully applicable to post-exhumation waste management at the West Valley site. Designing the CMF to retain all waste handling, processing, packaging, handling, and interim storage activities under a common roof will minimize the risk of worker exposure and environmental release. The design of the facility to Performance Category 3 standards and the robust radiation controls being proposed will further enhance the level of protection against natural hazards, worker exposure, and releases of radiologically and chemically contaminated materials to the environment during all facets of the waste management process.

Limitations on Use: One “unproven” component of the waste management process is the Rotary Waste Dryer that is being required due to the expectation that a portion of the waste that is exhumed from the NDA and SDA will be wet, if not saturated with water. While there is nothing known at this time that would challenge the selection of a rotary drum dryer to perform the waste drying, there remains an uncertainty as to the capacity and flexibility of that specific dryer to effectively accommodate the expected highly variable nature of the waste forms requiring the drying step. Any operational deficiency in the rotary drum dryer would not, however, preclude the selection and implementation of the CMF concept as a whole. Supplementary or alternate drying systems could likely be introduced into the process chain if necessary.

A second concern regarding the CMF is a potential lack of design flexibility when the facility is being designed to effectively address wastes from multiple sources under a full exhumation alternative. Significant changes in process selection and design could result from a decision to pursue only selective removal scenarios at the SDA and NDA. While some of the underlying decisions will be made prior to final design, thus allowing for some of the resultant process changes to be incorporated prior to CMF construction, the possibility exists that exhumation projects across the WVDP will be staggered in time and not all decisions will be made upfront. This situation could lead to an over-design of the CMF at higher cost; however, this would not in and of itself preclude the concept of a centralized waste handling, processing, packaging, and characterization facility when ranked against the other available options discussed below.

Cost Considerations: Based on information provided in URS (2009), the estimated costs to construct, operate, and then decommission the CMF are shown in Table VI-1. A large percentage of the Construction Materials cost of $85.8 million would not be unique to the CMF and would be required regardless of the waste processing approach. For example, $36 million of the Construction Materials cost is for the purchase of 18 gamma scan units for waste characterization at $2 million each.

CMF Effort	Materials	Labor	Waste Disposal	Contingency	Total Cost
Construction	$88,528,300	$62,124,000	$502,200	$37,663,200	**$188,817,700**
Operation	$13,852,500	$487,203,600	$3,222,400	$251,333,800	**$755,612,300**
Closure	$2,582,700	$20,904,300	$6,896,100	$7,595,900	**$37,979,000**

Source: URS 2009, Table 3-18

Table VI- 1: FEIS CMF Estimated Cost

2. Option 1: Localized Waste Processing

Description: Under Option 1, the centralized CMF would be replaced by a series of operations performed within the individual protective enclosures at the NDA and SDA. The prototype for this option is the method used at INL to exhume TRU waste and LLW from trenches. As waste was removed from the ground, it was placed into a lined tray. The tray was then transported by forklift (telehandler) to a Drum Packaging Station within an airlock for further processing (DOE 2008b). The Drum Packaging Station was a modified glovebox designed to allow operators to examine and repackage all targeted waste for eventual disposition as TRU or LLW (Exhibit VI-1).

Precedent Applications: As indicated, the waste processing method proposed as Option 1 was successfully applied at INL, which occurred subsequent to the issuance of the FEIS. The waste retrieval project at INL appears to be similar to the exhumation of waste from the SDA and NDA; however, importance differences do exist. The waste retrieved at INL was better defined and not as variable as the SDA and NDA waste, and all the waste was packaged either in drums or boxes that accommodated transport to and processing within the Drum Packaging Stations. For the most part, the INL waste could also be identified and distinguished through visual inspection due to specific characteristics of the waste, which originated at Rocky Flats and was shipped to INL for retrievable storage. Most importantly, the INL waste did not require a pre-drying step.

Summary of Applicability: The general concept of separately processing waste within the SDA and NDA enclosures could likely be implemented, but the process chain would have to be expanded beyond what was used at INL to accommodate the full range of waste forms and types. The primary advantage of moving to localized waste processing would be if the various waste sources were highly different and would require different processes to meet site-specific needs. This is not the case with the NDA and SDA waste, however, and both sites would need the same processes being planned for the CMF.

Exhibit VI- 1: Targeted Waste Sorting and Segregation at a DPS

Limitations on Use: There are three primary features of the waste potentially exhumed from the SDA and/or NDA that would make localized waste processing difficult. First, at least a portion of the waste exhumed from the SDA and NDA is expected to be saturated with water due to its long-term exposure to leachate within the disposal trenches/holes. Second, depending on whether or not there is a decay period and the duration of any decay period, the SDA/NDA waste has the potential to have very high contact dose rates (e.g., greater than 1 roentgen per hour [R/hr]), which would exclude glovebox processing. An example would be the leached hulls and fuel assembly hardware from the NDA Deep Holes. And third, the sheer size of some of the waste forms (e.g., the concrete casks) would be difficult to accommodate with an on-site processing facility contained within the environmental enclosures.

Cost Considerations: The cost information that is available on the INL waste retrieval project does not cater to breaking out the cost of the waste processing operation. On the one hand, incorporating process facilities within the environmental enclosures already planned for the SDA and NDA would eliminate the need for the CMF and its very high cost. On the other hand, because the individual waste processing components would still be needed, the use of localized facilities would result in a duplication of process equipment and redundant capital costs, and to some degree a duplication of operating costs. Based on the FEIS cost summary reported in Table VI-1, which shows operating costs to dominate capital costs, one can only conjecture that there would not be a significant cost savings in moving to localized waste processing facilities. In fact, Option 1 may prove to have a higher cost than the use of the CMF proposed as the FEIS base case due to the duplication of processes and their operation.

3. Option 2: Site-Wide Waste Processing Facility

Description: Option 2 would involve the consolidation of the CMF and the waste processing facilities currently proposed for the HLW tanks (see Section VIII.B.1) into a single facility located in the same area as the CMF.

Precedent Applications: As discussed in both Section VI.B.1 above and Section VIII.B.1, no precedent project was found that matches the exact process train proposed in the FEIS, although the individual processes have been previously applied at other sites for radiological waste handling, processing, packaging, and characterization. The most apparent difference in the CMF when compared to facilities at other sites is the need for a rotary drum dryer due to the wet nature of a portion of the SDA and NDA waste.

Summary of Applicability: The individual waste processing facilities for the WTF and the other waste sources were concluded to be generally applicable to the corresponding waste streams. One can reasonably assume, therefore, that a consolidation of the two sets of processes would remain generally applicable as long as all of the individual processes are accounted for and appropriately sized.

Limitations of Use: There are several drawbacks to utilizing the concept of a consolidated waste processing facility. First, the material coming out of Tanks 8D-1 and 8D-2 is expected to be much more radioactive and different in form than the material exhumed from either the SDA or the NDA. Second, some of the material exhumed from the SDA and NDA is expected to be saturated with water from being exposed to trench leachate. Third, the centralized waste processing facility would combine radioactive materials that are under different regulatory frameworks (State vs. Federal). Finally, transporting the tank waste from the North Plateau to the South Plateau, or the reverse, would add a transport component to the waste processing operation and increase both the exposure/release potential and the cost. For these reasons, though potentially applicable, a site-wide waste processing facility for all waste would likely not be cost-effective, preferred, or sufficiently protective.

Cost Considerations: The use of a consolidated waste processing facility would likely not result in significant cost savings. An enlarged Category 3 CMF structure would still be required, as would a variation of the robust rigid enclosure to support the removal of Tanks 8D-1 and 8D-2 even if the waste processing facilities are moved out of that facility. Dual use of waste processing equipment would likely not be widespread given the significant differences in the form and activity of the tank waste versus the NDA/SDA wastes. Reduced labor costs is one area of potential savings that could result from the consolidation of operations into a single facility; however, any reduction in labor costs would likely be offset by the operational limitations identified above.

C. Comparison of Options

A comparison of Option 1 with the FEIS base case indicates that the use of a centralized waste management facility (i.e., the CMF as proposed in the FEIS) for the SDA, NDA, and other waste sources would be favored over the processing of waste in the vicinity of the waste exhumation operations. The one exception to this determination would be if selective exhumation scenarios are eventually selected for the SDA or NDA that do not require the full set of waste management processes currently envisioned. In that case, consideration should be given to the use of separate facilities at the SDA and NDA.

The consolidation of waste processing operations for the HLW tanks and the other waste sources into a single facility would typically have certain operational and cost advantages over the FEIS base case. However, there are aspects of the sitewide waste processing facility that represent significant limitations when viewed within the context of technical, regulatory, and risk factors. These limitations revolve around major differences in the characteristics of the waste streams and the distance across which the waste would have to be transferred. There is also a high level of uncertainty as to what a consolidated facility would look like and how operations would be conducted, which could eventually increase costs and compromise some of the advantages of a consolidated facility. In general, the use of a sitewide consolidated facility is not recommended for further consideration in the Phase 2 decision process.

VII. Interim Waste Storage

A. Summary of Need

Table VII-1 highlights the distribution of solid waste types expected to require disposal under the full exhumation alternative at West Valley (URS, 2008b).

Waste Type	Estimated Disposal Volume (CY)	% of Total
Low-Specific Activity	1,782,230	91.0%
Class A	160,366	8.2%
Mixed	748	<0.1%
Class B	3,356	0.2%
Class C	5,179	0.3%
TRU	1,329	0.1%
GTCC	5,534	0.3%
Total	**1,958,741**	**100.0%**

Table VII- 1: Distribution of Waste Volumes by Type

The waste types shown in the last four rows of Table VII-1 are referred to as orphan wastes, which have no currently available option for permanent off-site disposal. Included are pre-project Class B and Class C low-level radioactive waste, GTCC waste, and TRU waste. Pre-project waste is waste that was buried before DOE assumed control of a portion of the site and would, therefore, not qualify for disposal at a DOE facility such as the Nevada National Security Site (formerly the Nevada Test Site). Off-site disposal of any TRU waste generated from the SDA is complicated by the fact that the waste is not defense-related and, as such, is not eligible for disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico. Interim waste storage is, therefore, required for orphan waste until an off-site disposal option becomes available. The interim on-site storage of orphan waste is addressed in Section VII.B below.

As shown in Table VII-1, less than 1% of the total waste volume will be orphan waste. The remaining 99% of the generated waste – LSA, Class A, and mixed wastes – is expected to be shipped off site as it is exhumed and processed, such that no temporary on-site storage is being provided except for whatever is available within the waste shipment area of the planned CMF. Because continuous shipment may not be practical at all times, potential options for the interim on-site storage of LSA, Class A, and mixed wastes must also be considered. Options for the storage of non-orphan wastes are presented in Section VII.C below.

B. Interim Storage of Orphan Waste

1. Potentially Applicable Technologies

a) FEIS Base Case: Interim Storage within CMF

Description: As developed in the FEIS, interim storage of pre-project Class B and C low-level radioactive waste, GTCC waste, and TRU waste would be provided within an addition to the CMF. This portion of the building was designed as a single-story, warehouse-type structure that contains a floor area of 70,000 square feet, which will provide adequate storage capacity for the total volume of orphan waste expected to be generated under the full removal alternative. The waste generated from the removal of the HLW tanks will also be stored within this area of the CMF after processing within a separate facility at the WTF.

The integrated addition would be constructed of shielded walls consistent with the CMF, which is being designed and built to meet the requirements of a Performance Category 3 structure (as defined by DOE Standard 1020-2002). The interim waste storage facility would be used until an off-site disposal facility becomes available to accept the stored waste, with the building demolished after all wastes have been removed.

Precedent Applications: While no other site was found that integrated the interim waste storage facility within a multi-purpose waste processing building, on-site interim waste storage facilities similar in concept to that proposed for the storage wing of the CMF have been used throughout the DOE complex and in commercial operations. One aspect of the situation at West Valley that could distinguish this facility from those at other sites is the potential long timeframe that the ‘interim’ facility may remain operational due to the uncertain future availability of an approved off-site disposal option for the orphan waste.

Summary of Applicability: The proposed facility is fully applicable to the West Valley site for the interim storage of the volumes and types of waste expected to be generated. The design of the facility as part of a Performance Category 3 structure will achieve protection against natural hazards and releases of radiologically and chemically contaminated materials to the environment. Designing the interim storage facility as part of the CMF will also retain all waste handling, processing, and storage activities under a common roof to minimize the risk of worker exposure and environmental release.

Limitations on Use: The use of an integrated interim storage facility has two minor disadvantages, neither of which would necessarily prohibit its use for the Phase 2 decommissioning project at West Valley. These include:

1. The likelihood exists that the storage portion of the CMF will have to be maintained beyond the completion of work that requires use of the CMF. In this case, either the larger facility would also have to be maintained or a separate capital project would

be required to isolate the interim storage facility to accommodate demolition of the remainder of the CMF.

2. As with the leachate treatment facility, the eventual size and nature of the interim storage area could be reduced if a selective exhumation alternative is eventually selected. Tying the storage facility to the CMF reduces the flexibility in responding to changes in the exhumation strategy over time.

Cost Considerations: The cost information available to ECS does not segregate the costs of the interim storage area from the costs of the CMF. The total consolidated costs of construction, operation, and demolition are estimated to be $189 million, $756 million, and $38 million, respectively, in 2008 dollars (URS 2009). If one assumes that at least half of the construction and demolition costs would be associated with the interim storage area given that it makes up about 75% of the building footprint, this would result in a cost of more than $110 million in 2008 dollars exclusive of operating, maintenance, and monitoring of the waste storage area. The inflated future costs would be much greater, although the operating life is difficult to determine given the uncertainty as to when off-site disposal facilities will become available.

b) Option 1: Stand-Alone Interim Storage Facility

Description: The stand-alone interim storage facility is, in essence, a replication of the base case, but as a stand-alone facility rather than having the storage area integrated within the CMF. While this option could eliminate some of the limitations of the FEIS base case noted above, the differences from an applicability standpoint are minor and will not be addressed further in this section. A stand-alone facility would also have to be constructed to the same performance standards as proposed under the FEIS base case due to the waste types being stored, and thus the capital and annual operating costs would be expected to be comparable to the interim waste storage area under the FEIS base case.

c) Option 2: Off-Site Storage and Disposal

Description: The off-site storage option refers to two radiological disposal areas at the Waste Control Specialists (WCS) facility in Andrews County, Texas (WCS, 2017), which are introduced in this section because each of the areas has opened since the issuance of the FEIS in 2008 and provides an option for the immediate off-site shipment of the pre-project Class B and Class C waste planned for storage within the CMF. With reference to Table VII-1 above, more than half of the orphan waste is made up of Class B or Class C waste, such that a significant reduction in the size of the orphan waste storage area should be possible if only TRU and GTCC wastes require long-term on-site storage at West Valley. The two recently permitted disposal areas at WCS include:

1. The Federal Waste Disposal Facility (FWF), which was designed, permitted, and constructed subsequent to the FEIS for the sole purpose of disposal of Class A, Class B, and Class C wastes, as well as mixed low-level waste (MLLW) that are the responsibility of the Federal Government. The FWF opened on June 6, 2013. Upon

full build-out, the FWF will have a licensed capacity of up to 26,000,000 CF and 5,600,000 curies total. However, the disposal capacity is not to exceed 8,100,000 CF and 5,500,000 curies of containerized Class A, Class B and Class C waste through September 2024. WCS obtained a license for the facility for 15 years with a provision for 10-year renewals.

All hazardous and radioactive wastes at the FWF are being encapsulated in a robust liner and cover system, featuring a 7-ft thick liner system that includes a 1-ft thick layer of reinforced concrete, and a Resource Conservation and Recovery Act (RCRA)-compliant geosynthetic layer. The waste is buried within the highly impermeable red bed formation that extends for hundreds of feet beneath the deepest layer of waste.

2. The Texas Compact Waste Facility (CWF), which has been operational since the Spring of 2012 with a capacity of 2,310,000 CF of disposal space and 3,890,000 curies. The CWF is operated by WCS, but is owned and licensed by the State of Texas. The facility is the only commercial facility in the United States licensed in the past 40 years for the disposal of Class A, Class B, and Class C radiological waste. The member states of the Texas Compact Commission are Texas and Vermont. However, the CWF is also available to generators from the 34 U.S. states that do not have access to a Compact disposal facility, which includes New York. Out-of-Compact generators must, however, submit an import petition to the Texas Compact Commission for approval prior to shipping.

Precedent Applications: The disposal of Class A, Class B, and Class C waste at a compact waste facility has precedents at two facilities – the Energy Solutions Barnwell Operations, located in Barnwell, South Carolina, which accepts waste from the Atlantic Compact states of Connecticut, New Jersey, and South Carolina; and the U.S. Ecology facility, located in Richland, Washington, which accepts waste from the Northwest and Rocky Mountain Compacts. The dedication of a separate commercial facility for the disposal of Class A, Class B, and Class C wastes that remain the responsibility of the Federal Government is unique to WCS. Several DOE sites have already shipped waste to WCS for permanent disposal. It is noted that the disposal of the K-65 silo waste from the former Fernald Feed Materials Production Center at WCS was done at a separately licensed facility within the WCS complex, and thus would not serve as a precedent case for the more routine disposal of Class B and C waste at the FWF or CWF.

Summary of Applicability: An engineering report prepared in support of the FEIS (URS, 2008b) lists the proposed final disposal options for the various waste types expected to be generated under the full exhumation alternative. Of the approximate 225,000 CF of Class B and Class C waste to be generated, more than 172,000 CF (primarily from the SDA and NDA) were identified for disposal at an undefined commercial facility because at that time there was no commercial Class B or Class C LLW disposal facility available for West Valley waste. Although information from the Barnwell, South Carolina disposal site was used for costing purposes in support of the FEIS (URS 2008b, page 107), no waste from West Valley could be shipped to Barnwell following passage of South

Carolina's *Atlantic Interstate Low-Level Radioactive Waste Compact Implementation Act* (South Carolina, 2000). This Act specifically prohibits the Atlantic Compact from authorizing the importation of any non-regional waste for purposes of disposal after 2008. Therefore, the subsequent opening of the WCS disposal areas may provide the only viable off-site disposal option for West Valley Class B and Class C wastes. The combination of the FWF and CWF should be able to accept all the West Valley Class B and Class C wastes.

No stringent volume restrictions similar to those that were in place at the Barnwell facility appear to exist for the much larger capacity of the WCS, although the required prior approval of the Texas Compact Commission could place some restrictions on the rate of waste acceptance. This is an important consideration for the CMF, as no interim storage would be required for Class B and Class C wastes if the wastes can be directly shipped to WCS as long as the rate of waste production does not exceed the approved rate of disposal.

Limitations on Use: The two primary limitations on implementing this option would be an annual volume restriction, which will not be known until a petition is made to the Texas Compact Commission as discussed above, and the potential for certain waste not to satisfy the WCS waste acceptance criteria. Published waste acceptance criteria are available for both the FWF (WCS 2015) and the CWF (WCS 2014), but a comparative evaluation of the West Valley waste streams against the waste acceptance criteria was beyond the scope of Study 3.

Cost Considerations: Assuming that all orphan waste will eventually be shipped off site, any costs incurred to dispose of waste at WCS will be borne regardless of whether the waste is temporarily stored at West Valley prior to disposal or shipped off-site as it is processed. Therefore, for purposes of comparing the cost of Option 2 with the FEIS base case, off-site disposal at WCS would represent a savings because the CWF storage area can be reduced in size at the time of construction (possibly up to 50% of its currently planned footprint).

2. Comparison of Options

As indicated above, the FEIS base case and Option 1 are highly similar and there are no criteria that would substantially favor one over the other. The stand-alone facility (Option 1) would provide a small degree of additional flexibility in the facility design if uncertainty remains as to the volume of waste that would require storage under a selective exhumation scenario, whereas a facility integrated with the CMF (FEIS base case) would reduce the risk of accidental release and exposure because the processed waste would remain within the CMF and would not have to be moved to a separate location.

The comparison of the FEIS base case with Option 2 becomes one of comparing conditions at the time the FEIS was issued with conditions today, as the intent in the FEIS was always to ship waste out of the CMF once a commercial disposal facility became available. The current availability of a commercial disposal facility at WCS that appears to have the capacity to take all the West Valley Class B and Class C wastes defines Option 2. Under this option, the flow-through rate of waste to WCS could potentially keep up with the rate of waste production from the SDA and NDA, thus reducing or eliminating the need for previously planned interim storage at the CMF. The beneficial consequences would be a reduction in the size of the CMF and a shorter timeframe for getting the Class B and C waste to an off-site disposal facility.

C. Interim Storage of LSA, Class A, and Mixed Wastes

1. Potentially Applicable Methods and Technologies

a) FEIS Base Case: No On-Site Interim Storage

Description: Under the full exhumation alternative, the FEIS provides for no interim storage facility for LSA, Class A, and mixed wastes (non-orphan wastes), much of which will be excavated soil that is slightly radiologically or chemically impacted. The reason is that it is being assumed that sufficient commercial disposal capacity exists to maintain a continuous flow of off-site shipments as waste is produced and processed. For example, it is stated in Appendix C of the FEIS that for the trenches in the SDA, "...all the material bounded within the sheet piling would be systematically excavated. Material brought to the surface would be placed into appropriate containers and transferred to the Container Management Facility for processing, packaging, characterization, and transport off site." (Page C-82, URS 2008a). According to information presented in URS (2008b), all LSA, Class A, and mixed waste is intended to be shipped to either the DOE disposal area at the Nevada Test Site (now the Nevada National Security Site) or the Energy Solutions disposal facility in Clive, Utah.

Precedent Applications: The strategy of shipping all low-level and mixed waste generated as a result of site remediation to an off-site disposal facility was adopted at both Rocky Flats (Colorado) and Mound Laboratory (Ohio). In neither case was a new engineered interim storage facility constructed on site.

Summary of Applicability: The applicability of the "no interim storage" approach is dependent on the continuous availability of off-site disposal capacity to match the rate of waste production and processing. While this remains an uncertainty, there is nothing known at this time that would invalidate this assumption.

Limitations on Use: The primary potential limitation of the FEIS base case is the rate of waste production and processing that can be achieved without exceeding the tipping capacities of off-site disposal facilities. Off-site tipping capacity is not in the control of West Valley, and thus could pose limitations on waste exhumation operations.

Cost Considerations: The FEIS base case represents a "no cost" option in that no interim storage facility will be constructed at West Valley.

b) *Option 1: On-Site Interim Storage Facility*

Description: On-site interim waste storage areas can involve a wide variety of structure types and designs. For purposes of this study, the interim storage facility would be constructed either as a metal-sided building or a fabric sprung structure with a concrete floor. The design would be similar to one of the facilities featured in the next section.

Precedent Applications: The EXWG completed a preliminary study of existing retrievable waste storage facilities under Task 3.2. The study addressed existing facilities at DOE sites, commercial waste storage facilities, storage facilities associated with power plants, and non-U.S. sites. Of these, the facilities in use at other DOE sites are most applicable to conditions at West Valley and are included herein. These facilities represent a range of storage objectives driven by site-specific needs and decisions. Table VII-2 has been prepared to summarize the DOE site-specific waste storage strategies and the corresponding facilities.

Site	Strategy/Objective	Design Features	Comments
Idaho National Laboratory (Idaho)	Retrievable storage of mixed TRU waste from Rocky Flats for future shipment	313,000 SF pre-engineered metal building with height of 30-35 ft.; asphalt and concrete floor.	Open, stacked storage of drums and boxes; no special shielding; movable shrouds used to create isolated work areas.
	Retrievable storage of TRU waste from on-site projects	Commercially available 130 ft. x 160 ft. x 20-ft. tension-membrane structure capable of supporting seismic, snow, and wind loads; interior floor is a poured concrete slab; ventilation system prevents accumulation of VOCs.	55-gal drums stacked either 3 or 5 drums high; minimum of 20 ft. aisle space and 3 ft. between drums and building walls; no special shielding
Oak Ridge National Lab (Tennessee)	Retrievable storage of CH-TRU waste for shipment to WIPP	Metal-sided building with domed metal roof; three bay doors on two sides; concrete floor.	55-gallon drums stacked three high; no special shielding apparent
Los Alamos National Laboratory (New Mexico)	Retrievable storage of TRU wastes from clean-up activities and nitrate salt from production operations	Four fabric-covered control structures (PermaCon buildings); each structure equipped with fire suppression system, HEPA system, and climate control system.	4,850 CY of waste stored in 30-gal and 50-gal drums, drum overpacks, wood and metal boxes, and metal spheres; photos indicate no special shielding.
Nevada National Security Site (Nevada)	Temporary storage of mixed low-level radioactive waste from on-site remediation pending disposal.	230 ft. x 85 ft. metal structure covering TRU waste pad; floor has two layers of asphaltic concrete that sandwich a petrochemical liner; roll-up doors on each end.	Freight containers, waste boxes, and drums are stored in building; portion of building used to macro-encapsulate LLMW.
	Temporary storage of mixed low-level radioactive waste from unreported source(s)	Sprung structure building that measures 60 ft. x 35 ft.; floor is made up of a concrete portion and a gravel portion.	Little information available other than that drums and boxes are stored in the building.

Table VII- 2: Comparison of Interim Waste Storage Facilities at DOE Sites

The sites shown in Table VII-2 include interim storage for TRU, low-level, and mixed wastes that are awaiting future shipment to off-site disposal facilities. The noteworthy aspect of the interim storage facilities at these sites is that none is constructed of concrete or otherwise shielded, opting instead for metal or sprung fabric structures even for the interim storage of TRU waste. Local internal shielding may be required if any stored waste exceeds the 50 mrem/hr criterion (e.g., drums with high levels of Cs-137), but such shielding would be straightforward and of limited cost significance.

Retrievable LLW storage facilities with a 30-year design life being built by Atomic Energy of Canada, Ltd. were found to be an exception. In this case, pre-fabricated concrete technology is being used for the walls, columns, beams, and roof (Bhat, 2010). The walls have an approximate 14-inch shielding thickness. The roof is made of pre-cast concrete members that provide a concrete shielding thickness of at least 2 inches. The floor is a concrete slab on grade with a pre-molded membrane placed under the floor slab that serves as a secondary containment barrier against moisture.

Summary of Applicability: An on-site interim storage facility similar in design to those used at other DOE and commercial sites is applicable for the temporary storage of the 99% of the West Valley wastes that is non-orphan. This is particularly the case given that the TRU waste is being stored in the CMF and would not be included in the classes of waste proposed for a less robust temporary storage facility. It is expected that the design of the facility under this option would be based on the temporary storage of only a currently unknown percentage of the non-orphan waste given that the plan would still be to ship the waste off site as disposal capacity becomes available.

Limitations on Use: The use of an on-site interim storage facility is common throughout the DOE complex and various commercial operations, including scores of such facilities that are in place globally. No critical limitations on use have been identified. It is possible that one of the existing buildings at West Valley could serve as an interim storage facility for LLW, particularly under a partial removal alternative that would involve less waste.

Cost Considerations: No cost information could be found in the published literature related to the interim storage facilities described in Table VII-2. In order to get an approximate cost for the interim storage building, information was extracted from cost estimates for comparable sprung environmental enclosures used for waste exhumation projects at INL. On average, the reported procurement, construction, and demolition costs for nine enclosures ranging in size from about 33,000 SF to 73,000 SF (~50,000 SF average) was approximately $20 million per enclosure in 2008 dollars.

2. Comparison of Options

The comparison of the FEIS base case versus Option 1 boils down to whether the additional cost of an on-site interim storage facility is warranted in order to gain a level of backup storage capacity to avoid impacts on ongoing exhumation operations in the event that waste shipments cannot keep pace with waste production.

VIII. Waste Tank Farm

Section VIII is an extended section that captures all elements associated with removal of the HLW tanks from the WTF. The organization of the section is somewhat different from that of other sections because both the FEIS base case and the various options represent distinct sets of processes that must be addressed as complete 'packages' to fully recognize the features, advantages, and disadvantages of each optional approach. The overall approaches to tank removal are fundamentally driven by the methods employed to control worker exposure and environmental releases, which are addressed first in this section. Individual technology options for residual waste removal and removal of the tank shells are then addressed to cover the partial removal scenarios, as are options for processing of waste once removed from the tanks.

The components of the WTF that are of interest to this study are the four underground HLW storage tanks – Tanks 8D-1, 8D-2, 8D-3, and 8D-4 – with a particular emphasis on the two largest tanks, Tanks 8D-1 and 8D-2. Tank 8D-1 was used to house the STS ion exchange (IX) columns that contained zeolite resin for Cs-127 removal. During operations, spent zeolite resin loaded with Cs-137 was periodically dumped to the bottom of Tank 8D 1, resulting in what remains today as a dried, high-activity zeolite sludge at the bottom of Tank 8D-1. During reprocessing operations, high-level PUREX waste from the plant was sent to Tank 8D-2.

Tank 8D-4 is much smaller than Tanks 8D-1 and 8D-2, and its residual activity is comparatively low as a result of various waste removal efforts in the past. For these reasons, it is expected that Tank 8D-4 will not determine the removal approach for the WTF and does not require separate evaluation in this section. Rather, the tank exhumation approach will be determined by Tanks 8D-1 and 8D-2 due to the much higher cost of removal of these larger tanks. All approaches addressed in this section will be applicable to Tank 8D-4, even if some design modifications are necessary to achieve full compatibility with the specific features of that tank. Tank 8D-3 was mostly kept as a spare to Tank 8D-4 and does not require consideration.

Several other buildings and structures were included in the FEIS WMA 3 remediation plan, including the STS support building, STS equipment (within Tank 8D-1), HLW transfer trench, and pump support structure. Removal of these structures is not addressed in this section. Still other buildings/structures that were included in the FEIS WMA 3 analysis have been or will be removed under the Phase 1 decommissioning plan, including the equipment shelter and the associated condensers, the Con-Ed building, the HLW mobilization and transfer pumps in the underground waste tanks, and the piping and equipment within the HLW transfer trench.

A. Scenarios Evaluated

1. FEIS Base Case: Full Removal

The full removal of the HLW tanks would involve removing any residual activity, the carbon steel tank shells, and the concrete vaults. The FEIS assumed that all three of these activities would occur within the WTF Waste Processing Facility (WTFWPF), a fixed-base shielded structure that would provide radiation protection (Section VIII.B.2), accommodate tank removal operations (Sections VIII.C.2), and house waste processing, analysis, packaging, and load-in/load-out facilities (Section VIII.F.2).

A distinguishing feature of the full removal case is the removal of the tank vaults in addition to the tanks themselves. The tank vaults for Tanks 8D-1 and 8D-2 are situated about 15 feet from each other and have an outer diameter measuring 78.6 feet. The concrete vault walls are about 18 inches thick, with concrete roofs that measure 24 inches thick. The concrete vault floors are about 27 inches thick, but are thicker in a ring underneath six large concrete columns that extend upward through each of the tanks to provide structural support for the vault roofs. The roofs are covered by a layer of soil about 8-9 feet deep. (WVNS 2005)

Neither the vaults nor the materials underlying the tanks (pan, pea gravel, block, and gravel) are expected to be contaminated (WVNS 2005, page 6). However, removal of the steel shell of each tank is expected to contaminate the surface of each vault, which would need to be scabbled away. Once contamination has been removed from the inside surface of the vaults, they could be removed using conventional demolition techniques. Activities that do not involve the removal of residual radioactivity necessary to terminate the NRC license are outside the scope of NRC regulation (Regulatory Guide 1.202, page 2, NRC 2005), and their removal under the Sitewide Removal Alternative would not have to be included in the Decommissioning Plan submitted to the NRC.

2. Selective Removal Scenarios

Rather than perform the full exhumation of Tanks 8D-1 and 8D-2 and the associated vaults, it is possible to selectively remove only a portion of the activity. As indicated in Section II, the first selective removal scenario would be to remove only as much of the residual materials in the tanks as practical, with the second scenario adding the tank shells to complete the removal of residual activity. Insight as to what would be removed under these two general scenarios is provided in this section based on two selective removal targets – removal of those radionuclides that control the long-term risk of releases from the WTF to groundwater (i.e., "Controlling Nuclides"), and removal of Cs-137 and its decay product barium (Ba)-137m that represent the highest risk of direct exposure to workers.

Removal of Controlling Nuclides: The deterministic performance assessment reported in the FEIS (DOE and NYSERDA, 2010, Appendix H) identified Tc-99, iodine (I)-129, and neptunium (Np)-237 as the radionuclides that would control the calculated long-term dose for the groundwater pathway due to releases from the WTF. Table VIII-1 shows the reported percentage of each of these "Controlling Nuclides," as well as Cs-137, found in the major source elements in Tanks 8D-1 and 8D-2. The values in Table VIII-1 are based on decay and ingrowth calculations performed by ECS as part of Task 1.2 (ECS 2016b) using information originally reported in Table 38 of WVNS (2005). It is noted that Sr-90 and Pu were not included in Table VIII-1 because the FEIS did not identify these two radionuclides as "Controlling Nuclides" for the groundwater pathway in Appendix H.

Tank Element	Percentage of Tank Activity / Total Activity			
Tank 8D-1	**Cs-137**	**Tc-99**	**I-129**	**Np-237**
Sludge/Zeolite	62.2% / 48.0%	23.0% / 15.2%	10.7% / 8.6%	4.8% / 0.5%
Steel Shell	2.1% / 1.6%	3.8% / 2.5%	2.6% / 2.1%	64.0% / 6.6%
STS IX columns	33.0% / 25.5%	—	—	—
STS Equipment	2.6% / 2.0%	73.2% / 48.2%	86.7% / 70.2%	31.1% / 3.2%
Tank 8D-2	**Cs-137**	**Tc-99**	**I-129**	**Np-237**
Sludge/Zeolite	59.5% / 13.6%	82.2% / 28.0%	82.3% / 15.7%	33.5% / 30.0%
Steel Shell	40.5% / 9.3%	17.8% / 6.1%	17.7% / 3.4%	66.5% / 59.6%

Table VIII- 1: WTF “Controlling Nuclides” by Tank Element

For each radionuclide, the percentage of tank activity presented in Table VIII-1 was calculated based on mean activity. The first percentage shown in each cell of Table VIII-1 is the percent of activity in the corresponding tank, whereas the second percentage is the percent of total activity in both tanks. The percentages of activity in the sludge and spent zeolite resin are combined in Table VIII-1 because they are mixed together on the bottom of the tanks, and would be removed together. The values for the steel shell of Tank 8D-2 primarily represent the activity in the “bathtub ring” of contamination that has formed on the shell walls about 15-21 feet above the tank floor.

Table VIII-1 also shows the activity within the four STS IX columns, as well as the total activity in the other pieces of STS equipment in Tank 8D-1 (prefilter, supernatant feed tank, supernatant cooler, sand filter, sluice lift tank, and associated transfer piping). Because the zeolite used in the STS IX columns (i.e., Linde Ionsiv IE-96 synthetic zeolite) was used for the selective removal of Cs-137, it was ineffective at recovering Tc-99, I-129, or Np-237. Thus, there is no activity for these three radionuclides in the STS IX columns. A second titanium-treated zeolite resin (TIE-96) was also used in the IX columns for the selective removal of Pu. Whereas Np-237 would be associated with this zeolite as a daughter product of Pu-241, very little Np-237 would have actually been produced from the decay of Pu-241 on a curie basis. This is seen by comparing the half-lives – 14.4 years for Pu-241 versus 2.14 million years for Np-237. Based on information on the inventory of the STS IX columns in Tank 8D-1, as reported in Table 38 of WVNS (2005), decay and ingrowth calculations performed as part of Task 1.2 (ECS 2016b) show the ingrowth of Np-237 from Pu-241 in the IX columns to be only 7.8E-08 Ci in 2020.

Table VIII-1 shows that removing the STS Equipment from Tank 8D-1 would be most effective at reducing both the Tc-99 and I-129 activities. If removal of the equipment is combined with removal of the sludge/zeolite mixture, first from Tank 8D-2 and then from Tank 8D-1, nearly all of the activity from both Tc-99 and I-129 would be removed from the tanks. WVNS (2005) indicates that there is not much Tc-99 or I-129 activity associated with either tank shell, as shown in Table VIII-1, and thus there would be little value in removing the shells if Tc-99 and I-129 are the targeted radionuclides and effective removal of the equipment and sludge/zeolite could be achieved without removing the tank shells.

Table VIII-1 also indicates that most of the Np-237 activity is associated with the steel shell of Tank 8D-2. Exhibit VIII-1 shows that there is a significant amount of Np-237 contamination on the sidewall of Tank 8D-2, particularly in the "bathtub ring" region. Washing of Tank 8D-2 was performed between March and December 2001 using pressurized water to reduce the fixed surface activity. However, by comparing the pre-wash and post-wash burnishing sample results in Exhibit VIII-1, it is concluded that the washing did not significantly reduce the Np-237 activity embedded in the steel shell.

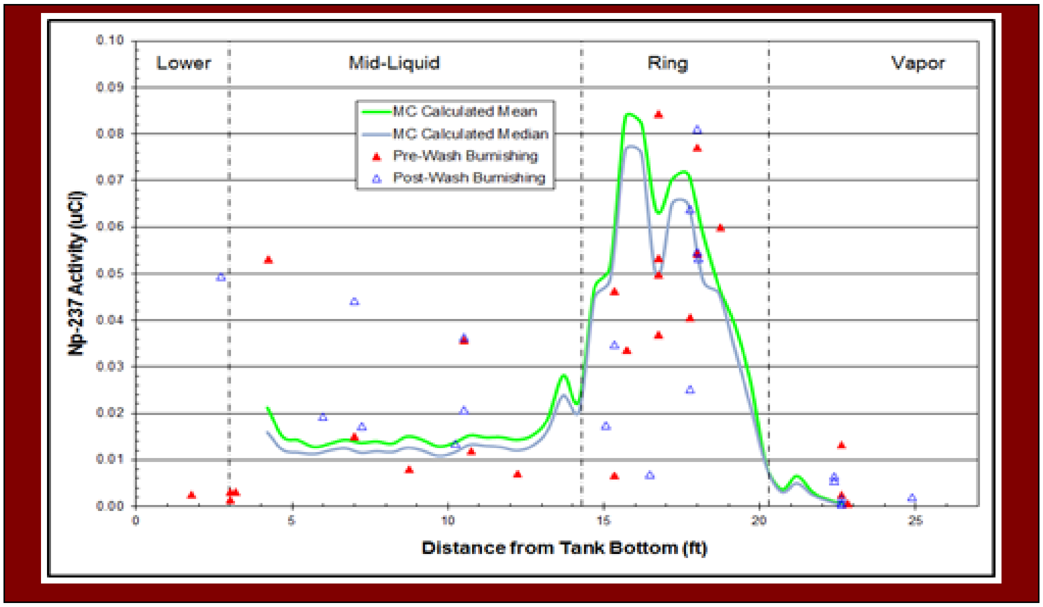


Exhibit VIII- 1: Tank 8D-2 Np-237 Burnishing Sample Results

Activity Removal: According to WVNS (2005), >99% and >70% of the activity in Tank 8D-1 and 8D-2, respectively, is due to Cs-137 and its decay product Ba-137m. Because of the strong gamma emitted by the decay of Ba-137m (i.e., 0.66 mega electron volt [MeV]), the protective measures required during any full or partial tank exhumation scenario would be driven by the presence of Cs-137 in almost all elements of the WTF. The only potential exception to this would be the removal of the STS equipment, which has only a small relative amount of Cs-137 as shown in Table VIII-1.

The largest component of the residual inventory of Cs-137 in both Tank 8D-1 and Tank 8D-2 (i.e., about 62% and 60%, respectively) is the spent sludge/zeolite mixture deposited on the tank floor. Therefore, if it would be feasible to use a waste dislodging and conveyance system to remove this material from both Tanks 8D-1 and 8D-2, a significant portion of the Cs-137 activity could be selectively removed. Most waste dislodging and conveyance systems that have been developed assume that the material can be sluiced; however, as discussed in Section VIII.C below, the material in Tanks 8D-1 and 8D-2 has been dried and may not be sluiceable.

The four IX columns contain most of the remaining Cs-137 inventory in Tank 8D-1 (about 33% of the total activity), while the other STS components in the tank contain less than 3%. Thus, removing the IX columns (with or without the STS equipment) would reduce Cs-137 activity in Tank 8D-1 by about a third. For Tank 8D-2, the remaining 40% of the residual inventory of Cs-137 is fixed to the carbon steel shell of the tank, which includes the “bathtub ring” of contamination on the shell wall. Because Tank 8D-1 never contained large amounts of liquids, there is much less contamination fixed to its carbon steel shell, i.e., about 2% of the Cs-137 activity (WVNS 2005, Table 38).

B. Overall Approaches to Tank Removal (Protective Measures)

1. Summary of Need

An indication of the high dose rates to which workers could be exposed during tank removal is provided by dose rate measurements taken at the M-4 and M-7 risers in Tank 8D-1 during the last transfer of zeolite that occurred out of Tank 8D-1 in 2001 (WVNS 2005). From February 4–6, 2001, dose rate measurements reflective of the residual radionuclide inventory were taken at the two risers as the water level was increased in the tank prior to zeolite transfer. A radiation detection probe was located 20.8 feet off the tank floor for both risers. Exhibit VIII-2 shows the dose rate measurements as a function of the Tank 8D-1 water level.

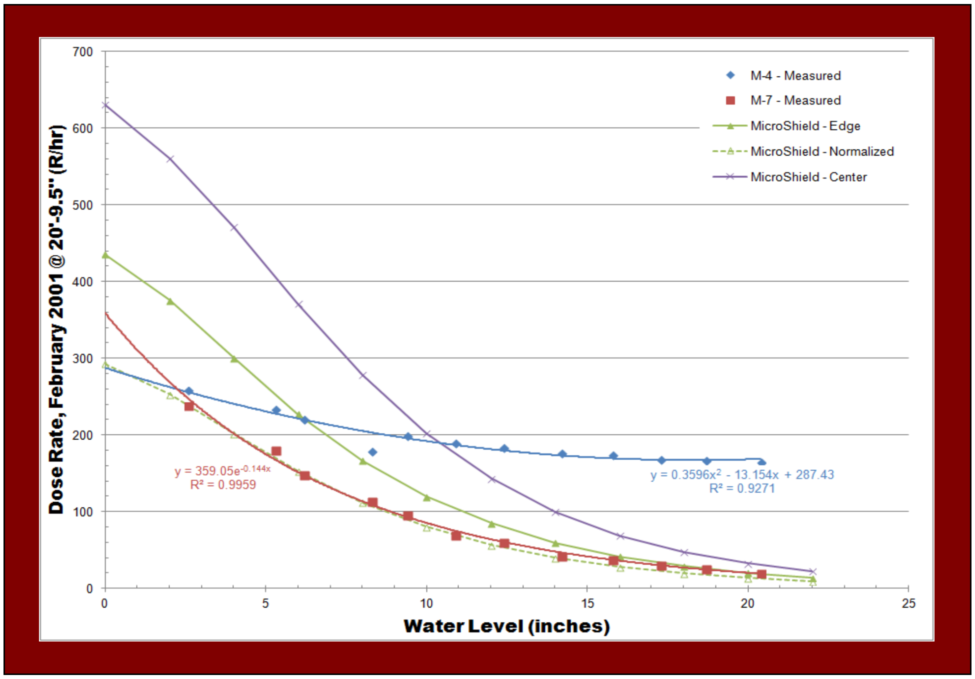


Exhibit VIII- 2: Measured and Calculated Dose Rates inside Tank 8D-1

In order to extrapolate the dose rate back to a zero water level, trend lines were fitted to the measured dose rates. Comparing the measured dose rates for the two risers, the M-4 dose rates did not reduce as much as the M-7 dose rates with increasing water level. This observation indicated that radiation from a source located above the water level is likely responsible for a portion of the M-4 measured dose rates. Thus, the extrapolated dose rate of 360 R/hr for M-7 was considered as a more representative value of the dose rate at zero water level (Exhibit VIII-2). Based on this dose rate, a worker would receive 72 times the annual occupational dose limit of 5 rem in just one hour. The LD 50/30[2] is in the range from 400 to 450 rem (NRC 2017), which illustrates the need for highly robust protective measures during tank removal operations.

2. Potentially Applicable Methods

a) FEIS Base Case: Removal Following Roof Removal within WTFWPF

Description: The FEIS assumed that removal of any residual activity in the tanks, the carbon steel tank shells, and the concrete vaults would occur following removal of the soil cover, vault roofs, and tank tops, all of which would be performed within the WTF Waste Processing Facility (WTFWPF). The WTFWPF would be designed for the specific purpose of safely dismantling the WTF and processing and packaging the dismantlement waste. The WTFWPF would be a large robust structure constructed of reinforced concrete and steel, and enclosed within an exterior sheet metal weather structure. The WTFWPF would be approximately 340 feet by 275 feet in size across an irregular footprint, providing approximately 50,000 square feet of confinement over Tanks 8D-1, 8D-2, 8D-3, and 8D-4 and their associated structures (Exhibit VIII-3).

As shown in Exhibit VIII-3, tank removal and waste processing, packaging, and shipping activities would be performed or supported in the following areas within the WTFWPF:

- *WTF Confinement Area* – This is the main area of the WTFWPF. It covers all the tanks to be exhumed, with shield walls of high-density concrete up to 5 feet thick for radiological shielding of operators. The Confinement Area would also provide confinement for any airborne radioactivity generated during dismantlement. All operations within the Confinement Area would be performed remotely.
- *Control Room* – The Control Room is an area from which operators would remotely control the waste retrieval and tank disassembly that is occurring within the WTF Confinement Area. The Control Room would be provided with shield windows so that the operators can observe what is occurring within the Confinement Area, as well as closed-circuit TV capabilities to observe what is occurring within the tanks.

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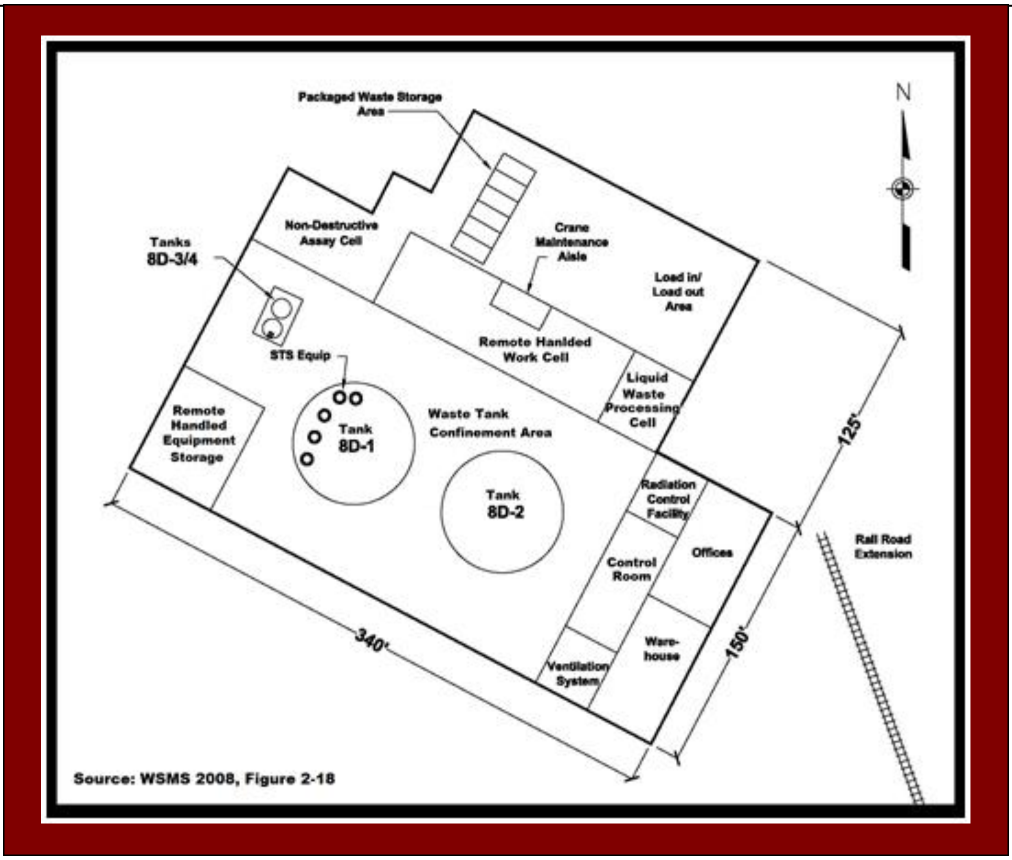
[2] LD 50/30 refers to the dose of radiation expected to cause death to 50 percent of an exposed population within 30 days (NRC 2017).



Source: WSMS 2008, Figure 2-18

Exhibit VIII- 3: WTFWPF Layout

- *Remote-Handled Work Cell* – Material brought out of the WTF Confinement Area would be processed, size reduced (if needed), and packaged in the Remote-Handled Work Cell using two telescoping work arm platforms equipped with grappling equipment, torches, and saw end effectors. The packaged waste would then go to the Waste Package Decontamination Area, and then to the Non-Destructive Assay Cell to characterize the waste for transport and disposal.
- *Liquid Waste Process Cell* – Water would be used for multiple purposes during tank removal operations, including use to dislodge the sludge/zeolite on the tank bottom for removal, as a coolant during tank shell cutting, and for the processing of waste material. Treatment of this water for re-use, solidification, or discharge would occur within the WTFWPF at the Liquid Waste Process Cell.
- *Load-In/Load-Out Area* – Material entering and exiting the WTFWPF, including all packaged waste shipments, would be managed through the Load-In/Load-Out Area. This area would also provide a limited amount of space to store packaged waste.
- *Miscellaneous Support Areas:* Support areas within the WTFWPF would include radiation control and ventilation systems, offices, and a warehouse.

Using the guidance in DOE-STD-1021-93: *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (DOE 1993[3]), it is anticipated that the WTFWPF would be a Performance Category (PC)-2 facility designed to withstand the WVDP Design Basis Earthquake. Earthquake loads and evaluation methods used in the design would be, at a minimum, in accordance with the International Building Code, modified with an importance factor of 1.25 as required for PC-2 facilities.

Precedent Applications: Although it is somewhat dated, the following statement remains valid: "*Although decommissioning and closure of waste storage tanks is under active study at a number of DOE sites, actual removal of a full-size tank has not been undertaken at any site to date*" (Skelly 1998, Page 19). As such, there is no precedent for the type of protective enclosure represented by the WTFWPF, or the full-scale removal of the tank residuals, shells, and vaults that would be performed within the WTFWPF.

Summary of Applicability: The WTFWPF would be fully applicable as the primary protective measure to control the release of radionuclides to the environment, with the individual structures within the WTFWPF providing worker protection. A primary advantage of the WTFWPF is that the entire vault roofs and tank tops could be removed given the coverage and level of protection afforded by the WTFWPF. This would give the remotely-operated manipulators access to the entire tank area to remove contamination and disassemble the steel shells. Also, if equipment breakdowns or malfunctions occur while within the tanks, the equipment can be more easily accessed and repaired once the vault roofs and tank tops have been removed.

Limitations on Use: The primary disadvantage of the WTFWPF is the cost involved in designing and constructing such a large and robust structure to PC-2 criteria. Also, because it destroys the integrity of the tanks and vaults, the WTFWPF approach would not be applicable to the selective removal of only the residual waste in the tanks. As with the protective enclosures proposed in the FEIS for the SDA and NDA, the question that must be addressed is whether the WTFWPF represents an overly conservative design to provide the necessary level of protection against environmental releases and worker exposure. Various options that could provide a comparable level of protection are addressed in the following sections.

b) Option 1: Removal "Through the Risers"

Description: Option 1 is based on an alternative developed in the 1996 DEIS (DOE and NYSERDA, 1996), in which case exhumation of Tanks 8D-1 and 8D-2 was assumed to be

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[3] Subsequent to the issuance of the FEIS, DOE Standard 1021-93 was superseded by Standard 1020-2012, which was then revised by Standard 1020-2016.

performed with an in-tank robotic system lowered into the tanks through the risers, with the waste removed from the tank through the risers and a shielded structure (i.e., a "gamma-gate") located over the center of each tank to reduce gamma-shine exposures (Exhibit VIII-4). An approximate 200-ft long by 100-ft wide and 35-ft high confinement building would also be constructed over the two tanks to control personnel access and to prevent excessive airborne radiation release and personnel over-exposure.

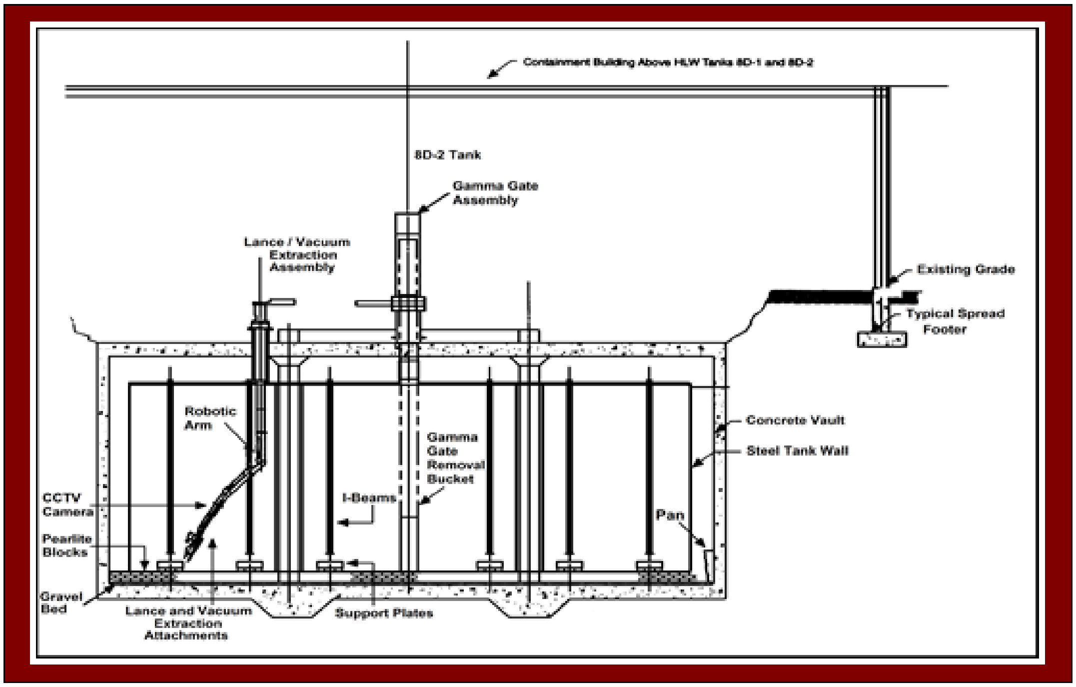


Exhibit VIII-4: In-Tank "Through the Risers" Removal System

Overhead cranes would be provided for emplacing and moving decontamination equipment, hoisting equipment and waste from the tank, and loading out the containerized waste for transport. Attached to the confinement building would be a support building that would house capabilities similar to those provided in the WTFWPF, including a control room, remote handled work cell, liquid waste processing cell, load-in/load-out area, waste storage area, and radiation control and ventilation systems.

Precedent Applications: No precedent application of this approach to disassemble and remove underground HLW storage tanks has been identified. However, a similar "through the risers" approach has been used with a wide variety of remotely-operated equipment to remove the residual radioactive heels from more than 50 storage tanks at the Savannah River Site (SRS), INL, and ORNL. Less than complete removal of the waste inventory was achieved due to limitations of the equipment used to dislodge, reposition, and extract the waste materials from the tanks. Upon removal of the residual waste to the extent practical within the limits of the equipment, the tanks were backfilled with grout and closed in place rather than having the steel shells removed. Additional details on the equipment utilized are provided in later sections.

Summary of Applicability: In concept, the “through the risers” approach is applicable for the selective removal of residual wastes from the tanks, as well as for complete removal. The primary advantages of the “through the risers” removal system, as compared to the WTFWPF, are the following: (1) the cover soil and vault roof would remain essentially in place and provide shielding until the tank and its associated contamination have been removed; (2) the “through the risers” removal system does not destroy the integrity of the tanks and vaults, and therefore could be used for the selective exhumation of only the sludge/zeolite or other source of residual activity from the tanks; and (3) the large robust containment building can be replaced with a sheet metal building or fabric weather containment structure to primarily act as a weather enclosure. The sheet metal and/or fabric structures would be Hazard Category-3. However, a more robust containment structure (Hazard Category-2) may have to surround the risers (depending on the assumed quantity of activity).

Limitations on Use: A primary limitation of this option is that all work would be performed through small openings, such that access to the work site would be difficult if an equipment breakdown occurred or if anything else went wrong. Also, this approach would require very sophisticated robotic devices, capable of freely moving (i.e., ‘snaking’) around the complex grids at the bottom of Tanks 8D-1 and 8D-2 and performing a variety of functions. Although a number of pertinent remotely-operated tools for waste mobilization and extraction have been developed for application at other DOE sites, none would be expected to be fully applicable to the specific tank conditions at West Valley and none has proven to be capable of full waste removal. Such a device would require development, and could be difficult to service and maintain. This is addressed in more detail in Section VIII.C below.

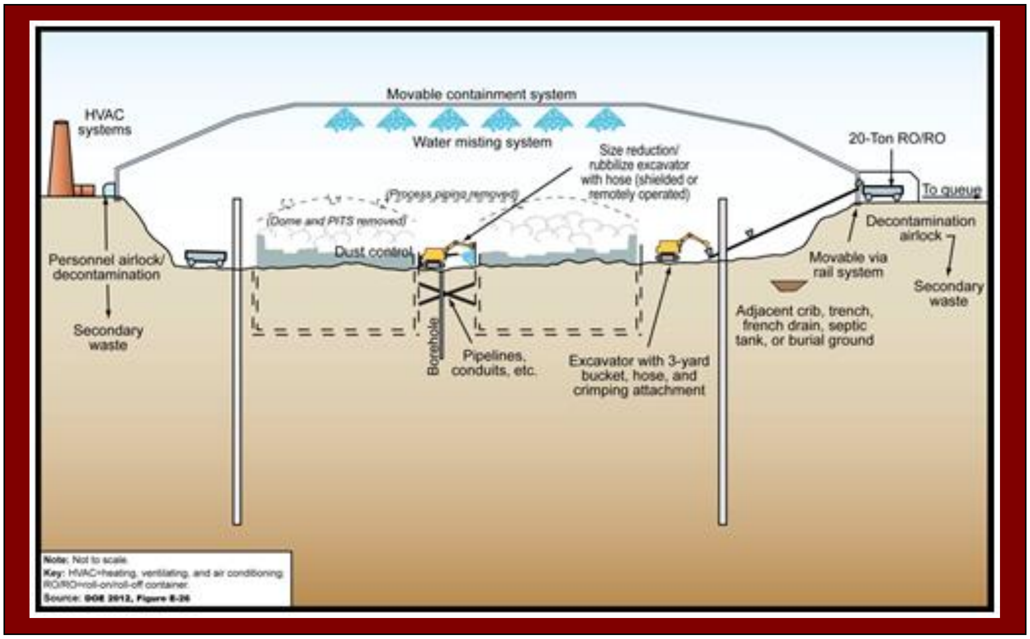
Other limitations regarding the in-tank “through the risers” removal system include:

1. All equipment (e.g., manipulators) must be sized to fit through the risers.
2. All actions taken to repair or replace equipment malfunctions must occur through the limited number of risers. For example, if a manipulator stops working while it is attached to an in-tank structure (e.g., a roof support column), it may not be possible to use a second manipulator to free the first.
3. Some material removed from the tanks would need to be size-reduced in the tank to fit through the risers.

Although the “through the risers” removal system would eliminate the need for the large, robust WTFWPF, a non-shielded confinement structure would likely still be required over the tanks. Also, a heavily shielded facility would be needed to process the material once it has been removed from the tanks and, if water is used to dislodge waste within the tanks, a second shielded facility would be needed to treat that water. In short, many of the WTFWPF support facilities would still be required to support a “through the risers” removal system.

c) *Option 2: Partial Layer of Grout*

Description: Although no project that addresses removal of a tank structure containing radioactive waste has been implemented at any DOE site, various alternatives for the closure of 149 single shell tanks (SSTs) at the Hanford Reservation were evaluated in DOE/EIS-0391 (DOE 2012b). Included among the alternatives were three that proposed "Clean Closure" of the SSTs, with "Clean Closure" being defined as the removal of the tanks, ancillary equipment, and contaminated soils as necessary to protect human health and the environment and to allow unrestricted use of the tank farm area (DOE 2012b, page 2-33). One clean closure alternative for removing the Hanford SSTs is shown in Exhibit VIII-5, and in concept defines Option 2 for removing Tanks 8D-1 and 8D-2 at West Valley.



Note: Not to scale.
Key: HVAC=heating, ventilating, and air conditioning; RO/RO=roll-on/roll-off container.
Source: **DOE 2012, Figure 8-26**

Exhibit VIII-5: Conceptual Drawing of the Hanford SST Partial Grouting Option

The Hanford concept can be described as an eight-step process (Skelly 1998), as follows:

1. Construction of Enclosure and Support Facility
2. Placement of Shielding Grout Inside Tanks
3. Removal of Cover Soil
4. Demolition/Removal of Tank Domes
5. Removal of Lateral Soil
6. Demolition of Tank Sidewalls
7. Removal of Base Slab and Footing Ring Along with Shielding Grout
8. Backfilling of the Excavation After Tank Removal

The placement of a one-foot thick layer of shielding grout across the bottom of the tanks is to provide protection to workers during the removal of the tank sidewalls.

The SSTs are reinforced concrete structures, with a 3/8-inch carbon steel liner sandwiched between two layers of concrete. In order to accommodate shearing of the steel liner into manageably small pieces suitable to be loaded into shielded containers, the plan at Hanford was to lift and curl up the steel liner until the concrete (and shielding grout on the tank bottom) would slough away. This approach would compromise the value of the grouting layer and expose a limited area of the liner surface with adhered tank waste, leading to a severe gamma radiation hazard posed by direct exposure to the tank bottoms. Continuous diligence would be required on the part of the excavator operators to do the work with the minimum essential amount of liner surface area exposed at any given time (Skelly 1998). This same approach would not be applicable at West Valley because the carbon steel tank shells are not sandwiched between layers of concrete.

At Hanford, the highly contaminated concrete debris, steel liner pieces, and any impacted soil removed from the tank bottom or from under the tank slab would be placed in shielded boxes (DOE 2012b, page E-147), removed from the Tank Farm Enclosure, and transported to a standalone 10-acre preprocessing facility for treatment using a strong acid wash. The washed soils and debris would be packaged and disposed on site. The contaminated liquid waste stream from the acid wash would be neutralized and sent to on-site double-shell tanks for treatment at the Hanford Waste Treatment Plant (DOE 2012b).

Precedent Applications: The removal approach of using a grout layer as the primary protective measure was originally proposed for four 1,000,000-gallon, 75-foot diameter tanks within the AX Tank Farm at Hanford (Skelly 1998), and then subsequently proposed for twelve 530,000 gallon, 75-foot diameter tanks of the C Tank Farm and for all 149 SSTs (DOE 2012b). However, “Clean Closure” was not the selected remedy in the Record of Decision (ROD) for the Hanford SSTs (DOE 2013). Therefore, the partial grout layer option has not progressed beyond the feasibility study stage.

Summary of Applicability: Although not being pursued at Hanford, tank removal using a layer of grout at the tank bottom was apparently deemed applicable for the Hanford tanks as evidenced by its proposed use for all the SSTs. However, for reasons given in the next section, this same approach would likely not be feasible for Tanks 8D-1 and 8D-2 at West Valley.

Limitations on Use: Because a significant amount of the Tank 8D-1 and 8D-2 residual activity is not located on the bottom of the tanks (Table VIII-1), applying a layer of grout is unlikely to reduce the dose rate to allow operator-driven demolition equipment. This is particularly the case for Tank 8D-2, which can be divided into four vertical regions: the vapor space, the bathtub ring, the mid-liquid, and the lower tank region. Samples were collected from the tank’s steel shell and analyzed for radionuclides. Exhibit VIII-6 shows the results of those analyses, and indicates that the Cs-137 median sample activity is about 100 µCi in the mid-liquid and bathtub ring regions, which converts to a Cs-137 surface concentration of about 80 µCi/cm^2 for the Tank 8D-2 vertical steel shell.

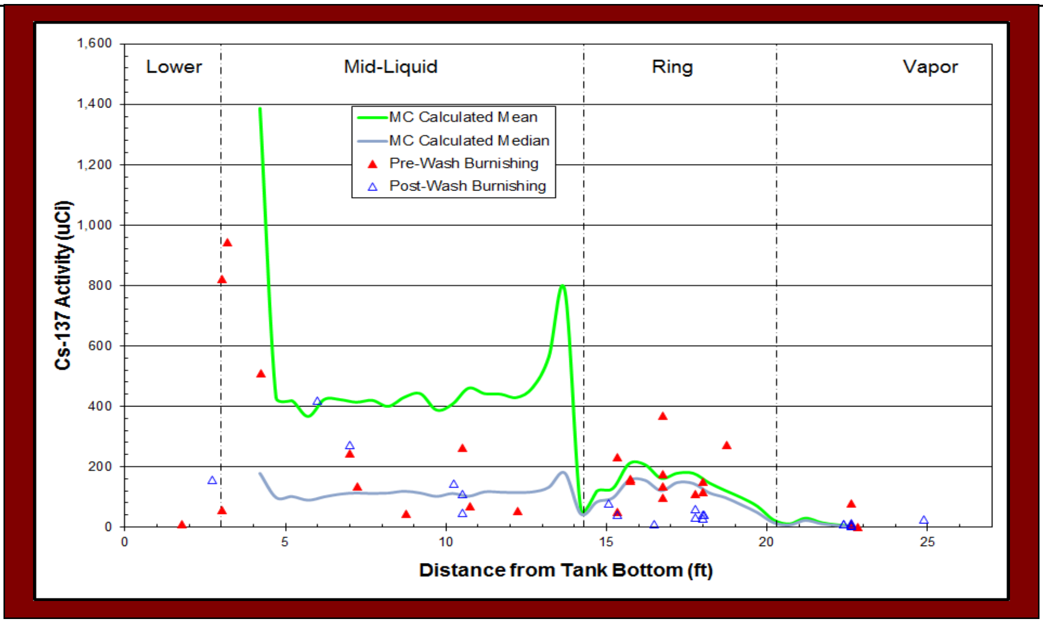


Exhibit VIII-6: Tank 8D-2 Cs-137 Burnishing Sample Results

A MicroShield model was developed assuming that the 80 µCi/cm^2 concentration is uniform over the entire Tank 8D-2 interior vertical surface. The dose rate five feet from the shell was determined to be about 3 R/hr. Because the burnishing samples were collected in 2001, the dose rate would be reduced by radiological decay to about 2 R/hr as of the 2020 base year. The dose rate to workers would, therefore, still be very high, and a grout layer placed on the floor of the tank would not protect workers from this exposure source.

As a corollary to the previous bullet, Tank 8D-1 also has residual Cs-137 in the STS IX columns. A layer of grout at the tank bottom would not shield this source, although the STS IX columns could be removed prior to tank removal.

There are several additional concerns regarding the application of the Hanford partial grouting concept to the WVDP Tanks 8D-1 and 8D-2. These include:

- There is an approximate order of magnitude difference between the higher residual Cs-137 activity in the WVDP tanks (Tank 8D-1: 1.8E+05 Ci; Tank 8D-2: 6.4E+04 Ci) and that in the Hanford AX tanks (maximum of 1.1E+04 Ci). Therefore, application of the approach at West Valley would require a thicker grout layer for shielding during vault/sidewall removal, and would still result in large doses during removal of the tank bottoms.
- The Hanford AX tanks are reinforced concrete structures, with a 3/8-inch carbon steel liner. The two WVDP tanks are carbon steel with side walls that taper from 1/2-inch at the bottom to 7/16-inch at the top with a 1/2-inch bottom thickness. To support the grouted tank bottom, the WVDP tank-vault annulus would likely need to be concurrently grouted.

- West Valley does not have the on-site waste treatment and disposal options that are available at Hanford, and thus the removal option would be incomplete regarding the processing, packaging, and shipment for disposal of the material removed, or for the processing of any liquid waste generated. This limitation could be overcome by providing a building that provided the necessary support facilities, similar to the WTFWPF support facilities, but at an additional high cost compared to the Hanford site.
- Because it destroys the integrity of the tanks and vaults, a Hanford-like approach could not be used for the selective exhumation of only the sludge/zeolite from the West Valley tanks.

d) Option 3: Full Grouting Before Removal

Description: Under Option 3, Tanks 8D-1 and 8D-2 and their vaults would be completely filled with grout, similar to what would be done for in-place closure. After the grout hardened, the tank/vault monolith would be cut using a diamond wire saw, packaged, and shipped for off-site disposal. Diamond wire cutting involves a series of guide pulleys that draw a continuous loop of wire, strung with a series of diamond beads and spacers, through a cut. The wire is wrapped around the object to be cut and contact tension is kept on the wire. This force, in combination with the spinning wire, cuts a path through the material. Linear wire speed and wire tension can be adjusted. Exhibit VIII-7 shows a diamond wire being used to cut a granite slab in a quarry—a similar setup would be used to cut the tank/vault monolith into shipment-sized blocks.

Exhibit VIII-7: Diamond Wire Cutting a Slab in a Quarry

Precedent Applications: No precedent application was identified where this concept was used to remove HLW tanks, although tank grouting has been used many times to decommission nuclear facilities in place. For example, tank grouting was successfully used at SRS to close eight underground HLW tanks (DOE 2016). Eight large-diameter gunite tanks were also filled with grout and stabilized in place at ORNL (Brill et al 2002), and seven large waste storage tanks were closed with grout at INL (Jensen 2013).

Diamond wire saws have, however, been used to disassemble many large radiologically contaminated structures, including the Fort St. Vrain Pre-Stressed Concrete Reactor Vessel (PCRV) and the Princeton Plasma Physics Laboratory Tokamak Fusion Test Reactor. At the Hanford 105-C reactor, debris and sediment were disposed in two fuel storage basin transfer pits. In 1998, the pits were filled with grout and a diamond wire saw was used to cut the pits away from the main portion of the 105-C basin. The resulting two 58-ton monoliths were disposed as LLW.

Summary of Applicability: Some limitations of the full grouting option exist (see next paragraph), but nothing would necessarily prohibit the application of this option at West Valley. The grouted tanks/vaults would essentially be the same as under the in-place closure alternative. Consequently, the tanks could be safely left in-place for an extended period of time following grouting, which would allow the Cs-137 contamination to decay before cutting and disposal of the grouted tanks.

Limitations on Use: A disadvantage of this approach is that cutting the monolith would generate a large volume of LLW, much of which would have little contamination. In particular, the large blocks cut from the interior portions of the monolith away from any of the tank's surfaces would be relatively free of radiological activity. Other limitations include:

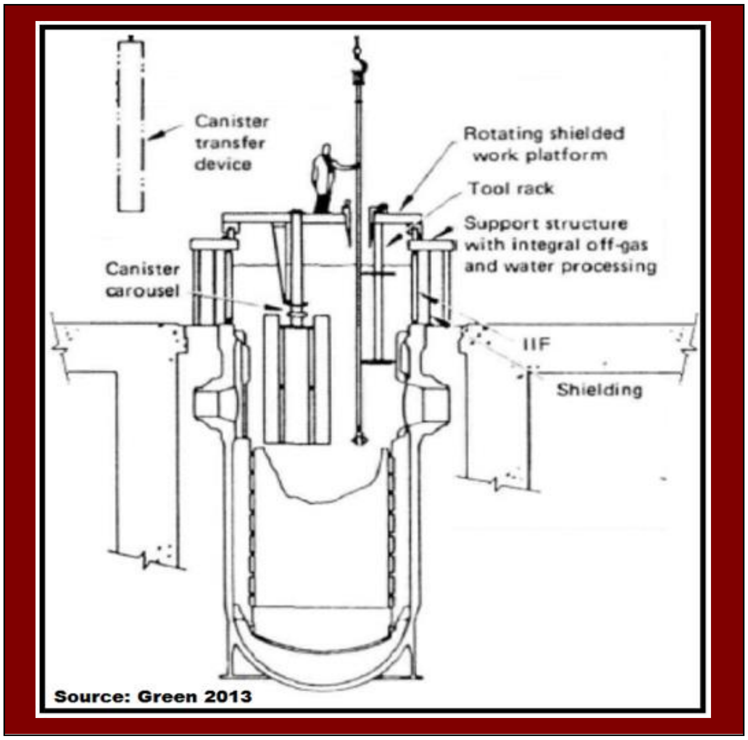
- When cutting through the heavily contaminated portions of the tanks, the liquid coolant would become contaminated and require collection and treatment.
- There could be direct dose concerns for workers near a block that contains an exposed edge of highly contaminated steel tank surface during and following cutting. However, this would be limited to the exposed edge and would have minimal surface area and a much lower dose rate than the tank surface itself.
- Because it destroys the integrity of the tanks and vaults, filling the tanks and vaults with grout could not be used for the selective exhumation of only the sludge/ zeolite.

e) Option 4: Fill Tanks with Water

Description: Under this option, the tanks/vaults would be flooded with water to provide shielding. The initial tank disassembly work could occur through the risers (similar to Option 1, above), but eventually the vault roofs would be removed giving operators access for the removal of the tanks and contents. All work would be performed under water, with workers standing over the tanks on a work platform to remotely cut/disassemble and load portions of the disassembled tank into shielded casks for removal from the vault. Depending on the effectiveness of the water as a radiation shield, the work platform could be either shielded or non-shielded.

Precedent Applications: No precedent project was found that addressed the flooding of large, underground HLW storage tanks and vaults with water for the purpose of disassembling and removing the tanks. However, this approach has been successfully used to disassemble at least two highly radiologically contaminated structures: the melted fuel from the damaged Three Mile Island Unit 2 (TMI-2) reactor, and the Fort St. Vrain PCRV.

During the March 1979 accident at TMI-2, much of the nuclear fuel in the core of the reactor melted or was otherwise damaged. As part of the post-accident recovery, the melted/damaged fuel needed to be removed from the reactor vessel. Because of the condition of the fuel, the TMI-2 defueling was performed manually. The reactor vessel head was removed, and an internals indexing fixture (IIF) was installed. The IIF was a 6-foot high aluminum cylinder normally used during refueling to guide reactor vessel internals into place, but was modified to accept a work platform that provided a shielded work area for defueling operations (Exhibit VIII-8).



Source: Green 2013

Exhibit VIII-8: TMI-2 Defueling Operations

The platform was a 17-ft diameter rotatable surface with a 6-inch thick steel plate shield. An adjustable slot and hand rail spanning the diameter provided access to the reactor core. Two jib cranes were mounted on the work platform to aid the operators in manipulating the long-handled manual, hydraulic, and mechanical defueling tools in the tool slot. The work platform also integrated a method for removing defueling canisters. Once the reactor vessel and the IIF were flooded with water, the defueling operations began. From 1985 to 1989, TMI-2 defueling operations and support personnel received a total of 1,533 person-rem, with an average dose rate of 12.3 mrem/hr and a maximum annual dose of 3.7 rem (GPU 2011, Tables 7-2, 7-3, and 7-6).

At Fort St. Vrain, the PCRV contained 90-95% of the on-site radioactivity after the spent fuel had been removed. A diamond wire saw was used to remove the head of the PCRV in twelve wedges, and the PCRV was then filled with water, which acted as shielding for removal of the components. As shown in Exhibit VIII-9, a rotating work platform was installed on a ledge at the top of the vessel opening, and components were removed through openings in the work platform, using shielded casks as necessary. Operating from this platform, the Fort St. Vrain team removed more than 5,000 graphite components from the upper plenum. These components, some of which read as high as 300 rem/hr, were removed and placed into a transfer basket that had been lowered into the water. The basket was then drawn into a lead shield bell and subsequently taken to a hot cell. There the basket was lowered into a shipping cask for shipment as low-level waste. (Fisher 1998).

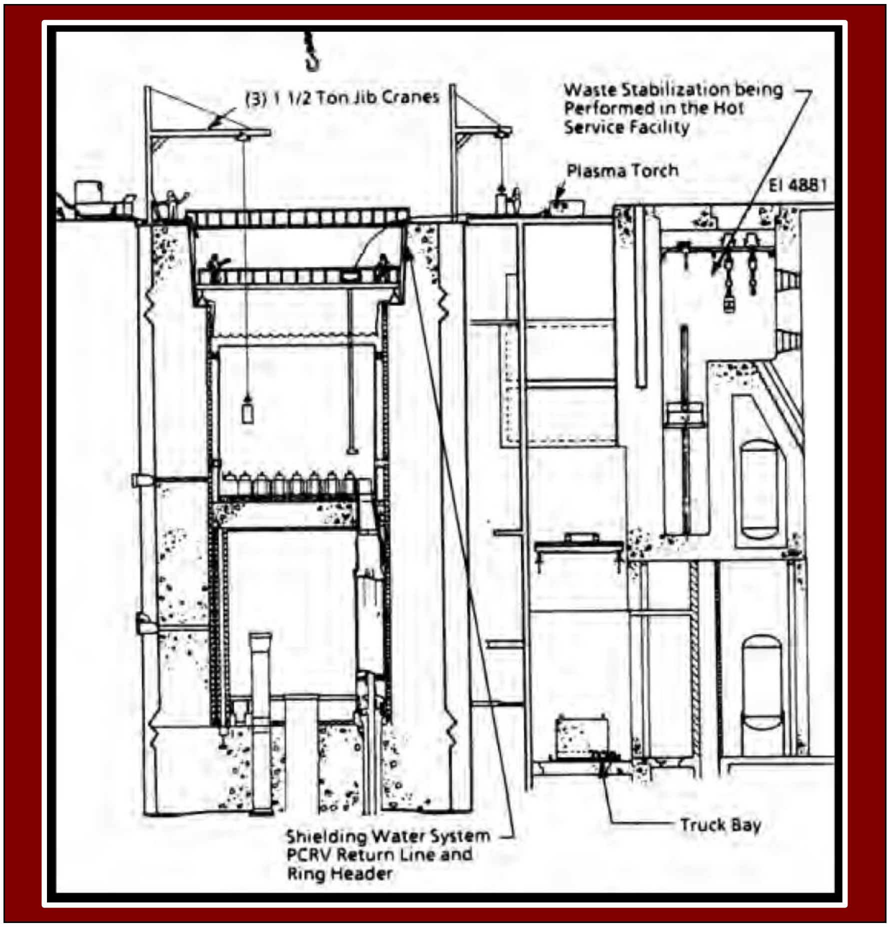


Exhibit VIII- 9: Underwater PCRV Dismantlement at Fort St. Vrain

The underwater segmenting and dismantling of the PCRV internal components required 39 months. The total radiation exposure for the Fort St. Vrain decommissioning, including PCRV dismantlement, was 380 person-rem.

Summary of Applicability: From the vantage point of providing adequate worker protection, Option 4 would be considered applicable to West Valley based on the use of a similar approach at TMI and Fort St. Vrain. The 300 rem/hr dose reported for the material removed from the PCRV is close to the dose rate extrapolated to the non-flooded condition inside Tank 8D-1, as previously shown in Exhibit VIII-2. The primary advantage with flooding the tanks and vaults is that during cleanout and disassembly operations, the water would shield the workers, eliminating the need for a large, robust structure. However, from an overall applicability standpoint, certain conditions at Tanks 8D-1 and 8D-2 may prohibit the use of tank flooding at West Valley. These are addressed in the following section.

Limitations on Use: A primary concern with this approach is that it has not been performed on structures as large as Tanks 8D-1 and 8D-2. The TMI-2 shielded work platform was sized to fit over the 17-foot diameter reactor vessel, and while the Fort St. Vrain work platform was larger to fit over the 31-foot diameter PCRV, there is no indication that it provided any significant shielding. Covering the entire 70-foot diameter of the Tank 8D-1 and 8D-2 vaults with a single work platform would probably not be feasible. However, it may be feasible to install a rail around the circumference of the vaults and 70-foot long beams across the vaults in such a manner that they ride on the rail. A work platform could then be installed on top of the beams that could travel back and forth on the beams. Using this approach, the workers would have access to the entire area of the vault. The work platform would have slots similar to the TMI-1 and Fort St. Vrain platforms, and could be shielded, with the shielding extending up the sidewalls if necessary. Working through the slots, workers could cut-up the tank shell, load the pieces into a shielded cask, and place the lid on the cask. An overhead crane could then remove the cask from the vault.

A second concern is that the West Valley vaults are not leak tight, and may not be able to hold water. The vaults were not designed to hold water, and during their construction an accumulation of water in the vault excavation area floated both of the Tank 8D-1 and 8D-2 concrete vaults. Following this incident, inspection of the vaults found several radial and circular cracks of various lengths and widths in the bottom and a pattern of radial cracks uniformly spaced around the Tank 8D-1 vault roof (GAO 1977). Water seeped into the vaults, and a dewatering well had to be installed to artificially lower the water table to minimize in-leakage of groundwater into the tank vaults. Even with the lowering of the water table, groundwater continues to seep into both vaults and has to be regularly pumped out (DOE 2009b, page 3-13).

The feasibility of Option 4 would, therefore, depend on the ability to develop an engineered solution to control water leakage out of the vaults, e.g., to maintain an artificially higher groundwater level around the vaults so that leakage would be into the vaults, or to install extraction wells around the vaults to collect any leaked water. However, in a precedent case involving the evaluation of flooding the core for the dismantlement of the fire-damaged Windscale Pile 1 (reactor) under water, no engineered solution to the leakage problem was found (Sheil and Sharpe 2000). Similar to Tanks 8D-1 and 8D-2, the primary reason was that Pile 1 was not designed as a pressure vessel and sealing could not be provided for the required hydraulic head.

Even if an effective pumping system was developed, the necessary pumping would generate a very large quantity of liquid effluent to be treated. A final concern with this approach is that in the case of Tank 8D-1, the STS IX columns are suspended from the roof risers, and there may not be a sufficient depth available to effectively shield their radiation.

3. Comparison of Options

Based on the tank exhumation options described in the preceding paragraphs, each option has been rated as being either more favorable, less favorable, or similar to the FEIS Base Case for each of the following seven criteria: worker protection, precedent applications, waste generation, maintainability, capital costs, operating costs, and decommissioning.

Worker Protection: With the exception of Option 2, it is believed that any of the options can be engineered to provide about the same level of worker protection. As explained above, because Tanks 8D-1 and 8D-2 each have significant radioactive contamination located above their floors, placement of a shielding layer of grout on the floors is unlikely to provide adequate worker protection. Thus, Option 2 was rated less favorable than the FEIS Base Case, while the other three options were rated as similar.

Precedent Applications: As stated above, actual removal of a full-size tank has not been undertaken at any site to date. As such, none of the options have directly applicable precedent applications. However, portions of the options have been implemented on either HLW tanks or other nuclear facilities with comparable levels of radiation. For example, for Option 1, a number of tanks at SRS and elsewhere have used the “through the riser” approach to clean out radioactive heels, although not to remove the steel shells. Also at SRS, a number of tanks have been backfilled with grout, similar to Option 3. Although the backfilled tanks were not cut up and removed, a number of other nuclear facilities have been cut up with diamond wire and removed, as discussed above. Melted fuel removal at TMI-2 and PCRV removal at Fort St. Vrain were performed under water, similar to what is being proposed under Option 4. Thus, these three options have been rated as more favorable than the FEIS Base Case for precedent application.

Waste Generation: It is expected that Options 1 and 2 would generate a similar amount of waste as the FEIS Base Case. Option 3 would generate more waste due to the need to grout the entire volume of each tank, and Option 4 would generate more waste than the FEIS Base Case due to the need to maintain water clarity and to eventually treat the large volume of water used to flood the tanks.

Maintainability: For Options 2 and 3, only the diamond wire saw needs to be maintained. Therefore, these two options were rated more favorable that the FEIS Base Case. For Option 1, all maintenance would have to be performed "through the risers," while for Option 4, maintaining the water clarity and controlling water leakage are expected to require considerable additional effort. Therefore, Options 1 and 4 have been rated as less favorable than the FEIS Base Case.

Capital Costs: It is believed that the construction of the WTFWPF under the FEIS Base Case would result in the largest capital cost of any of the options. Options 1 and 4 would require the construction of non-shielding confinement structures, as well as shielded waste processing buildings, which would result in more capital cost than either of the two grout options (Options 2 and 3).

Operating Costs: For Option 1, it is anticipated that more effort would be required to perform all operations "through the risers" than in the open space of the WTFWPF, and thus Option 1 was rated less favorable than the FEIS Base Case. Option 4 was also rated less favorable because of the extra effort required to maintain water clarity and to control leakage. Options 2 and 3 were rated more favorable than the FEIS Base Case because the grouting of the tanks is straightforward and diamond wire cutting is essentially a hands-off operation.

Decommissioning: Options 1 and 4 were deemed to be more favorable than the FEIS Base Case with regard to decommissioning, due primarily to the lack of a large robust confinement structure to disassemble and possibly dispose as radioactive waste. Options 1 and 4 would, however, still have shielded waste processing buildings that would require dismantlement. Options 2 and 3 (the two grout options) were deemed to be the most favorable because neither of these options is expected to have a heavily shielded waste processing building that would require dismantlement.

C. Removal of Tank Contents: Sludge/Zeolite

1. Summary of Need

Zeolite and sludge heels remain in both Tank 8D-1 and Tank 8D-2. Table VIII-1 indicates that about 60% of the residual activity in each tank is contained within these heels. At the SRS, ORNL, and other DOE sites, similar heels have been removed from large underground HLW storage tanks prior to the tanks being backfilled with grout and closed-in-place (DOE 2016, Brill et al 2002, Jensen 2013).

This section will address technologies for the selective removal of the sludge/zeolite while leaving the tank shells in place. If the tank shells are removed as part of the exhumation, then a separate effort to selectively remove the sludge/zeolite heels from Tanks 8D-1 and 8D-2 may not be required.

2. Potentially Applicable Removal Technologies

a) FEIS Base Case: Remote System After Roof Removal

Once the vault and tank roofs have been removed within the WTFWPF as discussed above, there would be unobstructed access to the entire tank area. As presented in the FEIS, any residual mobile radionuclide inventory in Tanks 8D-1 and 8D-2 would be removed using a yet-to-be-identified Waste Dislodging and Conveyance System. Work on the development of systems to retrieve the heels remaining in HLW tanks has been underway since the early 1990's at WVDP, ORNL, the Hanford site, the Pacific Northwest National Laboratory, the University of Missouri-Rolla (UMR), Waterjet Technology Incorporated, and elsewhere. Several HLW tank heel retrieval systems that have been developed as a result of these efforts were considered as the FEIS Waste Dislodging and Conveyance System, and are described in the following sections. The FEIS did not specify which system would be used, only that such systems existed or were in the development stage, and that an appropriate system would be selected during the detailed design phase if tank removal was selected as the closure alternative.

Once dislodged, the sludge and zeolite in the bottom of Tank 8D-1 would be transferred to the liquid waste storage tanks in the Liquid Waste Process Cell of the WTFWPF using the transfer pumps and associated piping. This waste would be pumped from the storage tanks to the centrifugal dewatering system, where the solids would be separated. The solids would be transferred to the Container Fill Area of the Liquid Waste Process Cell, where they would be mixed with grout produced in the Grout Batch Plant. The solids/grout mixture would be placed into 55-gallon drums for curing. Once the mixture cured, the drums would be transferred to the decontamination station in the Remote-Handled Work Cell. It was assumed in the FEIS that the stabilized solids would be disposed as TRU waste. (DOE and NYSERDA, 2010)

The cost estimate reported in the FEIS assumed that it would take approximately 59 weeks to remove about 138 ft^3 of sludge and zeolite heel containing about 1.5E+05 Ci of Cs-137 from Tank 8D-1, and that about 1,308 ft^3 of Class C waste would be generated. The 59-week duration was based on the operating data that was available at that time for the removal of the gunite tanks at ORNL (refer to Option 5 below). The volume of residual solids in Tank 8D-2 (estimated at 10.9 ft^3) is much smaller than the Tank 8D-1 volume (Drake, et al 2003).

b) Option 1: Confined Sluicing End Effector (ORNL)

At ORNL, a Confined Sluicing End Effector (CSEE) was developed that was equipped with three rotating cutting jets mounted 120° apart (Exhibit VIII-10). The jets, which are capable of delivering water at pressures up to 10,000 pounds per square inch (psi), converge at a point about two inches below the conveyance line intake on the end-effector. As the jets rotate, hard waste is dislodged, vacuumed up through the center of the CSEE, and into a 2-inch ID hose under the motive force provided by a jet pump. More information on ORNL's CSEE may be found in DOE/EM-0342 (DOE, 1996a).

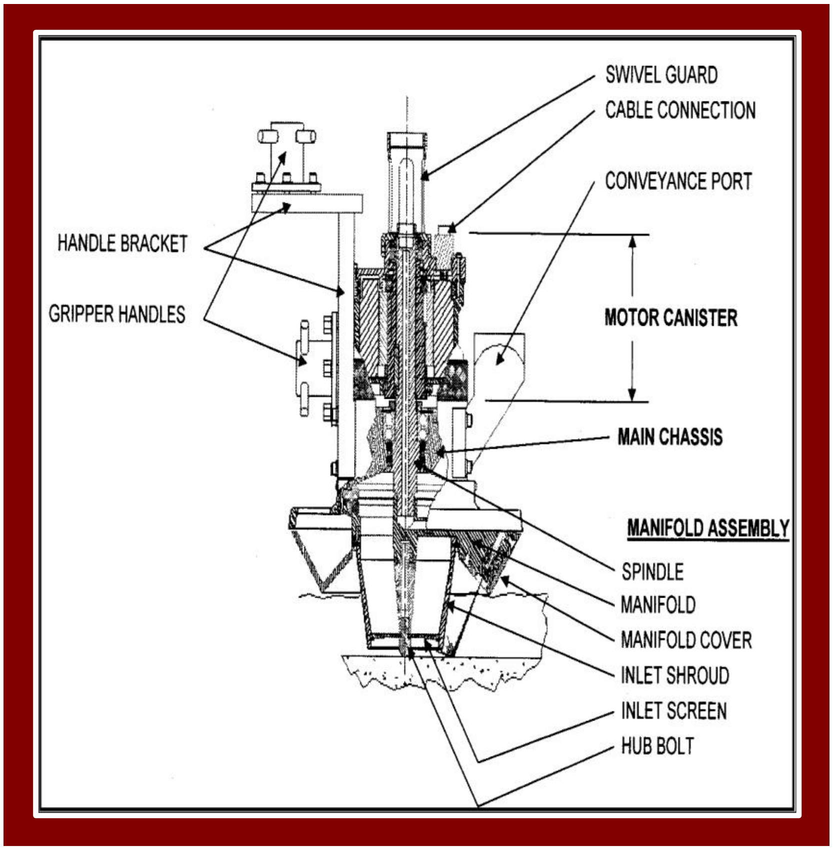


Exhibit VIII-10: ORNL Confined Sluicing End Effector

c) *Option 2: Light Weight Scarifier (Hanford)*

At the Hanford site, a light-weight scarifier (LWS) was developed that uses two ultra-high-pressure waterjets to fracture and dislodge the waste (Exhibit VIII-11). The ultra-high-pressure waterjets provide extreme power densities on the target and remove material at low water consumption rates. The waterjets require approximately 6 gpm of water at up to 50,000 psi. An electric motor rotates the jet manifold at speeds up to 1000 rpm. The LWS is coupled with an air conveyance system to pneumatically remove the dislodged waste and water. More information on the LWS may be found in PNL-SA-25132 (PNL 1995).

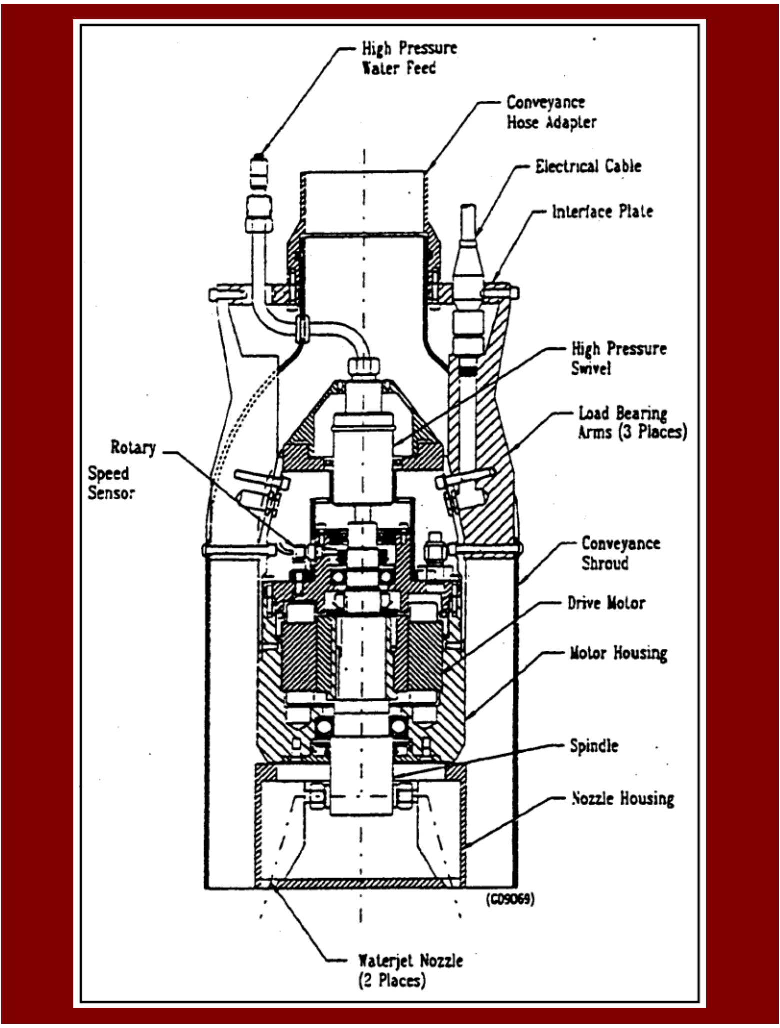


Exhibit VIII- 11*: Hanford Light Weight Scarifier*

a) Option 3: Gunite Scarifying End-Effector (ORNL)

In addition to the CSEE for sludge removal, ORNL developed the Gunite Scarifying End-Effector (GSEE) to clean tank walls. The waterjets on the GSEE were re-oriented so that they diverged to increase coverage from about 4 inches to about 14 inches per pass, and the pressure was increased to 30,000 psi. After undergoing extensive cold testing in the ORNL Tanks Technology Cold Test Facility, the GSEE system was placed into service in the gunite and associated tanks (GAAT) North Tank Farm (NTF) in July 1997. After completing the clean-up of two 25-ft. diameter waste storage tanks in the NTF, the system was redeployed to the South Tank Farm (STF) where it was subsequently used to complete clean-up of five additional 50-ft.-diameter tanks. Table VIII-2 presents the dates and operating history of the GSEE in the various tanks, while Table VIII-3 presents performance data from the cleanup efforts.

Tank		GSEE Deployed		Operating Hours
Identifier	Diameter	Dates	Weeks	
W-3	25 ft	June 97 – Sept 97	15	686
W-4	25 ft	Oct 97 – Mar 98	19	834
W-6	50 ft	April 98 – Aug 98	21	1153
W-7	50 ft	Sept 98 – Mar 99	22	1364
W-10	50 f	May 99 – Oct 99	22	1096
W-8	50 ft	Nov 99 – Mar 00	18	850

Source: ORNL, 1999

Table VIII- 2: GSEE Operating Data in the ORNL Gunite Tanks

Parameter	W-3	W-4	W-6	W-7	W-8	W-9	W-10	Total
Initial Sludge Volume (Gals)	5,500	13,500	12,880	10,000	10,300	9,200	24,400	85,780
Final Sludge Volume (Gals)	100	100	1,567	476	238	500	393	3,374
Initial Curies	340	924	2,255	4,581	7284	3,873	58,481	77,738
Final Curies	12	11	564	208	844	616	1,064	3,319
Water Used (Gals)	41,800	92,300	52,000	62,000	42,200	65,000	65,280	420,580
% Sludge Volume Removed	99.7	99.7	99.1	99.7	99.1	99.4	99.7	99.5
% Curies Removed	96.5	98.8	75.0	95.5	88.4	84.1	98.2	95.7

Source: ORNL, 2003

Table VIII- 3: Gunite Tank Sludge Removal Performance Summary

b) *Option 4: Silo Retrieval End Effector (Fernald)*

The Silo Retrieval End Effector (SREE) used at Fernald was based on the ORNL and Hanford end effectors. The SREE consisted of three rotating jets that were used to locally slurry material and direct the slurry to a 2-inch diameter central inlet. The three radial waterjets were placed such that they converged in the discharge nozzle of a radial waterjet pump integrated as close to the SREE as possible, thus creating a vacuum for a very short distance. The slurry from the SREE inlet port was sucked into the three jets, where it was pressurized and ‘pushed’ through the jet pump discharge nozzle up to a head of over 60 feet. The jet pump required approximately 10 gpm of water at about 10,000 psi pressure. When the SREE inlet was submerged in liquid, the jet pump could remove up to 100 gpm of water and liquid waste.

3. Cost Considerations

The cost of waste retrieval has decreased substantially in recent years based on an increasing level of operating experience with the various methods. The best example of this occurred at Hanford, where the combined cost of the first retrieval effort on a large tank (C-106) was about $140 million, whereas the comparable costs of more recent retrievals range from $20 million to $40 million. The projected cost for the next group of 55,000-gal tanks is a few million dollars each, with an estimated cost of about $15 million for a particularly large tank (NAS 2006, page 43).

4. Comparison of Options

Each of the options described above is potentially applicable to remove the heels from the floors of Tanks 8D-1 and 8D-2. The effectiveness and cost associated with each option are not expected to vary greatly from one option to another. However, due to the unique characteristics of Tanks 8D-1 and 8D-2 (i.e., the gridwork on the floors and the fact that the heels have been dried), it is expected that some modification will be required to whichever option is selected to address those characteristics.

Therefore, the selection of one option over another is not expected to greatly affect either the viability of removing only the sludge/zeolite or the related decision process. Should sludge/zeolite removal be selected as a partial removal scenario, then a detailed evaluation and comparison of the above described options (and perhaps others) would have to be undertaken to determine the most effective option to be implemented.

D. Removal of STS Equipment

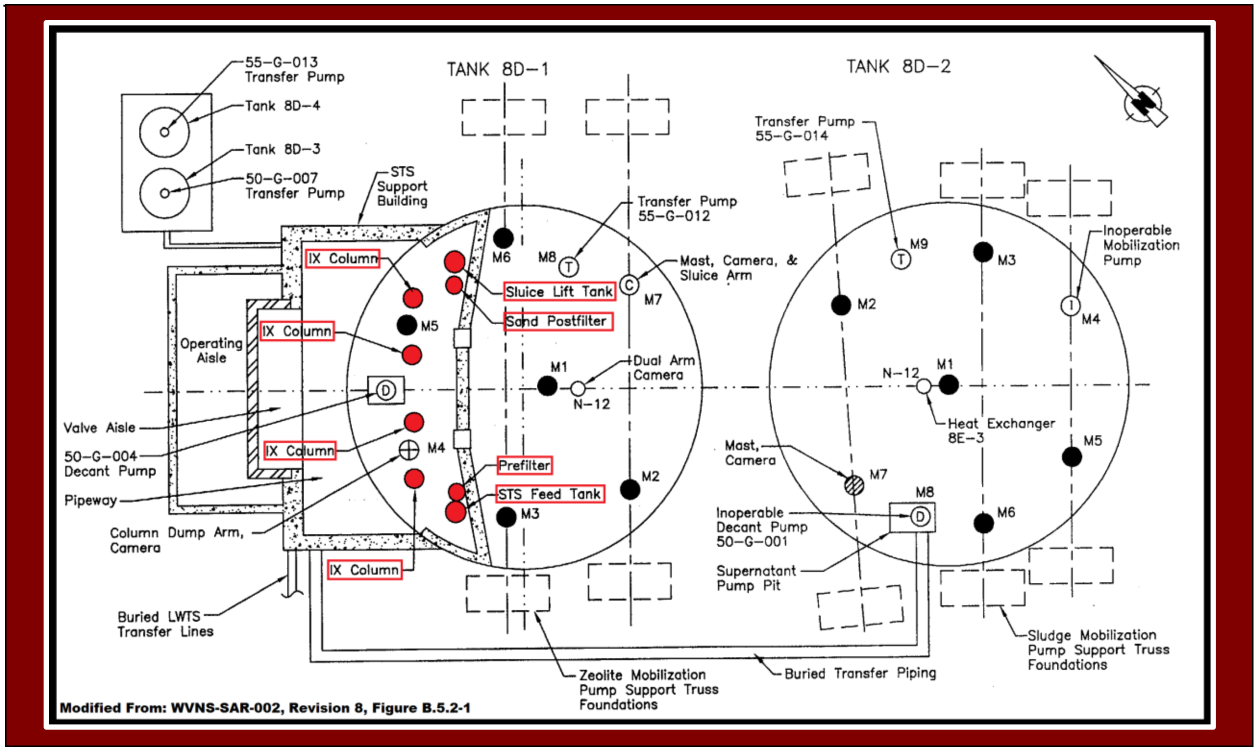
1. Summary of Need

The Tank 8D-2 supernatant was treated in the STS in Tank 8D-1 to remove cesium and, to a lesser degree, strontium and plutonium. As shown in Exhibit VIII-12 (plan view) and Exhibit VIII-13 (sectional view), the STS equipment consisted of a pre-filter, a supernatant feed tank, four IX columns, a sand post-filter, and a sluice feed tank. During STS operation, zeolite resin in the IX columns was used to selectively remove the cesium, strontium and plutonium from the supernatant. The treated supernatant was then solidified with cement in 71-gallon drums, which were removed from the site.

When the zeolite in any of the four IX columns became fully loaded, it was sluiced through a 4-inch ball valve at the bottom of the column into Tank 8D-1. Most of the zeolite was eventually transferred from the bottom of Tank 8D-1 to Tank 8D-2, and then to the melter in the vitrification facility to be incorporated into the vitrified waste. At the end of STS operation, any partially loaded zeolite resin was left in the four IX columns. With reference back to Table VIII-1, the resin remaining in the IX columns accounts for about 33% of the total Tank 8D-1 residual Cs-137 activity.

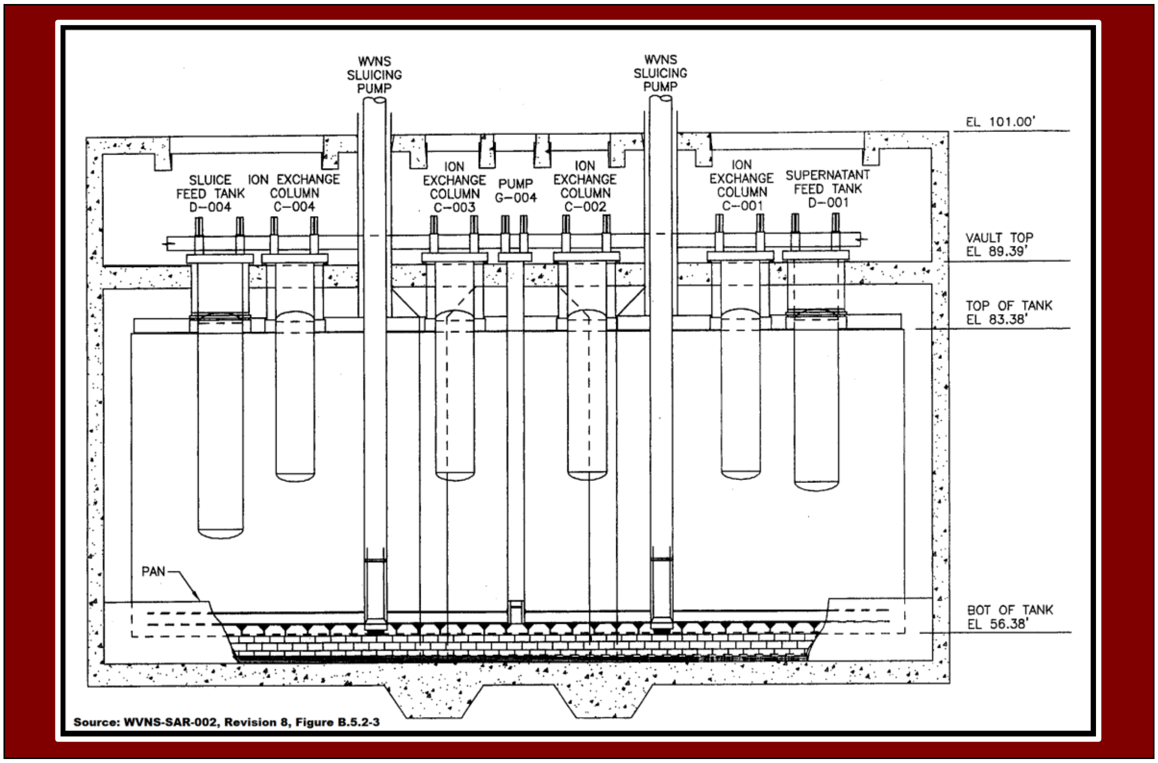
Several factors complicate the removal of the IX columns from Tank 8D-1, including:

- All four 4-inch ball valves used to sluice out the resin are either non-functioning or have been secured open and covered with a plug.
- The unshielded dose rate near the side of the IX columns containing the residual Cs-137 activity is calculated to be approximately 500 R/hr.



Modified From: WVNS-SAR-002, Revision 8, Figure B.5.2-1

Exhibit VIII- 12: Plan View of STS Equipment in Tank 8D-1



Source: WVNS-SAR-002, Revision 8, Figure B.5.2-3

Exhibit VIII- 13: Sectional View of STS Equipment in Tank 8D-1

- Zeolite beads are known to amalgamate together into a solid mass. This occurred at SRS Tank 19 when zeolite solidified into a mound that required high pressure water (i.e., 10,000 to 30,000 psi) to break it up (NAS 2006). It is uncertain (but expected) that such an amalgamation has occurred within the IX columns.

Several options for removing the STS equipment from Tank 8D-1 are presented below. The options focus on the removal of the IX columns, as they contain by far the most Cs-137 activity and would be the most difficult to remove. Some of the options depend on the condition of the zeolite within the IX columns, i.e., whether or not the zeolite has amalgamated into a solid mass. For example, the FEIS base case assumes that the zeolite has not amalgamated and that the columns can be emptied as they were originally designed. Options 2 and 3 assume that the zeolite has amalgamated and would need to be broken up before it could be removed. Options 1 and 4 could be employed regardless of whether or not the zeolite has amalgamated.

2. Potentially Applicable Removal Methods

a) *FEIS Base Case: Flushing of Zeolite Out of IX Columns*

For the FEIS, it was assumed that the zeolite in the four IX columns has not amalgamated and can be flushed out of the columns, processed to form solidified Class-C LLW, and shipped off site for disposal. The zeolite would be flushed through the J nozzles of the IX columns to the Liquid Waste Processing Cell of the WTFWPF for processing, and mixed with grout for solidification. The grout to zeolite ratio would be sufficient to produce a solidified product that meets the 10CFR §61.55 Class C concentration limit of 4,600 curies per cubic meter (Ci/m^3) for Cs-137. The zeolite/grout mixture would then be placed into 55-gallon drums for curing (URS 2009).

b) *Option 1: Remove IX Columns Intact*

It may be possible to remove the STS equipment (including the zeolite-loaded IX columns) intact by reversing their installation process. Because there was minimal radioactivity in Tank 8D-1 during column installation, the installation process was essentially a “hands on” operation. This would not be the case when removing the equipment. As stated above, based on the estimated residual Cs-137 activities, the dose rate on the side of the IX columns is expected to be approximately 500 R/hr. With such high dose rates, the IX columns would need to be remotely drawn into a heavily shielded box. The box would require 3.5 to 4 inches of lead to reduce the dose rate to the 20 to 100 mrem/hr range. Such a box alone would weigh 23 to 26 tons.

Once an IX column was in the box, it would be taken to a waste processing facility where the zeolite could be broken up, removed, and solidified into smaller packages, which could then be transported to a disposal site. Likewise, the IX column shells could be size-reduced, packaged, and transported for disposal. The referenced facility would be a new or existing on-site structure, and not an off-site facility. If a new facility is required, the additional cost would be significant and a major drawback of this option.

c) Option 2: Internally Break Up and Remove Zeolite

If the zeolite has amalgamated, it may be possible to break it up using some variation of a plumber's snake or concrete needle vibrator. Either approach would enter the IX column through the zeolite feed pipe, and would need to be modified for remote operation and tailored to the characteristics of the hardened zeolite. At least one industrial vibrator manufacturer offers a Pneumatic Whip Bin Cleaning System for cleaning blocked or compacted storage silos (Deca, 2017). The product is claimed to be a completely portable, remote-controlled tool that uses a variety of whips and cutting edges to knock down the toughest materials without damaging the walls of the storage silos. The applicability of this tool to de-amalgamate zeolite would need to be tested. Once the zeolite has been broken down, it could be flushed out of the IX columns and processed in much the same fashion as described for the FEIS base case.

d) Option 3: Externally Break Up and Remove Zeolite

One or more industrial vibrators could be installed on the outside of each IX column for use in breaking up amalgamated zeolite. Industrial vibrators are commercially available from many manufacturers and are used extensively in the food, pharmaceutical, and chemical industries to prevent clogging when moving bulk material. Examples include the unloading of grain, sand, and cement from railcars or storage silos. Although these vibrators are designed to keep material flowing by preventing clogging, rather than breaking up existing clogs, it may be feasible to work with a manufacturer to tailor a system such that enough energy would be provided to de-amalgamate the zeolite. Once the zeolite has been broken down, it could be flushed out of the IX columns and processed in much the same fashion as described for the FEIS base case.

e) Option 4: Hydrolance/Vacuum Zeolite from IX Columns

The aforementioned 42-inch high by 30-inch diameter mound of solidified zeolite in SRS Tank 19 was broken up with a high pressure (i.e., 10,000 to 30,000 psi) hydrolance. The hydroLance is a proprietary technology used to mobilize and transfer high solids-containing sludges and slurries using minimal additional water. It is a patented system comprised of an adjustable annular jet pump and fluidizing heads of various designs, and is usually deployed from above into a settled bed of solids or via a remote manipulator or vehicle. In a typical application, the fluidizing heads use water to mobilize solids in the region of the hydroLance suction, enabling the solids to be drawn into the ejector. The discharge side of the jet pump then provides the motive power to transport the solids downstream. (NuVision Engineering, 2017)

The most likely path to insert anything into the IX columns, including the hydrolance, would be through the fresh zeolite inlet pipe. Because this pipe is only 2½ inches in diameter and includes several bends, an evaluation would need to be performed to determine whether any off-the-shelf hydrolance could be inserted via this pipe, or whether an effective hydrolance could be designed to be inserted via the zeolite inlet pipe. If neither option is found to be feasible, then the viability of using the hydrolance to remove the zeolite is greatly diminished (if not eliminated).

3. Comparison of Options

Before a final evaluation of the options to remove the STS equipment from Tank 8D-1 can be made, a sampling program would have to be undertaken to establish the status of the zeolite within the IX columns, i.e., to determine if the zeolite has amalgamated or not. Lacking such sampling results, it has been assumed for purposes of this discussion that the zeolite has amalgamated based on experience at SRS.

The FEIS base case of flushing the zeolite out of the columns would not be a reasonable option to remove amalgamated zeolite from the IX columns. Under Option 1, attempting to remove the intact IX columns would likely either result in excessive radiological worker exposures or require a shielded box that would be excessively heavy. Thus, Option 1 is also not considered to be a reasonable option.

Options 2 and 3 both appear to be feasible; however, a testing program would be needed to determine the effectiveness of each at breaking up the zeolite.

Option 4, the use of a hydrolance, is the most promising option for removing the zeolite from the Tank 8D-1 IX columns. As discussed above, the hydrolance has been successfully used at SRS, so its effectiveness at breaking up amalgamated zeolite is known. The zeolite at West Valley differs somewhat from the SRS zeolite, however, so some additional testing may be required. Additionally, because of the limited access to the interior of the IX columns, there is a question as to whether a hydrolance can be implemented in Tank 8D-1.

E. Removal of Tank Shells

1. Summary of Need

The 70-foot diameter carbon steel tanks will need to be size-reduced if they are to be removed from their vaults. The various options for approaching tank removal from the perspective of worker and environmental protection were addressed in Section VIII.B. This section will address the specific methods for size-reducing the tank shells within the context of the options discussed in Section VIII.B. Any number of mechanical and thermal methods may be used to perform this size-reduction. The most applicable mechanical and thermal methods are presented in this section.

2. Potentially Applicable Methods

a) FEIS Base Case: Oxy-Fuel Cutting Torch Within WTFWPF

The FEIS assumed that the carbon steel shell of each tank would be cut into 38-inch by 57-inch segments using an oxygen-fuel (oxy-fuel) cutting torch in order to fit into a B-25 waste box (48-inches high by 48-inches wide by 72-inches long). Each segment would weigh about 310 pounds (lbs). Approximately 2,100 segments would be produced from each tank shell to satisfy this size criterion (Exhibit VIII-14). Additionally, there is a steel gridwork structure on the top and bottom of the tanks, steel surrounding the six concrete vault roof support columns, and 36 steel tank roof support columns that would need to be removed. For the FEIS, it was estimated that about 5,600 crew-hours would be required to remove all of the steel in the tanks. This estimate was based on the oxy-gasoline cutting rate, a factor to account for remote operations, downtime between cuts to allow for removing the segment and repositioning the torch, and a factor to account for a "smart" (i.e., computerized) torch repositioning system.

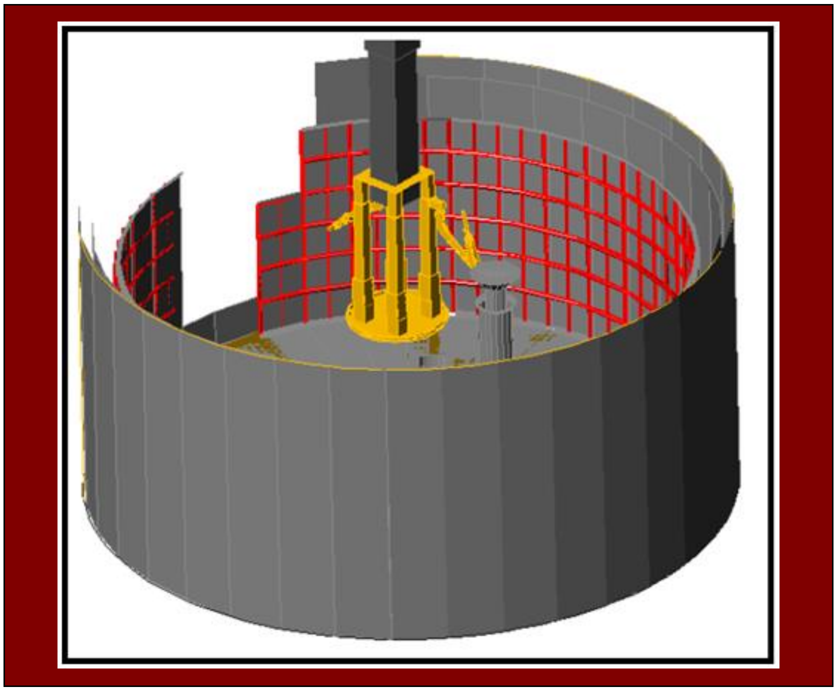


Exhibit VIII- 14: Schematic for Cutting Tanks 8D-1 and 8D-2 Sidewalls

An oxy-fuel cutting torch consists of a flowing mixture of a fuel gas and oxygen ignited at the orifice of the torch. The cutting tip of the torch consists of a main oxygen jet orifice surrounded by a ring of preheater jets. An oxygen/fuel gas flame preheats the steel to its ignition temperature, then a high-powered oxygen jet is directed at the metal, creating a chemical reaction between the oxygen and the metal to form iron oxide, also known as slag. The high-powered oxygen jet removes the slag from the kerf. Oxy-fuel torches are mobile and readily adaptable to automated positioning. The fuel gas may be acetylene, propane, propylene, natural gas, or gasoline. Fuel gases are typically chosen according to the cutting application, cost, heat output and oxygen consumption.

Based largely on the information provided in DOE/EM-0401 (DOE 1998), the FEIS assumed that an oxy-gasoline torch would be used to cut up the tanks, rather than the more widely used oxy-acetylene torch. Though initially the oxy-gasoline torch is more expensive than the oxy-acetylene torch, it is less costly to operate because it cuts faster and uses less expensive fuel. For example, to cut 2-inch think carbon steel, analysis indicates that the oxy-gasoline torch costs about 43% less than the oxy-acetylene torch

(Bossart and Walker 2000). However, the oxy-gasoline speed advantage over oxy-acetylene essentially vanishes when cutting ≤0.5-in. steel, such as the Tank 8D-1 and 8D-2 sidewalls (DOE 1998, Table 3). Unlike the oxy-acetylene torch, the oxy-gasoline torch is able to cut rusted surfaces.

Table VIII-4 shows some general advantages and disadvantages of using oxy-fueled torches for cutting metal. The advantages are only marginally applicable to segmenting Tanks 8D-1 and 8D-2 (e.g., operating costs are expected to be more important than initial costs, and complex shapes will not be cut). However, the fact that oxy-fuel cutting is slower than other cutting systems is an important disadvantage, which could increase operating costs.

Table VIII- 4: Oxy-Fuel Cutting Advantages and Disadvantages

Advantages	Disadvantages
Lower comparative initial cost	Comparatively slower than other cutting systems
Can have multiple cutting torches	Cannot cut stainless steel or cast iron
Can cut complex shapes	Cutting accuracy is not as good as plasma or laser
Can cut carbon and low carbon steel	Creates heat-affected zone

Source: Nouri 2013a

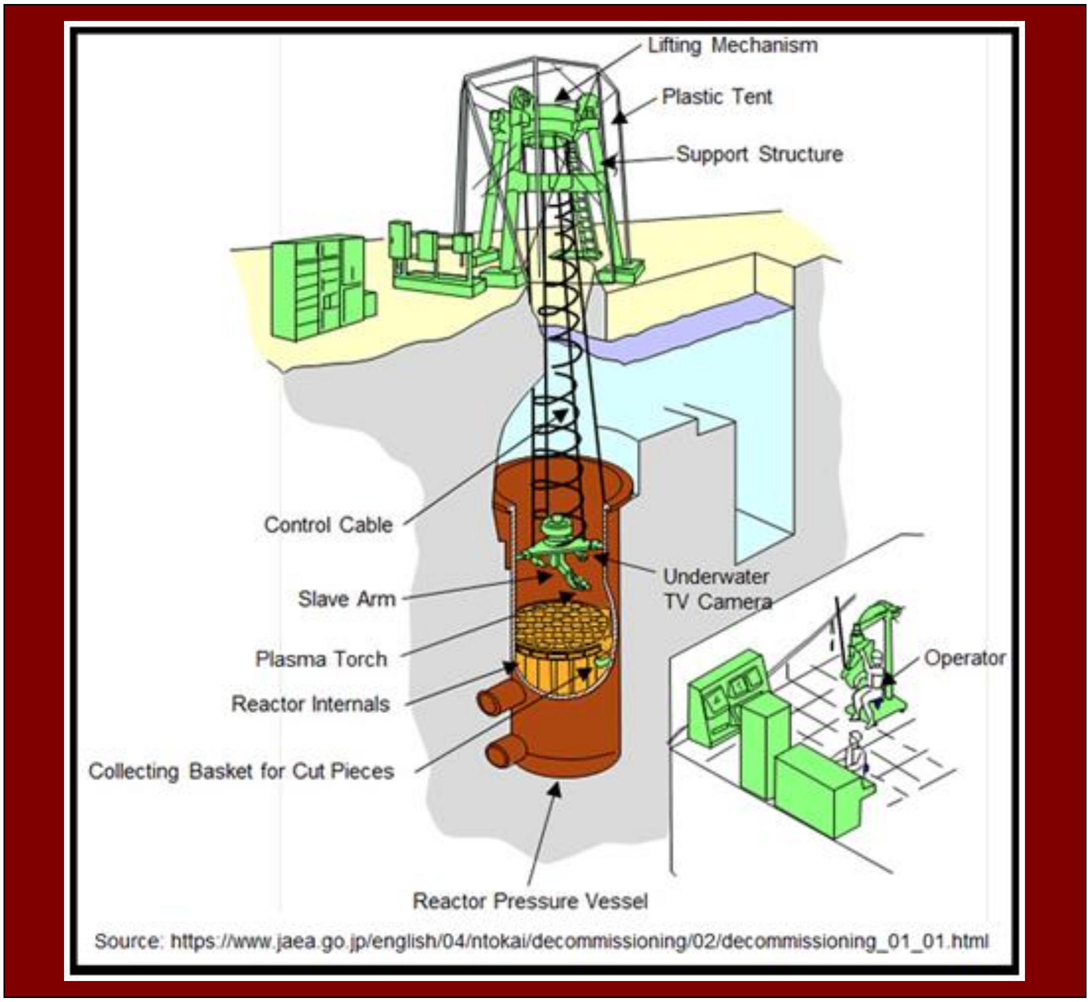
b) Option 1: Plasma Arc

Plasma is an ionized gas that conducts electricity. A plasma arc torch can be used to rapidly cut all conducting metals. The process is based on the establishment of a direct current arc between a tungsten electrode and the metal to be cut. The plasma arc formation begins when a gas such as oxygen, nitrogen, argon, or even shop air is forced through a small nozzle orifice inside the torch. An electric arc generated from an external power supply is then introduced to this high-pressured gas flow, resulting in what is commonly referred to as a “plasma jet.” The constricting effect of the orifice on both the gas and the arc results in very high current densities and temperatures (10,000 to 24,000°celsius [°C]) in the stream. The high temperature breaks the gas molecules into a high velocity plasma of positively charged ions and free electrons that, in conjunction with the arc, melts the metal being cut and blows away the vapors.

Plasma cutters are routinely used to perform cutting operations on metal, with the average hand-held system capable of cutting a metal thickness up to about 1 inch. One of plasma’s greatest advantages is its ability to cut non-ferrous metals such as aluminum, stainless steel, and cast iron, materials that are becoming more common in many applications. Speed and precision cutting are additional benefits of plasma, which typically cuts with minimal slag and can provide smooth cuts with a narrower kerf than that produced by an oxy-fuel torch. Plasma does not require the metal to be preheated before cutting, which saves time, and plasma cutters also outperform oxy-fuel torches when cutting stacked metals. Faster speeds can be achieved on thinner metals with plasma, with minimal or no metal distortion. Also, plasma systems are relatively simple to use compared to oxy-fuel systems, with the benefit of minimal cleanup.

On the other hand, the plasma cutter is generally more costly, and not as portable, durable, or rugged as other cutting technologies, including the oxy-gasoline torch. Another disadvantage is the particulate airborne contamination that is generated with the plasma technology, which tends to clog HEPA filters quickly. (DOE 1998)

Exhibit VIII-15, developed at the Japan Atomic Energy Agency's Tokai Research and Development Center, shows what a remotely operated plasma arc torch system might look like. Although Exhibit VIII-15 shows a reactor vessel being cut up under water, it could very easily be modified to show Tank 8D-1 or 8D-2 being cut up either in air or under water.



Source: https://www.jaea.go.jp/english/04/ntokai/decommissioning/02/decommissioning_01_01.html

Exhibit VIII- 15: Remotely Operated Plasma Arc Torch

Table VIII-5 presents general advantages and disadvantages of using plasma arc for cutting metal. The most important advantage applicable to segmenting Tanks 8D-1 and 8D-2 is the fast cutting speed, which would help to reduce operating costs. However, although the Electric Power Research Institute (EPRI) (2001) found that the absolute cutting speed of the plasma arc method was much faster than other metal cutting methods, the effective cutting speed of the plasma arc was only slightly faster due to the longer preparation time and longer debris cleanup time for the plasma arc system. Another advantage is that no hazardous gases are required, again reducing both exposure risk and operating costs. The fact that plasma torch is initially expensive is expected to be offset by operating cost savings.

Table VIII- 5: Plasma Arc Cutting Advantages and Disadvantages

Advantages	Disadvantages
Fast cutting speeds	Not readily portable (needs electricity)
No hazardous gases needed	Plasma torch is initially expensive
Can cut all metals	Hardens materials next to the cut
Little distortion from heat	Metal fumes created can be a health hazard
Oxygen-based system does not leave nitride deposits	Creates a heat affected zone

Source: Nouri 2013a

c) Option 2: Nibblers and Shears

A nibbler is a punch and die cutting-tool that normally operates at a rapid reciprocation rate of the punch against the die, "nibbling" a small amount of sheet metal with each stroke. A shear is a two-bladed or two-cutter tool that operates on the same principle as a conventional pair of scissors. A bladed shear is used primarily for in-line cutting of sheet metal.

Consideration of nibblers and/or shears to segment Tanks 8D-1 and 8D-2 was largely driven by their successful application at Hanford. The single-shelled tanks (SSTs) at Hanford were constructed of concrete with a ¼-inch to 3/8-inch thick carbon steel liner. The Hanford approach to deconstruct the SSTs was to utilize an excavator with impact breaker and shear jaw attachments to break up the concrete and cut through the steel liner. However, based on information provided in Wiese (1998), it is unlikely that either nibblers or shears would be suitable for segmenting the ½-inch steel shells of Tanks 8D-1 and 8D-2.

d) Option 3: Laser

The laser cutting process is suitable for cutting mild steel up to about 1.25 inches in thickness, so the ½-inch thick sidewalls of Tanks 8D-1 and 8D-2 are well within that capability. Laser cutting is not a very fast process, because on low carbon steel it is basically just a burning process that uses the extreme heat of a focused laser beam instead of a preheat flame. Therefore, the cutting speed is limited by the speed of the chemical reaction between iron and oxygen. OCR (2013) reported that maximum cutting speeds using 4.8kW of laser power in a dry environment were 43 inches per minute (in./min.) and 12 in./min. for material thicknesses of 0.5 and 1.0 inches, respectively. OCR (2013) also reported that there was an approximate 50% reduction in cutting speed when cutting steel under water.

EPRI (2001) noted that laser methods had been considered for segmenting reactor pressure vessels, but were still considered experimental and had not been used as of 2001. Boing (2012) concurred with that assessment by concluding that laser cutting for nuclear plant dismantlement "…*needs further development*." Therefore, laser cutting will likely not be applicable for Tanks 8D-1 and 8D-2 unless it is decided to use the tanks to develop and demonstrate carbon steel cutting capabilities of a laser.

e) Option 4: Abrasive Water Jet

The abrasive water-jet cutting technique involves the use of highly pressurized water containing an abrasive to erode away the material. The technique can cut virtually all materials. Different types of abrasives are available, such as quartz sand, corundum, and silica carbide. Abrasive water-jet cutting is not as fast as plasma cutting, but requires less energy. The abrasive water-jet operates in the range of 40,000 to 60,000 psi at flow rates of 5 to 8 gpm. Several reactor pressure vessel segmentation projects have used abrasive water-jet cutting as the primary cutting method, including Connecticut Yankee, Maine Yankee, San Onofre 1, and Rancho Seco (EPRI, 2001).

One disadvantage is that abrasive water-jet cutting generates large quantities of water and waste grit. It is possible to recycle the water, but such a recycling effort requires an ultra-pure filtration system with sufficient capacity to support operations. Grit addition is on the order of several pounds per minute, and recycling of the grit is generally not performed.

f) Option 5: Mechanical Saws – Carbide Blades

Because of their low operating cost and high cutting speed, mechanical saws are routinely used for cutting metal piping systems. In recent years, several reactor vessel internals have been segmented using mechanical saws with carbide blades, rather than thermal or water-jet cutting. Examples include Fermi Unit 1, Humboldt Bay, Rancho Seco, and Zion. Two distinct advantages of mechanical saws over plasma arc and oxy-fuel techniques are a reduction in fire hazard and an increase in the control of radioactive contamination (because there are no fumes or gases).

g) Option 6: Diamond Wire

For Protective Measures Options 2 and 3 discussed in Section VIII.B, the tanks and/or vaults would be partially or fully filled with grout. A diamond wire is believed to be the best method for cutting the resulting monoliths into smaller blocks, which would then be characterized, packaged, and transported off site for disposal. Almost any thickness can be cut with this technique. More information on diamond wire cutting is provided in Section VIII.B.2.d above.

One of the major benefits of the diamond wire saw is the flexibility of its pulley system, which allows it to cut unusual configurations of any thickness. This flexibility also allows easy and safe cutting in difficult access areas, without removing obstructions. The diamond wire saw also lends itself to remote cutting in hazardous, radioactive, or underwater environments. Another advantage is that once the wire has been threaded, the cutting process can be performed without any further worker involvement, thereby greatly reducing the potential for radiation exposures. A potential concern is that contaminated chips and filings can be carried away from the cutting area by the wire, contaminating the wire saw itself, the areas along the path of the wire, and the area where the drive unit is located.

3. Comparison of Options

Svensk Kärnbränslehantering (SKB 2013) presented a summary of the advantages and disadvantages of thermal (e.g., plasma arc), water-jet, and mechanical (e.g., carbide blades) cutting techniques. The following primary findings were reported:

- Thermal techniques are generally faster than mechanical techniques in terms of both cutting and deployment speed, and have been the preferred cutting technique for reactor internals segmentation in the United States. They are also non-contact, non-reaction force techniques, which assist their remote deployment as there is no need for bulky reinforcing of deployment systems. This, coupled with the fact that these techniques can cut in any direction (compared to blades which cut only in the direction the blade is facing) makes them highly maneuverable and well-suited to cutting complex geometric structures.
- Thermal techniques also have disadvantages in that the off-gases from the process need to be captured if airborne contamination levels are to be controlled. More significantly, the off-gases can drive activated cutting debris up to the surface of the water during underwater cutting, resulting in increased exposure potential. For this reason, mechanical cutting techniques are typically used outside the U.S. for segmentation of reactor internal components.
- Abrasive water-jet cutting techniques are another technique typically used for segmentation of higher activity reactor internal components. These techniques can cut very thick metal sections, and also have the advantage that they do not drive material to the surface. However, abrasive water-jet cutting is slower than thermal techniques and also requires the introduction of a cutting abrasive material, which results in an additional waste stream. In extreme cases the quantity of abrasive material may reach unacceptable levels.
- Mechanical cutting has a number of general advantages over thermal and abrasive water-jet techniques. It produces no fumes and requires no cutting or fuel gas, both of which can bring radioactive material to the water surface resulting in the need to provide local ventilation at the water surface. Secondary wastes produced are in the form of cuttings and filings, which will be in relatively large pieces that are easily

collected. The larger pieces of cutting debris have less potential to disperse through the water than is the case for thermal or abrasive water-jet debris, thereby reducing the potential for the spread of contamination and reduction in visibility.

Hypertherm (2003) also presented a comparison of various steel cutting processes that concluded the following:

- Plasma is a universal process with the most metal applications, a wide capability, and a competitive price range. It is by far the most productive process on carbon steel from ¼-inch through 2-inch in thickness, with a moderate capital equipment cost and a low operating cost.
- Oxy-fuel cutting is necessary for carbon steel thicker than 2 inches, but is also effective down to about 3/8-inch thickness. The method is relatively inexpensive from a capital equipment standpoint, but higher than plasma in terms of operating cost.
- Laser is most productive on materials thinner than ¼-inch. Tolerances are excellent on most materials and thicknesses. Laser has high capital equipment cost and medium to high operating cost.

Diamond wire is not presented in the Hypertherm (2003) comparison, but would only be used if either Protective Measures Option 2 or Option 3 (i.e., partial or full grouting of the tanks) was selected. In this case, diamond wire would likely be the preferred option.

A third comparison is provided by Hylko (2014) based on the following progression of approaches as reported by John Sauger, Vice President and General Manager of the Zion Solutions Project.

- In the 1990s, the first reactor internals cutting projects were done with plasma cutters. While the method worked, there were drawbacks to using plasma cutters including the destruction of water clarity, the generation of a large volume of debris, and the spreading of contamination throughout the reactor pool.
- The next generation of methods tested at Maine Yankee was abrasive water-jet cutting. While there was improved water clarity, water-jet cutting generated more GTCC waste.
- The third generation of cutting technologies was mechanical cutting, which was found to be the best way to take care of the reactor internals. Very little secondary waste was generated, and there were no issues with water clarity.

In summary, there is no consensus as to the single preferred method for segmenting the Tank 8D-1 and Tank 8D-2 carbon steel shells. Rather, the method selected would likely be dependent on the overall tank removal approach chosen (Section VIII.B). For example:

- If either the FEIS base case (Roof Removal within the WTFWPF) or Option 1 (Existing Vault - "Through the Risers") is selected, then plasma arc would be a prime candidate, mainly due to its speed.
- If Option 2 (Partial Layer of Grout) is selected, then plasma arc would be recommended for the non-grouted portions and diamond wire for the grouted portions.
- If Option 3 (Full Layer of Grout) is selected, then diamond wire cutting would be recommended due to the depth of the cuts that would be required.
- If Option 4 (Filled with Water) is selected, then it is likely that the abrasive water-jet technique would be recommended to better maintain water clarity or, if the geometry of the tanks allows, mechanical saws might be the preferred choice for waste reduction and still better water clarity.

F. Waste Processing

1. Summary of Need

For the FEIS, it was estimated that the tank content material removed could be processed and reduced to Class C LLW. The carbon steel shell from Tank 8D-1 was also assumed to be processed to Class C, whereas the shell from Tank 8D-2 was judged to require disposal as TRU waste. The vault pan would be Class C and the vault concrete rubble would be LSA waste. This waste would need to be characterized, processed, packaged, and shipped. Due to the Cs-137 contamination, most of this processing would need to be performed from behind shield walls.

Before any material removed from the tanks can be disposed as LLW, it is anticipated that one or more waste incidental to reprocessing (WIR) determination(s) will need to be prepared to demonstrate that the material is not HLW. Such determinations were previously prepared for the Vitrification Melter (DOE 2012c), Concentrator Feed Makeup Tank, and Melter Feed Hold Tank at West Valley (DOE 2013). If the WIR does not demonstrate that material removed from the tanks is LLW, then it would need to be handled as HLW. The processing, packaging, transport, and disposal of HLW is much different from (and usually more expensive than) that of LLW.

The waste processing requirements will also be dependent on the overall approach to tank removal eventually selected. For example, if water is used for exhumation of Tanks 8D-1 and 8D-2 (e.g., either to remove the heel, to de-amalgamate zeolite, to feed an abrasive water-jet cutter, or as a protective measure under Option 4 [Filled with Water]), then an additional system would need to be provided to process that water. On the other hand, if Option 3 (Full Layer of Grout) is selected for exhumation of Tanks 8D-1 and 8D-2, then the blocks of waste could likely be packaged "in the field" and further waste processing might not be needed.

2. Potentially Applicable Methods

a) FEIS Base Case: Waste Processing Within the WTFWPF

The design of the WTFWPF included two waste processing areas – the Remote Handled Work Cell and the Liquid Waste Processing Cell. The Remote Handled Work Cell was assumed to be similar to the existing Remote Handled Waste Facility (RHWF) Work Cell, with provisions for remote handling, surveying, segmenting, decontaminating, and repackaging operations. The shielded space of the Remote Handled Work Cell would be approximately 55 feet by 22 feet by 37 feet high, and would be served by two bridge cranes – one designed for a 30-ton load, and the second with 3-ton capacity telescoping masts with two powered dexterous manipulator (PDM) arms. A jib crane with PDM arms would also be mounted on rails along the long wall over two workstations, each containing a shield window, a console to operate handling and cutting equipment, and CCTV monitors. The PDMs and end effectors would be interchangeable between the telescoping masts of the bridge crane and jib crane. A third workstation would be provided in the Sample Packaging and Screening Area to perform sampling and maintenance operations using master-slave manipulators.

The Liquid Waste Processing Cell would contain two holding tanks, a dewatering system, ion exchange columns, and a solidification unit. As presented in the FEIS, effluent from the Liquid Waste Processing Cell would be conveyed via a connection to the Low-Level Waste Treatment Building (LLW2) to allow for additional treatment and liquid releases via Lagoon 3. Since the LLW2 and the lagoons are being removed under the Phase 1 decommissioning program, another method would be needed if liquid releases to the environment are to remain within the design.

b) Option 1: WTF Dedicated Stand-Alone Facilities

Under Option 1, solid and/or liquid waste processing facilities similar to those proposed for the WTFWPF would be constructed as stand-alone units at the WTF in lieu of integrating them into the WTFWPF in order to retain additional flexibility pending decisions on the overall approach to tank removal. Several of the facilities would still require a shielded space in which to perform waste processing once the material has been removed from the tanks. For example, a remote handled solid waste processing facility would be needed for Option 1 (Existing Vault – “Through the Risers”), Option 2 (Partial Layer of Grout), and Option 4 (Filled with Water) to process the carbon steel shells as they are removed from their vaults. The existing RHWF could potentially be tailored to handle the tank shells. However, the RHWF is currently scheduled to be removed under Phase 1 decommissioning. It has also not been shown that attempting to tailor the existing facility to handle the tank shells would be more cost-effective than a new facility designed specifically for that purpose.

Likewise, a liquid waste processing facility would also be required for Protective Measures Option 1 (Existing Vault – “Through the Risers”) and Option 4 (Filled with Water) to treat water used during the shell removal process. If partial removal of only the material on the Tank 8D-1 and 8D-2 floors is selected, then a liquid waste processing facility would be needed to treat water used to mobilize the on-floor material.

c) *Option 2: Site-Wide Processing Facility*

If waste is being retrieved from the SDA and/or NDA, as well as from the WTF, then the option to utilize a site-wide waste processing facility to process all the waste being generated comes into play. This same option was considered in Section VII, and is repeated here as an option for processing the WTF waste. However, there are several drawbacks to utilizing this concept, and an extension of the centralized waste processing facilities to include either solid or liquid waste from the WTF is not considered applicable to the WVDP. These include:

- The material coming out of Tanks 8D-1 and 8D-2 is generally expected to be much more radioactive than the material exhumed from either the SDA or NDA.
- The material exhumed from either the SDA or the NDA is expected to be saturated with water from being exposed to leachate for over 50 years.
- A site-wide centralized waste processing facility would combine radioactive materials that are under different regulatory frameworks (State vs. Federal). The acceptability of this would have to be confirmed.
- Transporting the North Plateau waste to the South Plateau, or the reverse, would complicate the waste processing process, increase exposure risk, and add cost.

d) *Option 3: Off-Site Treatment*

If selective removal of only the material on the Tank 8D-1 and Tank 8D-2 floors (i.e., the “tank heel” of zeolite and sludge) is selected, then it may be feasible to transport the retrieved material off site for vitrification (or other treatment) prior to disposing the waste in a geologic repository. This option was addressed as far back as 1982 within the context of an EIS related to the long-term management of liquid high-level radioactive wastes stored at West Valley (DOE 1982, page H-10). At that time, however, the option was not carried forward because wastes in liquid form offer a much more serious potential for dispersal in the environment in the event of an accident, as well as legal and institutional issues that would arise to make the transfer of the liquid HLW to another location for solidification an unsuitable alternative. Although the referenced EIS was issued over 45 years ago, the continued relevance and importance of the conclusion was recently affirmed by the President’s Blue Ribbon Commission on America’s Nuclear Future, which recognized *that large-scale shipment of liquid wastes could be problematic* (BRC 2011).

If the WIR analysis determines that the tank heel is not HLW, then the above concerns would not strictly apply; however, the waste would nonetheless be highly radioactive. Additionally, because processing would be performed off site, the waste would be in liquid form when transported, and the legal and institutional issues raised in the 1982 EIS would still apply.

There are very few (if any) casks available to transport high activity liquid waste. A German cask, CASTOR V/HAWC, was identified for the 1996 WVDP DEIS (DOE and NYSERDA, 1996), but that cask had not been approved for use in the United States. Attempts to find more recent information on the CASTOR V/HAWC were unsuccessful, and it is judged that the CASTOR V/HAWC could not be used. Another potential option to transport Tank 8D-1 and Tank 8D-2 waste off site for processing is the NAC-LWT cask. However, the NAC-LWT cask is currently only approved to carry High Enriched Uranyl Nitrate Liquid rather than high activity liquid waste, and thus its certificate of compliance would likely need to be extended even if the cask was deemed to be acceptable for Tank 8D-1 and Tank 8D-2 waste.

Transporting the steel shells of Tanks 8D-1 and 8D-2 off site for treatment is not considered to be cost effective, primarily because an on-site facility would still need to be constructed to process and package the waste in preparation for off-site transport.

e) Option 4: Laser Milling

The FEIS WTFWPF Remote Handled Work Cell was envisioned to be a facility where the steel tank shell would be characterized, size reduced (as necessary), and packaged for shipment to an off-site disposal facility. It was not envisioned to be a facility to decontaminate the steel tank shell, which would reduce the volume of steel requiring disposal. Recently, The Welding Institute (TWI) of Cambridge, England demonstrated a method using lasers to reduce the amount of contaminated steel requiring disposal by almost 90%. TWI began developing laser equipment for nuclear decommissioning in 2010, and in November 2014 applied lasers for the first time to cut radioactive material at the Hinkley Point A nuclear power station in Somerset, United Kingdom (UK).

The work at Hinkley Point A involved dismantling radioactive steel waste skips (i.e., metal storage containers) in order to store the material more effectively. The process started by using a robot-mounted laser to cut each skip into five sections – the four walls and the floor. The laser then performed five-axis milling of the material, removing around 1.3 mm of surface material over the entire surface of each piece of metal. By removing the radioactive surface material, the process reduced a 450 kg skip to 50 kg of active, highly compacted waste, and 400 kg of steel that was recycled. The TWI solution was estimated to save £30 million for processing 300 skips (ILS, 2015).

3. Comparison of Options

With the exception of Option 4 (Laser Milling), the waste processing options discussed above differ more by where the waste processing would occur than by how the waste processing would be performed. If the FEIS base case is used, then space within the WTFWPF would be provided for both solid and liquid waste processing. If one of the options to the WTFWPF was to be selected, a stand-alone shielded building located near the WTF would be the best choice for performing the necessary waste processing. The options to construct a site-wide processing facility (Option 2) or to ship the waste off site for processing (Option 3) were each considered to be more costly and less feasible than constructing a facility near the WTF that would be dedicated to HLW tank removal (Option 1).

Option 4 is a laser-based system that could reduce the volume of contaminated steel requiring disposal by up to 90%. Because Tank 8D-1 and Tank 8D-2 each contain about 590,000 pounds of steel, reducing the mass of steel requiring disposal by up to 90% would result in significant packaging, transport, and disposal cost savings. The laser milling system has been tested at Hinkley Point A and found to be effective, but no instances were found of its application to a large-scale production such as that represented by the mass/volume of steel in Tanks 8D-1 and 8D-2.

Because the precedent work was done in the United Kingdom, the EXWG was not able to locate detailed capital or operating cost information on the laser-milling system. There would likely be a large initial cost to procure the 5-axis laser milling machine, but this would not compromise the overall cost-effectiveness of its application to the HLW tanks at West Valley given the very large amount of steel that could be recycled rather than disposed as radioactive waste. Therefore, because of its effectiveness and waste reduction potential, consideration should be given to using a similar laser-based system at the West Valley, perhaps as a demonstration project.

G. Impacts of Radiological Decay on Technology Applicability

Exhibit VIII-16 (ECS 2016b, Figure V-4) shows what the dose rate inside Tank 8D-1 would be over the time period of interest. As of 2140, the dose rate would remain greater than 10 R/hr, or more than three orders of magnitude greater than the 2.5 mrem/hr occupational exposure limit that would allow for contact-handled operations (based on an annual limit of 5 rem divided by 2,000 work hours per year). To determine the date at which the 2.5 mrem/hr dose rate would be achieved, the decay calculations were extended beyond 2140. The results of this analysis are shown by the same set of curves in Exhibit VIII-16, but using the right and top axes as the points of reference. The point of intersection of each curve with the dash-dot line at 2.5 mrem/hr (on the right axis) gives the year (on the top axis) at which the occupational exposure limit would be satisfied. As shown, it would be necessary to wait until about 2510 before the Tank 8D-1 dose rate decayed sufficiently to allow for contact-handled operation.

Therefore, over the time period of interest, delaying WTF exhumation to take advantage of radiological decay is not expected to eliminate the need to perform the work remotely from behind shielding. However, the amount of required shielding would decrease the longer WTF exhumation is delayed. Unfortunately, the major cost driver is the fact that the work must be done remotely, not the amount of shielding material required (i.e., an extra few inches of concrete shield wall thickness is not expected to have a major cost impact). Therefore, it is not expected that delaying WTF exhumation over the time period of interest would modify the selected approach or greatly reduce its cost.

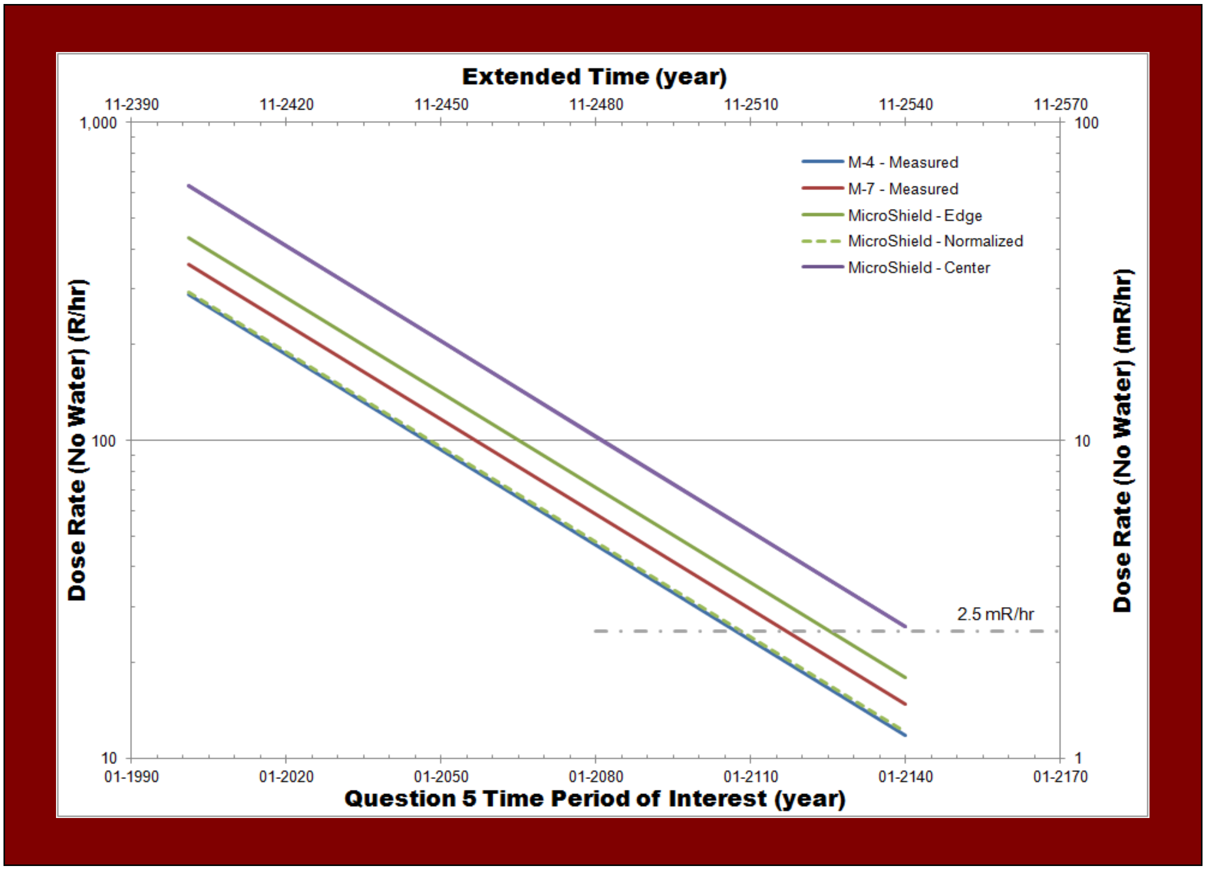


Exhibit VIII- 16: Tank 8D-1 Dose Rates over Time

IX. Study 3: Summary and Conclusions

A focus of Study 3 was the evaluation of whether any options to the methods and technologies proposed for the Sitewide Removal Alternative in the FEIS could achieve the project objectives at lower cost without jeopardizing worker and community safety. The findings of Study 3 indicate that the FEIS base case represents the most comprehensive, protective, and costly of almost all options due to its development as a Sitewide Removal Alternative. As summarized in this section, options do exist for some processes that provide a comparable level of protection at lower cost while retaining applicability across all waste classes under the Sitewide Removal Alternative. Even greater cost savings could be achieved by using other optional methods, but with the limitation that these methods would only apply to certain selective exhumation scenarios that do not involve high exposure rate conditions.

The primary trade-off that came out of Study 3 for consideration in the Phase 2 decision process is the range of radiological activity for which a given method can provide adequate protection versus the cost of implementing that method. That trade-off provides the foundation for a summary comparison of options in this section based on the reported findings of Study 3. Major advantages and disadvantages are cited for each optional approach to provide DOE and NYSERDA with important information in support of the Phase 2 decision process, as well as to identify potential critical flaws in a given method as related to the range of exhumation scenarios that could eventually be selected.

The summary and conclusions presented in this section are generally limited to those of Study 3, as supported by earlier work of the EXWG, for the following elements of the exhumation process:

- Leachate Management and Treatment
- Protective Measures
- Waste Exhumation: Trenches and NDA Special Holes
- Waste Exhumation: NDA Deep Holes
- Waste Processing
- Interim Waste Storage
- High Level Waste Tanks – All Processes

For the convenience of the reader, each element is presented on a separate page. A summary of the overall work performed by the EXWG and related conclusions are presented in Section X within the framework of seven topical questions previously prepared by DOE and NYSERDA. The seven questions helped focus the EXWG on those areas for which further study would facilitate interagency consensus related to exhumation alternatives.

A. Leachate Treatment

A comparative summary of the advantages and disadvantages of the FEIS base case and the two optional approaches for the treatment of leachate extracted from the waste units is provided in Exhibit IX-1. The general conclusion reached by the EXWG is that the FEIS base case is a viable option for the Sitewide Removal Alternative, due primarily to its multiple treatment processes and applicability to the full range of radiological and chemical constituents in the various influent streams. However, based on precedent applications, both of the options considered in Study 3 are also capable of treating the constituents in the leachate that would be extracted from the SDA, NDA, and other sources.

The primary discriminators among the three approaches are cost, leachate volume (or flow rate) capacity, and how the high levels of tritium in the leachate are addressed, as follows:

- The evaporation option, and to a lesser extent the leachate grouting option under low leachate volumes, would provide for significantly lower cost treatment under certain selective removal alternatives. Evaporation would be favored over grouting unless the leachate volume is low due to the complications and high cost of grout disposal.
- All three methods can treat the expected volume and flow rate of leachate requiring treatment, with evaporation and grouting far more scalable than the centralized treatment plant proposed under the FEIS base case.
- The tritium issue remains unresolved under the FEIS base case, and is most effectively addressed under the grouting option. Whereas evaporation would release tritium to the atmosphere without additional treatment, such a release has not been shown to be a public health concern under precedent applications.

FEIS BASE CASE **CENTRAL TREATMENT PLANT**	**OPTION 1** **GROUTING**	**OPTION 2** **EVAPORATION**
Key Advantages	**Key Advantages**	**Key Advantages**
• Applicable for the treatment of the full range of organic and radionuclide constituents • Range of treatment processes allows for design flexibility and process-specific optimization	• Low cost with scalability to match leachate volume generated • Proven precedent performance in treating similar leachate • Capability to bind tritium in grout mixture	• Lowest cost option with scalability by mobilizing additional units • Proven precedent performance in treating similar leachate, with amount of tritium released to atmosphere far below applicable standards.
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• Tritium not treated; dependent on LLWTF & lagoons for tritium dilution prior to discharge, which may not be available at the time of project initiation • Once constructed, lack of flexibility in response to possible future selective removal decisions if overall project is phased.	• Large volume of residual waste (grout) generated in proportion to leachate volume • High cost of off-site disposal; on-site disposal not compatible with full exhumation alternative • Low potential for long-term leaching of contaminants from grout	• Tritium not treated; however, release of tritium to atmosphere considered preferable to discharge to surface water under FEIS base case • Evaporation concentrates waste stream instead of providing destructive treatment; need to address concentrated residuals

Exhibit IX- 1: Comparison of Methods: Leachate Treatment

B. Protective Measures

The analysis of protective measures by the EXWG found this element of the waste exhumation process to be the most representative of the two overall study findings. These include:

1. The proposed use of rigid outer enclosures that would span entire waste disposal areas with modular inner enclosures at the excavation area is a prime example of the FEIS base case remedy representing the most comprehensive, most protective, and most costly of the available options. No precedent project has required this level of robust protection under conditions generally similar to those expected at West Valley.
2. The three options represent a clear trade-off of the range of radiological activity for which a given method can provide adequate protection versus the cost of implementing that method. As indicated in Exhibit IX-2, a less costly option used at other sites appears to be available in the form of modular tension-membrane enclosures (Option 1), with improved design technology since the issuance of the FEIS in 2010. Under Option 1, a less robust outer enclosure would be paired with an interior enclosure comparable to that proposed under the FEIS base case. As such, the enclosures of Option 1 may be sufficient to safely complete waste exhumation without the higher level of protection afforded by the FEIS base case. The preference for Option 1 would increase under a selective exhumation scenario that targets long-lived radionuclide removal while avoiding trenches of high gamma activity that pose the greatest dose threat to workers. Consideration of the lowest-cost single enclosure (Option 2) would be feasible only if a selective exhumation scenario would limit exposure to short-lived radionuclides, or if the short-lived radionuclides were allowed to decay before removal.

FEIS BASE CASE FIXED OUTER ENCLOSURE; MODULAR INNER ENCLOSURE	OPTION 1 MODULAR TENSION-MEMBRANE OUTER AND INNER ENCLOSURES	OPTION 2 SINGLE ENCLOSURE WITH LOCKOUT AREAS TO SUPPORT OPERATIONS
Key Advantages	**Key Advantages**	**Key Advantages**
• Generally applicable to all waste types and operations; protects against "surprises" if waste inventories are not fully accurate • Outer enclosures cover entire footprint of NDA and SDA waste units	• Demonstrated success at other sites • Modular nature provides scalability for selective removal scenarios • Inner enclosures (MSEEs) that provide primary exposure protection remain unchanged from FEIS	• Lowest cost option with room for operation of heavy equipment • Modular structures could be sized for project and reused
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• "One size fits all" nature leads to conservative design and high costs. • Inconsistent with less robust methods used successfully at other sites	• Less robust protection against unexpected waste conditions • Need to establish structural integrity under West Valley weather conditions.	• Applicable only to low exposure situations such as certain selective removal scenarios or if the project is put off for several decades • Retains risk of encountering unexpected conditions

Exhibit IX- 2: Comparison of Methods: Protective Measures

C. Waste Exhumation: Trenches and NDA Special Holes

Exhibit IX-3 summarizes the comparison of optional approaches for the exhumation of waste from the SDA and NDA trenches and the NDA Special Holes. The most significant difference in the options is a move away from remote exhumation using a crane system (FEIS base case) to the use of manually-operated earth-moving equipment either within the waste units (Option 1) or outside the waste units (Option 2). Although the FEIS base case represents the safest approach to protect workers, the fact that about 90% of the SDA waste and most (if not all) of the NDA Special Hole and trench waste does not exceed the 50 mrem/hr criterion cited in the FEIS for remote operation indicates that the two options should be considered for more extensive application at West Valley. At a minimum, the additional cost of using remote operations across all the SDA trenches does not appear to be warranted given the widespread use of contact-handled approaches using standard earth-moving equipment at several precedent projects.

Both Option 1 and Option 2 represent approaches used successfully and safely at other DOE sites, with further analysis required to determine which of the two optional approaches would be most applicable for the various waste units given their stated advantages and limitations. Option 2 has apparent safety advantages in that the operators and equipment are kept out of the waste units, but questions remain as to whether current excavation equipment would be capable of reaching the necessary horizontal and vertical distances from the sides of the trenches without special engineering.

FEIS BASE CASE REMOTELY-OPERATED CRANE WITH Z MAST ATTACHMENTS	OPTION 1 MANUALLY-OPERATED EQUIPMENT WITHIN TRENCH	OPTION 2 MANUALLY-OPERATED EQUIPMENT FROM OUTSIDE OF TRENCH
Key Advantages	**Key Advantages**	**Key Advantages**
• Highest level of worker protection; protects against "surprises" if waste inventories are not fully accurate • Linear operation of crane enables use within confines of MSEEs	• Higher level of operational control and higher rate of production • Less performance uncertainty • Successful and safe application on precedent projects at other sites • More flexibility to match equipment size/capacity to specific waste forms	• Similar advantages as Option 1 without the need for operator entry into trenches
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• Questions remain as to the ability of end effectors attached to the arm of a crane to exhume the full range of waste forms in the trenches • Entry into trenches may still be required to attach/remove casks and large tanks	• Operator shielding may not provide adequate protection against an unexpected radiological release • Need for expanded working space may not be compatible with MSEEs • Remote operation would likely still be necessary for some trenches	• Similar disadvantages as Option 1, with additional concern as to whether equipment reach would be sufficient to effectively remove waste from entire width and depth of trenches

Exhibit IX- 3: Comparison of Methods: Waste Removal - Trenches & Special Holes

D. Waste Exhumation: NDA Deep Holes

The excavation of wastes from vertical pipe units (VPUs) at the Hanford 618-10 and 618-11 areas was the only precedent project identified by the EXWG that involved waste removal from units similar to the NDA Deep Holes. Among the various removal methods either considered or actually employed for that project, only one option was considered to be sufficiently applicable to the NDA Deep Holes to be carried through to the Study 3 evaluation. This method involved the in-situ grouting of the waste prior to extracting the grouted mass, versus the FEIS base case under which the waste would be directly extracted using end effectors on the Z mast of a remotely-operated crane.

At this point of study, and with a lack of detailed cost information to differentiate the two options, the approaches are considered to be generally comparable. Distinct advantages and disadvantages do exist, however, as indicated in Exhibit IX-4. Both the FEIS base case and Option 1 involve remote operations to protect against worker exposure. Additional studies, including possibly pilot studies in a non-waste area of the site, would likely be required to determine both the relative applicability of the two methods and their respective costs.

Both approaches apply to the removal of individual Deep Holes, as each approach involves the extraction of waste using equipment with a limited lateral extension but capable of reaching depths exceeding 50 feet. Nevertheless, a more efficient multi-hole strategy could be adopted through the use of a single, larger MSEE across several holes and a potential revision to the sheet piling configuration for leachate control and hole stabilization. Under the FEIS base case, a single crane system capable of lateral movement similar to that proposed for the SDA trenches could be used to span multiple Deep Holes using a single crane/enclosure set up, although the removal itself would still be sequential from hole to hole. Any type of mass excavation of the Deep Holes is limited by the 55-foot depth of the holes, the difficulty in stabilizing such a deep and large excavation, and the large volume of soil that would have to be concomitantly removed and disposed along with the waste contained in the Deep Holes.

FEIS BASE CASE **REMOTELY-OPERATED CRANE WITH Z MAST ATTACHMENTS**	**OPTION 1** **WASTE GROUTING AND CORING**
Key Advantages	**Key Advantages**
• Highest level of worker protection; protects against "surprises" if waste inventories are not fully accurate • No depth restriction on operation of crane within confines of MSEEs	• Cement grout stabilizes waste and provides a level of shielding prior to bringing waste to the surface • Leachate will be captured within grout and may not require separate extraction and treatment
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**
• Questions remain as to the ability of end effectors attached to the arm of a crane to exhume closely-packed drums at depths of ~55 ft within a 3 ft x 7 ft hole	• Size of Deep Holes will require different over-casing and grouting techniques than used at Hanford; pilot study likely required • Volume of waste (including grout) will approximately double compared to FEIS base case.

Exhibit IX- 4: Comparison of Methods: Waste Exhumation – NDA Deep Holes

E. Waste Processing

The primary difference among the three waste processing options is the degree of consolidation of the operations. The FEIS base case represents a hybrid case between the full separation of waste processing by waste area (Option 1) and the full consolidation of waste processing operations across the site (Option 2). For reasons cited in Exhibit IX-5, all three waste processing options are judged to be of comparable cost due to the underlying need to implement the full suite of waste processing, classification, packaging, and handling processes regardless of the option. As such, there is no overriding reason to move away from the FEIS base case unless a selective exhumation scenario does not require the full suite of process technologies.

Option 1 could remain under consideration as part of the Phase 2 decision process, whereas Option 2 has a number of key drawbacks that would likely eliminate it from further consideration. Primary among these drawbacks is the fundamental difference in waste types and activities coming out of the HLW tanks versus those associated with the SDA and NDA. A site-wide centralized waste processing facility (Option 2) would also be complicated because it would combine radioactive materials that are under different regulatory frameworks.

FEIS BASE CASE **CENTRAL CONTAINER MANAGEMENT FACILITY**	**OPTION 1** **LOCALIZED WASTE MANAGEMENT**	**OPTION 2** **SITEWIDE WASTE MANAGEMENT FACILITY**
Key Advantages	**Key Advantages**	**Key Advantages**
• Individual processes designed specifically for WVDP wastes • All waste processing, packaging, handling, and interim storage activities under a common roof minimizes the risk of worker exposure and release. • Design to Performance Category 3 standards and robust radiation controls enhance level of protection	• Processes can be designed for only what is needed for a given waste area (however, such distinctions do not generally exist at the SDA and NDA, and all processes may have to be duplicated) • Demonstrated performance on precedent projects (although key differences exist relative to NDA and SDA site/waste conditions)	• Integration of WTF wastes into the central CMF would consolidate operations and could provide cost savings by eliminating process and operational redundancy
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• A key component – the rotary kiln dryer – is unproven in terms of its capacity and flexibility to process the potential range of waste forms • Requires conservative design at high cost to account for performance and waste uncertainties	• Potential cost savings, if any, would be minimal due to need to include same processes at each area • The key step of waste drying would still be required for the NDA and SDA wastes • Waste processing operations at the SDA and NDA would further crowd environmental enclosures	• Cost savings would be compromised due to key differences in WTF waste versus SDA and NDA waste (level of activity, wet vs. dry, etc.) • Need to transport waste from North Plateau to South Plateau (or vice versa) would increase risk of exposure and release. • Complications resulting from combining radioactive materials that are under different regulatory frameworks

Exhibit IX- 5: Comparison of Methods: Waste Processing

F. Interim Waste Storage

Only orphan waste with no currently available option for permanent off-site disposal is planned for interim storage at the CMF under the FEIS base case. This would include pre-project Class B and Class C low-level radioactive waste, GTCC waste, and TRU waste. The comparison of approaches summarized in Exhibit IX-6 is, therefore, limited to the interim storage of orphan waste.

Option 1 is closely comparable to the FEIS base case and provides no significant advantage in either applicability or cost other than possibly providing additional flexibility in design as the Phase 2 decision process progresses. Option 2 is quite different and would take advantage of the availability of an off-site facility (WCS) for the disposal of Class B and Class C waste that was licensed subsequent to the issuance of the FEIS. The use of the WCS facility by West Valley, as well as the capacity that would be made available, would require approval by the Texas Compact Commission. This introduces a continuing source of uncertainty as to whether off-site storage capacity would be available year-to-year unless an upfront commitment from the Commission could be secured (possibly at higher cost). On-site storage for TRU and GTCC waste would still be required at the CMF, albeit at a reduced scale.

FEIS BASE CASE INTERIM STORAGE WITHIN CONTAINER MANAGEMENT FACILITY	OPTION 1 STAND-ALONE INTERIM STORAGE FACILITY	OPTION 2 OFF-SITE STORAGE AND DISPOSAL
Key Advantages	**Key Advantages**	**Key Advantages**
• Integration of waste storage facility within the CMF reduces risk of exposure and release by minimizing waste movement • Waste storage occurs within facility constructed to Category 3 standards	• Additional flexibility in design when not attached to CMF could offset disadvantages of the FEIS base case. • Otherwise, generally similar to the FEIS base case	• Accommodates the direct shipment of waste upon processing/testing. • Would result in up to 50% decrease in the volume of waste requiring interim storage at the CMF (to ~8,000 CY of TRU and GTCC waste)
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• Storage duration is unknown and could be lengthy; entire CMF may have to be maintained due to stored waste. • Reduced flexibility if future Phase 2 decisions modify storage volumes or shielding requirements	• Costs could actually be higher than FEIS base case if same performance standards are required due to potentially higher O&M costs	• Because New York is not a member state of Compact, there would remain uncertainty on capacity to accept WVDP waste over time • TRU and GTCC wastes do not qualify under waste acceptance criteria; does not eliminate the need for on-site interim storage at West Valley.

Exhibit IX- 6: Comparison of Methods: Interim Storage of Orphan Waste

An assumption underlying the FEIS base case is that all LSA and Class A wastes, as well as mixed waste, which represent an estimated 99% of the wastes expected to be generated, would be shipped directly to off-site disposal facilities. As a result, no provision was made in the FEIS for interim storage of this waste, much of which would be impacted soil. The possibility exists, however, that the availability of off-site disposal capacity will not keep up with the rate of soil/waste production at West Valley. To address this possibility, the EXWG also evaluated a temporary on-site LLW storage facility for Class A, LSA, and mixed waste similar to what has been used at several other DOE sites. Interim storage facilities currently in use at DOE sites are relatively low-cost metal or sprung fabric structures with shielding only in special cases.

G. High-Level Waste Tanks

Full tank removal has no precedent at other sites, many of the individual technologies have not been applied under conditions similar to those at the WTF, and very limited cost information is available for comparative purposes. For these reasons, the comparison of options for the removal of the HLW tanks became an exception to the general approach used for other processes. In this case, five overall approaches to tank removal that are highly related to how worker protection would be achieved are first addressed. The summary-level comparison of key advantages and disadvantages/limitations of these five optional approaches is provided in Exhibit IX-7. A series of individual technologies for distinct aspects of removing either the tank contents or the tank shells are then evaluated using a narrative form to address their comparative advantages and disadvantages.

FEIS BASE CASE ROOF REMOVAL WITHIN WTF WASTE PROCESSING FACILITY	OPTION 1 REMOVAL OF WASTE "THROUGH THE RISERS"	OPTION 2 PARTIAL GROUTING OF BOTTOM OF TANKS
Key Advantages	**Key Advantages**	**Key Advantages**
• Allows for all operations to be conducted within a single enclosure • Allows for removal of the tank and shell roofs that provides for unencumbered access to the tanks and their contents	• Cover soil and roofs would remain in place to provide shielding • WTFWPF could be replaced by much lower cost metal building • Maintains integrity of tanks; suitable for selective removal of residual waste from tanks • Precedent applications at other sites	• Binds residual waste on tank bottom into grout prior to removal • Provides shielding from high activity waste on bottom of tanks • Provides low-cost option for worker protection and waste removal
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**	**Key Disadvantages/Limitations**
• High cost due to the size and robust design features of the WTFWPF • Destroys integrity of tanks by removing the roofs; would not be appropriate if only residual waste (sludge/zeolite) is to be removed.	• Technology development would be required and would be subject to many operational constraints • Technology limitations would likely prevent 100% waste removal • Would still require many of the high cost WTFWPF support facilities and processes	• Would not prevent exposure to residual activity on tank walls • High levels of exposure could still occur if grout separates from steel during removal • No proven application and likely not feasible for conditions of the HLW tanks at West Valley

OPTION 3 FULL GROUTING OF TANKS BEFORE REMOVAL	OPTION 4 FILL TANKS WITH WATER BEFORE REMOVAL
Key Advantages	**Key Advantages**
• Accommodates full removal of residual waste and tanks • Provides shielding of tank bottoms, walls, IX columns, etc. • Eliminates need for WTFWPF • After grouting, tanks could be left in place until decay reduces activity before removing tanks and contents	• Use on precedent projects demonstrates that water can control worker exposure rates • Eliminates need for WTFWPF
Key Disadvantages/Limitations	**Key Disadvantages/Limitations**
• Generates a large volume of waste, much of which would be of low activity • Potential exists for high levels of exposure along exposed edges when cutting into steel	• Approach not proven on structures as large as HLW tanks • Need to control high potential for leakage from tanks • Produces large volume of high activity water requiring treatment

Exhibit IX- 7: Comparison of Methods: HLW Tank Removal

Based on the information provided in Exhibit IX-7, it can be generally concluded that any of the options, when compared to the FEIS base case, represents a trade-off of costs versus some degree of performance uncertainty, exposure risk, and technical limitation. Except for the partial grouting option (Option 2), the other options have technical applicability as demonstrated on precedent projects and are worth further consideration in the Phase 2 decision process as a balance against the exceptionally high cost of the FEIS base case.

Beyond these general removal scenarios is the issue of what specific technologies may be applicable to complete the individual steps in the tank removal process and how they compare to each other. The following summaries of the Study 3 findings address this issue.

Removal of Tank Contents: Sludge/Zeolite

- Work on the development of systems that could be applicable for retrieval of the heels remaining in the HLW tanks has been underway at DOE sites, universities, and private companies. The FEIS did not specify which system would be used, only that such systems exist or were in the development stage, and that an appropriate system would be selected during the detailed design phase if tank removal is selected as the closure alternative.
- Available options have already been employed for the removal of tank wastes at ORNL, Hanford, and Fernald. Each of these options is potentially usable to remove the heels from the floors of Tanks 8D-1 and 8D-2, and the effectiveness and cost associated with each option are not expected to vary greatly from one option to another.
- Due to the unique characteristics of Tanks 8D-1 and 8D-2 (i.e., the gridwork on the floors, the fact that the heels have been dried), it is expected that some modification would be required to whichever technology is selected for sludge/zeolite removal. Should heel removal be selected as a partial removal scenario, then a detailed evaluation and comparison of the various options would have to be undertaken to determine the most effective option to be implemented.

Removal of STS Equipment:

- The options for removing the STS equipment from Tank 8D-1 were focused on the removal of the IX columns, as they contain by far the most Cs-137 activity and would be the most difficult STS component to remove. The evaluation of options is complicated by uncertainty regarding the condition of the zeolite within the IX columns, i.e., whether or not the zeolite has amalgamated into a solid mass. Before a final evaluation of the options to remove the STS equipment from Tank 8D-1 can be made, a sampling program would have to be undertaken to establish the status of the zeolite within the IX columns.
- The FEIS base case assumed that the zeolite in the four IX columns has not amalgamated and can be flushed out of the columns, processed to form solidified Class-C LLW, and shipped off site for disposal. Consequently, the FEIS base case would not be a reasonable option to remove the IX columns if it is found that the zeolite has amalgamated.
- The first option considered was to remove the zeolite-loaded IX columns intact by reversing their installation process. This would allow the columns to be taken to a separate on-site

waste processing facility where the zeolite could be broken up, removed, and solidified into smaller packages for disposal. However, the IX columns that were installed clean are now highly contaminated. Attempting to remove the intact IX columns would likely either result in excessive radiological worker exposures or require a shielded box that would be excessively heavy. Therefore, Option 1 is not considered to be a reasonable option.

- Options 2 and 3 were developed to address the case of the zeolite being amalgamated. Option 2 would involve breaking up the amalgamated zeolite within the IX columns by inserting some variation of a plumber's snake or concrete needle vibrator into the columns, whereas under Option 3 industrial vibrators would be positioned on the outside of each IX column to break up the zeolite. Once the zeolite has been broken down, it could be flushed out of the IX columns and processed in much the same fashion as described for the FEIS base case. Options 2 and 3 both appear to be feasible; however, a technology development and testing program would be needed to determine the effectiveness of each tool at breaking up the zeolite.
- Option 4, the use of a hydrolance to break up and flush the zeolite, is the most promising option for removing the zeolite from the Tank 8D-1 IX columns regardless of the zeolite condition. A hydrolance has been successfully used at SRS, so its effectiveness at breaking up amalgamated zeolite is known. The key uncertainty in this case is whether any off-the-shelf hydrolance is small enough to be inserted into the IX columns via the fresh zeolite inlet pipe, or whether an effective hydrolance could be designed to be inserted via this pipe.

Removal of Tank Shells:

- The FEIS assumed that an oxy-gasoline torch would be used to cut up the tanks, rather than the more widely used oxy-acetylene torch. Each has its advantages and disadvantages, and either method would be generally applicable for cutting up the tanks.
- The other tank-cutting methods that were considered by the EXWG included plasma arc (Option 1), nibblers and shears (Option 2), laser (Option 3), abrasive water jet (Option 4), mechanical saws (Option 5), and diamond wire (Option 6). Several published comparisons of these methods were cited in Section VIII.E.3.
- Based on the comparative information compiled, the EXWG concluded that there is no consensus as to a single preferred method for segmenting the Tank 8D-1 and Tank 8D-2 carbon steel shells. Rather, the method selected would likely be dependent on the overall approach for tank removal chosen. In particular, the following conclusions were reached:
  - If either the FEIS base case (Roof Removal within WTFWPF) or Option 1 (Existing Vault - "Through the Risers") is selected, then plasma arc would be a prime candidate, mainly due to its speed.
  - If Option 2 (Partial Layer of Grout) is selected, then plasma arc would be recommended for the non-grouted portions and diamond wire for the grouted portions.
  - If Option 3 (Full Layer of Grout) is selected, then diamond wire cutting would be recommended due to the depth of the cuts that would be required.

  - If Option 4 (Filled with Water) is selected, then it is likely that the abrasive water-jet technique would be recommended to better maintain water clarity or, if the geometry of the tanks allows, mechanical saws might be the preferred choice for waste reduction and still better water clarity.

Waste Processing:

The waste processing options considered for the WTF tank wastes differed more by where the waste processing would occur than by how the waste processing would be performed. As such, there was not a significant difference among the options and any preference would depend on the general method selected for tank removal. An exception to this evaluation of options is Option 4, which involved a laser-based system that could reduce the volume of contaminated steel requiring disposal by up to 90%. The system has been tested in a precedent application and found to be effective, but no instances were found of its application to a large-scale production such as that represented by the mass/volume of Tank 8D-1 and Tank 8D-2 steel. Because of its effectiveness and waste reduction potential, consideration should be given to using a similar laser-based system at the WVDP, perhaps as a demonstration project.

X. EXWG Phase 1 Studies: Summary and Conclusions

Throughout the EXWG's work, the Agencies have maintained a focus on how any proposed work or study findings contribute to the resolution of seven topical questions in order to facilitate interagency consensus related to exhumation alternatives. In this section, responses are provided to each of the seven questions based on the consolidated work of the EXWG. The responses to some questions are further developed in previous sections of this report or in task-specific reports previously prepared by the EXWG, as cited in the responses below. The "at what cost" add-on to several questions was addressed in previous sections to the extent that relevant cost information was available in publicly-available documents.

A. Question 1: Selective Removal Alternatives

Question: Can the long-lived inventory in the SDA, NDA, and WTF be somehow selectively removed to reduce the time that these facilities will pose a hazard? If so, at what cost?

Response: Based on the analyses performed for the SDA and NDA under Task 1.3, selective removal of long-lived radionuclides is a viable option that warrants consideration in the Supplemental EIS. Various selective removal scenarios for the SDA and NDA were evaluated under Task 1.3, with related aspects addressed under other tasks. The results indicate that high percentages of the activity associated with certain targeted radionuclides can be removed through the exhumation of comparatively small volumes of the buried waste due to differences in waste disposal patterns. The specific categories of selective exhumation scenarios for the SDA and NDA selected for purposes of this report are discussed in Section II.

Important related questions that have also been addressed by the EXWG include:

1. Are the published waste inventories reliable enough to confidently decide on selective exhumation scenarios? Results of a geophysics prove-out study indicate that this is the case for the SDA to the extent that the expected waste forms correlated well with the geophysics study results. The SDA inventory carried the highest level of uncertainty due to the reliance on shipping records of unknown completeness and accuracy.
2. What selective exhumation scenarios provide the optimum cost-benefit value for a given exhumation objective? A range of beneficial scenarios was identified and documented in the Task 1.3 Technical Memorandum for the SDA and NDA. Differences in the scenarios depend on the objective being sought (e.g., maximizing the overall reduction in total activity) versus targeting the removal of a particular radionuclide or group of radionuclides.
3. How might the various selective exhumation scenarios differ in both the risk to workers during implementation and the reduction in long-term risk following implementation? This question was also addressed in the Task 1.3 Technical Memorandum, which showed significant differences in potential dose to workers depending on the selective exhumation scenario selected. These differences could be instrumental in the final selection of the most

cost-effective method for waste removal, processing, and management, as addressed in Sections III-VIII of this report and summarized in Section IX.

For the WTF, much of the activity is contained within the sludge at the bottom of the tanks, the IX columns in Tank 8D-1, or the “bathtub ring” on the sidewall of Tank 8D-2. Therefore, the location of each of these potentially removable items is already well known, and it would not be of value to target specific radionuclides or to determine what percentage of a particular radionuclide would be selectively removed under various scenarios similar to what is being proposed for the SDA and NDA. Rather, as addressed in Section VIII and in the Response to Question 3 below, the partial removal scenarios for the tanks include residual waste removal only, and residual waste and task shell removal while leaving the tank vaults in place.

B. Question 2: Mining of Waste from Surrounding Soil

Question: If the long-lived inventory cannot be selectively removed from the disposal areas, can the waste be "mined" out of the SDA and NDA while leaving a majority of the surrounding soil in place? If so, at what cost?

Response: The direct answer to this question is that it is not practical to mine waste and leave the comparatively narrow soil zone that separates waste trenches in place. The deeper soil zone along the sides of the trenches is in contact with saturated waste and is, therefore, expected to be radiologically impacted. The shallower soil will likely require removal in order to access the deeper soil or to lay back the waste excavations for slope stability. It can be assumed, therefore, that the soil zone between trenches will be removed along with the waste. The methods for waste exhumation from the SDA and NDA trenches addressed in Section V of this report included the removal of adjacent and underlying impacted soil.

This would not be the case, however, for the NDA Deep Holes and certain NDA Special Holes that are not in close proximity to each other. The approaches developed for these cases target only waste removal with a localized extension into the adjacent soil zone to address any impacted soil. The FEIS base case did include a mass excavation of soil following removal of the NDA Deep Holes and Special Holes, but this is likely not required under any alternative other than the Sitewide Removal Alternative for which unrestricted use standards are to be met.

A variation of this question raised by NYSERDA is whether the soil volumes subject to removal at the SDA, as reported in the FEIS, are reasonable. An EXWG evaluation showed that the assumed lateral and vertical extent of impacted soil was not unreasonably conservative, and that what appears to be an exceptionally high soil volume in the FEIS can be explained by factors other than the assumed extent of soil impacts. The basis of these conclusions is explained in a memo prepared by the EXWG, dated December 3, 2016 (ECS, 2016c).

C. Question 3: Selective Tank Removal

Question: If the long-lived inventory cannot be selectively removed from the tanks, could portions of the tanks be removed while leaving surrounding tank material, or just the vaults, in place? If so, at what cost?

Response: Removal of only the tank contents is a credible approach worthy of consideration to target long-term risk reduction, but complete content removal is likely not achievable without removal of at least the tank shells due to technology limitations, as discussed in Section VIII. Precedent projects at other sites have targeted only content removal of tanks; however, those projects with the highest degree of similarity to the West Valley tanks have not achieved complete removal. Removal of the tank shells separate from the vaults is viable and worth consideration to achieve full removal of both the tank contents and the tank shells. Any project that involves the removal of the tank shells and vaults, including the use of those methods identified in Section VIII, would be unprecedented at the scale of the West Valley tanks.

D. Question 4: Protective Enclosures

Question: Are the robust facilities shown in the FEIS for conducting tank and disposal area removals necessary, or can removals be done using less robust, yet still protective methods, at lower cost?

Response: Required enclosures are highly dependent on a number of factors that will vary with the removal scenario, including the waste type and container, the size of the excavation zone, and the timing of the project as a result of radioactive decay of the short-lived radionuclides. The protective enclosures documented for the Sitewide Removal Alternative in the FEIS represent the most robust and costly of the available options. Less robust options have been successfully employed on several precedent projects at other sites, and should be considered for the SDA and NDA, particularly under selective removal scenarios. General categories of lower-priced options were evaluated by the EXWG under Task 2.4, as documented in Section IV of this report.

E. Question 5: Impacts of Radioactive Decay

Question: Would answers to any of the above questions change if we waited for 30, 60, 90, or 120 years before undertaking the action? For example, could the action go from a remote action to a contact-handled action?

Response: Radioactive decay of the waste inventory over the time periods of interest was evaluated under Task 1.2, with the potential effects on dose under various removal scenarios evaluated as part of Task 1.3. As would be expected, the decay of the short-lived radionuclides in the SDA and NDA would eventually result in dose rates to workers below 2.5 mrem/hr and allow for contact handling of waste well before the 120-year timeframe. An exception is the NDA Deep Holes, which would likely require remote operations for waste removal even beyond the 120-year timeframe.

Recognizing that the impacts of radiological decay represent a continuum in terms of when waste exhumation may actually occur, no specific time period was assumed for purposes of this report. Nevertheless, as illustrated in the Section IX summary charts, there are a number of optional methods that would provide a lower-cost option than the FEIS base case under low activity conditions. As such, it can be concluded that waiting for the decay of the short-lived radionuclides would significantly lower the cost of waste removal for the SDA and portions of the NDA.

The benefit to be gained by delaying waste exhumation depends on the threshold dose rate set for contact-handled (vs. remote or shielded) operation. The FEIS used a dose rate of 50 mrem/hr as the value above which remote/shielded operations would be required, whereas the EXWG used a value of 2.5 mrem/hr as the threshold value for evaluating enclosure and shielding requirements. Reasons for this difference are explained in Section IV.A, where an example is also provided that shows that delaying waste exhumation of the SDA trenches would have little benefit under the 50 mrem/hr threshold, but the percentage of trench segments achieving the 2.5 mrem/hr threshold would increase significantly by waiting for 60 years or more.

For the WTF, the Task 1.2 report showed that about 500 years would be necessary to allow for “hands on” work to proceed. Therefore, for purposes of this study, only remote operations were considered to be applicable for the WTF. Several different methods to provide for worker protection are available, and in fact become instrumental in the overall approach to be used for tank removal. These methods were addressed in Section VIII.

F. Question 6: Reduction in Uncertainty

Question: With respect to each of these questions, what are the uncertainties associated with estimations of changes in source term and cost given currently available information? Would additional studies likely better quantify and/or reduce these uncertainties? If so, what are these additional studies?

Response: Given that a focus of the Phase I Studies was selective removal as a new alternative that had not been previously addressed in the FEIS, the critical uncertainty was determined to be the reliability of the published waste inventories. In short, how much confidence should one have in the inventories when prioritizing selective removal alternatives and their expected benefits that depend on the waste being where it is reported to be? As indicated in Section I.B.2, initial plans to statistically analyze inventory reliability based on new field studies proved to be impracticable. However, the results of a follow-on geophysics prove-out study provided evidence of a qualitative agreement between the geophysical results and the waste forms reported in the inventories in several of the most important trench segments, thus increasing the level of confidence without providing quantification of the uncertainty or confidence level.

As related to the various methods analyzed in Sections III-VIII, it was found that many of the methods either have no precedent application or were not applied to conditions comparable to those at West Valley. While there remains a level of uncertainty as to the applicability and future performance of the methods under the specific conditions at West Valley, the applicability of the methods is considered to be sufficiently supported by the information from precedent projects contained in this report to retain any recommended methods in the Phase 2 decision process. Nevertheless, the lack of directly relevant precedent application and the corresponding performance uncertainty would likely require additional studies of some methods prior to full-scale application.

G. Question 7: Pilot Studies

Question: Are there exhumation uncertainties or data needs that can be addressed only through a pilot exhumation? Would such a pilot exhumation action be feasible and reasonable considering health and safety, worker exposure, waste generation, and cost? Given these considerations, what would be the costs/benefits of a pilot exhumation?

Response: There remains a level of uncertainty regarding inventory reliability that most likely can only be addressed through a pilot exhumation. The cost/benefit aspect of a pilot-scale exhumation may not, however, justify such a study when compared to a continued reliance on the published inventories (as somewhat verified by the geophysics study). A pilot study would necessarily require construction of all process elements required for the prototype work, and therefore the cost and required time for such a study will be exceptionally high both in total and per unit volume of waste/activity removed. This was the case for a similar pilot study previously conducted at INL, the cost of which was $67.5 million. It must also be recognized that the non-homogeneous nature of both the SDA and NDA disposal units would also limit the value of any pilot study. For example, a technique shown to be effective at removing 55-gallon drums of low activity waste in one trench segment may not be applicable 10 or 20 feet down the trench where the need is to exhume a large concrete cask of high dose rate waste.

The pilot study concept would make practical sense if the pilot study takes the form of a selective removal as the first phase of a larger exhumation program. In this case, a commitment would already have been made for the prototype project, and the pilot study would be used more to reduce uncertainty in the selected exhumation approach than to reduce uncertainty as part of the Phase 2 decision-making process. Another option would be to perform pilot studies for the purpose of evaluating the applicability of individual technologies once the technologies are preliminarily selected as part of a broader alternative in the FEIS. These studies could be performed in clean areas of the site rather than in waste units in order to negate the need for high-cost support operations such as leachate treatment, protective enclosures, and waste processing facilities.

The 1986 exhumation of NDA Special Holes SH-10 and SH-11 could be considered as a pilot study for waste exhumation at the NDA, and to some degree for the SDA given the fact that the Special Holes are in essence small trenches. The tanks leaking kerosene were successfully removed and the project was eventually completed despite a level of uncertainty regarding the nature and condition of the tanks and other waste materials disposed in the holes. The mechanical equipment for waste exhumation, tank cutting, and waste/leachate transfer reportedly performed as expected. A number of lessons learned were identified in the completion report for the kerosene removal project (Blickwedehl et al, 1987). Several of the lessons learned dealt with the protective enclosures and the unexpected high level of groundwater management needed. The latter issue may not be applicable to future actions given that the 1986 removal pre-dated the impermeable covers over the NDA and SDA, and infiltration rates were exacerbated by poor soil cover conditions that channeled surface water vertically through fissures directly into the Special Holes being excavated.

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