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ANL/EVS/R-10/9

Conceptual Designs for Greater-Than-Class C Low-Level Radioactive Waste Land Disposal Facilities

Environmental Science Division

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Conceptual Designs for Greater-Than-Class C Low-Level Radioactive Waste Land Disposal Facilities

by
Environmental Science Division, Argonne National Laboratory

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CONTENTS

CONTENTS (Cont.)

CONTENTS (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

FIGURES

FIGURES (Cont.)

NOTATION

ACRONYMS AND ABBREVIATIONS

4WD	four-wheel drive
AMC	activated metal canister
CCTV	closed-circuit television
cfm	cubic foot (feet) per minute
CFR	*Code of Federal Regulations*
CH	contact handled
CONUS	continental or contiguous United States
CY	cubic yards(s)
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
gpm	gallon(s) per minute
GTCC	greater-than-Class C
GVW	gross vehicle weight
HVAC	heating, ventilation, and air conditioning
ID	inside diameter
I/O	input/output
ISFSI	independent spent fuel storage installation
LANL	Los Alamos National Laboratory
LF	linear foot (feet)
LLRW	low-level radioactive waste
LLRWPAA	Low-Level Radioactive Waste Policy Amendments Act
LS	lump sum
MCC	motor control center
Mcf	thousand cubic feet
ML	million liters
NAAQS	National Ambient Air Quality Standard(s)
NEPA	National Environmental Policy Act of 1969
NMHC	nonmethane hydrocarbon
NO_x	nitrogen oxides

NRC	U.S. Nuclear Regulatory Commission
o.c.	on-center
OD	outside diameter
OSRP	Off-Site Source Recovery Project
PE	professional engineer
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 μm or less
PM_{10}	particulate matter with an aerodynamic diameter of 10 μm or less
PSD	Prevention of Significant Deterioration
psf	pound(s) per square foot
psi	pound(s) per square inch
PVC	polyvinyl chloride
RH	remote handled
RSM	registered site manager
S/C	subcontract
SF	square foot (feet)
SNF	spent nuclear fuel
SO_x	sulfur oxides
SWB	standard waste box
SY	square yard(s)
TRU	transuranic
TRUPACT-II	Transuranic Package Transporter-II
UPS	uninterruptible power supply
USACE	U.S. Army Corps of Engineers
USG	U.S. gallon(s)
VLF	vertical linear foot (feet)
WIPP	Waste Isolation Pilot Plant
WRS	Waste Receiving and Storage

UNITS OF MEASURE

A	ampere(s)
ac	acre(s)
cm	centimeter(s)
d	day(s)
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
gal	gallon(s)
h	hour(s)
hp	horsepower
in.	inch(es)
$in.^2$	square inch(es)
kg	kilogram(s)
kVA	kilovolt(s)-ampere
kW	kilowatt(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m^3	cubic meter(s)
min	minute(s)
mrem	millirem
MW	megawatt(s)
MWh	megawatt-hour(s)
R	roentgen(s)
V	volt(s)
yd^3	cubic yard(s)
yr	year(s)

CONVERSION TABLE

Multiply	By	To Obtain
English/Metric Equivalents		
acres (ac)	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
degrees Fahrenheit (ºF) –32	0.5555	degrees Celsius (ºC)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.9072	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
Metric/English Equivalents		
centimeters (cm)	0.3937	inches (in.)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius (ºC) +17.78	1.8	degrees Fahrenheit (ºF)
hectares (ha)	2.471	acres (ac)
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
kilometers per hour (kph)	0.6214	miles per hour (mph)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

CONCEPTUAL DESIGNS FOR GREATER-THAN-CLASS C LOW-LEVEL RADIOACTIVE WASTE LAND DISPOSAL FACILITIES

by

Environmental Science Division
Argonne National Laboratory

1 INTRODUCTION

Greater-than-Class C (GTCC) low-level radioactive waste (LLRW) is defined by the U.S. Nuclear Regulatory Commission (NRC) as LLRW that has radionuclide concentrations exceeding the limits for Class C LLRW established in Title 10, Part 61, of the *Code of Federal Regulations* (10 CFR Part 61), "Licensing Requirements for Land Disposal of Radioactive Waste." In 10 CFR 61.55, the NRC classifies LLRW as A, B, and C according to the concentration of specific short- and long-lived radionuclides, with Class C having the highest radionuclide concentration limits. GTCC LLRW is generated by activities licensed by the NRC or Agreement States and cannot be disposed of in currently licensed commercial LLRW disposal facilities.

Section 3(b)(1)(D) of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) assigned the responsibility for the disposal of GTCC LLRW to the federal government. The LLRWPAA specifies that GTCC LLRW covered under Section 3(b)(1)(D) is to be disposed of in a facility that is to protect public health and safety and is licensed by the NRC. The U.S. Department of Energy (DOE) is the federal agency responsible for disposing of GTCC LLRW.

DOE is currently examining disposal methods to identify those that are protective of human health and the environment and that may be licensed by the NRC. In addition to the GTCC LLRW stored and projected inventory, DOE is including stored and projected DOE LLRW and transuranic (TRU) waste referred to as "GTCC-like waste." GTCC-like waste refers to radioactive waste that is owned and generated by DOE and has characteristics sufficiently similar to those of GTCC LLRW such that a common disposal approach may be appropriate. GTCC-like waste consists of high-activity LLRW and potential non-defense-related TRU waste that has no identified path for disposal. The use of the term "GTCC-like" does not have the effect of creating a new DOE classification of radioactive waste. Although GTCC-like waste is not subject to the requirements in the LLRWPAA, DOE also intends to determine a path to disposal that is similarly protective of public health and safety for the GTCC-like waste that it owns and generates.

This report discusses three land disposal methods that DOE is considering for evaluation. Each conceptual facility is designed to provide the entire disposal capacity needed for current stored inventories in addition to those expected to be generated in the near future. However, a combination of disposal methods and locations may be appropriate, depending on the characteristics of the waste and other factors.

1.1 SCOPE

Three land disposal methods for GTCC LLRW and GTCC-like waste are being investigated: enhanced near-surface trench disposal, intermediate-depth borehole disposal, and above-grade vault disposal. This report presents conceptual disposal facility designs for these methods. The level of detail presented in this report for the proposed designs is sufficient for use in a National Environmental Policy Act (NEPA) analysis. Further studies, including a site-specific safety analysis report, would be necessary to support further decision-making efforts for the implementation of any of the three methods.

The disposal facility designs are sized to accommodate disposal of approximately 11,650 m^3 of GTCC LLRW and GTCC-like waste that is expected to be generated through the year 2083 (Argonne 2010). The disposal facilities are designed as stand-alone operations. Depending on the final location of the facility, certain components such as buildings, equipment, or personnel could be shared with or obtained from existing facilities, thus lowering anticipated costs.

The remainder of this chapter summarizes the wastes evaluated for disposal and the assumptions about packaging on which the facility designs are based. Chapter 2 provides descriptions of the three land disposal methods considered. Conceptual designs of the proposed facilities are presented in Chapter 3. Chapter 4 discusses the number and cost of personnel required for construction and operation of the facilities. Estimates of resource materials and utilities needed for construction and operations are provided in Chapter 5. Estimated emissions and wastes from construction and operations are discussed in Chapter 6, and data on emissions from material deliveries and worker vehicles are provided in Chapter 7.

Note that the number of construction workers required at any one time during site preparation and facility construction would be variable because of the temporary nature of the work and because certain tasks can be accomplished concurrently while others must occur consecutively. On the other hand, a minimum number of workers is necessary to operate the facility and is dependent on the waste receipt rate, as discussed further in Section 4.2. Thus, the estimated resources and emissions from facility operations presented in Chapters 5, 6, and 7 are based on the personnel estimates given in Section 4.2.

1.2 TRANSPORTATION AND PACKAGING

The packaging used for shipping radioactive materials must be designed, constructed, and maintained to ensure that it can contain and shield the contents during normal transportation. For more highly radioactive material, the packaging must contain and shield the contents in severe accidents. The type of packaging used is determined by the radioactive hazard associated with the packaged material. The basic types of packaging required by the applicable regulations are designated as Type A, Type B, or industrial packaging (generally for low-specific-activity material).

Type A packaging must withstand the conditions of normal transportation without the loss or dispersal of the radioactive contents, as specified in 49 CFR 173.413 (Additional Design Requirements for Type A Packages). "Normal" transportation refers to all transportation conditions except those resulting from accidents or sabotage. Approval of Type A packaging is obtained when it is demonstrated that the packaging can withstand specified testing conditions intended to simulate normal transportation. Type A packaging usually does not require special handling, packaging, or transportation equipment.

In addition to meeting all the Type A standards, Type B packaging must also provide a high degree of assurance that the package integrity would be maintained even during severe accidents, with essentially no loss of the radioactive contents or serious impairment of the shielding capability. Type B packaging is required for shipping large quantities of radioactive material and must satisfy stringent testing criteria (as specified in 10 CFR Part 71). The testing criteria were developed to simulate conditions of severe hypothetical accidents, including impact, puncture, fire, and immersion in water. The most widely recognized Type B packages are the massive casks used to transport highly radioactive spent nuclear fuel (SNF) from nuclear power stations. Large-capacity cranes and mechanical lifting equipment are usually necessary for handling Type B packaging. Many Type B packages are transported on trailers specifically designed for that purpose.

It is assumed that the GTCC LLRW and GTCC-like waste would be shipped to the disposal facility in their final disposal containers. Thus, the disposal facilities have been designed to most efficiently accommodate the types of containers that would most likely be used to transport and dispose of these wastes. GTCC LLRW and GTCC-like waste are assumed to be transported by truck and rail to the disposal facility in Type B shipping packages. The waste for disposal would include contact-handled (CH) waste, remote-handled (RH) waste, and activated metals, as discussed in Section 1.3. The number of existing truck casks needed for shipping CH waste (<200 mrem/h dose rate at the package surface) is more readily available, while the number needed for transport of RH waste is more limited, especially for RH waste with external radiation rates on the order of 1,000 R/h at the container surface. Rates this high are characteristic of the activated metal waste discussed in Section 1.2.2. On the other hand, rail casks can accommodate larger waste containers and payloads than can truck casks, and these rail casks have sufficient shielding for waste with high external radiation rates. Table 1-1 provides examples of Type B shipping packages that could be used for the transport of GTCC LLRW and GTCC-like waste, some of which are discussed further in Sections 1.2.1 and 1.2.2.

Note that not all GTCC LLRW or GTCC-like waste would necessarily require shipment in Type B packaging, as discussed in the following sections. Because the levels of radioactivity of the CH waste (including the sealed sources) in their Type A containers (i.e., 208-L [55-gal] drums and SWBs) would be near the upper limits specified in 10 CFR Part 71, with multiple drums or SWBs per shipment, the use of Type B shipping packaging would have to be

TABLE 1-1 Representative Sample of Type B Shipping Packages with the Potential for Transport of GTCC LLRW and GTCC-Like Waste[a]

Package	Internal Diameter in m (in.)	Internal Length in m (in.)	Maximum Payload in kg (lb)	Maximum Gross Weight in kg (lb)	Waste Type		Transport Mode	
					CH	RH[b]	Truck[c]	Rail
TRUPACT-II	1.85 (73)	1.91 (75)	3,300 (7,265)	8,700 (19,250)	X		X	
HalfPACT	1.85 (73)	1.14 (45)	3,400) (7,600)	8,200 (18,100)	X		X	
CNS 10-160B	1.73 (68)	1.96 (77)	6,600 (14,500)	32,700 (72,000)		X	X	
RH 72-B	0.79 (31)	3.30 (130)	3,600 (8,000)	15,200 (33,500)		X	X	
CNS 3-55[d]	0.91 (36)	2.82 (111)	4,200 (9,220)	31,800 (70,000)		X	X	
3-60B[e]	0.89 (35)	2.77 (109)	4,300 (9,500)	36,300 (80,000)		X	X	
TN-RAM	0.89 (35)	2.82 (111)	4,300 (9,500)	36,300 (80,000)		X	X	
NAC STC	1.80 (71)	4.19 (165)	8,500 (18,700)[f]	118,000 (260,000)		X		X
NAC UMS	1.73 (68)	4.90 (193)	9,100 (20,000)[f]	113,000 (250,000)		X		X
125-B	1.30 (51)	4.90 (193)	20,000 (44,000)	82,300 (181,500)		X		X
TS 125	1.70 (67)	4.90 (193)	38,000 (85,000)	129,000 (285,000)		X		X

[a] Package internal dimensions and weight limits taken from NRC (2006).

[b] Casks designed to handle RH waste may also transport CH waste.

[c] Truck casks may also be used for rail transport.

[d] The certificate of compliance expired in October 2008 and will not be renewed.

[e] Proposed design intended for replacement of the CNS 3-55 cask (Carlson et al. 2006; EnergySolutions 2008).

[f] Listed payload weight is that specified for the transport of GTCC waste.

determined, and some of the CH waste might be shipped in the Type A containers without additional packaging.

1.2.1 Contact-Handled Waste

A common container for the storage of CH and RH GTCC LLRW and GTCC-like waste is the 55-gal (208-L) drum (referred to as drum(s) in the remainder of this report). In addition, some stored and projected CH wastes may be packaged for disposal in SWBs. This report explicitly assumes the disposal of CH waste, with the exception of the cesium (Cs) irradiators discussed in Section 1.3.2, to be in drums and SWBs. Both drums and SWBs are examples of Type A packaging. Although the CH waste under consideration may be placed in Type A packaging, it is assumed to be transported in Type B containers. The Transuranic Package Transporter-II (TRUPACT-II) Type B package (DOE 2005) is an example of what can be used to transport the CH waste for disposal. This package is in widespread use for transporting similar types of waste to the Waste Isolation Pilot Plant (WIPP). Two common shipping configurations for waste for the TRUPACT-II container are two stacked 7-drum packs (i.e., seven 55-gal [208-L] drums in a hexagonal array with one in the middle) or two stacked SWBs.

For the purposes of this report, the external volume occupied by a drum is assumed to be 0.267 m^3, which assumes a right circular cylinder with an outside diameter of 0.610 m (2.0 ft) and a length of 0.914 m (3.0 ft). This volume is in the upper range of 0.226 to 0.283 m^3 (DOE 2006a) that is expected for these types of drums at a LLRW disposal site but is not considered to be overly conservative. The internal volume of a 55-gal (208-L) drum is 0.208 m^3. The outside dimensions of an SWB are a length of 1.80 m (71 in.), width of 1.37 m (54 in.), and height of 0.94 m (37 in.) (DOE 2004). The approximate internal and external volumes of a SWB are 1.88 m^3 and 2.08 m^3, respectively. SWBs are rounded on the ends for use as shipping containers within TRUPACT-II shipping casks, with two SWBs to a cask in a stacked configuration.

While other shipping configurations (e.g., 85- and 100-gal [321- and 378-L] drums as well as 10-drum overpacks) might be possible with the TRUPACT-II or other casks, their use is not explicitly considered in this report, but the use of other container types could be accommodated in the current disposal facility designs. Also, GTCC LLRW and GTCC-like CH waste may be found in storage in containers larger than SWBs at some sites, but there are currently no viable casks available for transport. Stacking arrangements in the CH disposal cells could be modified accordingly in the future if such packages became available (e.g., TRUPACT-III [DOE 2007b]).

1.2.2 Remote-Handled Waste

A number of Type B casks are available for the transport of RH waste. Selection of the proper cask would depend on the external dose rate and on the shipping container/canister that is appropriate for use with a given cask. Except for activated metal waste (which has a high external dose rate similar to that of SNF), the majority of the RH wastes being considered for disposal can be packaged in drums and shipped in truck casks, such as the RH 72-B (DOE 2006b) and 10-160B (NRC 2005), or in a rail cask such as the NAC storage transport cask (STC; see NAC International 2004). This report assumes that all RH waste, except for the activated metal waste types, is packaged for disposal in drums. If shipped in the RH 72-B cask, three drums can be packaged in an RH canister (DOE 1995) that is designed for use with this cask. The RH canister has a length of 3.07 m (121 in.), diameter of 0.66 m (26 in.), wall thickness of 0.0064 m (0.25 in.), and an internal volume of 0.89 m^3 (31.4 ft^3). As an alternative, RH waste can be loaded directly into the canister for disposal (DOE 2006c). The proposed facility designs can accommodate both drums and RH canisters, as discussed further in Sections 2.1.2.2, 2.2.2.2, and 2.3.2.2.

Activated metal is assumed to be packaged in unshielded right circular stainless-steel canisters (activated metal canisters or AMCs). To facilitate potential shipment by truck as well as rail and to provide flexibility in the facility design (as discussed in Sections 2.1.2.2, 2.2.2.2, and 2.3.2.2), the size and weight of these canisters were selected to be compatible with existing containers and weight limitations of truck casks. AMCs are assumed to have an external length of 1.22 m (48 in.), outside diameter of 0.66 m (26 in.), external volume of 0.418 m^3 (14.8 ft^3), and internal volume of 0.370 m^3 (13.1 ft^3), with a wall thickness of 1.27 cm (0.5 in.) and an end plate thickness of 2.54 cm (1 in.). The external diameter of 0.66 m (26 in.) was chosen to match that of the RH canister (DOE 1995) and remain close to the 0.61 m (24 in.) diameter of drums used for other RH waste. A loaded AMC is estimated to weigh approximately 2,600 kg (5,800 lb). This weight was based on a fill fraction of 75% (Sandia 2008a).

Most Type B casks would need to be re-certified to transport activated metals. A recent investigation into appropriate truck and rail casks for the transport of activated metals showed that few options are available, primarily because of the cargo's high external dose rates (Carlson et al. 2006). The certificate of compliance for the heavily shielded CNS 3-55 truck cask is no longer valid (it expired in October 2008). However, EnergySolutions is in the process of supplying an equivalent replacement, the 3-60B cask (EnergySolutions 2010). The TN-RAM is also a candidate truck cask, but only one cask is in existence (Carlson et al. 2006). On the other hand, the TN-RAM and/or the CNS 3-55 design could be used as the basis for another certificate of compliance submittal. Both the 3-60B and TN-RAM designs have a payload capacity of 4,300 kg (9,500 lb) and internal dimensions that could support a longer AMC. The facility designs presented in Chapter 2 can support AMC lengths up to about 4.3 m (14 ft) if necessary. However, for a final design, an iterative process considering waste characteristics and handling, AMC dimensions, other disposal container dimensions, and facility dimensions would produce an optimal use of disposal space and minimize costs.

The present length of the AMC was selected to keep it compatible with the RH 72-B and 10-160B packages. For containers with lower dose rates, an AMC could be shipped with spacers in the RH 72-B, which has a 3,600-kg (8,000-lb) payload. The 10-160B is certified to transport activated metals and has a 6,580-kg (14,500-lb) payload. However, additional shielding would be needed for the AMCs with radiation rates on the order of 1,000 R/h at contact. The payload limit includes any additional shielding and bracing needed, which would likely require recertification of the package.

1.3 WASTE INVENTORY

The inventory is presented here in the grouped format as used in the supplement inventory report (Argonne 2010). Group 1 consists of wastes already generated and in storage or those projected to be generated by existing facilities, such as commercial nuclear power plants. Group 2 consists of wastes that may be generated in the future at facilities that may or may not exist now or from actions that may or may not take place, including several DOE projects and new nuclear power plants that have not yet been licensed by the NRC or constructed. In addition, three distinct waste categories — activated metals, sealed sources, and Other Waste — have been used to differentiate the types of GTCC LLRW and GTCC-like waste on the basis of common characteristics (DOE 2007a).

The disposal facilities considered in this report are designed to accommodate approximately 11,650 m^3 of GTCC LLRW and GTCC-like waste currently under consideration for disposal. Table 1-2 gives a summary breakdown of the waste volumes. A more detailed breakdown of the waste volumes by group and category is provided in Table 1-3, along with the number of estimated disposal containers.

1.3.1 Activated Metals

1.3.1.1 Characteristics

The activated metal wastes consist of steel, stainless steel, and a number of specialty alloys used in nuclear reactors. Portions of the reactor assembly and other components near the nuclear fuel are activated by high fluxes of neutrons during reactor operations for long periods of time, producing high concentrations of some radionuclides. Many of these have very short half-lives from days to several weeks, such as cobalt-58 (Co-58), zirconium-95 (Zr-95), and niobium-95 (Nb-95), and decay rapidly. Others have longer half-lives — in some cases, thousands of years, such as carbon-14 (C-14) and nickel-59 (Ni-59) — and remain radioactive for an extended period of time. Most of the activated metal waste would be generated in the

TABLE 1-2 Summary of GTCC LLRW and GTCC-Like Waste Volumes Considered for Disposal

	Volume (m^3)		
Waste Type	GTCC Waste	GTCC-Like LLRW	Total
Activated metals	1,994	13	2,007
Sealed sources	2,829	1	2,830
Other Waste	3,988	2,822	6,810
Total	8,811	2,836	11,646

future from the decommissioning of commercial nuclear power reactors. The neutron activation products expected to be most prevalent in these wastes at the time the wastes are available for disposal are C-14, manganese-54 (Mn-54), iron-55 (Fe-55), Co-60, Ni-59, Ni-63, molybdenum-93 (Mo-93), and Nb-94. Lower concentrations of some fission products (including strontium-90 [Sr-90], technetium-99 [Tc-99], and cesium-137 [Cs-137]) and actinides (such as various isotopes of plutonium) are also expected to be present on these materials as surface contamination.

While the majority of GTCC LLRW generated by nuclear reactors is activated metal (DOE 1994), only a very small fraction of the metallic waste generated by decommissioning commercial nuclear power plants would be GTCC LLRW. Most of the waste would be Class A, B, or C LLRW that can be disposed of at existing commercial radioactive waste disposal sites. For purposes of analysis, all of the GTCC LLRW activated metal waste is taken to be RH waste on the basis of the expected high concentrations of gamma-emitting radionuclides in this material. These wastes would need a significant amount of shielding to reduce the levels of radiation to acceptable levels and/or would have to be handled remotely. The physical form of this waste is solid metal, which is both physically and chemically inert. In addition, there is a small inventory of DOE-owned activated metal that has characteristics similar to the GTCC LLRW activated metal from commercial nuclear reactors.

1.3.1.2 Volumes

Approximately 1,258 m^3 of GTCC activated metal in 3,485 AMCs (Table 1-3) from past, existing, and proposed reactors was estimated to require disposal through 2083. Currently, there are 12 spent nuclear fuel dry storage canisters filled with activated metal GTCC LLRW at seven decommissioned reactor independent spent fuel storage installations (ISFSIs). These canisters have an approximate outer diameter of 1.68 m (66 in.) and range in external length from about 3.10 to 4.88 m (122 to 192 in.). If no re-packaging of this waste occurred, these canisters could be shipped by rail to the disposal facility in their respective shipping casks. Disposal of this type of canister could also be accommodated by the facility designs presented in this report.

GTCC activated metal at the West Valley Demonstration Project would require 1,990 AMCs for disposal of an estimated volume of 735 m^3. The GTCC-like activated metal inventory of 12.8 m^3 was estimated to require 38 AMCs for disposal.

1.3.2 Sealed Sources

1.3.2.1 Characteristics

The possession and use of sealed sources in the commercial sector are licensed by the NRC and its Agreement States. The term “sealed radioactive source” refers to a radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. A

TABLE 1-3 Estimated GTCC Waste Volumes and Associated Number of Containers Used for Disposal in a Conceptual Land Disposal Facility[a]

Shipment Site	Handling	Volume (m^3)	Container Type	Number of Containers
Group 1				
GTCC LLRW				
Activated metals				
Past/present commercial reactors[b]	RH	882.38	AMC	2,450
Sealed sources[c]				
Small sealed sources				
Commercial Am-241	CH	920.60	55-gal drum	4,426
Commercial Cm-244	CH	0.208	55-gal drum	1
Commercial Pu-238	CH	733.61	55-gal drum	3,527
Commercial Pu-239	CH	155.58	55-gal drum	748
Cesium irradiators				
Commercial irradiators	CH	1,018.85	Self-contained	1,435
Other Waste				
WCS (Gulf Nuclear waste)	CH	42.07	55-gal drum	203
BWXT	RH	33.6	55-gal drum	162
GTCC-like waste				
Activated metals				
INL (stored)		3.3	AMC	9
INL (projected)		6.55	AMC	18
ORR (stored)		2.93	AMC	11
Sealed sources				
Small sealed sources[c]	CH	0.832	55-gal drum	4
Other Waste				
BWXT (stored)	CH	3.41	55-gal drum	17
INL (stored)	CH	30.516	55-gal drum	156
West Valley	CH	708.76	SWB	381
BWXT (stored)	RH	14.57	55-gal drum	71
BWXT (projected)	RH	0.6	55-gal drum	3
INL (stored)	RH	19.466	55-gal drum	99
ORR (stored)	RH	4.03	55-gal drum	22
ORR (projected)	RH	133	55-gal drum	642
West Valley	RH	544.64	55-gal drum	2,625
Group 1 total		5,259.50		17,010

TABLE 1.3-2 (Cont.)

Shipment Site	Handling	Volume (m^3)	Container Type	Number of Containers
Group 2				
GTCC LLRW				
New reactors				
Proposed commercial BWRs	Activated metal	72.61	AMC	202
Proposed commercial PWRs	Activated metal	303.36	AMC	833
West Valley				
West Valley	Activated metal	735.33	AMC	1,990
West Valley	CH	1,550.97	SWB	829
West Valley	RH	1,974.12	55-gal drum	9,500
GTCC-like waste				
Mo-99 production				
Medical isotope production system	RH	355	55-gal drum	1,707
Missouri University research reactor	RH	32.66	55-gal drum	158
Pu-238 production project				
Pu-238 production project	CH	264	SWB	141
Pu-238 production project	RH	116	55-gal drum	558
Other Waste				
West Valley	CH	224.29	SWB	120
West Valley	RH	758.41	55-gal drum	3,649
Group 2 total		6,386.75		19,687
Total Groups 1 and 2		11,646		36,697

[a] AMC = activated metal canister, BWR = boiling water reactor, CH = contact handled, INL = Idaho National Laboratory, ORR = Oak Ridge Reservation, OSRP = Off-Site Source Recovery Project, PWR = pressurized water reactor; RH = remote-handled, SWB = standard waste box, WCS = Waste Control Specialists.

[b] There are two types of commercial nuclear reactors in operation in the United States, BWRs and PWRs. Different factors were used to estimate the volume and activities of activated metal wastes for these two types of reactors.

[c] Sealed sources may be physically small, but they have high concentrations of radionulides.

sealed radioactive source consists of a known or estimated quantity of radioactive material that is (1) contained within a sealed capsule, (2) sealed between layer(s) of nonradioactive material, or (3) firmly fixed to a nonradioactive surface by electroplating or anther means intended to prevent leakage or escape of the radioactive material. These sources are commonly used to sterilize medical products, detect flaws and failures in pipelines and metal welds, determine the moisture content in soil and other materials, and diagnose and treat illnesses such as cancer. Only a relatively small fraction of the sealed sources would be GTCC LLRW, depending on the specific radionuclides present in the sources and the quantity (in curies) of the source. Most sealed sources are Class A, B, or C LLRW and can be disposed of at existing LLRW disposal facilities. The sealed sources that are GTCC LLRW are those that represent a long-term hazard to human health and the environment and exceed the radionuclide concentrations for classification as Class C LLRW given in 10 CFR 61.55.

Essentially all of the sealed sources being addressed are in Group 1 (Argonne 2010). It is assumed that the GTCC LLRW sealed sources would be packaged in 55-gal drums by radionuclide on the basis of packaging factor limits developed by the DOE Off-Site Source Recovery Project (OSRP) at Los Alamos National Laboratory (LANL). In addition to these small sealed sources, there are 1,435 large Cs-137 sources (Cs irradiators) in the waste inventory. These sources cannot be packaged in 55-gal (208-L) drums but are assumed to be disposed of individually in their original shielded devices with dimensions of 0.62 × 0.65 × 1.5 m (24.6 × 25.6 × 59.1 in.).

Sealed sources can encompass several physical forms, including ceramic oxides, salts, or metals. Cesium chloride salt was generally used in older Cs-137 sources, and newer sources typically have the radionuclide bonded in a ceramic. Of these two forms, cesium chloride salt is much more water soluble. For the rest of the sealed sources, the radionuclides are assumed to be in the form of oxides. While there are some sealed sources currently in storage, most of this waste would be generated in the future.

The sealed sources generally have relatively low exposure rates when packaged for disposal. As noted in Sandia (2008a), all of the packaged sealed sources are expected to be CH waste. As part of the Group 2 wastes, approximately 23 m^3 of sealed sources from West Valley may be disposed of (Argonne 2010), but those sources may require disposal as RH waste. For the purposes of this report, this small amount of RH waste is included with the Other Waste classification for the purpose of determining the disposal facility characteristics.

1.3.2.2 Volumes

As shown in Table 1-3, all sealed sources are in Group 1, with approximately 1,810 m^3 of small GTCC waste sources being packaged in 8,702 drums. The estimated number of GTCC Cs irradiators is 1,435, with a volume of 1,019 m^3. With regard to GTCC-like small sources, it is estimated that approximately 0.83 m^3 are packaged in four drums.

1.3.3 Other Waste

1.3.3.1 Characteristics

Other Waste consists of a wide variety of materials, including contaminated equipment, sludges, salts, charcoal, scrap metal, glove boxes, solidified solutions, particulate solids, filters, and organic and inorganic debris (including debris from future decontamination and decommissioning activities). This category of waste includes those GTCC LLRW and GTCC-like wastes that do not fall into one of the other two categories (activated metals or sealed sources). This waste can be in a number of physical forms, and a range of radionuclides may be present. Much of the waste in this category is expected to meet the current DOE definition of TRU waste.

1.3.3.2 Volumes

The total volume of 6,810 m^3 of Other Waste has more GTCC LLRW than GTCC-like waste, as shown in Table 1-2. About 2,800 m^3 of this waste is CH waste, and 4,000 m^3 is RH waste, as given in Table 1-3. The majority of the Other Waste, 1,500 m^3, is part of Group 1, while the remaining 5,300 m^3 is in Group 2, as given in Table 1-3.

2 LAND DISPOSAL METHODS

Three land disposal methods are considered: intermediate-depth borehole (borehole), enhanced near-surface trench (trench), and enhanced near-surface above-grade vault (vault). Each conceptual design must accommodate both CH and RH waste, as discussed in Chapter 1. Because RH waste poses a greater direct radiation hazard than CH waste, more precautions must be taken in handling and disposing of RH waste. In particular, disposal package configurations for RH waste should reflect a judicious use of space and materials; they must ensure that workers are properly shielded from previously emplaced waste and that additional waste is emplaced in an expeditious manner.

For each of the three land disposal methods considered, CH waste containers are emplaced in a disposal unit directly by using forklifts and/or cranes. RH waste is emplaced in disposal units by using a shielded transfer cask in conjunction with forklifts, cranes, and/or hoists. The concept of using a shielded transfer cask with bottom-loading/discharge capabilities has been used or considered at some disposal sites (Gonzalez et al. 2006; Harvego et al. 2007) and is incorporated in many SNF transfer and storage cask designs (EnergySolutions 2007; Holtec International 2006; NAC International 2004). While the basic conceptual design for each disposal option is the same for both CH and RH waste, the configurations of the CH and RH disposal containers are different from each other in the designs presented here.

2.1 TRENCH DISPOSAL

2.1.1 Conceptual Trench Design

The basic design for the trench disposal facility utilizes trenches that are 3-m (10-ft) wide, 10.6-m (34.8-ft) deep, and 100-m (329-ft) long. The trench width and depth were selected to optimize the disposal capacity per trench within the limits of excavation equipment that is readily available and shoring equipment that is commercially available. The conceptual drawing of a cross section of the basic trench design (Figure 2-1) illustrates the trench design features and dimensions. In addition, the conceptual design is deeper and narrower for a trench facility than for conventional near-surface LLRW disposal facilities in order to minimize the potential for inadvertent human intrusion during the post-closure period.

The side walls of the trench would be vertically constructed. A well-compacted material would be placed on top of the native material in the floor of the trench. A layer of sand or gravel (0.3-m thick) would be placed on top of the compacted material to improve stability. The nature of the compacted material would be selected to be compatible with the surrounding geologic material. The trench sidewalls would be constructed with temporary metal shoring. The metal shoring would be removed when the trench was closed.

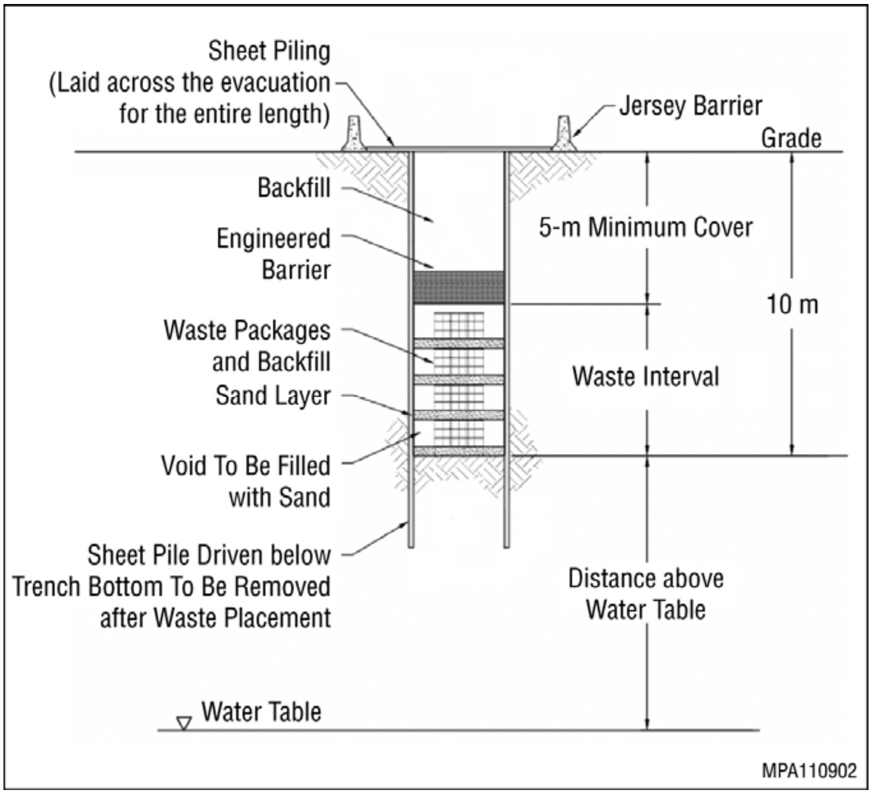

FIGURE 2-1 Cross Section of a Conceptual Disposal Trench (Source: Modified from Sandia 2007)

The waste packages would be placed into the trench, and a fine-grained cohesionless fill (sand) would be used to backfill around the waste containers to fill voids. After the trench was filled with the waste containers and backfill, a reinforced concrete layer 1.14-m (3.75-ft) thick would be placed over the waste packages to help mitigate any future inadvertent intrusion. Use of 6-in. (15-cm) on-center steel reinforcement (rebar), in two perpendicular layers, would strengthen the concrete. In addition to adding strength to the concrete layer, the spacing of the rebar would provide protection against inadvertent drilling straight down into the trenches. For this reason, the concrete would have two sets of perpendicular steel reinforcement, one near the top face and the other near the bottom face of the barrier. With a spacing of 6 in. (15 cm), most drill bits would not pass into the trench without encountering the steel reinforcement first (discouraging further penetration), if they had not initially been stopped by the concrete itself.

It is anticipated that clean fill from construction would be used to backfill the trench above the concrete layer. Each trench could be capped with a cover system consisting of a geotextile membrane overlain by gravel, sand, and topsoil layers (similar to that shown for the vault design final cover system depicted later in Figure 2-8). In the case of the trench, the top of the cover system would be flush with or slightly elevated above the surrounding ground surface, depending on the final design.

2.1.2 Disposal Package Configurations

2.1.2.1 Contact-Handled Waste

The assumed packing arrangement for 208 L (55-gal) drums and SWBs in a 10-m (33-ft) section of trench is shown in Figure 2-2. Up to 5 layers of drums or SWBs could be accommodated, with approximately 0.3 m (1 ft) of fill above and below each layer, for a total of 3,000 drums or 500 SWBs per trench. For the larger Cs irradiators, three layers with 560 units per layer (four across the trench width) were assumed, for a total of 1,680 Cs irradiators per trench. During disposal operations for CH waste, one end of a trench would have a ramp to the surface to allow entry by a forklift carrying CH waste packages (a pallet of four drums, four Cs irradiators, or a single SWB) for emplacement.

2.1.2.2 Remote-Handled Waste

Additional features would be necessary in the trenches where RH waste would be buried to provide shielding for the workers once the waste was in place. The RH waste packages (AMCs, drums, and RH canisters) would be disposed of in vertical reinforced concrete cylinders with concrete shield plugs (1.2-m [4-ft] thick) on top of each cylinder. This design is similar to that proposed for activated metal disposal (Harvego et al. 2007). A mating flange would enable coupling of the bottom-loading transfer cask to a given cylinder for transfer of the waste package into the disposal unit. The transfer cask would be moved off an on-site transport truck into position by an overhead crane. Figure 2-3 shows a top view of a 10-m section of an RH waste disposal trench. Each cylinder is capable of holding up to three AMCs, four individual 208-L (55-gal) drums, or one RH canister. With 302 cylinders per trench, as many as 906 AMCs, 1,208 drums, or 302 RH canisters could be emplaced in one trench.

2.2 BOREHOLE DISPOSAL

2.2.1 Conceptual Borehole Design

Intermediate-depth borehole disposal entails emplacement of waste in boreholes at depths below 30 m (98 ft) but above 300 m (984 ft). Boreholes can vary widely in diameter from 0.3 to 3.7 m (1 to 12 ft), and the proximity of one borehole to another can vary depending on the design of the facility. The technology for drilling larger-diameter boreholes is simple and widely available. The current conceptual design employs boreholes that are 2.44 m (8 ft) in diameter and 40-m (131-ft) deep in unconsolidated to semi-consolidated soils, as shown in Figure 2-4.

A bucket auger would be used to drill the large-diameter borehole (see Figure 2-5), and a smooth steel casing would be advanced to the depth of the borehole during the drilling and construction of the borehole. The casing would provide stability to the borehole walls and ensure

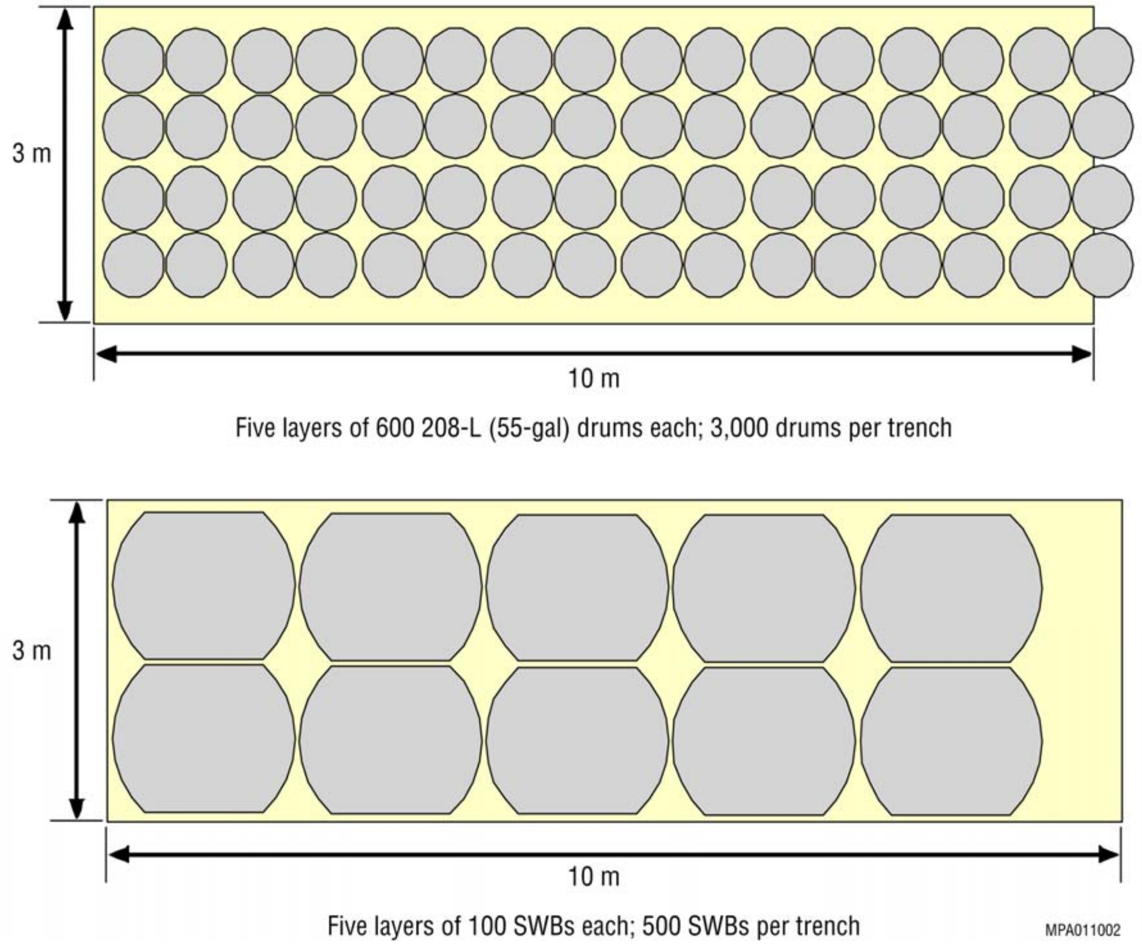

FIGURE 2-2 Top View of 10-m (33-ft) Section of Trench Packed with Contact-Handled Waste

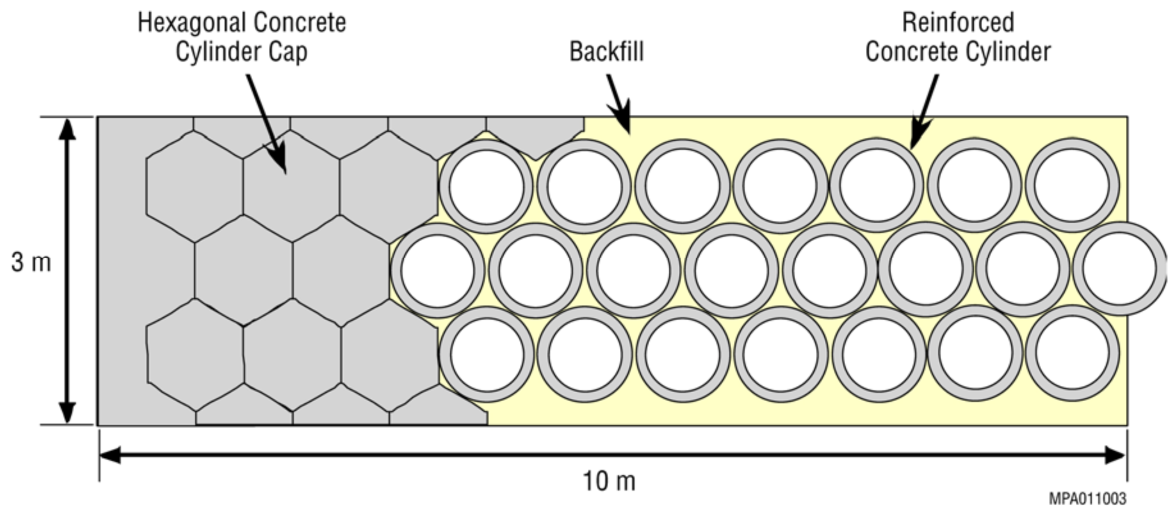

FIGURE 2-3 Top View of a 10-m (33-ft) Section of Trench for Disposal of Remote-Handled Waste

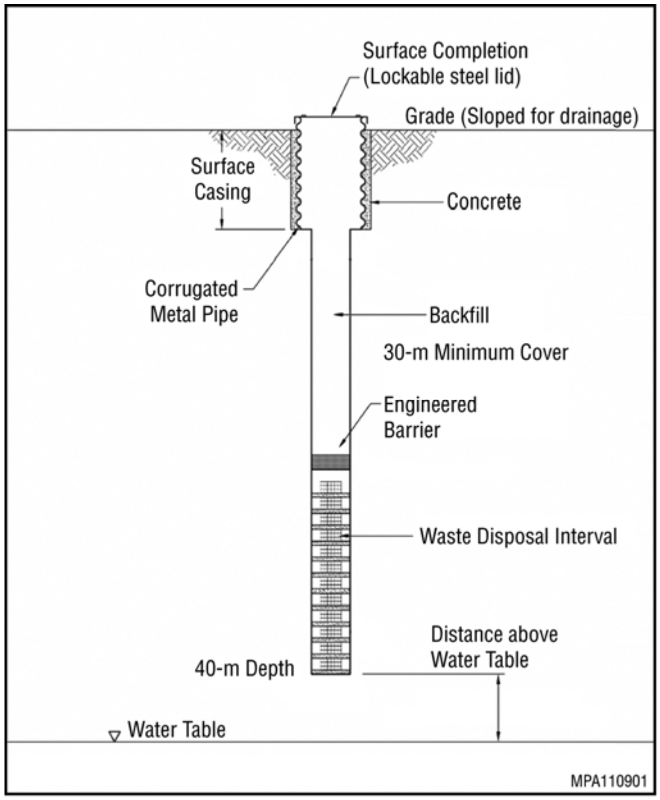

FIGURE 2-4 Cross Section of a Conceptual 40-m (130-ft) Intermediate-Depth Borehole (Source: Modified from Sandia 2007)

that waste packages would not snag and plug the borehole as they were lowered and would sit in an upright position when they reached the bottom. The upper 30 m (98 ft) of smooth steel casing would be removed upon closure of the borehole. In some cases where consolidated materials might be encountered, a more robust drilling technology would be required. A casing would also be used in this latter case as an aid to waste package placement.

The waste packages would be placed into the borehole, and a fine-grained cohesionless fill (sand) would be used to backfill around the waste containers to fill voids. After the borehole was filled with the waste containers and backfill, a reinforced concrete layer would be placed over the waste packages to help mitigate any future inadvertent intrusion. Use of 6-in. (15-cm) on-center steel reinforcement (rebar), in two perpendicular layers, would strengthen the concrete. In addition to adding strength to the concrete layer, the spacing of the rebar would provide protection against inadvertent drilling straight down into a borehole. For this reason, the concrete would have two sets of perpendicular steel reinforcement, one near the top face and the other near the bottom face of the barrier. With a spacing of 6 in. (15 cm), most drill bits would not pass into the borehole without encountering the steel reinforcement first (discouraging further penetration), if they had not initially been stopped by the concrete itself.

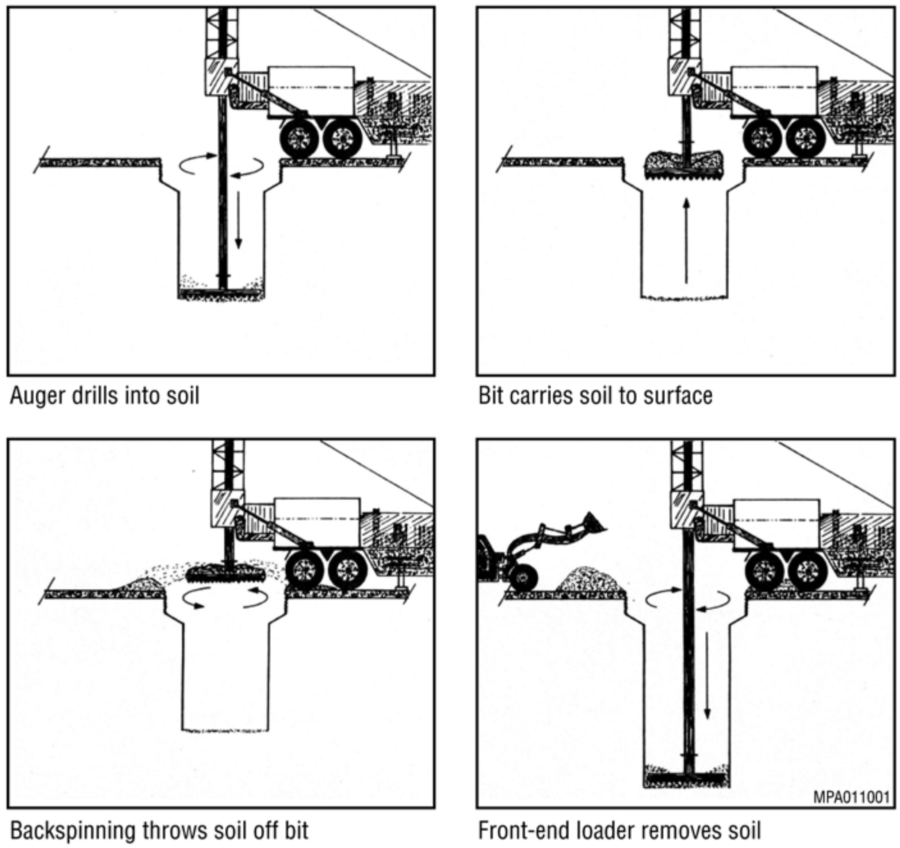

FIGURE 2-5 Process Schematic for Drilling a Large-Diameter Borehole by Using a Bucket Auger (Source: Sandia 2007)

It is anticipated that clean fill from the construction of the facility would be used to backfill the borehole above the concrete layer. Each borehole could be capped with a cover system consisting of a geotextile membrane overlain by gravel, sand, and topsoil layers, similar to that discussed for trench disposal in Section 2.1.1 and shown for the vault design final cover system depicted later in Figure 2-8. In the case of the borehole, the top of the cover system would be flush with or slightly elevated above the surrounding ground surface, depending on the final design.

2.2.2 Disposal Package Configurations

2.2.2.1 Contact-Handled Waste

CH waste would be taken off the on-site transport vehicle and lowered by crane into a borehole for emplacement. For a borehole, assumed packing arrangements for CH waste are eight intervals (levels) of 208-L (55-gal) drum 7-packs (56 drums), five intervals of Cs irradiator 4-packs (20 Cs irradiators), or eight intervals of one SWB (eight SWBs). Approximately 0.3 m

(1 ft) of fill would be used between intervals. Single-interval packing arrangements are shown in Figure 2-6.

2.2.2.2 Remote-Handled Waste

For RH waste, three intervals of two 3-packs of RH canisters or six intervals of two 3-packs of AMCs are assumed. Thus, 18 RH canisters or 36 AMCs could be emplaced in a borehole. RH canisters could be direct loaded or could contain up to three 55-gallon drums of RH waste. Boreholes for disposal of RH waste would have a shielded cover once the RH waste was emplaced, prior to being full and backfilled. On-site transport of RH waste would occur in shielded bottom-loading transfer casks (e.g., smaller versions of the type used at ISFSIs for the movement of SNF) that would mate with ports on a borehole cover. Once the transfer cask was mated to the borehole cover, the RH waste would be lowered into place.

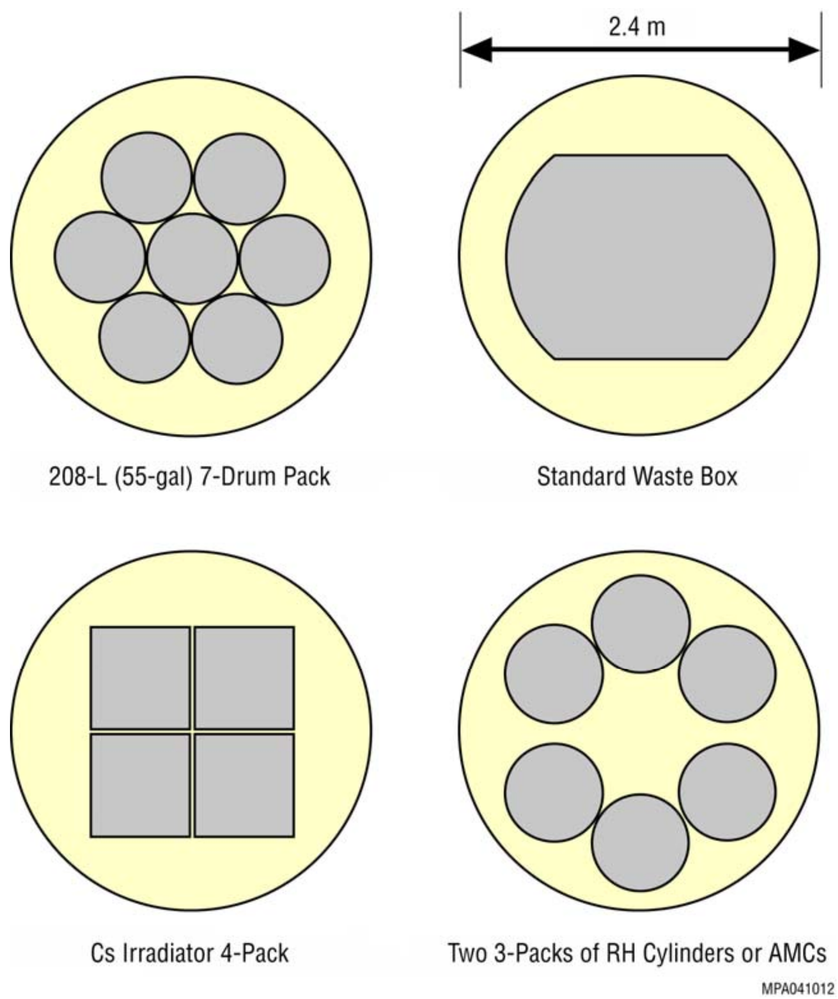

FIGURE 2-6 Top View of Single-Interval Packing Arrangements in 2.4-m-Diameter (8-ft-Diameter) Boreholes for Different Container Types

2.3 VAULT DISPOSAL

2.3.1 Conceptual Vault Design

The conceptual design for the above-grade disposal of GTCC LLRW is a reinforced concrete vault constructed near grade level, with the footings and floors of the vault situated in a slight excavation just below grade. The design is a modification of one disposal concept proposed by Henry (1993) for GTCC LLRW and is similar to a belowground vault LLRW disposal option previously investigated by the U.S. Army Corps of Engineer (USACE) (Denson et al. 1987). A similar below-grade concrete vault structure is currently in use for disposal of higher-activity LLRW at the Savannah River Site (MMES et al. 1994).

2.3.1.1 Vault System

Each vault would be 10.5-m (34.5-ft) wide, 94.2-m (309-ft) long, and 7.9-m (26-ft) tall, with 11 disposal cells situated in a linear array. Interior cell dimensions would be 8.23-m (27.0-ft) wide, 7.47-m (24.5-ft) long, and 5.5-m (18-ft) high, with an internal volume of 338 m^3 per cell. Double interior walls with an expansion joint would be included after every second cell. Figure 2-7 shows a schematic cross section of a vault cell.

The exterior walls and roof would be composed of 1.14-m (3.75-ft) thick reinforced concrete. In addition to adding strength and durability to the vault, the concrete would also serve to attenuate the radiation emanating from the RH waste component of the material destined for disposal. The most hazardous of the waste in this respect would be the activated metals from

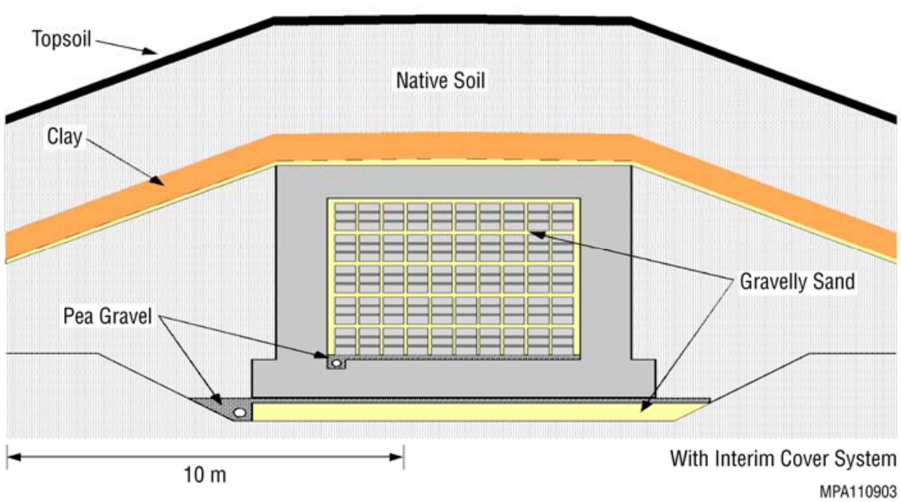

FIGURE 2-7 Cross Section of a Conceptual Above-Grade Vault Design (drawn to scale)

reactor decommissioning, which could have external radiation rates (primarily from Co-60) of a few thousand roentgens per hour at the waste package surface (Sandia 2008a). With an attenuation of Co-60 gamma rays of one-half for about every 6.2 cm of concrete (Shleien 1992), a reduction in radiation (by a factor of more than 260,000) to background levels is expected.

Six-inch (15-cm) on-center steel reinforcement (rebar), in two perpendicular layers, would be used to strengthen the concrete in the floor, walls, and vault cap (ceiling). In addition to adding strength to the vault construction, the spacing of the rebar would provide protection against inadvertent drilling into the disposal cells. For this reason, the vault cap would have two sets of perpendicular steel reinforcement, one near the exterior face of the cap and the other near the interior face of the cap. With a spacing of 6 in. (15 cm), most drill bits would not pass into the vault without encountering the steel reinforcement first (discouraging further penetration), if they had not been initially stopped by the concrete itself. Steel reinforcement was included in the walls because of the increased use of directional drilling at lower depths for utility work, which could expose the walls as well as the top of the vault to drilling.

2.3.1.2 Engineered Cover Systems

An engineered cover would be used to help isolate the waste from the environment over the long term. In addition to the protection afforded by the vault and its internal backfill, the thickness of the cover would help assure that external exposure rates remained at background levels. The design would direct surface water away from the waste and help deter intrusion by humans, plants, and animals. Minimum and maximum slope requirements would be incorporated to assure adequate drainage and to reduce erosion and maintain slope stability, respectively.

Two engineered cover systems are included in the design for the vaults, as shown in Figure 2-8. The first would be put in place after a vault was filled with waste and permanently closed, or it could be implemented incrementally as the vault was filled (the interim cover with a rise-to-run of 1:3 from the vault edge to ground level). The second cover system would partially replace the interim cover prior to closure of the disposal facility (the final cover with a rise-to-run of 1:5 from the vault edge to ground level). A graded slope of 3% would be used over the top of the vaults. Both covers would have a minimum depth of 5.0 m (16.5 ft) over any portion of a vault, with a 15.2-cm (0.5-ft) layer of gravelly sand over a vault followed by a 0.9-m (3-ft) thick layer of clay, as shown in Figure 2-8. The next layer in the interim cover would consist of 3.66 m (12.0 ft) of native soil followed by 0.3 m (1 ft) of topsoil. In the final cover, the next layer over the clay layer would have 2.75 m (9.0 ft) of native soil, followed by a geotextile layer, 0.6 m (2 ft) of gravel, 15.2 cm (0.5 ft) of pea gravel, 15.2 cm (0.5 ft) of sand, and 0.3 m (1 ft) of topsoil (Henry 1993). If needed, rock armor could also be incorporated into the final cover to further protect against erosion

The conceptual vault cell cross section shown in Figure 2-7 depicts the interim cover system covering a vault. Figure 2-9 illustrates a cross section of the conceptual vault final cover system.

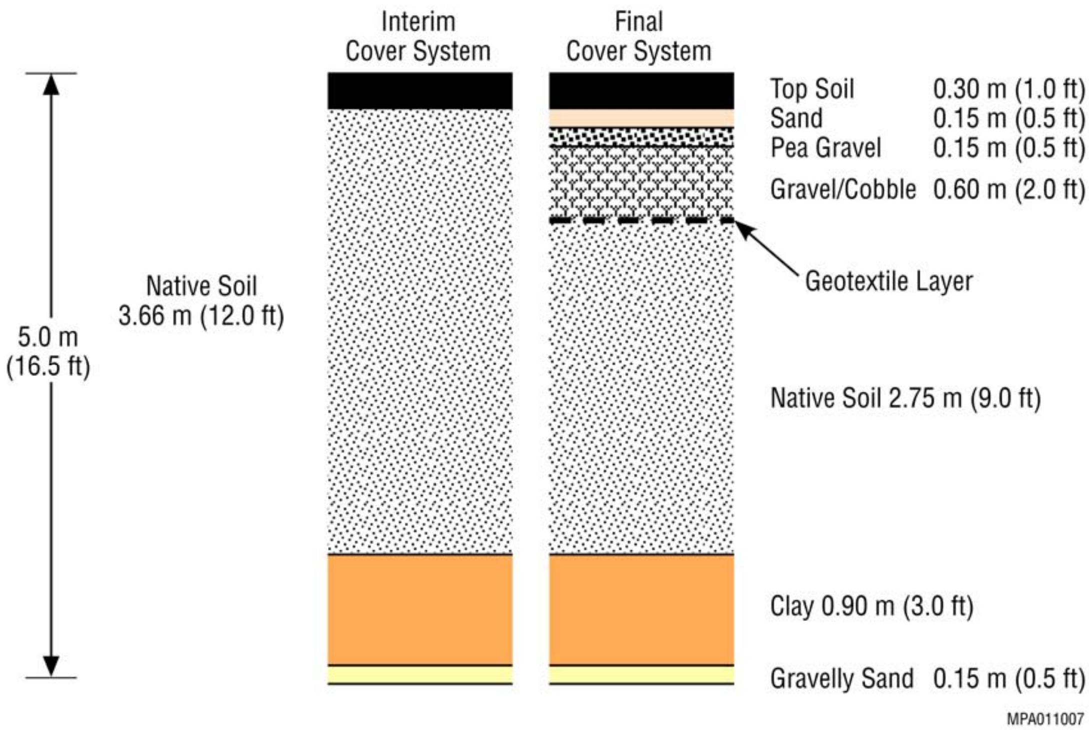

FIGURE 2-8 Conceptual Cover Systems for the Above-Grade Vault Disposal Facility (Source: Modified from Henry 1993)

2.3.2 Disposal Package Configurations

2.3.2.1 Contact-Handled Waste

The packing arrangement of CH 208-L (55-gal) drums in a cell assumes placement of 7-drum packs as received at the facility in a TRUPACT-II Type B transportation package. Figure 2-10 shows the arrangement for the CH drums with 18 7-packs per layer. With five layers, 630 drums could be accommodated in each cell. For SWBs, 20 would be arranged in one layer (see Figure 2-11) with five layers for 100 SWBs in one vault cell. In addition, it is estimated that about 300 Cs irradiators (three layers of 10 × 10) would fit in one cell. A layer of fill would be used between layers of disposal containers to minimize void spaces. SWBs, 7-drum packs, and 4-packs of irradiators would be taken off an on-site transport truck and loaded into the cell by an overhead crane.

2.3.2.2 Remote-Handled Waste

Vault cells for disposal of RH waste would be similar in design to the trench approach, as discussed in Section 2.1.2.2. RH AMCs, 208-L (55-gal) drums, or canisters would be lowered

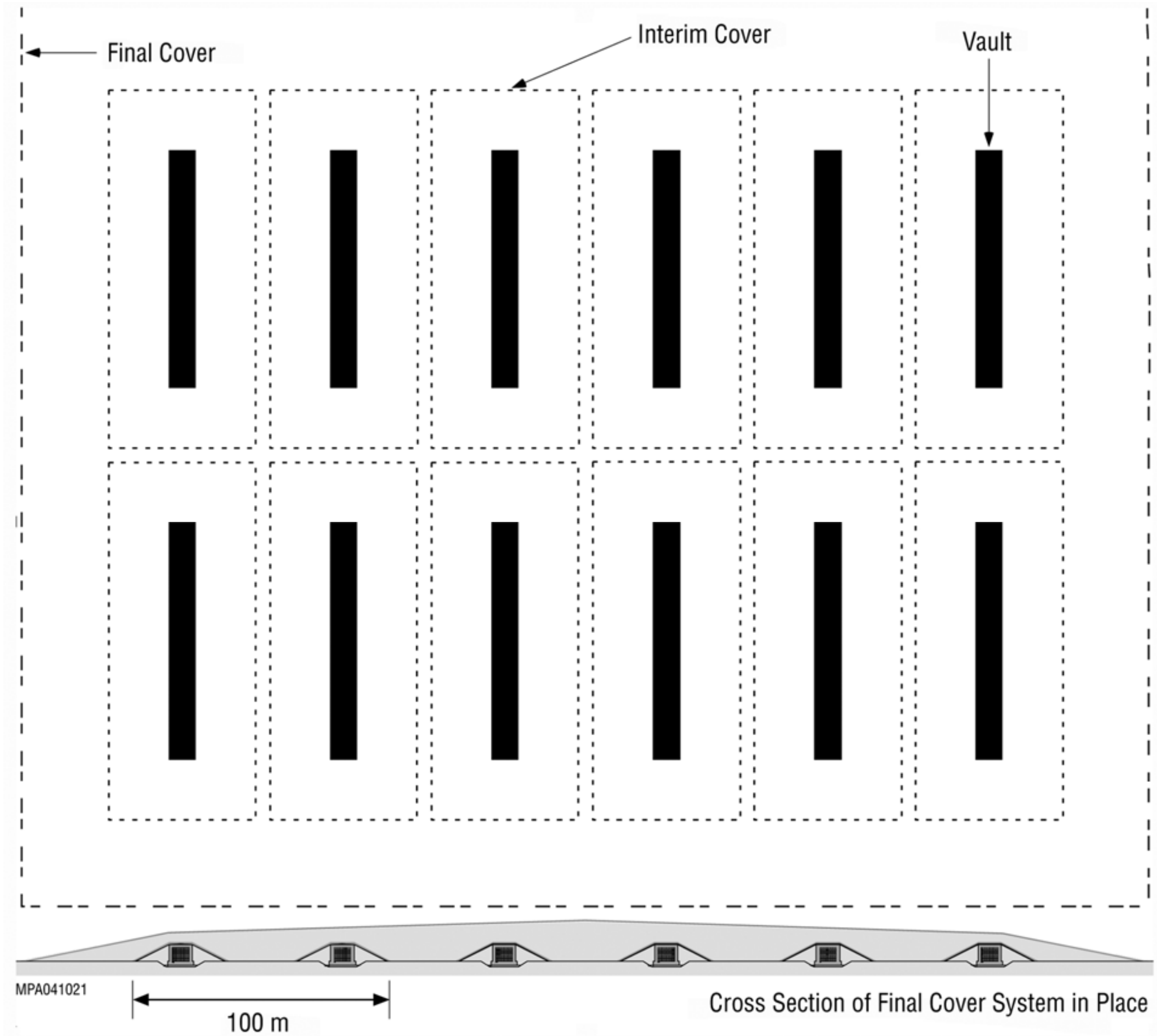

FIGURE 2-9 Cross Section of Vault Final Cover System (bottom) below Top View of Vault Disposal Area (both images are drawn to the same scale)

from a bottom-loading transfer cask into vertical reinforced concrete cylinders, with thick concrete shield plugs within each cell. Figure 2-12 provides a view from the top of a vault cell. The cylinder loading would be the same as that for the trench: three AMCs, four 208-L (55-gal) drums, or one RH canister per cylinder. With 72 cylinders per cell, 216 AMCs, 288 drums, or 72 RH canisters, respectively, could be emplaced in each vault cell.

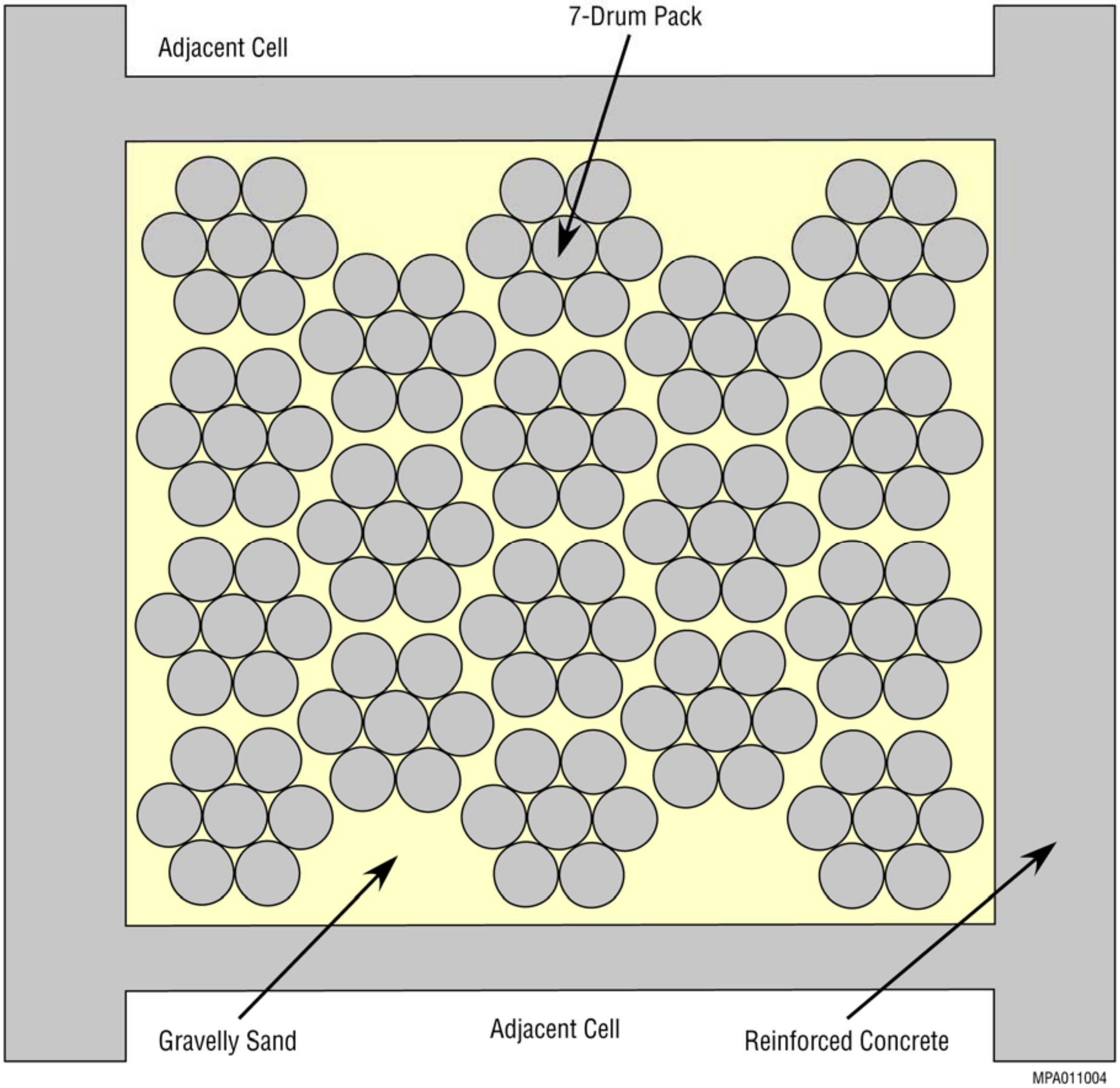

FIGURE 2-10 Top View of a Single-Layer Packing Arrangement of Contact-Handled Waste in 208-L (55-gal) 7-Drum Packs in a Vault Cell

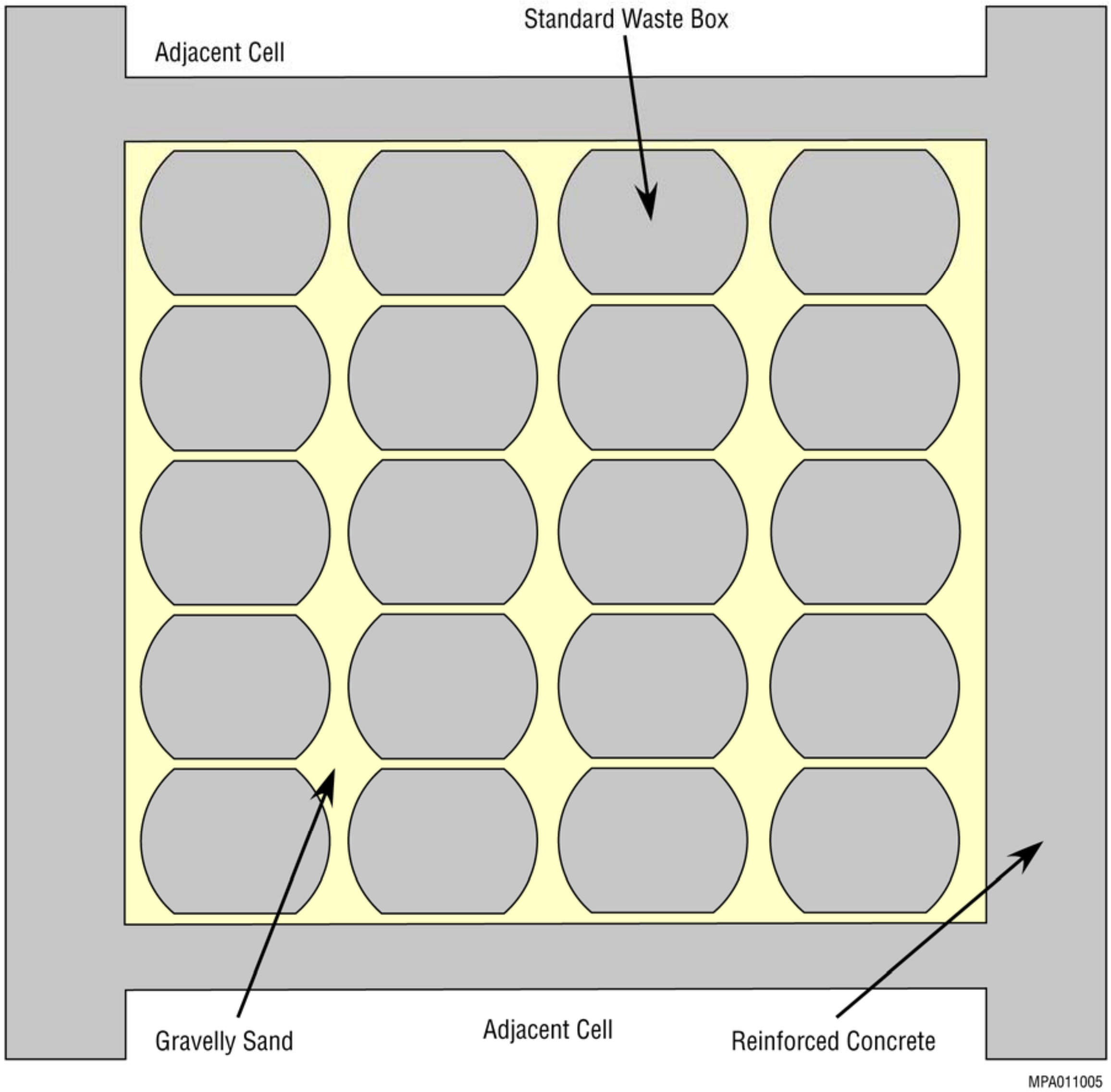

FIGURE 2-11 Top View of a Single-Layer Packing Arrangement of Contact-Handled Waste in Standard Waste Boxes in a Vault Cell

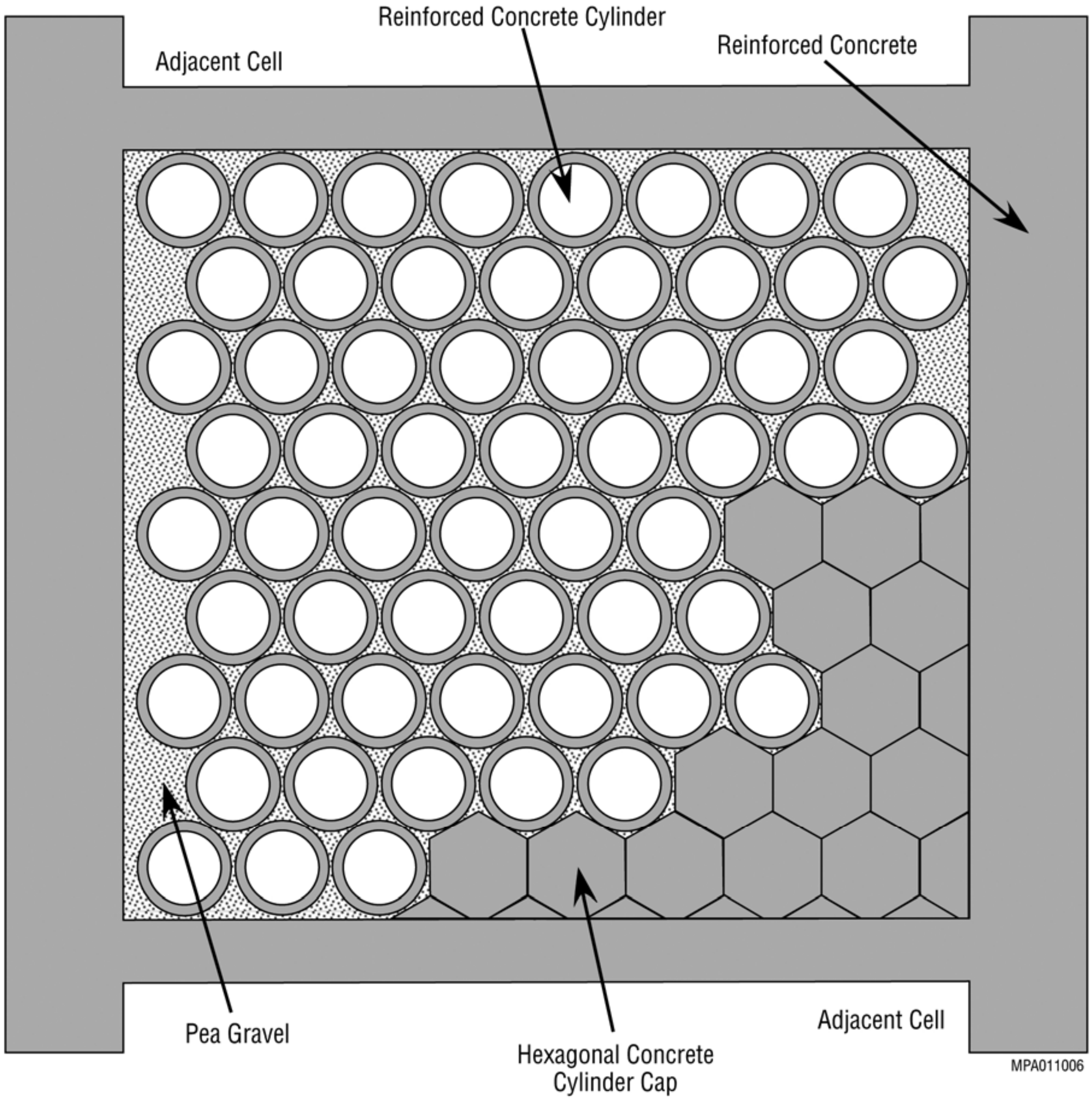

FIGURE 2-12 Top View of a Vault Cell for Disposal of Remote-Handled Waste

3 CONCEPTUAL FACILITY LAYOUTS

Conceptual facility layouts are provided for the trench, borehole, and above-grade vault designs. Each layout assumes emplacement of the entire 11,650 m^3 of GTCC LLRW and GTCC-like waste discussed in Section 1.3 using the designs presented in Chapter 2.

3.1 DISPOSAL METHODS

The support facilities required for all three methods are the same because the same functionality is required, as discussed in Section 3.2. Each option includes a security gate building, an administration building, a waste receipt and storage (waste handling) building, a maintenance and storage building, a utilities building, and a laboratory. For all methods, an outside fence maintains a minimum buffer of 30.5 m (100 ft) around the site, with a larger buffer where the retention pond and site support facilities might be located.

3.1.1 Trench Disposal

Figure 3-1 shows the layout of a conceptual enhanced near-surface trench waste disposal facility. It is estimated that approximately 29 trenches would be required for the disposal of the 11,650 m^3 of waste currently under consideration. Trenches would be spaced 30 m (98 ft) apart within a facility footprint of about 45.5 ac that is 550 × 334 m (1,808 × 1,096 ft) at the fenceline. The conceptual design incorporates a retention pond that would be 251 × 55 × 0.30 m (825 × 180 ×1 ft) in size to manage stormwater runoff. The proposed size of the pond may need to be modified depending on site-specific conditions, including precipitation.

3.1.2 Borehole Disposal

Figure 3-2 shows the layout of a conceptual borehole facility, which covers about 110 ac. It is estimated that approximately 930 boreholes 131-ft (40-m) deep would be required for the disposal of the 11,650 m^3 of waste currently under consideration. Boreholes would be spaced 10 m (33 ft) apart on-center with 30-m (98-ft) spacing between rows. The conceptual design incorporates a retention pond that would be 236 × 137 × 0.30 m (775 × 450 × 1 ft) in size to manage stormwater runoff. The proposed size of the pond might need to be modified depending on site-specific conditions, including precipitation. The dimensions of the facility footprint would be approximately 514 × 869 m (1,685 × 2,850 ft) at the fenceline.

3.1.3 Vault Disposal

The conceptual vault system design consists of 12 vaults with a total land use requirement of about 63 ac within the outer perimeter fence, as shown in the layout of the

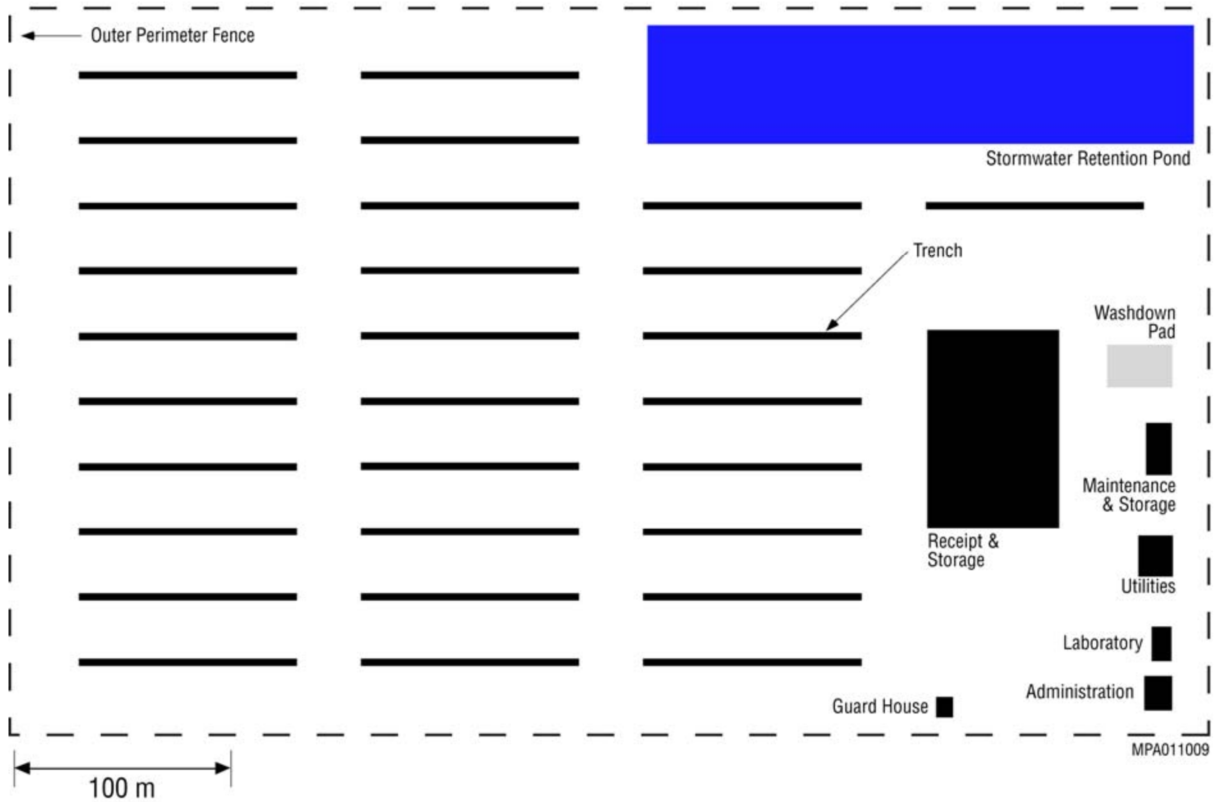

FIGURE 3-1 Layout of a Conceptual Trench Disposal Facility

conceptual facility presented in Figure 3-3. Approximately 40 ac would be required for the 12 disposal vaults and their final cover system. The vaults would be spaced to (1) provide adequate room for the interim cover systems (2.1 ac each) to be emplaced as each one was completely filled, (2) protect site workers, and (3) isolate the waste before decommissioning and emplacement of the final cover system prior to facility closure. The dimensions of the facility footprint would be about 607 × 419 m (1,990 × 1,375 ft) at the fenceline.

Ditches would separate the vaults with their interim cover systems to minimize standing water and provide site drainage. The conceptual design incorporates a retention pond that would be 177 × 107 × 0.30 m (580 × 350 × 1 ft) in size to manage stormwater runoff. The proposed size of the pond might need to be modified depending on site-specific conditions, including precipitation.

3.2 MAJOR STRUCTURES

The same support functions would be needed for all three disposal methods, because the GTCC LLRW and GTCC-like waste would arrive at the disposal facility in the same packaging and disposal containers. The primary differences would be found in the actual waste disposal units themselves and the equipment used to emplace the waste. Forklifts would be used for the

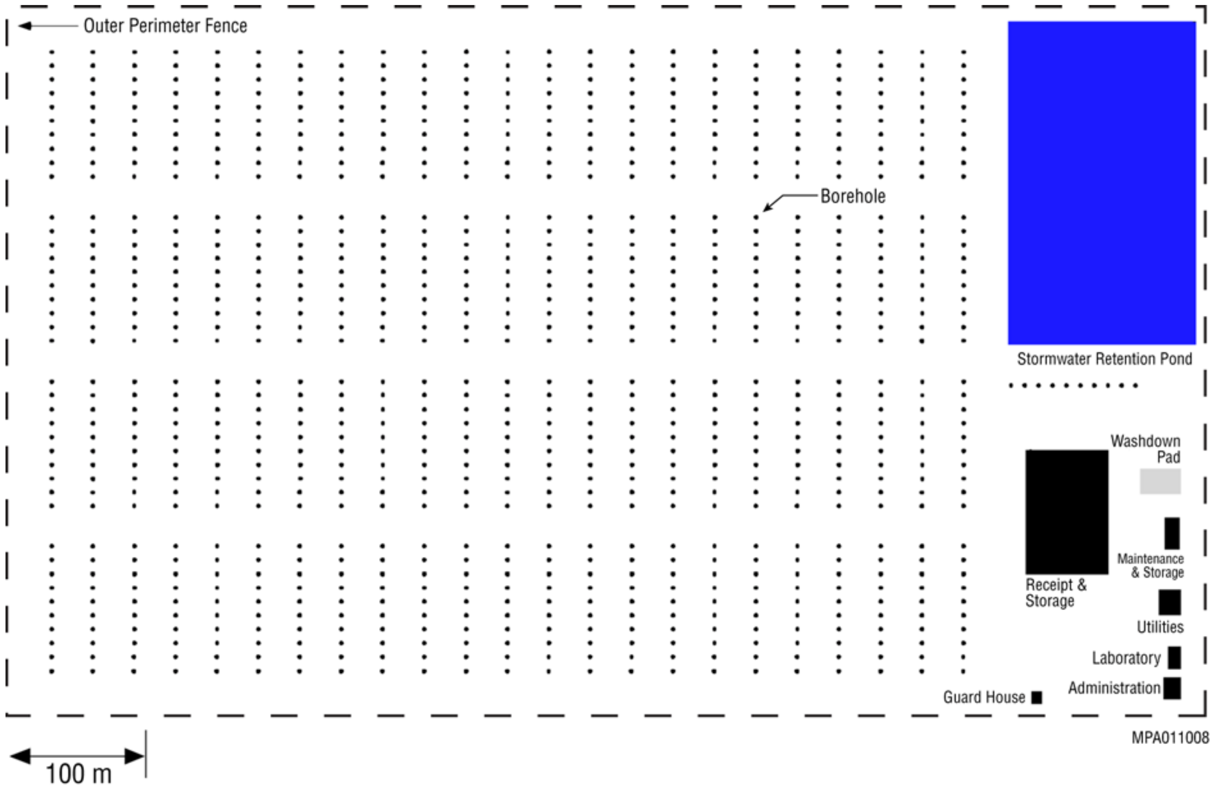

FIGURE 3-2 Layout of a Conceptual Borehole Disposal Facility

trench option, and overhead cranes would be used for the borehole and above-grade vault options. The number and function of support buildings would be patterned after similar designs in Henry (1993) and Sandia (2008b). A detailed breakdown of construction materials and costs is provided in Appendix D.

3.2.1 Security Gate Building

A guard house would restrict access to the site. Located at the site entrance along the perimeter fence, this one-story, insulated metal building would be 7.3 × 9.1 m (24 × 30 ft) in size and built on a concrete slab. The building would provide a base of operations for security personnel responsible for verifying the credentials of site workers, visitors, and incoming shipments.

3.2.2 Administration Building

An administration building would provide the base for site operations; it would have offices, waiting areas, records storage, and personnel support facilities (meeting rooms, locker rooms, etc.). The one-story, insulated metal building would be 12.2 × 15.2 (40 × 50 ft) in size and built on a concrete slab.

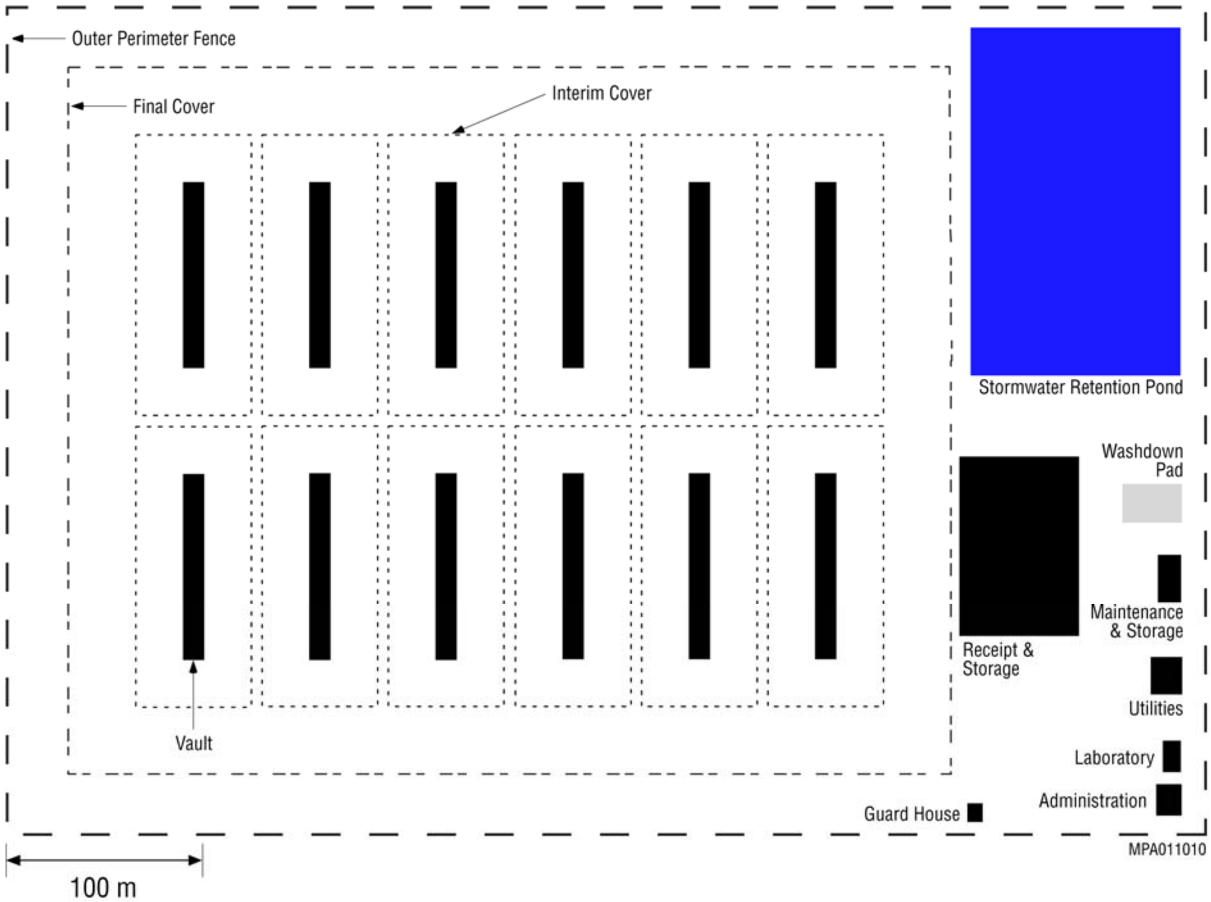

FIGURE 3-3 Layout of a Conceptual Vault Disposal Facility

3.2.3 Receipt and Storage Building (Waste Handling Building)

A waste handling building would provide space for inspecting newly received waste for disposal, offloading the waste, and temporarily storing the waste before its emplacement in the disposal vaults. The building would contain four receiving bays, each of which would be 9.1 × 9.1 m (30 × 30 ft), and two change rooms for personnel, each of which would be 9.1 × 9.1 m (30 × 30 ft). The main portion of the building would be 61.0 × 82.3 m (200 × 270 ft) in size and built on a reinforced concrete slab, with interior concrete block walls to shield and separate the different functional areas (e.g., change rooms, receiving bays, and storage areas).

3.2.4 Maintenance and Storage Building

Vehicles, equipment, and supplies necessary for site operations would be maintained, repaired, and stored in a maintenance and storage building. The one-story, insulated metal, high-bay building would be 12.2 × 24.4 m (40 × 80 ft) in size and built on a reinforced concrete slab.

3.2.5 Laboratory

This building would provide space for analyzing the sample monitoring swipes taken from the exterior of waste packages and equipment. The one-story, insulated metal building would be 6.1 × 21.3 m (20 × 70 ft) in size and built on a concrete slab.

3.2.6 Utilities

A utilities building would house a boiler and refrigeration system as well as pump equipment for maintaining proper water levels for an on-site water tank that would support potable and sanitary water systems, fire protection systems, and dust suppression. The one-story, insulated metal building would be 280 m^2 (3,000 ft^2) in size and built on a concrete slab.

3.3 INFRASTRUCTURE SUPPORT

A concrete washdown pad 15.2 × 30.5 m (50 × 100 ft) in size would be provided for cleaning vehicles and equipment. As a mitigation measure, the pad would be designed for the water runoff to go into holding tanks if radioactive contamination was detected. No contamination is expected because all disposal containers would arrive at the disposal site in a sealed condition and would not be opened. Unless there was an accident, contamination would be possible only if a container partially failed during handling (crack or a seal failure) or if a transport vehicle was not properly cared for prior to shipment to the disposal facility.

A retention pond would be incorporated into all the designs to handle water runoff on site. The size of the pond would be proportional to the size of the disposal facility land area, as based on the designs in Henry (1993). The sizes of the retention pond for each of the conceptual designs are given in Sections 3.1.1 through 3.1.3. These sizes are only approximate and would be revised for a specific location on the basis of a number of relevant factors, including facility size, topography, existing drainage, and annual precipitation.

Natural gas, water, electric, and communications utilities would be required for facility operations. The availability and cost of bringing these utilities to the disposal facility would be site-specific and are not addressed in this report. However, the amount of natural gas, water, and electricity required for facility operations is estimated in Chapter 5 for each disposal option.

4 STAFFING AND COST ESTIMATES

4.1 CONSTRUCTION

The construction labor force that would be needed can be organized into five groups, as described below.

1. *Management, engineering, design, and permitting (Home Office).* This group would include personnel involved in management, planning, engineering through Title III, and permitting. Permitting would involve licensing activities and NEPA documentation. This group would typically be located at the contractor's home or regional office rather than in the field.

2. *Management and supervision at the construction site (Field Office).* This group would represent overall field management and supervision during actual construction and excavation. Personnel would initially be stationed in trailers and would then relocate to finished buildings (e.g., administration building) upon their completion. This group would expend one relatively constant level of effort for initial construction of the disposal facility and disposal units. Other levels of effort would be expended for intermittent construction of the other disposal units and installation of the final cover system.

3. *Site preparation.* This group would include the surveyors, operating engineers, truck drivers, and laborers who would provide the initial construction entrance, temporary (gravel) roads, stormwater management, initial grubbing, installation of utility services, and associated activities. The level of effort for this group would be greatest during site preparation leading up to construction of the first disposal unit.

4. *Construction.* This group would include those personnel who would be involved in building the trenches, boreholes, or vaults and constructing the support buildings.

5. *Checkout and startup.* This group would include personnel involved in readiness assessments, final licensing and permitting activities, and training and certification of the operating staff.

Summaries of estimated labor and costs are provided in Tables 4-1 through 4-4 for construction of the disposal facility. More detailed information can be found in Appendices A, B, and C for trench, borehole, and vault construction, respectively. All cost estimates are based on RS Means construction data (RS Means 2004, 2006).

TABLE 4-1 Estimated Person-Hours and Direct Costs ($) Associated with the Construction of the Conceptual Disposal Facilities

Activity	Person-Hours	Material Cost	Labor Cost	Subcontract Cost	Total Cost
Trench					
Geotechnical investigation	256	16,682	11,642	0	28,324
Shoring placement	1,786	264,430	80,370	0	344,800
Drilling deflector	1,073,870	9,395,942	33,119,498	0	42,515,440
Site preparation	44,516	1,023,756	1,214,013	3,363,058	5,600,827
Earthwork grading	1,466	88,829	58,559	0	147,388
RH trenches	154,976	7,682,937	5,730,710	0	13,413,647
Trench closure	20,600	869,051	586,180	0	1,455,231
Support facilities	75,432	4,257,312	2,208,132	1,038,029	7,503,474
Total direct costs	1,372,902	23,598,939	43,009,104	4,401,087	71,009,130
Borehole					
Geotechnical investigation	256	16,682	11,642	0	28,324
Borehole	167,635	102,787,884	13,489,545	0	116,277,429
Drilling deflector	91,966	33,054,096	2,100,463	0	35,154,559
Site preparation	81,513	1,622,959	2,222,686	1,321,546	5,167,191
Earthwork grading	3,654	219,973	145,988	0	365,961
Support facilities	88,722	5,120,692	2,527,682	1,090,317	8,738,692
Total direct costs	433,746	142,822,286	20,498,006	2,411,863	165,732,156
Vault					
Vault site preparation	69,832	13,695,145	1,907,846	1,662,988	17,265,979
Vault construction	3,566,832	60,790,541	179,791,908	799,859	241,382,307
Vault cap	306,788	12,726,106	8,650,714	0	21,376,820
Support facilities	113,711	4,873,169	3,331,869	1,482,253	9,687,291
Total direct costs	4,057,162	92,084,961	193,682,337	3,945,100	289,712,398

TABLE 4-2 Estimated Total Construction Full-Time Equivalents (FTEs)

	FTE (years) per Method		
Construction Phase	Trench	Borehole	Vault
Direct construction	686	217	2,029
Indirect construction (20% of above)	137	43	406
Total construction	824	260	2,434

TABLE 4-3 Project Management Labor Staffing

Project Management Labor	Value (FTE-years) per Method		
	Trench	Borehole	Vault
Program Manager	1.5	0.5	5.6
Project Manager	7.2	2.3	21.1
Program QA/QC Manager[a]	0.5	0.1	1.2
Construction Manager	43.3	13.7	127.6
Project QA Inspector	15.1	4.8	44.6
Health and Safety Officer	43.3	13.7	127.6
Administrative Assistant	22.7	7.2	67.0
Accounting Clerk	3.8	1.2	11.1

[a] QA = quality assurance, QC = quality controls.

TABLE 4-4 Total Estimated Construction Costs

Cost Summary	Cost ($) per Method		
	Trench	Borehole	Vault
Subcontractor costs	71,009,130	165,732,156	289,712,398
Engineering and design fees	2,840,365	6,629,286	11,588,496
Other direct costs (ODC)	532,568	1,242,991	2,172,843
Subtotal ODC and subcontracts	74,382,064	173,604,433	303,473,737
Markup (15%)	11,157,310	26,040,665	45,521,061
Project management labor costs	1,115,731	2,604,066	4,552,106
Estimated construction costs	86,655,104	202,249,165	353,546,904
Professional services contingency	989,024	2,308,338	4,035,150
Total cost	87,644,128	204,557,503	357,582,054

4.2 OPERATIONS

4.2.1 Staffing Level Methodology

To assure that trained personnel are available at a standalone facility, the estimates presented here assume that the disposal facility would remain open on a continuous basis. In other words, the facility would not open periodically to receive a short shipping campaign and then close again until a sufficient amount of waste required disposal. This continuous operation would ensure that the same trained personnel would be available to operate the facility and that institutional knowledge would not be lost. In addition, a minimum number of personnel are necessary for proper operation of the facility, but that number would not scale linearly as the receipt rate increased. Thus, single value cost estimates or full-time equivalent (FTE) values per shipment or unit volume of waste received are not used.

Coupled with the assumptions on waste receipt rates at the facility, the assumption that the disposal facility would operate on a continuous basis provides for conservative estimates of staffing levels and associated impacts. As discussed below, the number of staff members required to operate the facility is based on potential waste receipt rates in the years following the opening of the facility, which is the time when the majority of the waste would be emplaced. The remaining years of operation would likely require lower staffing levels. Depending on the actual schedules of when the waste could be delivered, the facility could operate on an interim-type basis. In such a case, a pool of trained workers would need to be available when required.

The estimates of the number of personnel and their functions were based on the functions of the facility, waste volume receipt rates at the facility, and onsite movements of waste packages for final disposal. Details of the time-motion information (unit operations) used to determine the average number of workers required for operations are presented in Appendix E for trench (Table E-6), borehole (Table E-7), and vault (Table E-8) operations. The time period through 2035 was used to estimate the size of the workforce because the majority of the waste under consideration (approximately 75% by volume) would be available for disposal by that time. Between 2019 and 2035, an annual average receipt rate of approximately 570 truck shipments was estimated. As a conservative measure, this receipt rate was used to estimate impacts from operations for the entire period a disposal facility would be open, from 2019 to 2083.

4.2.2 Normal Operations

Table 4-5 provides information on the numbers and functions of personnel required to operate the facility. Annual costs for labor, consumables, and equipment are provided in Tables 4-6, 4-7, and 4-8 for trench, borehole, and vault disposal, respectively. More detailed supporting information on operating equipment costs can be found in Table E-5 in Appendix E.

TABLE 4-5 Detailed Worker Breakdown for Disposal Facility Operations

	Number of FTEs		
Labor Category	Trench	Borehole	Vault
Officials and managers	1	1	1
Professionals	1.1	0.6	1.1
Technicians	8	5	8
Security	11	11	11
Craft workers (maintenance)	2	3	2
Office and clerical	6	6	6
Line supervisors	4	4	4
Operators	15	8	18
Total personnel	48	38	51

TABLE 4-6 Annual Operating and Maintenance Costs for a Conceptual Trench Disposal Facility

Description	Quantity	Unit	Unit Cost ($)	Total Cost ($)
Consumables				
Diesel fuel	210,000	gal/yr	2.49	522,900
Electricity	1,160	MWh/yr	89.00	103,240
Water	1,100,000	gal/yr	0.002	2,498
Natural gas	11,200	Mcf/yr	12.00	134,400
Total consumables cost				763,038
Equipment				
Tractor trailers	3	each	7,500.00	22,500
Emplacement cranes	1	each	11,000.00	11,000
Fork lift trucks	3	each	1,500.00	4,500
Vibratory compactor	1	each	8,500.00	8,500
End-loaders	1	each	7,950.00	7,950
Pick up trucks	5	each	1,100.00	5,500
Miscellaneous tools	1	year	8,805.87	8,806
Maintenance allowance	1	year	19,000.00	19,000
Total equipment cost				87,756
Labor				
Officials and managers	1.0	FTE	160,000	160,000
Professionals	1.1	FTE	130,000	142,544
Technicians	7.7	FTE	100,000	774,351
Security	10.7	FTE	100,000	1,066,611
Craft workers (maintenance)	2.4	FTE	100,000	237,500
Office and clerical	6.0	FTE	80,000	480,000
Line supervisors	4.0	FTE	100,000	400,014
Operators	15.2	FTE	100,000	1,523,673
Indirect costs (at 12%)				574,163
Total labor cost				5,358,856

		Contingency		
Description	Subtotal ($)	%	Amount ($)	Total Cost ($)
Consumables	763,038	40	305,215	1,068,254
Equipment	87,756	30	26,327	114,083
Labor	5,358,856	25	1,339,714	6,698,570
Total costs	6,209,651		1,671,256	7,880,907

TABLE 4-7 Annual Operating and Maintenance Costs for a Conceptual Borehole Disposal Facility

Description	Quantity	Unit	Unit Cost ($)	Total Cost ($)
Consumables				
Diesel fuel	80,000	gal/yr	2.49	199,200
Electricity	970	MWh/yr	89.00	86,330
Water	410,000	gal/yr	0.002	931
Natural gas	11,200	Mcf/yr	12.00	134,400
Total consumables cost				420,861
Equipment				
Tractor trailers	3	each	7,500.00	22,500
Emplacement cranes	1	each	11,000.00	11,000
Fork lift trucks	3	each	1,500.00	4,500
Vibratory compactor	1	each	8,500.00	8,500
End-loaders	1	each	7,950.00	7,950
Pick up trucks	4	each	1,100.00	4,400
Miscellaneous tools	1	year	5,133.60	5,134
Maintenance allowance	1	year	19,000.00	19,000
Total equipment cost				82,984
Labor				
Officials and managers	1.0	FTE	160,000	160,000
Professionals	0.6	FTE	130,000	78,419
Technicians	5.5	FTE	100,000	545,135
Security	10.7	FTE	100,000	1,066,611
Craft workers (maintenance)	2.7	FTE	100,000	265,000
Office and clerical	6.0	FTE	80,000	480,000
Line supervisors	4.0	FTE	100,000	400,078
Operators	7.6	FTE	100,000	761,721
Indirect costs (at 12%)				450,836
Total labor cost				4,207,799

Description	Subtotal ($)	Contingency %	Contingency Amount ($)	Total Cost ($)
Consumables	420,861	40	168,344	589,206
Equipment	82,984	30	24,895	107,879
Labor	4,207,799	25	1,051,950	5,259,748
Total costs	4,711,644		1,245,189	5,956,833

TABLE 4-8 Annual Operating and Maintenance Costs for a Conceptual Vault Disposal Facility

Description	Quantity	Unit	Unit Cost ($)	Total Cost ($)
Consumables				
Diesel fuel	210,000	gal/yr	2.49	522,900
Electricity	1,150	MWh/yr	89.00	102,350
Water	1,090,000	gal/yr	0.002	2,476
Natural gas	11,200	Mcf/yr	12.00	134,400
Total consumables cost				762,126
Equipment				
Tractor trailers	3	each	7,500.00	22,500
Emplacement cranes	1	each	11,000.00	11,000
Fork lift trucks	3	each	1,500.00	4,500
Vibratory compactor	1	each	8,500.00	8,500
End-loaders	1	each	7,950.00	7,950
Pick up trucks	6	each	1,100.00	6,600
Miscellaneous tools	1	year	10,009.12	10,009
Maintenance allowance	1	year	19,000.00	19,000
Total equipment cost				90,059
Labor				
Officials and managers	1.0	FTE	160,000	160,000
Professionals	1.1	FTE	130,000	141,606
Technicians	7.7	FTE	100,000	770,803
Security	10.7	FTE	100,000	1,066,611
Craft workers (maintenance)	2.3	FTE	100,000	225,000
Office and clerical	6.0	FTE	80,000	480,000
Line supervisors	4.0	FTE	100,000	400,015
Operators	17.8	FTE	100,000	1,776,823
Indirect costs (at 12%)				602,503
Total labor cost				5,623,360

Description	Subtotal ($)	Contingency %	Contingency Amount ($)	Total Cost ($)
Consumables	762,126	40	304,850	1,066,976
Equipment	90,059	30	27,018	117,077
Labor	5,623,360	25	1,405,840	7,029,201
Total costs	6,475,545		1,737,708	8,213,253

5 RESOURCE ESTIMATES

Resources needed for the construction and operation of a GTCC LLRW disposal facility can be divided into two classes: materials and utilities. Materials are the substances used to construct the disposal trenches, boreholes, or vaults and support buildings such as sand, clay, gravel, and concrete. This category also includes the excavated materials. Utilities include electricity, natural gas or propane, water, and diesel fuel. Materials would be consumed primarily during construction. Utilities would be consumed during both construction and operations.

5.1 CONSTRUCTION

Table 5-1 summarizes materials and resources consumed during construction of a GTCC waste disposal facility. The large amount of soil required for vault disposal is necessary for the final 5-m (16-ft) cover depth. More detailed supporting information on resources required for construction can be found in Appendices A through D.

5.2 OPERATIONS

Operational activities would include receiving packages of waste, inspecting them, potential temporary storage, potential reconfiguration for disposal (e.g., bundling RH canisters into 3-packs for borehole disposal), transporting the waste containers to the disposal cells, and emplacing them. To some extent, construction activities and operational activities would be concurrent. For example, one or more trenches, boreholes, or vaults would be in the process of being filled while others were being constructed. Once all the GTCC LLRW and GTCC-like waste had been emplaced and the facility had undergone closure, a period of institutional control would follow. An institutional control program would include physical control of access to the site, an environmental monitoring program, periodic surveillance, and custodial care. The use of utilities would be much greater during the operational period than the institutional control period. Therefore, utility use during the institutional control period is not considered here.

5.2.1 Materials

The only major consumable materials used during operations would be pallets for potential bundling operations, sand for backfill, and chemicals used to treat the water used on site, as shown in Table 5-2.

TABLE 5-1 Estimates of the Materials and Resources Consumed during Construction of the Conceptual Disposal Facilities

Construction Materials and Resources	Total Consumption		
	Trench	Borehole	Vault
Utilities			
Water (gal)[a]	5,300,000	2,800,000	17,100,000
Electricity (MWh)[b, c]	34,200	10,800	101,000
Solids[c]			
Concrete (yd^3)	25,600	18,600	88,200
Steel (tons)	2,000	1,400	7,960
Gravel (yd^3)	36,100	25,300	156,400
Sand (yd^3)	3,600	27,900	198,300
Clay (yd^3)	12,900	5,180	56,000
Soil (off-site) (yd^3)	–[d]	–	254,000
Liquids			
Fuel (gal)[b]	750,000	2,030,000	3,380,000
Oil and grease (gal)	18,000	48,000	86,000
Gases			
Industrial gases (propane) (gal)[b]	5,400	4,300	13,600

[a] Water requirement estimated based on DOE (1997), in which each FTE required 20 gal/d, and cementation required 26.1 lb of water per 100 lb cement.

[b] Scaling methodology based on LLNL et al. (1997). More details on fuel consumption can be found in Table F-2 in Appendix F.

[c] Peak demand of 1.71, 0.54, or 5.05 MWh for the trench, borehole, and vault disposal facilities, respectively.

[d] A dash indicates not applicable.

5.2.2 Utilities

The utilities required for operations are summarized in Table 5-3. Water and sewage usage are based on the staffing requirements discussed in Chapter 3. Gas, oil, and electricity consumption are necessary primarily to keep the facility buildings operational, with minor amounts of electricity required for operation of the overhead cranes during unloading operations. Utility consumption is shown in Table 5-4. More information on utility demand can be found in Tables E-1 through E-3 in Appendix E.

TABLE 5-2 Annual Consumption of Materials during Normal Operations[a]

Material/Chemical[b]	Quantity (lb/yr) Trench	Borehole	Vault
Sand	2.59E+05	5.20E+04	9.80E+03
Standard pallet (pallet for trench = 48-in. wide × 48-in. long × 7.5-in. tall; steel pallet for borehole)	140	5.84E+05	–[c]
Hydrochloric acid (37% HCl)	277	103	275
Sodium hydroxide (50% NaOH)	227	85	225
Sodium hypochlorite	107	40	106
Copolymers	150	56	149
Phosphates	17	6	17
Phosphonates	16	6	15

[a] See Kemmer (1988) for water treatment.

[b] The following chemicals are used to treat the raw water (see Table 5-3).

[c] A dash indicates not applicable.

TABLE 5-3 Average-Day Utility Consumption during Disposal Operations

Utilities[a]	Average-Day Consumption Trench	Borehole	Vault
Potable water (USG/d)	1,300	1,000	1,300
Raw water (USG/d)[b]	4,600	1,700	4,500
Sanitary sewer (USG/d)	1,300	1,000	1,300
Natural gas (Mcf/d)	47	47	47
Fuel oil (USG/d)	900	300	900
Electricity (MWh)[c]	4.8	4.0	4.8

[a] USG/d = U.S. gallons per day, Mcf/d = thousand cubic feet per day.

[b] Includes potable water and water used in truck washdown. Estimate assumes that on average, 605 gal of water is used to wash down the truck transporting the GTCC waste, as based on Table 6-1 in EPA (2001).

[c] Peak-day demand of 0.5, 0.5, and 0.5 MW for the trench, borehole, and vault disposal facilities, respectively.

TABLE 5-4 Annual Utility Consumption during Disposal Operations

Utilities[a]	Annual Consumption[b]		
	Trench	Borehole	Vault
Potable water (USG/yr)[b]	310,000	240,000	310,000
Raw water (USG/yr)[c]	1,100,000	410,000	1,090,000
Sanitary sewer (USG/yr)	310,000	240,000	320,000
Natural gas (Mcf/yr)	11,200	11,200	11,200
Fuel oil (USG/yr)	210,000	80,000	210,000
Electricity (MWh)	1,160	970	1,150

[a] USG/d = U.S. gallons per day, Mcf/d = thousand cubic feet per day.

[b] Based on 240 operations-day per year.

[c] Includes potable water and water used in truck washdown. Estimate assumes that on average, 605 gal of water is used to wash down the truck transporting the GTCC waste, as based on Table 6-1 in EPA (2001).

6 FACILITY EMISSIONS AND WASTES

6.1 CONSTRUCTION

Wastes generated during construction of the disposal facility would be typical of those from large construction projects. Wastes would consist primarily of construction debris, including concrete fragments, and sanitary wastes generated by the labor force. Emissions would result primarily from using fuels to construct the facility, removing construction debris, and disturbing the land (fugitive dust). The amount of concrete waste was estimated on the basis of the assumption that 0.65% of the concrete usage would be spoilage. The other solid wastes, which would include construction debris and rock cuttings, were taken to be eight times the volume of the concrete spoilage. Steel waste was taken to be 0.5% of the steel requirements. These solid nonhazardous wastes would be disposed of in a municipal solid waste landfill. The amount of sanitary waste was estimated on the basis of the total construction workforce. Liquid (sanitary) nonhazardous wastes would either be treated in a portable system or hauled off site for treatment and disposal. Table 6-1 summarizes the amount of waste that would be generated during construction.

Estimates of criteria pollutant emissions generated during construction were based on the estimated amounts of fuel used by the trucks, cranes, and other heavy equipment during construction. Standard U.S. Environmental Protection Agency (EPA) emission factors from the WebFire database (http://cfpub.epa.gov/oarweb/index.cfm?action=fire.main) were used in these calculations. Emissions were calculated on the basis of the total quantity of liquid fuel consumed (diesel). Dust was estimated on the basis of the amount of disturbed land area and the duration that the disturbed area would be under construction. National Ambient Air Quality Standards (NAAQS) for criteria air pollutants are given in Table 6-2. Estimates of construction emissions are given in Table 6-3 for the disposal facilities. The initial construction period was assumed to be 3.4 years (824 days for site preparation and construction of support facilities, 240 working days per year). Although disposal unit construction may span more than 60 years because it is assumed that the disposal units would be constructed as the waste would become available for disposal, a total of 20 years of actual time for construction operations was assumed, because this duration corresponds to the period when most of the GTCC waste is expected to be received for disposal. Emissions of the following criteria air pollutants were estimated: sulfur oxides (SO_x) as sulfur dioxide (SO_2), nitrogen oxides (NO_x) as nitrogen dioxide (NO_2), nonmethane hydrocarbons (NMHCs), carbon monoxide (CO), methane (CH_4), particulate matter with a diameter of 10 micrometers or less (PM_{10}), and particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$). The construction equipment fuel use and emission factors can be found in Table F-2 in Appendix F.

6.2 OPERATIONS

Annual facility waste estimates are provided in Table 6-4. Fixed facility and mobile source emissions are provided in Tables 6-5 and 6-6, respectively. A fixed facility source would

TABLE 6-1 Total Wastes Generated during Construction

Waste Category	Trench	Borehole	Vault
Hazardous solids (yd^3)	57	18	168
Hazardous liquids (gal)	23,100	7,300	68,200
Nonhazardous solids			
Concrete (yd^3)[a]	170	120	570
Steel (tons)[b]	10	7	40
Other (yd^3)[c]	1,400	1,000	4,600
Excavated materials (from trench or borehole construction)	62,000	294,400	–[d]
Nonhazardous liquids			
Sanitary (gal)[e]	3,340,000	1,050,000	9,860,000
Other (gal)	1,484,000	467,000	4,382,000

a Amount of concrete (nonhazardous solid) waste was estimated by assuming 0.65% of concrete usage is spoilage, as based on LLNL et al. (1997).

b Amount of steel waste stream was estimated as 0.5% of steel requirement, as based on LLNL et al. (1997).

c Amount of "other" stream was estimated as eight times "concrete," stream, as based on LLNL et al. (1997).

d A dash indicates not applicable.

e Amount of sanitary waste was estimated on the basis of the total construction workforce.

TABLE 6-2 National Ambient Air Quality Standards (NAAQS) for Criteria Air Pollutants

Criteria Air Pollutant	Averaging Time	Primary Standard
CO	1 hour	40 mg/m^3
	8 hours	10 mg/m^3
Hydrocarbons	3 hours	160 $\mu g/m^3$
NO_x (as NO_2)	Annual	100 $\mu g/m^3$
SO_x (as SO_2)	24-hours[a]	365 $\mu g/m^3$
	Annual	80 $\mu g/m^3$
PM_{10}	24 hours	150 $\mu g/m^3$
$PM_{2.5}$	24 hours	35 $\mu g/m^3$
	Annual	15 $\mu g/m^3$

a Not to be exceeded more than once a year.

Source: 40 CFR Part 50.0 et seq.

TABLE 6-3 Estimated Air Emissions during Construction[a]

Criteria Pollutant	Total Emissions (tons) per Method			Peak-Year Emissions (tons/yr) per Method		
	Trench	Borehole	Vault	Trench	Borehole	Vault
Total hydrocarbons	13.5	32.5	65.1	0.9	2.8	3.7
Reactive organic compounds	12.9	31.2	62.4	0.9	2.7	3.6
NO_x	111.5	269.0	540.8	8.1	26.1	31.0
SO_2	11.6	31.6	52.7	0.9	3.0	3.2
CO	38.9	109.4	186.4	3.3	10.8	11.3
Total suspended particulates	53.9	61.0	67.1	5.1	12.8	8.8
PM_{10} [b]	24.8	59.8	64.8	5.0	12.7	8.6
$PM_{2.5}$ [c]	11.8	29.5	43.5	1.5	4.1	3.6
Carbon dioxide (CO_2)	8,382	22,852	38,164	666.4	2,189	2,331.4

[a] Excludes delivery and commuter vehicles.

[b] Assumes construction emission factor for fugitive dust PM_{10} is 0.22 ton/acre-month (average conditions); see http://www.urbemis.com/software/URBEMIS9%20Users%20Manual%20Appendices.pdf.

[c] Assumes 21% of fugitive dust PM_{10} is $PM_{2.5}$ and that 89% of combustion PM_{10} is $PM_{2.5}$; see www.aqmd.gov/CEQA/handbook/PM2_5/handout1.doc.

TABLE 6-4 Annual Waste Generated during Operations

Waste Category	Treatability Category	Average Annual Generation Rate (m^3/yr) per Method		
		Trench	Borehole	Vault
Radioactive waste				
Spent HEPA filters	Noncombustible, compactable LLRW	5	5	5
Water from truck washdown[a]	Liquid LLRW	3,000	650	2,970
Other LLRW	Combustible solid LLRW	7	3	7
Nonradioactive waste				
Nonhazardous (sanitary) wastes	Not applicable	1,165	920	1,222
Nonhazardous (other) wastes[b]	Not applicable	92	73	96
Recyclable wastes[c]	Not applicable	37	29	39

[a] The water used to wash down the truck after it delivers the GTCC waste to the disposal facility could be contaminated, but it is not likely. This analysis conservatively assumes that the washdown water would be considered to be liquid LLRW until proven otherwise.

[b] Nonhazardous (other) wastes include domestic trash and office waste.

[c] Recyclable wastes include paper, aluminum, etc. generated by the facility.

TABLE 6-5 Estimated Annual Emissions of Criteria Pollutants from Fixed Facility Sources

Criteria Pollutant	Emissions (tons/yr) from Mission-Critical Equipment per Method			Emissions (tons/yr) from Process Steam Boiler per Method		
	Trench	Borehole	Vault	Trench	Borehole	Vault
SO_2	3.57E-02	3.57E-02	3.57E-02	3.4E-03	3.4E-03	3.4E-03
NO_x	5.44E-01	5.44E-01	5.44E-01	2.8E-01	2.8E-01	2.8E-01
CO	1.17E-01	1.17E-01	1.17E-01	4.7E-01	4.7E-01	4.7E-01
PM_{10}	1.26E-02	1.26E-02	1.26E-02	4.3E-02	4.3E-02	4.3E-02
$PM_{2.5}$	1.26E-02	1.26E-02	1.26E-02	4.3E-02	4.3E-02	4.3E-02
Total organic compounds	4.44E-02	4.44E-02	4.44E-02	3.2E-02	3.2E-02	3.2E-02
CO_2	2.03E+01	2.03E+01	2.03E+01	6.7E+02	6.7E+02	6.7E+02

TABLE 6-6 Estimated Annual Emissions of Criteria Pollutants from Mobile Sources[a]

Criteria Pollutant	Emissions (tons/year) from Mobile Equipment per Method		
	Trench	Borehole	Vault
SO_2	3.23E+00	1.20E+00	3.27E+00
NO_x	2.58E+01	9.06E+00	2.59E+01
CO	1.25E+01	4.63E+00	1.26E+01
PM_{10}	2.38E+00	8.46E-01	2.39E+00
$PM_{2.5}$	2.12E+00	7.53E-01	2.12E+00
Total organic compounds	2.91E+00	1.02E+00	2.91E+00
CO_2	2.34E+03	8.73E+02	2.37E+03

[a] Mobile emission sources include forklifts and mobile cranes.

be the process steam boiler used for space and water heating and periodic testing of backup diesel generators for electrical power. Mobile emission sources would include tractor trailers, end-loaders, cranes, and forklifts.

7 TRANSPORTATION

7.1 CONSTRUCTION

Local transportation of workers and materials can lead to significant amounts of vehicle emissions that could affect the local air quality. Large volumes of materials, especially sand and backfill, would be required for the construction of the GTCC LLRW disposal facility. Approximately 13,700, 36,600, or 74,200 truck shipments for trench, borehole, or vault disposal, respectively, would be required, as summarized in Table 7-1. Estimates of emissions from these shipments are provided in Table 7-2. Additional vehicles required for worker intra-site transportation would also result in some emissions during construction, as indicated in Table 7-2, which also provides estimates for emissions that would result from worker commuter trips.

7.2 OPERATIONS

Estimates of emissions for local transportation of disposal site workers (i.e., daily commutes) are provided in Table 7-3.

TABLE 7-1 Rough Order-of-Magnitude Estimates of the Number of Truck Shipments of Construction Materials[a]

		Total Consumption per Method			No. of Truck Shipments per Method		
Resource	Truck Capacity	Trench	Borehole	Vault	Trench	Borehole	Vault
Portland cement (yd^3)[b]	10	2,816	2,046	9,702	282	205	971
Gravel (yd^3)[b]	10	46,596	32,926	192,562	4,660	3,293	19,257
Sand (yd^3)[b]	10	10,256	32,736	221,232	1,026	3,274	22,124
Clay (yd^3)	10	12,900	5,177	56,000	1,290	518	5,600
Steel (tons)[c]	21	2,000	1,400	7,960	96	67	380
Asphalt paving (tons)[d]	20	600	900	700	30	45	35
Backfill (yd^3)[e]	10	–[f]	–	254,000	–	–	25,400
Fuel (gal)[g]	9,000	7.5E+05	2.0E+06	3.4E+06	84	226	376
Excavated materials (from borehole construction)	10	62,000	294,400	–	6,200	29,440	–
Total (rounded up)					13,700	37,100	74,200

[a] Calculation neglects truck deliveries of process equipment and related items (which should be few in comparison with other shipments).

[b] Assumes that concrete is composed of 11% Portland cement, 41% gravel, and 26% sand and is shipped to the site in a standard 10-yd^3 end-dump truck.

[c] Assumes that the net payload for steel transport to the site is 42,000 lb.

[d] Assumes hot mix asphalt is loaded into 20-ton-capacity tri-axle trucks for transport to the paving site.

[e] Assumes shipment is made in standard 10-yd^3 end-dump trucks.

[f] A dash indicates not applicable.

[g] Assumes shipment is made in a U.S. Department of Transportation 406/MC-306 atmospheric-pressure tank truck with a capacity of 9,000 gal.

TABLE 7-2 Estimated Annual Emissions from Construction Vehicles[a]

Criteria Pollutant	Emissions (tons/yr) from Delivery Vehicles per Method[b]			Emissions (tons/yr) from Support Vehicles per Method[c]			Emissions (tons/yr) from Worker Commuter Vehicles per Method[d]		
	Trench	Borehole	Vault	Trench	Borehole	Vault	Trench	Borehole	Vault
SO_x	1.09E-04	2.96E-04	5.92E-04	1.66E-04	5.35E-05	4.87E-04	2.62E-03	8.26E-04	7.73E-03
NO_x	6.85E-03	1.86E-02	3.71E-02	1.04E-02	3.36E-03	3.06E-02	6.15E-02	1.94E-02	1.82E-01
CO	2.62E-02	7.09E-02	1.42E-01	3.99E-02	1.28E-02	1.17E-01	1.63E+00	5.16E-01	4.82E+00
PM_{10}	1.43E-03	3.88E-03	7.77E-03	2.19E-03	7.02E-04	6.40E-03	1.26E-02	3.99E-03	3.74E-02
$PM_{2.5}$	7.63E-04	2.07E-03	4.13E-03	1.16E-03	3.74E-04	3.41E-03	6.10E-03	1.93E-03	1.80E-02
Volatile organic compounds	4.28E-03	1.16E-02	2.32E-02	6.52E-03	2.10E-03	1.91E-02	7.85E-02	2.48E-02	2.32E-01
CO_2	1.59E+01	4.29E+01	8.59E+01	2.42E+01	7.77E+00	7.08E+01	1.66E+02	5.23E+01	4.89E+02

[a] Assumes a construction period of 20 years.

[b] Assumes 13,700, 37,100, and 74,200 one-way trips by auto to the construction site on the basis of the total number of deliveries for trench, borehole, and vault facility construction, respectively. One-way trip distance of 20 mi is based on DOE (1997). Emissions are based on round-trip distances.

[c] Assumes one support vehicle per 30 construction workers (824, 260, or 2,434 FTEs are assumed for trench, borehole, or vault construction, respectively), as taken from LLNL et al. (1997) and NRC (1994). Assumes 10 miles per day of travel per vehicle, as taken from Table 4.5 on page 4-15 of NRC (1994).

[d] Assumes 9,885, 3,123, and 29,212 one-way trips by auto to the construction site on the basis of the total number of workers needed for trench, borehole, and vault facility construction, respectively. Assumes 240 workdays per year. One-way trip distance of 20 mi is based on DOE (1997). Emissions are based on round-trip distances.

TABLE 7-3 Estimated Annual Emissions from Commuter Vehicles during Operations[a]

Criteria Pollutant	Emissions (tons/yr) per Method		
	Trench	Borehole	Vault
SO_x	3.1E-03	2.4E-03	3.2E-03
NO_x	7.2E-02	5.7E-02	7.5E-02
CO	1.9E+00	1.5E+00	2.0E+00
PM_{10}	1.5E-02	1.2E-02	1.5E-02
$PM_{2.5}$	7.1E-03	5.6E-03	7.5E-03
Volatile organic compounds	9.2E-02	7.2E-02	9.6E-02
CO_2	1.9E+02	1.5E+02	2.0E+02

[a] Assumes 11,548, 9,117, and 12,116 one-way trips by auto to the disposal facility on the basis of the total number of workers needed for trench, borehole, and vault facility operations, respectively. Assumes 240 workdays per year. One-way trip distance of 20 mi is based on DOE (1997). Emissions are based on round-trip distances.

8 REFERENCES

Argonne (Argonne National Laboratory), 2010, *Supplement to Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste Inventory Reports*, ANL/EVS/R-10/1, prepared by Argonne, Argonne, Ill., for U.S. Department of Energy, Office of Environmental Management, Oct.

Carlson , T., et al., 2006, *Low-Level Waste Disposal Alternatives Analysis Report, Appendix E, Activated Metals Cask Search and Selection*, INL/EXT-06-11601, Rev. 1, Idaho National Laboratory, Idaho Falls, Id., Sept.

Denson, R.H., et al., 1987, *Recommendations to the NRC for Review Criteria for Alternative Methods of Low-Level Radioactive Waste Disposal, Task 2a: Below-Ground Vaults*, Vol. 1, NUREG/CR-5041, prepared by U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., for the Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C.

DOE (U.S. Department of Energy), 1994, *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics*, DOE/LLW-114, prepared by Idaho National Engineering Laboratory, Idaho Falls, Id., Sept.

DOE, 1995, *Remote-Handled Transuranic Waste Study, Appendix A — RH-TRU Shield Plug and Canister Description*, DOE/CAO 95-1095, Carlsbad Area Office, Carlsbad, N.M., Oct.

DOE, 1997, *Final Waste Management Programmatic Environmental Impact Statement for Managing, Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*, DOE/EIS-0200-F, Office of Environmental Management, Washington, D.C., May.

DOE, 2004, *Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2004*, *Appendix DATA, Attachment H*, DOE/WIPP 2004-3231, Carlsbad Area Office, Carlsbad, N.M.

DOE, 2005, *TRUPACT-II Safety Analysis Report, Rev. 21*, Carlsbad Field Office, Carlsbad, N.M., Feb.

DOE, 2006a, *Nevada Test Site Waste Acceptance Criteria*, DOE/NV-325-Rev. 6-02, National Nuclear Security Administration, Nevada Site Office, Waste Management Project, Las Vegas, Nev.

DOE, 2006b, *RH-TRU 72-B Safety Analysis Report, Rev. 4*, Carlsbad Field Office, Carlsbad, N.M., June.

DOE, 2006c, *RH-TRAMPAC, Rev. 0*, Carlsbad Field Office, Carlsbad, N.M., June.

DOE, 2006d, “Natural Gas Consumption and Expenditure Intensities for Non-Mall Buildings, 2003,” Table C24 released in Oct. 2006 in *2003 Commercial Buildings Energy Consumption Survey: Consumption and Expenditure Tables*, Energy Information Administration, http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set11/2003pdf/c24.pdf. Accessed Dec. 19, 2007.

DOE, 2007a, *Greater-Than-Class C Low-Level Radioactive Waste and DOE Greater-Than-Class C-Like Waste Inventory Estimates,* prepared by Sandia National Laboratories for DOE Office of Environmental Management, Washington, D.C., July.

DOE, 2007b, *Supplement Analysis for the Transportation of Transuranic Waste in TRUPACT-III Containers*, DOE/EIS-0026-SA-06, Carlsbad Field Office, Carlsbad, N.M., Sept.

EnergySolutions, 2007, *FuelSolutions™ Storage System Final Safety Analysis Report, Rev. 4*, Document No. WSNF-220, EnergySolutions Spent Fuel Division, Inc., Campbell, Calif., Apr.

EnergySolutions, 2008, *Safety Analysis Report for Model 3-60B Type B Shipping Cask, Rev. 0* , Columbia, S.C., Jan.

EnergySolutions, 2010, *Response to Request for Additional Information and Revised Application for EnergySolutions 3-60B, Docket No. 71-9321 and TAC No. L24354*, letter from M. Baig (Technical Services Manager, Engineering and Licensing, EnergySolutions) to U.S. Nuclear Regulatory Commission, July 27.

EPA (U.S. Environmental Protection Agency), 2001, *Permit Guidance Document, Transportation Equipment Cleaning Point Source Category (40 CFR § 442)*, EPA-821-R-01-021, Office of Water, Washington, D.C., Mar.

Gonzalez, W., et al., 2006, “Remote-Handled Transuranic Waste Retrieval at Los Alamos National Laboratory,” presented at Waste Management 2006 Conference, Tucson, Ariz., Feb. 26–Mar. 2.

Harvego, L., et al., 2007, *Conceptual Design Report for the Remote-Handled Low-Level Waste Disposal Facility*, INL/EXT-07-12901, draft, prepared by Idaho National Laboratory and North Wind, Inc., Idaho Falls, Id., Aug.

Henry, K., 1993, *Technically Feasible Systems for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste, Final Draft*, DOE/LLW-176, prepared by Rogers & Associates Engineering Corporation and ERM-Program Management Company for the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, DOE Idaho Field Office, Idaho Falls, Id.

Holtec International, 2006, *Storage, Transport, and Repository Cask System (HI-STAR Cask System) Safety Analysis Report, Rev. 12, 10 CFR 71, DOCKET 71-9261*, Report No. HI-951251, Marlton, N.J., Oct.

Kemmer, F.N., 1988, *NALCO Water Handbook (2nd Edition)*, McGraw-Hill.

LLNL (Lawrence Livermore National Laboratory) et al., 1997, *Depleted Uranium Hexafluoride Management Program; the Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride*, UCRL-AR-124080, Volumes I and II, Revision 2, prepared by LLNL, Science Applications International Corporation, Bechtel, and Lockheed Martin Energy Systems for U.S. Department of Energy, May.

MMES (Martin Marietta Energy Systems, Inc.) et al., 1994, *Radiological Performance Assessment for the E-Area Vaults Disposal Facility*, WSRC-RP-94-218, prepared by MMES, EG&G Idaho, Inc., and Westinghouse Savannah River Company, Aiken, S.C.

NAC International, 2004, *NAC-STC (NAC Storage Transport Cask) Safety Analysis Report,* NRC Docket No. 71-9235, Rev. 15, Norcross, Ga.

NRC (U.S. Nuclear Regulatory Agency), 1994, *Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center, Homer, Louisiana*, NUREG-1484, Office of Nuclear Safety and Safeguards, Washington, D.C.

NRC, 2005, "Certificate of Compliance for Radioactive Material Packages, Model No. 10-160B," Certificate Number 9204, Rev. 11, Licensing Section, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, Dec.

NRC 2006, *Directory of Certificates of Compliance for Radioactive Materials Packages*, Vol. 2, Rev. 26, NUREG-0383, Office of Nuclear Material Safety and Safeguards, Washington, D.C., Dec.

RS Means, 2004, *Environmental Remediation Cost Data — Unit Price*, 10th annual edition, Kingston, Mass.

RS Means, 2006, *Mechanical Cost Data*, 29th annual edition, Kingston, Mass.

Sandia (Sandia National Laboratories), 2007, *Two Technology Conceptual Designs for Disposal of GTCC LLW*, prepared for U.S. Department of Energy, Nov.

Sandia, 2008a, *Basis Inventory for Greater-Than-Class-C Low-Level Radioactive Waste Environmental Impact Statement Evaluations*, Task 3.2 Report, Rev. 1, prepared by Sandia, Albuquerque, N.M., for U.S. Department of Energy, Office of Environmental Management, May.

Sandia, 2008b, *Surface and Subsurface Construction of an Enhanced Near Surface Disposal Facility*, Task 3.6 Report, Rev. 2, prepared by Sandia, Albuquerque, N.M., for U.S. Department of Energy, Office of Environmental Management, June.

Sandia, 2008c, *GTCC LLW Environmental Impact Statement: Pre-Closure Assessment Data Package, Waste Isolation Pilot Plant*, prepared for U.S. Department of Energy, Washington, D.C., Oct.

Shleien, B. (editor), 1992, *The Health Physics and Radiological Health Handbook, Revised Edition*, Scinta, Inc., Silver Spring, Md.

Teicholz, E., 2001, *Facility Design and Management Handbook*, McGraw-Hill Professional, New York, N.Y.

APPENDIX A:

TRENCH CONSTRUCTION DATA

TABLE A-1 Geotechnical Investigation: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 Gross Vehicle Weight (GVW), 4×2, 2 Axle	Flatbed, 8×16 ft	Driller/ Auger	Driller/ Coring
Drawings showing boring details	1	16	0	0	0	0
Report and recommendations from professional engineer (PE)	1	16	0	0	0	0
Mobilization and demobilization	1	4	0	0	0	0
Mobilization and demobilization, over 500 mi	2	10	0	0	0	0
Auger holes in earth, no samples, 2.5 in.	3	33	2	1	1	0
Drilling in rock, "NX" code, no sampling, includes bit, layout, and setup	3	33	2	1	0	1
Total equipment operating hours			133	67	33	33

TABLE A-2 Geotechnical Investigation: Labor and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit[a]	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Drawings showing boring details	4	total	0.00	4.00E+00	16	46.25	0	740	0	740
Report and recommendations from PE	2	total	0.00	8.00E+00	16	51.88	0	830	0	830
Mobilization and demobilization	1	total	202.00	4.00E+00	4	41.25	202	165	0	367
Mobilization and demobilization, over 500 mi	600	mile	1.80	3.33E-02	20	44.10	1,080	882	0	1,962
Auger holes in earth, no samples, 2.5 in.	500	LF	10.30	2.00E-01	100	42.00	5,150	4,200	0	9,350
Drilling in rock, "NX" code, no sampling, includes bit, layout, and setup	250	LF	41.00	4.00E-01	100	48.25	10,250	4,825	0	15,075
Totals					256		16,682	11,642	0	28,324

TABLE A-3 Site Preparation: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Dozer, Crawler, D-5H	Front-End Loader, Wheeled, 3.0 Cubic Yards (CY), 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Hydraulic Crane, 20T/70 ft Boom	Grader, Self-Propelled, 40,000 lb	Vibratory Roller, Sheepsfoot	Tractor Loader, Wheeled, 4×4, 2.5–3.5 CY	Truck, Dump, Tandem, 12 yd^3	Water Truck, Off-Highway, 6,000-gal Capacity
Site Selection											
Site selection	3	60	0	0	0	0	0	0	0	0	0
Site Improvements											
Clearing and grubbing	9	88	1	0	0	0	1	1	1	1	1
Fine grading	1	16,335	1	0	0	0	0	0	0	0	0
Excavation											
Clay installation	3.5	125	0	1	0	0	0	1	0	1	1
Sand installation	1.25	578	0	1	0	0	0	1	0	1	0
Drain excavation	3.25	17	0	0	1	0	0	0	0	0	0
Drain installation	3.25	17	0	0	1	0	0	0	0	0	0
Roads, asphalt (based on disposal facility perimeter)	4	0	0	0	0	0	0	1	0	0	2
Parking areas (for the construction employees, location for GTCC waste retrieval, etc.)	4	0	0	0	0	0	0	0	0	1	1
Sidewalk, concrete, cast-in-place with 6×6 - W1.4 × W1.4 mesh, broomed finish, 3,000 lb/in.^{2} or psi, 5-in. thick, excludes base	1	183	0	0	0	0	0	0	0	0	0
Aggregrate base course, for roadways and large paved areas, crushed stone base, compacted, crushed 1.5-in. stone base, to 12-in. deep	1	418	0	1	0	0	0	0	0	0	0
Storm sewer	6	4,254	0	0	1	0	0	0	0	0	0
Equipment											
Sump pumps	2.5	64	0	0	0	1	0	0	0	0	0
Monitoring pipes	5.5	44	0	0	0	1	0	0	0	0	0
Site Restoration											
Revegetation	6	1,453	0	0	1	0	0	0	0	0	0
Total equipment operating hours			16,423	1,121	5,741	108	88	791	88	791	213

TABLE A-4 Site Preparation: Labor and Costs[a]

Item	Quantity	Unit[a]	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Site Selection										
Site selection	1	each							400,000	400,000
Subtotal Site Selection									400,000	400,000
Site Improvements										
Mobilization and demobilization	1								186,000	186,000
Clearing and grubbing	37.5	acre	595.43	21.09	791	27.23	22,329	21,544	0	43,872
Drainage control, drainage ditches	800	yd^3	8.95						7,160	7,160
Stripping topsoil and stockpiling	30,300	yd^3	6.20						187,860	187,860
Fine grading	1,633,500	ft^2	0.00	0.01	16,335	27.23	0	444,875	0	444,875
Excavation	124,000	yd^3	7.5						930,000	930,000
Off-site hauling	62,000	yd^3	5						310,000	310,000
Clay installation	2,300	yd^3	12	0.19	437	27.23	27600	11,900	0	39,500
Sand installation	3,800	yd^3	12	0.19	722	27.23	45600	19,660	0	65,260
Drain excavation	220	yd^3		0.25	55	27.23		1,498	0	1,498
Drain installation	220	yd^3	12	0.25	55	27.23	2640	1,498	0	4,138
Dewatering	7,300	day	135						985,500	985,500
Roads, asphalt (based on disposal facility perimeter)	5,800	LF	90.00	S/C				0	522,000	522,000
Parking areas (for construction employees, location for GTCC waste retrieval, etc.)	79,000	SF	1.75	S/C				0	138,250	138,250
Sidewalk, concrete, cast-in-place with 6×6 - W1.4 × W1.4 mesh, broomed finish, 3000 psi, 5-in. thick, excludes base	3,700	SF	2.31	0.05	183	30	8,547	5,476	0	14,023
Aggregrate base course, for roadways and large paved areas, crushed stone base, compacted, crushed 1.5-in. stone base, to 12-in. deep	22,000	SY	15.32	0.02	418	30	337,040	12,540	0	349,580
Storm sewer	11,600	LF	50.00	2.20	25,520	27.23	580,000	695,024	0	1,275,024
Site security fence, 8-ft chain link	5,808	LF	16.00	S/C				0	92,928	92,928
Main gate	24	LF	140.00	S/C				0	3,360	3,360
Subtotal Site Improvements					44,516		1,023,756	1,214,013	3,363,058	5,600,827

TABLE A-4 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Equipment										
Sump pumps	29	each	4,300	8	160	37.5	124,700	6,000	0	130,700
Monitoring pipes	58	each	150	4	240	37.5	8,700	9,000	0	17,700
Subtotal Equipment					400		133,400	15,000	0	148,400
Site Restoration										
Revegetation	37.5	acre	18,002	232.32	8,712	27.61	675,075	240,525	0	915,600
Subtotal Restoration									0	915,600
Consumables										
Water	20	ML	2,500				50,208		0	50,208
Electricity	410	kWh	0.11				45,100		0	45,100
Subtotal Consumables							95,308		0	95,308

[a] LF = linear foot (feet), SF = square foot (feet), SY = square yard(s), ML = million liters.

TABLE A-5 Shoring Placement: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Flatbed, 8×16 ft	Compactor, Rammer, 13×11-in. Shoe	Hydraulic Crane, Four-Wheel Drive (4WD), 40T/84-ft Boom
Field personnel, superintendent, maximum	1	160	1	0	0
Mobilization, 150 tons, set up and remove crane with pile leads and pile hammer	2	71	0	0	1
Demobilization, 150 tons, set up and remove crane with pile leads and pile hammer	2	71	0	0	1
Sheet piling, steel, 38 lb/ft^2 or psf, 40 ft, drive, extract, and salvage, excludes wales	6	225	0	1	1
Sheet piling, wales, connections, and struts	1	0	0	0	0
Total equipment operating hours			160	225	367

TABLE A-6 Shoring Placement: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Field personnel, superintendent, maximum	4	week	0.00	40	160.00	45.00	0	7,200	0	7,200
Mobilization, 150 tons, set up and remove crane with pile leads and pile hammer	1	each	4,375.00	141	140.56	45.00	4,375	6,325	0	10,700
Demobilization, 150 tons, set up and remove crane with pile leads and pile hammer	1	each	4,375.00	141	140.56	45.00	4,375	6,325	0	10,700
Sheet piling, steel, 38 psf, 40 ft, drive, extract, and salvage, excludes wales	324	ton	640.00	4.15	1,344.89	45.00	207,360	60,520	0	267,880
Sheet piling, wales, connections, and struts	160	ton	302.00	0	0.00	45.00	48,320	0	0	48,320
Totals					1,786.00		264,430	80,370	0	344,800

TABLE A-7 Additional Remote-Handled Waste Trench Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Gas Engine - Vibrator	Hydraulic Crane, 4WD, 40T/84-ft Boom	Front-End Loader, Wheeled, 3.0CY, 950E	Compactor, Rammer, 13×11-in. Shoe
Concrete Pipe and Caps						
Construct forms to hold concrete pipe in place	4	20,427	0	0	0	0
Cut and notch reinforced concrete pipe at bottom for water drainage purposes	2.5	6,250	0	0	0	0
Emplace reinforced concrete pipe between forms (storm sewer pipe: 28-in. inside diameter [ID], 36-in. outside diameter [OD], 18-ft long, Class IV/V, C wall, approx. 420 lb per linear foot, 302 pipes per trench)	6	790	0	1	0	0
Fill void spaces between concrete pipes with pea gravel	1	8,935	0	0	1	0
Compact pea gravel with vibrating plate (Safety Level E assumed)	3	1,735	0	0	0	1
Construct hexagonal concrete cylinder cap (3-ft thick on top, 1-ft thick within concrete plug, 302 total)	9	2,460	1	0	0	0
Construct concrete side plugs (pour concrete on top of aggregate to smooth finish)	9	515	1	0	0	0
Miscellaneous concrete allowance, approx. 15%	9	1,214	1	0	0	0
Concrete finishing, concrete cylinder caps	1	1,086	0	0	0	0
Total equipment operating hours			4,189	790	8,935	1,735

TABLE A-8 Additional Remote-Handled Waste Trench Construction: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Concrete Pipe and Caps										
Construct forms to hold concrete pipe in place	5,836	100 SF	250	14	81,706	33.77	1,459,040	2,759,513	0	4,218,553
Cut and notch reinforced concrete pipe at bottom for water drainage purposes	6,666	each	31	2	15,623	37.60	204,246	587,441	0	791,687
Emplace reinforced concrete pipe between forms (storm sewer pipe: 28 in. ID, 36-in. OD, 18-ft long, Class IV/V, C wall, approx. 420 lb per linear foot, 302 pipes per trench)	133,320	LF	28.70	0.036	4,739	165.69	3,826,284	785,255	0	4,611,539
Fill void spaces between concrete pipes with pea gravel	17,398	yd^3	24.00	0.51	8,934	32.15	417,556	287,234	0	704,790
Compact pea gravel with vibrating plate (Safety Level E assumed)	17,398	yd^3	0.36	0.30	5,203	29.55	6,263	153,762	0	160,025
Construct hexagonal concrete cylinder cap (3-ft thick on top, 1-ft thick within concrete plug, 302 total)	7,524	yd^3	175	2.94	22,134	29.76	1,316,617	658,626	0	1,975,243
Construct concrete side plugs (pour concrete on top of aggregate to smooth finish)	1,574	yd^3	175	2.94	4,632	29.76	275,521	137,827	0	413,348
Miscellaneous concrete allowance, approx. 15%	1,365	yd^3	130	8.00	10,918	29.76	177,410	324,862	0	502,272
Concrete finishing, concrete cylinder caps	72,380	ft^2	0	0.015	1,086	33.33	0	36,190	0	36,190
Totals					154,976		7,682,937	5,730,710	0	13,413,647

TABLE A-9 Concrete Cap: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Gas Engine-Vibrator	Cement Truck
Elevated concrete on forms, 3.75-ft thick (Safety Level D assumed due to little potential for extreme surface rad levels for CH trenches)	9	28	1	1
Cap exterior face, both ways, #7 at 6-in. on-center (o.c.) (Safety Level D assumed for CH trenches)	4	500	0	0
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level D assumed for CH trenches)	4	500	0	0
Elevated concrete on forms, 3.75-ft thick (Safety Level A assumed due to potential for extreme surface rad levels for RH trenches)	9	56	1	1
Cap exterior face, both ways, #7 at 6-in. o.c. (Safety Level A assumed for RH trenches)	4	1,000	0	0
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level A assumed for RH trenches)	4	1,000	0	0
Total equipment operating hours			84	84

TABLE A-10 Concrete Cap: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Elevated concrete on forms, 3.75-ft thick (Safety Level D assumed due to little potential for extreme surface rad levels for CH trenches)	3,199	yd^3	250	30.00	95,958	29.76	799,653	2,855,337	0	3,654,990
Cap exterior face, both ways, #7 at 6-in. o.c. (Safety Level D assumed for CH trenches)	141	ton	2,000	70.00	9,885	36.91	282,440	364,907	0	647,347
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level D assumed for CH trenches)	104	ton	2,000	70.00	7,264	36.91	207,546	268,146	0	475,692
Elevated concrete on forms, 3.75-ft thick (Safety Level A assumed due to potential for extreme surface rad levels for RH trenches)	10,053	yd^3	500	81.08	815,090	29.76	5,026,389	24,253,830	0	29,280,219
Cap exterior face, both ways, #7 at 6-in. o.c. (Safety Level A assumed for RH trenches)	444	ton	4,000	189.19	83,969	36.91	1,775,337	3,099,593	0	4,874,930
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level A assumed for RH trenches)	326	ton	4,000	189.19	61,703	36.91	1,304,577	2,277,685	0	3,582,262
Totals					1,073,870		9,395,942	33,119,498	0	42,515,440

TABLE A-11 Trench Closure: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4x2, 2 Axle	Flatbed, 8×16 ft	Compactor, Rammer, 13×11-in. Shoe	Front-End Loader, Wheeled, 2.5CY	Front-End Loader, Wheeled, 3.0CY, 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Tiller, 5×7, V-Shaped, Deep	Dozer, Crawler, D-3C
Fill void spaces on top of concrete caps with gravelly sand (conservatively assume 41% overall waste placement efficiency in cell)	1	925	0	0	0	0	1	0	0	0
Compact aggregate with vibrating plate (Safety Level A assumed)	3	180	0	0	1	0	0	0	0	0
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	1	2,014	0	0	0	0	0	0	1	1
Native soil installation (5.25-ft thick)	1	3,534	0	0	0	0	1	0	0	0
Geotextile (100 mil polymeric liner, polyvinyl chloride [PVC], 33-08-0586)	8	894	1	1	0	0	0	0	0	0
Gravel/cobble layer installation on top of geotextile (2-ft thick)	1	1,349	0	0	0	0	1	0	0	0
Pea gravel installation (0.5-ft thick)	1	342	0	0	0	0	1	0	0	0
Sand installation (0.5-ft thick)	1	342	0	0	0	0	1	0	0	0
Topsoil installation (1-ft thick)	1.5	618	0	0	0	1	0	0	0	0
Compact soil with vibrating plate	3	1,161	0	0	1	0	0	0	0	0
Total equipment operating hours			894	894	1,341	618	6,492	0	2,014	2,014

TABLE A-12 Trench Closure: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Fill void spaces on top of concrete caps with gravelly sand (conservatively assume 41% overall waste placement efficiency in cell)	1,800	yd^3	24	0.51	924	32.15	43,200	29,717	0	72,917
Compact aggregate with vibrating plate (Safety Level A assumed)	1,800	yd^3	0.36	0.30	538	29.55	648	15,908	0	16,556
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	10,600	yd^3	11.12	0.19	2,014	33.65	117,872	67,771	0	185,643
Native soil installation (5.25-ft thick)	18,600		12	0.19	3,534	27.23	223200	96,231	0	319,431
Geotextile (100 mil polymeric liner, PVC, 33-08-0586)	95,000	ft^2	1.98	0.08	7,147	27.91	188,100	199,500	0	387,600
Gravel/cobble layer installation on top of geotextile (2-ft thick)	7,100	yd^3	12	0.19	1,349	27.23	85,200	36,733	0	121,933
Pea gravel installation (0.5-ft thick)	1,800	yd^3	12	0.19	342	27.23	21,600	9,313	0	30,913
Sand installation (0.5-ft thick)	1,800	yd^3	12	0.19	342	27.23	21,600	9,313	0	30,913
Topsoil installation (1-ft thick)	7,100	yd^3	22.89	0.13	927	31.10	162,519	28,826	0	191,345
Compact soil with vibrating plate	28,400	yd^3	0.18	0.12	3,483	26.67	5,112	92,868	0	97,980
Totals					20,600		869,051	586,180	0	1,455,231

TABLE A-13 Site Grading: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Front-End Loader, Wheeled, 2.5CY	Front-End Loader, Wheeled, 3.0CY, 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Tiller, 5×7, V-Shaped, Deep	Vibratory Roller	Cement Truck
Field personnel, superintendent, maximum	1	160	0	0	0	0	0	0	0	0
Backhoe-loader, wheel type, 1.25CY capacity, with operator	1	160	0	0	0	0	1	0	0	0
Grader, self-propelled, 40,000 lb, with operator	1	160	0	0	0	0	0	1	0	0
Vibratory roller, sheepsfoot, with operator	1	160	0	0	0	0	0	0	1	0
Tractor loader, wheeled, 4×4, 2.5–3.0CY, with operator	1	160	0	0	0	1	0	0	0	0
Truck, dump, tandem, 12 yd^3, with driver	1	160	1	0	0	0	0	0	0	0
Water truck, off-highway, 6,000-gal capacity, with operator	1	160	0	0	0	0	0	0	0	1
Conventional surveying, crew for site grading layout, 3-person crew	1	192	0	1	0	0	0	0	0	0
Corrugated galvanized or aluminum oval arch culverts, coated and paved, 28×20 in.	1	154	1	0	1	0	0	0	0	0
Total equipment operating hours			314	192	154	160	160	160	160	160

TABLE A-14 Site Grading: Construction Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person -Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Field personnel, superintendent, maximum	4	week	0	40	160	46.88	0	7,500	0	7,500
Backhoe-loader, wheel type, 1.25CY capacity, with operator	4	week+	1,427	40	160	41.25	5,708	6,600	0	12,308
Grader, self-propelled, 40,000 lb, with operator	4	week+	3,680	40	160	41.25	14,720	6,600	0	21,320
Vibratory roller, sheepsfoot, with operator	4	week+	1,885	40	160	35.63	7,540	5,700	0	13,240
Tractor loader, wheeled, 4×4, 2.5–3.0 CY, with operator	4	week+	1,745	40	160	41.25	6,980	6,600	0	13,580
Truck, dump, tandem, 12 yd^3, with driver	4	week+	1,850	40	160	35.63	7,400	5,700	0	13,100
Water truck, off-highway, 6,000-gal capacity, with operator	4	week+	4,460	40	160	41.25	17,840	6,600	0	24,440
Conventional surveying, crew for site grading layout, 3-person crew	8	day	58	24	192	40.42	464	7,760	0	8,224
Corrugated galvanized or aluminum oval arch culverts, coated and paved, 28×20 in.	470	LF	60	0.33	154	35.63	28,177	5,499	0	33,676
Totals					1,466		88,829	58,559	0	147,388

APPENDIX B:

BOREHOLE CONSTRUCTION DATA

TABLE B-1 Geotechnical Investigation: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Driller/ Auger	Driller/ Coring
Drawings showing boring details	1	16	0	0	0	0
Report and recommendations from PE	1	16	0	0	0	0
Mobilization and demobilization	1	4	0	0	0	0
Mobilization and demobilization, over 500 mi	2	10	0	0	0	0
Auger holes in earth, no samples, 2.5 in.	3	33	2	1	1	0
Drilling in rock, "NX" code, no sampling, includes bit, layout, and setup	3	33	2	1	0	1
Total equipment operating hours			133	67	33	33

TABLE B-2 Geotechnical Investigation: Labor and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Drawings showing boring details	4	total	0.00	4.00E+00	16	46.25	0	740	0	740
Report and recommendations from PE	2	total	0.00	8.00E+00	16	51.88	0	830	0	830
Mobilization and demobilization	1	total	202.00	4.00E+00	4	41.25	202	165	0	367
Mobilization and demobilization, over 500 mi	600	mile	1.80	3.33E-02	20	44.10	1,080	882	0	1,962
Auger holes in earth, no samples, 2.5 in.	500	LF	10.30	2.00E-01	100	42.00	5,150	4,200	0	9,350
Drilling in rock, "NX" code, no sampling, includes bit, layout, and setup	250	LF	41.00	4.00E-01	100	48.25	10,250	4,825	0	15,075
Totals					256		16,682	11,642	0	28,324

TABLE B-3 Site Preparation: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Dozer, Crawler, D-5H	Front-End Loader, Wheeled, 3.0CY, 950E	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Hydraulic Crane, 20T/70-ft Boom	Grader, Self-Propelled, 40,000 lb	Vibratory Roller, Sheepsfoot	Tractor Loader, Wheeled, 4×4, 2.5–3.5 CY	Truck, Dump, Tandem, 12 yd^3	Water Truck, Off-Highway, 6000-gal Capacity
Site Selection													
Site selection	3	60	0	0	0	0	0	0	0	0	0	0	0
Site Improvements													
Clearing and grubbing	9	241	1	0	0	0	0	0	1	1	1	1	1
Fine grading	1	38,333	1	0	0	0	0	0	0	0	0	0	0
Roads, asphalt			0	0	0	0	0	0	0	1	0	0	2
Parking areas			0	0	0	0	0	0	0	0	0	1	1
Sidewalk, concrete	1	183	0	0	0	0	0	0	0	0	0	0	0
Aggregrate base course, for roadways and large paved areas	1	798	0	1	0	0	0	0	0	0	0	0	0
Storm sewer	6	6,674	0	0	0	0	1	0	0	0	0	0	0
Total equipment operating hours			38,574	798	0	0	6,674	0	241	241	241	241	241

TABLE B-4 Site Preparation: Labor and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	Nor. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Site Selection	1	each							400,000	400,000
Subtotal Site Selection									400,000	400,000
Site Improvements										
Mobilization and demobilization	1								17,970	17,970
Clearing and grubbing	102.4	acre	595.43	21.09	2,160	27.23	60,972	58,828	0	119,800
Fine grading	3,833,280	ft^2	0.00	0.01	38,333	27.23	0	1,043,974	0	1,043,974
Roads, asphalt (based on perimeter of the disposal facility)	9,100	LF	90.00	S/C[a]				0	819,000	819,000
Parking areas (for construction employees, location for GTCC waste retrieval, etc.)	192,000	SF	1.75	S/C				0	336,000	336,000
Sidewalk, concrete, cast-in-place with 6×6 - W1.4 × W1.4 mesh, broomed finish, 3000 psi, 5-in. thick, excludes base	3,700	SF	2.31	0.05	183	30	8,547	5,476	0	14,023
Aggregrate base course, for roadways and large paved areas, crushed stone base, compacted, crushed 1.5-in. stone base, to 12-ft deep	42,000	SY	15.32	0.02	798	30	643,440	23,940	0	667,380
Storm sewer	18,200	LF	50.00	2.20	40,040	27.23	910,000	1,090,468	0	2,000,468
Site security fence, 8-ft chain link	9,076	LF	16.00	S/C				0	145,216	145,216
Main gate	24	LF	140.00	S/C				0	3,360	3,360
Subtotal Site Improvements					81,513		1,622,959	2,222,686	1,321,546	5,167,191
Consumables										
Water	145	ML	2,500				363,398		0	363,398
Electricity	2.6E+08	kWh	0.11				28,336,000		0	28,336,000
Subtotal Consumables							28,699,398		0	28,699,398

[a] S/C = subcontract.

TABLE B-5 Borehole Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Front-End Loader, Wheeled, 2.5CY	Water Truck	Driller/ Auger	Cement Truck
Geotechnical services, RSM	1	0	0	0	0	0	0
General contractor, RSM	1	0	0	0	0	0	0
Drilling, transport × 500 mi	2	114	2	0	0	0	0
Drilling, augered shaft	2	66,628	1	1	1	1	0
Place and grout casing	3	11,384	0	0	0	0	1
Total equipment operating hours			66,856	66,628	66,628	66,628	11,384

TABLE B-6 Borehole Construction: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Geotechnical services, RSM	1	LS	48,000	0.00E+00	0	40.00	48,000	0	0	48,000
General contractor, RSM	1	LS	373,000	0.00E+00	0	40.00	373,000	0	0	373,000
Drilling, transport × 500 mi	2	LS	75,000	2.28E+02	228	96.13	165,000	21,870	0	186,870
Drilling, augered shaft	57,938	VLF	1,300	2.21E+00	133,256	79.37	75,318,884	10,577,004	0	85,895,888
Place and grout casing	18,540	VLF	1,450	36.84	34,151	84.64	26,883,000	2,890,671	0	29,773,671
Totals					167,635		102,787,884	13,489,545	0	116,277,429

TABLE B-7 Borehole Closure: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Compactor, Rammer, 13×11-in. Shoe	Front-End Loader, Wheeled, 2.5CY	Front-End Loader, Wheeled, 3.0CY, 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Tiller, 5×7, V-Shaped, Deep	Dozer, Crawler, D-3C	Hydraulic Crane, 4WD, 40T/84-ft Boom
Concrete layer above waste	3	0	0	0	0	0	0	0	0	0	0
Remove upper borehole casing	5.5	8,121	0	0	0	0	0	0	0	0	1
Sandy gravel installation (assuming 3-ft overlay on top of concrete plug, Safety Level A conditions assumed)	1	1	0	0	0	0	1	0	0	0	0
Compact aggregate with vibrating plate (Safety Level A assumed)	3	1	0	0	1	0	0	0	0	0	0
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	1	1	0	0	0	0	0	0	1	1	0
Geotextile (100 mil polymeric liner, PVC, 33-08-0586)	8	1	1	1	0	0	0	0	0	0	0
Native soil installation on top of clay layer (85-ft thick, 18 05 0301)	1.5	1	0	0	0	1	0	0	0	0	0
Gravel/cobble layer installation on top of native soil layer (2-ft thick)	1	1	0	0	0	0	1	0	0	0	0
Pea gravel installation (0.5-ft thick)	1	1	0	0	0	0	1	0	0	0	0
Sand installation (0.5-ft thick)	1	1	0	0	0	0	1	0	0	0	0
Topsoil installation (1-ft thick)	1.5	1	0	0	0	1	0	0	0	0	0
Compact soil with vibrating plate	3	1	0	0	1	0	0	0	0	0	0
Revegetation (sodding, average CONUS)[a]	6	39	0	0	0	0	0	1	0	0	0
Total equipment operating hours			1	1	2	2	4	39	1	1	8,121

[a] CONSU = continental or contiguous United States.

TABLE B-8 Borehole Closure: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Concrete layer above waste	12,767	m^3	2,250	0	0	40.00	28,725,207	0	0	28,725,207
Remove upper borehole casing	87,532	VLF[a]	6.85	0.51	44,664	16.19	599,694	723,159	0	1,322,853
Sandy gravel installation (assuming 3-ft overlay on top of concrete plug, Safety Level A conditions assumed)	5,177	yd^3	24	0.51	2,659	32.15	124,256	85,475	0	209,731
Compact aggregate with vibrating plate (Safety Level A assumed)	5,177	yd^3	0.36	0.30	1,548	29.55	1,864	45,757	0	47,620
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	5,177	yd^3	11.12	0.19	984	33.65	57,572	33,101	0	90,673
Geotextile (100 mil polymeric liner, PVC, 33-08-0586)	46,596	ft^2	1.98	0.08	3,506	27.91	92,260	97,852	0	190,112
Native soil installation on top of clay layer (85-ft thick, 18 05 0301)	146,562	yd^3	22.89	0.13	19,133	31.10	3,354,811	595,043	0	3,949,854
Gravel/cobble layer installation on top of native soil layer (2-ft thick)	3,452	yd^3	12.00	0.19	656	27.23	41,419	17,857	0	59,276
Pea gravel installation (0.5-ft thick)	153	yd^3	12.00	0.19	29	27.23	1,830	789	0	2,620
Sand installation (0.5-ft thick)	153	yd^3	12.00	0.19	29	27.23	1,830	789	0	2,620
Topsoil installation (1-ft thick)	305	yd^3	22.89	0.13	40	31.10	6,983	1,239	0	8,222
Compact soil with vibrating plate	150,624	yd^3	0.18	0.12	18,470	26.67	27,112	492,541	0	519,653
Revegetation (sodding, average CONUS)	1.070	acre	18,002	232.32	249	27.61	19,257	6,861	0	26,118
Totals					91,966		33,054,096	2,100,463	0	35,154,559

[a] VLF = vertical linear foot (feet).

TABLE B-9 Site Grading: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Front-End Loader, Wheeled, 2.5CY	Front-End Loader, Wheeled, 3.0CY, 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Tiller, 5×7, V-Shaped, Deep	Vibratory Roller	Cement Truck
Field personnel, superintendent, maximum	1	400	0	0	0	0	0	0	0	0
Backhoe-loader, wheel type, 1.25CY capacity, with operator	1	400	0	0	0	0	1	0	0	0
Grader, self-propelled, 40,000 lb, with operator	1	400	0	0	0	0	0	1	0	0
Vibratory roller, sheepsfoot, with operator	1	400	0	0	0	0	0	0	1	0
Tractor loader, wheeled, 4×4, 2.5–3.0CY, with operator	1	400	0	0	0	1	0	0	0	0
Truck, dump, tandem, 12 yd^3, with driver	1	400	1	0	0	0	0	0	0	0
Water truck, off-highway, 6,000-gal capacity, with operator	1	400	0	0	0	0	0	0	0	1
Conventional surveying, crew for site grading layout, 3-person crew	1	480	0	1	0	0	0	0	0	0
Corrugated galvanized or aluminum oval arch culverts, coated and paved, 28×20 in.	1	374	1	0	1	0	0	0	0	0
Total equipment operating hours			774	480	374	400	400	400	400	400

TABLE B-10 Site Grading: Materials, Labor, and Cost

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Field personnel, superintendent, maximum	10	week	0	40	400	46.88	0	18,750	0	18,750
Backhoe-loader, wheel type, 1.25CY capacity, with operator	10	week+	1,427	40	400	41.25	14,270	16,500	0	30,770
Grader, self-propelled, 40,000 lb, with operator	10	week+	3,680	40	400	41.25	36,800	16,500	0	53,300
Vibratory roller, sheepsfoot, with operator	10	week+	1,885	40	400	35.63	18,850	14,250	0	33,100
Tractor loader, wheeled, 4×4, 2.5–3.0 CY, with operator	10	week+	1,745	40	400	41.25	17,450	16,500	0	33,950
Truck, dump, tandem, 12 yd^3, with driver	10	week+	1,850	40	400	35.63	18,500	14,250	0	32,750
Water truck, off-highway, 6,000-gal capacity, with operator	10	week+	4,460	40	400	41.25	44,600	16,500	0	61,100
Conventional surveying, crew for site grading layout, 3-person crew	20	day	58	24	480	40.42	1,160	19,400	0	20,560
Corrugated galvanized or aluminum oval arch culverts, coated and paved, 28×20 in.	1,140	LF	60	0.33	374	35.63	68,343	13,338	0	81,681
Totals					3,654		219,973	145,988	0	365,961

APPENDIX C:

VAULT CONSTRUCTION DATA

TABLE C-1 Site Preparation: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Dozer, Crawler, D-5H	Front-End Loader, Wheeled, 3.0CY, 950E	Truck, Hwy, 24500 GVW, 4×2, 2 axle	Flatbed, 8×16 ft	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Hydraulic Crane, 20T/70-ft Boom	Grader, Self-Propelled, 40,000 lb	Vibratory Roller, Sheepsfoot	Tractor, Loader, Wheeled, 4×4, 2.5–3.5CY	Truck, Dump, Tandem, 12 yd^3	Water Truck, Off-Highway, 6,000-gal Capacity
Site Selection													
Site selection	3	60	0	0	0	0	0	0	0	0	0	0	0
Site Improvements													
Clearing and grubbing	9	129	1	0	0	0	0	0	1	1	1	1	1
Mass earthwork	5	980	1	0	0	0	0	0	1	0	1	4	0
Imported yard fill (10%)	4	354	0.5	0	0	0	0	0	0	0	0.8	0.8	0.5
Fine grading	1	18,942	1	0	0	0	0	0	0	0	0	0	0
Sandy gravel installation	1	2,222	0	1	0	0	0	0	0	0	0	0	0
Pea gravel installation	1	667	0	1	0	0	0	0	0	0	0	0	0
Moisture barrier, slab	8	592	0	0	1	1	0	0	0	0	0	0	0
Drain excavation	1.5	367	1	0	0	0	0	0	0	0	0	0	0
Drain installation	3.25	170	0	0	0	0	1	0	0	0	0	0	0
Open trench (ditch) development (around vault)	5	825	1	0	0	0	0	0	1	0	1	4	0
Roads, asphalt	–[a]	–	0	0	0	0	0	0	0	1	0	0	2
Parking areas	–	–	0	0	0	0	0	0	0	0	0	1	1
Sidewalk, concrete	1	1	0	0	0	0	0	0	0	0	0	0	0
Aggregate base course	1	1	0	1	0	0	0	0	0	0	0	0	0
Storm sewer	6	4,914	0	0	0	0	1	0	0	0	0	0	0
Equipment													
Sump pumps	4	40	0	0	0	0	0	0.3	0	0	0	0	0
Monitoring pipes	6	40	0	0	0	0	1	0	0	0	0	0	0
Total equipment operating hours			21,420	2,890	592	592	5,124	12	1,934	129	2,217	7,632	306

[a] Dash means not applicable, subcontracted.

TABLE C-2 Site Preparation: Labor and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Site Selection	1	each							400,000	400,000
Subtotal Site Selection									400,000	400,000
Site Improvements										
Mobilization and demobilization	1								64,784	64,784
Clearing and grubbing	55.0	acre	595.43	21.09	1,160	27.23	32,749	31,597	0	64,346
Mass earthwork	49,004	yd^3	4.78	0.10	4,895	27.23	234,236	133,313	0	367,550
Imported yard fill (10% assumed)	4,900	yd^3	7.15	0.29	1,412	27.23	35,038	38,468	0	73,506
Fine grading	1,894,140	ft^2	0.00	0.01	18,941	27.23	0	515,859	0	515,859
Sandy gravel installation	11,692	yd^3	12	0.19	2,222	27.23	140,307	60,492	0	200,799
Pea gravel installation	3,508	yd^3	12	0.19	666	27.23	42,092	18,148	0	60,240
Moisture barrier, slab	157,845	ft^2	0.10	0.03	4,735	27.23	15,785	128,965	0	144,749
Drain excavation	2,201	yd^3		0.25	550	27.23		14,983	0	14,983
Drain installation	2,201	yd^3	12	0.25	550	27.23	26,411	14,983	0	41,393
Dewatering (assuming each vault is completed within 6 months, conservative estimate)	2,160	day	135						291,600	291,600
Open trench (ditch) development (around vault)	41,280	yd^3	4.78	0.10	4,123	27.23	197,315	112,300	0	309,616
Roads, asphalt (based on vault facility perimeter)	6,700	LF	90.00	S/C				0	603,000	603,000
Parking areas (for construction employees, location for GTCC waste retrieval, etc.)	110,000	SF	1.75	S/C				0	192,500	192,500
Sidewalk, concrete, cast-in-place with 6×6 - W1.4 × W1.4 mesh, broomed finish, 3,000 psi, 5-in. thick, excludes base	3,700	SF	2.31	0.05	183	30	8,547	5,476	0	14,023
Aggregrate base course, for roadways and large paved areas, crushed stone base, compacted, crushed 1.5-in. stone base, to 12-in. deep	27,000	S.Y.	15.32	0.02	513	30	413,640	15,390	0	429,030
Storm sewer	13,400	LF	50.00	2.20	29,480	27.23	670,000	802,872	0	1,472,872
Site security fence, 8-ft chain link	6,734	LF	16.00	S/C				0	107,744	107,744
Main gate	24	LF	140.00	S/C				0	3,360	3,360
Subtotal Site Improvements					69,432		1,816,119	1,892,846	1,262,988	4,971,953

TABLE C-2 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Equipment										
Sump pumps (one for each cell, conservatively assuming all cells constructed at once)	132	each	4,300	8	160	37.5	567,600	6,000	0	573,600
Monitoring pipes	264	each	150	4	240	37.5	39,600	9,000	0	48,600
Subtotal Equipment					400		607,200	15,000	0	622,200
Consumables										
Water	65	ML	2,500				161,826		0	161,826
Electricity	1.0E+08	kWh	0.11				11,110,000		0	11,110,000
Subtotal Consumables							11,271,826		0	11,271,826

TABLE C-3 Vault Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Gas Engine - Vibrator	Core Drill, Electric, 2.5 hp	Hydraulic Crane, 4WD, 40T/84-ft Boom
Concrete					
Foundation mat, 4.25-ft thick	9	15,460	1	0	0
External concrete walls, 3.75-ft thick	9	68,800	1	0	0
Internal concrete walls, 2-ft thick	9	20,160	1	0	0
Elevated concrete on forms, 3.75-ft thick (Safety Level A assumed due to potential for extreme surface rad levels)	9	160,327	1	0	0
Miscellaneous concrete allowance, approx. 15%	9	9,014	1	0	0
Reinforcing Steel					
Cap exterior face, both ways, #7 at 6-in. o.c. (Safety Level A assumed)	4	37,163	0	0	0
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level A assumed)	4	61,816	0	0	0
Exterior wall, exterior face, #8 at 6-in. o.c.	4	21,316	0	0	0
Exterior wall, interior face, #7 at 6-in. o.c.	4	16,318	0	0	0
Floor, exterior face, both ways, #8 at 6-in. o.c.	4	17,962	0	0	0
Floor, interior face, both ways, #10 at 6-in. o.c.	4	28,947	0	0	0
Miscellaneous steel allowance, approx. 15%	4	18,175	0	0	0
Architectural					
Paint structural steel	2	7,963	0	0	0
Miscellanous interior finish	2	0	0	0	0
Fire Protection					
Temporary fire sprinkler system					
Power and Control					
Main power distribution and transformer					
480-V motor control center (MCC), 800 A	2	360	0	0	0
480-V power distribution panel	1	432	0	0	0
480 – 120/208-V transformer, assume 30 kVA	1	480	0	0	0
Local 120/208-V distribution panel	1	768	0	0	0

TABLE C-3 (Cont.)

Item	No. of Workers	Equipment Operating Hours	Gas Engine - Vibrator	Core Drill, Electric, 2.5 HP	Hydraulic Crane, 4WD, 40T/84-ft Boom
Uninterruptible power supply (UPS), 100-kVA battery bank	1	600	0	0	0
Cable tray	3	97,920	0	1	0
Power and control conduit	3	133,980	0	0	0
Instrument conduit	3	45,960	0	0	0
Emergency generator, 500 kW	4.13	30	0	0	0.13
Temporary Lighting					
Fixtures (assume 4 fixtures per vault)	4.66	408	0	0	0
Lighting panels, 1 per 100 fixtures	5	48	0	0	0
Raceway	3	1600	0	0	0
Cable including connections	3	528	0	0	0
Communication					
Speaker systems	3	48	0	0	0
Raceway, 300 ft per system	3	540	0	0	0
Cable including connections, 3 per raceway	3	72	0	0	0
Safeguards and Security					
Intrusion detection devices	1	6,000	0	0	0
Alarms	1	2,400	0	0	0
Closed-circuit television (CCTV) with motion detectors	1	12,000	0	0	0
Central CCTV monitoring system	1	2,400	0	0	0
Fire Alarm System					
Fire alarm system	2	4,736	0	0	0
Grounding					
Grounding	2	2,368	0	0	0

TABLE C-3 (Cont.)

Item	No. of Workers	Equipment Operating Hours	Gas Engine - Vibrator	Core Drill, Electric, 2.5 HP	Hydraulic Crane, 4WD, 40T/84-ft Boom
Instrumentation					
Waste container assay device (gamma)	2	300	0	0	0
Air monitoring system	2	3,600	0	0	0
Computerized material control and accountability system, bar code reader, rad monitors	2	250	0	0	0
Integrated chemical hazardous waste monitoring system	2	3,000	0	0	0
Weight/measurement equipment	2	150	0	0	1
Heating, ventilation, and air conditioning (HVAC) control and monitoring system	2	1,440	0	0	0
Instrument valves	2	0	0	0	0
Calibration, testing, and start-up	2	2,600	0	0	0
Monitoring Wells					
One well per vault, assume about 60-ft deep	3	0	0	0	0
Total equipment operating hours			273,761	97,920	154

TABLE C-4 Vault Construction: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Concrete										
Foundation mat, 4.25-ft thick	24,846	yd^3	150	5.60	139,137	29.76	3,726,896	4,140,175	0	7,867,071
External concrete walls, 3.75-ft thick	20,640	yd^3	210	30.00	619,200	29.76	4,334,400	18,424,923	0	22,759,323
Internal concrete walls, 2-ft thick	4,320	yd^3	235	42.00	181,440	29.76	1,015,200	5,398,931	0	6,414,131
Elevated concrete on forms, 3.75-ft thick (Safety Level A assumed due to potential for extreme surface rad levels)	17,796	yd^3	500	81.08	1,442,939	29.76	8,898,125	42,936,116	0	51,834,241
Miscellaneous concrete allowance, approx. 15%	10,140	yd^3	130	8.00	81,123	29.76	1,318,243	2,413,887	0	3,732,130
Subtotal Concrete	77,743	yd^3	943	31.69	2,463,839	29.76	19,292,864	73,314,032	0	92,606,896
Reinforcing Steel										
Cap exterior face, both ways, #7 at 6-in. o.c. (Safety Level A assumed)	786	ton	4,000	189	148,648	36.91	3,142,846	5,487,153	0	8,630,000
Cap interior face, both ways, #9 at 6-in. o.c. (Safety Level A assumed)	1,307	ton	4,000	189	247,262	36.91	5,227,826	9,127,359	0	14,355,185
Exterior wall, exterior face, #8 at 6-in. o.c.	1,218	ton	2,000	70.00	85,262	36.91	2,436,065	3,147,347	0	5,583,412
Exterior wall, interior face, #7 at 6-in. o.c.	932	ton	2,000	70.00	65,272	36.91	1,864,913	2,409,430	0	4,274,342
Floor, exterior face, both ways, #8 at 6-in. o.c.	1,026	ton	2,000	70.00	71,844	36.91	2,052,691	2,652,035	0	4,704,725
Floor, interior face, both ways, #10 at 6-in. o.c.	1,654	ton	2,000	70.00	115,785	36.91	3,308,138	4,274,047	0	7,582,185
Miscellaneous steel allowance, approx. 15%	1,039	ton	2,000	70.00	72,698	36.91	2,077,071	2,683,534	0	4,760,606
Subtotal Reinforcing Steel	7,962	ton	2,000	70	72,698		2,077,071	2,683,534	0	4,760,606
Architectural										
Paint structural steel	1,592,421	ft^2	0.25	0.01	15,924	30.42	398,105	484,382	0	882,488
Miscellanous interior finish	29,106	ft^2	8.50	S/C	0	0.00	0	0	247,401	247,401
Subtotal Architectural					15,924		398,105	484,382	247,401	1,129,889
Fire Protection										
Temporary fire sprinkler system	157,845	SF	3.50	S/C	0	0.00	0	0	552,458	552,458
Subtotal Fire Protection	157,845	SF	0	0.00	0		0	0	552,458	552,458

TABLE C-4 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Power and Control										
480-V MCC, 800 A	12	each	25,000	60.00	720	31.47	300,000	22,655	0	322,655
480-V power distribution panel	12	each	1,500	36.00	432	31.47	18,000	13,593	0	31,593
480 – 120/208-V transformer, assume 30 kVA	24	each	1,650	20	480	31.47	39,600	15,103	0	54,703
Local 120/208-V distribution panel	24	each	950	32	768	31.47	22,800	24,165	0	46,965
UPS, 100-kVA battery bank	1,200	kVA	1,300	0.50	600	31.47	1,560,000	18,879	0	1,578,879
Cable tray	172,800	LF	18.50	1.70	293,760	31.47	3,196,800	9,243,273	0	12,440,073
Power and control conduit	1,148,400	LF	1.75	0.35	401,940	31.47	2,009,700	12,647,199	0	14,656,899
Instrument conduit	459,600	LF	1.10	0.30	137,880	31.47	505,560	4,338,448	0	4,844,008
Emergency generator, 500 kW	1	each	80,000	120.00	120	30.32	80,000	3,638	0	83,638
Subtotal Power and Control					836,700		7,732,460	26,326,955	0	34,059,415
Temporary Lighting										
Fixtures (assume 4 fixtures per vault)	528	each	120	3.60	1,901	31.47	63,360	59,809	0	123,169
Lighting panels, 1 per 100 fixtures	6	each	1,000	40.00	240	31.47	6,000	7,552	0	13,552
Raceway	19,200	LF	2.00	0.25	4,800	31.47	38,400	151,034	0	189,434
Cable including connections	79,200	LF	0.10	0.02	1,584	31.47	7,920	49,841	0	57,761
Subtotal Temporary Lighting	528	each	220.71		8,525	31.47	115,680	268,236	0	383,916
Communication										
Speaker systems	12	each	1,000.00	12.00	144	31.47	12,000	4,531	0	16,531
Raceway, 300 ft per system	3,600	LF	1.70	0.45	1,620	31.47	6,120	50,974	0	57,094
Cable including connections, 3 per raceway	10,800	LF	0.10	0.02	216	31.47	1,080	6,797	0	7,877
Subtotal Communication	12	each	1,644.00		1,980	31.47	19,200	62,301	0	81,501
Safeguards and Security										
Intrusion detection devices	120	each	5,000	50	6,000	31.47	600,000	188,792	0	788,792
Alarms	120	each	1,000	20	2,400	31.47	120,000	75,517	0	195,517
CCTV with motion detectors	120	each	10,000	100	12,000	31.47	1,200,000	377,585	0	1,577,585
Central CCTV monitoring system	12	lot	20,000	200	2,400	31.47	240,000	75,517	0	315,517
Subtotal Safeguards and Security					22,800	31.47	2,160,000	717,411	0	2,877,411

TABLE C-4 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Fire Alarm System										
Fire alarm system	157,845	SF	1.00	0.06	9,471	31.47	157,845	297,999	0	455,844
Grounding										
Grounding	157,845	SF	0.60	0.03	4,735	31.47	94,707	149,000	0	243,707
Instrumentation										
Waste container assay device (gamma)	1	system	95,000	600	600	30.47	95,000	18,285	0	113,285
Air monitoring system	12	system	250,000	600	7,200	30.47	3,000,000	219,419	0	3,219,419
Computerized material control and accountability system, bar code reader, rad monitors	1	system	100,000	500	500	30.47	100,000	15,237	0	115,237
Integrated chemical hazardous waste monitoring system	12	system	100,000	500	6,000	30.47	1,200,000	182,849	0	1,382,849
Weight/measurement equipment	1	system	20,000	300	300	30.47	20,000	9,142	0	29,142
HVAC control and monitoring system	360	I/O[a]	1,000	8	2,880	30.47	360,000	87,768	0	447,768
Instrument valves	480	each	22.50	0	0	30.47	10,800	0	0	10,800
Calibration, testing, and start-up	1	lot	22.50	0	5,200	30.47	90,000	158,469	0	248,469
Subtotal Instrumentation					22,680		4,875,800	691,169	0	5,566,969
Consumables										
Water	0	ML	2,500				0		0	0
Electricity	0	kWh	0.11				0		0	0
Subtotal Consumables							0		0	0
Monitoring Wells										
One well per vault, assume about 60-ft deep (based on text)	720	LF	27.63	0	0	30.47	19,894	0	0	19,894

[a] I/O = input/output.

TABLE C-5 Contact-Handled Waste Vault Closure: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Compactor, Rammer, 13×11-in. Shoe	Front-End Loader, Wheeled, 2.5CY	Front-End Loader, Wheeled, 3.0CY, 950E	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Tiller, 5×7, V-Shaped, Deep	Dozer, Crawler, D-3C
Vault Closure										
Fill void spaces between containers with gravelly sand	1	17,614	0	0	0	0	1	0	0	0
Sandy gravel installation	1	4,982	0	0	0	0	1	0	0	0
Compact aggregate with vibrating plate (Safety Level A assumed)	3	4,387	0	0	1	0	0	0	0	0
Concrete cap (costs already included in Initial Construction costs)										
Gravelly sand installation on top of concrete vault (0.5-ft thick)	1	28,120	0	0	0	0	1	0	0	0
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	1	10,640	0	0	0	0	0	0	1	1
Geotextile (100 mil polymeric liner, PVC, 33-08-0586)	8	4,703	1	1	0	0	0	0	0	0
Native soil installation on top of clay layer (25.5-ft thick, 18 05 0301)	1.5	19,234	0	0	0	1	0	0	0	0
Gravel/cobble layer installation on top of native soil layer (2-ft thick)	1	11,780	0	0	0	0	1	0	0	0
Pea gravel installation (0.5-ft thick)	1	3,040	0	0	0	0	1	0	0	0
Sand installation (0.5-ft thick)	1	3,040	0	0	0	0	1	0	0	0
Topsoil installation (1-ft thick)	1.5	2,873	0	0	0	1	0	0	0	0
Compact soil with vibrating plate	3	43,001	0	0	1	0	0	0	0	0
Revegetation (sodding, average CONUS)	6	2,440	0	0	0	0	0	1	0	0
Total equipment operating hours			4,703	4,703	47,388	22,107	68,576	2,440	10,640	10,640

TABLE C-6 Contact-Handled Waste Vault Closure: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person -Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Fill void spaces between containers with gravelly sand (conservatively assume 41% overall waste placement efficiency in cell)	34,300	yd^3	24	0.51	17,614	32.15	823,200	566,274	0	1,389,474
Sandy gravel installation (assuming 3-ft overlay on top of GTCC containers, Safety Level A conditions assumed)	9,700	yd^3	24	0.51	4,981	32.15	232,800	160,142	0	392,942
Compact aggregate with vibrating plate (Safety Level A assumed)	44,000	yd^3	0.36	0.30	13,160	29.55	15,840	388,865	0	404,705
Concrete cap (costs already included in Initial Construction costs)	0	lot	0	0.00	0	29.76	0	0	0	0
Gravelly sand installation on top of concrete vault (0.5-ft thick)	148,000	yd^3	12	0.19	28,120	27.23	1,776,000	765,708	0	2,541,708
Compacted bentonite layer installation on top of gravelly sand (3-ft thick)	56,000	yd^3	11.12	0.19	10,640	33.65	622,720	358,036	0	980,756
Geotextile (100 mil polymeric liner, PVC, 33-08-0586)	500,000	ft^2	1.98	0.08	37,618	27.91	990,000	1,050,000	0	2,040,000
Native soil installation on top of clay layer (25.5-ft thick, 18 05 0301)	221,000	yd^3	22.89	0.13	28,851	31.10	5,058,690	897,260	0	5,955,950
Gravel/cobble layer installation on top of native soil layer (2-ft thick)	62,000	yd^3	12	0.19	11,780	27.23	744,000	320,769	0	1,064,769
Pea gravel installation (0.5-ft thick)	16,000	yd^3	12	0.19	3,040	27.23	192,000	82,779	0	274,779
Sand installation (0.5-ft thick)	16,000	yd^3	12	0.19	3,040	27.23	192,000	82,779	0	274,779
Topsoil installation (1-ft thick)	33,000	yd^3	22.89	0.13	4,308	31.10	755,370	133,980	0	889,350
Compact soil with vibrating plate	1,052,000	yd^3	0.18	0.12	129,002	26.67	189,360	3,440,040	0	3,629,400
Revegetation (sodding, average CONUS)	63	acre	18,002	232.32	14,636	27.61	1,134,126	404,082	0	1,538,208
Totals					306,788		12,726,106	8,650,714	0	21,376,820

TABLE C-7 Additional Remote-Handled Waste Vault Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Gas Engine - Vibrator	Hydraulic Crane, 4WD, 40T/84-ft Boom	Front-End Loader, Wheeled, 3.0CY, 950E	Compactor, Rammer, 13×11-in. Shoe
Concrete Pipe and Caps						
Construct forms to hold concrete pipe in place	4	11,428	0	0	0	0
Cut and notch reinforced concrete pipe at bottom for water drainage purposes	2.5	6,278	0	0	0	0
Emplace reinforced concrete pipe between forms (storm sewer pipe: 28-in. ID, 36-in. OD, 18-ft long, Class IV/V, C wall, approx. 420 lb per linear foot, 72 pipes per vault)	6	794	0	1	0	0
Fill void spaces between concrete pipes with pea gravel	1	4,858	0	0	1	0
Compact pea gravel with vibrating plate (Safety Level E assumed)	3	943	0	0	0	1
Construct hexagonal concrete cylinder cap (3-ft thick on top, 1-ft thick within concrete plug, 72 total)	9	2,471	1	0	0	0
Construct concrete side plugs (pour concrete on top of aggregate to smooth finish)	9	111	1	0	0	0
Miscellaneous concrete allowance, approx. 15%	9	1,053	1	0	0	0
Concrete finishing, concrete cylinder caps	1	923	0	0	0	0
Total equipment operating hoiurs			3,635	794	4,858	943

TABLE C-8 Additional Remote-Handled Waste Vault Construction: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subonctract ($)	Total ($)
Concrete Pipe and Caps										
Construct forms to hold concrete pipe in place	3,265	100 S.F.	250	14	45,711	33.77	816,270	1,543,828	0	2,360,098
Cut and notch reinforced concrete pipe at bottom for water drainage purposes	6,696	each	31	2	15,694	37.60	205,165	590,085	0	795,250
Emplace reinforced concrete pipe between forms (storm sewer pipe: 28-in. ID, 36-in. OD, 18-ft long, Class IV/V, C wall, approx. 420 lb per linear foot, 72 pipes per vault)	133,920	LF	28.70	0.036	4,761	165.69	3,843,504	788,789	0	4,632,293
Fill void spaces between concrete pipes with pea gravel	9,459	yd^3	24.00	0.51	4,857	32.15	227,012	156,160	0	383,173
Compact pea gravel with vibrating plate (Safety Level E assumed)	9,459	yd^3	0.36	0.30	2,829	29.55	3,405	83,596	0	87,001
Construct hexagonal concrete cylinder cap (3-ft thick on top, 1-ft thick within concrete plug, 72 total)	7,557	yd^3	175	2.94	22,234	29.76	1,322,542	661,590	0	1,984,132
Construct concrete side plugs (pour concrete on top of aggregate to smooth finish)	339	yd^3	175	2.94	996	29.76	59,251	29,640	0	88,891
Miscellaneous concrete allowance, approx. 15%	1,184	yd^3	130	8.00	9,475	29.76	153,971	281,943	0	435,914
Concrete finishing, concrete cylinder caps	61,520	ft^2	0	0.015	923	33.33	0	30,760	0	30,760
Totals					107,480		6,631,121	4,166,391	0	10,797,512

APPENDIX D:

SUPPORT FACILITY CONSTRUCTION DATA

TABLE D-1 Support Facility Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Dozer, Crawler, D-3C	Gas Engine - Vibrator	Hydraulic Crane, 4WD, 40T/84-ft Boom	Welder, 200 amp, Axle Trailer	Cement Truck
Admin/Ops Support Bldg.										
Building	–[a]	3,500	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Office furniture	2	13	0	1	0	0	0	0	0	0
Personal computers	2	13	0	1	0	0	0	0	0	0
Waste Receiving and Storage (WRS) Bldg.	–	36,207	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Maintenance and Storage Bldg.										
Building	–	4,800	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Shop equipment allowance	4	25	0	1	0	0	0	0	0	0
Guard House, Entry Control										
Building	–	1,440	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Metal detectors, misc. detection equipment	2	10	0	1	0	0	0	0	0	0
Lab Building										
Building	–	826	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Analytical laboratory equipment allowance	1	700	0	0	0	0	0	0	0	0
Solid waste glove boxes	5	16	0	0	0	0	0	0	1	0
Emergency generator, 300 kW	6	20	0	0.25	0	0	0	0	0	0
Truck Washdown										
Truck washdown pad, concrete	9	15	0	0	0	0	1	0	0	0
Tank foundations	9	209	0	0	0	0	1	0	0	0
Utilities Bldg. (includes equipment for Pump House)										
Building	–	4,500	0.06035	0.00017	0	0.08021	0.06706	0.00323	0.00298	0.08990
Boiler, 20,000 lb/h	5	70	1	0	0	0	0	1	1	0
Demineralized water system	5	40	1	0	0	0	0	1	1	0

TABLE D-1 (Cont.)

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Loader, Backhoe, Wheeled, 1.38CY, Front-End Bucket	Dozer, Crawler, D-3C	Gas Engine - Vibrator	Hydraulic Crane, 4WD, 40T/84-ft Boom	Welder, 200 amp, Axle Trailer	Cement Truck
Air compressor, 300 ft^3/min (cfm)	4	24	0	0	0	0	0	0.2	1	0
Air dryer	4	15	0	0	0	0	0	0.2	1	0
Packaged refrigeration system, 800 tons	5	115	1	0	0	0	0	1	1	0
Chillers, 250 tons, 3 each	5	150	1	0	0	0	0	1	1	0
Fire water pump, electric, 2,000 gal/min (gpm)	5	40	1	0	0	0	0	1	1	0
Fire water pump, diesel, 2,000 gpm	5	50	1	0	0	0	0	1	1	0
Fuel tank, double wall, 10,000 gal	4	22	0	0	0	0	0	0	0	0
Stack and exhaust duct	3	84	0	0	0	0	0	1	0	0
Piping allowance, average 4 in.	6	250	0	0	1	0	0	0	0	0
Power equipment and motor control centers (MCCs)	3	150	0	0	0	0	0	0	0	0
Power and control conduit	3	600	0	0	0	0	0	0	0	0
Instrumentation conduit	3	260	0	0	0	0	0	0	0	0
Power and control cable	3	420	0	0	0	0	0	0	0	0
Instrumentation cable	3	240	0	0	0	0	0	0	0	0
Plant security systems	1	60	0	0	0	0	0	0	0	0
Field-mounted instruments	1	300	0	0	0	0	0	0	0	0
Total equipment operating hours			3,559	74	250	4,112	3,662	722	673	4,609

TABLE D-2 Support Facility Construction: Materials, Labor, and Costs[a]

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Site Improvements										
Clearing and grubbing	8	acre	1,000	S/C	0		0	0	8,000	8,000
Landscaping	5	acre	10,000	S/C	0		0	0	53,333	53,333
Total Site Improvements					0		0	0	61,333	61,333
Admin/Ops Support Bldg.										
Building	2,000	SF	75.00	1.75	3,500	30.42	150,000	106,463	0	256,463
Office furniture	50	set	2,000	0.50	25	30.42	100,000	760	0	100,760
Personal computers	50	set	2,000	0.50	25	30.42	100,000	760	0	100,760
Total Admin/Ops Support Bldg.					3,550	30.42	350,000	107,984	0	457,984
Total WRS Bldg.	59,400	SF	10	0.61	36,207	29.96	586,776	1,084,766	429,408	2,100,950
Maintenance and Storage Bldg.										
Building	3,200	SF	75.00	1.50	4,800	30.42	240,000	146,006	0	386,006
Shop equipment allowance	1	lot	100,000	100	100	30.32	100,000	3,032	0	103,032
Total Maintenance and Storage Bldg.					4,900	30.42	340,000	149,038	0	489,038
Guard House, Entry Control										
Building	720	SF	250.00	2.00	1,440	30.42	180,000	43,802	0	223,802
Metal detectors, misc. detection equipment	1	set	100,000	20.00	20	31.47	100,000	629	0	100,629
Total Guard House, Entry Control					1,460	30.42	280,000	44,431	0	324,431
Lab Building										
Building	1,400	SF	34.00	0.6	826	30.32	47,600	25,043	0	72,643
Analytical laboratory equipment allowance	1,400	SF	50	1	700	30.32	70,000	21,223	0	91,223
Solid waste glove boxes	1	each	30,000	80	80	30.32	30,000	2,425	0	32,425
Emergency generator, 300 kW	1	each	70,000	120	120	30.32	70,000	3,638	0	73,638
Total Lab Building					1,726		217,600	52,329	0	269,929
Truck Washdown										
Truck washdown pad, concrete	5,000	SF	3.48	0.026	132	32.29	17,400	4,250	0	21,650
Tank foundations	125	CY	150	15.00	1,875	29.76	18,750	55,793	0	74,543
Holding (service water) tank, 50,000 gal	2	each	50,000	S/C	0		0	0	100,000	100,000
Total Truck Washdown					2,007		36,150	60,043	100,000	196,193

TABLE D-2 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
Utilities Bldg. (includes equipment for Pump House)										
Building	3,000	SF	75.00	1.50	4,500	30.42	225,000	136,881	0	361,881
Boiler, 20,000 lb/h	1	each	160,000	350	350	30.32	160,000	10,611	0	170,611
Demineralized water system	1	system	30,000	200	200	30.32	30,000	6,064	0	36,064
Air compressor, 300 cfm	2	each	40,000	50	100	30.32	80,000	3,032	0	83,032
Air dryer	2	each	13,000	30	60	30.32	26,000	1,819	0	27,819
Packaged refrigeration system, 800 tons	1	each	350,000	575	575	30.32	350,000	17,433	0	367,433
Chillers, 250 tons, 3 each	750	ton	400	1	750	30.32	300,000	22,738	0	322,738
Fire water pump, electric, 2,000 gpm	1	each	30,000	200	200	30.32	30,000	6,064	0	36,064
Fire water pump, diesel, 2,000 gpm	1	each	50,000	250	250	30.32	50,000	7,579	0	57,579
Fuel tank, double wall, 10,000 gal	1	each	38,446	86.71	87	41.00	38,446	3,555	0	42,001
Stack and exhaust duct	1	LS[a]	75,000	250	250	30.32	75,000	7,579	0	82,579
Piping allowance, average 4 in.	600	LF	280.00	2.50	1,500	30.31	168,000	45,467	0	213,467
Power equipment and MCCs	300	kW	350	1.5	450	31.47	105,000	14,159	0	119,159
Power and control conduit	6,000	LF	2.25	0.30	1,800	31.06	13,500	55,916	0	69,416
Instrumentation conduit	3,000	LF	1.80	0.26	780	31.06	5,400	24,230	0	29,630
Power and control cable	18,000	LF	0.90	0.07	1,260	31.06	16,200	39,141	0	55,341
Instrumentation cable	12,000	LF	0.60	0.06	720	31.06	7,200	22,366	0	29,566
Plant security systems	3	each	500.00	20.00	60	31.06	1,500	1,864	0	3,364
Field-mounted instruments	30	I/O	850.00	10.00	300	30.47	25,500	9,142	0	34,642
Software development	30	I/O	1,000	S/C			0	0	30,000	30,000
Total Utilities Bldg.					14,192	30.47	1,706,746	435,642	30,000	2,172,388
Miscellaneous										
Fire water tank, elevated - 180,000 gal	1	each	321,000	S/C	0		0	0	321,000	321,000
Main gate	24	LF	140.00	S/C	0		0	0	3,360	3,360
Total Miscellaneous					0		0	0	324,360	324,360

TABLE D-2 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)
DISPOSAL-METHOD-SPECIFIC										
Site Improvements for Trench										
Stormwater retention pond	6,000	CY	123.34	1.90	11,391	24.05	740,040	273,900	0	1,013,940
Site security fence, 8-ft chain link	5,808	LF	16.00	S/C	0		0	0	92,928	92,928
Total Site Improvements for Trench					11,391	24	740,040	273,900	92,928	1,106,868
Site Improvements for Borehole										
Stormwater retention pond	13,000	CY	123.34	1.90	24,680	24.05	1,603,420	593,450	0	2,196,870
Site security fence, 8-ft chain link	9,076	LF	16.00	S/C	0		0	0	145,216	145,216
Total Site Improvements for Borehole					24,680	24	1,603,420	593,450	145,216	2,342,086
Site Improvements for Vault										
Stormwater retention pond	8,000	CY	123.34	1.90	15,188	24.05	986,720	365,200	0	1,351,920
Site security fence, 8-ft chain link	6,734	LF	16.00	S/C	0		0	0	107,744	107,744
Total Site Improvements for Vault					15,188	24	986,720	365,200	107,744	1,459,664

[a] LS = lump sum.

TABLE D-3 Waste Handling Building Construction: Workers Required and Equipment Operating Hours

Item	No. of Workers	Equipment Operating Hours	Truck, Hwy, 24,500 GVW, 4×2, 2 Axle	Flatbed, 8×16 ft	Dozer, Crawler, D-3C	Gas Engine - Vibrator	Hydraulic Crane, 4WD, 40T/84-ft Boom	Welder, 200 amp, Axle Trailer	Cement Truck[a]
Foundations									
Footings and foundations	9	351	0	0	0	1	0	0	1
Excavations and backfill	1	2,904	0	0	1	0	0	0	1
Substructure									
Slab on grade	9	459	1	0	0	1	0	0	0
Exterior Closures									
Walls	9	666	1	0	0	1	0	0	0
Doors, emergency exits	4.5	1	0	1	0	0	0.5	0	0
Doors, steel overhead	4	6	0	0	0	0	1	0	0
Roofing									
Roof coverings	2.5	635	0	0	0	0	0	0	0
Openings and specialties	2.5	31	0	0	0	0	0	0	0
Interior Construction									
Partitions	9	952	1	0	0	1	0	0	0
Interior doors	4.5	5	0	1	0	0	0.5	0	0
Mechanical									
Plumbing	6	16							
Heating	5	108	1	0	0	0	1	1	0
Cooling	5	0	1	0	0	0	1	1	0
Total equipment operating hours			2,185	6	2,904	2,428	117	108	3,255

[a] Cement truck required only for the trench and borehole facilities. The vault facility has an on-site concrete batch plant.

TABLE D-4 Waste Handling Building Construction: Materials, Labor, and Costs

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)	Total Cost ($)
Foundations											
Footings and foundations	Pour concrete, strip and spread footings and 4-ft foundation wall	306	CY	146	10.30	3,151	29.76	44,665	93,775	0	138,440
Excavations and backfill	Site preparation for slab and trench for foundation wall and footing	6,600	CY	1.02	0.44	2,904	27.23	6,732	79,076	0	85,808
Substructure											
Slab on grade	5-in. reinforced concrete with vapor barrier and granular base	917	CY	147	4.50	4,125	29.76	134,750	122,760	0	257,510
Superstructure											
Roof	Metal deck, open web steel joists, beams, columns	59,400	SF roof	5.50					0	326,700	326,700
Exterior Closures											
Walls	Concrete block	56,000	SF wall	1.20	0.11	5,992	29.76	67,200	178,322	0	245,522
Doors	Emergency exits, fire door, “A” label, 3 hour, 3×7 ft	2	each	207	1.07	2.14	29.76	414	64	0	478
	Steel overhead, hollow metal, truck, bay doors	2	each	950	10.67	21.34	29.76	1,900	635	0	2,535
Roofing											
Roof coverings	Built-up tar and gravel with flashing	594	square[a]	58.30	2.67	1,586	30.42	34,630	48,246	0	82,876
Openings and specialties	Gravel stop, hatches, and skylight	1,180	LF	1.95	0.07	76.70	30.42	2,301	2,333	0	4,634

TABLE D-4 (Cont.)

Item	Quantity	Unit	Unit Cost ($)	Person-Hour Unit	No. of Person-Hours	Rate ($/h)	Materials ($)	Labor ($)	Subcontract ($)	Total ($)	Total Cost ($)
Interior Construction											
Partitions	Concrete block (Health Physics/Change, receiving bay, storage rooms)	80,000	SF partition	1.20	0.11	8,560	30.42	96,000	260,395	0	356,395
Interior doors	Single leaf, hollow metal	8	each	275	2.29	18.32	30.42	2,200	557	0	2,757
Wall finishes	Paint	160,000	SF surface	0.09	0.01	1600	30.42	14,400	48,672	0	63,072
Floor finishes	90% hardener, 10% vinyl composite tile	59,400	SF floor	1.95	0.10	5,940	30.42	115,830	180,695	0	296,525
Interior surface/exterior wall	Paint	56,000	SF wall	0.09	0.01	560.00	30.42	5,040	17,035	0	22,075
Mechanical											
Plumbing	Toilet and service fixtures, supply and drainage	8	each	225	11.40	91.20	30.31	1,800	2,764	0	4,564
Fire protection	Sprinklers, extra hazard	59,400	SF floor	1.70						100,980	100,980
Heating	Oil-fired, hot water, unit heaters	54,000	SF floor	0.75	0.01	540	30.97	40,500	16,724	0	57,224
Cooling	Single zone unit, gas heating, electric cooling	3,600	SF floor	0.48						1,728	1,728
Electrical											
Service and distribution	200-amp service, panel board and feeders	59,400	SF floor	0.06	0.01	594	31.47	3,564	18,693	0	22,257
Lighting and power	Fluorescent fixtures, receptacles, switches and misc. power, 1 fixture/400 SF	149	SF floor	100	3.00	446	31.47	14,850	14,020	0	28,870
						36,207		586,776	1,084,766	429,408	2,100,950

[a] Square is a measure of roofing material; it is the quantity required to cover 100 ft^2 of roof.

APPENDIX E:

DISPOSAL FACILITY OPERATIONS DATA

TABLE E-1 Estimated Annual Demand for Natural Gas for Building Space Heating[a]

Building	Footprint (ft^2)	Unit Annual Natural Gas Demand (ft^3/ft^2)[b]	Annual Natural Gas Demand (Mcf/yr)[c]
Admin/Ops Support Building	2,000	0.0502	660
WRS Building	59,400	0.0234	9,132
Maintenance and Storage Building	3,200	0.0234	492
Guard House, Entry Control	720	0.0502	237
Lab Building	1,400	0.0234	215
Utilities Bldg. (includes equipment for Pump House)	3,000	0.0234	461
Total	69,720		11,198

[a] The assumption is that all buildings would operate 6,570 hours annually.

[b] Source: DOE (2006d).

[c] Mcf = thousands of cubic feet.

TABLE E-2 Estimated Annual Demand for Electricity for Mission-Critical Equipment

Major Equipment	Rating (kW)	Hours Used per Shipment	Unit Electric Power (kWh/shipment)	Average Annual No. of On-Site Movements per Method			Annual Electric Demand per Method (kWh/yr)		
				Trench	Borehole	Vault	Trench	Borehole	Vault
25-ton crane	44.7	3.000	134.1	1,310	284	1,295	175,671	38,084	173,660
6-ton crane	5.6	2.000	11.2	1,310	284	1,295	14,646	3,175	14,478
Waste hoist	447.0	0.083	37.1	1,310	284	1,295	48,602	10,537	48,046
Total	497.3		182.4	1,310	284	1,295	238,919	51,796	236,183

Source: Sandia (2008c).

TABLE E-3 Estimated Annual Demand for Electricity for Building Lighting[a]

Building	Footprint (ft^2)	Annual Electric Demand (kWh/yr)
Admin/Ops Support Building	2,000	26,280
WRS Building	59,400	780,516
Maintenance and Storage Building	3,200	42,048
Guard House, Entry Control	720	9,461
Lab Building	1,400	18,396
Utilities Bldg. (includes equipment for Pump House)	3,000	39,420
Total	69,720	916,121

[a] The assumption is that all buildings would operate 6,570 hours annually. Building codes generally allow lighting between 1.5 and 2.5 watts per square foot (Teicholz 2001). An average of 2 watts per square foot is assumed for the lighting load for all buildings.

TABLE E-4 Estimated Annual Demand for Diesel Fuel for Mission-Critical Equipment

Description	Unit Hourly Consumption of Diesel (gal/h)	Quantity per Method			Annual Operating Hours per Method			Annual Diesel Demand per Method (gal/yr)		
		Trench	Borehole	Vault	Trench	Borehole	Vault	Trench	Borehole	Vault
Tractor trailers	6.7	3	3	3	2,963	911	2,933	59,548	18,303	58,945
Emplacement cranes	9.2	1	1	1	3,442	1,178	3,414	31,669	10,837	31,405
Forklift trucks	6	3	3	3	3,021	911	2,933	54,385	16,391	52,787
Vibratory compactor	0	1	1	1	2,963	911	2,933	0	0	0
End-loaders	12.2	1	1	1	2,963	911	2,933	36,144	11,109	35,778
Pickup trucks	3.9	5	4	6	1,320	1,320	1,320	25,740	20,592	30,888
Emergency diesel generator	36.6	1	1	1	48	48	48	1,757	1,757	1,757
Total diesel use								210,000	80,000	210,000

TABLE E-5 Equipment Costs

Description	Unit Cost ($)	Assumed Economic Life (years)	Quantity per Method			Total Cost ($) per Method			Annual Cost ($) per Method		
			Trench	Borehole	Vault	Trench	Borehole	Vault	Trench	Borehole	Vault
Tractor trailers	150,000	20	3	3	3	450,000	450,000	450,000	22,500	22,500	22,500
Emplacement cranes	220,000	20	1	1	1	220,000	220,000	220,000	11,000	11,000	11,000
Forklift trucks	30,000	20	3	3	3	90,000	90,000	90,000	4,500	4,500	4,500
Vibratory compactor	170,000	20	1	1	1	170,000	170,000	170,000	8,500	8,500	8,500
End-loaders	159,000	20	1	1	1	159,000	159,000	159,000	7,950	7,950	7,950
Pickup trucks	22,000	20	5	4	6	110,000	88,000	132,000	5,500	4,400	6,600
Miscellaneous tools ($500 per craft worker)	8,806 (Trench) 5,134 (Borehole) 10,009 (Vault)		1	1	1	8,806	5,134	10,009	8,806	5,134	10,009
Maintenance allowance (2.5% of above costs)	19,000		1	1	1	19,000	19,000	19,000	19,000	19,000	19,000
Total diesel use						1,230,000	1,200,000	1,250,000	87,756	82,984	90,059

TABLE E-6 Trench Operations Time Motion Data

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
OPERATIONS WORKFORCE																					
SHIPPING AND RECEIPT																					
Receive shipping container in controlled area.	571	1	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.2	228.4
Inspect preliminary paperwork and start radiological survey.	571	1	0.2	0	0.0	1	0.2	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	342.6
Move truck into parking area after preliminary inspections are performed.	571	1	0.1	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Verify shipment paperwork and complete radiological survey.	571	1	1.5	0	0.0	1	1.5	0	0.0	1	1.5	0	0.0	0	0.0	0	0.0	0	0.0	1.5	2,569.5
Position truck for unloading of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	57.1
Unload shipping container from trailer and stage it at waste handling dock.	571	1	0.4	0	0.0	0	0.0	2	0.4	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	0.4	913.6

TABLE E-6 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
PAYLOAD PROCESSING AND CONFIGURATION																					
Remove outer lid(s) and place lid(s) into storage.	571	1	0.3	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	856.5
Perform radiological survey of inside of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Remove inner lid(s) and place hood over the shipping container.	571	1	0.5	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.5	1,427.5
Take rad air reading.	571	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	342.6
Remove payload by using existing lifting points and store it in facility cask (RH-72B only).	1,170	1	0.3	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1,053.0
Replace and re-bolt inner lid.	571	1	0.1	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	742.3
Release truck, trailer, and shipping container to return to generator.	571	1	0.2	1	0.2	0	0.0	2	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.8	1,142.0
Bundle RH into disposal package configuration. Secure top plate of disposal pallet (RH canisters only).	1,170	0	0.0	0	0.0	0	0.0	2	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1.0	2,340.0

TABLE E-6 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
Transfer completed bundle to facility cask (RH canisters only) by using overhead crane.	1,170	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	702.0
Bundle CH-7 drum arrangement into 4-drum disposal package configuration. Secure top plate of disposal pallet.	30	1	0.3	0	0.0	0	0.0	2	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	30.0
Move 4-drum waste package to storage area.	53	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	31.5
ON-SITE SHIPPING AND DISPOSAL																					
Load container on transport to disposal area.	1,310	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,930.0
Transport container to disposal area.	1,310	1	1.0	0	0.0	1	1.0	2	1.0	1	1.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	1.0	6,550.0
Unload container from transport at disposal area.	1,310	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,930.0
Remove cover from trench opening by using crane.	1,310	1	0.1	0	0.0	0	0.0	4	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	524.0
Position CH waste package for placement in trench by using 15-ton forklift.	140	1	0.3	0	0.0	0	0.0	4	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	210.0

TABLE E-6 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver #	Truck Driver Duration (hr)	Gate Guard (Security) #	Gate Guard (Security) Duration (hr)	Transportation Engineer #	Transportation Engineer Duration (hr)	Waste Handling Technician #	Waste Handling Technician Duration (hr)	Radiation Technician #	Radiation Technician Duration (hr)	Other Security #	Other Security Duration (hr)	Maintenance (Craft) #	Maintenance (Craft) Duration (hr)	Office and Clerical #	Office and Clerical Duration (hr)	Managers/ Supervisors #	Managers/ Supervisors Duration (hr)	Total Step Duration (h)	Person-Hours per Year
Place CH drum waste package in trench by using forklift.	140	1	0.2	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	47.6
Position other CH waste package for placement in trench by using overhead crane.	0	1	0.3	0	0.0	0	0.0	4	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	0.0
Place other CH waste package in trench by using crane.	0	0	0.0	0	0.0	0	0.0	4	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	0.0
Remove cap/cover from concrete pipes used for RH disposal.	1,170	0	0.0	0	0.0	0	0.0	2	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	585.0
Position RH waste package for placement in concrete pipe by using overhead crane.	1,170	1	0.3	0	0.0	0	0.0	4	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1,755.0
Place RH waste package in trench by using crane.	1,170	0	0.0	0	0.0	0	0.0	4	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	994.5
Replace cap/cover on concrete pipes containing RH waste.	1,170	0	0.0	0	0.0	0	0.0	2	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	585.0
Fill void space between disposal packages with sand and compact sand (in cubic yards)	96	2	1.3E-02	0	0.0	0	0.0	1	1.3E-02	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1.3 E-02	1.3E-02	3.3
Replace cover over trench opening.	1,310	1	0.1	0	0.0	0	0.0	4	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	524.0

TABLE E-6 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
Fill entire trench with clean soil and compact it (included in Construction Impacts).	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0
Remove shoring (included in Construction Impacts).	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0
Wash down truck.	1,310	1	2.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	0	0.0	2.0	5,240.0
WASTE RECEIVING AND STORAGE BUILDING																					
Warehouse storage surveillance	520	0	0.0	0	0.0	0	0.0	1	8.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	8,320.0
Building management	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	2,080.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
Building operations	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	8.0	2	8.0	8.0	16,640.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	8.0	0	0.0	0	0.0	0	0.0	8.0	17,520.0
DISPOSAL AREA																					
Disposal area surveillance	520	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	4,160.0
Disposal management	520	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	4,160.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0
Subtotal Operations Workforce																					**95,145.4**
Number of Full-Time Equivalents																					**45.7**

TABLE E-6 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver #	Truck Driver Duration (hr)	Gate Guard (Security) #	Gate Guard (Security) Duration (hr)	Transportation Engineer #	Transportation Engineer Duration (hr)	Waste Handling Technician #	Waste Handling Technician Duration (hr)	Radiation Technician #	Radiation Technician Duration (hr)	Other Security #	Other Security Duration (hr)	Maintenance (Craft) #	Maintenance (Craft) Duration (hr)	Office and Clerical #	Office and Clerical Duration (hr)	Managers/ Supervisors #	Managers/ Supervisors Duration (hr)	Total Step Duration (h)	Person-Hours per Year
MAINTENANCE WORKFORCE																					
WASTE RECEIVING AND STORAGE BUILDING																					
Overhead crane	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	52.0	0	0.0	0	0.0	52.0	104.0
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
High-efficiency particulate air (HEPA) filter	2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	26.0	0	0.0	0	0.0	26.0	104.0
Monitoring station equipment	4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	104.0
Decontamination equipment	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
DISPOSAL AREA																					
Sump pump	29	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	754.0
Trench monitoring equipment	29	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	754.0
Subtotal Maintenance Workforce																					**4,940.0**
Number of Full-Time Equivalents																					**2.4**
Total Number of Full-Time Equivalents			**4.0**		**0.1**		**1.1**		**11.3**		**7.7**		**10.5**		**2.4**		**6.0**		**5.0**		

TABLE E-7 Borehole Operations Time Motion Data

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver #	Truck Driver Duration (hr)	Gate Guard (Security) #	Gate Guard (Security) Duration (hr)	Transportation Engineer #	Transportation Engineer Duration (hr)	Waste Handling Technician #	Waste Handling Technician Duration (hr)	Radiation Technician #	Radiation Technician Duration (hr)	Other Security #	Other Security Duration (hr)	Maintenance (Craft) #	Maintenance (Craft) Duration (hr)	Office and Clerical #	Office and Clerical Duration (hr)	Managers/ Supervisors #	Managers/ Supervisors Duration (hr)	Total Step Duration (hr)	Person-Hours per Year
OPERATIONS WORKFORCE																					
SHIPPING AND RECEIPT																					
Receive shipping container in controlled area.	571	1	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.2	228.4
Inspect preliminary paperwork and start radiological survey.	571	1	0.2	0	0.0	1	0.2	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	342.6
Move truck into parking area after preliminary inspections are performed.	571	1	0.1	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Verify shipment paperwork and complete radiological survey.	571	1	1.5	0	0.0	1	1.5	0	0.0	1	1.5	0	0.0	0	0.0	0	0.0	0	0.0	1.5	2,569.5
Position truck for unloading of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	57.1
Unload shipping container from trailer and stage it at waste handling dock.	571	1	0.4	0	0.0	0	0.0	2	0.4	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	0.4	913.6
PAYLOAD PROCESSING AND CONFIGURATION																					
Remove outer lid(s) and place lid(s) into storage.	571	1	0.3	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	856.5
Perform radiological survey of inside of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Remove inner lid(s) and place hood over the shipping container.	571	1	0.5	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.5	1,427.5

TABLE E-7 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver #	Truck Driver Duration (hr)	Gate Guard (Security) #	Gate Guard (Security) Duration (hr)	Transportation Engineer #	Transportation Engineer Duration (hr)	Waste Handling Technician #	Waste Handling Technician Duration (hr)	Radiation Technician #	Radiation Technician Duration (hr)	Other Security #	Other Security Duration (hr)	Maintenance (Craft) #	Maintenance (Craft) Duration (hr)	Office and Clerical #	Office and Clerical Duration (hr)	Managers/ Supervisors #	Managers/ Supervisors Duration (hr)	Total Step Duration (hr)	Person-Hours per Year
Take rad air reading.	571	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	342.6
Remove payload by using existing lifting points and store it in facility cask (RH-72B only).	160	1	0.3	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	144.0
Replace and re-bolt inner lid.	571	1	0.1	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	742.3
Release truck, trailer, and shipping container to return to generator.	571	1	0.2	1	0.2	0	0.0	2	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.8	1,142.0
Bundle into disposal package configuration. Secure top plate of disposal pallet (RH canisters only).	160	0	0.0	0	0.0	0	0.0	2	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1.0	320.0
Transfer completed bundle to facility cask (RH canisters only).	160	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	96.0
ON-SITE SHIPPING AND DISPOSAL																					
Load container on transport to disposal area.	284	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	852.0
Transport container to disposal area.	284	1	1.0	0	0.0	1	1.0	2	1.0	1	1.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	1.0	1,420.0
Unload container from transport at disposal area.	284	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	852.0
Remove lid from borehole opening.	284	1	0.3	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	426.0
Place waste package in borehole.	284	1	1.0	0	0.0	0	0.0	4	1.0	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	1.0	1,704.0

TABLE E-7 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (hr)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
Fill void space between disposal packages with sand and compact sand (in CUYD).	521	2	1.3E-02	0	0.0	0	0.0	1	1.3E-02	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1.3E-02	1.3E-02	17.9
Replace lid from borehole opening.	284	1	0.3	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	426.0
Wash down truck.	284	1	2.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	0	0.0	2.0	1,136.0
WASTE RECEIVING AND STORAGE BUILDING																					
Warehouse storage surveillance	520	0	0.0	0	0.0	0	0.0	1	8.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	8,320.0
Building management	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	2,080.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
Building operations	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	8.0	2	8.0	8.0	16,640.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	8.0	0	0.0	0	0.0	0	0.0	8.0	17,520.0
DISPOSAL AREA																					
Disposal area surveillance	520	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	4,160.0
Disposal management	520	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	4,160.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0
Subtotal Operations Worforce																					**73,504.4**
Number of Full-Time Equivalents																					**35.3**
MAINTENANCE WORKFORCE																					
WASTE RECEIVING AND STORAGE BUILDING																					
Overhead crane	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	52.0	0	0.0	0	0.0	52.0	104.0

TABLE E-7 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (hr)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)		
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
HEPA	2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	26.0	0	0.0	0	0.0	26.0	104.0
Monitoring station equipment	4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	104.0
Decontamination equipment	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
DISPOSAL AREA																					
Sump pump	40	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	1,040.0
Borehole monitoring equipment	40	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	1,040.0
Subtotal Maintenance Workforce																					**5,512.0**
Number of Full-Time Equivalents																					**2.7**
Total Number of Full-Time Equivalents			**1.8**		**0.1**		**0.6**		**5.8**		**5.5**		**10.5**		**2.7**		**6.0**		**5.0**		

TABLE E-8 Vault Operations Time Motion Data

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hrs)	#	Duration (hr)		
OPERATIONS WORKFORCE																					
SHIPPING AND RECEIPT																					
Receive shipping container in controlled area.	571	1	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.2	228.4
Inspect preliminary paperwork and start radiological survey.	571	1	0.2	0	0.0	1	0.2	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	342.6
Move truck into parking area after preliminary inspections are performed.	571	1	0.1	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Verify shipment paperwork and complete radiological survey.	571	1	1.5	0	0.0	1	1.5	0	0.0	1	1.5	0	0.0	0	0.0	0	0.0	0	0.0	1.5	2,569.5
Position truck for unloading of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.1	57.1
Unload shipping container from trailer and stage it at waste handling dock.	571	1	0.4	0	0.0	0	0.0	2	0.4	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	0.4	913.6
PAYLOAD PROCESSING AND CONFIGURATION																					
Remove outer lid(s) and place lid(s) into storage.	571	1	0.3	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	856.5
Perform radiological survey of inside of shipping container.	571	1	0.1	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0.1	114.2
Remove inner lid(s) and place hood over the shipping container.	571	1	0.5	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.5	1,427.5

TABLE E-8 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hrs)	#	Duration (hr)		
Take rad air reading.	571	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	342.6
Remove payload by using existing lifting points and store it in facility cask (RH-72B only).	1,170	1	0.3	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1,053.0
Replace and re-bolt inner lid.	571	1	0.1	0	0.0	0	0.0	4	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	742.3
Release truck, trailer, and shipping container to return to generator.	571	1	0.2	1	0.2	0	0.0	2	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.8	1,142.0
Bundle RH into disposal package configuration. Secure top plate of disposal pallet (RH canisters only).	1,170	0	0.0	0	0.0	0	0.0	2	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1.0	2,340.0
Transfer completed bundle to facility cask (RH canisters only) by using overhead crane.	1,170	0	0.0	0	0.0	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.3	702.0
ON-SITE SHIPPING AND DISPOSAL																					
Load container on transport to disposal area.	1,295	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,885.0
Transport container to disposal area.	1,295	1	1.0	0	0.0	1	1.0	2	1.0	1	1.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	1.0	6,475.0
Unload container from transport at disposal area.	1,295	1	0.5	0	0.0	0	0.0	4	0.5	1	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,885.0
Remove cover from vault opening.	1,295	1	0.5	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,237.5

TABLE E-8 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hrs)	#	Duration (hr)		
Position CH waste package for placement in vault by using overhead crane.	125	1	0.3	0	0.0	0	0.0	4	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	187.5
Place CH waste package in vault by using crane.	125	0	0.0	0	0.0	0	0.0	4	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	106.3
Remove cap/cover from concrete pipes used for RH disposal.	1,170	0	0.0	0	0.0	0	0.0	2	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	585.0
Position RH waste package for placement in concrete pipe by using overhead crane.	1,170	1	0.3	0	0.0	0	0.0	4	0.3	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1,755.0
Place RH waste package in vault by using crane.	1,170	0	0.0	0	0.0	0	0.0	4	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	994.5
Replace cap/cover on concrete pipes containing RH waste.	1,170	0	0.0	0	0.0	0	0.0	2	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0.2	585.0
Fill void space between disposal packages with sand and compact sand (in CUYD).	98	2	1.3E-02	0	0.0	0	0.0	1	1.3E-02	0	0.0	0	0.0	0	0.0	0	0.0	0.3	1.3E-02	1.3E-02	3.4
Replace cover over vault opening.	1,295	1	0.5	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.5	3,237.5
Wash down truck.	1,295	1	2.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	0	0.0	2.0	5,180.0
WASTE RECEIVING AND STORAGE BUILDING																					
Warehouse storage surveillance	520	0	0.0	0	0.0	0	0.0	1	8.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	8,320.0
Building management	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	2,080.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0

TABLE E-8 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hrs)	#	Duration (hr)		
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
Building operations	260	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	8.0	2	8.0	8.0	16,640.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	8.0	0	0.0	0	0.0	0	0.0	8.0	17,520.0
DISPOSAL AREA																					
Disposal area surveillance	520	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	0	0.0	0	0.0	0	0.0	0	0.0	8.0	4,160.0
Disposal management	520	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	8.0	8.0	4,160.0
Security	1,095	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2.0	2,190.0
Subtotal Operations Workforce																					**100,322.1**
Number of Full-Time Equivalents																					**48.2**
MAINTENANCE WORKFORCE																					
WASTE RECEIVING AND STORAGE BUILDING																					
Overhead crane	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	52.0	0	0.0	0	0.0	52.0	104.0
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
HEPA	2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	26.0	0	0.0	0	0.0	26.0	104.0
Monitoring station equipment	4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	104.0
Decontamination equipment	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
ADMINISTRATION/OPERATIONS SUPPORT BUILDING																					
HVAC	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	520.0	0	0.0	0	0.0	520.0	1,040.0
DISPOSAL AREA																					
Sump pump	12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	312.0

TABLE E-8 (Cont.)

Description	Operations per Year (Operations) Number of Components (Maintenance)	Truck Driver		Gate Guard (Security)		Transportation Engineer		Waste Handling Technician		Radiation Technician		Other Security		Maintenance (Craft)		Office and Clerical		Managers/ Supervisors		Total Step Duration (h)	Person-Hours per Year
		#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hr)	#	Duration (hrs)	#	Duration (hr)		
Monitoring wells	24	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	624.0
Vault monitoring equipment	12	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	26.0	0	0.0	0	0.0	26.0	312.0
Subtotal Maintenance Workforce																					**4,680.0**
Number of Full-Time Equivalents																					**2.3**
Total Number of Full-Time Equivalents			**4.5**		**0.1**		**1.1**		**13.3**		**7.7**		**10.5**		**2.3**		**6.0**		**5.0**		

APPENDIX F:

EMISSION FACTORS

TABLE F-1 Criteria Pollutant Vehicle Emission Factors (g/mi)[a]

Criteria Pollutant	Delivery Vehicles	Support Vehicles	Commuter Vehicles
SO_x	0.00225	0.00225	0.006
NO_x	0.141	0.141	0.141
CO	0.539	0.539	3.745
PM_{10}	0.0295	0.0295	0.029
$PM_{2.5}$	0.0157	0.0157	0.014
Volatile organic compounds	0.0880	0.0880	0.18
CO_2	326	326	380

[a] Emission factors were determined by using Argonne GREET model, Version 2.8a, of August 30, 2007, available at http://www.transportation.anl.gov/software/GREET/greet_2-8a_beta.html.

TABLE F-2 Construction Equipment Fuel Consumption and Emission Factors

Construction Equipment	Consumption (gal/h) Diesel Fuel	Consumption (gal/h) Oil and Grease	Emission Factor (lb per 1,000 gal) THC[a]	ROC[b]	NO_x	SO_2	CO	TSP[c]	PM_{10}[d]	CO_2
Truck, Hwy, 24,500 GVW, 4×2, 2 axle	6.7	0.2	17.7	17.1	171.7	31.2	123.5	17.7	16.8	22,600
Flatbed, 8×16 ft	5.3	0.3	17.8	17.1	171.7	31.2	123.5	17.7	16.8	22,600
Compactor, rammer, 13×11-in. shoe	1.0	0.1	30.1	28.9	404.5	31.1	188.4	24.2	23.0	22,600
Front-end loader, wheeled, 2.5CY	12.2	0.2	43.2	41.4	321.2	31.2	98.7	29.3	27.8	22,600
Front-end loader, wheeled, 3.0CY, 950E	22.2	0.4	43.2	41.4	321.2	31.2	98.7	29.3	27.8	22,600
Loader, backhoe, wheeled, 1.38CY, front-end bucket	6.2	0.2	43.2	41.4	321.2	31.2	98.7	29.3	27.8	22,600
Tiller, 5×7, V-shaped, deep	7.8	0.3	27.6	26.5	284.9	31.1	78.5	25.3	24.0	22,600
Dozer, crawler, D-3C	3.0	0.1	13.2	12.6	286.1	31.2	123.5	14.8	14.1	22,600
Hydraulic crane, 20T/70-ft boom	6.1	0.4	28.8	27.6	171.0	31.1	78.5	25.3	24.0	22,600
Gas engine - vibrator	1.0	0.1	30.1	28.9	404.5	31.1	188.4	24.2	23.0	22,600
Welder, 200 amp, axle trailer	1.2	0.0	34.4	33.0	220.8	31.2	153.5	30.1	28.6	22,600
Grader, self-propelled, 40,000 lb	7.0	0.2	12.7	12.2	253.8	31.1	54.7	22.2	21.1	22,600
Vibratory roller, sheepsfoot	5.7	0.2	27.6	26.5	284.9	31.1	78.5	25.3	24.0	22,600
Tractor loader, wheeled, 4×4, 2.5–3.5CY	22.2	0.4	43.2	41.4	321.2	31.2	98.7	29.3	27.8	22,600
Truck, dump, tandem, 12 yd^3	6.7	0.2	17.7	17.1	171.7	31.2	123.5	17.7	16.8	22,600
Water truck, off-highway, 6,000-gal capacity	3.4	0.2	17.8	17.1	171.7	31.2	123.5	17.7	16.8	22,600
Driller/auger (200 to 650 hp)	32.7	0.4	3.9	3.7	25.7	0.0	15.3	2.2	2.1	22,600
Driller/coring (220 hp)	11.1	0.4	3.9	3.7	25.7	0.0	15.3	2.2	2.1	22,600
Cement truck	22.2	0.4	43.2	41.4	321.2	31.2	98.7	29.3	27.8	22,600

[a] Total hydrocarbons.

[b] Reactive organic compounds.

[c] Total suspended particulates.

[d] These emission factors are for combustion-derived PM_{10} emissions and do not include the fugitive dust component.

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