Defense Waste Salt Repository Study

Fuel Cycle Research & Development

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Used Fuel Disposition
Joe T. Carter, Philip O. Rodwell, SRNL
Bruce Robinson, LANL
Bob Kehrman, Washington TRU Solutions
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SUMMARY

In support of the Department of Energy's (DOE) Management and Disposition Task Force, Savannah River National Laboratory (SRNL) was requested to update the study SRNL-RP-2011-00149, Rev 0, *A Generic Salt Repository for Disposal of Waste from a Spent Nuclear Fuel Recycle Facility* [Carter 2011[41]] to a Defense Waste Repository (DWR) study evaluating disposal of DOE high-level waste and DOE and Naval spent nuclear fuel for disposal in a bedded salt geologic setting.

The scope of work [Buschman 2012[40]] required an executive summary-type report containing the essential findings and was met by Reference 42. A final report was required by May 15, 2012, which expands upon the bases for the findings, and is met by this document.

Defense Waste Repository Study Scope

The scope of work provided by DOE required that five cases be evaluated as combinations of the disposal inventory and facility location.

Table ES-1 provides the five case numbers resulting from the combinations of the inventory and location cases. The all-defense HLW case is evaluated at two locations to evaluate the difference with respect to location for a common inventory while the other three inventory cases are evaluated at a single location.

Table ES-1 Defense Waste Repository Case Matrix

Case Number	SRS HLW	All Defense HLW	All HLW + DOE Spent Fuel	All HLW + DOE and Navy Spent Fuel
WIPP Extension	1	2		
Generic Location		3	4	5

Defense Waste Repository Waste Inventory

Repository waste emplacement footprint is governed by two principle factors, mine or excavation stability considerations for minimum drift spacing and the decay heat areal density limit. The inventory for each case as a function of waste package decay heat is provided in Table ES-2. The total emplaced decay heat for the total inventory (Case 5) is about 3.6 million watts or about half of the value previously expected. The lower than anticipated decay heat reduces the emplacement footprint underground.

Table ES-2 Defense Waste Repository Waste Canisters Decay Heat Distribution

Decay heat per canister (watts)	**Savannah River Canisters Case 1** Number of canisters	**All DOE HLW Canisters Cases 2 and 3** Number of canisters	**All DOE HLW Canisters and DOE SNF Case 4** Number of canisters	**All Naval Fuel, DOE HLW Canisters and DOE SNF Case 5** Number of canisters
<50	2948	16630	17858	17858
50-100	459	1696	2261	2261
100-220	3891	4414	5203	5203
220-300	0	28	661	661
300-500	264	264	505	505
500-1000	0	0	55	55
1000-1500	0	0	10	10
1500 - 2000	0	0	1	1
>2000	0	0	20	420
Total	**7,562**	**23,032**	**26,574**	**26,974**
Total Decay Heat (watts)	**805,500**	**1,203,100**	**1,901,900**	**3,601,900**

Underground Waste Emplacement Strategy

Evaluation of the defense waste inventory reveals the vast majority of the packages are less than 100 watts each. This allows a much more efficient underground emplacement approach. The team developed an in-room disposal approach, with variable spacing, to accommodate varying waste packages decay heat loads. The minimum spacing selected is 1 foot between canisters (3 feet centerline spacing) to allow for a run-of-mine salt backfill and to ensure packages are not displaced from their intended location as additional waste packages are emplaced. Since canisters are 18”- 24” in diameter, except for the Naval fuel packages, and mine stability requires a minimum pillar thickness of 100 feet, each waste package is allowed to contain as much as 330 watts, based on the spacing and layout described in this study, and assuming the decay heat limit, for disposal in bedded salt, is 10 watts/m^2 (or 0.93 watts/ft^2). The 10 watts/m^2 limit is considered reasonable given that WIPP conducted heater tests during the 1980’s at 18 watts/m^2.

Defense Waste Repository Underground Configuration

The study team developed a repository panel layout consisting of 10 disposal rooms in each panel. The rooms are 10 ft. high by 20 ft. wide, and will allow waste emplacement for 500 linear feet each plus an allowance for run-of-mine backfill for shielding at both ends. The panel layout is shown in Figure 4-3 and Table ES-3 estimates the number of rooms and panels required for waste emplacement using the variable spacing for differing waste package decay heat. Table ES-3 also provides the waste emplacement rate and underground emplacement area (rooms and panels) used in this study, assuming a 40 year mission life as specified in the study scope of work.

Table ES-3 Waste Emplacement Rooms and Panel Requirements

Waste Package Spacing (Ft)	SRS HLW Case 1	HLW Waste Packages Cases 2, 3	HLW and SNF Case 4	HLW & SNF & Naval SNF Case 5
3	44	137	156	156
5	3	3	6	6
10	0	0	2	2
15	0	0	1	1
20	0	0	1	1
36	0	0	2	31
Total Rooms	**47**	**140**	**168**	**197**
Total Panels	**5**	**14**	**17**	**20**
Waste Emplacement Rate Packages /yr	189	576	664	674
Waste Emplacement Rates Rounded	200	675	675	675
Rooms per year	1.2	3.5	4.2	4.9
Panels/yr	0.12	0.35	0.42	0.49

Underground and Surface Facilities

Figures 4-4 and 4-5 provides the underground layout for Cases 1 and 2 for the proposed WIPP extension. The configuration is mandated by two key considerations: 1) working around the existing WIPP Defense TRU waste emplacement areas and 2) maintaining a one mile buffer to the WIPP land withdrawal act sixteen square mile perimeter.

The existing mine support infrastructure at WIPP is not adequate to support the additional mains and waste emplacement areas. The existing salt shaft is fully utilized by the defense TRU waste mission and the air intake and exhaust shafts are not adequate to provide the required ventilation for these new drift areas. Therefore, both Case 1 and 2 include three new shafts for salt removal, air intake and air exhaust.

Figure 4-6 provides the underground layout for Cases 3, 4 and 5. This generic location layout is more efficient since the 14, 17 or 20 panels required for Cases 3, 4, and 5 respectively can be placed along a linear set of mains. These cases require five access shafts for salt removal, air intake, air exhaust and two waste shafts.

The primary surface facility additions for Case 1 involves addition of a surface lag storage pad for 180 days of processing throughput, per the scope[40], which is estimated at approximately 100 loaded inbound transportation casks and impact limiters and approximately 50 unloaded outbound casks and their impact limiters.

Case 2 processes a much larger inventory of defense waste, involving waste packages of different sizes and weight. The Hanford canisters, which comprise almost 50% of the inventory for Cases 2 to 5, are planned to be 15 ft long. Two factors combine to require new remote handled waste facilities at WIPP for Case 2: 1) the increase in defense waste packages from ~200 per year to ~600 per year and 2) the current WIPP remote handled waste facility will not accommodate the longer Hanford waste package. Case 2 also requires a new waste shaft to support the increased annual waste emplacement rates.

Cases 3 to 5 are located at a generic location and require the full complement of waste receipt, lag storage, waste package handling, and waste package unloading infrastructure for transfer for subsurface emplacement.

Estimated Cost

Table ES-4 provides a summary of the design, construction start-up, operations, closure and monitoring cost (DCSOCMC) range for each of the five cases. These results indicate the cost of disposing of HLW ranges from $13.1 B to $17.9 B in 2012 dollars. This range is established by taking the low from Case 3 (HLW disposed in a generic location) and the high from Case 2 (HLW disposed in a WIPP extension). Although Case 2 is slightly higher than Case 3, the low-high range essentially overlaps indicating there is little cost difference between the two cases. This similarity is driven by the need for new surface facilities to accommodate the larger than WIPP design basis canisters and additional mains to "bypass" the current TRU emplacement area.

The incremental cost of adding the DOE SNF (3,542) canisters to a generic location repository is approximately $120 to $160 million or $34 K to $45 K per canister.

The incremental cost of adding the Naval Fuel (400) canisters to a generic location repository is approximately $1.9 to $2.8 million each. This large difference between the DOE SNF and the Naval SNF is due to the additional repository emplacement area and the additional surface infrastructure requirements. Due to its large size and weight the study team recommends alternative approaches be considered for the Naval Fuel, such as repackaging it into smaller, lighter emplacement canisters. This will allow use of mine hoist and handling equipment which is more standard in the industry.

A "pilot" Defense Waste Repository, which disposes of only the SRS canisters (Case 1), ranges from $8.6 to $11.6B or $1.1 to $1.5M for each canister. The economy of scale can be observed by comparing Cases 1 and Case2 (or 3) in which the cost per canister decreases by about half.

Table ES-4 also provides the DCSOCMC in escalated dollars. A centroid of expenditure methodology was utilized to develop escalated cost estimate ranges.

Table ES-4 Design, Construction, Start-up, Operations, Closure and Monitoring Cost Summary

($millions)	**Case 1**		**Case 2**		**Case 3**	
	Low Range	High Range	Low Range	High Range	Low Range	High Range
DCSOCMC	$ 8,550	$ 11,610	$ 13,230	$ 17,930	$ 13,080	$ 17,500
DCSOCMC (including Escalation)	$ 23,860	$ 40,840	$ 36,940	$ 63,050	$ 36,500	$ 61,540
	Case 4		**Case 5**			
DCSOCMC	$ 13,200	$ 17,660	$ 13,990	$ 18,790		
DCSOCMC (including Escalation)	$ 36,830	$ 62,110	$ 39,060	$ 66,070		

Conclusions and Recommendations

Based on the analysis provided in this scoping study, disposal of defense waste in a salt repository is feasible within a reasonable schedule and cost. The time to design, construct and start-up a salt repository is estimated to be 15 – 25 years after site selection. Some schedule savings are possible for the WIPP extension cases, but this was not investigated during the study due to the time limitations imposed.

The most significant assumption in the approach used to develop the disposal concept is that the waste canisters can be directly emplaced on the disposal room floor and covered with run-of-mine salt immediately. Additional engineered barriers will not be required.

The large Naval Fuel canisters are essentially incompatible with a shaft-hoist repository horizon access system. The hoist required exceeds industry standards and is not likely commercially available. The study team recommends alternatives be considered for this material including repackaging into packages compatible with the shaft-hoist access systems.

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ACRONYMS

ALARA	As Low As Reasonably Achievable
Am	Americium
ASF	Analytical Support Facility
BOP	balance of plant
BSG	borosilicate glass
C-14	Carbon 14
CAA	Clean Air Act
CAM	Continuous Air Monitor
CCC	Cask Crane Crawler
CCF	Central Control Facility
CCR	Central Control Room
CEAB	Central Engineering and Administration Building
CEMS	Central Equipment Maintenance Shop
CFR	Code of Federal Regulations
CFTC	Consolidated Fuel Treatment Center
CH	contact-handled
Cm	Curium
Cs	Cesium
CSS	Central Security Station
DCSOCMC	Design, construction, start-up, operations, closure, and monitoring cost
DHLW	Defense High Level Waste
DOE	Department of Energy
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
DWR	Defense Waste Repository
DWDU	Defense Waste Disposal Unit
EFFB	Exhaust Fan and Filter Building
EIS	Environmental Impact Statement
EOC	Emergency Operations Center
EMP	Environmental Monitoring Plan

EnPA	Energy Policy Act of 1992
EPA	Environmental Protection Agency
ERMB	Emergency Response and Medical Building
FEP	Features Events and Processes
FOEAS	Follow-on Engineering Alternative Study
F&OR	Functional and Operational Requirements
FR	Federal Register
FSC	Facility Shuttle Carrier
GMS	Geomechanical Monitoring System
GNEP	Global Nuclear Energy Partnership
GTCC	greater than class C
GRS	Gesellschaft für Anlagen und Reaktorsicherheit
H-3	Tritium
HEPA	High Efficiency Particulate Air
HIC	High Integrity Container
HIP	Hot Isostatic Press
HVAC	Heating Ventilation Air Conditioning
I-129	Iodine 129
Kr-85	Krypton 85
kW	kiloWatt
LA	License Application
LCC	Life Cycle Cost
LDR	Land Disposal Restrictions
LLW	Low Level Waste
LSPA	Lag Storage Pad Area
LWR	Light Water Reactor
MCL	Maximum Contaminant Levels
MGR	Monitored Geologic Repository
mrem	millirem
MSHA	Mine Safety and Health Administration
MT	Metric Ton
MTG	Metric Tons of Glass

MTHM	Metric Tons Heavy Metal
NEA	Nuclear Energy Agency
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982
OSHA	Occupational Safety and Health Administration
PA	Performance Assessment
PAS	Public Address system
PAU	Parking Area Unit
PC	performance confirmation
PCP	Performance Confirmation Program
PIC	passive intuitional controls
Pu	Plutonium
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RH	remote-handled
RMEI	reasonably maximally exposed individual
SNF	Spent Nuclear Fuel
Sr	Strontium
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
SWB	Standard Waste Box
TBD	To Be Determined
TDS	Total Dissolved Solids
TPD&CC	Total Project Design and Construction Cost
TRU	Transuranic
TSLCC	Total System Life Cycle Cost
TWP	Technical Work Plan
U	Uranium
U.S.	United States of America
UPS	Uninterruptible Power Supply

vol	volume
WHB	Waste Handling Building
WHEMF	Waste Handling Equipment Maintenance Facility
WIPP	Waste Isolation Pilot Plant
WRSF	Waste Receipt Support Facility
WRTF	Waste Receipt and Transfer Facility
WTP	Waste Treatment Plant
yr	year

DEFENSE WASTE SALT REPOSITORY STUDY

1. INTRODUCTION

In support of the Department of Energy's (DOE) Management and Disposition Task Force, Savannah River National Laboratory (SRNL) was requested to update the study SRNL-RP-2011-00149, Rev. 0, A Generic Salt Repository for Disposal of Waste from a Spent Nuclear Fuel Recycle Facility [Carter 2011[41]] to a Defense Waste Repository (DWR) study evaluating disposal of DOE high-level waste and DOE and Naval spent nuclear fuel for disposal in a bedded salt geologic setting.

The scope of work [Buschman 2012[40]] required an executive summary-type report containing the essential findings and was met by Reference 42. A final report was required by May 15, 2012, which expands upon the bases for the findings, and is met by this report.

This study considered the body of knowledge from domestic and international HLW repository research programs, and the experience gained from operating the DOE Waste Isolation Pilot Plant (WIPP) facility, for the disposal of transuranic (TRU) waste.. The concept of HLW glass disposal in geologic salt formations has been studied for many years (see Sections 1.2 and 1.3 below.) For example, the physical behavior of HLW glass at various temperatures and pressures have been thoroughly studied, and this study remains within those well-known parameters. Similarly the physical behavior of geologic salt formations at various temperatures and pressures has been studied for decades. Thermal modeling of the emplacement of this HLW in salt is a key parameter establishing the repository basis in this study, and an area where much more detailed analysis will be required if this concept is pursued.

This study is based on existing mining and waste handling technology. Most proposed equipment concepts have a history of proven reliability and therefore provide a good basis for these cost and schedule estimates. For example, the salt mining and waste handling equipment used in this study is the same or generally comparable to that already being used at the WIPP. Therefore, uncertainties in equipment requirements and mining technology are relatively low. This reliance on industrial equipment, which has a known performance history, greatly reduces the risk of cost increases and delays from the equipment perspective, which has been a problem with some DOE projects in the past (Reference GAO-07-336, March 2007).

Included in this report are the following:

- Scope and mission (see Sections 2 and 3)
- Physical description of a generic salt repository (see Section 4 for the waste disposal strategy and Section 5 for surface and underground support facilities
- Regulatory and licensing (see Section 6)
- Pre-conceptual cost and schedule ranges for design, construction, start-up, operation, closure and post closure monitoring (see Section 7)
- Conclusions and Recommendations (see Section 8)

1.1 Background

In the United States (U.S.), policy for disposal of SNF and high-level waste (HLW) is derived from the Nuclear Waste Policy Act (NWPA), as amended[3.] Currently, SNF is not reprocessed in the U.S., and most of the HLW inventory comes from past processing of defense-related materials.

The DOE has not made any decision regarding the disposition of defense HLW and SNF and is presently studying options. This study provides additional information for use in decision making and therefore includes several concept cases developed as a part of the information gathering process.

If the need for a defense waste repository is established and authorized, salt formations, including bedded salt and domes, could provide a good location for the repository. This study benefits from previous domestic and foreign salt repository programs and the ongoing experience with disposal of transuranic defense waste at the WIPP.

1.2 Waste Disposal in Salt - History in the United States

The disposal of high level nuclear waste in salt formations has been considered as a viable option for many years. In 1957, the National Academy of Sciences recognized the feasibility of disposing high level nuclear waste in salt and stated that[4]:

> *"The most promising method of disposal of high level waste at the present time seems to be in salt deposits. The great advantage here is that no water can pass through the salt. Fractures are self-sealing…"*

Salt can be mined easily, salt deformation is governed by plasticity and minimal fracture, salt is essentially impermeable, salt formations are plentiful in the contiguous 48 states and salt has a relatively high thermal conductivity.

Full-scale thermomechanical underground tests in salt formations have been conducted for repository purposes twice in the US: once near Lyons Kansas for Project Salt Vault and once during the characterization studies for WIPP. In addition a limited heater test was conducted in domal salt at Avery Island Louisiana[3]. In 1979, Congress authorized the development and construction of WIPP ''for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States.''[6]. Currently, the waste which may be emplaced in the WIPP is limited to transuranic (TRU) radioactive waste generated by defense activities associated with nuclear weapons: no high-level waste or spent nuclear fuel may be disposed of at the WIPP. TRU waste is defined as materials containing alpha-emitting radioisotopes, with half-lives greater than twenty years and atomic numbers above 92, in concentrations greater than 100 nanocuries per gram of waste.[7]

In regard to WIPP, the National Academy of Sciences concluded[8] that:

- Provided it is sealed effectively and remains undisturbed by human activity, the committee finds that the WIPP repository has the ability to isolate TRU waste for more than 10,000 years. The geologic stability and isolation capability of the Salado Formation, which consists of bedded salt, are the primary factors leading to this finding.

- The only known possibilities of serious release of radionuclides appear to be from poor seals or some form of future human activity that results in intrusion into the repository. The committee anticipates that the consequences of such human intrusion can be reduced based on available engineering design options and on improved understanding to be obtained from ongoing scientific studies.
- Environmental Protection Agency's (EPA's) standards (i.e., Code of Federal Regulation (CFR) Title 40 Part 191) relating to human intrusion do not take into account that, if radionuclide releases to the environment via groundwater pathways at WIPP occur, they will be predominantly in non-potable water. This greatly reduces the risk of human exposure compared to a similar release in potable water.

Although these conclusions were drawn for a repository that disposes transuranic waste, it is likely that the same conclusions would apply to a suitable salt repository for the disposal of other DOE defense wastes.

Consistent with the NWPA, an extensive survey and evaluation of possible sites that could potentially be considered for a HLW and SNF disposal repository in salt was completed by the DOE before the re-direction of site characterization activities to the Yucca Mountain site in 1987. The US expended considerable effort in the salt repository program, which is summarized below.

This scoping study for a defense waste salt repository assumes the repository will be situated in a salt formation in the contiguous 48 states. Four major regions of the United States where salt formations are found include: 1) the Gulf Coast; 2) the Permian Basin; 3) the Michigan-Appalachian Region; and 4) the Williston Basin. Domal salts are found in the Gulf Coast region, and bedded salts are present in the remaining three major salt regions of North America.

Screening of the entire United States in the 1960s and 1970s resulted in the identification of large regions that are underlain by rock salt of sufficient depth and thickness to accommodate a repository. The findings of previous siting studies identified three acceptable areas.

<u>Salt domes in the Gulf Coast</u>. The screening factors were the depth to the top of the dome and present use for gas storage or hydrocarbon production. Siting guidelines and evaluation reduced over 500 salt domes to seven potential repository locations. Applying criteria associated with the area needed for a repository resulted in the identification of the Cypress Creek, Richton, and Vacherie Domes as potentially acceptable sites.

<u>Bedded salt in Utah</u>. The primary screening factors used to identify potentially favorable locations were the depth to the salt, the thickness of the salt, proximity to faults and boreholes, and proximity to the boundaries of dedicated lands. The thickness of the salt, the thickness of the shale above and below the depth of a repository, and the minimum distance to salt-dissolution features were considered the most critical geologic discriminators. Davis Canyon and Lavender Canyon were identified as potentially acceptable sites.

<u>Bedded salt in west Texas and southeastern New Mexico</u>. The Permian bedded-salt deposits in Texas Panhandle and western Oklahoma had been identified as suitable for waste disposal. Screening focused on five subbasins: the Anadarko, Palo Duro, Dalhart, Midland, and Delaware Basins. The primary screening factors were the depth to, and the thickness of, the salt; faults; seismic activity; salt dissolution; boreholes; underground mines; proximity to aquifers; mineral

resources; and conflicting land uses, such as historical sites and state or national parks. All the subbasins contain salt beds of adequate thickness and depth. Because the Palo Duro and the Dalhart Basins had far less potential for oil and gas production and had not been penetrated as extensively by drilling, they were recommended for further studies.

More-detailed geologic and environmental studies of the Palo Duro and the Dalhart Basins began in 1977, and screening criteria were developed to define locations with favorable characteristics. Six locations in parts of Deaf Smith, Swisher, Oldham, Briscoe, Armstrong, Randall, and Potter Counties, Texas, met the screening criteria. A second set of criteria was then applied to further differentiate among the six locations: distance from the margins of the Southern High Plains, distance from known oil and gas fields, more than one potential repository horizon, depth of salt, number of boreholes that penetrate the repository horizon, large geographic area, low population densities, and potential land-use conflicts. After applying these criteria, the DOE decided to focus on the two locations that had the greatest likelihood of containing a suitable site, one in northeastern Deaf Smith and southeastern Oldham Counties and one in north-central Swisher County.

In 1985, the Secretary of Energy nominated 5 sites for further consideration, including the Deaf Smith County, Davis Canyon, and Richton Dome sites. The President ultimately selected the Deaf Smith County site as one of the three to fully characterize prior to the passing of the 1987 amendment to the Nuclear Waste Policy act which selected the Yucca Mountain site for full characterization. The defense waste repository study accepts the results of these previous siting investigations. For purposes of this study, the defense waste repository is assumed to be located in bedded salt, which is consistent with the findings above. Other information deriving from the previous site investigations, characterization, design and analysis, will be referenced in this scoping study.

1.3 Waste Disposal in Salt - History in Other Countries

Germany has taken a leading role in underground waste disposal in rock salt formations. In 1972, Germany converted a potash mine “Herfe-Neurode” into Germany’s first underground repository, and since then four more salt waste repositories have been licensed for a spectrum of toxic waste. These wastes are expected to be isolated at least 20 million years[33].

Germany has also focused considerable attention on disposal of radioactive waste in salt formations. Since 1967 a former salt mine (Asse) in north-central Germany fulfilled the technical criteria of a radioactive waste repository. Salt mining since the early 20th century created huge underground chambers, some of which were filled with low- and intermediate-level radioactive waste between 1967 and 1978. In total, the repository contains about 125,000 drums of low-level waste 725 m to 750 m below the surface and about 1,300 drums of intermediate-level waste 511 m below the surface[34]. The gross container volume is about 47,000 m^3, with a mass of about 90,000 MT. The total activity of the inventory at the time of disposal was about 7.8E15 Bq. The German authorities are in the process of closing the Asse mine.

The Asse mine was used as a research facility for a number of years. An experiment analogous to the generic salt disposal scheme was conducted in the Asse mine. This experiment was called TSDE (Thermal Simulation of Drift Emplacement) and involved two simulated emplacement drifts. Mock-ups of disposal casks were electrically heated to between 170 and 200 ^{o}C for longer than eight years. The heated drifts were backfilled with crushed salt. After the heating cycle, one drift was re-excavated and the backfill and disturbed rock zone were characterized, metal coupons were examined for corrosion, and measuring instruments were recovered and recalibrated[32]. Many of the results demonstrated good agreement between expected and observed phenomena. One notable recommendation deriving from these studies is to improve understanding of the constitutive behavior of dry consolidating salt.

Since 1978 East Germany disposed low and intermediate-level wastes in the Morsleben potash and salt mine (also known as ERAM). Disposal operations about 500 m below the surface were interrupted from 1991 to 1994 to conduct a technical re-evaluation after the re-unification of Germany. Disposal ceased altogether in 1998, and designs for closure have been developed since operations were terminated.

For two decades, the Gorleben salt dome in north-central Germany had been investigated for its suitability to host all categories of radioactive waste, including heat-generating high-level waste. During this time, no evidence came to light that would render the site unsuitable[35]. Owing to political decisions, work on the Gorleben salt repository was suspended in 2000. Experimental programs between the USA and German researchers actively collaborated on thermomechanical deformation of the host rock salts. The German programs have collaborated continuously with the US programs, most notably with WIPP. These programs collectively represent essentially all of the salt repository experience in the world.

1.4 Key Study Assumptions

The assumptions provided in the Scoping Task Plan[40] are essential foundations for the study. These assumptions were used in the study to the fullest extent possible. The assumptions are discussed further in the sections noted below:

1. The Salt Study will be closely coordinated with CBFO and the Task Manager.
2. Existing models, methods, approaches, etc., developed for the 2011 Generic Study[41] shall be used to the extent possible to minimize the resources required to complete the new Salt Study.
3. The repository will be built in a geologic salt formation.
4. It will be necessary to monitor repository performance for 50 years following closure.
5. The emplaced packages will not be maintained in a retrievable configuration. Heterogeneous individual HLW canisters and SNF packages will be placed in-drift and covered with run of mine salt from nearby just-in-time drift mining. Since the mined salt will be used for backfill shielding as emplacement proceeds, the amount requiring removal from the underground facility shall be minimized. As a contingency, the cost estimate will include the option of mining back into the salt to recover the materials, as in the current contingency plan at Waste Isolation Pilot Plant (WIPP).
6. Two disposal options will be analyzed to complete a cost estimate for the construction and operation of a salt repository for disposal of DOE defense waste (HLW and SNF):
   a. Extension of WIPP facility as constructed.
   b. Siting of a new salt repository.

7. Five analyses will be completed. The two disposal options will be analyzed for waste emplacement scenarios as follows:
    a. DOE defense SRS HLW for option 6a, the WIPP extension option. *(hereafter referred to as Case 1, in this document)*
    b. DOE defense HLW for both options 6a and 6b. *(hereafter referred to as Cases 2 and 3 respectively in this document)*
    c. Scenario 7b plus DOE SNF canisters (standard canisters and Hanford Multi-Canister Overpacks) for option 6b only (new salt repository) *(hereafter referred to as Case 4, in this document)*
    d. Scenario 7c plus naval reactor fuel (400 containers) for option 6 b only (new salt repository.) *(hereafter referred to as Case 5, in this document)*

	7a	7b	7c	7d
6a at WIPP	X *(Case 1)*	X *(Case 2)*		
6b new salt repository		X *(Case 3)*	X *(Case 4)*	X *(Case 5)*

8. The regulatory framework will be consistent with 10 CFR 63 and 40 CFR 191.
9. Costs associated with changing applicable legislation, completing licensing activities, performing community consultation activities, and packaging and transporting waste materials for disposal will not be included.
10. Truck and rail receipt options will be included in this study. The costs associated with long-distance shipments from other sites to the repository will not be included.
11. In-drift emplacement should be used when possible. Higher thermal outputs may require alcove emplacement.
12. The operational life and optimal throughput of the repository will be based upon WIPP's operating experience.
13. The facility layout should include surface facilities for waste receipt, 180 day storage, and infrastructure support such as security, administration, etc.
14. To preclude waste stream management at generator sites based on heat loading, the emplacement density of waste containers along drifts should be varied to optimize use of drift space. Hotter packages will be separated further apart than lower heat loading packages. A design basis thermal loading of approximately 10 watts per square meter shall be assumed.
15. HLW canisters have 24" diameters. SRS canisters are 10' long and Hanford canisters are expected to be 15' long. Calcine canisters are 24" diameter and 10' long.
16. SNF will be packaged in standard canisters, which come in four sizes: 18" or 24" diameter and either 10 or 15 feet tall. SNF will be packaged to achieve a thermal load of < 1000 watts/canister. 98% of projected DOE SNF canisters will contain < 500 watts/canister.

17. Naval reactor fuel is packaged in 400 containers, 310 are long canisters (212”) and 90 are short canisters (187”). Each has a maximum diameter of 66.5” and a design weight of 98,000 lbs. The average thermal load is 4,250 watts/container. Maximum is 11, 800 watts/container.
18. Development/testing of alternative waste forms is not within the scope of this study.
19. Costs to perform research and development, e.g., thermal tests, are outside of the scope of this study.

2. Repository Mission and Study Scope

The scope of work provided by DOE required that five cases be evaluated as combinations of the disposal inventory and facility location:

- Four waste inventory cases were evaluated to determine a range of waste emplacement requirements:
    1. Savannah River Site (SRS) Defense Waste Processing Facility (DWPF) borosilicate glass canisters,
    2. all DOE defense High-Level Waste (HLW), comprised of the SRS and Hanford borosilicate glass, and the Idaho calcined/HIPped canisters
    3. all DOE HLW as above plus DOE Spent Nuclear Fuel (SNF) canisters (standard canisters and Hanford Multi-Canister Overpacks)
    4. naval reactor fuel and all DOE HLW and DOE SNF canisters as above
- Two options evaluate disposal location as either an
    1. extension of the Waste Isolation Pilot Plant (WIPP) Facility as constructed or
    2. siting of a new salt repository at a generic or greenfield location

Table 2-1 provides the five case numbers resulting from the combinations of the four inventory cases and two location cases. The all DOE defense HLW case is evaluated at two locations to evaluate the difference in location for a common inventory while the other three inventory cases are evaluated at a single location.

Table 2-1 Defense Waste Repository Case Matrix

Case Number	SRS HLW	All HLW	All HLW + DOE Spent Fuel	All HLW + DOE and Naval Spent Fuel
Location				
WIPP Extension	1	2		
Generic Location		3	4	5

3. DOE Defense Waste Repository Inventory

The Repository waste emplacement footprint is governed by two principle factors, mine or excavation stability considerations for minimum drift spacing and the decay heat areal density limitations. The canister quantity breakdown for each of the four inventory scenarios, as a function of waste package decay heat, is provided below.

3.1 HLW Inventory - SRS Borosilicate Glass Inventory – Case 1

SRS began conversion of the liquid defense waste into borosilicate glass in 1996 and is the only DOE site with HLW in a packaged configuration. A total of 3,325 canisters have been produced through December, 2011. Therefore, the SRS inventory can be described as those canisters in the current inventory and those projected from future operations. Decay heat of the current inventory is based on radiological inventories contained in the production records for those canisters. The decay heat of future canisters is estimated based on radionuclide inventory of the inventory of HLW remaining in the liquid waste storage tanks. The radionuclide and resulting decay heat was calculated based on the year the canister is/will be produced. The total Savannah River canister count is based in information supporting Savannah River Liquid Waste Disposition Plan revision 16.

Table 3-1 provides the canister distribution of SRS canisters based on the nominal decay heat at the time of production. The data indicates: 39% of the Savannah River canisters will be less than 50 watts; 96% of the Savannah River canisters will be less than 300 watts; all the SRS canisters will be less than 500 watts.

Table 3-1 Savannah River Canister Decay Heat Distribution

Decay heat per canister (watts)	Savannah River Number of canisters	Cumulative %
<50	2948	39.0%
50-100	459	45.1%
100-220	3891	96.5%
220-300	0	96.5%
300-500	264	100.0%
500-1000	0	100.0%
1000-1500	0	100.0%
1500 - 2000	0	100.0%
>2000	0	100.0%
Total	**7,562**	
Total Decay Heat (watts)	**805,500**	

3.2 HLW Inventory – Hanford Borosilicate Glass and Idaho Calcine Waste Inventory - Case 2 and 3

Case 2 and 3, which differ in repository location, share a common inventory. This inventory includes the SRS and Hanford Borosilicate glasses and the Idaho calcine canisters.

3.2.1 Hanford Borosilicate Glass Canisters

The Hanford Waste Treatment Project (WTP) is currently under construction and therefore the Hanford borosilicate glass canisters are based on a projected inventory for their future production taken from the January 2011 Waste Treatment Plant document titled “2010 Tank Utilization Assessment”. The data in Table 3-2 indicates: 83% of the Hanford canisters will be less than 50 watts; and 100% of the Hanford canisters will be less than 300 watts. This decay heat estimate does not include the potential contribution from inclusion of the Hanford cesium capsules.

3.2.2 Idaho Calcine Waste Canisters

Decay heat of DOE HLW that has been calcined and is currently stored at the Idaho site is taken from the October 2005 Idaho Cleanup Project document titled “Decay Heat and Radiation from Direct Disposed Calcine”, EDF-6258 revision 0. Report EDF-6258 provides data for direct disposal of the calcine waste. The current Record of Decision for disposal of the calcine is for it to be treated using a hot isostatic pressing (HIP), which will result in an approximate 50% increase in the volume of material in each disposal canister and an 50% increase in the decay heat per canister.

Table 3-2 provides the distribution of DOE calcine canisters based on the nominal decay heat in the year 2016. The data indicates that 100% of calcine canisters will be less than 50 watts.

Table 3-2 Hanford and Idaho Waste Inventory

	Hanford Borosilicate Glass		Idaho Calcine	
Decay heat per canister (watts)	Number of canisters	Cumulative %	Number of canisters	Cumulative %
<50	9291	83.9%	4391	100.0%
50-100	1237	95.0%		
100-220	523	99.7%		
220-300	28	100.0%		
300-500	0	100.0%		
500-1000	0	100.0%		
1000-1500	0	100.0%		
1500 - 2000	0	100.0%		
>2000	0	100.0%		
Total	**11,079**		**4391**	

3.2.3 All DOE HLW Inventory Combined from SRS, Hanford and Idaho - Case 2 and 3

The combined inventory from all three sites, which is used in Cases 2 and 3, is presented in Table 3-3. The data indicates: 72% of the HLW canisters will be less than 50 watts; ~80% of the canisters will be less than 100 watts; almost 99% will be less than 300 watts and all the canisters will be less than 500 watts. The total decay heat to be emplaced in these cases is 1.2 million watts.

Table 3-3 Case 2 and 3 Inventory of All DOE HLW

	All DOE HLW Canisters	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	16630	72.2%
50-100	1696	79.6%
100-220	4414	98.7%
220-300	28	98.9%
300-500	264	100.0%
500-1000	0	100.0%
1000-1500	0	100.0%
1500 - 2000	0	100.0%
>2000	0	100.0%
Total	**23,032**	
Total Decay Heat (watts)	**1,203,103**	

Not included in Table 3-3 are a) 275 HLW canisters from West Valley, which have low heat values, b) does not include the potential contribution from inclusion of the Hanford cesium capsules and b) the Idaho HLW to be processed through the Integrated Waste Treatment Unit and then, per the associated Record of Decision, will be disposed of as RH-TRU.

3.3 DOE Spent Nuclear Fuel and HLW Inventory- Case 4

Decay heat of DOE Spent Nuclear Fuel (SNF) is based on the estimated radionuclide inventory. In support of the Yucca Mountain License Application, an analytical process, using process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE SNF was used to develop a conservative radionuclide inventory estimate. This methodology was applied to each fuel in the DOE SNF inventory to develop a radionuclide estimate. Also in support of the Yucca Mountain License Application, a packaging plan was developed using the DOE standardized canisters. These two data sources are used to estimate the decay heat per canister for DOE SNF.

The radionuclide and resulting decay heat was calculated in the year 2010 and 2030 to support the Yucca Mountain repository. Considering the time required before a repository for DOE SNF would be open to accept waste, these values are considered adequate for this scoping evaluation.

Table 3-4 provides the distribution of DOE SNF canisters based on the 2010 and 2030 nominal decay heat using the 2035 total canister count. The 2010 data indicates approximately 35% of the DOE SNF canisters will be less than 50 watts. Approximately 90% of the DOE SNF canisters will be less than 300 watts. Nearly all the DOE SNF canisters (>99%) will be less than 1 kW. Since the methodology used to calculate the radionuclide inventory is very conservative, some fuels have radionuclide amounts based on bounding assumptions resulting in extreme decay heat values.

Table 3-4 DOE Spent Nuclear Fuel Canister Decay Heat

	2010		**2030**	
Decay heat per canister (watts)	Number of canisters	Cumulative %	Number of canisters	Cumulative %
<50	1228	34.7%	1670	47.1%
50-100	565	50.6%	392	58.2%
100-220	789	72.9%	690	77.7%
220-300	633	90.8%	586	94.2%
300-500	241	97.6%	140	98.2%
500-1000	55	99.1%	41	99.4%
1000-1500	10	99.4%	4	99.5%
1500 - 2000	1	99.4%	5	99.6%
>2000	20	100.0%	13	100.0%
Total	**3542**		**3542**	

Does not include the Savannah River Site SRE fuel

Table 3-5 provides the combined HLW and SNF inventory data for Case 4. The total emplaced decay heat for this case is about 1.9 million watts.

Table 3-5 DOE HLW and SNF for Case 4

	All DOE HLW Canisters and DOE SNF	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	17858	67.2%
50-100	2261	75.7%
100-220	5203	95.3%
220-300	661	97.8%
300-500	505	99.7%
500-1000	55	99.9%
1000-1500	10	99.9%
1500 - 2000	1	99.9%
>2000	20	100.0%
Total	**26,574**	
Total Decay Heat (watts)	**1,901,928**	

3.4 Naval Reactor Fuel, DOE Spent Nuclear Fuel and HLW Inventory – Case 5

Naval reactor fuel is packaged in 400 containers, 310 are long canisters (212”) and 90 are short canisters (187”). Each has a diameter of 66.5” and a design weight of 98,000 lbs including the contents. The average thermal load is 4,250 watts/container. Maximum is 11, 800 watts/container.

Table 3-6 provides the combined inventory heat distribution for Naval SNF, DOE SNF and DOE HLW for Case 5. The total emplaced decay heat for this case is about 3.6 million watts or about half of the value previously expected. The lower than anticipated decay heat reduces the underground emplacement footprint.

Table 3-6 Naval and DOE SNF and DOE HLW for Case 5

	All Naval Fuel, DOE HLW Canisters and DOE SNF	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	17858	66.2%
50-100	2261	74.6%
100-220	5203	93.9%
220-300	661	96.3%
300-500	505	98.2%
500-1000	55	98.4%
1000-1500	10	98.4%
1500 - 2000	1	98.4%
>2000	420	100.0%
Total	**26,974**	
Total Decay Heat (watts)	**3,601,928**	

3.5 Defense Waste Canister Descriptions

3.5.1 Defense Waste Canister Summary Data

Defense waste canister descriptions vary in size depending on the type and source. Table 3-7 provides a summary of the key data associated with each. The figures that follow provide additional descriptive data for each.

Table 3-7 Defense Waste Canister Data

Waste	Canister Type	Nominal OD	Maximum External Length	Wall Thickness	Maximum Weight (Canister plus Contents)	Reference
SNF	18 in / 10 ft.	18 in.	118.14 in.	0.375 in.	5,005 lb	DOE/RW-0511, Rev. 4 (2008)[43] DOE/SNF/REP-011, Rev. 3 (1999)[44]
	18 in / 15 ft.	18 in.	118.14 in.	0.375 in.	6,000 lb	DOE/RW-0511, Rev. 4 (2008)[43] DOE/SNF/REP-011, Rev. 3 (1999)[44]
	24 in / 10 ft.	24 in.	179.92 in.	0.500 in.	8,996 lb	DOE/RW-0511, Rev. 4 (2008)[43] DOE/SNF/REP-011, Rev. 3 (1999)[44]
	24 in / 15 ft.	24 in.	179.92 in.	0.500 in.	10,000 lb	DOE/RW-0511, Rev. 4 (2008)[43] DOE/SNF/REP-011, Rev. 3 (1999)[44]
HLW	Savannah River	24 in.	118.06 in.	0.375 in.	5,512 lb	SRR-LWP-2009-00001, Rev. 17 (2012)[48], SRS Drawing W832094[45], DOE/RW-0511, Rev. 4 (2008)[43]
	Hanford	24 in.	176.82 in.	0.375 in.	9,260 lb	ORP-11242, Rev. 6 (2011)[49], DOE/RW-0511, Rev. 4 (2008)[43]
	West Valley	24 in.	117.87 in.	0.375 in.	5,512 lb	DOE/RW-0511, Rev. 4 (2008)[43]
Calcine	24 in / 10 ft. standard SNF canister	24 in.	179.92 in.	0.500 in.		Idaho EDF-6258, Rev. 0 (2005)[46]
Naval Reactor Fuel	Long	66.5 in. (max)	212 in.		98,000 lb (canister)	Task Statement 3/13/2012[40], DOE/RW-0511, Rev. 4[43] states Max fill wt. of 108,500 lb.
	Short	66.5 in. (max)	187 in.		98,000 lb (canister)	Task Statement 3/13/2012[40], DOE/RW-0511, Rev. 4[43] states Max fill wt. of 108,500 lb.

3.5.2 High Level Waste Canisters

<u>Savannah River HLW Canisters</u>

Drawing W832094[45] provides the dimensions and material composition for the DWPF canister. The outer canister diameter of 24 in (60.96 cm), height of 118 in (299.72 cm), side and bottom wall thicknesses of 3/8 in (0.9525 cm), and a top thickness of 5/8 in (1.5875 cm). Material composition is ASTM A240, type 304L stainless steel.

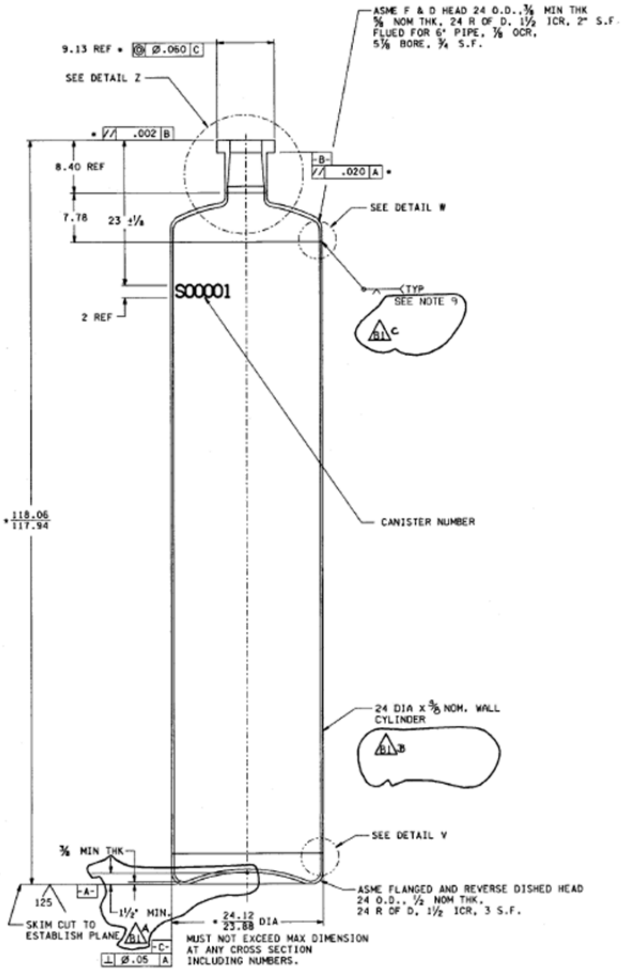


Figure 3-1, DWPF Canister Dimensions (W832094[45], DWPF – Canister Assembly Mechanical (U), Rev. B1, October 30, 1990.)

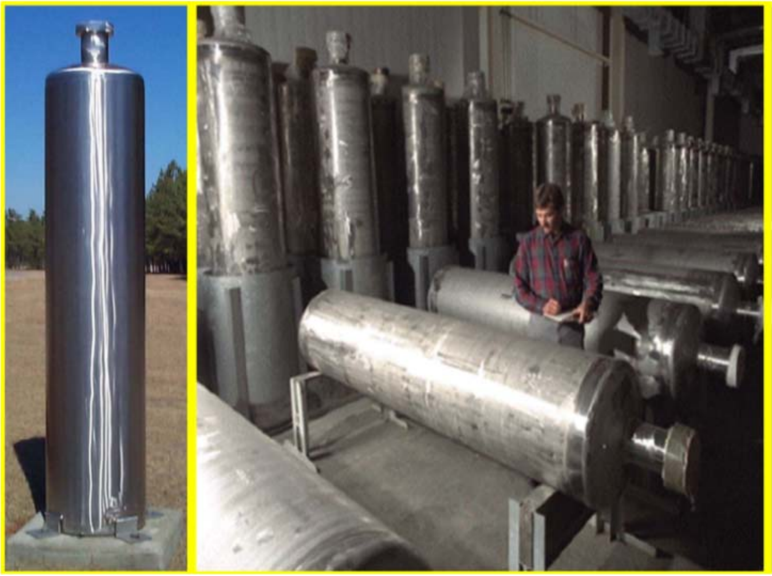


Figure 3-2 SRS HLW Canister And Canisters Being Received (prior to filling with radioactive glass)

Hanford HLW Canisters

HLW canisters have 24” diameters and are expected to be 15’ long.

Each HLW canister will have ⅜-in. thick walls, and will hold 3.02 metric tons of glass (MTG) on average.

Figure 3-3 Hanford High-Level Waste Canister (left) and Low-Activity Waste Container (right)

3.5.3 Spent Nuclear Fuel Canisters

Idaho – Calcine SNF Canisters
Calcine canisters are 24” diameter and 10’ long SNF canisters.

Source: EDF-6258, 2005[54], “Decay Heat and Radiation from Direct Disposed Calcine,” Rev. 0, Idaho National Engineering and Environmental Laboratory, October 2005.

Wall Thickness	0.5 in
Height (98% vol)	98.9 in
Radius	11.5 in
98% fill Vol.	41,092.8 in^3
Empty Weight	1,100 lb

This design, sometimes referred to as the “SNF canister”, has an overall length of 120 in. Its outside diameter is 24 in. The wall thickness is 0.5 in. Its approximate empty weight would be 1,100 lb. The canisters are to be of 304 or 316 stainless steel for which a value of 8.0 g/cm^3 was used for the canister wall density.

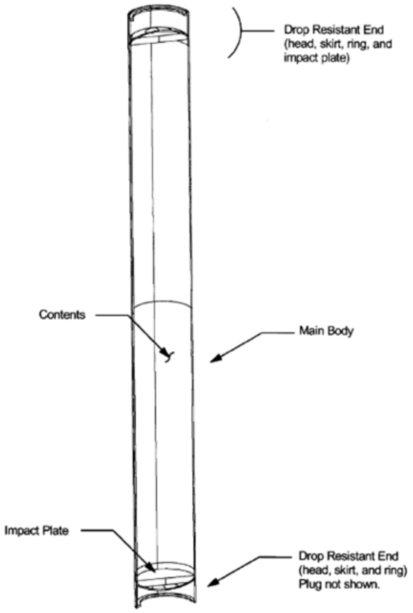


Figure 3-4 Section View of the 24-in. Spent Nuclear Fuel Canister Design

Source: EDF-4096[47], 2003, “FY2003 Conceptual Design Effort for the High Level Waste Disposal Canister,” Rev. 0, Idaho National Engineering and Environmental Laboratory, August 2003.

Note: More recent documents state the wall thickness may be reduced to 0.375 inches.

DOE Spent Nuclear Fuel Canisters

SNF will be packaged in standard canisters, which come in four sizes: 18” or 24” diameter and either 10 or 15 feet tall.

Naval Fuel Canisters

Naval reactor fuel is packaged in 400 containers, 310 are long canisters (212”) and 90 are short canisters (187”). Each has a maximum diameter of 66.5” and a design weight of 98,000 lbs.

3.6 Transportation Cask Data

Transportation casks provide the waste canister overpack vessel which provides shielding for the waste canister during handling and during transportation by rail or truck carrier. Due to the amount of shielding provided and their size, the weight of the combined cask and waste canister can be very large. The casks are typically fitted with lifting trunions, which allows an overhead crane or hoist to raise or lower them from or to a horizontal position or move them. When fully configured, the casks are fitted with impact limiters which are designed to reduce the potential for canister damage from design basis accidents, during lifting or transport. The casks are licensed transport packages and their license is directly related to the payloads which they are allowed to carry.

Figures 3-5 through 3-10 provide images of typical transportation casks for use on truck and rail carriers.

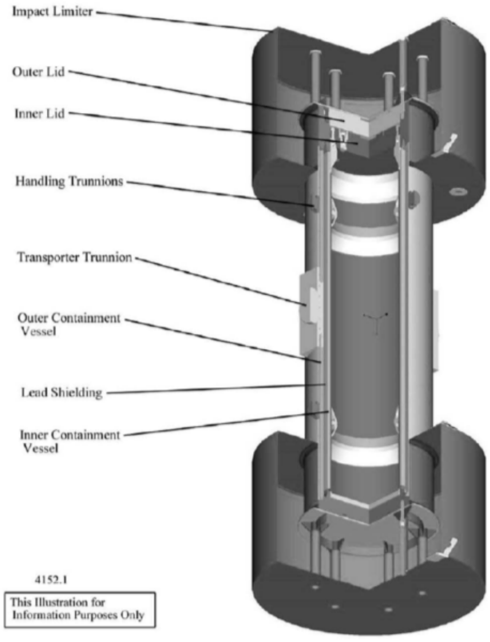


Figure 3-5 RH-72B Transportation Cask

Figure 3-6 RH-72B Transportation Cask & Impact Limiters On Carrier

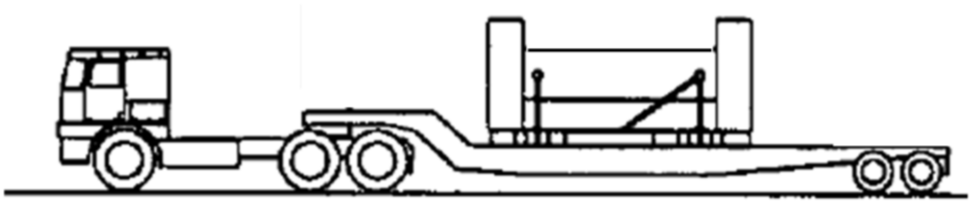


Figure 3-7 Typical View Of A Transportation Cask On A Truck Carrier[66]

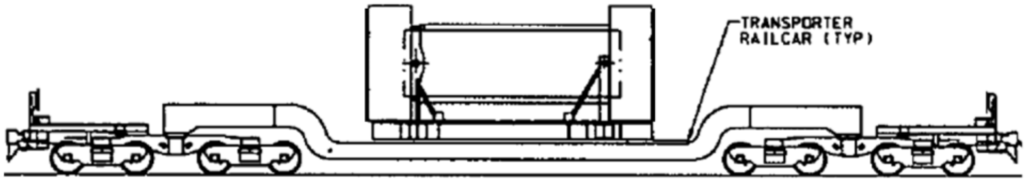


Figure 3-8 Typical View Of A Transportation Cask On A Rail Carrier[66]

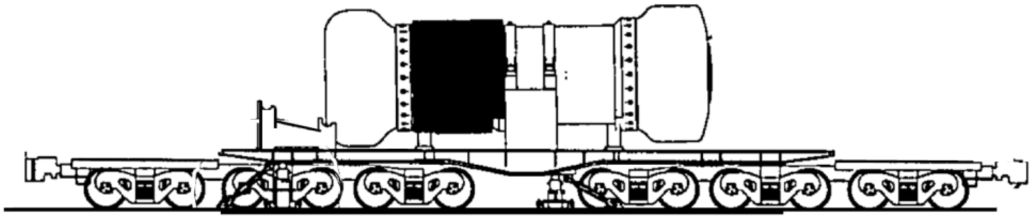


Figure 3-9 Typical View Of A Naval Fuel Transportation Cask On A Rail Carrier[66]

Figure 3-10 RH-72B Cask On A Truck Carrier

Casks have not been selected nor licensed for transportation of the DHLW and SNF discussed in this study. The RH-72 B cask is currently in use at WIPP for RH package transport and would be representative of a cask that might be adapted and licensed for defense HLW and DOE SNF packages for the DWR. It weighs a maximum of 22.5 tons including its payload. Commercial casks could also be adapted and licensed for such packages, as could DOE designs.

It should be noted that the Naval Fuel Cask shown in Figure 3-9 is described in DOE/RW-0511[66], Rev. 4 as a cask weighing 265 tons which would require a WHB receipt bay crane with an additional capacity, on the order of 35tons or more, considering cask lifting yokes and other cask hardware. Crane rigging hardware would further add to that load. Similar to the associated high capacity waste shaft hoist for Naval fuel, in Case 5, Section 5.2.1.5 assumes that that the WHB receipt bay crane would be rated at 400 tons for lifting the naval fuel casks in Case 5.

4. Underground Waste Emplacement Strategy

The mining layout was developed on the basis of thermal load and mining experience. The waste emplacement approach was altered from the prior Commercial SNF reprocessing waste study[41] in which one HLW canister was emplaced per alcove. To maintain the areal thermal limit of 39 watts/m^2 these alcoves were on a 40 foot square array. The canister was to be placed on the floor in the alcove and covered with at least 10 feet of mined salt to provide shielding between the canister and the room.

Evaluation of the defense waste inventory reveals the vast majority of the packages are less than 100 watts each. This allows a much more efficient underground emplacement approach. The team developed an in-room disposal approach, with variable spacing, to accommodate waste packages with higher heat loads. The minimum spacing selected is 1 foot between canisters (3 feet centerline spacing) to allow for a run-of-mine salt backfill and to ensure packages are not displaced from their intended location as additional waste packages are emplaced. Since canisters are 18" to 24" in diameter, except for the naval fuel packages, and mine or excavation stability requires a minimum pillar thickness of 100 feet, each waste package is allowed to contain as much as 330 watts, based on the 3' minimum centerline spacing and layout in this study and assuming the decay heat limit is 10 watts/m^2 (or 0.93 watts/ft^2). For estimation of required underground footprint for this study, all canisters except naval fuel were assumed to be 24" diameter, which provides a conservative estimate of total emplacement area. The 10 watts/m^2 limit is considered reasonable given that WIPP conducted heater tests during the 1980's at 18 watts/m^2.

4.1 Thermal Modeling and Results

A three-dimensional finite-volume heat transfer model was constructed for this study, using the computer code FEHM to investigate the temperatures due to waste disposal in a generic salt repository. The model was constructed in a manner so as to facilitate modification as the study progresses. The results of the modeling are included in a report[55] prepared for this study. For completeness and concurrent availability of that report together with this study, the contents of the report are included in their entirety in Appendix A1 and is summarized below.

The model domain is designed as an interior room within a panel. The model domain is designed to simulate temperature evolution in an interior room within a panel of rooms surrounded by other panels. Due to the symmetry of the room and surrounding panels, the model is limited to one half of the room (540 ft x 10 ft. was assumed for this analysis), extending halfway to the center of the salt pillar that separates the domain from the adjacent room. Figure 4-1 is a schematic diagram (plan view) of the model layout with the symmetry domain highlighted as a green box. Waste canisters are simulated as 2-ft diameter by 10 ft long canisters placed crosswise in the approximately 10-ft high by 20-ft wide room. Figure 4-2 shows the temperature after 200 years with 220 W canisters.

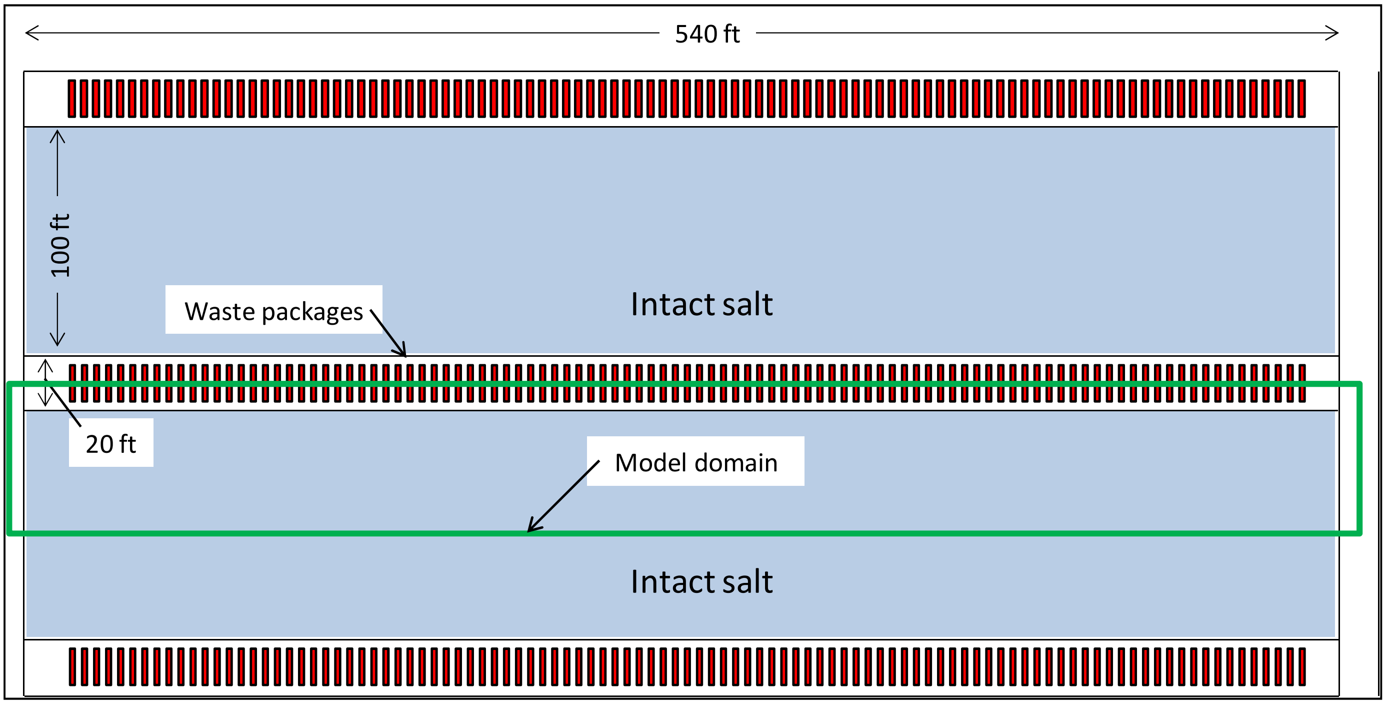


Figure 4-1. Plan View of the Modeled Waste Canister Configuration and Model Domain.

(Diagram is not precisely to scale. Model domain is shown outlined by the green line, while the surrounding rooms are shown to allow visualization of the reflection boundary conditions.)

Temperature influences from the reflected half of the room and adjacent rooms and panels are simulated using thermal reflection boundaries (no flow) along all four lateral sides of the model domain. Access drifts at both ends of the room are included to their centers where reflection boundaries have been imposed, representing panels of rooms that are assumed to extend in all directions. This domain would represent a portion of the repository near the center, where temperatures would be highest (disposal rooms on the edge of the repository would attain somewhat lower temperatures). Boundary conditions on the top and bottom of the model are set to fixed far-field temperatures approximating the initial temperature at the depth in the WIPP facility (~30^{o}C). Finally, the heat loads in the waste canisters are assumed to be continuous with no decay, leading to long-term steady-state temperature profiles as the energy flux from the canisters comes into equilibrium with the thermal gradient carrying heat to top and bottom boundaries of the model domain. Thus our calculations of maximum temperature are conservative, as the heat output of the real waste packages will decrease with time as the heat-generating radioactive components decay.

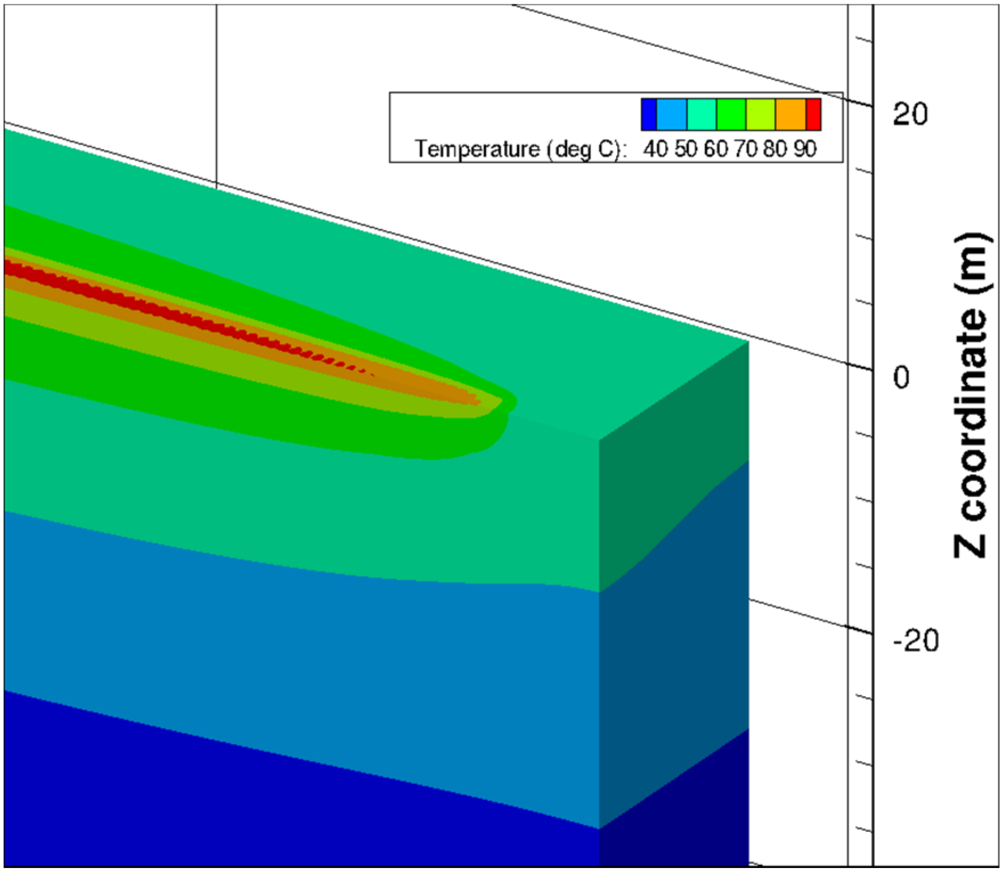


Figure 4-2 Temperature After 200 Years With 220 W Canisters

Upper part of model is cut out to view the center of the canisters.

Based on this preliminary set of heat flow simulations and neglecting decay, model results indicate that temperatures may reach a maximum of about 95°C for SRS and Hanford waste forms in a densely packed in-drift disposal scenario with run-of-mine salt applied for shielding. Temperature isotherms (> 5°C) reach a vertical distance of about 30 m for the SRS and Hanford waste forms. These results are conservative in that there is no decay with time, so temperatures never decrease with time. For SNF and NF waste packages, maximum temperatures of 250°C or less can be attained assuming that the per-package heat load is kept to between 1000 to 2000 W (by repackaging, if necessary), and by spacing the canisters within the drift.

4.2 Defense Waste Repository Underground Configuration

Table 4-1 provides the waste package distribution as a function of decay heat and linear spacing for each of the five cases.

Table 4-1 Defense Waste Package Spacing Distribution

Spacing Between Packages	Allowable Decay Heat (watts/package)	SRS HLW Case 1	HLW Waste Packages Cases 2, 3	HLW and SNF Case 4	HLW & SNF & Naval SNF Case 5
3	330	7298	22768	25983	25983
4	450	0	0	0	0
5	560	264	264	505	505
6	670	0	0	0	0
8	900	0	0	0	0
10	1100	0	0	55	55
15	1700	0	0	10	10
20	2200	0	0	1	1
36	4000	0	0	20	420

The study team developed a panel layout consisting of 10 disposal rooms in each panel. The rooms are 10 ft. high by 20 ft. wide, and will allow waste emplacement for 500 linear feet each plus an allowance for run-of-mine backfill, for shielding at both ends. The typical panel layout is shown in Figure 4-3 and Table 4-2 estimates the number of rooms and panels required for waste emplacement using the variable spacing in Table 4-1. Table 4-2 also provides the waste emplacement rate and underground emplacement area (rooms and panels) used in this study assuming a 40 year mission life as specified in the study scope[40] of work.

Table 4-2 Waste Emplacement Rooms and Panel Requirements

Waste Package Spacing (Ft)	SRS HLW Case 1	HLW Waste Packages Cases 2, 3	HLW and SNF Case 4	HLW & SNF & Naval SNF Case 5
3	44	137	156	156
5	3	3	6	6
10	0	0	2	2
15	0	0	1	1
20	0	0	1	1
36	0	0	2	31
Total Rooms	**47**	**140**	**168**	**197**
Total Panels	**5**	**14**	**17**	**20**
Waste Emplacement Rate Containers /yr	189	576	664	674
Waste Emplacement Rates Rounded	200	675	675	675
Rooms per year	1.2	3.5	4.2	4.9
Panels/yr	0.12	0.35	0.42	0.49

Figures 4-4 and 4-5 provides the underground layout for Cases 1, and 2, for the proposed WIPP extension. The configuration is mandated by two key considerations: 1) working around the existing WIPP Defense TRU waste emplacement areas and 2) maintaining a one mile buffer to the WIPP land withdrawal act sixteen square mile perimeter.

For Case 1, this configuration requires a set of four "U" shaped access mains to connect the current shaft pillar area to the south side of the current emplacement mains. The five defense waste emplacement panels are to the west side of these access mains. To accommodate the 14 panels required for Case 2, a second set of "U" shaped access mains is proposed on the east side of the current emplacement panels. Figure 4-5 reflects 17 panels, together with some unused space at the repository horizon, to indicate the waste emplacement area is adequate for more waste than strictly required for Case 2 . These long "U" shaped access panels contribute significantly to the Total Project Cost (TPC) as the west side mains are required to be completed as part of the initial construction. The west side mains are assumed to be constructed while the first five panels are being filled and are included in the Life Cycle Cost (LCC) estimate for Case 2.

The existing mine support infrastructure at WIPP is not adequate to support the additional mains and waste emplacement areas. The existing salt shaft is fully utilized by the Defense TRU waste mission and the air intake and exhaust shafts are not adequate to provide the required ventilation for these new drift areas. Therefore both Case 1 and 2 include three new shafts for salt removal, air intake and air exhaust.

The existing WIPP waste emplacement shaft is judged to be adequate for Case 1 in which 200 packages per year are required to be emplaced assuming a second shift operation at WIPP. However, a single waste shaft is not adequate for Case 2 in which nearly 600 waste packages per year need to be emplaced. As such the scope for Case 2 includes a new waste shaft.

Figure 4-6 provides the underground layout for Cases 3, 4 and 5. This generic location layout is more efficient, since the 14, 17 or 20 panels required for Cases 3, 4, and 5 respectively can be placed along a linear set of mains. These cases require five access shafts for salt removal, air intake, air exhaust and two waste shafts.

Underground openings are constructed using readily available mining equipment. Opening dimensions are selected to minimize the amount of mining needed. A continuous mining machine will cut an opening 11 ft wide by 10 ft. high in a single pass. The room dimensions are 10 ft. high by 20 ft. wide, to accommodate waste packages up to 15 ft. long and provide an allowance for the shielded conveyance which carries the waste packages to the emplacement areas.

Entries and haulage ways are mined taller and wider than disposal areas in order to accommodate the orderly flow of underground traffic and to accommodate the larger vehicles needed to support mining and waste emplacement. These are 20 feet high by 30 feet wide and require two vertical and three horizontal passes to mine. Adjustment to these dimensions may be made once a specific location (depth and salt horizon properties) has been established. Table 4-3 provides the linear feet of drifts for each case.

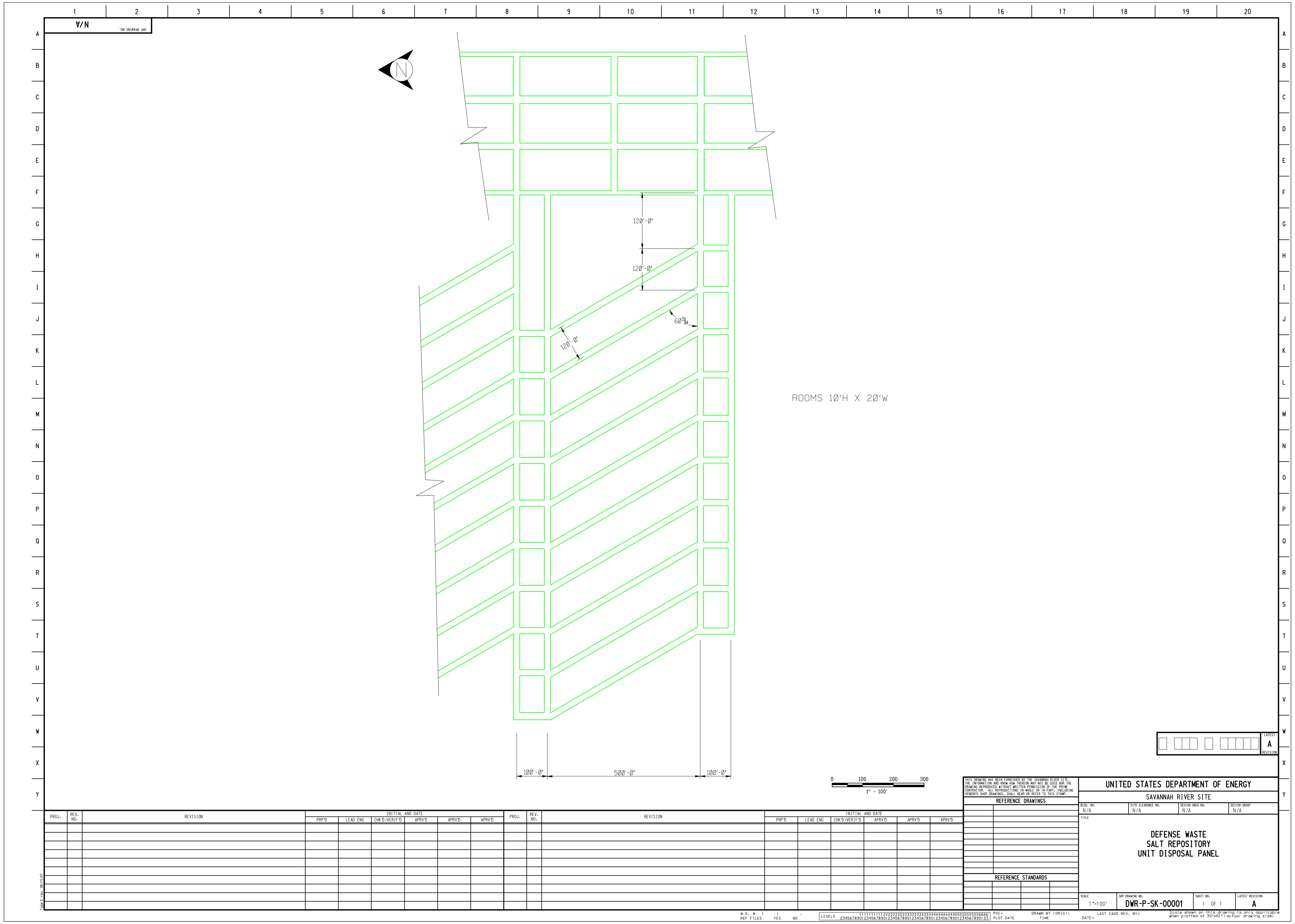


Figure 4-3 Disposal Panel Configuration

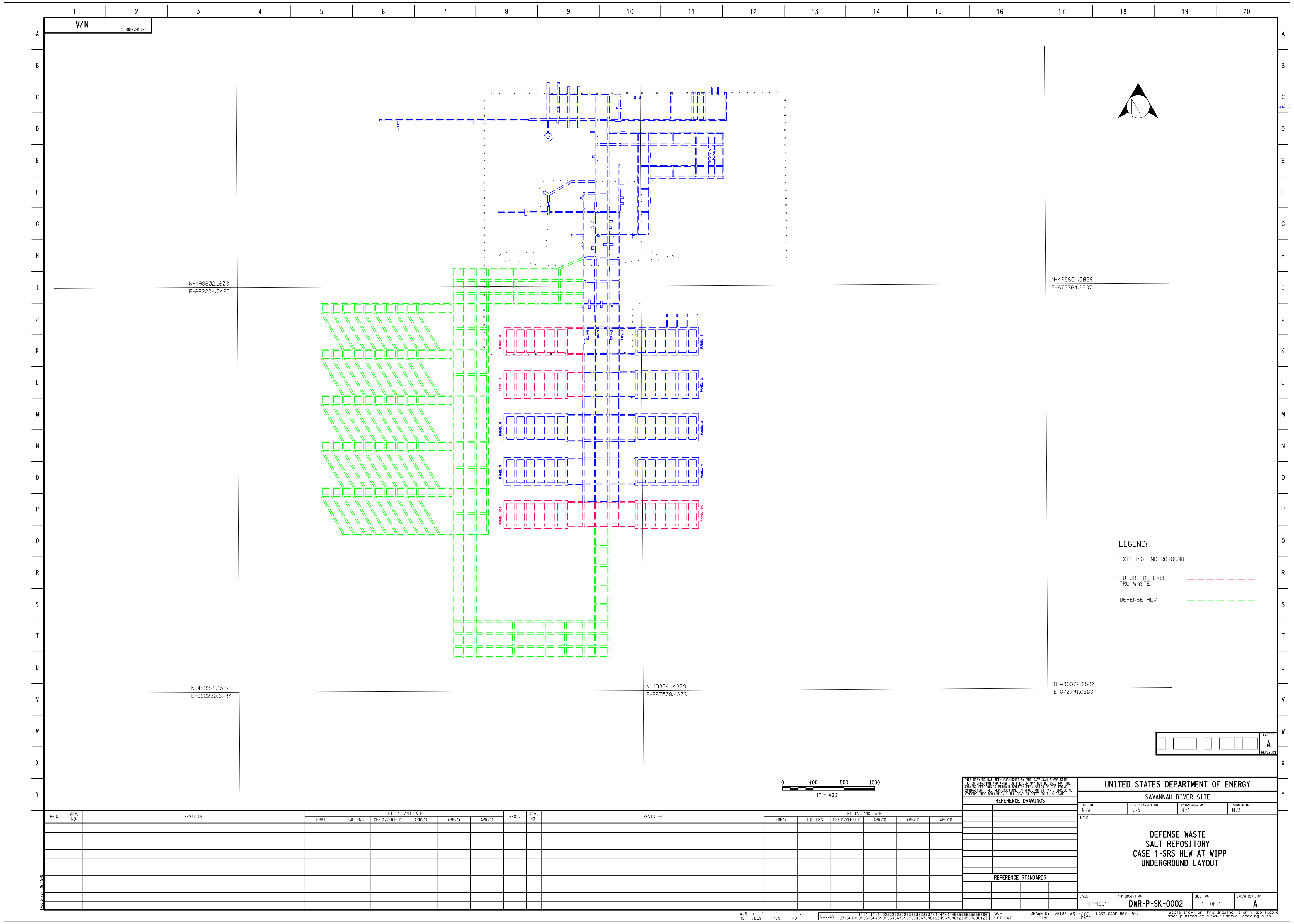


Figure 4-4 Case 1 SRS Waste at WIPP Underground Repository Plot Plan

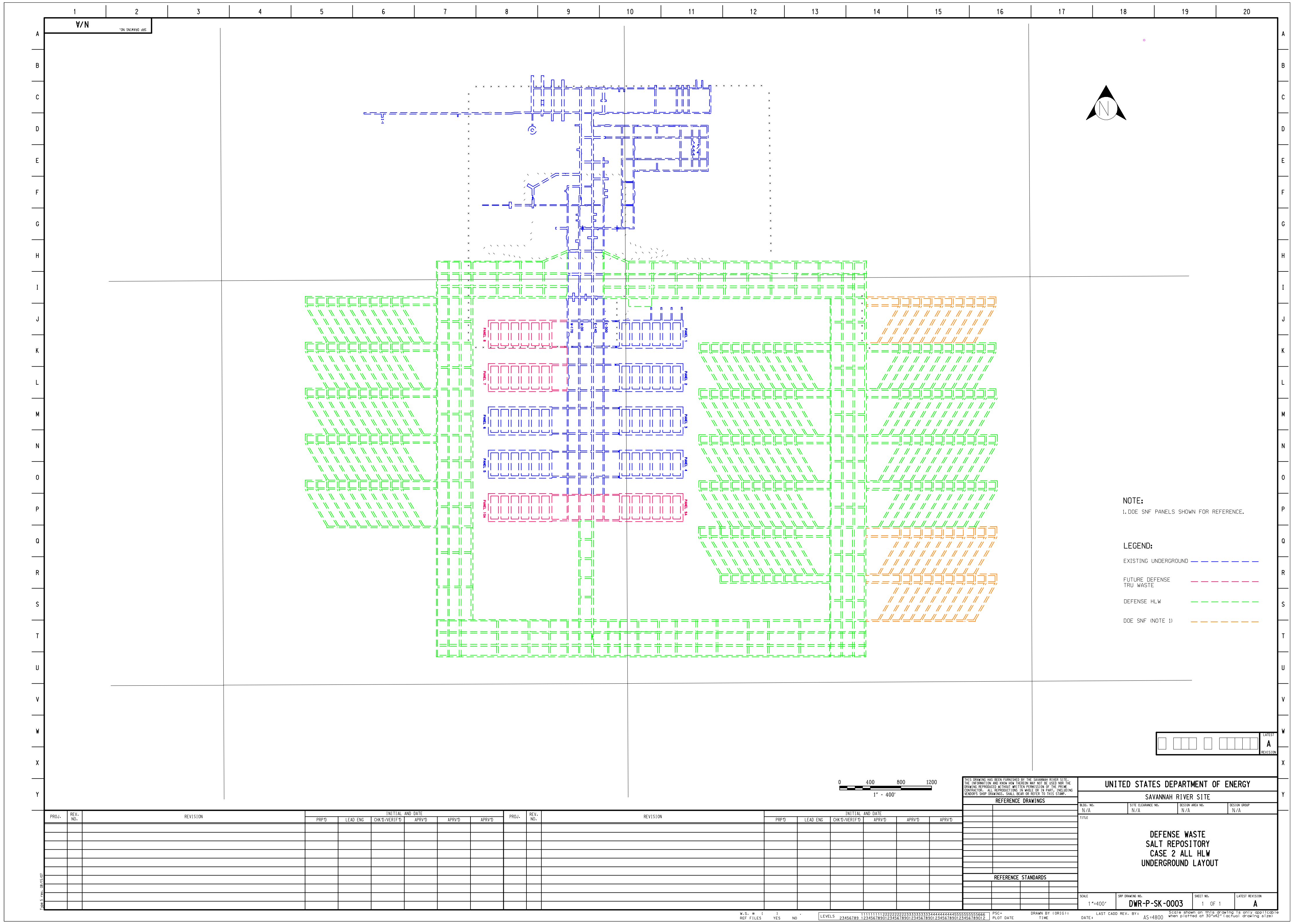


Figure 4-5 Case 2 All Defense Waste At WIPP Underground Repository Plot Plan

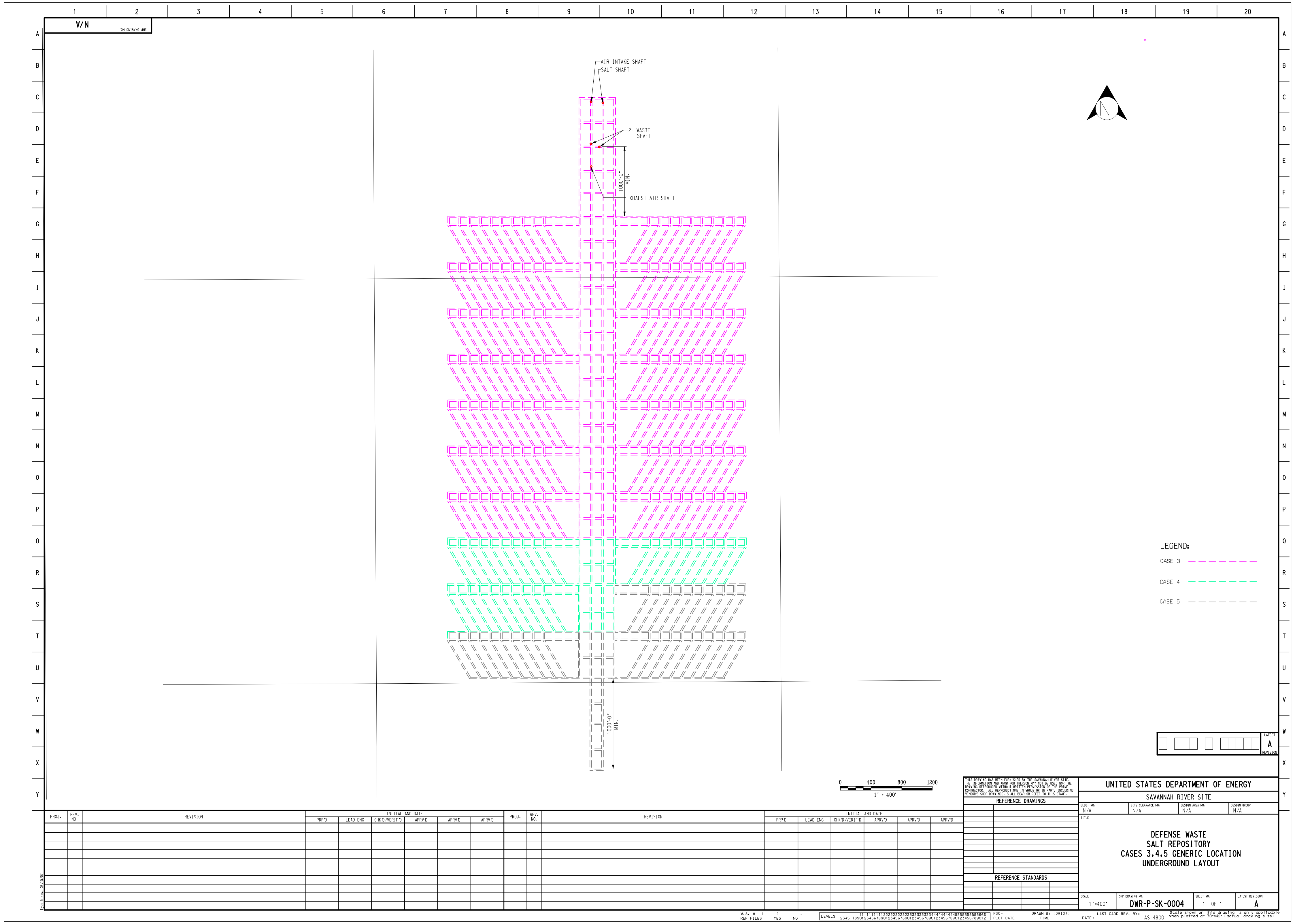


Figure 4-6 Case 3, 4 and 5 All Defense Waste At A Generic Location Underground Repository Plot Plan

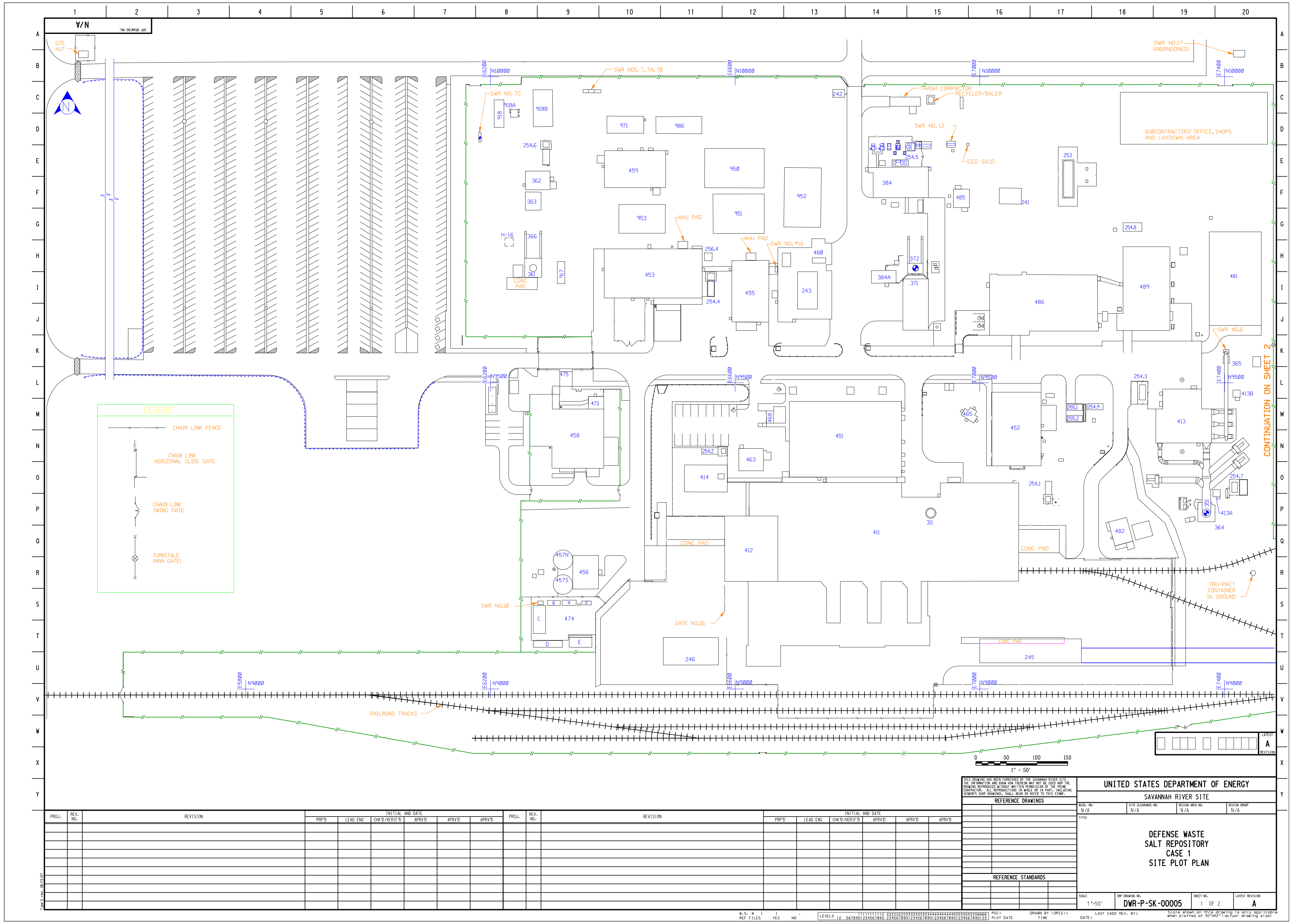
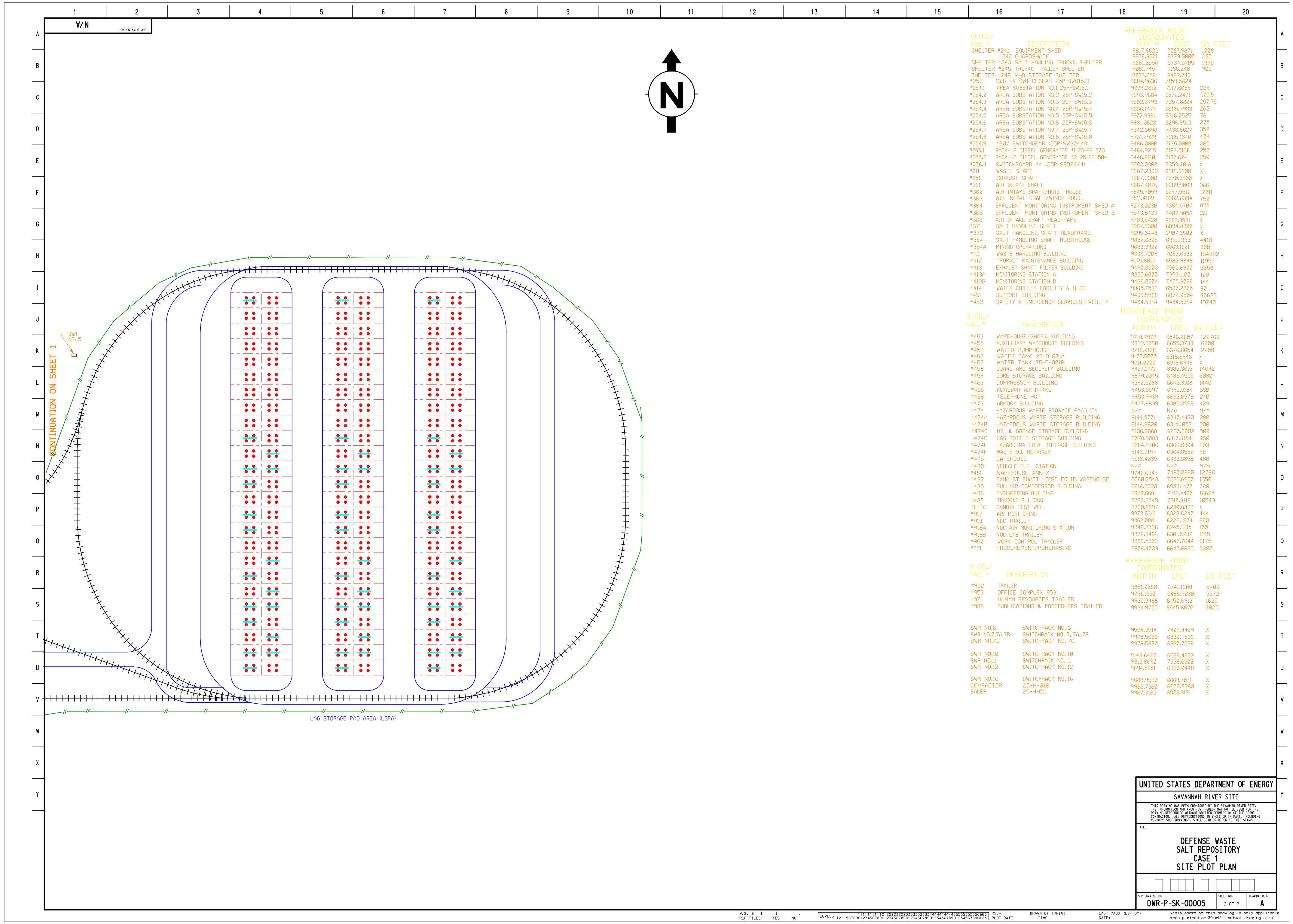


Figure 4-7A Case 1 WIPP Surface Facilities Sheet 1 – Site Plot Plan



BLDG./ FAC. #	DESCRIPTION	REFERENCE POINT COORDINATES NORTH	EAST	SQ FEET
SHELTER #241	EQUIPMENT SHED	9817.6622	7067.9871	1008
#242	GUARDSHACK	9978.8201	6779.0000	225
SHELTER #243	SALT HAULING TRUCKS SHELTER	9681.3556	6734.5705	1972
SHELTER #245	TRUPAC TRAILER SHELTER	9081.745	7166.240	905
SHELTER #246	MgO STORAGE SHELTER	9039.256	6482.742	
#253	13.8 KV SWITCHGEAR 25P-SWG15/1	9884.9636	7159.5624	
#254.1	AREA SUBSTATION NO.1 25P-SW15.1	9339.2612	7117.6055	229
#254.2	AREA SUBSTATION NO.2 25P-SW15.2	9393.9684	6572.2471	505.5
#254.3	AREA SUBSTATION NO.3 25P-SW15.3	9502.3793	7257.8804	257.75
#254.4	AREA SUBSTATION NO.4 25P-SW15.4	9666.1474	6565.7933	262
#254.5	AREA SUBSTATION NO.5 25P-SW15.5	9902.9361	6916.0525	76
#254.6	AREA SUBSTATION NO.6 25P-SW15.6	9881.0628	6296.8513	275
#254.7	AREA SUBSTATION NO.7 25P-SW15.7	9342.6898	7438.8627	350
#254.8	AREA SUBSTATION NO.8 25P-SW15.8	9761.2929	7265.1340	404
#254.9	480V SWITCHGEAR (25P-SWG04/9)	9466.0000	7175.0000	265
#255.1	BACK-UP DIESEL GENERATOR #1 25-PE 503	9464.9215	7167.8136	250
#255.2	BACK-UP DIESEL GENERATOR #2 25-PE 504	9446.8110	7167.6241	250
#256.4	SWITCHBOARD #4 (25P-SBD04/4)	9582.0900	7359.2016	X
#311	WASTE SHAFT	9287.2300	6919.8900	X
#351	EXHAUST SHAFT	9287.2300	7370.3900	X
#361	AIR INTAKE SHAFT	9687.4076	6269.9069	366
#362	AIR INTAKE SHAFT/HOIST HOUSE	9845.7059	6297.5511	1200
#363	AIR INTAKE SHAFT/WINCH HOUSE	9811.4189	6282.6384	750
#364	EFFLUENT MONITORING INSTRUMENT SHED A	9273.0230	7384.5707	896
#365	EFFLUENT MONITORING INSTRUMENT SHED B	9543.8433	7407.9056	221
#366	AIR INTAKE SHAFT HEADFRAME	9703.5428	6283.8591	X
#371	SALT HANDLING SHAFT	9687.2300	6894.8900	X
#372	SALT HANDLING SHAFT HEADFRAME	9695.3448	6907.3502	X
#384	SALT HANDLING SHAFT HOISTHOUSE	9852.6805	6916.1393	4410
#384A	MINING OPERATIONS	9683.3922	6863.1621	800
#411	WASTE HANDLING BUILDING	9336.7209	7063.6333	154882
#412	TRUPACT MAINTENANCE BUILDING	9175.8015	6582.9848	11997
#413	EXHAUST SHAFT FILTER BUILDING	9490.0500	7362.6800	5058
#413A	MONITORING STATION A	9325.6000	7393.1100	100
#413B	MONITORING STATION B	9488.0204	7425.6068	144
#414	WATER CHILLER FACILITY & BLDG	9365.7562	6587.2805	80
#451	SUPPORT BUILDING	9469.5568	6872.0504	45632
#452	SAFETY & EMERGENCY SERVICES FACILITY	9484.5394	9484.5394	19240

BLDG./ FAC. #	DESCRIPTION	REFERENCE POINT COORDINATES NORTH	EAST	SQ FEET
#453	WAREHOUSE/SHOPS BUILDING	9718.7978	6546.2807	122760
#455	AUXILLIARY WAREHOUSE BUILDING	9699.9590	6655.3738	6000
#456	WATER PUMPHOUSE	9218.0108	6376.6654	2200
#457	WATER TANK 25-D-001A	9170.5000	6318.6946	X
#457	WATER TANK 25-D-001B	9211.0000	6318.6946	X
#458	GUARD AND SECURITY BUILDING	9457.1771	6385.3615	14640
#459	CORE STORAGE BUILDING	9879.0045	6486.4525	6000
#463	COMPRESSOR BUILDING	9392.6088	6646.3108	1440
#465	AUXILIARY AIR INTAKE	9453.6597	6995.3189	360
#468	TELEPHONE HUT	9453.9939	6663.0378	240
#473	ARMORY BUILDING	9477.8899	6385.3956	429
#474	HAZARDOUS WASTE STORAGE FACILITY	N/A	N/A	N/A
#474A	HAZARDOUS WASTE STORAGE BUILDING	9144.9771	6340.4470	280
#474B	HAZARDOUS WASTE STORAGE BUILDING	9144.6620	6314.1053	200
#474C	OIL & GREASE STORAGE BUILDING	9136.3868	6290.2802	900
#474D	GAS BOTTLE STORAGE BUILDING	9078.9088	6317.6154	450
#474E	HAZARD MATERIAL STORAGE BUILDING	9084.2706	6366.0304	603
#474F	WASTE OIL RETAINER	9143.7197	6364.8580	90
#475	GATEHOUSE	9518.4035	6333.6858	480
#480	VEHICLE FUEL STATION	N/A	N/A	N/A
#481	WAREHOUSE ANNEX	9746.6347	7460.0980	12768
#482	EXHAUST SHAFT HOIST EQUIP. WAREHOUSE	9280.2548	7239.6920	1350
#485	SULLAIR COMPRESSOR BUILDING	9816.2320	6983.1477	780
#486	ENGINEERING BUILDING	9676.0681	7192.4400	16625
#489	TRAINING BUILDING	9722.2749	7310.8119	10549
#H-16	SANDIA TEST WELL	9730.6897	6230.8379	X
#917	AIS MONITORING	9973.6341	6328.6247	444
#918	VOC TRAILER	9962.0881	6222.1074	660
#918A	VOC AIR MONITORING STATION	9946.2026	6245.1185	100
#918B	VOC LAB TRAILER	9978.6466	6301.5732	1915
#950	WORK CONTROL TRAILER	9882.5303	6647.7644	6175
#951	PROCUREMENT/PURCHASING	9808.4009	6647.6685	5200

BLDG./ FAC. #	DESCRIPTION	REFERENCE POINT COORDINATES NORTH	EAST	SQ FEET
#952	TRAILER	9851.0080	6741.1200	5700
#953	OFFICE COMPLEX 953	9791.1650	6485.9230	3572
#971	HUMAN RESOURCES TRAILER	9935.3488	6450.6912	1625
#986	PUBLICATIONS & PROCEDURES TRAILER	9934.9755	6545.6070	2025
SWR NO.6	SWITCHRACK NO. 6	9554.3514	7407.4429	X
SWR NO.7,7A,7B	SWITCHRACK NO. 7, 7A, 7B	9978.5680	6380.7536	X
SWR NO.7C	SWITCHRACK NO. 7C	9978.5680	6380.7536	X
SWR NO.10	SWITCHRACK NO. 10	9143.6425	6286.4822	X
SWR NO.11	SWITCHRACK NO. 11	9312.8690	7338.6302	X
SWR NO.12	SWITCHRACK NO. 12	9894.5651	6960.0448	X
SWR NO.16	SWITCHRACK NO. 16	9689.9590	6669.7071	X
COMPACTOR	25-H-010	9966.7360	6902.9280	X
BALER	25-H-011	9967.3162	6923.9191	X

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TITLE
DEFENSE WASTE
SALT REPOSITORY
CASE 1
SITE PLOT PLAN

SRP DRAWING NO. DWR-P-SK-00005
SHEET NO. 2 OF 2
DRAWING REV. A

LAST CADD REV. BY:
DATE:

Scale shown on this drawing is only applicable when plotted at 30"x42" (actual drawing size)

Figure 4-7B Case 1 WIPP Surface Facilities, Sheet 2 – Lag Storage Area and Structures List

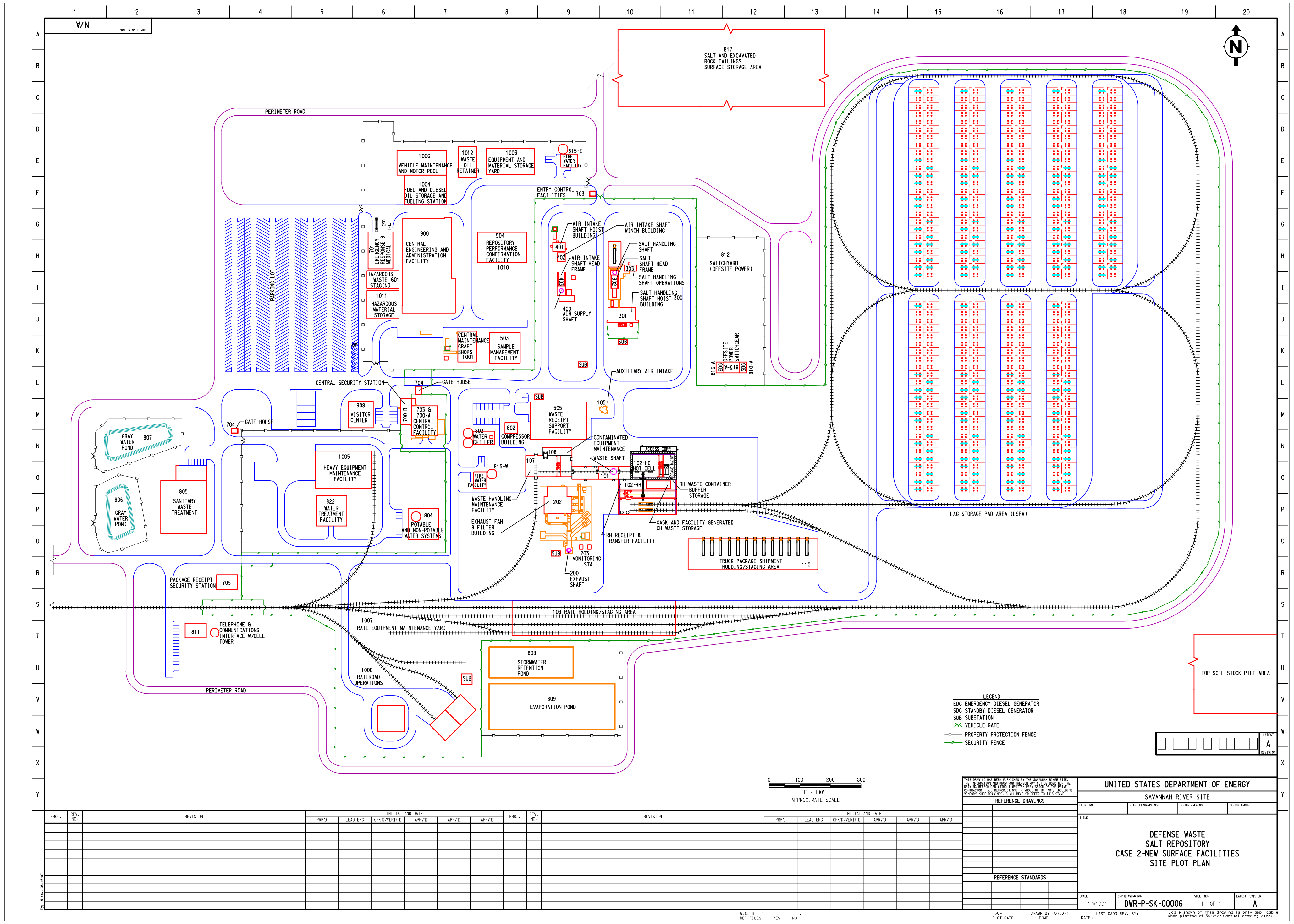


Figure 4-8 Case 2 WRTF Surface Facilities Site Plot Plan

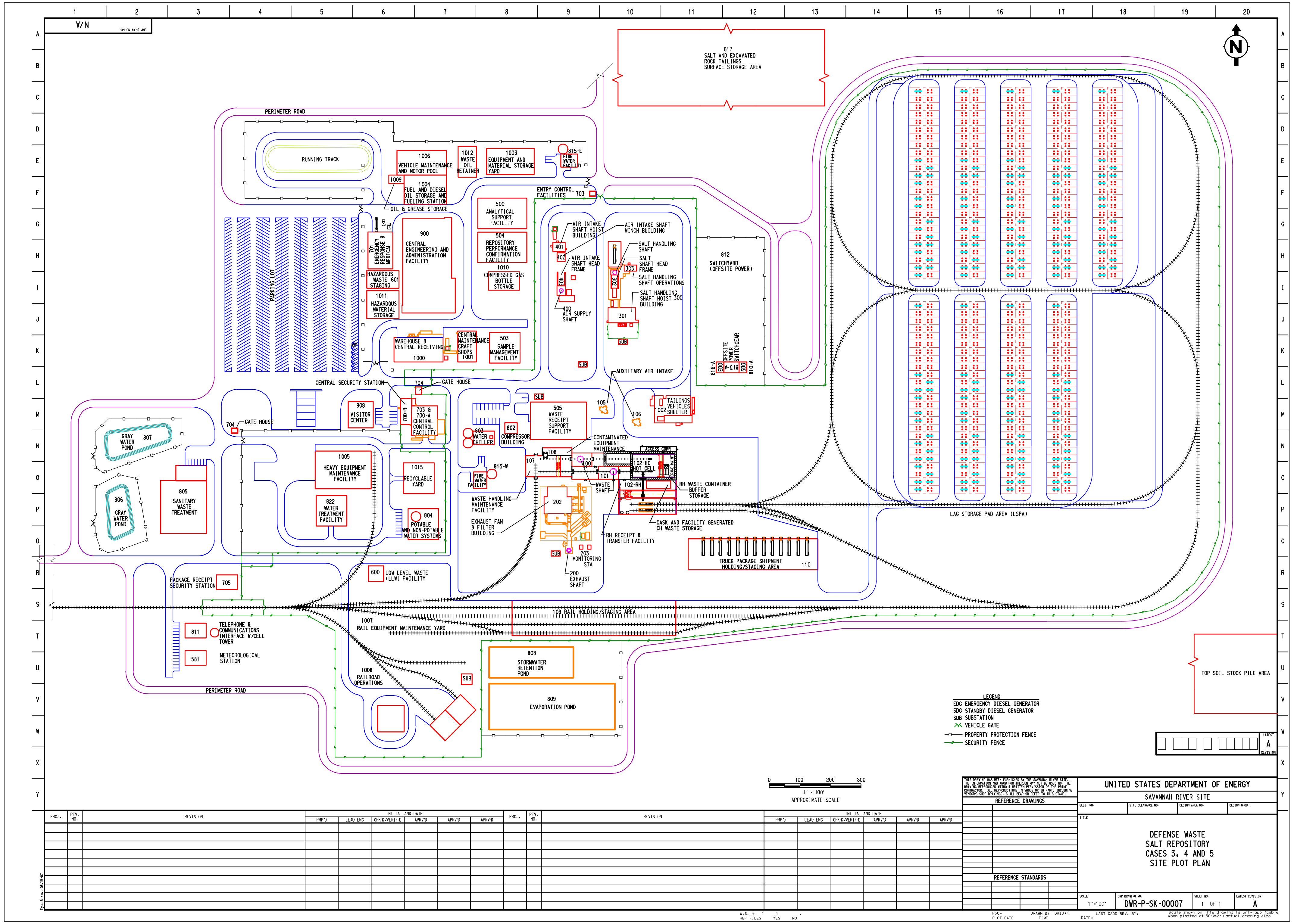


Figure 4-9 Cases 3, 4, 5 WRTF Surface Facilities Site Plot Plan

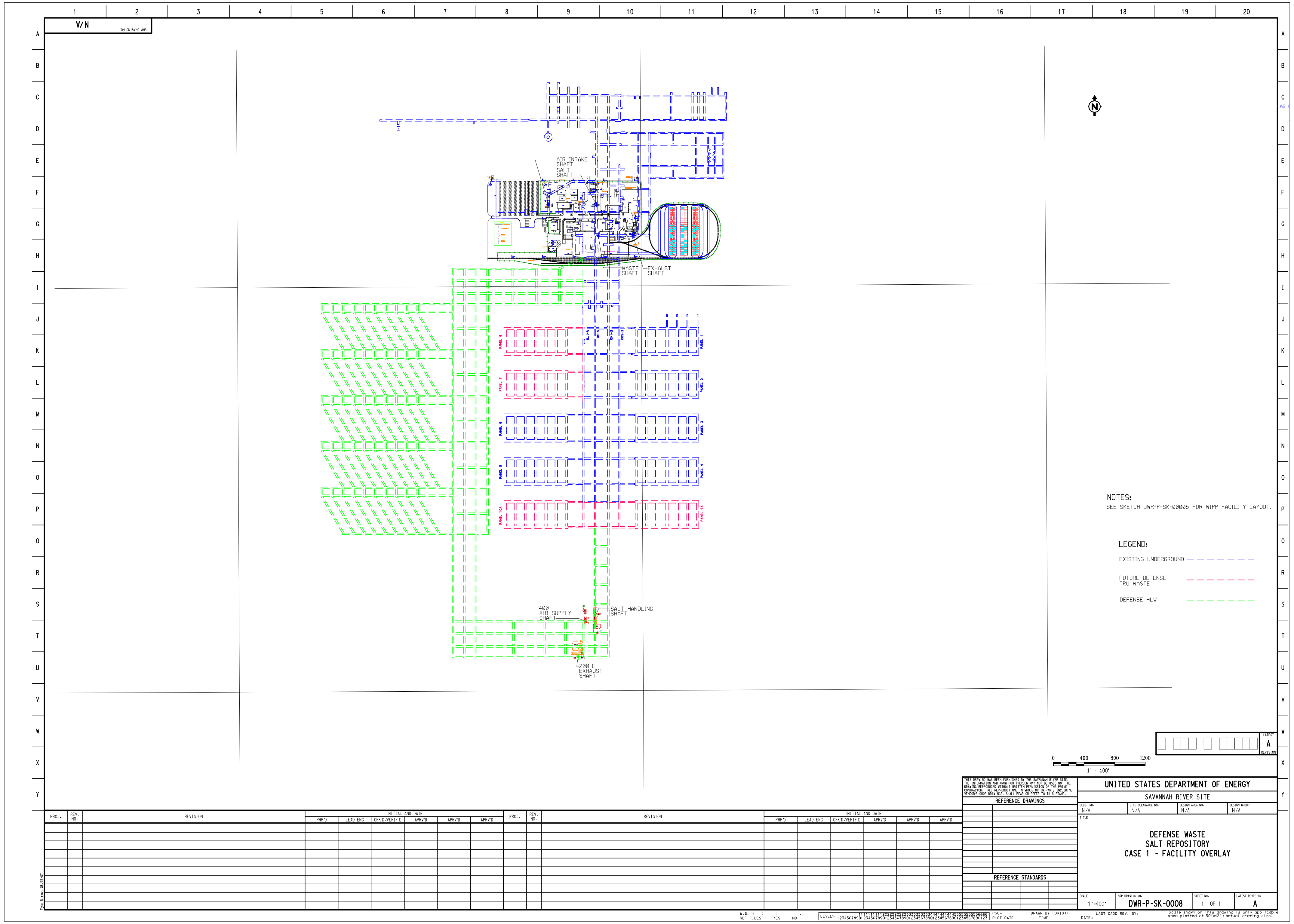


Figure 4-10 Case 1 Surface Facilities and Underground Overlay

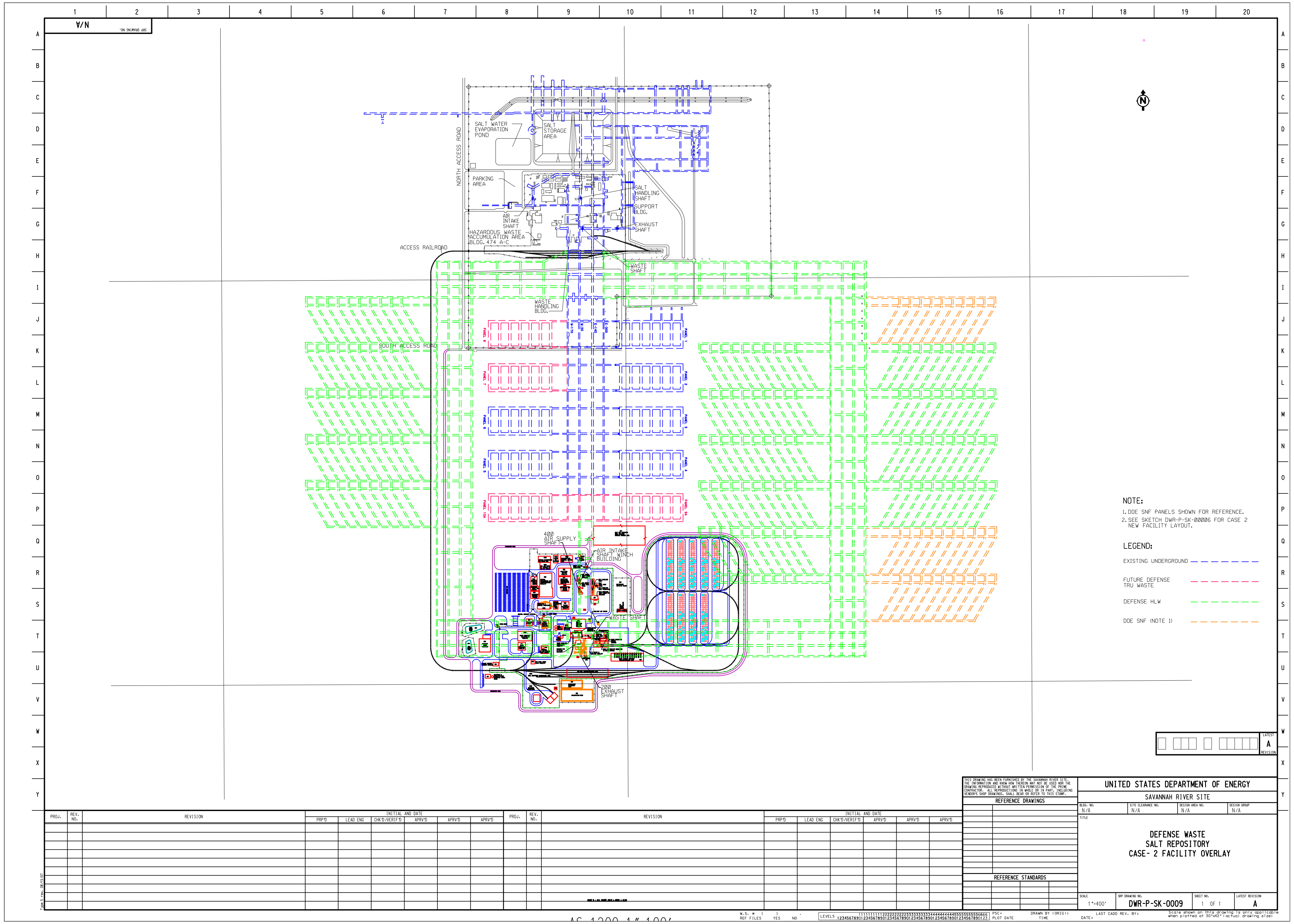


Figure 4-11 Case 2 Surface Facilities and Underground Overlay

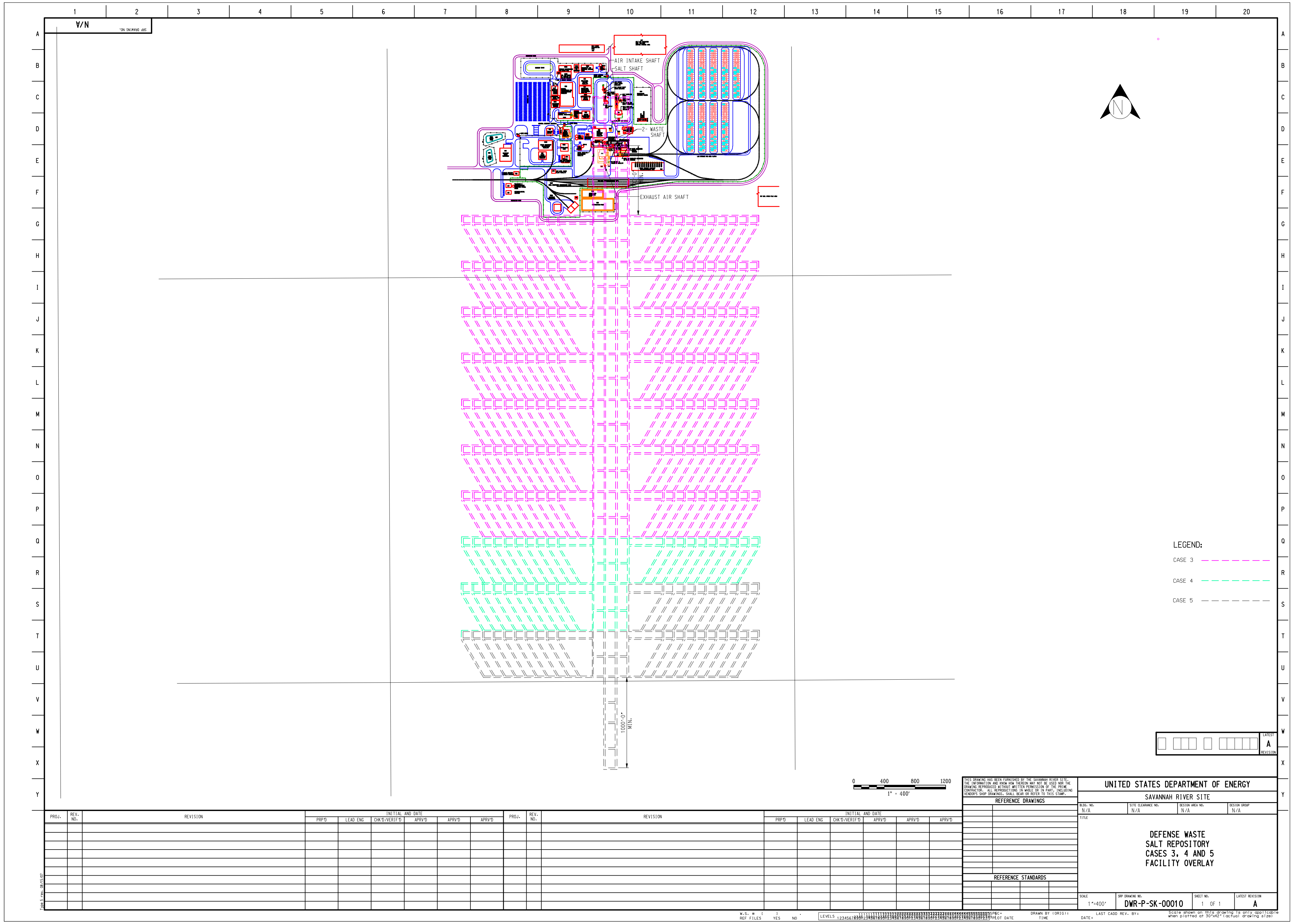


Figure 4-12 Cases 3, 4, 5 Surface facilities and Underground Overlay

Table 4-3 Emplacement Drift Single Pass Mining Length

		Case 1	Case 2	Case 3	Case 4	Case 5
Total Mains	**Lin Ft**	**270600**	**644700**	**251400**	**251400**	**251400**
TPC	Lin Ft	270600	270600	251400	251400	251400
LCC	Lin Ft		374100			
Total Panels	**Lin Ft**	**151000**	**422800**	**422800**	**513400**	**604000**
TPC	Lin Ft	24200	30200	30200	30200	30200
LCC	Lin Ft	126800	392600	392600	483200	573800
Annual in LCC	Lin Ft	3200	9800	9800	12100	14300
Grand Total	**Lin Ft**	**421,600**	**1,067,500**	**674,200**	**764,800**	**855,400**

Based on experience with mining salt in the United Sates and with WIPP specifically, a mining rate of 40 feet per day per mining machine is a reasonable assumption. The crew size required to support each mining machine is then used to establish the cost of the mining operations.

5. Surface and Underground Support Facilities

Surface facilities for the DWR are developed for the five cases ranging from Case 1, with WIPP existing surface facilities providing the majority of surface infrastructure needed to emplace the ~7600 SRS canisters over the DWR mission life, with very limited additional surface facility additions, to Cases 2 through 5 which provide additional surface and underground infrastructure in order to handle the additional inventory.

5.1 Waste Receipt and Transfer Facility Concept

The central concept for a waste receipt and transfer facility (WRTF) complex is that the complex provides the infrastructure to receive inbound waste transportation packages containing waste containers (Note: The terms transportation packages, shipping containers , transportation casks and shipping casks are standard industry terms for the vessels containing waste containers during shipment and are used interchangeably herein) provide interim sealed storage for some of the packages, unload the packages in a suitable radiologically shielded area, transfer the waste containers to shielded containers for transfer to the emplacement area, where the containers are then moved to the underground disposal area and emplaced. As described below, for each of the 5 cases, the WRTF for the DWR is discussed in terms of surface facilities, shafts and underground areas. Surface facilities provide the infrastructure to receive waste, unpackage it, transfer it to the underground repository horizon and associated surface infrastructure to support surface and underground operations. Shafts connect surface and underground areas to provide ventilation supply and exhaust air, mine excavation debris transfer to the surface, waste package transfer to the underground and personnel transport between surface and underground areas.

Principle WRTF differences for the DWR cases are summarized immediately below and developed more fully for each in the sections that follow.

For Case 1 the existing WIPP facility infrastructure provides most of the necessary surface capability and allows for expansion of the shaft and underground elements as an extension of the existing underground shafts and mains.

Extensions to WIPP can also be made to accomplish Case 2, with the addition of a new surface WRTF facility south of WIPP. A new generic complex can be sited for Case 3-5 as outlined below. Although estimates were not developed in this study related to this observation, it was also noted, as can be seen on Figures 4-5 and 4-11, that sufficient underground space should exist to potentially accommodate Cases 3-5 (20 panels total), at WIPP, with a new surface WRTF facility south of WIPP.

The primary surface facility additions for Case 1 involves addition of a surface lag storage pad for 180 days of processing throughput[40], as seen on Figure 4-7B, which is estimated at approximately 100 loaded inbound transportation casks and impact limiters and approximately 50 unloaded outbound casks and impact limiters. Approximately 8.25 acres and one cask shuttle crane crawler are assigned for this lag storage, conceptually located east of the current WIPP facility footprint in this study & layout.

Lag storage for this case could alternately be considered south of the existing WIPP facility rail area, although an underlying consideration for all lag storage pad areas in this study was to locate them beyond the facility's central area of rail and truck transport traffic, once received on site, in order to locate them where loaded waste transportation package transfers into the WHB and empty waste transportation packages returned from the WHB would not create additional traffic at the central area of facility rail and truck traffic. Once received, transportation package transfers to and from the lag storage pads, shown on Figure 4-7B and the WHB can, thus, take place independent of the facility's central transportation hub.

For this case a new air intake and air exhaust shaft will be provided south of the current mission footprint, with attendant surface infrastructure, including exhaust filter building, air intake shaft hoist building, air intake shaft winch building, exhaust shaft monitoring station, air intake shaft head frame, salt handling shaft hoist building, salt handling shaft operations building, salt handling shaft head frame and tailings vehicle shelter. These new shaft surface infrastructure elements, for Case 1, will be located approximately one mile south of the current WIPP facility surface facilities at the south end of new underground mains provided for the DWR. (see Figure 4-10)

Case 2 processes a much larger inventory of defense waste, involving waste packages of different sizes and weight. The Hanford canisters, which comprise almost 50% of the inventory for Cases 2, are planned to be 15 ft. long. Two factors combine to require a new remote handled WRTF facility at WIPP for Case 2: 1) The increase in defense waste packages from ~200 per year to ~600 per year and 2) the current WIPP remote handled waste facility will not accommodate the longer waste containers. On this basis a new remote handled WRTF complex can be located remote from the current WIPP facility, approximately one mile south. This complex will have similar surface infrastructure to WIPP with a larger lag storage pad complex than for Case 1, as shown on Figure 4-8. Figure 4-5 depicts the underground and shaft expansion options, for a WIPP-based WRTF associated with case 2 (and potentially other cases if elected) and Figure 4-11 reflects the surface WRTF infrastructure overlayed on the underground.

The WRTF for Case 3 to 5, as a generic DWR, can be located at a generic location and would require the full complement of surface waste receipt, lag storage, waste package handling, and waste package unloading infrastructure and related surface & shafts facility support services infrastructure for waste transfer for subsurface emplacement. The underground elements for a generic Case 3-5 DWR reflect a different underground straight mains and adjacent panels layout from that of one based at WIPP, as can be seen on Figure 4-6. Figure 4-9 reflects the associated WRTF surface plot plan and Figure 4-12 reflects the surface and underground overlay.

The new WRTF surface facilities for Case 2 will be equipped with similar air supply & air exhaust and salt handling surface facilities as would be included as for Case 1, with one 50 ton capacity waste hoist. Two 50 Ton waste hoists would be provided for Cases 3-4 and, for Case 5, one of the two waste hoists would be 50 ton capacity and one waste hoist would be 400 ton capacity, in order to handle the much larger Naval fuel waste packages.

As noted earlier, it is important to recognize that a 400 ton capacity hoist, which would be needed to transfer Naval fuel to the underground for Case 5, is beyond current mining industry use. The design construction and operations of this hoist is potentially a high risk item and the team recommends other options be considered such as repackaging the Naval Fuel Canisters into smaller packages that could more readily be accommodated by standard industry shaft hoists.

For Cases 2-5, larger rail and truck lag storage capability would be provided, on the order of 24 acres, for loaded inbound transportation casks & impact limiters and unloaded outbound casks & impact limiters. The new WRTF receipt facility would support package receipt and transfer to the underground through one new waste unloading area and waste shaft transfer path for Case 2 and two waste unloading areas & waste shaft transfer paths for Cases 3-5.

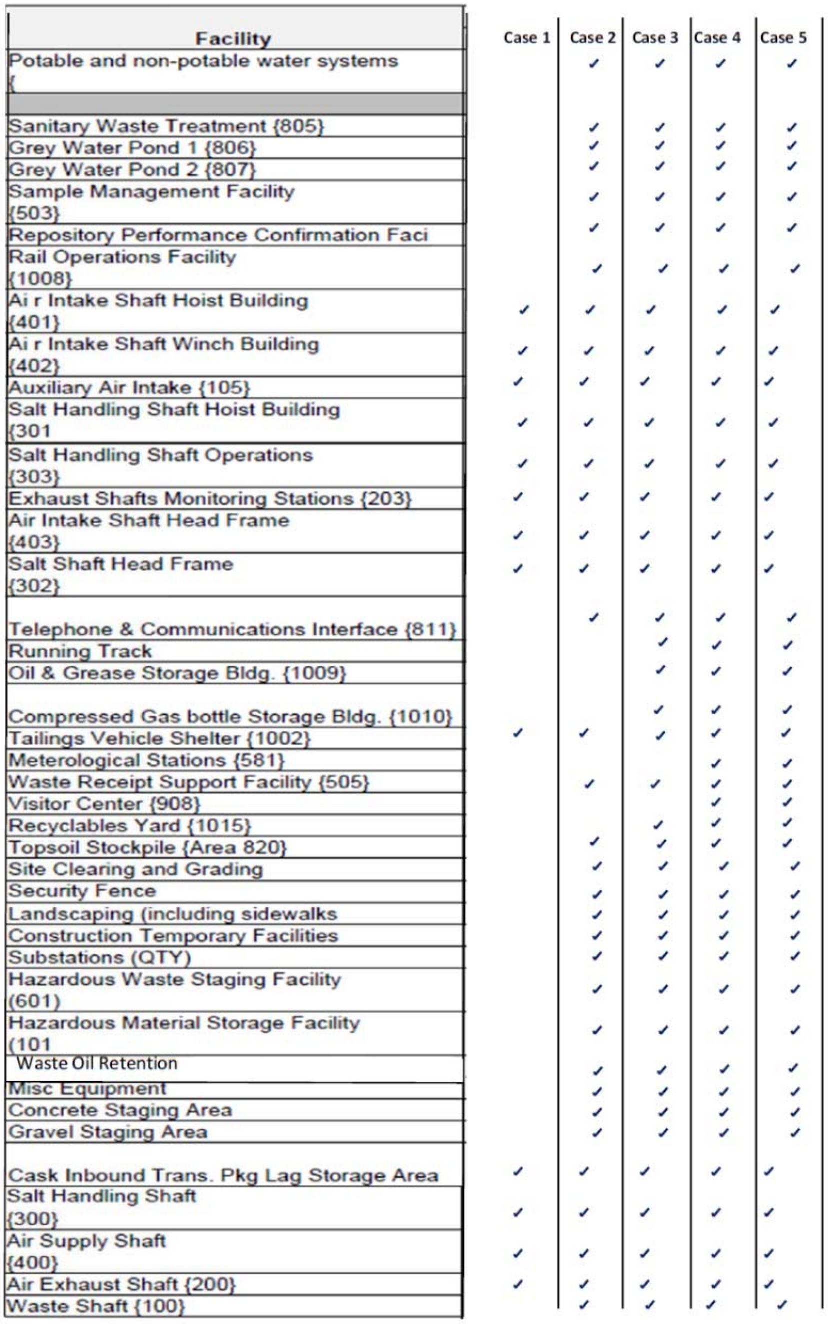
Table 5-1 summarizes key surface facility infrastructure elements for the five cases. The sections that follow provide more detailed discussion regarding the function and makeup of the principle surface and subsurface elements.

Table 5-1 Facility Listing for All Cases

Facility	Case 1	Case 2	Case 3	Case 4	Case 5
102-RH		✓	✓	✓	✓
102HC		✓	✓	✓	✓
109 - Rail Staging		✓	✓	✓	✓
110 - Truck Staging		✓	✓	✓	✓
Low Level Waste (LLW) Facility {600}			✓	✓	✓
Central Control Facility { 700A}		✓	✓	✓	✓
Waste Handling Maintenance Bldg 107		✓	✓	✓	✓
Cont. Equipment Maintenance Facility 108		✓	✓	✓	✓
Heavy Equipment Maintenance Facility {1005}		✓	✓	✓	✓
Warehouse & Central Receiving {1000}			✓	✓	✓
Analytical Support Facility {500}			✓	✓	✓
Emergency Diesel Generator Facility {816} {	✓	✓	✓	✓	✓
Compressor Building {802}	✓	✓	✓	✓	✓
Chilled Water Services and Cooling Tower	✓	✓	✓	✓	✓
Evaporation Pond(s) {809}	✓	✓	✓	✓	✓
Standby Diesel Generator Facility { 810	✓	✓	✓	✓	✓
Fuel & Diesel Oil Storage and Fueling St	✓	✓	✓	✓	✓
Switchyard (Offsite power) {812}		✓	✓	✓	✓
Offsite Power Switchgear Facility {813}		✓	✓	✓	✓
Fire Water Facility {815-E and 815-W}		✓	✓	✓	✓
Central Security Station {700B}		✓	✓	✓	✓
Package Receipt Security Station {705}		✓	✓	✓	✓
Stormwater Retention Pond {808}		✓	✓	✓	✓
Central Maintenance and Craft Shops {1001}		✓	✓	✓	✓
Exhaust filter building {202}	✓	✓	✓	✓	✓
Salt and Excavated Rock Tailings Surfac	✓	✓	✓	✓	✓
Emergency Response & Medical {701} (3 I		✓	✓	✓	✓
Entry Control Facilities {703}		✓	✓	✓	✓
Gate House {704}		✓	✓	✓	✓
Equipment and Materials/Yard Storage {1		✓	✓	✓	✓
Central Engineering and Administration F		✓	✓	✓	✓
Vehicle Maintenance & Motor Pool {1006}		✓	✓	✓	✓
Parking		✓	✓	✓	✓
Paved Roads		✓	✓	✓	✓
Gravel Roads		✓	✓	✓	✓
Railroads	✓	✓	✓	✓	✓

✓ = Infrastructure provided in addition to WIPP as applicable to case scope.

Table 5-1 (Continued)



Facility	Case 1	Case 2	Case 3	Case 4	Case 5
Potable and non-potable water systems {		✓	✓	✓	✓
Sanitary Waste Treatment {805}		✓	✓	✓	✓
Grey Water Pond 1 {806}		✓	✓	✓	✓
Grey Water Pond 2 {807}		✓	✓	✓	✓
Sample Management Facility {503}		✓	✓	✓	✓
Repository Performance Confirmation Faci		✓	✓	✓	✓
Rail Operations Facility {1008}		✓	✓	✓	✓
Ai r Intake Shaft Hoist Building {401}	✓	✓	✓	✓	✓
Ai r Intake Shaft Winch Building {402}	✓	✓	✓	✓	✓
Auxiliary Air Intake {105}	✓	✓	✓	✓	✓
Salt Handling Shaft Hoist Building {301	✓	✓	✓	✓	✓
Salt Handling Shaft Operations {303}	✓	✓	✓	✓	✓
Exhaust Shafts Monitoring Stations {203}	✓	✓	✓	✓	✓
Air Intake Shaft Head Frame {403}	✓	✓	✓	✓	✓
Salt Shaft Head Frame {302}	✓	✓	✓	✓	✓
Telephone & Communications Interface {811}		✓	✓	✓	✓
Running Track			✓	✓	✓
Oil & Grease Storage Bldg. {1009}			✓	✓	✓
Compressed Gas bottle Storage Bldg. {1010}			✓	✓	✓
Tailings Vehicle Shelter {1002}	✓	✓	✓	✓	✓
Meterological Stations {581}				✓	✓
Waste Receipt Support Facility {505}		✓	✓	✓	✓
Visitor Center {908}				✓	✓
Recyclables Yard {1015}			✓	✓	✓
Topsoil Stockpile {Area 820}		✓	✓	✓	✓
Site Clearing and Grading		✓	✓	✓	✓
Security Fence		✓	✓	✓	✓
Landscaping (including sidewalks		✓	✓	✓	✓
Construction Temporary Facilities		✓	✓	✓	✓
Substations (QTY)		✓	✓	✓	✓
Hazardous Waste Staging Facility (601)		✓	✓	✓	✓
Hazardous Material Storage Facility (101		✓	✓	✓	✓
Waste Oil Retention		✓	✓	✓	✓
Misc Equipment		✓	✓	✓	✓
Concrete Staging Area		✓	✓	✓	✓
Gravel Staging Area		✓	✓	✓	✓
Cask Inbound Trans. Pkg Lag Storage Area	✓	✓	✓	✓	✓
Salt Handling Shaft {300}	✓	✓	✓	✓	✓
Air Supply Shaft {400}	✓	✓	✓	✓	✓
Air Exhaust Shaft {200}	✓	✓	✓	✓	✓
Waste Shaft {100}		✓	✓	✓	✓

A general discussion of the existing WIPP facility surface and underground infrastructure is provided below, together with a discussion of principle WRTF differences for the various cases. In general, the WRTF process and handling elements discussed below and in the following sections apply across the cases and may be used as a reference to note key differences across the case discussions, by exception.

Section 5.2 provides additional details of the proposed layouts of the surface facilities, their functions and principle equipment, for the DWR cases. Section 5.3 provides additional details of underground elements of the DWR**.** Section 5.4 provides additional images of key equipment associated with waste handling and transfer.

WIPP Facility

The Waste Isolation Pilot Plant (WIPP) facility is designed to safely manage, store, and dispose of transuranic (TRU) and TRU mixed waste that originated from the defense activities of the United States. The layout and operation of the WIPP facility have been modified in this description to describe the disposal of defense high-level waste (DHLW) generated at the Savannah River Site (SRS) for Case 1 and all of the Department of Energy (DOE) DHLW (Case 2).

The WIPP site has three zones. The Property Protection Area (PPA) is surrounded by a chain-link security fence, encompasses about 60 acres, and provides security and protection for all major surface structures and a lag storage yard for DHLW canisters in their shipping casks. The WIPP Off-Limits Area encloses the PPA, and contains approximately 1,454 acres. These areas define the WIPP exclusion zone within which certain activities, items, and material are prohibited. The final zone is marked by the WIPP Site Boundary and is the so-called WIPP land withdrawal area (LWA), a 16-section federal land area under the jurisdiction of the U. S. Department of Energy (DOE).

Access to the WIPP facility is either by road or rail. The WIPP access road ties to US Highway 62-180 about 12 miles north of the WIPP site. Rail access is available along a spur railroad that ties to an industrial spur from the Burlington-Northern Santa Fe Rail Road about, 7 miles to the west.

Three basic groups of structures are associated with the WIPP facility: surface structures, shafts, and underground structures. The layout and relative positions of these structures are illustrated in Figures 5-1 and 5-2. Figures 4-7A and 4-7B provide additional data on the titles and locations of facility surface structures.

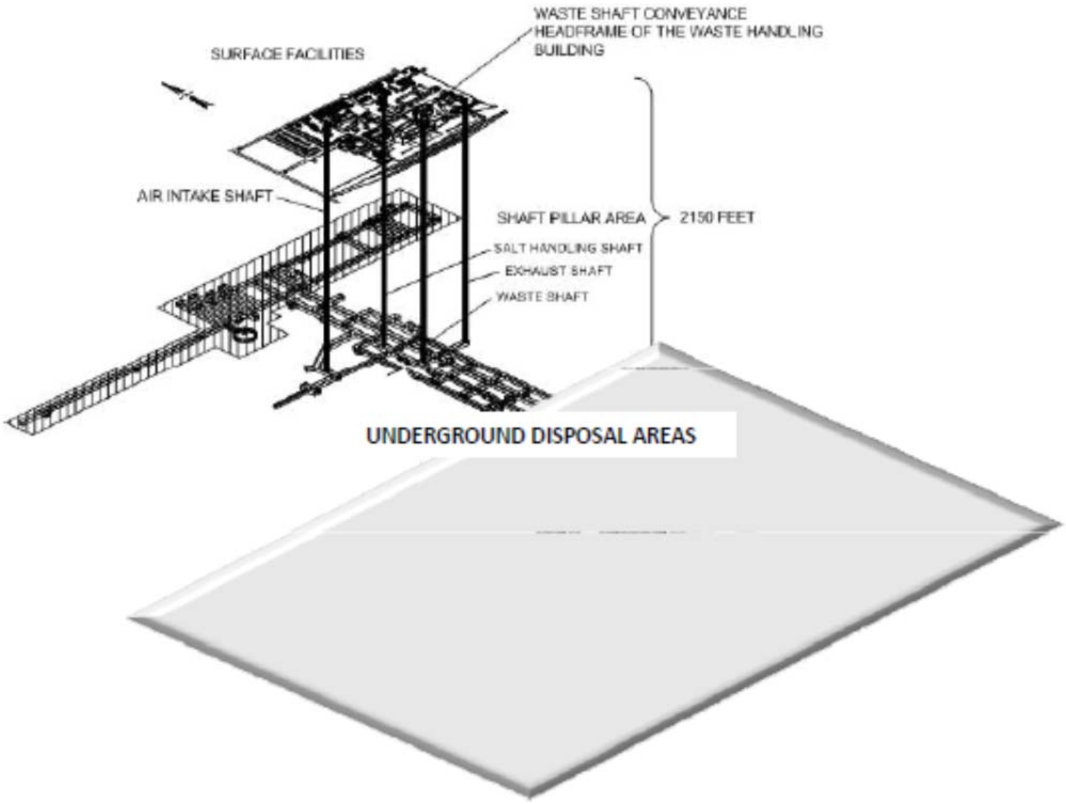


Figure 5-1 General Layout Of The WIPP Facility Relative To The Underground

The following are descriptions of those portions of the WIPP facility that will be used to safely manage and store defense waste for disposal in the underground repository.

Surface Facilities

The surface structures will accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of defense waste from the surface to the underground.

The WHB is the primary surface facility where DWR waste container handling activities will take place, for removal from their transportation packages and transfer of the waste packages to the underground repository. This could be in the existing WIPP WHB (Case 1) or in a new WRTF WHB facility, similar to WIPP but located south of WIPP for other DWR cases. The WHB is designed to meet DOE design and associated quality assurance requirements. The WHB RH Complex is the area within the WHB designed for the interim management, handling of defense waste prior to transfer underground. The RH Complex includes several areas: the RH bay, the Cask Unloading Room, the Hot Cell, the Transfer Cell, and the Facility Cask Loading Room. Figure 5-3 and Figure 5-10 reflect the WHB RH Complex for Case 1 and 2 respectively.

The details of the facilities and operations on the surface and underground at the WIPP facility, in support of the DWR mission, are contained in this section in conjunction with the discussions of the Cases in Sections 5.2 and 5.3 and the images provided in Section 5.4.

There are three primary surface locations where the waste will be managed.

The first surface waste management area is the Parking Area Container Storage Unit (PAU), an outside waste container storage area that extends south from the Waste Handling Building (WHB) to the railroad tracks (see Figures 5-2, 4-7A and 4-7B).

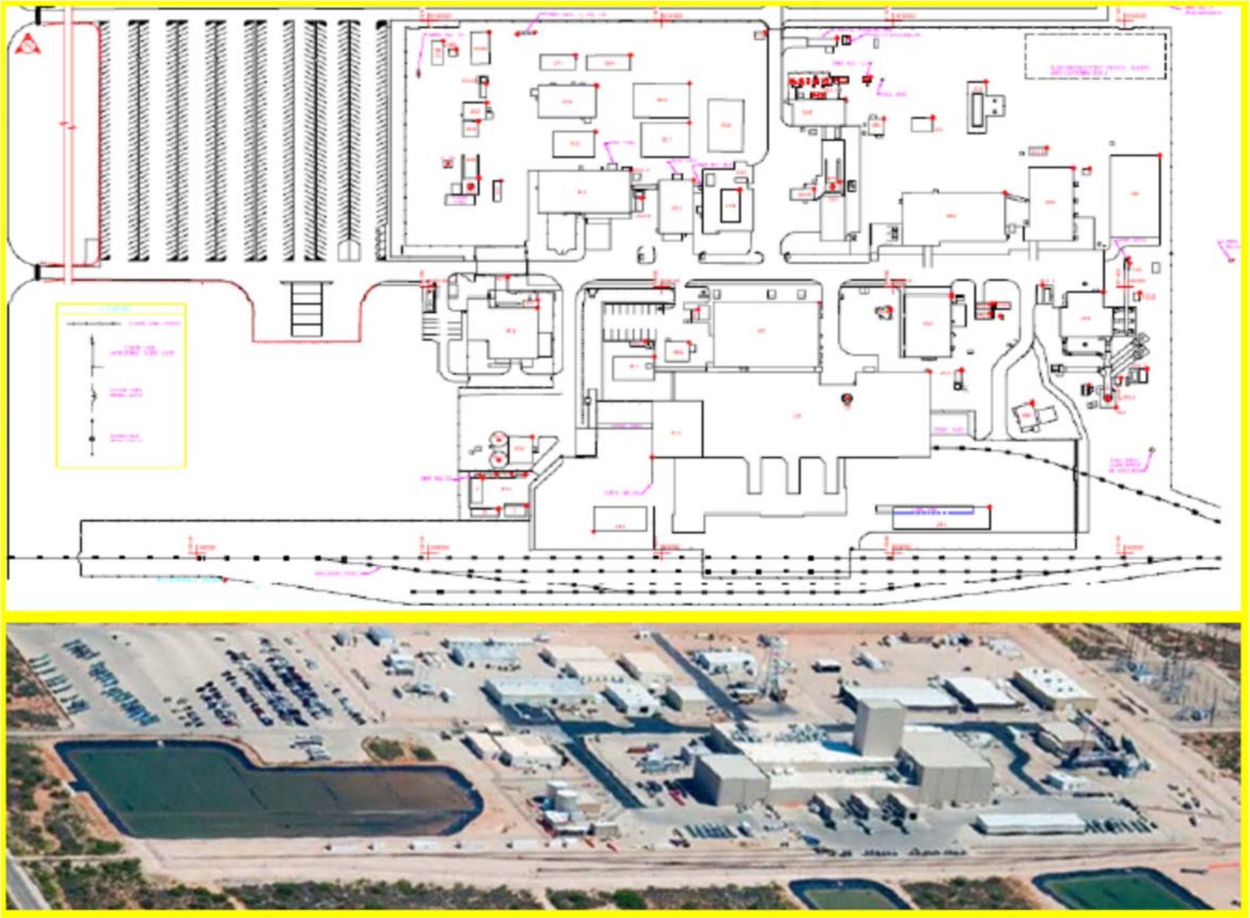


Figure 5-2 WIPP Facility Structures Plot Plan And Aerial View

The PAU is located south of the WHB and used for interim storage of waste containers within sealed transportation casks. Secondary containment and protection of the waste containers are provided by the sealed transportation casks. Waste placed in the PAU remains sealed in the casks at all times while in this area. In addition to the storage for the existing facility TRU waste mission, the PAU adjacent to each WHB will provide interim storage space for loaded transportation casks awaiting transfer into the WHB, for Cases 1 and 2.

The second surface management area includes the portion of the WHB, designated as the Remote-Handled (RH) Waste Complex, which prepares waste packages for transfer to the subsurface facilities. Within the RH Waste Complex, transportation casks are received and their waste containers are removed and transferred to a shielded facility package, in preparation for transfer to the emplacement location. When loaded, the shielded package is transferred to the waste shaft, to lower it to the underground DWR horizon. Figure 5-3 provides details of the current WIPP RH Waste Complex as will be employed for Case 1. For Case 2, a second RH Waste Complex will be constructed, at a new WRTF WHB, located south of the existing WIPP facility (Figure 4-8 and Figure 4-11), to enable processing of the additional waste associated with each case, concurrent with the current WIPP mission. Its functional features will be similar to the existing RH portion of the WIPP Waste Complex and associated support facilities but it will provide most of the surface infrastructure needed to support concurrent DWR operations at the remote location, south of WIPP.

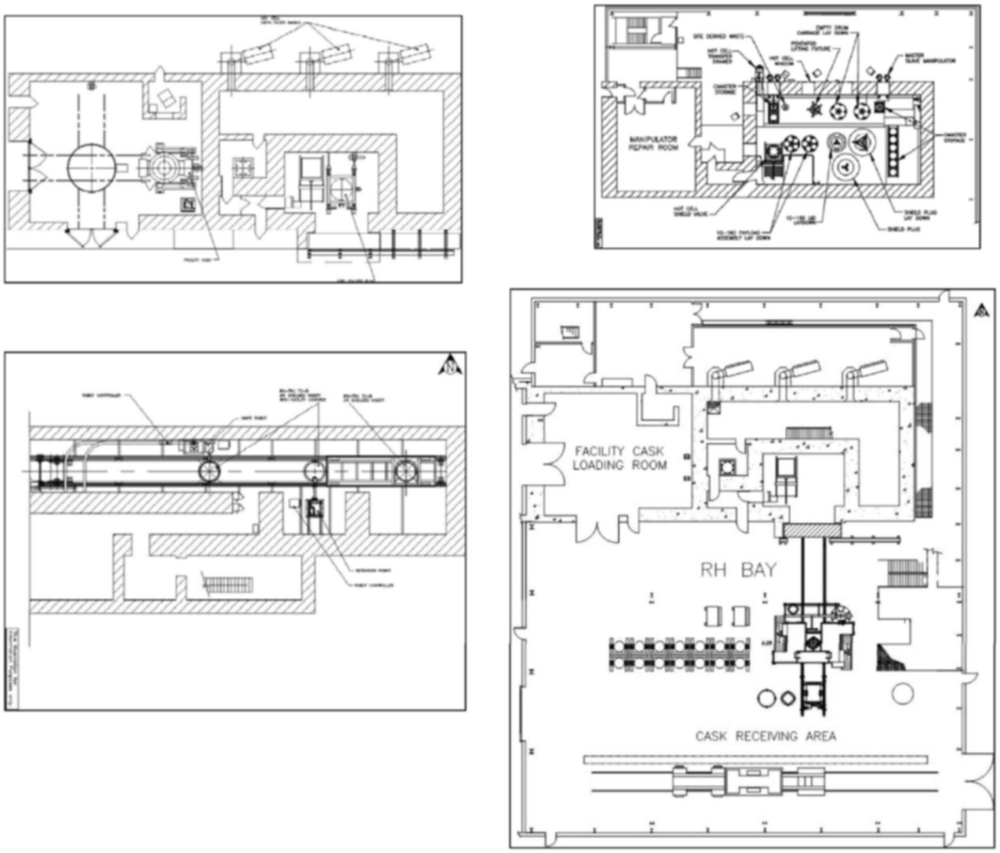


Figure 5-3 General Layout Of The WIPP DHLW RH Waste Handling Complex

The third surface defense waste management location will be a transportation package lag storage pad area (LSPA), located near to the WHB for each case. The purpose of the LSPA is to store approximately one half of one year's defense waste processing throughput shipments[40] on an asphalt, compacted material and concrete surface while awaiting selection for processing and rail or truck facility shuttle carrier (FSC) transfer into the WHB for processing, unloading and emplacement. Sealed shipping casks will be laid horizontally on prefabricated saddle blocks, distributed across the LSPA, pending transfer between the LSPA and the WHB, or transfer of the empty transportation package offsite. The LSPA for Case 1 is conceptually proposed to encompass approximately 8.25 acres (See Figure 4-7B) and allow interim storage of approximately 100 inbound and 50 outbound transportation casks and their impact limiters. The LSPA will be equipped with a cask crane crawler (CCC) to allow packages to be transferred between inbound, outbound facility FSC and offsite carrier transports and their respective LSPA pad positions.

For Case 2, as with Case 1, the LSPA will be located east and near to the new WRTF WHB to be constructed south of and remote from the current WIPP facility(see Figure 4-8). It will serve the same purpose as for Case 1 and will be sized for a larger inventory of inbound & outbound transportation casks and impact limiters. Up to 24 acres is reserved for this area, allowing for management of up to 350 inbound and 100 outbound transportation packages and their impact limiters.

Shafts

Figure 5-1 depicts the current WIPP shafts connecting the surface facilities to the underground subsurface emplacement area, where the WIPP underground structures are located in a mined salt bed, 2,150 ft. below the surface. Additional shafts will be added to the original WIPP design to accommodate the DWR mission. These new shafts will be located south of the existing WIPP facility, as seen on Figures 4-5 and 4-10, for Case 1, and Figure 4-11 for Case 2.

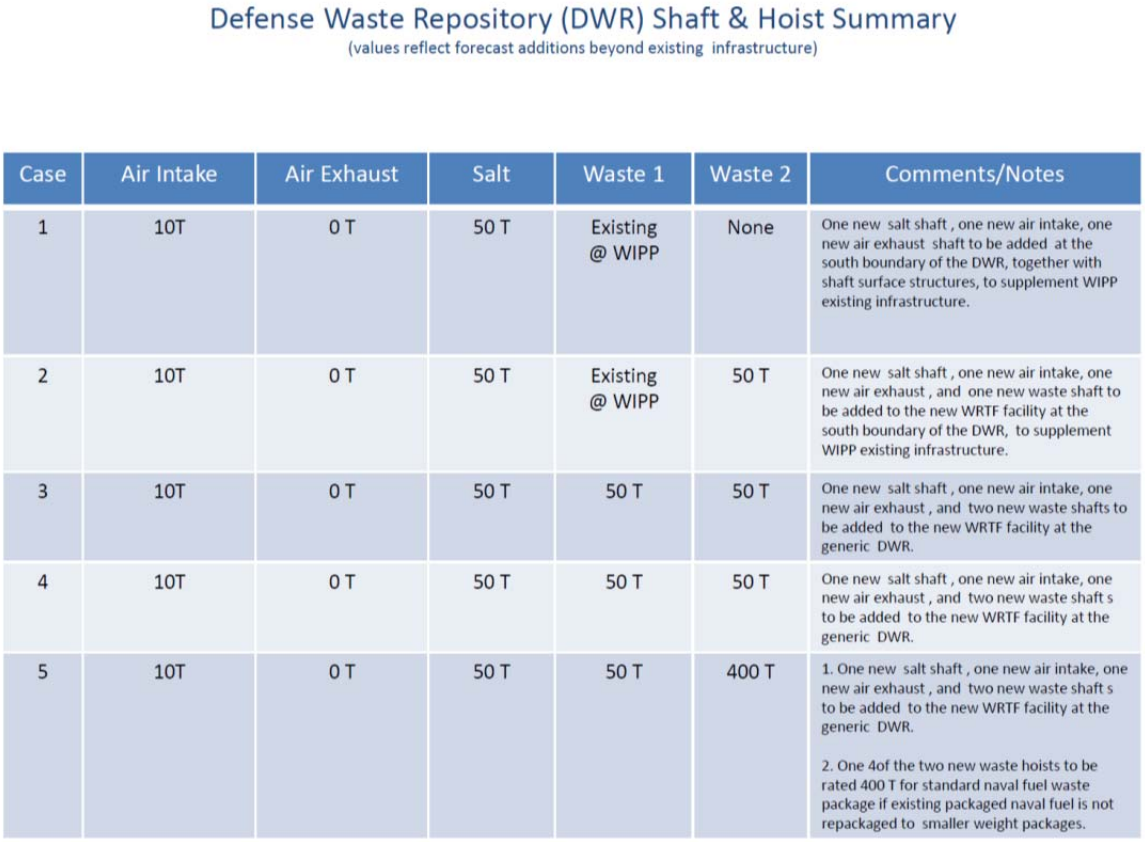
The underground structures to be added (Figures 4-4 and 4-5) include the new panels of underground Defense Waste Disposal Units (DWDUs), the shaft pillar areas, interconnecting drifts, and other underground areas.

For Case 1 one new salt shaft, one new air supply shaft and one new air exhaust shaft will be provided at the south of the new subsurface mains and panels to be constructed. This will support the ventilation and salt removal associated with the new mains for this case, concurrent with current WIPP operations. Waste transfer to the underground will employ the existing WIPP waste shaft at the current WIPP Facility.

For Case 2 the new salt shaft, one new air supply shaft and one new air exhaust shaft to be provided, as per Case 1, at the south of the new subsurface mains and panels, will be supplemented by a new waste shaft constructed at the new WRTF WHB facility, located south of WIPP. This will allow the new WHB to process the increased amount of defense waste concurrent with current WIPP mission operations.

For Cases 3-5, if constructed at WIPP, a second waste shaft would be provided, in addition to those of Case 2, at the new WRTF WHB facility, located south of WIPP.

Figure 5-4 provides a summary of the new shafts and associated hoists which would be added for Cases 1-5.



Defense Waste Repository (DWR) Shaft & Hoist Summary

(values reflect forecast additions beyond existing infrastructure)

Case	Air Intake	Air Exhaust	Salt	Waste 1	Waste 2	Comments/Notes
1	10T	0 T	50 T	Existing @ WIPP	None	One new salt shaft , one new air intake, one new air exhaust shaft to be added at the south boundary of the DWR, together with shaft surface structures, to supplement WIPP existing infrastructure.
2	10T	0 T	50 T	Existing @ WIPP	50 T	One new salt shaft , one new air intake, one new air exhaust , and one new waste shaft to be added to the new WRTF facility at the south boundary of the DWR, to supplement WIPP existing infrastructure.
3	10T	0 T	50 T	50 T	50 T	One new salt shaft , one new air intake, one new air exhaust , and two new waste shafts to be added to the new WRTF facility at the generic DWR.
4	10T	0 T	50 T	50 T	50 T	One new salt shaft , one new air intake, one new air exhaust , and two new waste shaft s to be added to the new WRTF facility at the generic DWR.
5	10T	0 T	50 T	50 T	400 T	1. One new salt shaft , one new air intake, one new air exhaust , and two new waste shaft s to be added to the new WRTF facility at the generic DWR. 2. One 4of the two new waste hoists to be rated 400 T for standard naval fuel waste package if existing packaged naval fuel is not repackaged to smaller weight packages.

Figure 5-4 - Defense Waste Repository Shaft Summary

Subsurface Areas

The WIPP underground disposal area is located in a thick, relatively impermeable formation of salt known as the Salado Formation (Salado). The Salado consists mainly of halite and anhydrite (see Figure 5-5). A considerable amount of information about the hydraulic properties of halite has been collected through field and laboratory experiments. Hydraulic tests have been performed in both impure and pure halite. Interpreted permeabilities using a Darcy-flow model vary from 1×10^{-23} to 4×10^{-18} square meters.

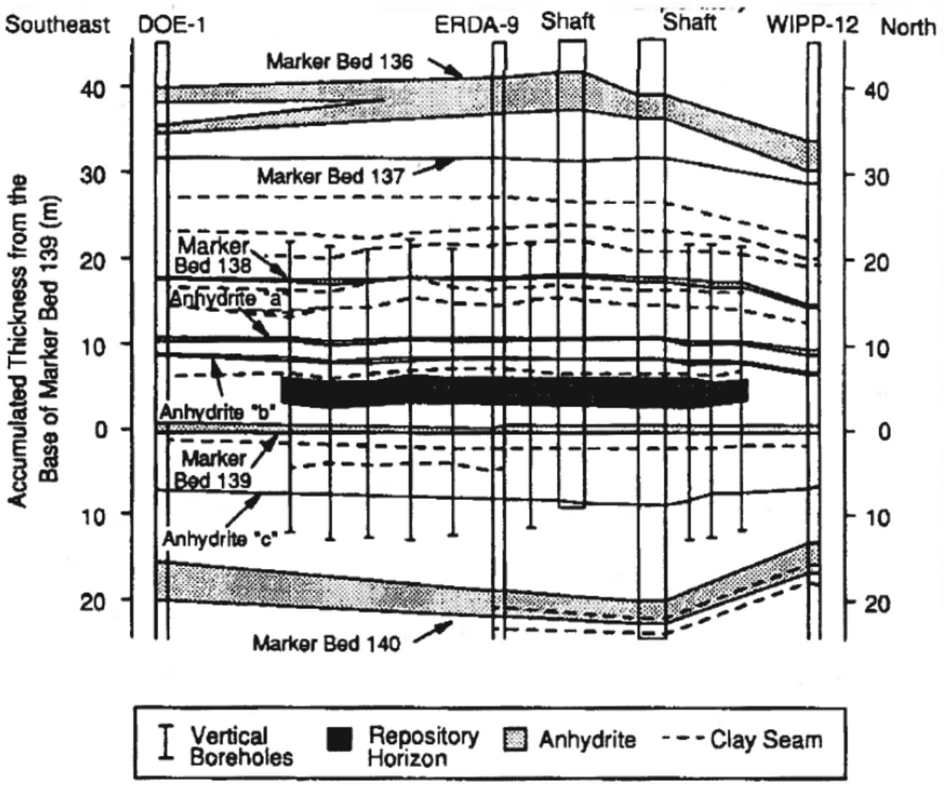


Figure 5-5 Cross Section of the SALADO Formation at the Repository Horizon

Numerous studies of the geohydrologic conditions in the area around the WIPP site have identified three principal water-bearing zones above the disposal area and one below. These zones above the Salado are the contact between the Rustler Formation (Rustler) and the Salado, the Culebra Dolomite Member (Culebra) of the Rustler, and the Magenta Dolomite Member (Magenta) of the Rustler (see Figure 5-6). The water bearing zone below the Salado consists of channel sandstones in the Bell Canyon Formation (Bell Canyon). Studies indicate that these water-bearing zones are effectively isolated from the disposal area by relatively impermeable evaporite strata.

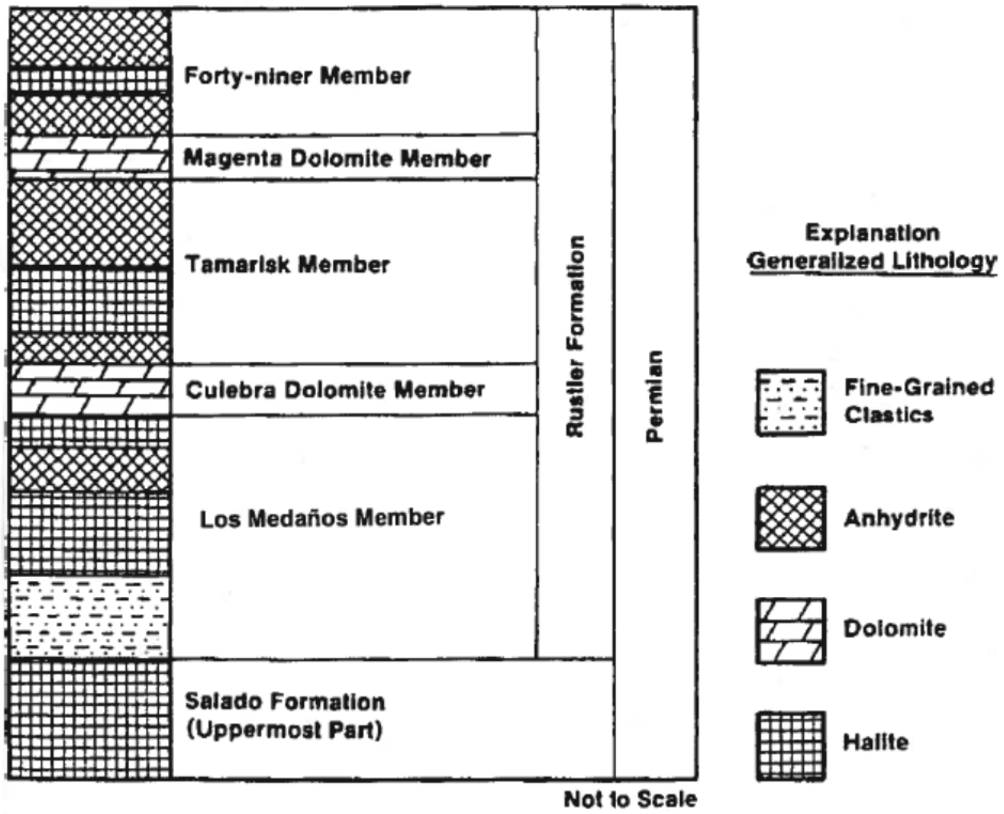


Figure 5-6 Geologic Column of the Rustler Formation

For cases 1 and 2 the DWR will be located as an extension of the existing WIPP underground facility horizon.

For these cases, underground Defense Waste Disposal Units (DWDUs) are added to the existing WIPP underground infrastructure to provide extensions to the existing subsurface complex to emplace waste for each case considered.

The underground DWDUs for Case 1 is defined as DWR panels D1 through D5 consisting of ten rooms and four access drifts off of the main drifts. Each of the ten emplacement rooms in a panel is approximately 500 ft. long, 20 ft. wide, and 10 ft. high, with 50 ft. added at each end for closure with salt backfill, or 600 feet overall. The rooms are separated by 100-ft-thick salt columns.

The underground DWDUs for Case 2, depicted on Figure 4-5 also show that additional underground space exists to potentially accommodate panels which could be used to accommodate other cases.

5.2 Surface Facilities and Support Services

The discussions that follow describe facility elements in the context of WIPP infrastructure and operations and, generally, will be similar in function and operation for all cases, unless noted otherwise.

5.2.1 Waste Receipt and Transfer Facility (WRTF) Concept

As noted earlier, the central concept for a WRTF is to provide surface and underground infrastructure to receive loaded waste packages, store them on an interim basis, transfer them to a handling facility where they can be moved into a shielded area for waste container unloading & placement into a shielded container, for transfer underground for emplacement. This section will review the principle surface infrastructure related to WRTF surface operations.

Defense waste canisters arrive in Type B shipping/transportation casks from the shipper site, by rail or truck carrier. It is assumed that shipping casks are used to transport canisters singly (one per cask), either with a single cask on a legal weight truck trailer, or multiple (up to 2) casks on a rail car. It is also assumed that, other than for Naval fuel that has not been repackaged, shipping casks will be similar to the RH 72-B shipping cask used for TRU waste, with additional shielding added to accommodate those canisters that exceed 1,000 Rem/hour. This additional shielding adds 50 percent to the weight of the RH 72-B cask. In addition, the shipping cask for 15 foot canisters of Hanford DHLW is assumed to be 50 percent larger than the cask for 10 foot waste forms. For Naval fuel that has not been repackaged for case 5, larger casks will be received. Also refer to Section 3.6 for further discussion on shipping casks.

Upon arrival, canisters, still in their shipping casks are stored in the PAU, adjacent to the WHB, if they are to be processed and emplaced on a near term basis, or are stored at the LSPA near the WHB until ready for processing and emplacement later. The LSPA will have the capacity for up to 180 days of shipments[40]. Storing waste in this manner facilitates the integration of the DWR mission into the existing WIPP TRU waste mission. Figures 4-10 and 4-11 show the locations of these storage areas.

The following describes the surface facilities for the DWR. Figure 5-1 indicates the applicability of the facilities to each case.

Because Cases 1 and 2 involve the existing WIPP facility, the existing surface structures and services available are discussed, for completeness. These are not proposed to change to accommodate the DWR mission except as noted in the detailed descriptions that follow. Specific dimensions, capacities, and other similar information are available in existing WIPP facility documentation and are not listed here. Refer to Figures 5-2, 4-7A and 4-7B for locations of existing WIPP structures. Principle surface facility elements related to Cases 1 and 2 are discussed below.

- Waste Handling Building (WHB) - includes the remote-handled (RH) Complex elements for receiving waste packages from offsite, unloading it and preparing it for disposal in the underground. For Case 1 the existing WHB contains an area for contact-handled (CH) TRU waste operations, as well.

- Parking Area Storage Unit –an outdoor area used to hold closed shipping packages prior to processing through facility.
- A Lag Storage Pad Area (LSPA) has been included for all cases to provide expanded storage for up to six months processing capacity.
- Exhaust Filter Building –houses the filter banks through which the underground ventilation can be diverted in the unlikely event of a release of radionuclides. In both Case 1 and 2, new ventilation shafts are proposed for installation, south of the WIPP facility, to accommodate the expanded mission. The ventilation exhaust will be equipped with an Exhaust Filter Building similar to the existing one at the WIPP facility.
- Air Intake Shaft Hoist Building – houses Air Intake Shaft hoisting equipment. In both Case 1 and 2, new ventilation shafts and associated support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Air Intake Shaft Winch Building – houses winch equipment for Air Intake Shaft. In both Case 1 and 2, new ventilation shafts and associated support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Auxiliary Air Intake – provides additional makeup air to waste the shaft. In both Case 1 and 2, new ventilation shafts and associated support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Air Intake Shaft Headframe – headframe structure used for hoisting. In both Case 1 and 2, new ventilation shafts and associated support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Salt Handling Shaft Hoist Building – houses hoisting equipment for the Salt Handling Shaft. In both Case 1 and 2, a new salt handling shaft and associated support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Salt Handling Shaft Operations Building – houses staff for salt hoisting activities. In both Case 1 and 2, a new salt handling shaft and associated surface support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Salt Handling Shaft Headframe – headframe structure used for hoisting. In both Case 1 and 2, a new salt handling shaft and associated surface support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission.
- Exhaust Shaft Monitoring Station – houses equipment that monitors effluent from the Exhaust Shaft. In both Case 1 and 2, new ventilation shafts and associated surface support facilities are proposed for installation south of the WIPP facility to accommodate the expanded mission. The ventilation exhaust will be equipped with exhaust ventilation monitoring equipment similar to the existing equipment at the WIPP facility.
- Exhaust Fans—ventilate the underground areas of the facility. In both Case 1 and 2, new ventilation shafts are proposed for installation south of the WIPP facility to accommodate the expanded mission. The ventilation exhaust shaft will be equipped with exhaust ventilation fans and monitoring equipment similar to the existing equipment at the WIPP facility.
- Guard and Security Building - houses the facility security personnel and communications equipment necessary for them to perform their duties, houses auditorium and cafeteria.

- Safety, Emergency Response & Medical Building - houses the surface emergency response vehicles (fire truck, rescue truck, ambulance), Health Services (first aid), the emergency response center, Industrial safety, Environmental Monitoring and radiological protection.
- Support Building – houses the centralized communication and sitewide monitoring and control systems, central communications, the Operations Department, procurement, Quality Assurance (QA), records, data acquisition, and central alarm system.
- Engineering Building - houses the offices for Engineering and Repository Development support staff.
- Warehouses– include central receiving and warehousing for all non-waste materials, consumables, bulk materials, engineered/procured items, overpacks, chemicals, geologic samples.
- Training Building – houses the training department and training facilities.
- Entry Facilities– includes Security Station for receipt of offsite shipments of waste, Gatehouses to control physical access to the site, Entry Control Facilities to control access between repository restricted areas and the site in general.
- Telephone and Communications Buildings – provides interface with landlines and cellular and microwave towers.
- Hazardous Waste Storage Facility – storage for site generated non-mixed hazardous waste awaiting offsite disposition.
- Oil and Grease Storage - area for storing fresh oil and grease for onsite use.
- Compressed Gas Bottle Storage – specialty storage area for compressed bottled gases.
- Hazardous Materials Storage Area – area for storage on bulk quantities of unused chemicals and other materials that are considered to be hazardous.
- Central Shops—provide primary maintenance services.
- Tailings Vehicle Shelter – provide shelter to protect surface tailings haulage vehicles. For both Case 1 and 2 an additional vehicle shelter is added to accommodate the increased mining activity.
- Water Treatment Facility – process water for effluent from oil/water separators, and other activities.
- Meteorological Station – provide onsite meteorological data for calculation of offsite deposition of airborne effluents.
- Evaporation Ponds – used to manage non-hazardous water collected from underground, condensate from underground ventilation system, groundwater sampling water, and other non-specific waters.
- Stormwater Retention/Detention Ponds – capture stormwater runoff from paved areas and roofs to allow sampling prior to discharge. In both Case 1 and 2, the runoff retention capacity is increased to deal with the increased amount of paved area.
- Fuel and Diesel Oil Storage and Fueling Station – stores and dispenses gasoline and diesel for site vehicles both on surface and underground (via transportable tank). Stores fuel for emergency and standby generators. In both Case 1 and 2, the fuel and diesel oil availability is increased to deal with the increased need for these services.
- Firewater Facility – provide storage of sufficient water to fight/extinguish facility fires.
- Equipment and Materials Storage Yards – include outdoor laydown areas to store and manage materials not requiring environmental control.

- Salt and Excavated Rock Tailings Storage Areas – include approximately 250 acres to store mined rock in piles to a height of 20 feet over lined surfaces with attached runoff evaporation ponds. In both Case 1 and 2, the mined salt storage capacity is increased to deal with the increased mining.
- Topsoil Storage Area – retain topsoil removed during site clearing to be used during decommissioning.
- Sanitary Waste Treatment Facility – sewage treatment facility and associated effluent gray-water ponds.
- Emergency and Standby Diesel Generator Facilities – provide emergency and standby power to designated loads throughout the facility. In both Case 1 and 2, the emergency diesel equipment is increased to deal with the increased base load for these generators.
- Compressor Building – provide compressed air services for surface and underground equipment. In both Case 1 and 2, the compressor services increased to deal with the increased need for compressed air.
- Chilled Water Services and Cooling Tower – provide chilled water and cooling facilities to support facility heating, ventilation and air conditioning (HVAC) and other needs. In both Case 1 and 2, the chilled water services increased to deal with the increased need for chilled water.
- Roadways and Access Routes – are designed to handle maximum truck and rail loads. In both Case 1 and 2, the rail receipt capability and roads are increased to accommodate shipment by rail, to provide additional lag storage with rail and road access.
- Fire Protection System - designed to ensure personnel safety, mission continuity, and property conservation.
- Electrical System - designed to provide normal and backup power, grounding for electrically energized equipment and other plant structures, lightning protection for the plant, and illumination for the surface and underground.
- Compressed Air System – provides main plant air compressors, salt hoist house, and the underground.
- Plant Monitoring and Communications Systems - include on-site and plant-to-off-site coverage and designed to provide immediate instructions to ensure personnel safety, facility safety and security, and efficient operations under normal and emergency conditions.
- Security Services – includes guard houses, and fences and provides 24-hour surveillance of and entry control to the active portion of the facility.
- Training Services - prepares personnel to operate the facility in a safe and environmentally sound manner.
- Radiological Protection Services - The radiological protection services program was established to ensure the exposure of employees and the general public to radiation and radioactive materials is within applicable requirements.

5.2.1.1 *Case 1—DHLW from the Savannah River Site*

When DHLW disposal begins, the Type B shipping cask will be received into the RH Waste Handling Complex by truck or rail through a set of double doors on the east side of the WHB. The RH Complex of the WHB Unit comprises the following locations: RH Bay (12,552 ft^2), the

Cask Unloading Room (382 ft^2), the Hot Cell (1,841 ft^2), the Transfer Cell (1,003 ft^2), and the Facility Cask Loading Room (1,625 ft^2). The major service areas of the RH Complex are shown in Figure 5-3.

The RH Bay is served by a 140 Ton overhead bridge crane used for shipping cask handling and maintenance operations. The shipping cask is assumed to weigh approximately 65,000 pounds. The RH Bay houses the cask transfer car which is used to transport the shipping cask from the vehicle to the cask unloading room. A cask preparation station allows personnel access to the top of the shipping cask in order to remove outer lid bolts, de-tension inner lid bolts and perform radiological checks. Interim storage in the RH Bay will occur in the shipping casks. Up to five shipping casks with canisters inside (up to four on vehicles and one in the transfer car) can be stored in the RH Bay. The existing RH Complex at the WIPP facility is constructed to handle payloads up to 10 feet in length and 24 inches in diameter.

The Cask Unloading Room provides for transfer of the waste canister from the shipping cask to the Hot Cell, then into a shielded insert in the Transfer Cell. Storage in the Cask Unloading Room will occur in the shipping casks and is limited to a single cask.

The Hot Cell is a concrete-shielded room in which canisters of waste will be transferred remotely from the shipping cask, staged in the Hot Cell for inspection, then lowered from the Hot Cell into the Transfer Cell shuttle car containing a shielded insert. Waste will be stored on an interim basis in the Hot Cell in canisters. The Hot Cell contains eight positions that may be used for storage of canisters.

The Transfer Cell houses the Transfer Cell shuttle car, which will move the DHLW canister in the shielded insert into position for transferring the canister to the facility cask. Storage in this area typically will occur at the end of a shift or in an off-normal event that results in the suspension of waste handling activities. One defense waste canister can be stored in the Transfer Cell.

The Facility Cask Loading Room provides for transfer of a canister to the facility cask for subsequent transfer to the waste hoist and to the underground HWDUs. The Facility Cask Loading Room also functions as an air lock between the waste shaft and the Transfer Cell. Storage in this area typically occurs at the end of a shift or in an off-normal event that results in the suspension of waste handling activities. One defense waste canister can be stored in the Facility Cask Loading Room.

The following are major pieces of equipment that will be used to manage DHLW.

RH Bay Overhead Bridge Crane: In the RH Bay, a 140 T overhead bridge crane will be used to lift the shipping cask from the truck trailer or rail car and place it on the cask transfer car. It also will be used to remove the impact limiters from the shipping casks. Case 1 uses the existing WIPP facility RH Bay Overhead Bridge Crane.

DHLW Cask Lifting Yoke: The Lifting Yoke is a lifting fixture that attaches to the overhead crane and is designed to lift and rotate the DHLW shipping cask onto the transfer car. This is a new piece of equipment for the DHLW mission. (See Figure 5-7 for an example of a cask lifting yoke)

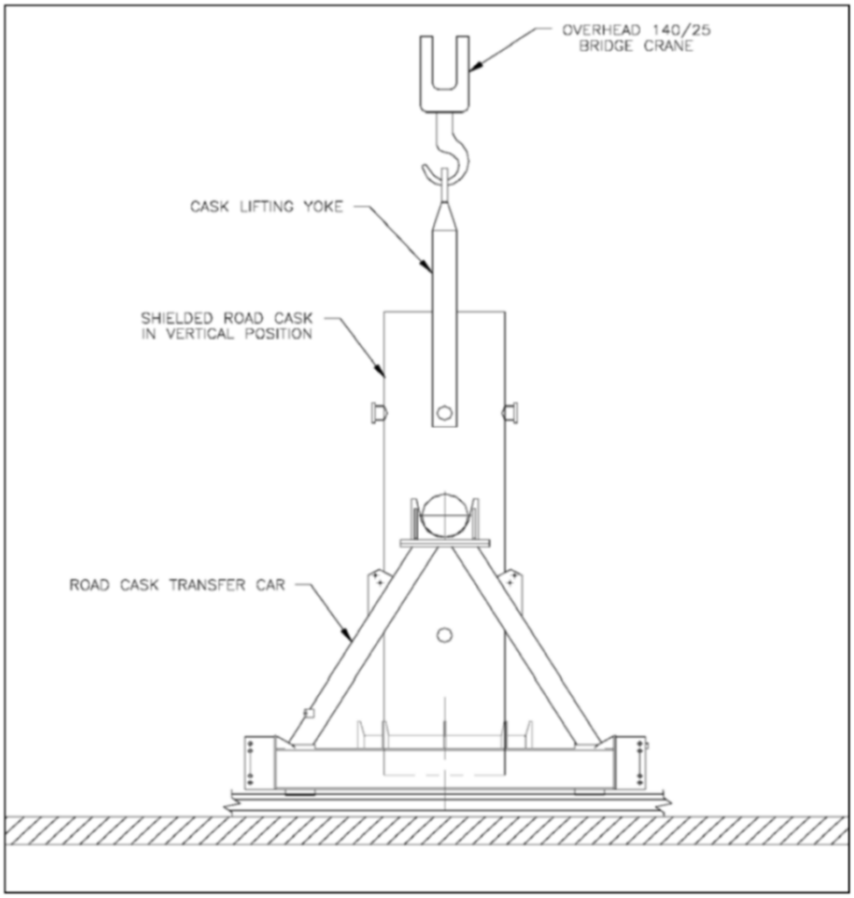


Figure 5-7 Typical DHLW Cask Lifting Yoke and Cask Transfer Car

DHLW Cask Transfer Car: The DHLW Cask Transfer Car, a self-propelled, rail-guided car, will transport the DHLW shipping cask between the RH Bay and the Cask Unloading Room. This is a new piece of equipment for the DHLW mission. (See Figure 5-7 for an example of a cask transfer car)

Hot Cell Overhead Bridge Crane: The Hot Cell Overhead Bridge Crane, outfitted with a rotating block and the facility grapple, will be used to lift the shipping cask lids and DHLW canister from the DHLW shipping cask into the Hot Cell. The Hot Cell crane also will be used to lower loaded canisters into the Transfer Cell. The DHLW mission uses the existing WIPP facility Hot Cell Overhead Bridge Crane.

Manipulators: There are two sets of fixed Manipulators in the Hot Cell. The manipulators will collect swipes of canisters as they are being lifted from the DHLW shipping cask and transfer the swipes to the shielded material transfer drawer. The DHLW mission uses the existing WIPP facility Manipulators.

Shielded Material Transfer Drawer: The Shielded Material Transfer Drawer will be used to transfer swipe samples obtained by the fixed manipulators to the Hot Cell Gallery for radiological counting. The DHLW mission uses the existing WIPP facility Shielded material transfer drawer.

Transfer Cell Shuttle Car: The Transfer Cell Shuttle Car will position the Shielded Insert under the Hot Cell Transfer Port. The DHLW mission uses the existing WIPP facility Transfer Cell Shuttle Car.

Shielded Insert: The Shielded Insert is used in the Transfer Cell to hold and transport DHLW canisters from the Hot Cell until loaded into the Facility Cask. The Shielded Insert, designed and constructed similar to the shipping cask, has a 29 in. inside diameter with an inside length of 130.5 in. to accommodate the DHLW canister. The DHLW mission uses the existing WIPP facility Shielded Insert.

DHLW Facility Shielded Cask: The DHLW Facility Shielded Cask body is a clamshell cask that consists of two concentric steel cylinders. The annulus between the cylinders is filled with lead, and gate shield valves are located at either end. The canister will be placed inside the DHLW facility cask for shielding during canister transfer from the surface to the underground for emplacement. This is a new piece of equipment for the DHLW mission. (See Figure 5-8 for an example of a facility cask.)

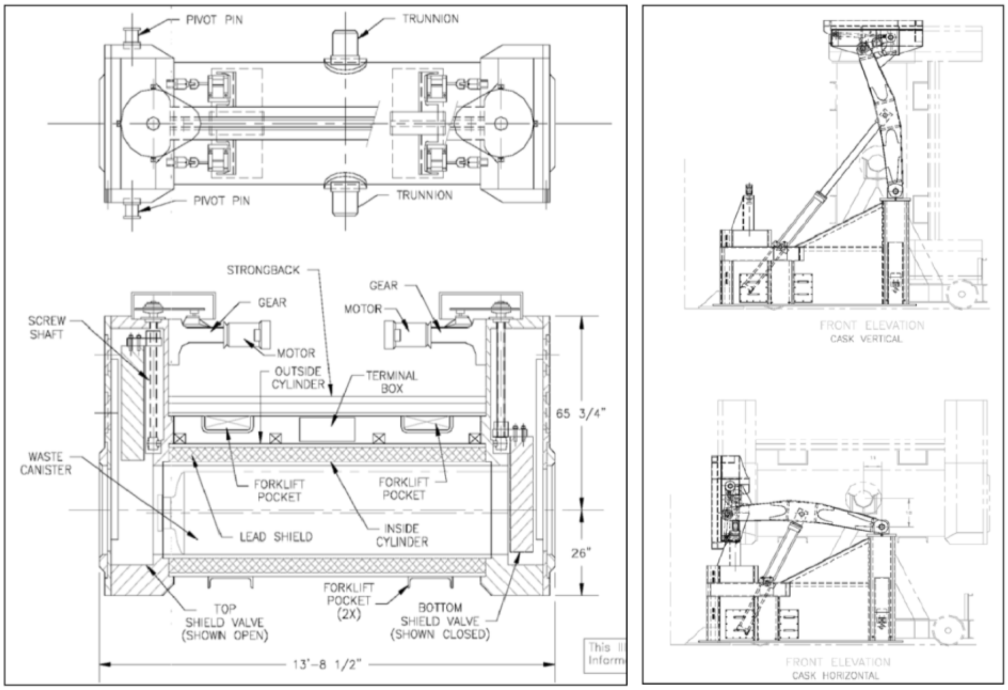


Figure 5-8 Typical DHLW Facility Cask and Cask Rotating Device

DHLW Facility Cask Rotating Device: The DHLW facility Cask Rotating Device, a floor mounted hydraulically operated structure, is designed to rotate the DHLW facility cask from the horizontal position to the vertical position for DHLW canister loading and then back to the horizontal position after the DHLW canister has been loaded into the DHLW facility cask. This is a new piece of equipment for the DHLW mission. (see Figure 5-8 for an example of a facility cask rotating device.)

Facility Cask Transfer Car: The Facility Cask Transfer Car is a self-propelled rail car that will be used to move the facility cask between the Facility Cask Loading Room and the shaft station underground. This is a new piece of equipment for the DHLW mission. (see Figure 5-9 for an example of a facility cask transfer vehicle.)

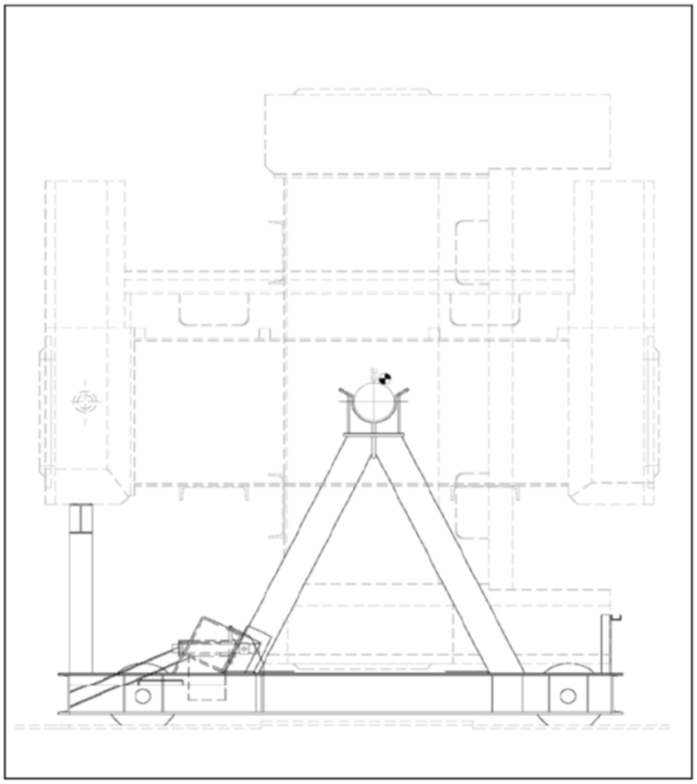


Figure 5-9 Typical DHLW Facility Cask Transfer Vehicle

The following steps are used to receive, manage, store, and dispose of DHLW at the WIPP facility. New equipment that is not currently in use at the WIPP facility is italicized in this discussion.

- DHLW waste arrives at the facility in single *DHLW canister casks* either by truck or rail. Rail shipments may contain two casks.

- DHLW shipping casks are long-term-stored in the LSPA while it waits processing. *The Cask Crawler Crane (CCC)* removes the cask from its transport vehicle and places the cask with the DHLW on *saddle blocks* in the LSPA. The LSPA storage area is accessible by both rail and road. Either truck or rail shipped casks may be shuttled directly to the WHB from the LSPA.

- DHLW casks are moved into the RH Bay of the WHB using the same *CCC* at the LSPA and a *facility shuttle vehicle* which may be dedicated to the Facility or employ a transport rail or truck vehicle.

- Once inside, if not previously removed and stored at the LSPA, the DHLW cask impact limiters are removed using the overhead bridge crane and *DHLW cask lifting yoke*. The cask is removed from the *shuttle vehicle* and placed on a *DHLW transport cask transfer car*.

- The *DHLW transport cask transfer car* moves the cask to the cask preparation stand where the outer lid is removed and inner lid bolts are detensioned.

- The *DHLW transport cask transfer car* moves the DHLW cask into the Cask Unloading Room and the shielding door is closed.

- The port in the bottom of the Hot Cell is opened by removing the port plug and the Hot Cell crane removes the inner cask lid and places it on the *lid stand* in the Hot Cell.

- The Hot Cell crane removes the DHLW canister and places it at the inspection station in the Hot Cell

- The cask inner lid is replaced and the Hot Cell floor port plug is replaced.

- The shipping cask is moved from the Cask Unloading Room and returned to the RH Bay where it is readied for return to the LSPA or the generator site.

- Once the DHLW canister inspection is completed, it is moved to one of the storage wells in the Hot Cell. If necessary, damaged canisters may be overpacked into a larger canister in the Hot Cell.

- Additional DHLW shipping casks can be unloaded at this time. Up to eight DHLW canisters can be in storage in the Hot Cell.

- DHLW canisters are moved from their storage location in the Hot Cell and lowered into the Transfer Cell into a pre-positioned shielded insert.

- The Shielded insert with the DHLW canister is repositioned under the Facility Cask Loading Room port.

- The *DHLW Facility Shielded Cask* is located in the *DHLW Facility Cask Rotating Device* in the Facility Cask Loading Room.

- The port is opened and the DHLW canister is hoisted up into the *DHLW Facility Cask* from the Shielded Insert. Once in the *DHLW Facility Shielded Cask* the port is closed and the loaded *DHLW Facility Cask* is rotated to the horizontal position.

- The loaded *DHLW Facility Shielded Cask* is placed onto the Facility Cask Transfer Car.

- The cask is transported to the Waste Hoist Conveyance and locked into position for hoisting into the mine.

5.2.1.2 *All DOE HLW at the WIPP Facility—Case 2*

The WIPP facility buildings, systems, and support services listed in Section 5.1 are generally the same for Case 2, with a new surface Waste Receipt and Transfer Facility (WRTF) and support complex (Figure 4-8) provided south of the current WIPP facility, in order to accommodate the additional Case 2 inventory and throughput, and because the existing WIPP waste handling process was designed to accommodate remotely handled waste that is no larger than 10 feet long. The second Waste Handling Building is shown at a new WRTF south of the current WIPP facility atop a new Waste Shaft, built to accommodate 15 foot DHLW packages. (See Figure 4-11)

To this extent, the Case 2 new WRTF facility is a stand-alone DHLW management facility that only shares the WIPP Land Withdrawal Area, access roads, utility (power and water) access, visitor center, recyclable yard, top soil storage area, salt water evaporation pond, oil and grease storage building, warehouse and central receiving, and portions of the repository horizon with the WIPP Project.

The new surface WRTF is specifically built to handle the defense waste packages. As such, it does not have all the functions that are found in the WIPP WHB, such as contact handled waste features. The WRTF will have five functional areas: cask receipt; cask unloading; payload inspection; facility transport cask loading; and hoisting to the underground. The surface WRTF for Case 2 has a total area of approximately 110,000 square feet (ft^2). The WRTF heating, ventilation and air conditioning (HVAC) system maintains the interior of the building at a pressure lower than the ambient atmosphere to ensure that air flows into the WRTF.

The WRTF complex and its associated support systems provide a set of structures to receive and unload DHLW from the incoming shipping packages and to transfer that waste to the underground disposal area via a waste shaft. The surface WRTF complex will be divided into the following key areas: the DHLW waste handling area; the Waste Receipt Support Facility (WRSF), the Waste Handling Equipment Maintenance Facility (WHMF) and the Contaminated Equipment Maintenance Shop (CEMS).

The construction of WRTF will comply with applicable safety and security codes and standards, and includes portions of the building, such as the hot cell complex, that will be constructed of concrete for shielding and structural purposes.

Waste handling areas subject to potential for contamination are provided with coatings that are easy to decontaminate.

The following provides an overview of key surface WRTF facility and equipment features.

The WRTF WHB will include the following locations: DHLW Receipt Bay, the DHLW WRTF Hot Cell containing the DHLW Cask Unloading Room, and the DHLW Canister Overpack and Buffer Storage areas.

The DHLW Receipt Bay is a high-bay area for receiving casks and subsequent handling operations. The trailer or railcar carrying the transport cask enters the Waste Receipt and Transfer Facility through a set of double doors. The DHLW Receipt Bay houses the rail guided, self-propelled DHLW Transport Cask Transfer Car, which transfers the transport casks between the DHLW Receipt Bay and the DHLW Cask Unloading Room. The DHLW Receipt Bay is served by the DHLW Receipt Bay Overhead Bridge Crane, used for cask handling and maintenance, and a cask preparation station that is used to remove the cask outer lid and de-tension the inner lid bolts. Space is also provided, within in the DHLW Receipt Bay, for interim staging of a limited number of offloaded transport casks, while awaiting subsequent processing.

The DHLW Cask Unloading Room provides for transfer of the waste canisters to the DHLW Facility Shielded Casks. Interim storage of open DHLW waste packages, while in the process of transfer to the underground, occurs within the DHLW Cask Unloading Room, with waste packages remaining in the transport cask and/or placed in the DHLW Facility Shielded Cask. Storage in this mode typically occurs at the end of a shift or in an off-normal event that results in the suspension of waste handling operations. A maximum of one transport cask and four loaded DHLW Facility Transfer Casks may be stored in the DHLW Cask Unloading Room.

The DHLW Canister Overpack and Storage Room is a shielded room connected to the DHLW Cask Unloading Room, in which waste packages will be transferred remotely, in the event they require inspection, repair, or overpacking. Buffer Storage is also provided in this area, for DHLW packages which have been removed from their transport packages in the DHLW Canister Overpack and Storage Room.

Within the WRTF, the Waste Shaft Conveyance Loading Room serves as an air lock, adjacent to its shaft, and is used for loading a DHLW Facility Transfer Cask onto the shaft conveyance. The doors connecting the shaft conveyance loading room with the DHLW Receipt and Transfer Facility are interlocked with the doors connecting the conveyance loading room with the shaft entry, such that only one can be open at a time, in order to maintain the requisite ventilation differential pressure. Fencing with gates is provided at the shaft collar to prevent inadvertent access to the shaft. The gates are interlocked such that if a gate is open, the conveyance cannot be moved, or if the conveyance is moving and a gate is opened, the conveyance emergency stop is actuated.

Ventilation Systems are provided with features to reestablish designed airflow patterns in the event of a temporary disruption. Ducts that carry potentially contaminated air are routed away from occupied areas. Systems are designed so that some components can be taken out of service for maintenance while the system continues to operate as designed.

The Mechanical Equipment Room is maintained at a pressure slightly below atmospheric, to minimize leakage of room air, which may contain airborne radioactive contaminants. Negative pressure is maintained by the same exhaust fan systems that exhaust air from the waste handling areas. The ventilation system provides filtration of supply air, unit heaters to prevent equipment from freezing, and a unit cooler to provide supplementary cooling of equipment in summer. Exhaust air flow is drawn through the waste hoist shaft tower and into the waste shaft, where it combines with incoming air from the Waste Shaft Auxiliary Air Intake Tunnel.

The Waste Handling Equipment Maintenance Facility provides the clean, dedicated area where periodic maintenance of the shipping casks will be performed, which may include maintaining cask lids and seals, mechanical damage repair to surfaces, leak tests of the seal systems and other activities required by the U. S. Nuclear Regulatory Commission (NRC) to maintain Certificates of Compliance.

The Contaminated Equipment Maintenance Shop provides support and maintenance space to perform non-routine maintenance on major pieces of waste handling equipment that may become contaminated. Decontamination of shipping casks, if required, would be accomplished in the WHB.

In addition to the WRTF Complex and associated buildings, the Southern Surface location includes the following WRTF facility support buildings and structures:

- Lag Storage Area –an outdoor area used to hold closed shipping packages of waste prior to processing through facility
- Exhaust Filter Building –houses the filter banks through which the underground ventilation can be diverted in the unlikely event of a release of radionuclides.
- Air Intake Shaft Hoist Building – houses Air Intake Shaft hoisting equipment.
- Air Intake Shaft Winch Building – houses winch equipment for Air Intake Shaft.
- Auxiliary Air Intake – provides additional makeup air to waste shaft.
- Air Intake Shaft Headframe –headframe structure used for hoisting.
- Salt Handling Shaft Hoist Building – houses hoisting equipment for the Salt Handling Shaft.
- Salt Handling Shaft Operations Building – houses staff for salt hoisting activities.
- Salt Handling Shaft Headframe –headframe structure used for hoisting.
- Exhaust Shaft Monitoring Station – houses equipment that monitors effluent from the Exhaust Shaft.
- Exhaust Fans—located at the exhaust fan and filter building, at the top of the air exhaust shaft, ventilate the underground areas of the DWR.
- Central Security Station - houses the facility security personnel and communications equipment necessary for them to perform their duties.
- Emergency Response and Medical - houses the surface emergency response vehicles (fire truck, rescue truck, ambulance), Health Services (first aid), the emergency operations center, and radiological protection.
- Central Engineering and Administration – houses administrative staff, engineering support staff, training, Quality Assurance (QA), procurement, cafeteria services, and records.
- Central Control Facility– houses the centralized communication and sitewide monitoring

and control systems, central alarm system, and data acquisition.

- Warehouses and Central Receiving– include central receiving and warehousing for all non-waste materials, consumables, bulk materials, engineered/procured items, overpacks, chemicals, geologic samples. For Case 2 the existing facility infrastructure will provide this capability.
- Entry Control Facilities and Gatehouse–to control physical access to the site, Entry Control Facilities to control access between repository restricted areas and the site in general.
- Telephone and Communications Buildings – provides interface with landlines and cellular and microwave towers.
- Hazardous Waste Storage and Staging Facility – storage for site generated non-mixed hazardous waste awaiting offsite disposition.
- Oil and Grease Storage - area for storing fresh oil and grease for onsite use. For Case 2 the existing facility infrastructure will provide this capability.
- Compressed Gas Bottle Storage – specialty storage area for compressed bottled gases. For Case 2 the existing facility infrastructure will provide this capability.
- Hazardous Materials Storage Area – area for storage on bulk quantities of unused chemicals and other materials that are considered to be hazardous.
- Central Maintenance and Craft Shops—provide primary maintenance services.
- Tailings Vehicle Shelter – provide shelter to protect surface tailings haulage vehicles.
- Water Treatment Facility – process water for effluent from oil/water separators, and other activities.
- Meteorological Station – provide onsite meteorological data for calculation of offsite deposition of airborne effluents. For Case 2 the existing facility infrastructure will provide this capability.
- Evaporation Ponds – used to manage non-hazardous water collected from underground, condensate from underground ventilation system, groundwater sampling water, and other non-specific waters.
- Stormwater Retention/Detention Ponds – capture stormwater runoff from paved areas and roofs to allow sampling prior to discharge.
- Fuel and Diesel Oil Storage and Fueling Station – stores and dispenses gasoline and diesel for site vehicles both on surface and underground (via transportable tank). Stores fuel for emergency and standby generators.
- Firewater Facility – provide storage of sufficient water to fight/extinguish facility fires.
- Equipment and Materials Storage Yards – include outdoor laydown areas to store and manage materials not requiring environmental control.
- Salt and Excavated Rock Tailings Storage Areas – include approximately 250 acres to store mined rock in piles to a height of 20 feet, over lined surfaces, with attached runoff evaporation ponds.
- Topsoil Storage Area – retain topsoil removed during site clearing to be used during decommissioning. For Case 2 the existing facility infrastructure will provide this capability.
- Sanitary Waste Treatment Facility – sewage treatment facility and associated effluent gray-water ponds.
- Emergency and Standby Diesel Generator Facilities – provide emergency and standby

power to designated loads throughout the facility

- Compressor Building – provide compressed air services for surface and underground equipment.
- Chilled Water Services and Cooling Tower – provide chilled water and cooling facilities to support facility heating, ventilation and air conditioning (HVAC) and other needs.
- Roadways, Access Routes, Parking Areas – are designed to handle maximum truck and rail loads and include paved and gravel areas.
- Railroad Operations Facility – The central rail operations facility control center for the WRTF.
- Rail Staging Area – A central rail yard local to the WRTF, for the staging of inbound and outbound rail carriers. Some HLW will arrive at the site in rail mounted shipping casks. The rail yard will be equipped with utility engines that will be used to move these packages in and out of the WRTF operations areas. In addition, rail maintenance equipment will be on hand to assure tracks and railroad beds meet performance standards.
- Truck Staging Facility-- Some HLW will arrive at the site in truck mounted shipping casks. The truck staging facility will be used to manage trucks and empty casks that are being sent back to generator sites. In addition, truck maintenance equipment will be on hand to assure vehicles meet performance standards.
- Low Level Waste Facility—a small amount of LLW may be generated by the receipt process and will be disposed at an approved offsite LLW facility. The storage facility will permit the accumulation of LLW until a sufficient quantity is available to constitute a shipment. For Case 2 the existing facility infrastructure will provide this capability.
- Heavy Equipment Maintenance Facility—to assure the mechanical workability of heavy equipment used at the repository. For Case 2 the existing facility infrastructure will provide this capability.
- Switchyard, Offsite Power Switchgear, and Substations—commercially purchased power will be used and will enter through a switchyard which will distribute it to the various areas of the facility.
- Package Receipt Security Station-- includes Security Station for receipt of offsite shipments of waste.
- Vehicle Maintenance and Motor Pool—to assure the operability of facility vehicles.
- Repository Performance Demonstration Facility--houses the personnel and equipment needed to demonstrate to the regulatory community and the public that the repository is performing as expected.
- Sample Management Facility--to store, in environmentally suitable conditions, geological, hydrological, and biological samples collected at the site and in the vicinity.
- Visitor Center--accommodates the mission of information dissemination with the public and regulators and provides an auditorium and display area. For Case 2 the existing facility infrastructure will provide this capability.
- Miscellaneous facilities—includes fencing, landscaping, concrete and gravel staging areas, temporary structures for construction, miscellaneous equipment.
- Fire Protection System - designed to ensure personnel safety, mission continuity, and property conservation.
- Electrical System - designed to provide normal and backup power, grounding for electrically energized equipment and other plant structures, lightning protection for the

plant, and illumination for the surface and underground.

- Compressed Air System – provides main plant air compressors for facility compressed air.
- Plant Monitoring and Communications Systems - includes on-site and plant-to-off-site coverage and designed to provide immediate instructions to ensure personnel safety, facility safety and security, and efficient operations under normal and emergency conditions.
- Waste receipt Support Facility – provides facility waste handling support staff office, locker room, break areas, showers and meeting space.
- Recyclables Yard – provides accumulation and storage area for recyclable materials. For Case 2 the existing facility infrastructure will provide this capability.
- Analytical Support Facility – provides infrastructure for support functions such as disposition of laboratory waste, radiological control laboratory functions, sample counting, whole body counting, TLD readings, radiological source control. For Case 2 the existing facility infrastructure will provide this capability.
- Waste oil Retention – provides for the accumulation of waste oil generated from facility operations. For Case 2 the existing facility infrastructure will provide this capability.
- Waste Handling Maintenance Building – provides for the inspection and maintenance of waste handling equipment, casks and seals etc.
- Contaminated Equipment Maintenance Facility – provides for the maintenance of contaminated or potentially contaminated equipment in a suitably isolated radiological environment.
- Heavy Equipment Maintenance – provides infrastructure for maintenance of facility operations heavy equipment.
- Grey Water Ponds – provide evaporation capability for grey water accumulation.

The principle facility equipment elements associated with DHLW waste receipt and transfer at the WRTF are listed below. All equipment is new equipment.

- DHLW Receipt Bay Facility Overhead Bridge Crane: the DHLW Receipt Bay Facility Overhead Bridge Crane is a 200 ton capacity crane that is used to lift the transport cask from the shuttle trailer or shuttle railcar and place it on the Transport Cask Transfer Car for movement to the Waste Inspection Station and the Hot Cell. It is also used to remove the impact limiters from the transport casks.
- DHLW Cask Lifting Yoke: the lifting yoke is a lifting fixture that attaches to the RH Receipt Bay Overhead Bridge Crane and is designed to lift and rotate the transport cask for outer lid removal and transfer onto the Transport Cask Transfer Car
- DHLW Hot Cell Bridge Crane: the DHLW Hot Cell Bridge Crane, outfitted with a rotating block and the DHLW Facility Grapple, will be used to lift the transport cask inner lid and remove the canister from the transport cask within the DHLW Hot Cell. The DHLW Hot Cell Bridge Crane is also used to move canisters to the DHLW Canister Overpack and Storage Room and back to the DHLW Hot Cell.
- DHLW Canister Grapple Hoist: the 6.25 Ton DHLW canister Grapple Hoist is used to transfer the canister from the transport cask into the Facility Shielded Cask

- DHLW Facility Shielded Casks (10 foot and 15 foot): the DHLW Facility Shielded Cask body consists of two concentric steel cylinders. The annulus between the cylinders is filled with lead. The cylinders open in clam-shell fashion to accept, transport, and emplace HLW canisters.
- DHLW Transport Cask Transfer Car: the Transport Cask Transfer Car is a self-propelled, rail-guided vehicle that transports casks within the DHLW Receipt Bay and into the Hot Cell.
- Manipulators: there are two operational sets of fixed Manipulators in the facility. The Manipulators collect swipes of canisters and support remote operations.
- Closed-Circuit Television Cameras: the Closed-Circuit Television Camera monitors remote operations. These operations are observed from an operating gallery. Shielded viewing windows allow operators to visually observe operations in addition to using the remote cameras

The DHLW handling process for Case 2 is somewhat different than for Case 1. This is because the transfer of waste from the cask to the underground transporter is done directly and does not need the multiple handling processes required if using the WIPP facility Hot Cell Complex in Case 1. Remotely operated equipment is used to extract the canister, inspect it, and place it into the clamshell transport cask, for subsequent transfer to the underground. A more detailed description follows.

- The DHLW will be received from offsite in transportation casks loaded on a trailer or on a railcar.
- Upon arrival at the gate, external radiological surveys, security checks, and shipping documentation reviews are performed.
- Following receipt inspections, loaded transportation casks may be placed in the LSPA or delivered directly to the WHB for unloading, depending on operations priorities for waste receipts at any time. If delivered to the LSPA they will subsequently be brought to the WHB for unloading, based on operations priorities. When left in the staging areas, shipping casks will have their impact limiters removed and will be placed on stand-offs for interim storage. Up to six months of lag storage is provided.
- When ready for unloading, the transport cask and shuttle trailer or railcar are moved into the WHB or temporarily held in the staging area prior to transfer into the WHB. Figure 5-10 reflects the Case 2 WHB RH Complex area associated with receipt and transfer of HLW packages.

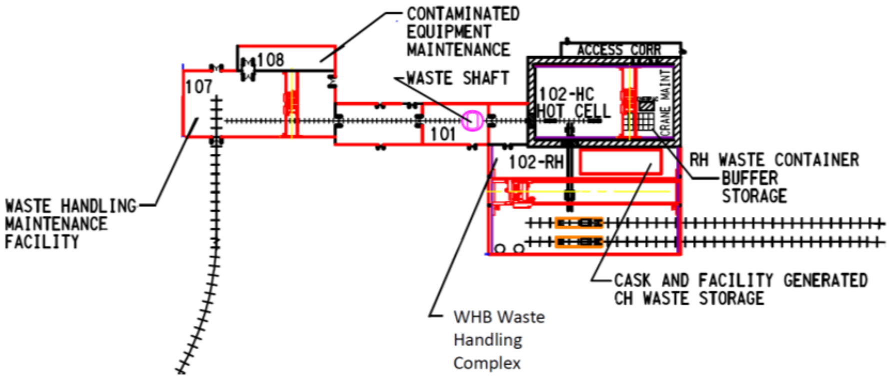


Figure 5-10 Case 2 – WRTF WHB RH Complex Area

- The waste handling process begins in the DHLW Receipt Bay where the impact limiter(s) are removed from the transport cask if they have not already been removed in the LSPA.
- Additional radiological surveys are conducted on the end of the cask previously protected by the impact limiter(s) to verify the absence of contamination.
- The cask is unloaded from the transport vehicle using the DHLW Receipt Bay Facility Overhead Bridge Crane and placed on the DHLW Transport Cask Transfer Car, where it is moved to an adjacent work stand or cask inspection station.
- The head area of the transport cask is surveyed for radiological contamination and inspected for physical damage or minor maintenance, and decontamination can be performed, if necessary.
- The outer head of the cask is removed and inner bolts are loosened. Buffer storage is provided within the hot cell area, providing shielded storage for a limited number of DHLW packages.
- The DHLW Transport Cask Transfer Car then moves the transport cask to the Cask Unloading Room within the WRTF hot cell.
- The inner lid is then removed to provide access to the waste canister.
- Using the remotely-operated cranes in the DHLW Cask Unloading Room, the canister is pulled from the transport cask, inspected remotely for damage and to verify identification numbers and placed horizontally into a DHLW Facility Shielded Cask. Two facility shielded casks are available: one for 10 foot canisters and one for 15 foot canisters. Once secured in the DHLW Facility Shielded Cask, the DHLW Facility Shielded Cask is closed.
- When ready for transfer to the underground, the DHLW Facility Cask Transfer Car moves the loaded DHLW Facility Shielded Cask, from the hot cell and onto the waste hoist conveyance, within the Southern WRTF Waste Shaft.
- The DHLW Facility Cask Transfer Car is pinned to the hoist conveyance platform to avoid movement during hoisting. It is then lowered to the Waste Shaft Station underground.

5.2.1.3 *All DOE HLW at the New WRTF Facility—Case 3*

Surface structures and facilities for Case 3 will be the same as for Case 2, however the WRTF WHB RH Complex area layout is slightly different, to accommodate two waste shafts in the WHB. The two waste shafts provided for Case 3 (and Cases 4 and 5) can be tied to a single WHB Waste Handling Complex on the surface and the DWR underground mains below. This is shown in Figure 5-11 and Figure 4-12 respectively.

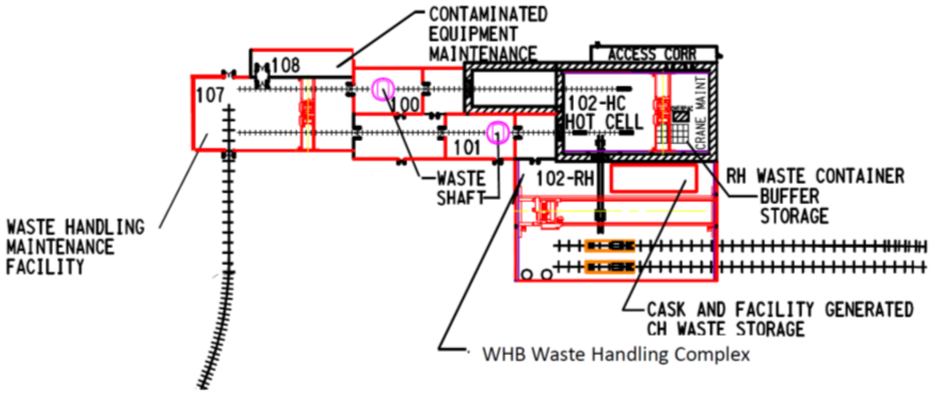


Figure 5-11 Case 3 (And Cases 4 and 5) – WRTF WHB RH Complex Area

Figure 4-9 provides a surface facilities layout for Case 3 (and Cases 4 and 5)

The following is the list of surface facilities for Case 3:

- Waste Receipt and Transfer Facility WHB-- will have five functional areas: cask receipt; cask unloading; payload inspection; facility transport cask loading; and hoisting to the underground.
    - Waste Receipt Bay-- is a high-bay area for receiving casks and subsequent handling operations.
    - Cask Unloading Room--provides for transfer of the waste canisters to the DHLW Facility Shielded Casks.
    - Canister Overpack and Storage Room--is a shielded room connected to the Cask Unloading Room, in which waste packages will be transferred remotely, in the event they require inspection, repair, or overpacking.
    - WRTF Waste Shaft Conveyance Loading Room--serves as an air lock, adjacent to its shaft, and is used for loading a Facility Transfer Cask onto the shaft conveyance.
    - Mechanical Equipment Room--is maintained at a pressure slightly below atmospheric to minimize leakage of room air, which may contain airborne

  radioactive contaminants.
  - Waste Handling Equipment Maintenance Facility--provides the clean, dedicated area where periodic maintenance on the shipping casks will be performed, which may include maintaining cask lids and seals, mechanical damage repair to surfaces, leak tests of the seal systems and other activities required by the U. S. Nuclear Regulatory Commission (NRC) to maintain Certificates of Compliance.
  - Contaminated Equipment Maintenance Shop--provides support and maintenance space to perform non-routine maintenance on major pieces of waste handling equipment that may become contaminated. Decontamination of shipping casks, if required, would be accomplished in the Contaminated Equipment Maintenance Shop.
- Lag Storage Pad Area – an outdoor area used to hold closed shipping packages of waste prior to processing through facility.
- Exhaust Filter Building – houses the filter banks through which the underground ventilation can be diverted in the unlikely event of a release of radionuclides.
- Air Intake Shaft Hoist Building – houses Air Intake Shaft hoisting equipment.
- Air Intake Shaft Winch Building – houses winch equipment for Air Intake Shaft.
- Auxiliary Air Intake – provides additional makeup air to waste shaft.
- Air Intake Shaft Headframe –headframe structure used for hoisting.
- Salt Handling Shaft Hoist Building – houses hoisting equipment for the Salt Handling Shaft.
- Salt Handling Shaft Operations Building – houses staff for salt hoisting activities.
- Salt Handling Shaft Headframe –headframe structure used for hoisting.
- Exhaust Shaft Monitoring Station – houses equipment that monitors effluent from the Exhaust Shaft.
- Exhaust Fans—ventilate the underground areas of the facility.
- Central Security Station - houses the facility security personnel and communications equipment necessary for them to perform their duties.
- Emergency Response and Medical - houses the surface emergency response vehicles (fire truck, rescue truck, ambulance), Health Services (first aid), the emergency operations center, and radiological protection.
- Central Engineering and Administration – houses administrative staff, engineering support staff, training, Quality Assurance (QA), procurement, cafeteria services, and records.
- Central Control Facility– houses the centralized communication and sitewide monitoring and control systems, central alarm system, and data acquisition.
- Warehouses and Central Receiving– include central receiving and warehousing for all non-waste materials, consumables, bulk materials, engineered/procured items, overpacks, chemicals, geologic samples.
- Entry Control Facilities and Gatehouse–to control physical access to the site, Entry Control Facilities to control access between repository restricted areas and the site in general.
- Telephone and Communications Buildings – provides interface with landlines and cellular and microwave towers.
- Hazardous Waste Storage and Staging Facility – storage for site generated non-mixed

hazardous waste awaiting offsite disposition.

- Oil and Grease Storage - area for storing fresh oil and grease for onsite use.
- Compressed Gas Bottle Storage – specialty storage area for compressed bottled gases.
- Hazardous Materials Storage Area – area for storage on bulk quantities of unused chemicals and other materials that are considered to be hazardous.
- Central Maintenance and Craft Shops—provide primary maintenance services.
- Tailings Vehicle Shelter – provide shelter to protect surface tailings haulage vehicles.
- Water Treatment Facility – process water for effluent from oil/water separators, and other activities.
- Meteorological Station – provide onsite meteorological data for calculation of offsite deposition of airborne effluents.
- Salt Water Evaporation Ponds – used to manage non-hazardous water collected from underground, condensate from underground ventilation system, groundwater sampling water, and other non-specific waters.
- Stormwater Retention/Detention Ponds – capture stormwater runoff from paved areas and roofs to allow sampling prior to discharge.
- Fuel and Diesel Oil Storage and Fueling Station – stores and dispenses gasoline and diesel for site vehicles both on surface and underground (via transportable tank). Stores fuel for emergency and standby generators.
- Firewater Facility – provide storage of sufficient water to fight/extinguish facility fires.
- Equipment and Materials Storage Yards – include outdoor laydown areas to store and manage materials not requiring environmental control.
- Salt and Excavated Rock Tailings Storage Areas – include approximately 250 acres to store mined rock in piles to a height of 20 feet, over lined surfaces, with attached runoff evaporation ponds.
- Topsoil Storage Area – retain topsoil removed during site clearing to be used during decommissioning.
- Sanitary Waste Treatment Facility – sewage treatment facility and associated effluent gray-water ponds.
- Emergency and Standby Diesel Generator Facilities – provide emergency and standby power to designated loads throughout the facility
- Compressor Building – provide compressed air services for surface and underground equipment.
- Chilled Water Services and Cooling Tower – provide chilled water and cooling facilities to support facility heating, ventilation and air conditioning (HVAC) and other needs.
- Roadways, Access Routes, Parking Areas – are designed to handle maximum truck and rail loads and include paved and gravel areas.
- Railroad Operations Facility – Some HLW will arrive at the site in rail mounted shipping casks. The rail yard will be equipped with utility engines that will be used to move these packages in and out of the WRTF operations areas. In addition, rail maintenance equipment will be on hand to assure tracks and railroad beds meet performance standards.
- Truck Staging Facility-- Some HLW will arrive at the site in truck mounted shipping casks. The truck staging facility will be used to manage trucks and empty casks that are being sent back to generator sites. In addition, truck maintenance equipment will be on hand to assure vehicles meet performance standards.

- Low Level Waste Facility—a small amount of LLW may be generated by the receipt process and will be disposed at an approved offsite LLW facility. The storage facility will permit the accumulation of LLW until a sufficient quantity is available to constitute a shipment.
- Heavy Equipment Maintenance Facility—to assure the mechanical performance of heavy equipment used at the repository
- Switchyard, Offsite Power Switchgear, and Substations—commercially purchased power will be used and will enter through a switchyard which will distribute it to the various areas of the facility.
- Package Receipt Security Station-- includes Security Station for receipt of offsite shipments of waste.
- Vehicle Maintenance and Motor Pool—to assure the operability of facility vehicles.
- Repository Performance Demonstration Facility--houses the personnel and equipment needed to demonstrate to the regulatory community and the public that the repository is performing as expected.
- Sample Management Facility--to store, in environmentally suitable conditions, geological, hydrological, and biological samples collected at the site and in the vicinity.
- Visitor Center--accommodates the mission of information dissemination with the public and regulators and provides an auditorium and display area.
- Miscellaneous facilities— includes fencing, landscaping, concrete and gravel staging areas, temporary structures for construction, miscellaneous equipment.
- Analytical Support Facility—provides laboratories to analyze environmental and health samples.

Both waste shafts are constructed to a 24 foot diameter accommodate the larger Hanford HLW canisters. Two waste shafts facilitate a throughput rate of 675 canisters per year and a disposal rate of 2 to 3 canisters per day, assuming 250 work days per year.

The waste operations process is as described in Section 5.2.1.2.

5.2.1.4 *All DOE HLW and SNF At The New WRTF Facility—Case 4*

Surface structures and facilities for Case 4 will be the same as for Case 3. (see Figure 4-9)

Both waste shafts are constructed to a 24 foot diameter accommodate the larger Hanford HLW canisters. Two waste shafts facilitate a throughput rate of 675 canisters per year and a disposal rate of 2 to 3 canisters per day, assuming 250 work days per year.

Equipment for Case 4 will be the same as for Case 3 with the following exceptions.

- DHLW/SNF Receipt Bay Facility Overhead Bridge Crane: the DHLW/SNF Receipt Bay Facility Overhead Bridge Crane is a 300 ton capacity crane that is used to lift the transport cask from the trailer or railcar and place it on the Transport Cask Transfer Car for movement to the Waste Inspection Station and the Hot Cell. It is also used to remove the impact limiters from the transport casks, if not removed at the LSPA.

- SNF Cask Lifting Yoke: the lifting yoke is a lifting fixture that attaches to the DHLW/SNF Receipt Bay Overhead Bridge Crane and is designed to lift and rotate the SNF transport cask for outer lid removal and transfer onto the Transport Cask Transfer Car
- DHLW/SNF Hot Cell Bridge Crane: the DHLW/SNF Hot Cell Bridge Crane, outfitted with a rotating block and the DHLW/SNF Facility Grapple, will be used to lift the transport cask inner lid and remove the canister from the transport cask within the Hot Cell. The DHLW/SNF Hot Cell Bridge Crane is also used to move canisters to the Canister Overpack and Storage Room and back to the Hot Cell.
- DHLW/SNF Canister Grapple Hoist: the 6.25 Ton DHLW/SNF Canister Grapple Hoist is used to transfer the canister from the transport cask into the DHLW/SNF Facility Shielded Cask
- DHLW/SNF Facility Shielded Casks (10 foot and 15 foot): the DHLW/SNF Facility Shielded Cask body consists of two concentric steel cylinders. The annulus between the cylinders is filled with lead. The cylinders open in clam-shell fashion to accept, transport, and emplace HLW or SNF canisters.
- DHLW/SNF Facility Cask Transfer Car: the DHLW/SNF Transport Cask Transfer Car is a self-propelled, rail-guided vehicle that transports casks within the Receipt Bay and into the Hot Cell.

Operations for Case 4 will be the same as for Case 3.

5.2.1.5 *All DOE HLW and SNF and Naval SNF at the New WRTF Facility—Case 5*

Surface structures and facilities for Case 5 will be the same as for Case 4. (see Figure 4-9) For this case, one of the two waste shafts is constructed to a 30 foot diameter to accommodate the heavy Naval SNF canisters. This shaft will be outfitted with a 400 ton hoist. The two waste shafts facilitate distributing the lighter loads to the 50 ton hoist and the heavier spent fuel loads to the 400 ton hoist.

Equipment for Case 5 will be the same as for Case 4 with the following exceptions.

- DHLW/SNF Receipt Bay Facility Overhead Bridge Crane: the DHLW/SNF Receipt Bay Facility Overhead Bridge Crane is a 400 ton capacity crane that is used to lift the transport cask from the trailer or railcar and place it on the Transport Cask Transfer Car for movement to the Waste Inspection Station and the Hot Cell. It is also used to remove the impact limiters from the transport casks, if not removed at the LSPA.
- Naval SNF Cask Lifting Yoke: the lifting yoke is a fixture that attaches to the DHLW/SNF Receipt Bay Overhead Bridge Crane and is designed to lift and rotate the Naval SNF transport cask for outer lid removal and transfer onto the Transport Cask Transfer Car.
- Naval SNF Facility Shielded Cask (18 foot): the Naval SNF Facility Shielded Cask body consists of two concentric steel cylinders. The annulus between the cylinders is filled with

lead. The cylinders open in clam-shell fashion to accept, transport, and emplace SNF canisters.

- Naval SNF Facility Cask Transfer Car: the Naval SNF Transport Cask Transfer Car is a self-propelled, rail-guided vehicle that transports casks within the Receipt Bay and into the Hot Cell.

Operations for Case 5 will be the same as for Case 3.

5.3 Underground Facilities

This section provides a scoping level description of the configuration of the underground facilities, their excavation and associated operations. General features of the underground are first described followed by more specific details of key elements. The DHLW underground facility includes the waste disposal, construction, and shaft pillar areas. For Cases 1 and 2, these are added to the present WIPP facility underground design as discussed in Section 4. For the other cases, a new DWR underground facility is depicted. The shaft pillar area contains the facilities to service and maintain underground equipment for mining and waste disposal operations. The construction area is where disposal area mining and outfitting takes place. It is generally segregated from the waste disposal areas, for operational and ventilation purposes. Because of the relatively slow throughput rates, concurrent mining construction activities are planned within active disposal panels. These activities will be separated using schedule coordination, ventilation controls, and temporary bulkheads. Underground cavity dimensions will incorporate the results of experience at the WIPP facility; however, for Cases 3 through 5 where a new site and facility are assumed, some appropriate modeling analyses using site specific parameters will be needed prior to final design. Waste canisters are placed on the floor of disposal rooms and covered with a crushed salt backfill. The salt will originate from the mined tailings in the construction area. Enough tailings will be transported to the disposal area to cover the canisters with mined salt, for shielding and room closures, with the balance transferred to the surface.

The main underground support facilities in the shaft pillar area are shop areas, a vehicle parking and charging area, materials storage area, empty cask holding area, and underground offices. Other facilities provided include electrical substations, emergency vehicle parking alcoves, and a diesel equipment fueling station. These facilities will comply with best management practices and relevant regulations regarding fire suppression, emergency escape, and ventilation control and flow. The amount of mining in the shaft pillar area is restricted to minimize the amount of subsidence that may occur around the shafts in order to accommodate the eventual closure of the shafts.

The underground disposal area is a static barrier that provides secondary confinement should a waste container breach. As such the ventilation flow paths, quantities and differential pressures are maintained such that any air leakage is from non-waste areas to the disposal area. The layout allows for the provision of exhaust filtration, the configuration of which will be determined by the facility safety analysis. The underground ventilation system is designed as an exhausting system that will supply sufficient quantities of air to all areas of the repository, such that all best management practices and regulatory requirements are met.

The underground ventilation system consists of centrifugal exhaust fans at each exhaust shaft. Main fans are the normal flow path and three smaller fans are the filtration flow path. The main fans are used during normal operation to provide a nominal underground flow. The main fans are located near the exhaust shaft. The smaller filtrations fans are located at the Exhaust Fan and Filter Building (EFFB). These fans route the air through banks of high efficiency particulate air (HEPA) filters, designed to remove airborne particulate from the air stream.

Facility excavation and maintenance uses commercially available mining machinery. Mining is performed by continuous mining machines. Mined salt is transported by either diesel haul trucks or belts depending on the rate of excavation required to support disposal operations. Roof support, if needed, will be performed using roof bolting, as for the existing Facility. All mining, maintenance, and other operations will be conducted in compliance with best current practices and regulatory requirements.

A backfill staging area, located underground, will be provided to provide crushed salt as a shielding material over emplaced waste canisters. All remaining mine tailings will be hoisted to the surface through the Salt Handling Shafts and disposed of in an appropriately lined and capped surface pile.

Mining is performed and disposal rooms prepared as they are needed. The mining rate will be such that the amount of time needed to mine and outfit (e.g., localized roof bolting; placement of geomechanical monitoring points; lighting and compressed air as needed) will be the same as the amount of time needed to fill a disposal room with waste. Disposal rooms are constructed with a nominal standup time of 5 years without the need for significant roof bolting. Based on WIPP experience, conventional equipment can easily manage the excavation rates required.

Depending on the case being examined, shafts provide up to seven independent vertical openings that extend from the surface to the underground disposal horizon. The shaft collars, located at the bottom of the shafts, are situated above historic flood levels and the collar slab around the shaft is at a higher elevation than the surrounding ground.

Air intake shafts are the primary intake source of fresh air needed to ventilate the mine. These will be equipped with a hoist and conveyance suitable for handling personnel and materials. The salt handling shafts (up to 2) are the primary path for handling mined salt. In addition, the conveyances will be capable of handling personnel in an emergency. These shafts are also secondary intake sources of fresh air to the mine.

The Waste Shafts are the path for moving waste canisters and waste handling equipment between the surface and the underground disposal horizon. The waste shaft conveyance will be capable of handling large material (e.g. mining machinery components) and personnel. These shafts will be configured to ensure that air flow is toward the repository.

The Exhaust Shafts are the only path by which air is removed from the repository. These shafts will not be equipped or accessible.

The design operating life for the shafts is 50 years. The shaft liners will be designed to meet the site geological and hydrological conditions. If a liner is required, it will be keyed-in at a suitable horizon.

Head frames, hoist houses, and related facilities will be designed to withstand site-related design basis seismic and weather loadings.

All hoists, conveyances, and related equipment will meet the relevant requirements of Federal and State regulations.

Underground openings are constructed using readily available mining equipment. Opening dimensions are selected to minimize the amount of mining needed. To this end, DWR disposal rooms have dimensions that allow mining to occur in a single vertical pass and two horizontal passes. This means that the physical reach of the mining machine is such that the full dimension of the opening can be mined without having to relocate the mining machine vertically and only once horizontally.

Entries and haulage ways are mined wider than disposal areas in order to accommodate the orderly flow of underground traffic and require multiple passes to mine. Adjustment to these dimensions may be made once a specific location (depth and salt horizon properties) has been established for the non-WIPP cases.

Based on experience with mining salt in the United Sates and with WIPP specifically, a mining rate of 40 feet per day per mining machine is a reasonable assumption.

The disposal area provides disposal rooms and panels for the waste. Configurations were discussed in Section 4 and are summarized here. The disposal areas are accessed by four main entry systems. The waste disposal area is designed so that each DWDU contains ten rooms. Each room has nominal dimensions of 20 feet wide by 10 feet high and a 500 foot emplacement area length. An additional 50 feet is provided at each end for placement of salt for shielding and room closure. Rooms are separated by 100 foot wide pillars and are angled, at 60 degrees with respect to mains, to facilitate the movement of mining and emplacement equipment.

The physical configuration of waste packages, panels, rooms and the total amount of waste in each room is limited principally by thermal considerations as discussed in Section 4. As discussed earlier, the emplacement spacing is minimal for most canisters; however, it can be adjusted to provide larger spacing for high-wattage canisters.

Mains serve to provide access and also to control ventilation to the disposal and construction areas. The safety of the underground excavations is evaluated on the basis of criteria established from actual measurements of rock behavior. A geotechnical monitoring program provides measurement of rock mass performance for design validation, routine evaluation of the safety and stability of the excavations, and provides information necessary to predict the short- and long-term behavior of underground excavations. Monitoring radiation and other hazardous emissions or conditions can be done using current techniques and equipment, such as those now in use at WIPP. These will impact power and cabling requirements but do not significantly affect the excavated footprint or facility operations.

The ground-control program at the DWR includes a very methodical approach to ensure that the underground is safe from any unplanned roof or rib falls. From the moment an excavation is mined and throughout the life of the opening, care is taken to remove or restrain any loose, unsafe pieces of ground. As the opening ages, areas of the roof, ribs, and floor may become unstable. To prevent this from occurring, a comprehensive ground control monitoring and support system has been implemented and would be applied to the DWR. Support systems will include rock-bolting and, when needed, supplementary systems. The rock-bolt systems are mechanically anchored bolts and resin-anchored threaded bar. The supplementary systems include cable with mesh and trusses. Prior to waste emplacement in any specific area, spot bolting with short, mechanically anchored bolts is used as necessary, if spalls or loose salt are encountered during and after mining. Mesh may be used in conjunction with these bolts to secure any loose ground encountered during normal inspection processes. As deteriorating ground conditions require, pattern bolting may commence at any time after excavation.

Backfill is placed over disposed waste to provide shielding. Salt will come directly from the mining area with little preparation other than screening to assure no large pieces are used. A remotely operated slinger will be used to place the backfill. (See Figure 5-12)

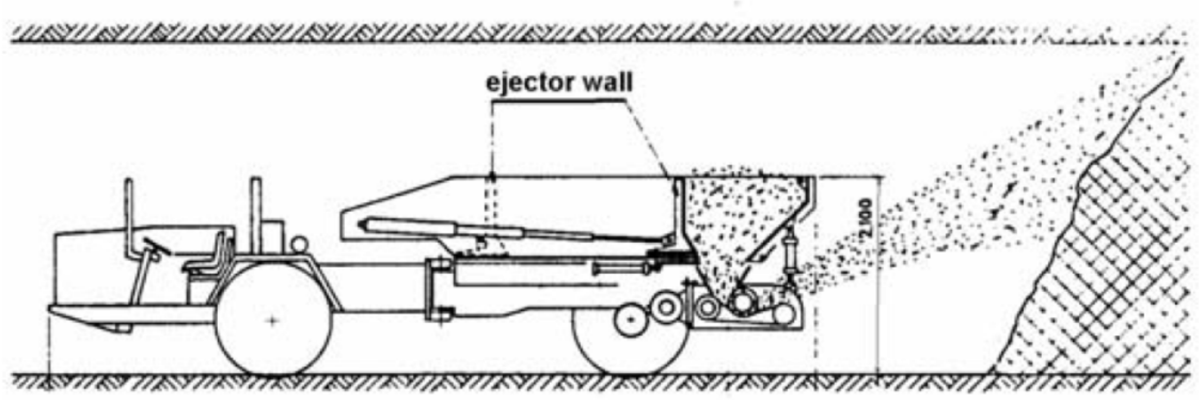


Figure 5-12 Typical Run of mine Salt Backfill Emplacement “Slinger”

The filled 500 foot emplacement rooms will be closed with run-of mine salt. Closure thicknesses are estimated to be 50 feet at the base at each end, making the room overall lengths approximately 600 foot long (covered emplacements plus closures). The entry at the beginning of the room will be blocked with 50 feet of run-of-mine salt, initially to a height of 6 feet, prior to starting waste emplacement. The first canister will be placed adjacent to the initial closure salt and waste emplacement will proceed down the room, leaving the final 50 feet for closing the entry to the room. When leaving the room, both end of room entries will be filled to the roof to block ventilation and complete the room closure. Bulkheads may also be used as part of the room closure if needed. See Figures 5-13 and 5-14 for simplified schematics.

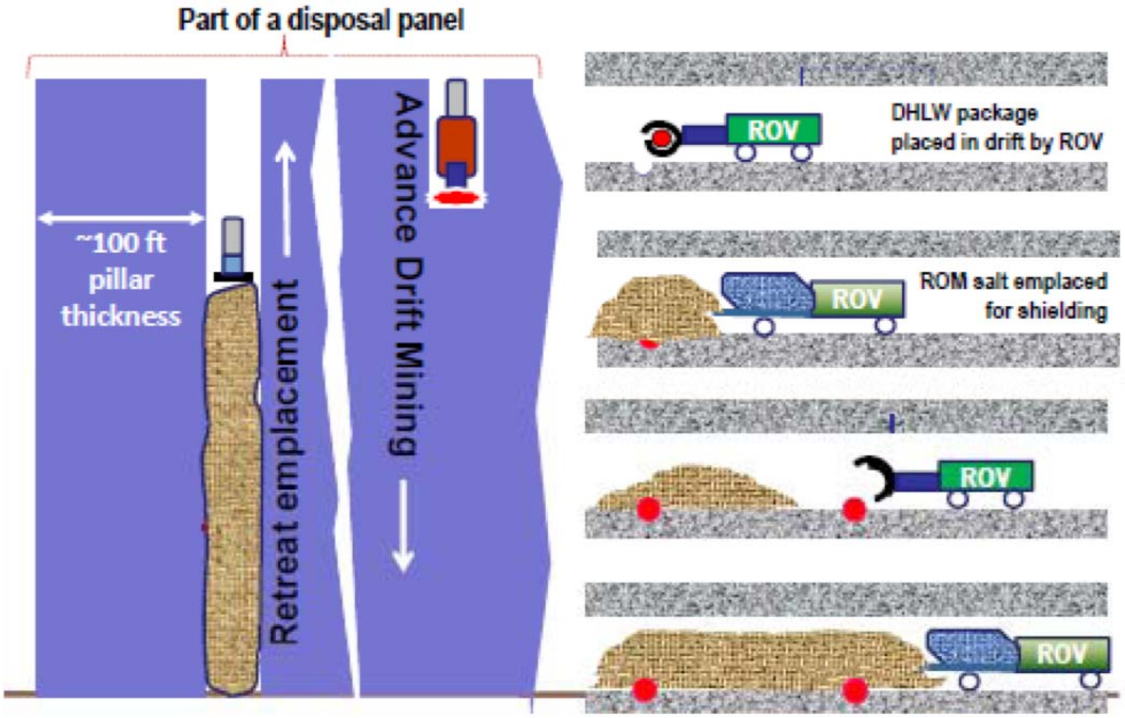


Figure 5-13 Emplacement and Backfill Schematic

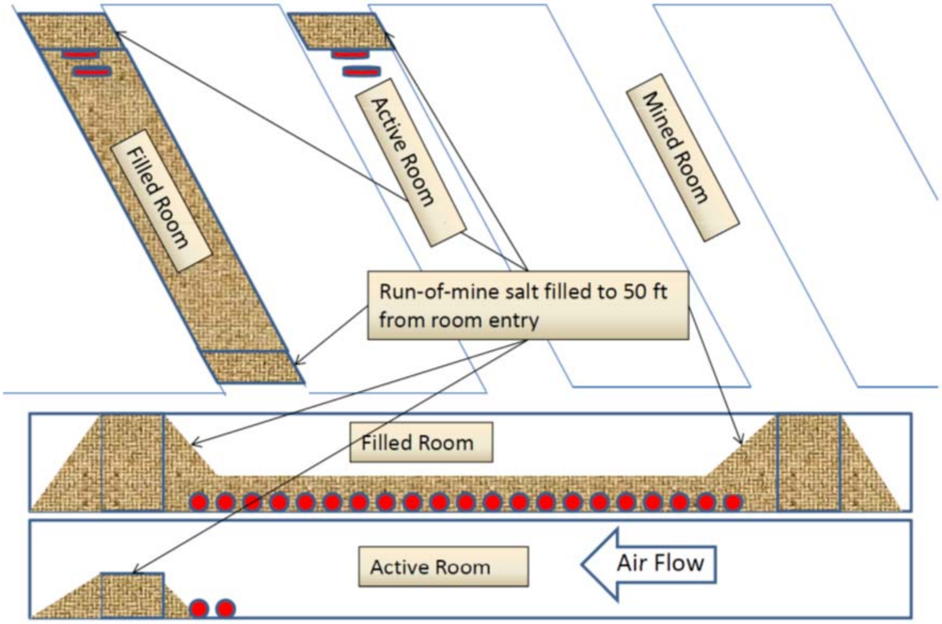


Figure 5-14 Room Closure Schematic

5.3.1 Underground Facilities Mining Considerations

The following is a general description of the DWR for disposing DHLW at the WIPP facility for Cases 1 and 2. Mining considerations at a generic DWR would be similar and would also be based on site specific conditions associated with the generic location such as natural phenomena design basis factors for that location, repository horizon etc. .

The WIPP geologic repository is mined within a 2,000-foot thick bedded-salt layer (Salado). The underground disposal units are located 2,150 ft. (655 m) beneath the ground surface. Defense high-level waste management activities underground will be confined to the western portion of the 1,280-acre mined area (see Figures 4-4, 4-5, 4-10, 4-11 and 5-1).

Vertical shafts connect the underground area with the surface. The waste shaft head frames and hoists are within the WHB and are used to transport containers of DHLW, equipment, and materials to the repository horizon. The waste hoists are used to transport personnel and materials. The air intake shafts provide ventilation to all areas of the mine except for the waste shaft station. The salt handling shafts are used to hoist mined salt to the surface and serve as the principal personnel transport shaft. The exhaust shaft serves as an exhaust air duct for all areas of the mine. The DHLW mission requires the construction of three or more new shafts depending on the specific case examined.

The Waste Hoist Conveyance and shaft furnishings are designed to resist the dynamic forces of the hoisting system and to withstand a design basis earthquake of 0.1 g. The Waste Hoist is equipped with a control system that will detect malfunctions or abnormal operations of the hoist system (such as over-travel, over speed, power loss, circuitry failure, or starting in a wrong direction) and will trigger an alarm that automatically shuts down the hoist. The Waste Hoist is a multirope, friction-type hoist. A counterweight is used to balance the waste hoist conveyance. The Waste Hoist conveyance (outside dimensions) is 30 ft. high by 10 ft. wide by 15 ft. deep and can carry a payload of 45 tons. During loading and unloading operations, it is stabilized by fixed guides. The hoist maximum rope speed is 500 ft per minute. The Waste Hoist system has two sets of brakes and is designed so that either set, acting alone, can stop a fully loaded conveyance under all emergency conditions. The Case 1 DWR mission uses the existing WIPP facility Waste Hoist and shaft furnishings. A new hoist is needed at the new WRTF, to be provided south of WIPP, for the Case 2 DWR concept, due to the length of the Hanford canisters

Underground development for the DHLW mission will proceed generally as follows. The extension of the north-south WIPP facility mains will be mined using the existing mining and hoisting capabilities. Once the mains reach their southernmost point (see Figures 4-4, 4-5, 4-10 and 4-11), mining will drive to the west, beginning with the northernmost tunnel. Once these tunnels are driven to their westernmost point, the mining will turn north to complete the new north-south mains. Finally, the new mains will be tied into the existing WIPP repository by mining connector tunnels from the new north-south mains. Once the southernmost mains are completed to the location of the three new shafts, shaft construction will be initiated. Completing these shafts will facilitate the remaining mining operations and minimize impacts on the WIPP facility TRU waste mission. It is estimated that developing the new Mains and shafts will require about 7 years assuming 2 mining crews working two shifts per day for 250 days per year.

The southernmost DHLW disposal unit will be the first to be mined. The sequence will be to mine the east-west access tunnels to establish separate ventilation circuits for mining and disposal. Because of the low waste throughput rates mining and disposal will be occurring in the same disposal panel simultaneously. Mining will be one room ahead of disposal.

The typical single shift mining rate for salt is 40 feet per day for an 11 foot by 10 foot opening. This means that a 500 foot emplacement room (approximately 600 foot long, counting two 50 foot closure ends), 20 feet wide and 10 feet high will require two mining passes and is equivalent to 1,200 feet of mining, which will take 30 days to mine. Ground control and outfitting may require an additional 30 days, so that a new room can be ready every 60 days. Waste receipt rates for Case 1 require 1.2 rooms per year and for Case 2, 3.5 rooms per year. This requires a new room every 10 months and 3.5 months respectively. This leads to the conclusion that mining on a single shift, at least one room ahead of emplacement should accommodate proposed throughputs.

Prior to moving waste to the underground disposal room, guidance transponders will be placed in the room to direct the remote controlled vehicle to its proper location. These guidance devices may need to be relocated after several emplacements are competed and after the backfill has been placed over the waste. A commercially available diesel-powered fork lift will remove the DHLW facility cask from the Waste Hoist and move it to the underground disposal unit. At this point, a remotely operated emplacement vehicle will move the DHLW facility cask to the emplacement position and place the DHLW canister on the floor of the drift at the pre-determined spacing. Subsequent to emplacement, the remotely operated slinger will be used to place run-of-mine salt over the emplaced canisters to provide shielding. Both the remotely operated emplacement vehicle and the salt slinger are new pieces of equipment to support the DHLW mission.

The following is a general description of the underground repository waste handling operations for disposing DHLW in the WIPP facility. Operations for a generic DWR will be similar.

Equipment used in these processes, for Cases 1 and 2, that are not currently in use at the WIPP facility is shown in italics.

- Once in the mine, the Facility Cask Transfer Car moves the loaded DHLW Facility Cask to the middle of the E-140 drift where a 40-ton forklift removes the cask and transports it to the active DHLW disposal room.

- The *DHLW Facility Cask* is transferred to a remotely operated *DHLW Emplacement Vehicle*.

- The *DHLW Emplacement Vehicle* proceeds to take the *DHLW Facility Cask* to the designated disposal location. Movable guidance devices are in place in the room to assure proper placement of the canister.

- The clamshell on the *DHLW Facility Cask* is then opened and the canister is placed on the floor of the drift.

- The empty *DHLW Facility Cask* will be returned to the hoist for return to the surface.

- After three canisters are emplaced, or at the end of the shift, whichever occurs first, the remotely operated *Salt Slinger* is moved into the disposal room and places a minimum of four feet of run-of-mine salt backfill over the emplaced canisters.

- Radiation control technicians will measure dose rates to assure safe entry by DWR workers. Additional backfill is applied if needed. Once it is determined that entry is safe, waste management workers will relocate the guidance devices in preparation for the next emplacements. In addition, the next emplacement areas will be inspected to assure they are ready to receive waste during a following shift.

- Canister locations will be recorded on mine maps and entered into waste management databases as required by operating permits and DOE Orders.

- Once a room is filled, it will be closed with 50 feet of run of mine salt, placed to the roof using conventional equipment.

- On completion of waste emplacement in each disposal panel, ventilation in that panel is no longer necessary. The installation of a permanent panel closure system will proceed as required by facility Permits.

5.4 Additional Surface and Underground Images

This section provides additional images related to surface and underground waste handling operations and equipment at a WRTF. Images are related to current WIPP operations but are representative of typical WRTF operations, as discussed in the foregoing sections.

Figure 5-15 A RH-72B Transportation Cask Is Trailered Into The WRTF WHB Receipt Bay

Figure 5-16 Impact Limiters Are Removed From A Transportation Cask

Figure 5-17 A Transportation Cask Is Rotated to A Vertical Position For Placement On A Cask Transfer Car

Figure 5-18 A Transportation Cask Loaded On a Cask Transfer Car At The WHB Receipt Bay Inspection Station

Figure 5-19 Transportation Cask Lid Bolts are Loosened And Radiological Surveys Are Performed Above The Inner Cask Lid

Figure 5-20 A Transportation Cask Is Moved By The Transfer Car Into The Cask Unloading Room

Figure 5-21 A Transportation Cask Is Lowered Into The Transfer Cell

Figure 5-22 A Facility Cask Is Moved Into The Unloading Station And Rotated To A Vertical Position To Receive The Waste Canister

Figure 5-23 The Facility Cask Containing The Waste Canister Is Rotated To A Horizontal Position Prior To Transfer Onto The Waste Shaft Hoist Conveyance

Figure 5-24 The Loaded Facility Cask Is Moved Onto The Waste Shaft Hoist Conveyance For Transfer To The Underground

Figure 5-25 Underground Receipt And Transfer Of The Facility Cask For Emplacement

6. Policy and Regulatory

In a predecessor to the current study, Carter et al. (2011, SRNL-RP-2011-00149, Rev 0[41]) provided a detailed summary of the regulatory framework in place for the management and disposal of spent nuclear fuel and high-level waste. The reader is referred to that report for a summary of the regulatory requirements and methodologies in place with respect to:

- Standards for Post Closure
- Licensing Activities (Site Selection, Construction Authorization, License to Receive and Possess Waste, to Repository Closure)
- Performance Assessment Methodologies for Demonstrating Compliance
- Requirements of the Performance Confirmation Program
- Monitoring Requirements

To ensure safety, these activities will continue to be regulated in any future high-level waste repository program, including the one presumed in the present study, namely the development of a repository for defense HLW and SNF in salt. However, several policy and regulatory changes will need to take place as a precursor to the establishment of a specific salt repository site. Furthermore, if the current WIPP repository is expanded to include disposal of defense HLW (as in Cases 1 and 2) or a new repository is constructed within the WIPP LWA area (as might be the case for Cases 3, 4, and 5), additional policy and law changes to the LWA would be necessary. It is outside the scope of the present study to recommend such changes: the present study takes no position with respect to these issues. Rather, the purpose of this section is to provide a review of the policy and regulatory issues that logically follow from the pursuit of any of the options analyzed herein.

National policy for managing and disposing spent nuclear fuel and high-level nuclear waste is established in the NWPA[10]. Inasmuch as the regulatory and policy structure in place is specifically tailored to Yucca Mountain, changes to that structure would need to be made in order for any high-level waste disposal approach to be taken that does not include Yucca Mountain as the first option. Therefore, the decision to halt work at Yucca Mountain has resulted in an impasse, with the nation no longer on a viable path to a solution to the disposal problem.

Accordingly, the principle focus of Blue Ribbon Commission on America's Nuclear Future (BRC) Report to the Secretary of Energy (BRC, 2012) was to offer policy recommendations for managing the nation's civilian and defense SNF and HLW. While it is uncertain whether some or all of the recommendations will be acted upon, they provide a useful framework for discussing the policy and regulatory issues associated with the development of a salt repository for defense high-level waste and SNF. For our purposes, the recommendations of greatest relevance to the issue of disposal of defense SNF and HLW are those related to the future regulatory aspects of the policy, as well as the issue of whether or not defense and civilian wastes should be commingled in a future repository. Conversely, other issues such as the establishment of a new organization responsible for waste management, access to the nuclear waste fund, and the recommendation to establish consolidated interim storage facilities for civilian SNF, while important, have no direct bearing on the options analyzed in the present study. In the subsections that follow, we summarize the BRC recommendations relevant to the development of a salt-based repository for defense waste.

NWPA: The NWPA, including the 1987 Amendment, designates that a License Application be developed for a repository for high-level waste and SNF to be disposed of at Yucca Mountain, up to a legislatively mandated limit of 70,000 Metric Tons Heavy Metal (MTHM). Of this capacity, 10%, or 7,000 MTHM (or equivalent, in the case of HLW) is to be devoted for disposal of defense waste, leaving 63,000 MTHM available for civilian SNF. The implication of the BRC recommendations and Administration policy is clearly that this law will need to be overhauled in order to pursue other alternatives. Currently, there is approximately 65,000 MTHM of civilian SNF on hand at current and former reactor sites, a total that is growing at roughly 2,000 MTHM per year. The quantities of defense waste in need of disposal are more difficult to calculate in that the HLW after processing into borosilicate glass logs must be assigned an equivalent MTHM value. For the method used to make this calculation, the quantity of defense waste exceeds the 7,000 MTHM allotted to defense waste at Yucca Mountain. Therefore, even under the current path prescribed by the NWPA, the 70,000 MTHM limit has been exceeded for civilian and defense waste combined. The NWPA contemplates the construction of a second repository, but prohibits the development of that repository or a monitored retrievable storage facility of SNF until Yucca Mountain is operational. Therefore, the development of a second repository, including one specifically for defense waste, is not prohibited by the NWPA, but is, in practical terms, deferred for many years while the Yucca Mountain repository is developed. Changes to the NWPA are therefore required to implement a defense waste repository solution of the type considered in the present study. More broadly, the BRC advocates a series of recommendations that in essence would constitute a complete overhaul of the NWPA.

Commingling of defense and civilian waste: The BRC report provides a summary of the implications of the decision to commingle civilian and defense wastes in the Yucca Mountain repository; a brief summary of this issue is provided herein. A Presidential decision in 1985 concluded that a separate repository for defense high-level waste was not required, and that the DOE could "commingle" all defense high-level waste and SNF in a repository for commercial waste developed under the NWPA. Therefore, a decision to reverse the 1985 decision to commingle defense and civilian waste for disposal (as is pre-supposed in the options examined in the present study) would require a re-examination of the factors that led to the presidential decision. However, if this is done, and it is decided that a separate repository for defense wastes is desirable, the President could reverse this decision. The BRC lists the following factors that would need to be considered in making a judgment that the commingling decision should be reversed (BRC, 2012):

- "The sharp shift in focus at DOE from the production of materials for nuclear weapons to the cleanup and disposal of legacy wastes from the Cold War.

- The establishment of legally-binding site clean-up commitments that require DOE to remove defense wastes from some sites where they are currently stored by 2035.

- The current lack of statutory authority to develop a repository at a site other than Yucca Mountain under the Nuclear Waste Policy Act.

- Successful development and operation of a geologic repository (WIPP), with a mission explicitly limited to the disposal of transuranic waste only from defense nuclear activities.

- [The BRC's] recommendation to establish a new organization outside of DOE to develop and operate repositories under an amended NWPA."

Thus, there appears to be a method, consistent with the NWPA, to reverse the 1985 decision to commingle civilian and defense wastes. The current study envisions a future in which such a decision is made, and a separate repository for defense waste is developed.

LWA: The LWA established the location of the WIPP repository, setting aside the 16 square miles within which the repository would be constructed. In addition, as observed above, the LWA explicitly limited the repository to the disposal of transuranic waste of defense origin. Thus, the LWA prohibits the disposal of high-level waste and SNF of defense or civilian origin within the LWA boundary. Clearly, any concept that involves HLW disposal in salt at WIPP or within the LWA area would require a fundamental change to this aspect of the LWA. It is again important to point out that it is beyond the scope of this study to recommend such a change; our charter is simply to conduct the analyses and provide information relevant to future nuclear waste management and disposal policy.

Regulatory issues: The current regulatory framework for high-level waste disposal includes provisions for NRC regulation to EPA-established site-specific standards. While these site specific standards do not currently exist for any site other than Yucca Mountain, our study further assumes regulatory guidelines will be similar in content and requirements as the proposed 10 CFR Part 63, Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Specifically, we presume that a dose-based standard will be applied over an extended regulatory time period for a salt-based repository for defense HLW and SNF. Compliance with that standard will need to be demonstrated through the development of a safety case consisting of systematic analysis of data for relevant Features, Events, and Processes, the collection of data and development of numerical models of the total system, and a performance assessment that compares the performance of the repository to the regulatory standard, with quantified uncertainties.

These fundamental steps, and operational considerations from construction through closure, will dictate the duration of the repository program and its ultimate cost, regardless of the regulatory structure put in place. However, even though there are probably no implications to cost, we observe that there are two functioning regulatory frameworks that are relevant to the present study, and versions of either of these approaches could apply to a defense waste repository. The NWPA, the current law for high-level waste, directed the EPA (Sec. 121a) to “promulgate generally applicable standards for protection of the general environment from offsite releases from radioactive material in repositories.” The NWPA also directed the NRC (Sec. 121b) to promulgate technical requirements and criteria that will apply in approving or disapproving 1) applications for authorization to construct repositories; 2) applications for licenses to receive and possess spent nuclear fuel and high-level radioactive waste in such repositories; and 3) applications for authorization for closure and decommissioning of such repositories.

In contrast, The WIPP LWA, which established the site for the disposal of defense-related transuranic wastes, established the EPA as the certifying authority. In accordance with the WIPP Land Withdrawal Act, the WIPP must meet the environmental protection standards established under:

- 40 CFR 191: Environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes.

In addition, the EPA must certify the DOE’s compliance with the 40 CFR 191 disposal and groundwater protection standards in accordance with criteria established under:

- 40 CFR 194: Criteria for the certification and re-certification of the Waste Isolation Pilot Plant's compliance with the 40 CFR Part 191 disposal regulations.

We observe that the development of a defense waste repository opens the possibility for developing a regulatory framework patterned after either of these examples. It is beyond the scope of this study to make a specific recommendation, but we point out that the BRC considered recommendations from a variety of stakeholders on this issue. The conclusion of the BRC is that, although process improvements are possible, “the general division of roles and responsibilities that currently exists between EPA (establishing standards) and NRC (licensing and regulating waste management facilities) is appropriate and should be preserved.” However, the context for this conclusion was the regulatory framework for the general problem of waste disposal without specific reference to defense or civilian wastes, or to a specific repository site. In contrast, the present study specifically deals with defense wastes and, for some scenarios, the WIPP repository or a repository on the LWA area. Therefore, it stands to reason that a regulatory framework that has been shown to work for the WIPP repository might be considered as a basis for the development of regulations for a new salt repository.

7. Schedule and Cost Estimates

The costs and schedules for all cases were developed by the collective experiences of the task team. The scope of work provided by DOE for this study specified a 40-year operational life. The team used the same durations for the Conceptual, Preliminary and Final Designs and Construction and Start-up periods previously developed in the prior salt repository study. The schedules presented in this section do not include the important activities of site screening, site characterization, site selection and these may vary significantly across the cases.

The team also used the same cost estimate models developed for the prior salt repository study as discussed in scoping task plan assumption 2. However, assumption 9 requested that licensing activities be excluded. Since the cost model generates this portion of the estimate the data has been included as discussed in Section 7.2. The cost associated with changing legislation, community consultation, packaging and transportation have been excluded as requested in assumption 9.

7.1 Schedule Range

The schedule for the repository was developed for four major phases: 1) design and construction (which includes conceptual, preliminary, and final design, construction and start-up activities), 2) operations, 3) closure and 4) post closure monitoring. The schedule was developed as a point estimate for a generic location repository and the team applied uncertainty based on their professional judgment which results in the schedule ranges presented in Table 7-1. Some schedule savings are possible for the WIPP extension cases but this was not investigated during the study due to the time limitations imposed.

Table 7-1 Repository Schedule Estimates

Phase	**Duration Range** (yrs)
Conceptual Design	3 – 9
Preliminary Design	1.5 – 2
Final Design	4 – 5.5
Construction and Start-up	6.5 – 8
Total Design and Construction	15 - 24.5
Operations	40
Closure	9 – 12
Post Closure Monitoring	50 (scoping task plan assumption 4)

7.2 Design, Construction, Start-up, Operations, Closure and Monitoring Cost Range

The design, construction start-up, operations, closure and monitoring cost (DCSOCMC) estimate range is determined based upon the schedule (Section 7.1) and type of activities conducted in each of the four schedule phases.

Table 7-2 provides a summary of the DCSOCMC range for each of the five cases. The costs are detailed by the same estimating categories in the original Salt Repository Study. These results indicate the cost of disposing of HLW ranges from $13.1 B to $17.9 B in 2012 dollars. This range is established by taking the low from Case 3 (HLW disposed in a generic location) and the high from Case 2 (HLW disposed in a WIPP extension). Although Case 2 is slightly higher than Case 3, the low-high range essentially overlaps indicating there is little cost difference between the two cases. This conclusion is driven by the need for new surface facilities to accommodate the larger than WIPP design basis canisters and emplacement capacity.

The incremental cost of adding the DOE SNF (3,542) canisters to a generic location repository is approximately $120 to 160 million or $34 K to $45 K per canister.

The incremental cost of adding the Naval Fuel to a generic location repository is approximately $790 to $1,130million or $1.9 to $2.8 million per canister. This large difference between the DOE SNF and the Naval SNF is due to the additional repository emplacement area to accommodate the high thermal load and the additional surface infrastructure requirements. The study team recommends alternative approaches be considered for the Naval Fuel.

A "pilot" Defense Waste Repository which disposes of the SRS only canisters (Case 1) ranges from $8.6 to $11.6B or $1.1 to $1.5M for each canister. The economy of scale can be observed by comparing Cases 1 and Case 2 (or 3) in which the cost per canister decreases by about half.

Table 7-2 also provides the DCSOCMC in escalated dollars. A centroid of expenditure methodology was utilized to develop escalated cost estimate ranges. This method uses a single cumulative escalation rate as published by the DOE Office of Engineering and Construction Management web page. The rate is calculated to the centroid of expenditures. This method was used to calculate both the TPC and DCSOCMC escalated cost ranges.

Table 7-3 provides the DCSOCMC cost detailed by the schedule phase in both 2012 and escalated dollars.

7.2.1 Contingency

Contingency was estimated based upon team collective experiences. Table 7-4 provides the general contingency guidelines used in the DCSOCMC estimates. These guidelines were evaluated for each element of the cost estimate and adjusted as appropriate based upon the range of uncertainties determined by the study team. Application of the contingency provides the high and low ranges of the DCSOCMC estimates.

Table 7-2 Design, Construction, Start-up, Operations, Closure and Monitoring Cost Summary by Cost Element ($MM)

Element	Case 1		Case 2		Case 3		Case 4		Case 5	
	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
FACILITY DESIGN, CONSTRUCTION & STARTUP	1,750	2,522	3,938	5,473	3,749	5,140	3,754	5,146	4,110	5,672
OPERATIONS & MAINTENANCE (O&M)	3,665	4,747	3,798	4,919	3,722	4,820	3,731	4,831	3,731	4,831
CLOSURE	717	1,143	717	1,143	717	1,143	717	1,143	717	1,143
WASTE PACKAGES	1	1	3	3	3	3	3	4	3	4
REGULATORY & LICENSING	268	277	343	354	806	840	806	840	806	840
MONITORING	756	1,031	1,375	1,875	1,188	1,620	1,291	1,761	1,455	1,985
PERFORMANCE CONFIRMATION PROGRAM	272	371	623	849	601	820	602	821	654	892
INTEGRATION	1,116	1,518	2,431	3,307	2,286	3,110	2,286	3,110	2,511	3,416
DCSOCMC	**$ 8,550**	**$ 11,610**	**$ 13,230**	**$ 17,930**	**$ 13,080**	**$ 17,500**	**$ 13,200**	**$ 17,660**	**$ 13,990**	**$ 18,790**
DCSOCMC (including Escalation)	**$ 23,860**	**$ 40,840**	**$ 36,940**	**$ 63,050**	**$ 36,500**	**$ 61,540**	**$ 36,830**	**$ 62,110**	**$ 39,060**	**$ 66,070**

Table 7-3 Design, Construction, Start-up, Operations, Closure and Monitoring Cost Summary by Schedule Phase ($MM)

	Case 1		Case 2		Case 3		Case 4		Case 5	
Phase	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
Early Project Costs and Pre- Conceptual Design	75	101	133	180	197	264	197	264	204	274
Conceptual Design & Site Characterization	533	701	1,103	1,465	1,205	1,546	1,210	1,552	1,301	1,677
Preliminary Design	151	206	324	440	328	435	328	436	355	473
Final Design	340	471	728	994	725	968	726	970	791	1,063
Construction	1,735	2,447	3,359	4,638	3,273	4,451	3,284	4,465	3,565	4,880
Operational	4,630	6,051	6,163	8,120	5,974	7,820	6,027	7,891	6,289	8,248
Closure	901	1,386	1,082	1,630	1,078	1,614	1,089	1,629	1,119	1,669
Post Closure	180	246	336	458	292	398	328	447	364	497
DCSOCMC	**$ 8,550**	**$ 11,610**	**$ 13,230**	**$ 17,930**	**$ 13,080**	**$ 17,500**	**$ 13,200**	**$ 17,660**	**$ 13,990**	**$ 18,790**
DCSOCMC (including Escalation)	**$ 23,860**	**$ 40,840**	**$ 36,940**	**$ 63,050**	**$ 36,500**	**$ 61,540**	**$ 36,830**	**$ 62,110**	**$ 39,060**	**$ 66,070**

Table 7-4 DCSOCMC Estimate Contingency Guidelines (%)

Facility	**Contingency** (Scope/pricing uncertainty)		**Technical Risk (T&PRA)** (Process/Equipment uncertainty)		**Total Contingency**	
	Low	**High**	**Low**	**High**	**Low**	**High**
Infrastructure & Balance of Plant						
Similar facilities/estimates model	5	30	0	0	5	30
R.S. Means	5	30	0	0	5	30
Uncertainties in size/layout/conditions:	5 - 20	50	0	0	5 - 20	50
Site Infrastructure actual average:			0	0		
Process Facilities/Buildings, Waste Packages						
First-of-a-kind, hardened/shielded/high-rad	20	50	0	25	20	75
Nth-of-a-kind, hardened/shielded/high-rad	10	40	0	0	10	40
Nth-of-a-kind, low rad	5	30	0	0	5	30
Process Facilities / Buildings actual average:						
Mining	5	30	30	70	35	100

7.2.2 Facilities Design and Construction Cost

Table 7-5 provides a summary of the facilities design and construction cost for the surface and sub-surface facilities for the five cases considered in this study. The surface facilities are described in Section 5.

Facilities Estimate

The facilities design and construction cost was estimated for Case 3 (new generic location defense waste salt repository) by developing a facilities list that includes a description and size of the building. Cases 1 and 2 were developed by evaluating the existing WIPP facilities versus these requirements. Where adequate those facilities were excluded from the facilities estimate. Cases 4 and 5 were done in a similar manner increasing the facilities size or capacity as needed for the increased inventory. These additions and deletions are described in Section 5 and detailed in Table 5-1.

For each facility the anticipated hazard category was used to select a cost model for the individual structures. The cost model derives from recent Follow-on Engineering Alternatives Studies estimates for the recycling facility[16]. Low and high contingencies were assessed for each facility based on their complexity and relative degree of uncertainty.

Mining Estimate

Underground mining is estimated in Table 4-3 which identifies those portions needed to support initial operations (included in the facilities design and construction cost) and those portions completed on a just-in-time mining basis (included in Operations and Maintenance cost). The mining estimate is then converted to manpower given a mining rate of 40 linear feet per shift-crew. Each mining crew is 18 employees and they are supported by crews of: 18 assigned to hoisting, 20 mine engineers, 10 geotechnical engineers, and 25 underground maintenance workers.

Table 7-5 Facilities Design and Construction Cost Cases 1 to 5

Facilities	**Case 1**		**Case 2**		**Case 3**		**Case 4**		**Case 5**	
	Low Range $ millions	**High Range $ millions**	**Low Range $ millions**	**High Range $ millions**	**Low Range $ millions**	**High Range $ millions**	**Low Range $ millions**	**High Range $ millions**	**Low Range $ millions**	**High Range $ millions**
Major surface facilities	40	50	626	791	755	953	757	954	757	954
Balance of Plant and support surface facilities	137	170	421	521	451	559	454	562	454	562
Sub-surface facilities	918	1,412	1,399	2,152	1,104	1,699	1,104	1,699	1,334	2,053
Total Facilities Construction Cost	**$ 1,095**	**$ 1,632**	**$ 2,445**	**$ 3,464**	**$ 2,311**	**$ 3,210**	**$ 2,314**	**$ 3,215**	**$ 2,544**	**$ 3,569**
Total Facilities (including Escalation)	**$ 1,830**	**$ 3,435**	**$ 4,085**	**$ 7,293**	**$ 3,861**	**$ 6,758**	**$ 3,867**	**$ 6,767**	**$ 4,251**	**$ 7,513**

The total area of the underground for the 40-year operational period ranges from approximately 1 to 2 square miles depending upon the case. Table 8-5 provides the volume of the excavation, the volume of the run-of-mine salt produced by the excavation, the approximate volume used in backfilling and the volume of salt which is anticipated to be hauled to the surface via the salt removal shaft. The percentage of the salt used in the room backfilling operation is less than 15% of the total salt generated

Due to the uncertainty of thermal loading and associated mining layout, 30% contingency was added to the mining estimate for the low range and 100% was added for the high range.

Table 8-5 Excavation Volume (Ft^3)

	SRS HLW Case 1	**HLW Waste Packages Case 2**	**HLW Waste Packages Case 3**	**HLW and SNF Case 4**	**HLW & SNF & Naval SNF Case 5**
Volume of Mains	27,061,200	64,471,200	25,140,000	25,140,000	25,140,000
Volume of Panels	15,100,000	42,280,000	42,280,000	51,340,000	60,400,000
Volume Total	42,161,200	106,751,200	67,420,000	76,480,000	85,540,000
Volume of run-of-mine Salt	59,025,680	149,451,680	94,388,000	107,072,000	119,756,000
Volume Used in Backfill	4,000,000	11,200,000	11,200,000	13,600,000	16,000,000
Volume of Excavated Salt	55,025,680	138,251,680	83,188,000	93,472,000	103,756,000
Percentage of Salt Used in Backfill	6.8	7.5	11.9	12.7	13.4

7.2.3 Operations and Maintenance Cost

Operations and maintenance cost are provided for each case in Table 7-2. Annual O&M costs for Case 1 and 5 are presented in Table 7-1 and 7-2 to illustrate the cash flow requirement for these selected cases. The O&M costs were developed based on the full time equivalent (FTE) employees. Figure 7-3 provides the total operations and maintenance staffing for all cases. The manpower basis is described in the sections below.

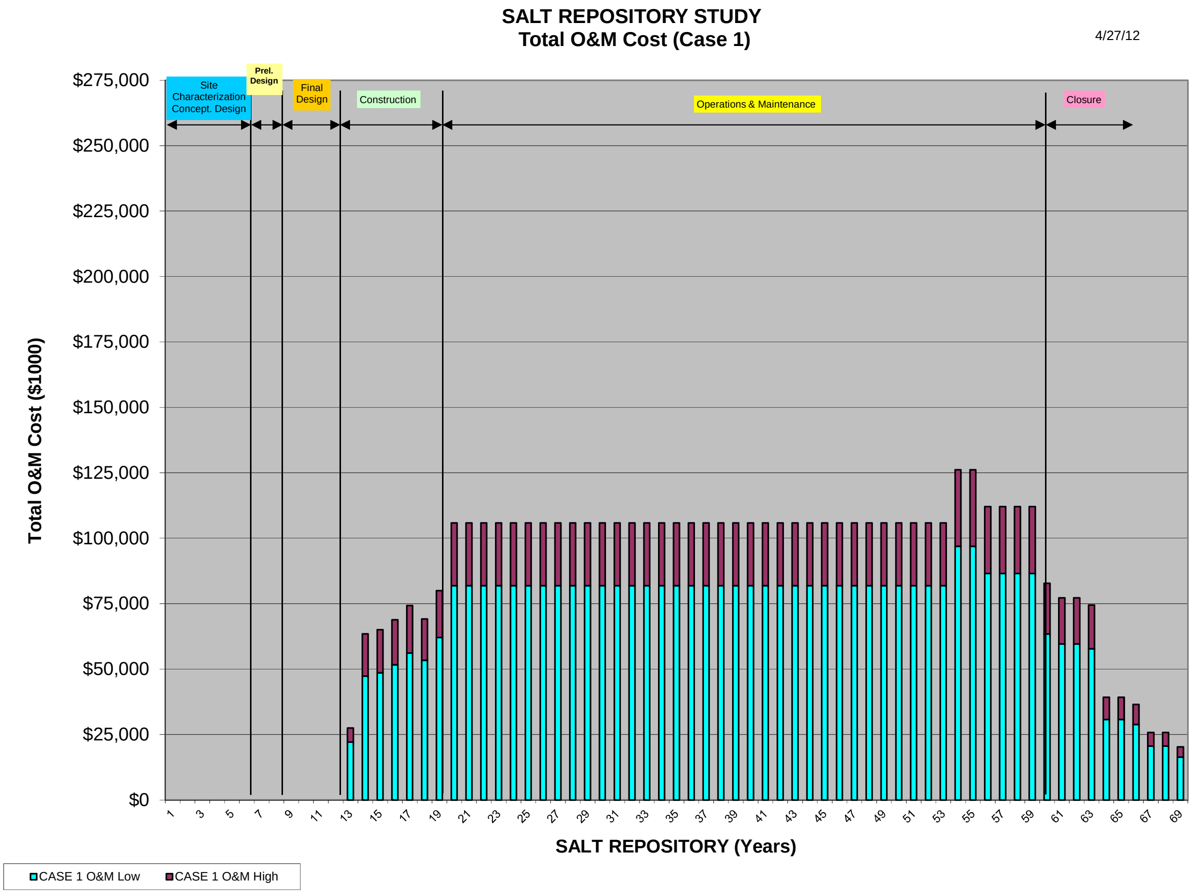


Figure 7-1 Case 1 Annual Operations and Maintenance Costs

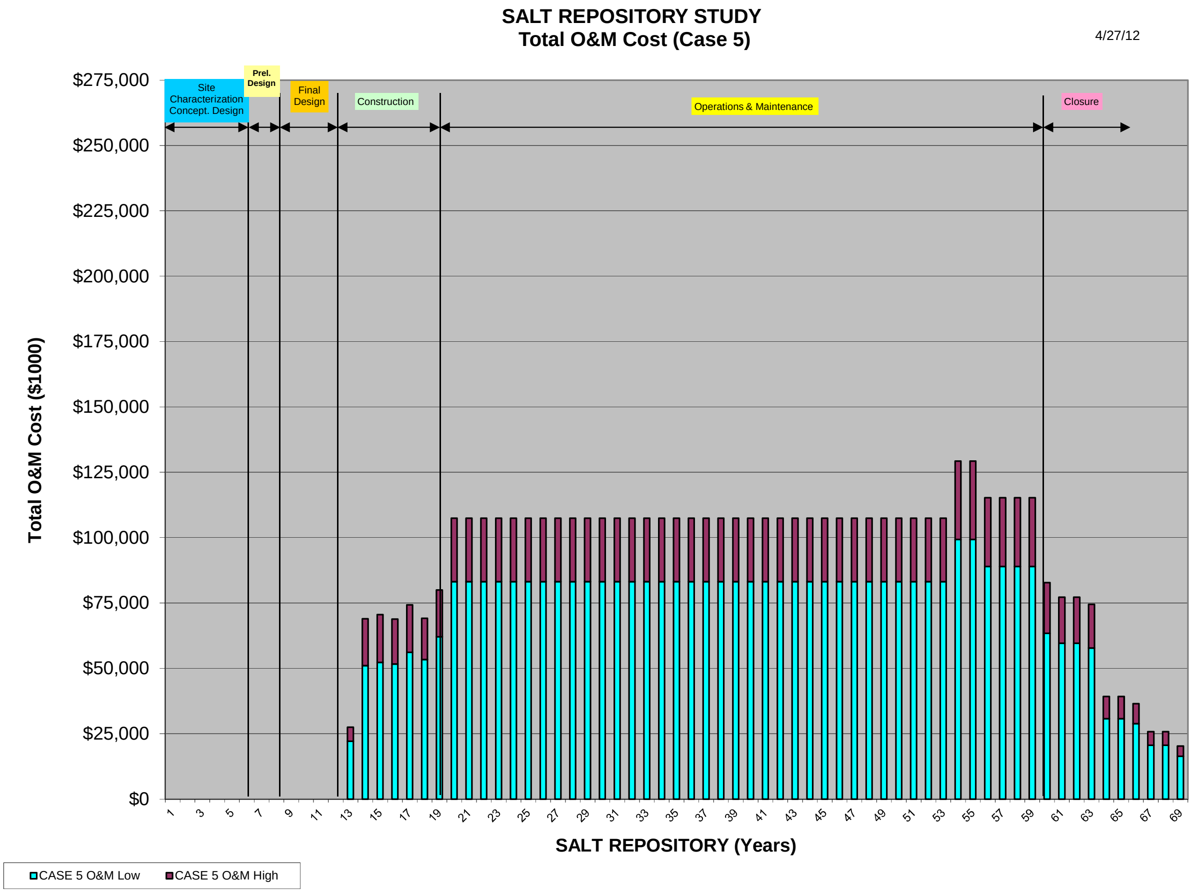


Figure 7-2 Case 5 Annual Operations and Maintenance Costs

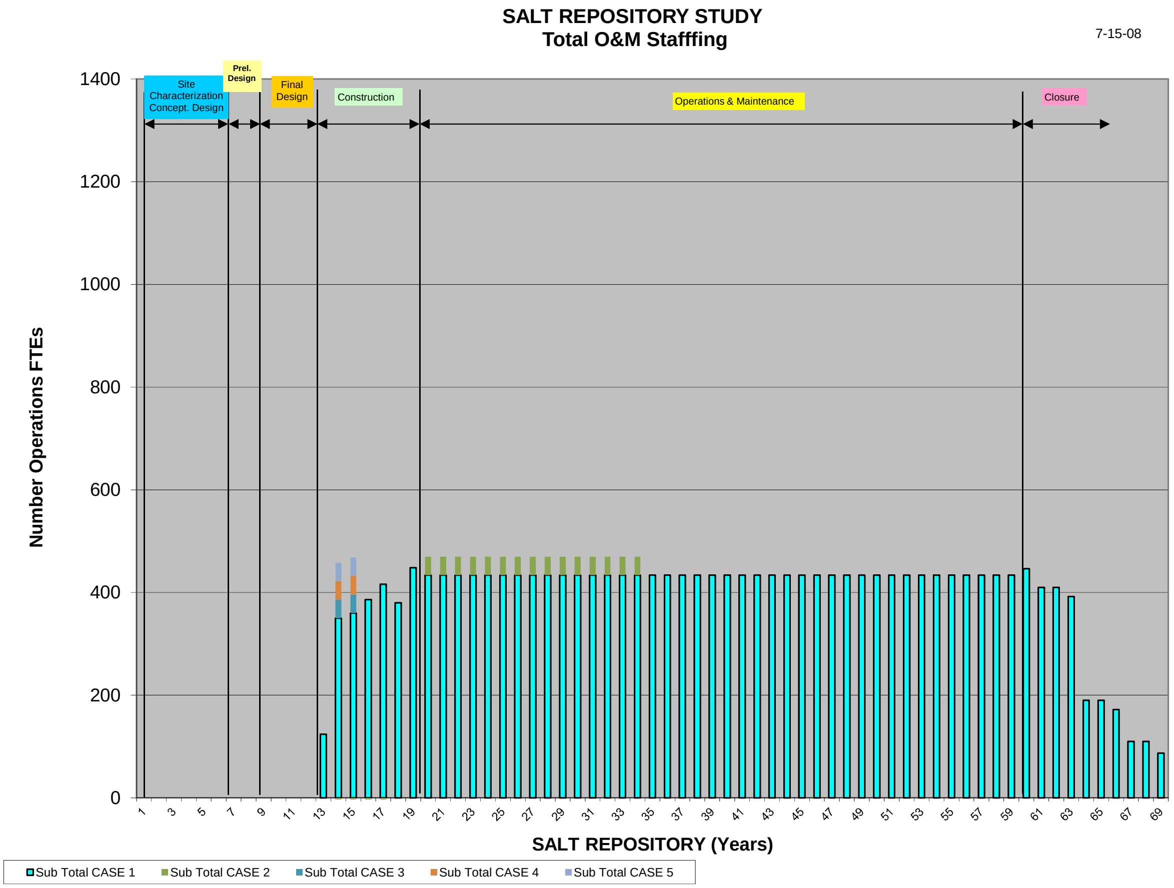


Figure 7-3 Operations and Maintenance Staffing for All Cases

7.2.3.1 *Waste Handling Staffing*

The estimate of the staffing needs for waste handling operations is derived from the experience with the WIPP. The following assumptions were used in developing this estimate:

- Waste handling will occur on two shifts per day, with up to two crews on each shift. Typical RH crew size is 10 including supervisory personnel. One RH package is emplaced each shift. One additional crew is included to accommodate vacations and training periods.
- RADCON occurs during the day shift and whenever waste handling is underway
- Quality Assurance staff is available whenever waste handling is underway
- Information Technology provides waste data base administrators whenever waste handling is underway

7.2.3.2 *Support Staffing Bases*

The support staffing is derived from the experience with the WIPP. The following assumptions were used in developing this estimate:

- Hoisting is available for three shifts per day
- RADCON occurs during the day shift and whenever waste handling is underway
- Surface and underground maintenance occur on one shift per day

- Engineering occurs during one shift per day
- Security is available 24 hours per day
- Emergency response is available 24 hours per day
- Quality Assurance is available whenever waste handling is underway
- Information Technology provides waste data base administrators whenever waste handling is underway
- All other functions are single shift.

Since some support staffing is population dependent, appropriate increases were made during the ramp to higher throughputs.

Standard Savannah River Site labor, overhead and fee costs were used to convert the estimated operations and maintenance staffing into estimates of annual operating cost for each case[37]. Allowances were added for additional costs which are applicable (e.g., replacement of continuous mining machines, other small projects and materials), as well as utility costs. 5% contingency (30% for mining and security) was then added to these calculated costs to establish the low range estimate, and 30% contingency (100% for mining and security) was added to them for the high range estimate.

7.2.4 Waste Packages

The disposal concept (Section 3) envisioned by the study team places the canister directly on the salt and immediately backfills the alcove with crushed salt. This concept does not rely upon additional containerization of the waste packages. The only waste packages required for the Defense Waste Salt Repository are standard waste boxes for packaging the repository generated waste and in the abnormal event of a leaking HLW canister, the leaking canister can be placed inside an overpack. These costs are approximately $1M to $4M including contingency over the facility life cycle[37]. Contingency of 5% (low range) to 30% (high range) is included.

7.2.5 Regulatory and Licensing

Regulatory and licensing cost are a part of the existing cost estimating model and have been included in Tables 7-2 and 7-3 above. If desired these costs can be subtracted from the totals in Tables 7-2 where they are itemized by estimate category. These costs span across all schedule phases and so removing them from Table 7-3 is more difficult and will require a cost model change if a decision is made to remove this category from the estimate.

This category includes the preparation of environmental assessments, site characterization studies and federal and state regulator support. This category does not include costs associated with changing legislation, or community consultation.

Cost including low contingency ranges from $37 million for Case 1 to ~$125 million for Case 5. The cost model reflects variations in the waste package quantity and underground footprint between the cases.

7.2.6 Monitoring

Monitoring cost including the low contingency ranges from ~ $750 million for Case 1 to ~ $1,450 million for case 5. The cost methodology reflects the variation in underground footprint between the cases. Contingency of 10% (low range) and 50% (high range) was applied.

7.2.7 Performance Confirmation

Performance confirmation costs including low contingency ranges from $270 million to ~ $650 million. The cost methodology reflects variation in the facility design and construction costs between the cases.

7.2.8 Program Integration

Program integration costs are includes four components:

- Owner cost
- Program manager integrator cost
- Program independent quality assurance cost.

These cost ramp up over the the conceptual design period and remains at this level through the closure time period. The cost methodology reflects variation in the facility design and construction costs between the cases.

Contingency is then added 10% (low range) and 50% (high range).

7.2.9 Repository Closure

Repository closure will include backfilling and closing underground areas, shaft sealing and backfilling, surface facilities decontamination, as necessary, demolition and removal of surface structures, and site reclamation and restoration. It is expected that detailed planning and preparation for closure would commence before the end of the operations period and that actual closure activities would require approximately ten years.

Closure costs are estimated by ramping down the operations and maintenance staffing over the ten year closure period. Capital projects for active and passive institutional controls are estimated by using 15% of the facility design and construction point estimate. Contingency of 10% (low range) and 50% (high range) was applied.

7.3 Waste Recovery Costs

Assumption 5 in the scoping task plan requested an additional contingency estimate for “the cost of mining back into the salt to recover the materials, as in the current contingency plan at WIPP”. The current cost model does not include this additional contingency however it is not unreasonable to expect the extraction process to be equal in duration to the emplacement process. Therefore to a first approximation, the recovery cost would be equal to the operations and maintenance cost in Table 7-2 which range from $3.6 to 4.8 billion dollars.

8. Conclusions and Recommendations

Based on the analysis provided in this scoping study, disposal of defense waste in a salt repository is feasible within a reasonable schedule and cost. The time to design, construct and start-up a salt repository is estimated to be 15 – 25 years after site selection. Some schedule savings are possible for the WIPP extension cases but this was not investigated during the study due to the time limitations imposed.

The most significant assumption in the approach used to develop the disposal concept is that the waste canisters can be directly emplaced on the disposal room floor and covered with run-of-mine salt immediately. Additional engineered barriers will not be required.

The large Naval Fuel canisters are essentially incompatible with a shaft-hoist repository horizon access system. The hoist required exceeds industry standards and is not likely commercially available. The study team recommends alternatives be considered for this material including repackaging into packages compatible with the shaft-hoist access systems.

9. References

(Note: References in this section also include many reflected in Carter, J. T. et al, "Disposal of Recycling Facility Waste in a Generic Salt Repository", SRNL-RP-2011-00149, PREDECISIONAL DRAFT, Rev 0, January 2011[41] for continuity with that prior salt repository study).

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10. ACKNOWLEDGEMENTS

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Washington TRU Solutions provided expertise for the development of the underground disposal concepts, and provided real world experiences for operations of a waste repository in a salt environment.

Sandia National Laboratory had previously provided technical expertise for waste disposal in salt, both U.S based and foreign country operations, and Los Alamos National Laboratory provided regulatory guidance and expertise.

Appendix

A-1 NUMERICAL ANALYSIS OF HEAT TRANSFER IN A GENERIC WASTE REPOSITORY FOR DEFENSE HIGH LEVEL WASTE

The pages that follow reflect the full content of Reference 55 to support concurrent availability of that document, together with this study.

Numerical Analysis of Heat Transfer in a Generic Waste Repository fo Defense High Level Waste

Earth and Environmental Sciences Division
Computational Earth Sciences Group

Los Alamos National Laboratory

P.H. Stauffer
D.R. Harp
D.G. Levitt
M.K. Phoolendra
B.A. Robinson

Introduction

This report describes simulations of heat flow in salt that were conducted using the LANL porous flow simulator, Finite Element Heat and Mass Transfer Code (FEHM, http://fehm.lanl.gov/; Zyvoloski 2007). FEHM has been used extensively for simulations involving multiphase heat and mass transport and has been cited in over 100 peer reviewed publications (FEHM 2012). These simulations investigate the temperature regimes generated by the disposal of high-level waste (HLW) canisters in a generic salt repository. These simulations build on the lessons learned from previous heat flow simulations in bedded salt formations including those described in Clayton and Gable (2009), and in DOE (2012). Clayton and Gable (2009) describe 3D simulations that were conducted using FEHM to simulate heat flow in a generic salt repository. DOE (2012) describes a preliminary scoping exercise in which 3D simulations of heat flow were conducted using five waste canisters with variable heat loads ranging from 500 to 2,000 Watts. The simulations represent the heat transfer behavior for an in-drift disposal scenario in which waste packages are placed on the drift floor and covered with run-of-mine salt.

Heat flow simulations performed for this report are conducted using both deterministic and Monte Carlo approaches to investigate various waste canister disposal configurations in order to answer the following questions:

- What is the likely highest canister/salt contact temperature reached?
- How far vertically and laterally from waste canisters do elevated temperatures reach?
- How does canister burial depth in run-of-mine salt impact temperature profiles?
- How does canister spacing impact temperature profiles?

Model Set-up

A three-dimensional finite-volume heat transfer model has been constructed using the computer code FEHM to investigate the temperatures that would be attained in a generic salt repository for defense HLW. For these bounding simulations, thermal conduction is assumed to be the predominant mode of heat transfer.

Material Properties:

FEHM has been modified to include two models for salt thermal conductivity as a function of temperature (Clayton and Gable, 2009). First, intact salt follows the Munson et al. (1990) relationship:

$$\lambda_{salt}(T) = \lambda_{300}\left(\frac{300}{T}\right)^{\gamma} \qquad \text{Eq. 1}$$

where λ_{300} is the thermal conductivity of salt at T = 300 K (5.4 W/m K), and γ is a material constant of 1.14. The thermal conductivity of crushed salt is based on the BAMBUS II study (Bechtold et al., 2004) and results in the following equation (From Clayton and Gable, 2009):

$$\lambda_{c-salt}(T) = k_{cs}(\varphi)\left(\frac{300}{T}\right)^{\gamma} \qquad \text{Eq. 2}$$

With the porosity (φ) dependent thermal conductivity k_{cs} as:

$$k_{cs}(\varphi) = (-270\varphi^4 + 370\varphi^3 - 136\varphi^2 + 1.5\varphi + 5)\cdot 1.08 \qquad \text{Eq.3}$$

Other material properties used in the model are given in Table 1, where the waste containers are assumed to have the thermal properties approximating a borosilicate glass (Clayton and Gable, 2009). All simulations assume that the air in the simulated tunnels and rooms is stagnant with no advective heat transfer. Porosity of the crushed salt (i.e., run of mine salt) is assumed to be 0.35.

Table 1

Material	Thermal Conductivity (W/m K)	Specific Heat (J/kg/K)	Density (kg/m^3)	Thermal Diffusivity (m^2/s) at 300 K
Waste Canister	1.0	840	2200	5.4e-7
Intact Salt	Eq. 1 5.4@300K	931	2190	2.6e-6
Crushed Salt	Eq. 2 0.73@300K	931	1423	5.5e-7
Air	0.03	1000	1.0	3.0e-5

Model Domain and Boundary Conditions

The model domain is designed to simulate temperature evolution in an interior room within a panel of rooms surrounded by other panels. Due to the symmetry of the room and surrounding panels, the model is limited to one half of the room (540 ft x 10 ft), extending halfway to the center of the salt pillar that separates the domain from the adjacent room. Figure 1 is a schematic diagram (plan view) of the model layout with the symmetry domain highlighted as a green box. Waste canisters are simulated as 2-ft diameter by 10 ft long canisters placed crosswise in the approximately 10-ft high by 20-ft wide room. Figure 2 shows a 3D representation of the model domain. The model uses an orthogonal grid with refinement within and near the room (0.3 m node spacing), expanding geometrically to the boundaries. Grid generation is automated to facilitate modifications to the canister dimensions and spacing, room dimensions, and general spacing (GRIDDER, 2012).

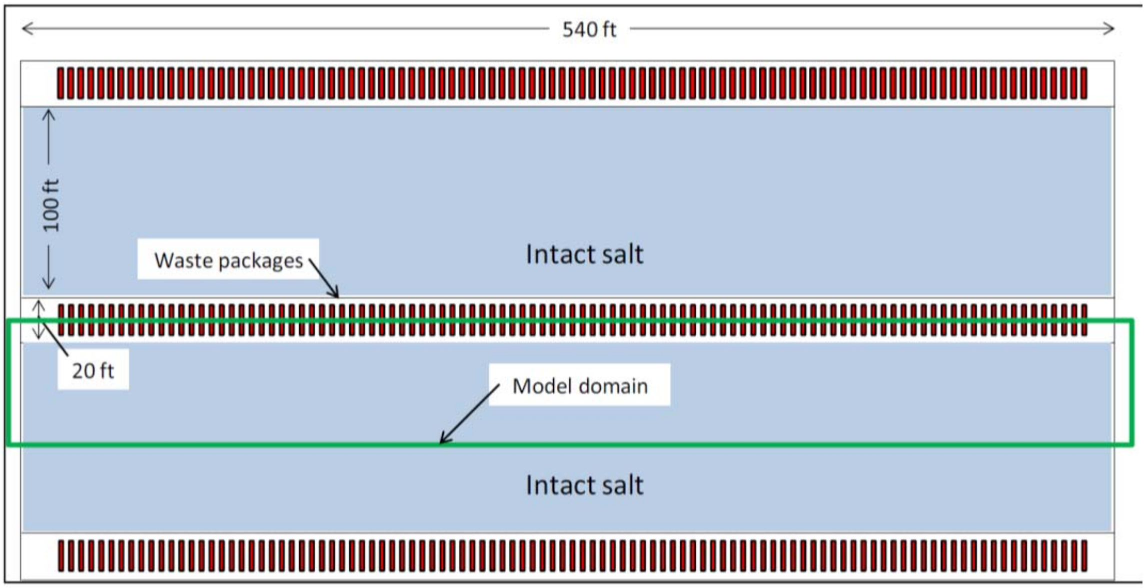

Figure 1. Plan view of the modeled waste canister configuration and model domain. Diagram is not

precisely to scale. Model domain is shown outlined by the green line, while the surrounding rooms are shown to allow visualization of the reflection boundary conditions.

Temperature influences from the reflected half of the room and adjacent rooms and panels are simulated using thermal reflection boundaries (no flow) along all four lateral sides of the model domain. Access drifts at both ends of the room are included to their centers where reflection boundaries have been imposed, representing panels of rooms that are assumed to extend in all directions. This domain would represent a portion of the repository near the center, where temperatures would be highest (disposal rooms on the edge of the repository would attain somewhat lower temperatures). Boundary conditions on the top and bottom of the model are set to fixed far-field temperatures approximating the initial temperature at the depth in the WIPP facility (~30°C). Finally, the heat loads in the waste canisters are assumed to be continuous with no decay, leading to long-term steady-state temperature profiles as the energy flux from the canisters comes into equilibrium with the thermal gradient carrying heat to top and bottom boundaries of the model domain. Thus our calculations of maximum temperature are conservative, as the heat output of the real waste packages will decrease with time as the heat-generating radioactive components decay.

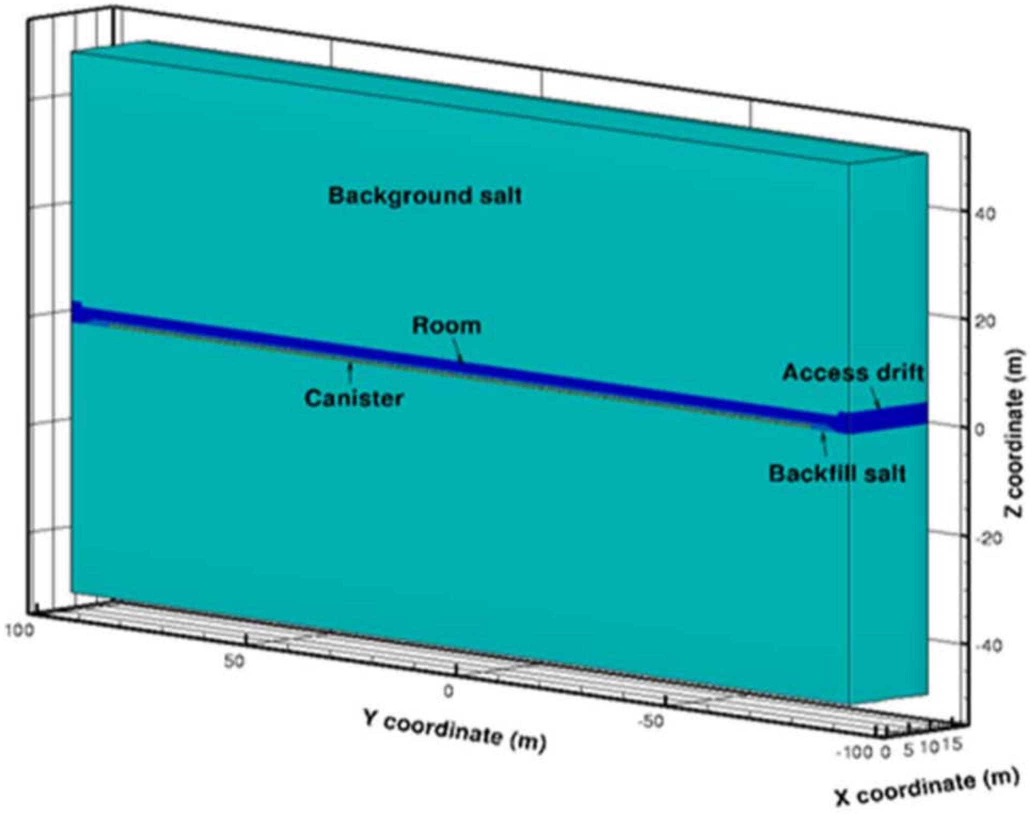

Figure 2. 3D view of model layout.

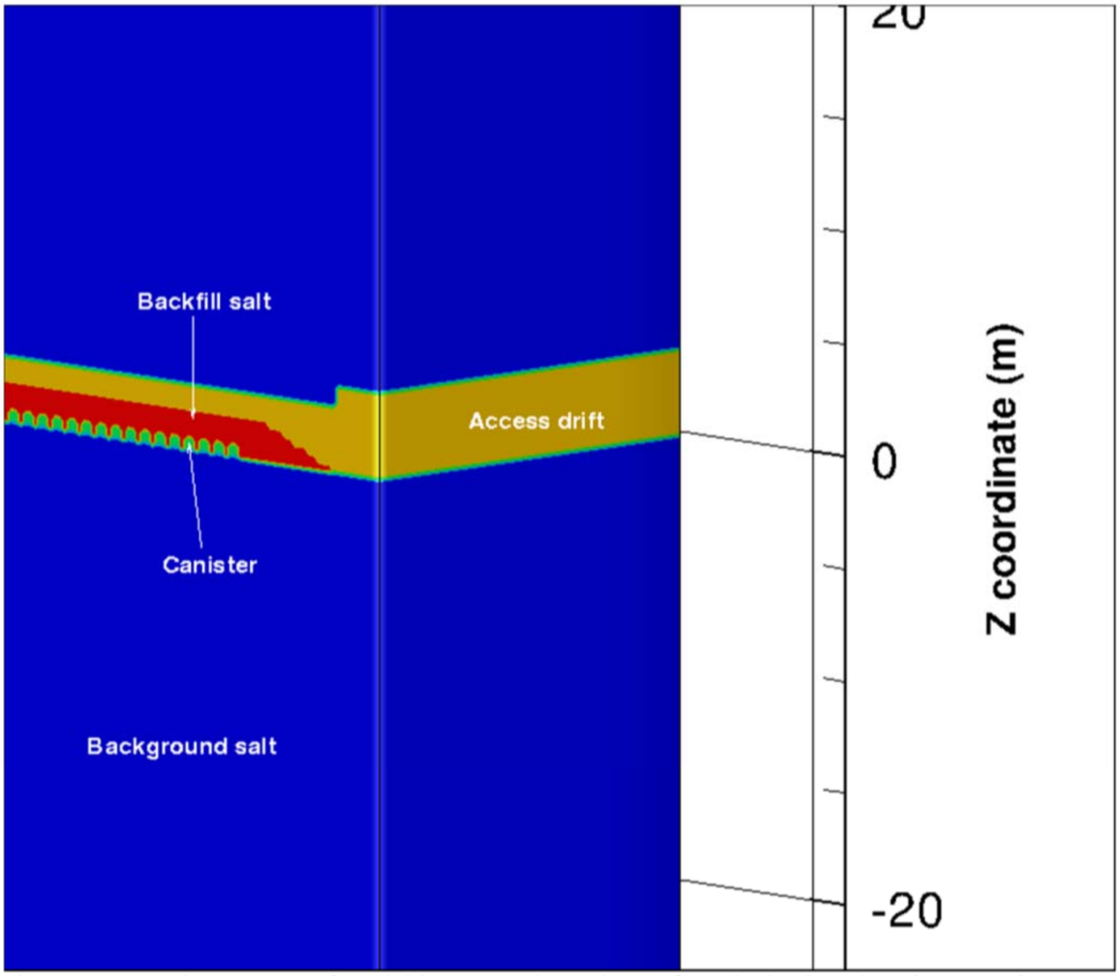

Figure 3. Zoom into corner of model layout to show slope of crushed salt and canister spacing.

DAKOTA implementation

The design optimization, parameter estimation, uncertainty quantification, and sensitivity analysis code DAKOTA (Adams et al., 2011) has been configured to perform parallel executions of the 3-D waste emplacement model. A python code has been written to allow DAKOTA to investigate model parameters and configurations. This framework (FEHM, python code, and DAKOTA) allows multi-dimensional parameter/design studies to be conducted to investigate the effects of canister spacing, canister heat load, and depth of salt backfill on the temperature regime.

General Model Behavior

In this section we discuss model behavior that is common to all simulations presented.

Steady State

First, the characteristic time to steady state is on the order of 60 years. Figure 4 shows time evolution of temperature for two heat loads at both the center of the canisters and at the center of the pillar separating rooms. To ensure steady state results, we present all calculations at 200 years. Figure 5 shows a typical simulation result at steady state (200 yrs), for a case of 220 W/canister with 0.3 m (1 ft.) separation between canisters.

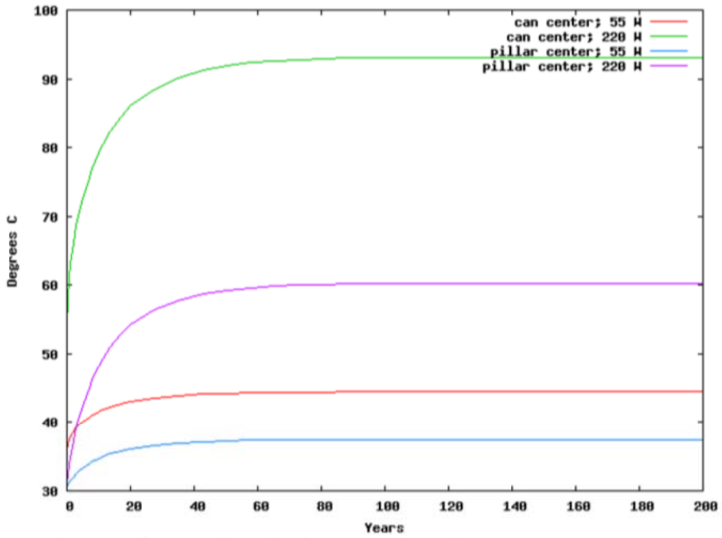

Figure 4. Time to steady state for two heat loads at two locations

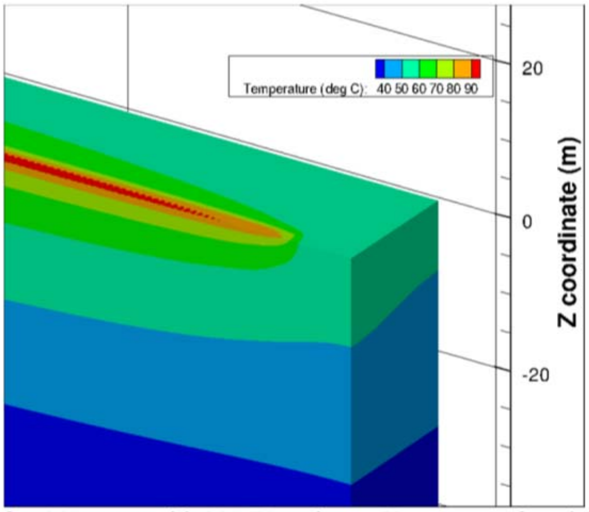

Figure 5. Temperature after 200 years with 220 W canisters. Upper part of model is cut out to view the

center of the canisters.

Waste/Salt interface

Because of concerns over how temperatures will evolve at the material contact between the canisters and the surrounding salt, we present results from a separate analytical analysis (Appendix 1) that illustrate the behavior in close vicinity of the canister. In our 3-D simulations, the material contact cannot be captured at high resolution. In fact, we have node spacing on the order of 0.3 m (1 ft.) around the waste packages so that each waste package is 2 nodes wide by two nodes high. The analytical approach in the Appendix allows us to explore temperature variation at much higher resolution. Results from the analytical model show 1) that temperatures at the waste/salt interface are well behaved and 2) that using the temperature in the center of the waste package is a close approximation to the salt temperatures at the canister-salt interface.

Simulation Strategy

In the results that follow, three sets of heat flow simulations are presented:

1) Deterministic simulations of Savannah River Site (SRS) and Hanford waste forms at discrete heat loads per package (55, 110, and 220 W, covering a ranging encompassing the borosilicate glass waste in the HLW inventory). These simulations are used to explore impacts of salt burial depth, canister spacing, and heat load on temperature profiles.
2) Deterministic simulations of Spent Nuclear Fuel (SNF) and Naval Fuel (NF) waste forms (1 kW, 1.5 kW, and 2 kW, covering a representative range for SNF). These simulations are used to explore how waste canister spacing impacts temperature profiles at different heat loads.
3) Monte Carlo sampling of SRS waste heat loads with constant canister spacing of 1 ft. (0.3 m) crushed salt between canisters. These simulations are used to estimate probabilities associated with temperature profiles given uncertainty in the heat output of any given canister.

Waste Canister Thermal Data

We next present the data used to inform our simulations on possible heat loading from canisters that may be part of the waste stream to our hypothetical salt repository. Table 2 shows an estimate of container heat loads for high-level waste (HLW) from the Savannah River Site (SRS) that may be available through 2023. These data show that 96.5% of the expected waste packages are at or below 220 W. These data are used to guide our deterministic cases where each canister is given the same heat output of either high (220 W), medium (110 W) or low (55 W). HLW from Idaho and Hanford fall within the bounds of this distribution and are thus covered under the same analysis.

Table 2 SRS HLW Heat Loads

Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	2948	39.0%
50-100	459	45.1%
100-220	3891	96.5%
220-300	0	96.5%
300-500	264	100.0%
500-1000	0	100.0%
1000-1500	0	100.0%

1500 - 2000	0	100.0%
>2000	0	100.0%

The NF/SNF simulations are predicated on the assumption that the existing large (98,000 lb) NF waste forms totaling 1.7 million watts will be repackaged into smaller canisters with lower heat loads of between 1000 – 2000 W. Table 3 shows how this repackaging leads to an increase in the number of canisters from the presumed 400 waste packages. Furthermore, the total number of canisters in the SNF inventory that are greater than or equal to 1000 W is small (less than 1% or 31/3542). Thus, by examining high (2000 W), medium (1500 W) and low (1000 W) deterministic scenarios where each canister in a room is given the same heat load, we ensure that our simulations span the range of behavior likely to be seen in rooms packed with the hotter NF/SNF components of the waste stream.

Table 3

Repackaged Navy Fuel (NF) Canisters	Total Canisters per scenario
1000 W	1700
1500 W	1133
2000 W	850

Finally, the distribution of waste seen in Table 2 is used to drive the probabilistic simulations where random waste packages from this distribution are used to populate a given room. These data give insight into what the mean and standard deviation of temperatures will be in an operational system with HLW waste arriving randomly to the repository.

Deterministic simulations of Savannah River Site (SRS) waste

Multi-dimensional parameter studies using this framework (FEHM, python code, and DAKOTA) have been conducted for the SRS and Hanford waste forms to investigate the effects of canister spacing, canister heat load, and depth of salt backfill on the temperature regime. Canister spacing is assigned to be 3, 4, or 6 ft between canister centers (corresponding to 1, 2, and 4 ft gaps between canisters). Heat loads are assigned as 55, 110, or 220 Watts, and backfilled salt depths were set to 4, 6, and 8 and 10 ft from the room floor (corresponding to air gaps of 6, 4, 2, and zero feet, respectively).

With spacing fixed at 1 ft (0.3 m) and thermal output fixed at 220 W/canister, the run-of-mine salt burial depth ranging from 4 ft to 10 ft results in peak temperatures at the center waste package of between 90°C to 95°C. Interestingly, the deeper salt burial leads to higher maximum temperatures. This is because the thermal diffusivity of salt is an order of magnitude lower than the thermal diffusivity of air (Table 1). Figures 6, 7, and 8 illustrate the profiles of temperature laterally through the waste package to the center of the pillar (Figure 6), vertically through a waste package above and below (Figure 7), and for different waste package spacings (Figure 8).

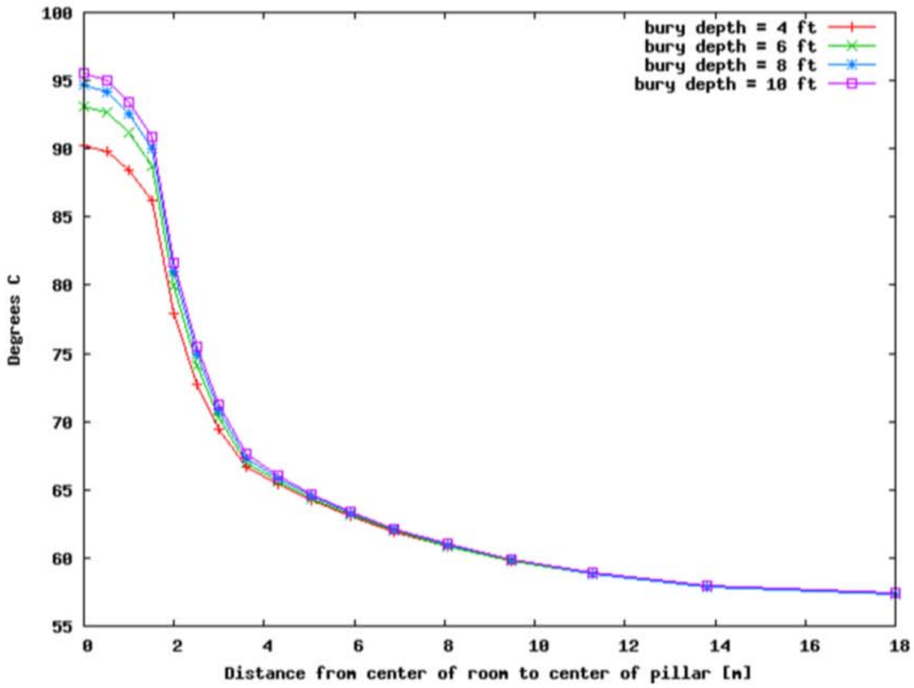

Figure 6. Lateral temperature variation through the centerline of a waste canister to the middle of the pillar for different run-of-mine burial depths; fixed 220W/canister waste and fixed 1 ft spacing between canisters.

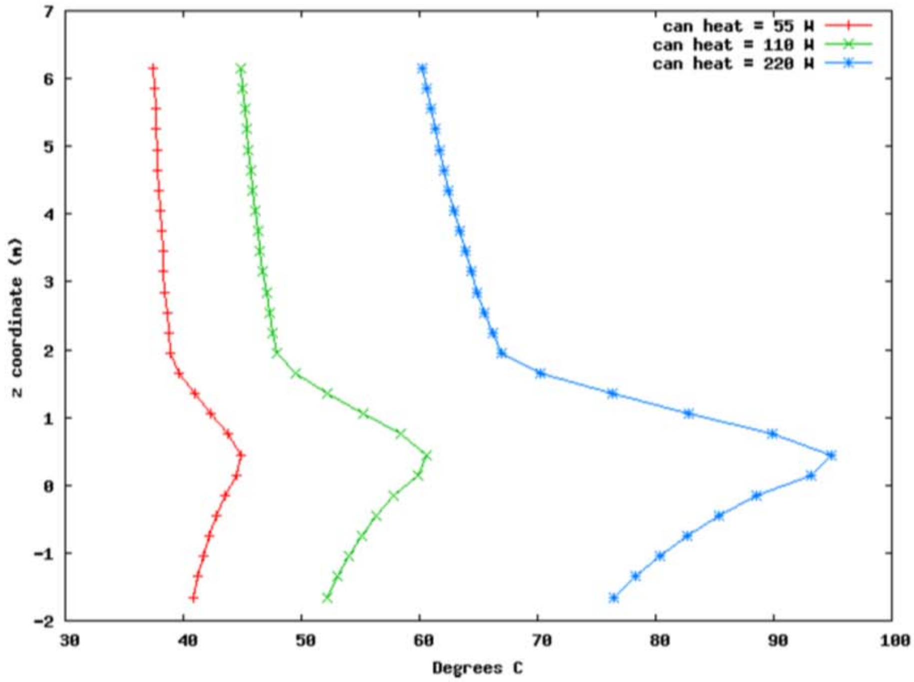

Figure 7. Vertical temperature variation as a function of heat source for fixed burial depth of 6 ft (1.8 m) measured from the room floor and fixed 1 ft spacing between canisters.

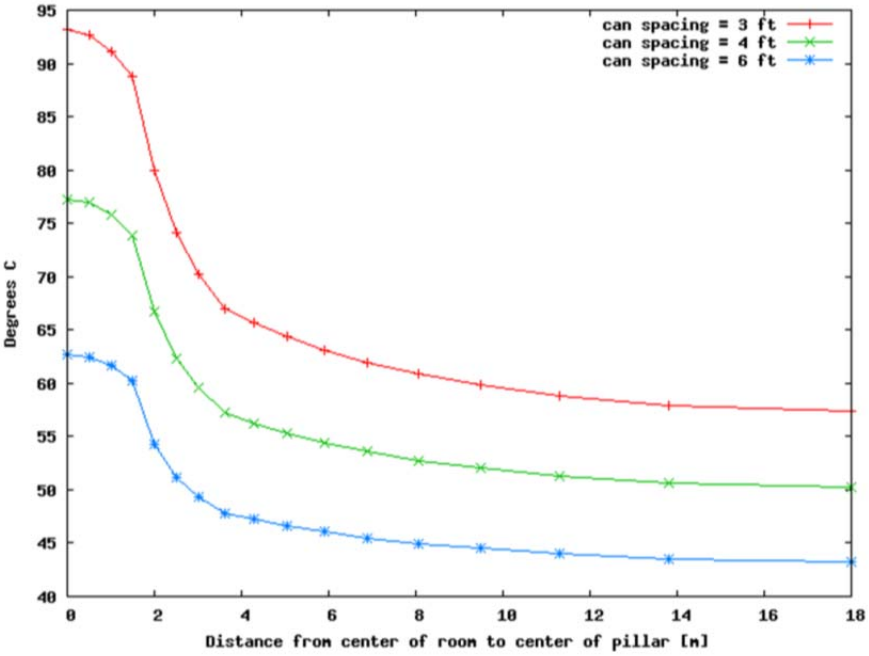

Figure 8. Lateral temperature variation as a function of canister spacing for fixed burial depth of 6 ft (1.8 m) measured from the room floor and a fixed 220 W/canister heat load.

Deterministic simulations of Naval Fuel (NF) and Spent Nuclear Fuel (SNF)

This set of simulations is designed to show how canister spacing impacts temperature profiles for heat loads of 1000 W/canister to 2000 W/canister. Figure 9 shows that as canister spacing increases, peak temperatures drop from over 450°C at a spacing of 3 ft (1 ft between canisters) to less than 250°C at a spacing of 6 ft (4 ft between canisters). By presenting the extreme thermal profiles at such close package spacing, we do not intend to suggest that these temperatures are reasonable. Rather, we are intending to illustrate that for these heat loads, significant spacing between packages is required to achieve a reasonable temperature limit (nominally, 250°C maximum temperature). At a spacing of 6 ft, each 150 m room would be able to hold approximately 75 canisters. This corresponds to about 23 rooms needed to if the NF is repackaged to 1700 canisters with 1000 W each. Next, Figure 10 shows the same information for a 2000 W/canister thermal load. For this scenario, maximum temperatures below 250°C only occur for the 20 ft spacing (18 ft between canisters) scenario. This scenario would permit 25 canisters per room and would result in 34 rooms needed to house the NF repackaged at 2000 W/canister. Thus it is apparent that by using thermal modeling in conjunction with assumptions about repackaged waste heat loads, we are in a position to make predictions that can be used to optimize the repackaging/disposal plans. Finally, we present the vertical thermal profiles corresponding to Figures 9 and 10 in Figures 11 and 12.

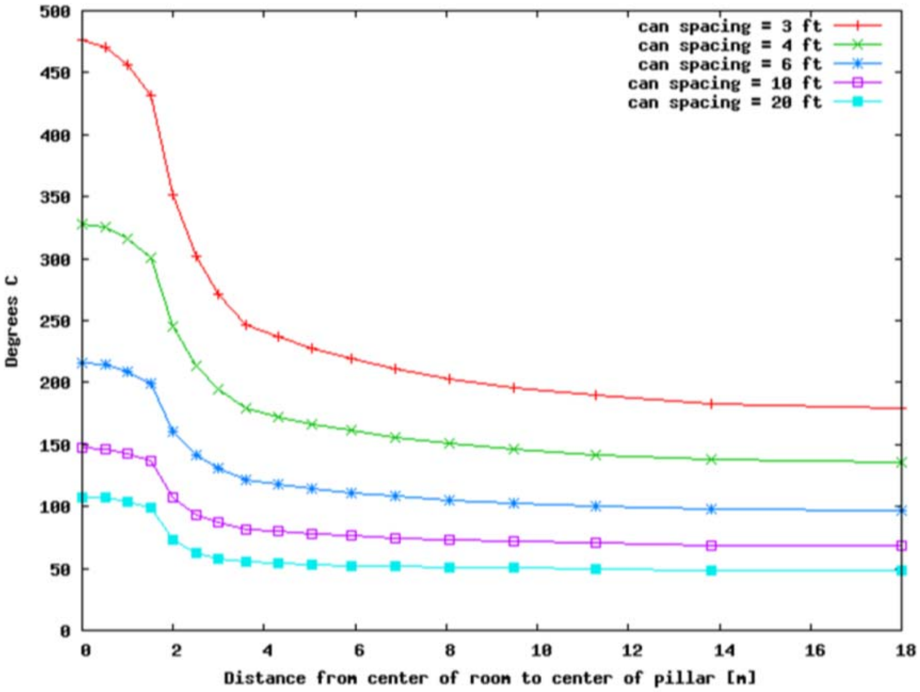

Figure 9. Lateral temperature variation as a function of canister spacing for fixed burial depth of 4 ft (1.2 m) measured from the room floor and a fixed 1000 W/canister heat load.

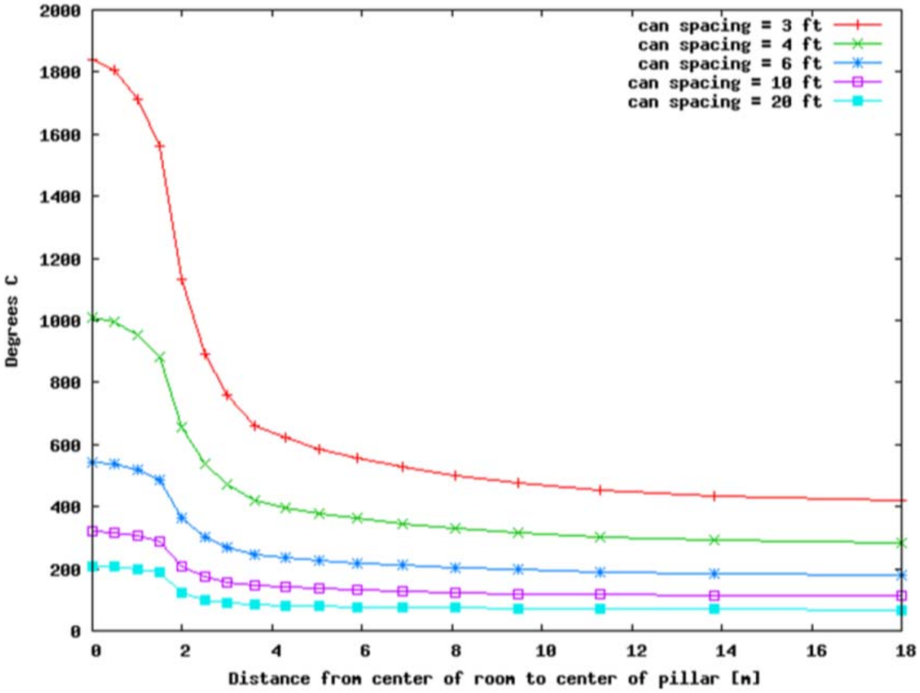

Figure 10. Lateral temperature variation as a function of canister spacing for fixed burial depth of 4 ft

(1.2 m) measured from the room floor and a fixed 2000 W/canister heat load.

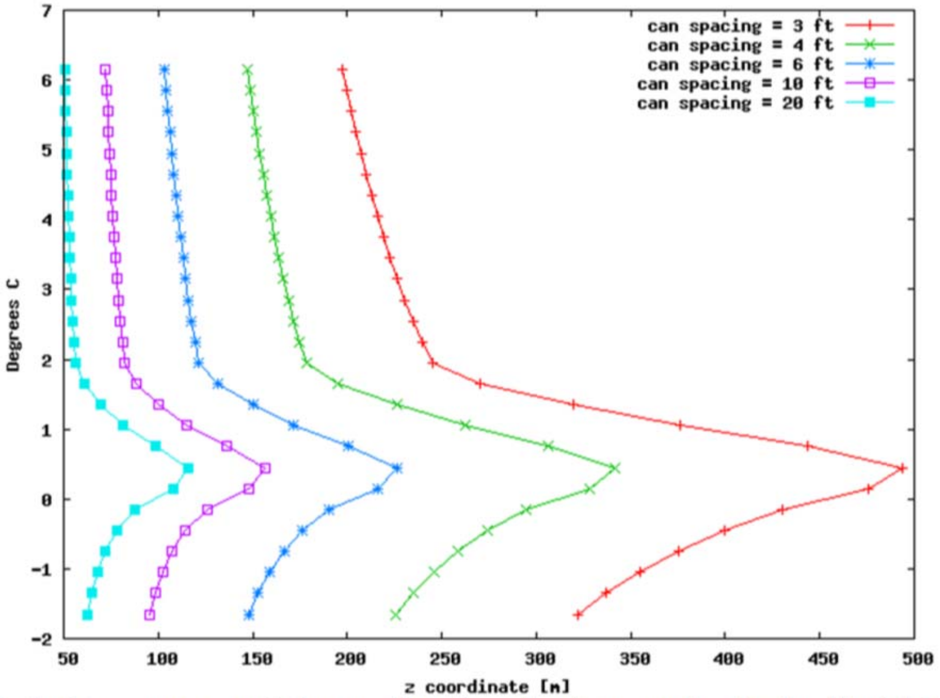

Figure 11. Vertical temperature variation as a function of canister spacing for fixed burial depth of 4 ft (1.2 m) measured from the room floor and a fixed 1000 W/canister heat load.

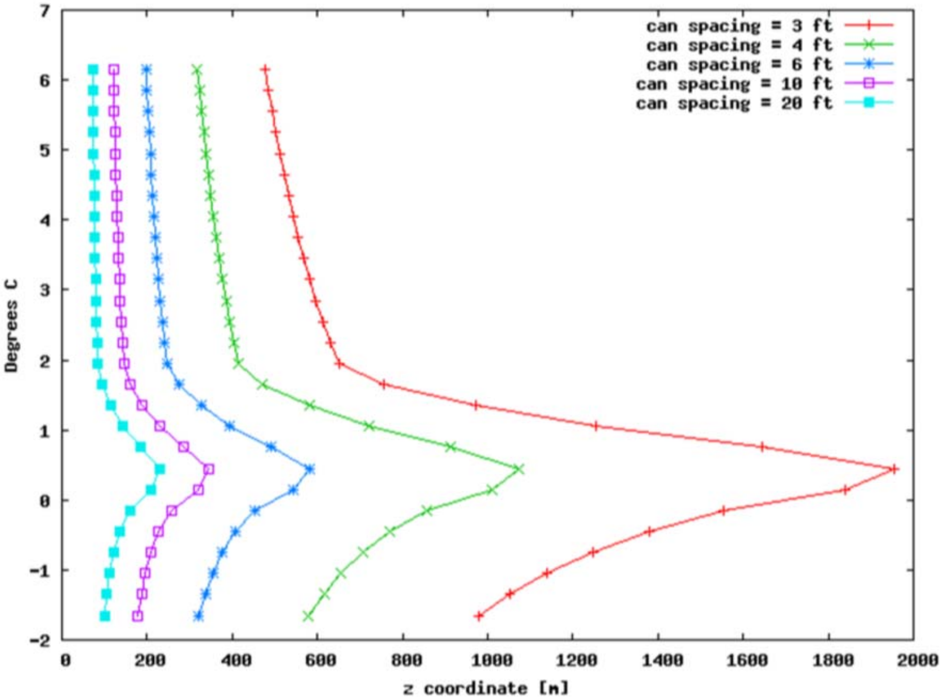

Figure 12. Vertical temperature variation as a function of canister spacing for fixed burial depth of 4 ft

(1.2 m) measured from the room floor and a fixed 2000 W/canister heat load.

Monte Carlo Simulations of SRS waste distribution

A Monte Carlo sampling of 100 realizations (Set #3) was conducted in which individual canister heat loads were randomly selected from a histogram of waste canister heat loads based on the SRS inventory (Table 2). Figure 13 shows the 100 picks for heat load at the center canister and compares well to the data presented in Table 2.

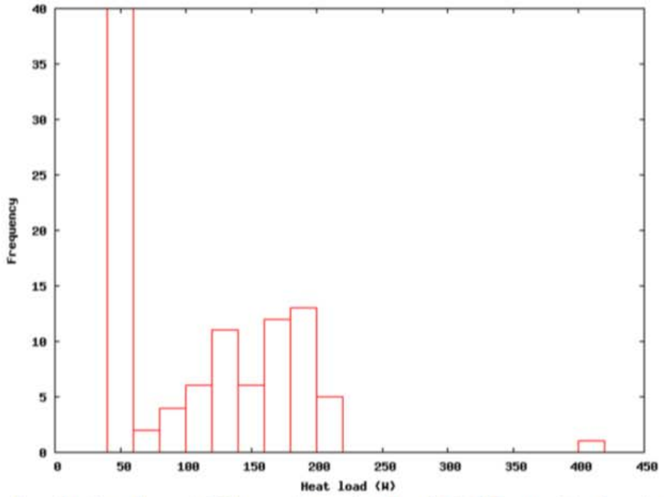

Figure 13. Sampled heat loads for the middle canister in the 100 Monte Carlo simulations of SRS canister probabilities.

Figure 14 shows the lateral temperature distribution mean and 5-95% confidence bounds for the 100 Monte Carlo simulations. Although high heat canisters could all be put together, the likelihood of this occurring is quite low in a truly random process, and the maximum temperature of 60°C is tightly bounded by the upper and lower confidence intervals with temperatures of 55°C and 67°C.

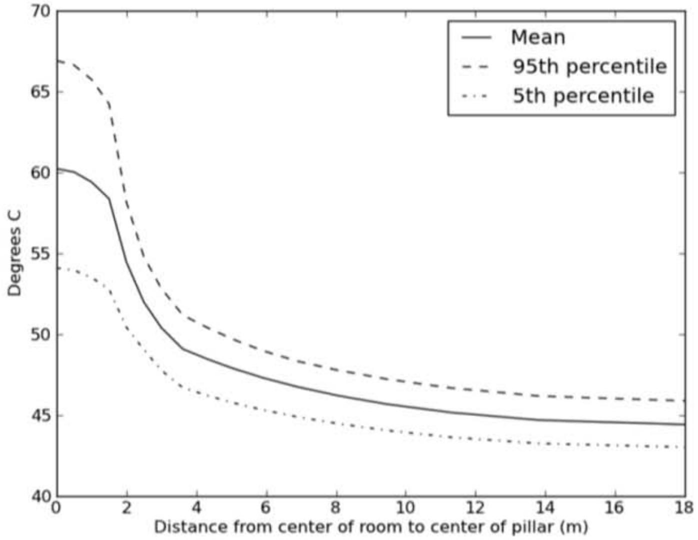

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Figure 14. Lateral temperature distribution mean and 5-95% confidence bounds for the 100 Monte Carlo simulations for SRS waste with fixed 4 ft burial depth and 1 ft spacing between canisters.

Figure 15 shows the same simulation results for the vertical temperature variation. From these results it is clear that 1 ft spacing between canisters is sufficient to keep the HLW inventory in a very modest temperature range well below 100°C. Assuming 150 canisters per room in this scenario, the 23032 canisters of HLW would require on the order of 154 rooms.

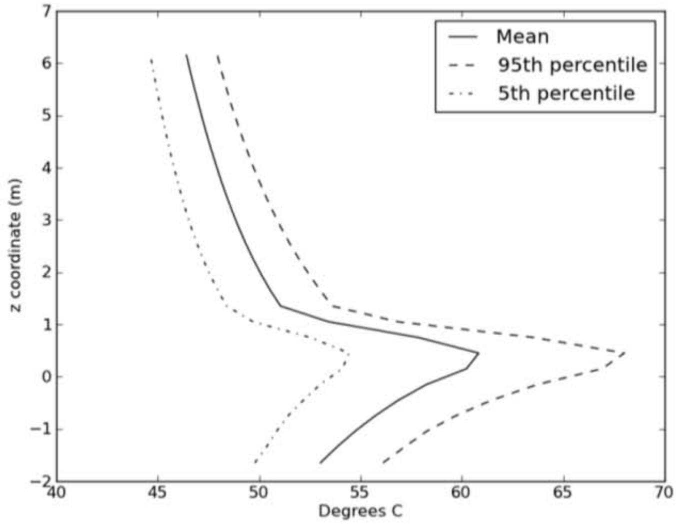

Figure 15. Vertical temperature distribution mean and 5-95% confidence bounds for the 100 Monte Carlo simulations with fixed 4 ft burial depth and 1 ft spacing between canisters.

Conclusions

Based on this preliminary set of heat flow simulations using both and Monte Carlo simulations, and neglecting decay, model results indicate that temperatures may reach a maximum of about 95°C for SRS and Hanford waste forms in a densely packed in-drift disposal scenario with run-of-mine salt applied for shielding. Temperature isotherms (> 5°C) reach a vertical distance of about 30 m for the SRS and Hanford waste forms. These results are conservative in that there is no decay with time, so temperatures never decrease with time. For SNF and NF waste packages, maximum temperatures of 250°C or less can be attained assuming that the per-package heat load is kept to between 1000 to 2000 W (by repackaging, if necessary), and by spacing the canisters within the drift.

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Appendix 1 Analytical Solution

Phoolendra K Mishra

Here we implement a two-material heat flow solution as given by Carslaw and Jaeger (1959). Consider a region $0 \leq r < a$ in a cylindrical coordinate system of one material with thermal conductivity K_1, specific heat capacity C_1 and density ρ_1 and another region $r > a$ of another material (salt) with properties K_2, C_2 and ρ_2. Consider both materials to be at initial normalized temperature of zero, and there is constant rate q_0 per unit time per unit volume heat production source in region $0 \leq r < a$ for all times ($t > 0$). The heat flow in these materials under these conditions is governed by

$$K_1 \left\{ \frac{\partial^2 T_1}{\partial r^2} + \frac{1}{r} \frac{\partial T_1}{\partial r} \right\} - C_1 \rho_1 \frac{\partial T_1}{\partial t} = -q_0 \tag{1}$$

$$K_2 \left\{ \frac{\partial^2 T_2}{\partial r^2} + \frac{1}{r} \frac{\partial T_2}{\partial r} \right\} - C_2 \rho_2 \frac{\partial T_2}{\partial t} = 0 \tag{2}$$

Taking Laplace transform of (1) and (2) gives

$$\frac{d^2 \overline{T}_1}{dr^2} + \frac{1}{r} \frac{d \overline{T}_1}{dr} - \frac{C_1 \rho_1}{K_1} p \overline{T_1} = -\frac{q_0}{pK_1} \tag{3}$$

$$\frac{d^2 \overline{T}_2}{dr^2} + \frac{1}{r} \frac{d \overline{T}_2}{dr} - \frac{C_2 \rho_2}{K_2} p \overline{T_2} = 0 \tag{4}$$

The solution to the ordinary differential equations (3) and (4) in Laplace space is given by Carslaw and Jaeger (1959) as:

$$\overline{T}_1 = \frac{\alpha_1 q_0}{K_1 p^2} - \frac{q_0 K_2 \alpha_1^{3/2}}{K_1 p^2 \Delta} K_1(q_2 a) I_0(q_1 r) \tag{5}$$

$$\overline{T}_2 = \frac{q_0 \alpha_1 \alpha_2^{1/2}}{p^2 \Delta} I_1(q_1 a) K_0(q_2 r) \tag{6}$$

where $\alpha_i = K_i / \varrho_i C_i$, $q_i = \sqrt{p/\alpha_i}$, $\Delta = K_2 \alpha_1^{1/2} I_0(q_1 a) K_1(q_2 a) + K_1 \alpha_2^{1/2} I_1(q_1 a) K_0(q_2 a)$.

Introducing dimensionless quantities $p_D = pt$, $t_D = \alpha_1 t / r^2$, $r_D = r/a$, $\alpha_D = \alpha_2 / \alpha_1$, $K_D = K_2 / K_1$ gives

$$\overline{T}_1 = \frac{q_0 t}{K_1 / a^2} \left[1 - \frac{K_D K_1(q_{1D} / r_D) I_0(q_{1D})}{\Delta_D} \right] \frac{r_D^2 t_D}{p_D^2} \tag{7}$$

$$\overline{T}_2 = \frac{q_0 t}{K_1/a^2} \alpha_D^{1/2} \left[\frac{I_1(q_{1D}/r_D) K_0(q_{2D})}{\Delta_D} \right] \frac{r_D^2 t_D}{p_D^2} \qquad (8)$$

where $\Delta_D = K_D I_0(q_{1D}/r_D) K_1(q_{2D}/r_D) + \alpha_D^{1/2} I_1(q_{1D}/r_D) K_0(q_{2D}/r_D)$, $q_{1D} = \sqrt{p_D/t_D}$, $q_{2D} = \sqrt{p_D/\alpha_D t_D}$.

The inverse Laplace transform of above equations are given formally by Mellin's inversion formula

$$f(t) = \frac{1}{2\pi i} \int_{\gamma - i\infty}^{\gamma + i\infty} (e^{p_D} - 1) \frac{f(p_D)}{t} dp_D \qquad (9)$$

where $\gamma > 0$ is a real constant and p_D is a complex variable. Here we evaluate the time domain temperature variations $T_1(t)$ and $T_2(t)$ by numerical inversion of $\overline{T_1}$ and $\overline{T_2}$, respectively, using an algorithm due to de Hoog.

Figure A1 shows temperature variation over time, and Figures A2 and A3 show temperature variation with distance between two canisters at an early time (t=0.03 years) and late time (t=300 years). After the initial transient period, the temperature gradients between the two materials (the waste package material and the run-of-mine salt) become very small, implying that the temperature profile within the waste is a close approximation of the temperature at the waste package-salt interface. Therefore, our results of the temperature profiles through the waste package can equally be interpreted as the temperature of the salt that the interface.

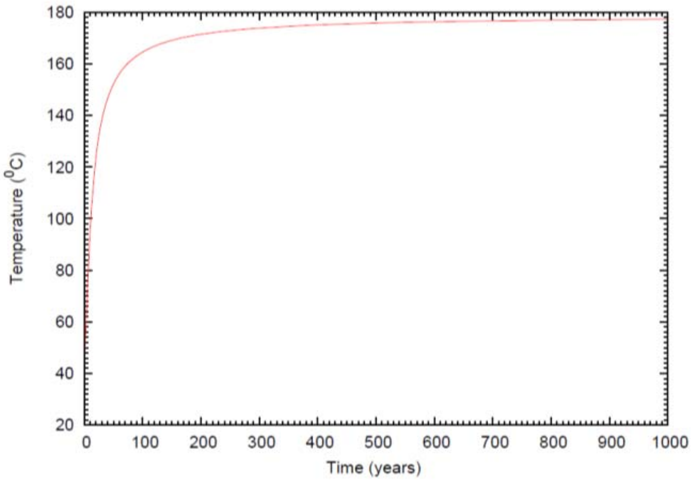

Figure A1: Temporal variation of temperature at distance 0.001 m from the surface of cylinder

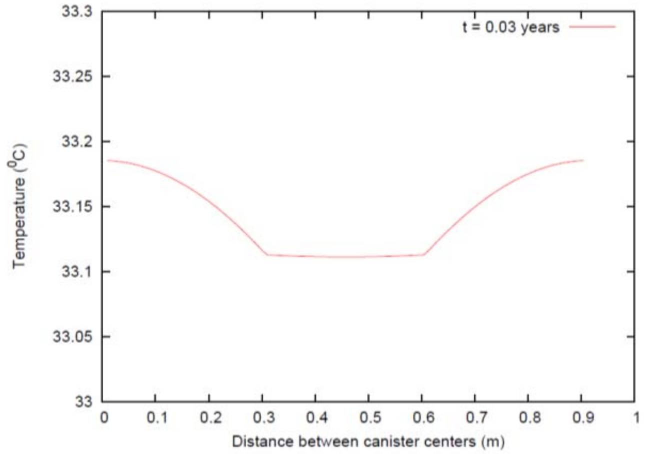

Figure A2: Distance vs temperature between two cylinders at 0.03 years

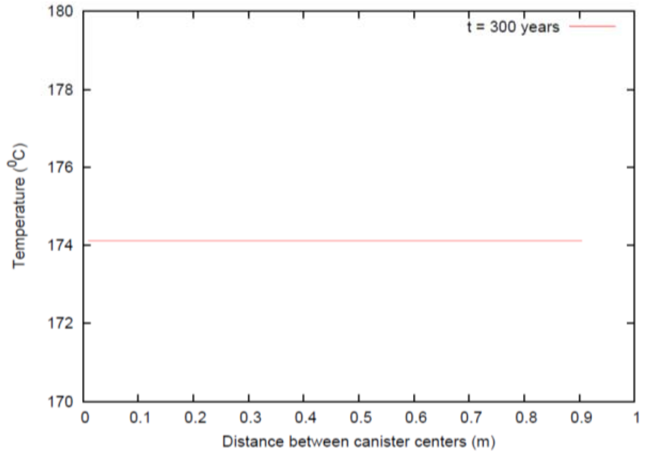

Figure A3: Distance vs temperature between two cylinders at 300 years

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