# Two Technology Conceptual Designs for Disposal of GTCC LLW

## Prepared by Sandia National Laboratories
## Task 3.4: Develop Conceptual Designs

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# 1. INTRODUCTION

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) assigned the United States (U.S.) Federal Government the responsibility for disposing of Greater-Than-Class C (GTCC) low-level radioactive waste (LLW) generated by activities licensed by U.S. Nuclear Regulatory Commission (NRC) or Agreement States (42 USC 2021 as amended). The LLRWPAA requires that the Federal Government provide for the disposal of GTCC LLW in a facility that adequately protects the safety and health of the public and is licensed by NRC. As part of the responsibilities assigned to the U.S. Department of Energy (DOE) in the LLRWPAA, the DOE has begun the environmental impact statement (EIS) process for development of a disposal capability for GTCC LLW. In addition, DOE has proposed to include DOE GTCC-like waste[1] in the scope of this EIS.

The sites under consideration in the GTCC LLW EIS for disposal of GTCC LLW are the Waste Isolation Pilot Plant (WIPP), the Yucca Mountain (YM) repository, other DOE sites with a waste disposal mission, and generic commercial sites. The other DOE sites and the generic commercial sites are the focus of this report and are referred to as land disposal sites throughout the remainder of this document.

This report is one of a multi-task project that supports development of the EIS. It describes an enhanced near-surface disposal (ENSD) trench technology conceptual design and an intermediate-depth borehole disposal (IDBD) technology conceptual design that could be implemented at the land disposal sites. These two conceptual designs will be considered in the EIS evaluation of alternatives for disposal of GTCC LLW. The ENSD and IDBD technology conceptual designs will be used in subsequent tasks to help evaluate pre- and post-closure impacts of proposed alternatives.

## 1.1 PURPOSE AND SCOPE

This report is one of a multi-task project that supports development of the EIS. It describes an enhanced near-surface disposal (ENSD) trench technology conceptual design and an intermediate-depth borehole disposal (IDBD) technology conceptual design that could be implemented at the land disposal sites. These two conceptual designs will be considered in the EIS evaluation of alternatives for disposal of GTCC LLW. The ENSD and IDBD technology conceptual designs will be used in subsequent tasks to help evaluate pre- and post-closure impacts of proposed alternatives. Figure 1 shows how the results presented in this document are related to other documents being produced in support of the EIS.

[1] DOE GTCC-like waste is DOE LLW and transuranic waste having characteristics similar to GTCC LLW and which may not have an identified path to disposal.

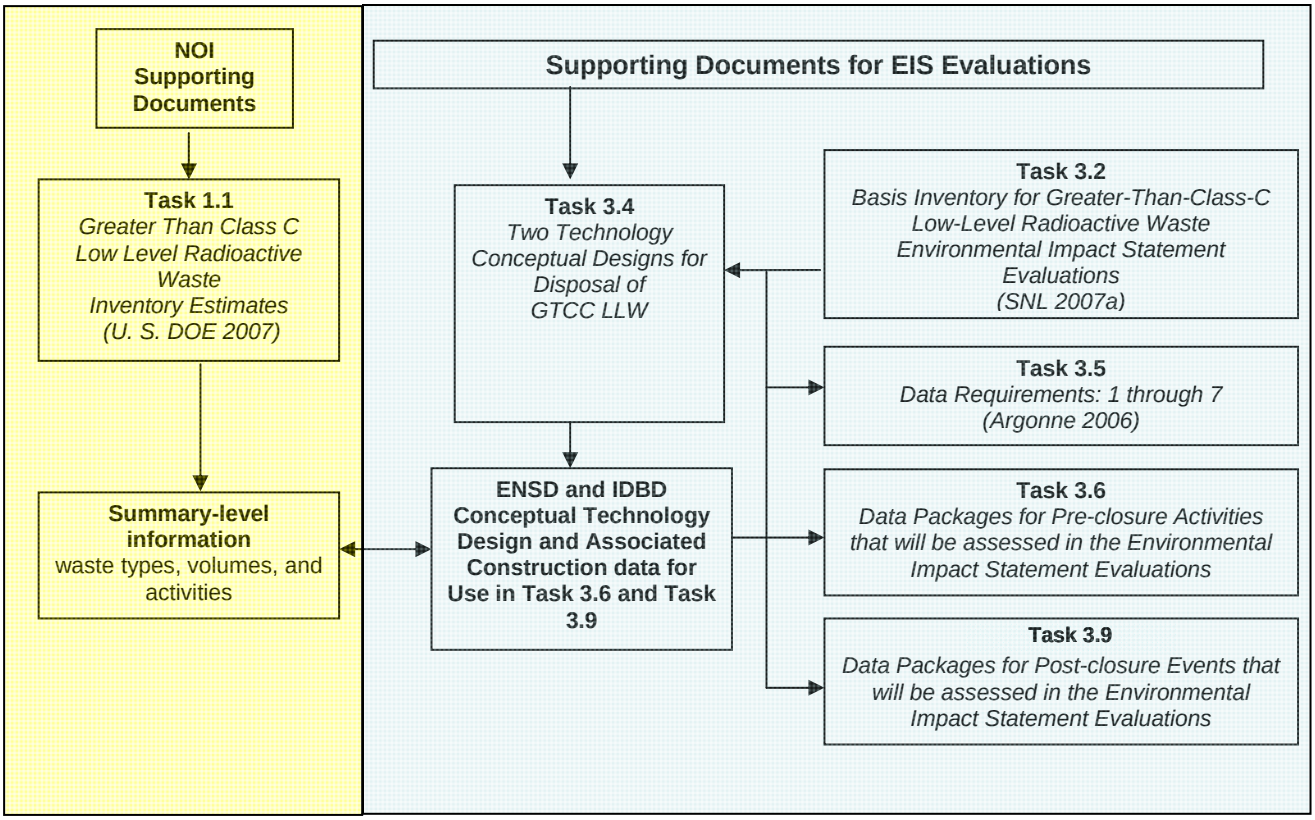


Figure 1. Relationship between Tasks that Support the GTCC LLW EIS

This report provides the following information for each conceptual design:

- A description of the design,
- A conceptual drawing,
- The per unit disposal capacity,
- The per unit resources required for construction,
- The per unit cost estimate to construct,
- The volume of construction wastes, and
- The per unit near-term environmental releases associated with the use of each design.

## 1.2 TYPES OF GTCC LLW AND DOE GTCC-LIKE WASTE

GTCC LLW is defined by the NRC in 10 CFR 72.3 as "low-level radioactive waste that exceeds the concentration limits of radionuclides established for Class C waste in 10 CFR 61.55." In 10 CFR 61.55, the NRC defines classes of LLW as A, B, and C by the concentration of specific short- and long-lived radionuclides, with Class C LLW having the highest radionuclide concentration limits. The GTCC LLW and DOE GTCC-like waste can be divided into three categories:

- Sealed sources,

- Activated metals, and
- Other miscellaneous waste.

The DOE GTCC-like waste is included as a subset within each of these categories.

### 1.2.1 Sealed Sources

GTCC LLW and DOE-GTCC like sealed sources are typically small, sources of radioactive material that are permanently sealed in a capsule or closely bonded in a solid form. The encapsulated radioactive materials are present in several forms, including ceramic oxides, salts or metals. The sealed source category includes intact irradiators containing $^{137}$Cs sealed sources. Cesium chloride (CsCl) salt was used in older $^{137}$Cs sources; newer $^{137}$Cs sources involve bonding the radioactive materials in a ceramic matrix. Sealed sources comprise two waste streams: drums containing long-lived sealed sources (principally $^{241}$Am, $^{238}$Pu, $^{239}$Pu, and $^{240}$Pu), and medium-lived sealed sources (principally $^{137}$Cs sealed sources in irradiators).

### 1.2.2 Activated Metals

Activated metal GTCC LLW is typically steel or stainless steel material that has been subjected to neutron flux for sufficient periods of time to cause activation of some of the elements in the metal. Much of this waste will come from the decontamination and decommissioning of nuclear power reactors. These waste forms, although chemically and physically inert, are highly radioactive due to short-lived radionuclides such as $^{60}$Co and $^{55}$Fe (5.27 and 2.7 year half-lives, respectively). Other longer-lived radionuclides of greater concern to post-closure performance of the disposal site include $^{63}$Ni, $^{54}$Mn, $^{59}$Ni, $^{14}$C, $^{93}$Mo, and $^{94}$Nb.

DOE GTCC-like activated metals are similar to activated metals from the commercial nuclear utilities. They consist of steel or stainless steel that has been activated by neutron bombardment. These waste forms, although chemically and physically inert, are highly radioactive because of radionuclides such as $^{14}$C, $^{54}$Mn, $^{55}$Fe, $^{59}$Ni, $^{60}$Co, $^{63}$Ni, $^{93}$Mo, and $^{94}$Nb.

### 1.2.3 Other Waste

Other miscellaneous waste includes all GTCC LLW that is not sealed sources or activated metals, such as contaminated debris and other waste types generated by the manufacturing of sealed radioactive sources, fuel fabrication, commercial research, and similar activities. The principal radionuclides of concern include, $^{90}$Sr, $^{137}$Cs, $^{238}$Pu, $^{239}$Pu, $^{240}$Pu, $^{241}$Am, and $^{241}$Pu. The DOE GTCC-like waste within the other waste category largely consists of transuranic waste from the decontamination and decommissioning of facilities.

## 1.3 TYPES OF DISPOSAL TECHNOLOGIES

Three general disposal technologies may be considered for evaluation in the EIS: enhanced near-surface disposal (< 30 m deep); intermediate depth borehole disposal

(30-300 m deep); and mined geologic repositories. This document presents conceptual designs for the ENSD and IDBD technologies.

### 1.3.1 Enhanced Near-Surface Disposal (Trench)

Near-surface disposal involves disposal of radioactive waste in or within 30 meters of the earth's surface (10 CFR 61.2). This type of disposal typically involves the use of relatively shallow trenches to dispose of LLW with relatively short half-lives or with long half-lives and low radionuclide concentrations. Near-surface disposal includes disposal in engineered facilities which may be built totally or partially above-grade provided that such facilities have protective earthen covers (10 CFR 61.7).

Near-surface trench disposal is successfully used at commercial and DOE LLW disposal facilities in the U.S. Based on U.S. experience, some of the advantages of near-surface trench disposal are: construction is simple, using common earth-moving equipment; and construction is inexpensive, with wastes being placed relatively near the land surface.

If near-surface disposal is to be considered for GTCC LLW, the technology must be enhanced in some way to provide greater protection to the public than is normally provided for Class A, B, and C LLW. These enhancements could include greater depth of disposal and an intruder barrier. Inadvertent human intrusion into the wastes is unlikely if the wastes are buried at depths greater than 5 meters and/or there is an intruder barrier system. In addition, minimizing the "footprint" of a trench reduces the probability of inadvertent human intrusion. With such enhancements, one of the disposal technologies that may be considered in the EIS is near-surface disposal in trenches.

### 1.3.2 Intermediate Depth Borehole Disposal

For this study, intermediate depth borehole disposal is defined as emplacement of waste in boreholes at depths greater than 30 m but less than 300 m. Boreholes can vary widely in diameter (from 0.3 to 3.7 m), 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. Figure 2 shows a schematic of the process for using a bucket auger to drill a large diameter borehole.

Although much less common than near-surface trench disposal, intermediate depth boreholes have been successfully used in the U.S. for disposal of wastes with characteristics similar to GTCC LLW as part of the DOE's Greater Confinement Disposal (GCD) Project at the Nevada Test Site (NTS). Limited amounts of DOE GTCC-like LLW and classified TRU waste were disposed in the NTS GCD boreholes, which were 3 meters in diameter and 36 meters deep. Four of the boreholes contain classified TRU waste and other boreholes received high-specific-activity sealed sources and radioisotope thermoelectric generators. The performance assessment for the NTS GCD boreholes (Colaruso et al. 2003) of the classified TRU wastes was reviewed and accepted by a DOE Federal Review Group in 2001 as meeting the EPA standards found in 40 CFR 191 (*Environmental Radiation Protection Standards For Management And*

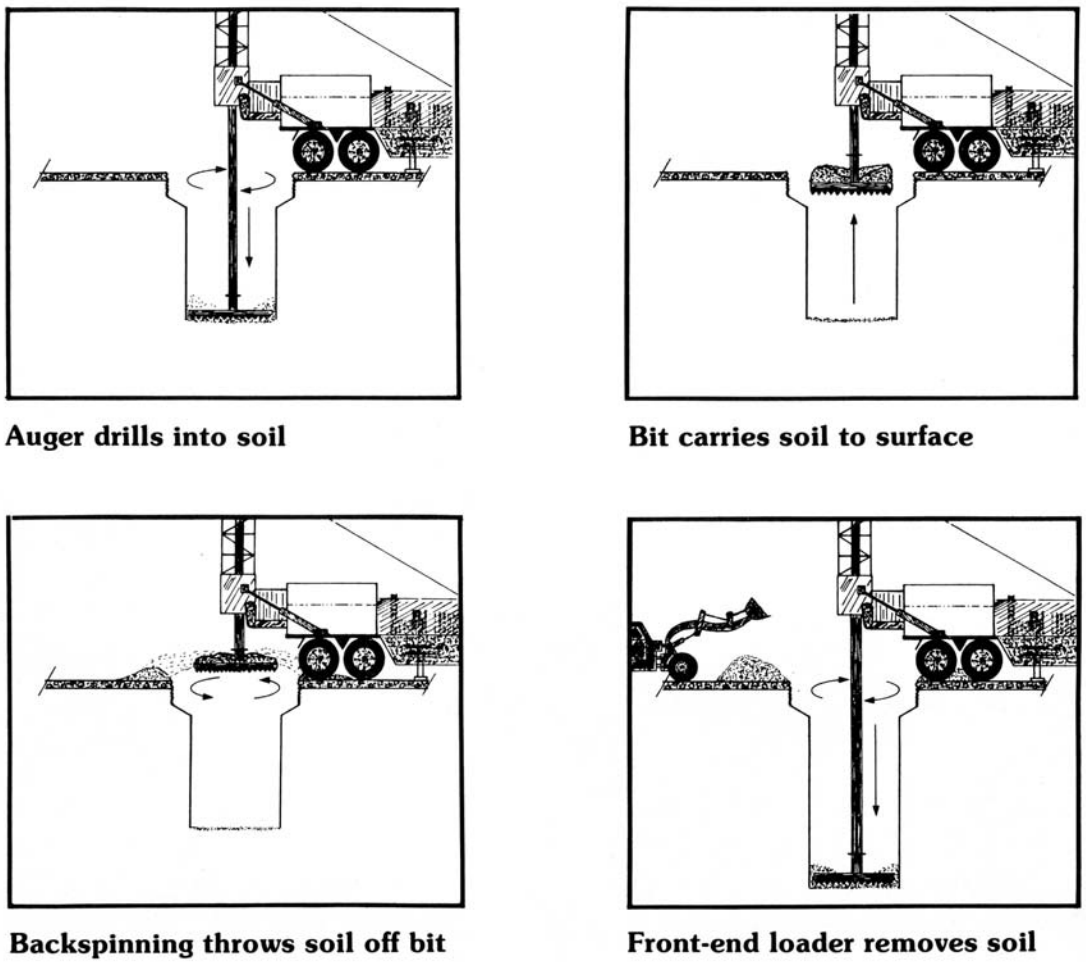


Figure 2. A Schematic of the Process for Drilling a Large Diameter Borehole Using a Bucket Auger

*Disposal Of Spent Nuclear Fuel, High-Level And Transuranic Radioactive Wastes)*, (Colarusso et al. 2003).

In addition, the Los Alamos National Laboratory (LANL) has disposed of LLW in shallower shafts (similar to boreholes), which are up to 20 meters deep and range in diameter from 0.5 to 5 meters. Material Disposal Area G at LANL includes over 180 such vertical shafts used for disposal of LLW (U. S. DOE 2000; LANL 2002). The shafts are filled with generally higher-activity wastes that require additional confinement from that provided in disposal trenches and pits.

Based on U.S. experience, some of the advantages of IDBD are: the drilling technology is available; inadvertent human intrusion is unlikely because the depth of burial minimizes most types of inadvertent human intrusion, except human intrusion by well-

drilling; the relatively small "footprint" greatly reduces the probability of inadvertent human intrusion by well-drilling; a relatively small intruder barrier can be used to protect a relatively large volume of waste; and boreholes are easily co-located with existing or other planned disposal facilities.

## 2. DEVELOPMENT OF CONCEPTUAL DESIGNS

This section provides a summary of the factors that were considered in developing the ENSD and the IDBD technology conceptual designs for consideration in the GTCC LLW EIS. The conceptual designs presented in this report for ENSD and IDBD were selected to represent the range of designs that are applicable for disposal of GTCC LLW. For actual construction of a disposal system using these concepts, further optimization may be necessary. This optimization may consider the following factors: the facility design (conceptual in this report), the characteristics of the disposal site, the characteristics of the waste, the metrics for measuring safety, the characteristics of the waste containers, and the period of active institutional control.

For each technology, the conceptual design is composed of several functional elements. These functional elements or design parameters include:

- maximum depth of burial and thickness of the disposal zone
- covers and other barriers
- foundations, walls, and backfill
- the widths for trenches or diameters for boreholes

The conceptual designs presented in this report (in combination with the characteristics of the disposal site, the inventory, and the waste form) are intended to achieve the following objectives:

a. protect the general public from long-lived radionuclides potentially migrating away from the disposal system,
b. protect an individual who might occupy the disposal site after active and passive controls are no longer present and engage in normal activities such as agriculture, dwelling construction, or other pursuits in which the individual might be unknowingly exposed to radiation from the waste, and
c. provide stability of the site after closure without the need for ongoing active maintenance.

Therefore, functional elements for the conceptual designs presented in this report were chosen with objectives a, b, and c in mind. In addition, the choice of functional elements that formulate the conceptual designs was based in part on current practice and expert judgment. Most disposal technologies implement these functional elements in varying ways; the approaches used in this report are intended to be representative of these functions, with the understanding that alternative designs may also be appropriate.

## 2.1 MAXIMUM DEPTH, THICKNESS OF DISPOSAL ZONE, COVERS AND BARRIERS

As described in (SNL 2007a), the GTCC LLW inventory contains long-lived radionuclides in relatively high-specific activity packages. Examples of GTCC LLW radionuclides with very long half-lives include $^{243}$Am at 432 years and $^{239}$Pu at 24,000 years.

Disposal at depths greater than 5 m is a commonly accepted method for protecting an inadvertent human intruder from exposure to higher activity, long-lived wastes like GTCC LLW. Both the ENSD-Trench and the IDBD designs being proposed for consideration will place waste more than 16 feet (5 m) below the land surface. Disposal at depths greater than 16 feet (5 m) removes the wastes from most normal human activities such as basement construction, construction of utility trenches, septic tank lines and road cuts. Institutional control, historical knowledge, markers, waste recognition, and burial depth work together to greatly reduce the chance that an individual would inadvertently access buried wastes.

It remains possible, that in the far future all controls, knowledge and indications of waste disposal are lost, and an individual inadvertently drills through the buried GTCC LLW looking for natural resources[2]. Such a disruption could bring material to the surface (leading to human dose) and such a disruption could "puncture" the disposal system (altering future performance of the disposal system). Therefore, a subsurface deflection shield is recommended as an enhancement to the ENSD and IDBD conceptual designs.

A recent review (Hart et al. 2007) indicates that a reasonable range of barriers to commercially available drilling technologies includes: obstacles on the surface to prevent placement of a drilling rig over the wastes; a subsurface drilling deflector to deflect the drill bit; a subsurface obstacle to stop a drill bit, and a subsurface drilling obstacle that would cause a loss of drilling fluid or binding of the drill bit.

A deflection shield, constructed below the land surface is favorable because subsurface barriers and covers are less likely to be scavenged by humans for building materials and the subsurface options are less likely to be eroded by the weather over hundreds to thousands of years. Of the subsurface options evaluated (Hart et al. 2007), the drilling deflector made with concrete and steel with 30 degree angle from vertical was selected because of its ability to deflect the drill bit as opposed to stopping the drill bit. Appendix A of this report describes the subsurface deflection shield recommended for the ENSD and IDBD facilities.

The subsurface deflection shield may serve several purposes. In shallow configurations, it will prevent animal and plant root intrusion into the wastes. In humid and even semi-arid settings, it may deflect infiltrating water. Finally, the subsurface deflection shield may serve as a warning or a barrier to inadvertent human intrusion.

[2] Drilling for resources is the most likely activity that could cause an inadvertent human intruder to be exposed to wastes buried at depths greater than 5 m (16 ft).

The proposed ENSD and IDBD conceptual designs for disposal of GTCC LLW have two primary enhancements to similar designs for LLW: disposal at depth and a subsurface deflection shield. With wastes a minimum of 5 m deep, the construction of a 3 m deep basement will not intersect waste intervals. As a defense-in depth, the subsurface deflection shield will alert an intruder to the presence of GTCC LLW.

## 2.2 FOUNDATIONS, WALLS, AND BACKFILL

A cornerstone of long-term disposal system performance is stability (objective c above) - stability of the waste and stability of the disposal site. Stability of a near-surface disposal system is achieved by: (1) proper site selection (e.g., avoiding areas of mass wasting), (2) properly backfilling around and above the waste packages and (3) not disposing of waste packages that contain significant voids or materials that will decay to produce significant voids.

As a design consideration, there must be adequate space around and between the waste packages for placement and compaction of backfill. A minimum of 0.3 m (1 ft) is needed between waste packages and the sidewalls to allow placement of backfill in “lifts” and compacted. For the IDBD boreholes, the backfill will be placed and compacted remotely (without people in the borehole) as discussed in the Task 3.6 reports. Placement and compaction of trench backfill will also be done remotely.

Table 1 summarizes the type and dimensions of waste containers that are identified for disposal of GTCC LLW (SNL 2007a).

Table 1. Summary of Waste Container Types for GTCC LLW Analysis

| Category | Waste Container | | |
|---|---|---|---|
| | Type | Length | Diameter |
| Activated Metal (Nuclear Utility LLW) | AMCs/SAMCs | 110 in. (2.8 m) | 28 in. (0.71 m) |
| Activated Metal (Nuclear Utility LLW) | half-SAMCs | 55 in. (1.4 m) | 28 in. (0.71 m) |
| Sealed Sources | 55 gallon drum | 35 in. (0.9 m) | 24 in. (.61 m) |
| Sealed Sources (Cs Irradiators) | Blood Irradiator Model IBL-43 | 59.1 in. (1.5 m) | 26.4 in. (0.67 m) |
| Activated Metal (DOE Activated Metals) | AMCs/SAMCs | 110 in. (2.8 m) | 28 in. (0.71 m) |
| Other Miscellaneous Waste (CH Process Waste) | 55 gallon drum | 35 in. (0.9 m) | 24 in. (.61 m) |
| Other Miscellaneous Waste (RH Process Waste) | RH canisters | 121 in. (3.1 m) | 26 in (0.66 m) |

The ENSD-Trench and the IDBD designs presented in this report would require a foundation that is durable, long-lived and sturdy enough to support heavy loads, because the AMCs/SAMCs may weigh up to 11,000 kg or 12 tons when loaded (Hillesheim et al.

2007). The foundation envisioned would be permeable to allow drainage (thus preventing bath tubing) in the unlikely event the system filled with water. A compacted cohesionless fill, such as sand, is strong, durable, long-lived, inexpensive and permeable. Calculations performed by Sandia indicate that a foundation of sand can withstand the load of AMCs/SAMCs expected. Therefore, the two conceptual designs will have foundations made of compacted cohesionless fill, such as sand.

The disposal system sidewalls are designed to not collapse during construction and waste placement. If the soil / rock will not safely support the vertical walls of the excavation, then some type of sidewall will need to be placed. For these designs, temporary steel piling will be used to support the sidewalls, in locations where the sidewalls will not support themselves. Like the foundation, the sides of the design will be permeable.

Where site conditions do not provide a stable sidewall, metal shoring (or casing in the case of the borehole technology) will be used to hold the sidewalls of the trench open during construction and waste placement. In the process of physically closing a trench, the zone above the waste will be backfilled with native material and the metal shoring will be removed above the waste disposal zone. The native backfill will be placed in lifts and compacted to native soil densities. Pulling the shoring and backfilling the trench will be done to insure that the soil conditions above the waste are similar to the original, undisturbed soil conditions.

The shoring will be pulled to eliminate any potential “fast flow” paths that may develop along the sides of the steel shoring. These fractures or flow paths along the sides of the shoring could develop as a result of bumping the shoring with construction equipment during closure or due to differential thermal expansion or movement. Such preferential flow paths would allow the rapid movement of water from the surface to the disposal horizon. Pulling the shoring will also eliminate possible fast flow paths for gas flow from the waste to the surface, and pulling the shoring will eliminate preferential paths for root intrusion into the waste disposal zone.

When the soil column above the waste is hydrologically homogeneous on the scale of the disposal system, infiltrating surface water forms a uniform, stable wetting front that moves downward parallel to the soil surface. However, fast flow, via fractures, and cracks could cause much more rapid “preferential” transport, than the transport based on average soil properties.

An analysis of tracer data in a field study found that the preferential flow component of recharge was minimal in unconsolidated alluvial tracts and that preferential flow recharge process contributes very significantly (an average of 75% of total recharge) in the case of fractured materials such as granites (Sukhija et al. 2003). Stated generally, the presence of fractures and other channel-like openings in the vadose zone poses a particularly significant problem, because such features are potential avenues for rapid transport of water and contaminants (Hendrickx et al. 2001). In summary, pulling the shoring from above the disposal zone insures that the hydrogeologic conditions above the waste will be similar to the native hydrogeologic conditions with no fast-flow paths.

While the AMCs/SAMCs are heavy, they are strong, durable and will not collapse (Herrick et al. 2007). This enhances the long-term stability of the facility. On the other hand, some of the waste will be packaged in 55-gallon drums, which cannot be considered strong and durable. It is likely that, if the containers have voids, the 55-gallon drums will collapse over long timeframes (Herrick et al. 2007).

Both the ENSD-Trench and IDBD presented in this report include a backfill material to enhance long-term stability of the site. Waste containers will be placed in layers, called "lifts." Backfill material would be placed around the waste containers to fill any voids between containers. Cohesionless fill, such as sand has been selected as a backfill material. Sand is strong, durable, long lived, inexpensive and permeable. Further, for waste in 55-gallon drums, limiting the amount of void space in the waste will promote long-term site stability.

## 2.3 TRENCH WIDTHS AND BOREHOLE DIAMETERS

A conventional LLW disposal trench is typically wide and relatively shallow. This typical wide/shallow configuration allows the operator to transport containers one-by-one into the trench with a forklift and efficiently stack the containers in order to save space. However, this is not the case for the ENSD trenches or the IDBD boreholes.

The ENSD trenches are narrow and deep (3 m in width and 10 m in depth). The ENSD-Trench and IDBD conceptual designs require the lowering of waste packages using a crane. When lowering packages with a crane, it is more efficient to place a bundle of several waste containers in the disposal system, rather than placing containers one-at-a-time. It would be extremely difficult to place several waste containers side-by-side in a 30 to 70 m (100 to 230 ft) deep borehole, unless the waste packages are bundled together before lowering them into the disposal system.

Bundling involves physical grouping individual containers together. The containers can be bundled in a variety of configurations ranging from three-pack to seven-pack configurations. Bundling allows for efficient packing. Bundling also increases the stacking stability of the packages. Multiple package configurations are less likely to turn over than a single container placed within a trench or borehole. So, the concept of bundling the waste is driven by the way waste will be emplaced in the trenches and boreholes.

The bundling configuration that would be implemented in the actual disposal facility could be optimized by taking into consideration several factors such as the total weight of a bundle, the external dose rate and the cost to construct trenches/boreholes of various widths/diameters.

Currently, the WIPP manages and disposes of transuranic (TRU) waste packaged in 55-gallon drums configured as seven-packs. A seven-pack of 55-gallon drums has a diameter of 1.83 m (~ 6 ft). Utilizing the seven-pack configuration greatly reduces the number of

bundled units that must be managed. The WIPP example has shown that bundling 55-gallon drums in seven-packs is stable, stackable and very workable.

The ENSD trench width and the IDBD borehole diameter were selected to accommodate seven-packs of 55-gallon drums. The ENSD trench width needs to be larger than the diameter of the seven-pack (1.83 m) to accommodate imperfections in the constructed trench, to accommodate slightly larger package diameters (e.g., SAMCs) and to allow room for placement and compaction of backfill. For these reasons, 3 m (10 ft) was selected as the width of the ENSD trench.

A diameter of 2.44 m (8 ft) was selected for the borehole design by adding 0.3 m (1 ft) on all sides of the 1.83 m (~ 6 ft) seven-packs; this diameter will allow room for placement of waste package bundles and adequate backfill.

The seven-pack configuration of AMCs/SAMCs/RH canisters is very stable and tip resistant. Using the seven-pack configuration for AMCs/SAMCs/RH canisters has advantages in terms of vertical stability and overall handling efficiency (i.e., handling fewer packages), but the seven-pack configuration for AMCs/RH canisters has disadvantages in terms of potentially high dose rates or very heavy bundles (for a seven-pack of AMCs/SAMCs/RH canisters). As a result, a smaller bundle may be warranted for lowering AMCs/SAMCs/RH canisters into the disposal system. The AMCs/SAMCs/RH canisters could be lowered in as 3-packs, and combined as two 3-packs in the disposal system (see Figure 8 for an example of a “two 3-pack” disposal configuration). The trench width and borehole diameter are designed to accommodate seven-packs of 55 gallon drums, AMCs, SAMCs and RH canisters, even if operationally, some of the containers are lowered as 3-packs.

Except for the $^{137}$Cs irradiators, all of the GTCC LLW packages have similar diameters, ranging from 24 to 28 inches (0.61 to 0.71 m). This means that the outer diameters of a seven-pack of 55-gallon drums is very similar to the outside diameter of a seven-pack of RH canisters or a seven-pack of AMCs/SAMCs. Because they are square and very heavy, it is assumed that the $^{137}$Cs irradiators would be disposed of in four-packs approximately 50 inches (1.27 m) on a side.

The maximum diameter of a seven-pack is 84 inches (2.1 m) for the AMCs/SAMCs. Therefore, both the ENSD and IDBD conceptual designs would accommodate seven-packs that are 84 inches (2.1 m) in diameter.

## 3. ENHANCED NEAR SURFACE DISPOSAL CONCEPTUAL DESIGN

One basic conceptual design and a variation of the basic design have been developed for the conceptual ENSD-trench facility. The design variations are intended to allow implementation of the ENSD facility in either consolidated or unconsolidated environments. In general, land disposal sites that should be considered for the ENSD-trench technology should have a minimum depth to water many meters greater than the depth of the trench bottom.

## 3.1 BASIC DESIGN

The basic design for the conceptual ENSD-trench facility utilizes trenches that are three (3) m wide, 10 m deep, and 100 m long. The trench width was selected to allow disposal of the largest disposal package as described in Section 2.3. Trench depth was chosen to optimize 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 the basic trench design (Figure 3) illustrates the trench design features, dimensions, and the anticipated layers of future waste placement.

The side walls of the trench will be vertically constructed. A well compacted material will be placed on top of the native material in the floor of the trench. A layer of sand (0.3 meters) will be placed on top of the compacted material.

The floor of the trench will be constructed so that it is permeable, in order to prevent water from possibly accumulating in the bottom of the trench (i.e., to prevent "bathtubbing"). Liners and/or a leachate collection/monitoring system could be placed in a LLW disposal system, but liners and leachate collection/monitoring systems are not required components of NRC or DOE regulated LLW disposal systems. For example, the Final EIS for the regulation governing land disposal of NRC-regulated LLW disposal systems states that:

> *Reducing the contact time of water with the waste by using freely-draining granular backfill should be considered. In addition, the accumulation of water in the disposal unit (the bathtub effect) must be avoided. This can normally be accomplished if the bottom of the disposal unit can drain at least as readily as water can infiltrate into the disposal unit through the cover or sides…* (U.S. NRC, NUREG-0945, Vol. 1, p. 5–14) (NRC 1982).

Also, for NRC regulated LLW disposal systems, the NRC requires long-term system stability – without active institutional control. (see 10 CFR 61.7(b)(2), 61.12(b), 61.13(d) and 61.59(b)) A leachate collection/monitoring system requires long-term active institutional controls. DOE Manual 435.1-1 IV.M(3)(d) states that LLW disposal facilities shall be designed to minimize to the extent practical, the contact of waste with water after disposal; thus advocating the use of free-draining granular backfill material to minimize the likelihood of water accumulating in the bottom of the disposal system.

The trench sidewalls will be constructed with temporary metal shoring. The metal shoring will be removed when the trench is closed.

The waste packages will be placed into the trench and a fine-grained cohesionless fill (sand) will be used to backfill around the waste containers to fill voids. After the trench has been filled with the waste containers and backfill, a subsurface deflection shield, as described in Appendix A will be placed over the waste packages. It is anticipated that clean fill from the construction would be used to backfill the trench above the subsurface deflection shield. The backfill would be screened to remove large diameter rock and vegetative materials, as required. The backfill will be placed in lifts and compacted to prevent future subsidence and insure long-term site stability. The ENSD trench design

presented in this report will place waste packages a minimum of 5 m (16 ft) below the land surface. An ENSD system would be further optimized to meet specific design requirements developed for the actual disposal option chosen and the minimum depth of burial could be greater than 5 m.

The dimensions of the trench enable a sheet piling to be placed over the trench during construction and waste placement. This temporary cover would prevent unwanted intruders and precipitation from entering the trench during the placement of the waste containers.

The trench would be excavated to the pre-determined depth and all materials obtained during trench excavation are assumed to be clean and available for re-use. Soils generated during trench excavation would be stored within the project site. Soils would be stockpiled for re-use as clean fill material in stockpiles that are no greater than seven meters tall. Stockpiled soil would not be stored on liner or other synthetic material, as it would be clean materials. In arid climates, where wind may be a factor, dust suppression would be conducted on an as needed basis.

For waste requiring remote handling, an additional feature is envisioned for the basic trench. The additional feature, a series of concrete culverts placed in the trench for worker protection during handling is described in *GTCC LLW Environmental Impact Statement: Construction Data Associated With An Earthen Berm And In-Trench Disposal Cells For Use At An ENSD Facility (SNL 2007b)*.

## 3.2 DESIGN VARIATIONS

### 3.2.1 Variation A

The basic ENSD-trench facility design with metal shoring can be implemented in unconsolidated environments. Variation A utilizes the Basic Design principles discussed in Section 3.1 (above) however, metal shoring is not required due to the presence of competent rock trench sidewalls. This design is referred to as ENSD Variation A throughout this document.

## 3.3 DISPOSAL CAPACITY

The basic ENSD facility trench design accommodates the package types discussed in Section 2.2 as shown in Table 1.

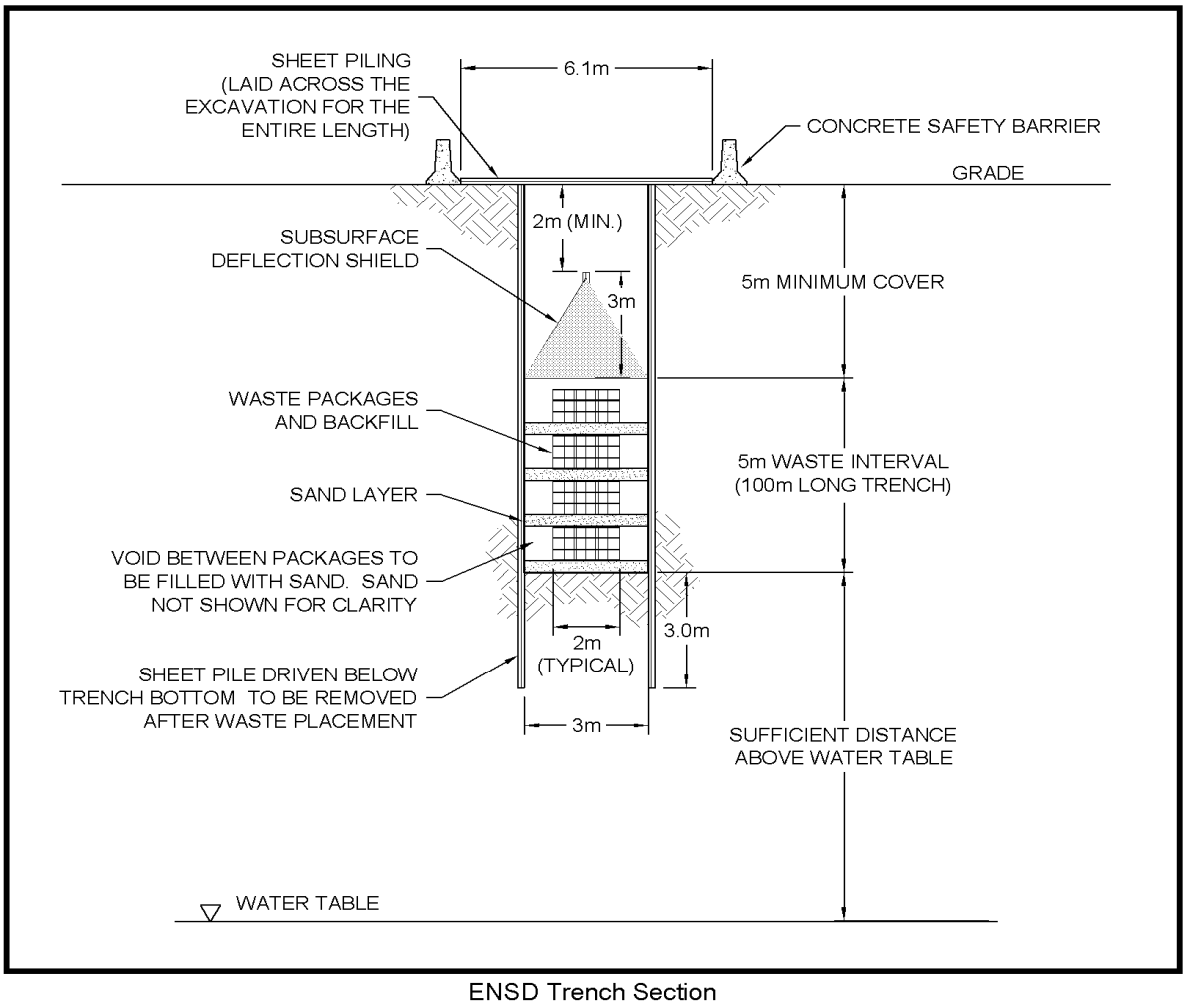


Figure 3. Conceptual Drawing of the ENSD Basic Trench Design

The basic ENSD facility trench design has a five meter thick disposal zone. Given the dimensions of the 55-gallon drums, four layers can be stacked in the trench resulting in a disposal capacity of 200 seven-packs of 55-gallon drums in a trench (Figure 5). Given the dimensions of the four-packs of cesium irradiators, three layers can be stacked in the trench resulting in a disposal capacity of 180 four-packs of cesium irradiators in a trench (Figure 6). Given the dimensions of the half-SAMCs, three layers can be stacked in the trench resulting in a disposal capacity of 150 seven-packs of half-SAMCs in a trench (Figure 7). Given the dimensions of the AMCs/SAMCs and the RH canisters, only one layer of these disposal packages can be placed in a trench as shown in Figure 8. This allows for disposal of 90 three-packs of RH canisters or AMCs/SAMCs in a trench. The disposal capacities of the ENSD Trench are summarized in Table 2.

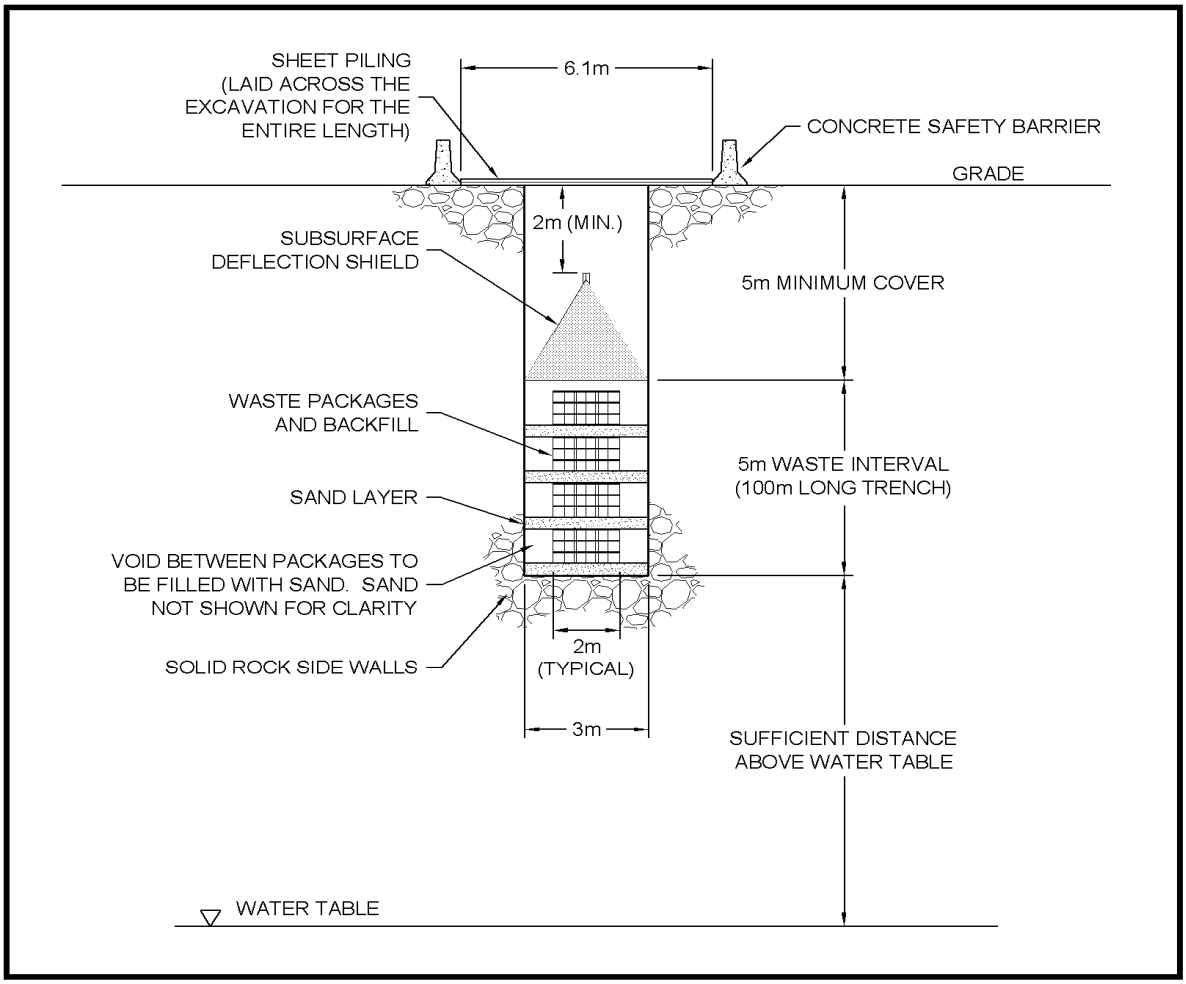


Figure 4. Conceptual Drawing of the ENSD Trench Design Variation A

Table 2. Disposal Capacity for the ENSD Facility Trenches

| Package Type | Disposal Configuration | # waste intervals | packs per layer | # container per layer | # container per trench | Packs per trench |
|---|---|---|---|---|---|---|
| 55-gallon drums | 7-pack | 4 | 50 | 350 | 1400 | 200 |
| AMCs/SAMCs | Two 3-packs | 1 | 45 | 270 | 270 | 45 |
| Half-SAMCs | 7-pack | 3 | 50 | 350 | 1050 | 150 |
| RH Canisters | Two 3-packs | 1 | 45 | 270 | 270 | 45 |
| $^{137}$Cs Irradiators | 4-pack | 3 | 60 | 240 | 720 | 180 |

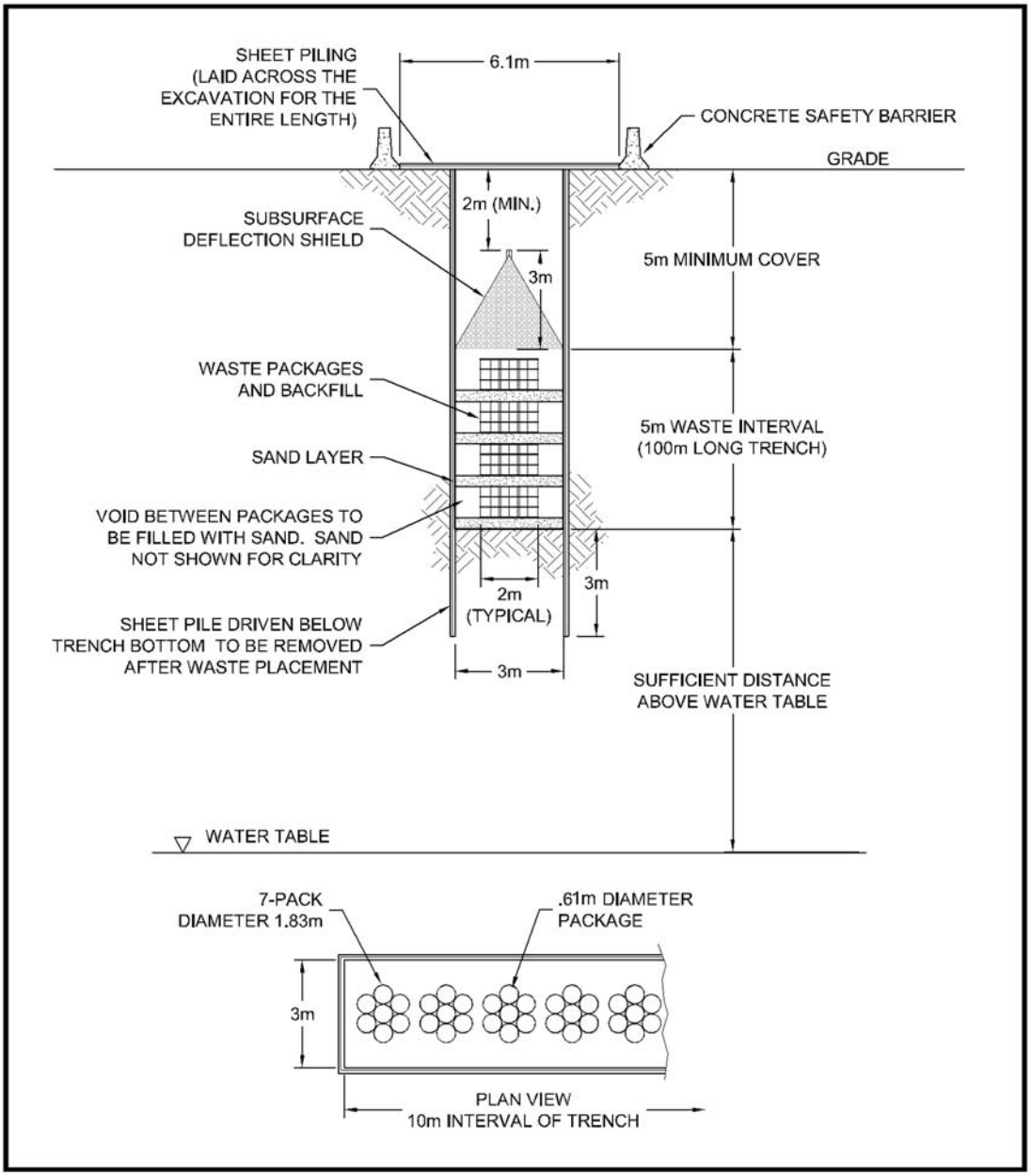


Figure 5. Emplacement of 55-gallon drums in an ENSD Facility Trench

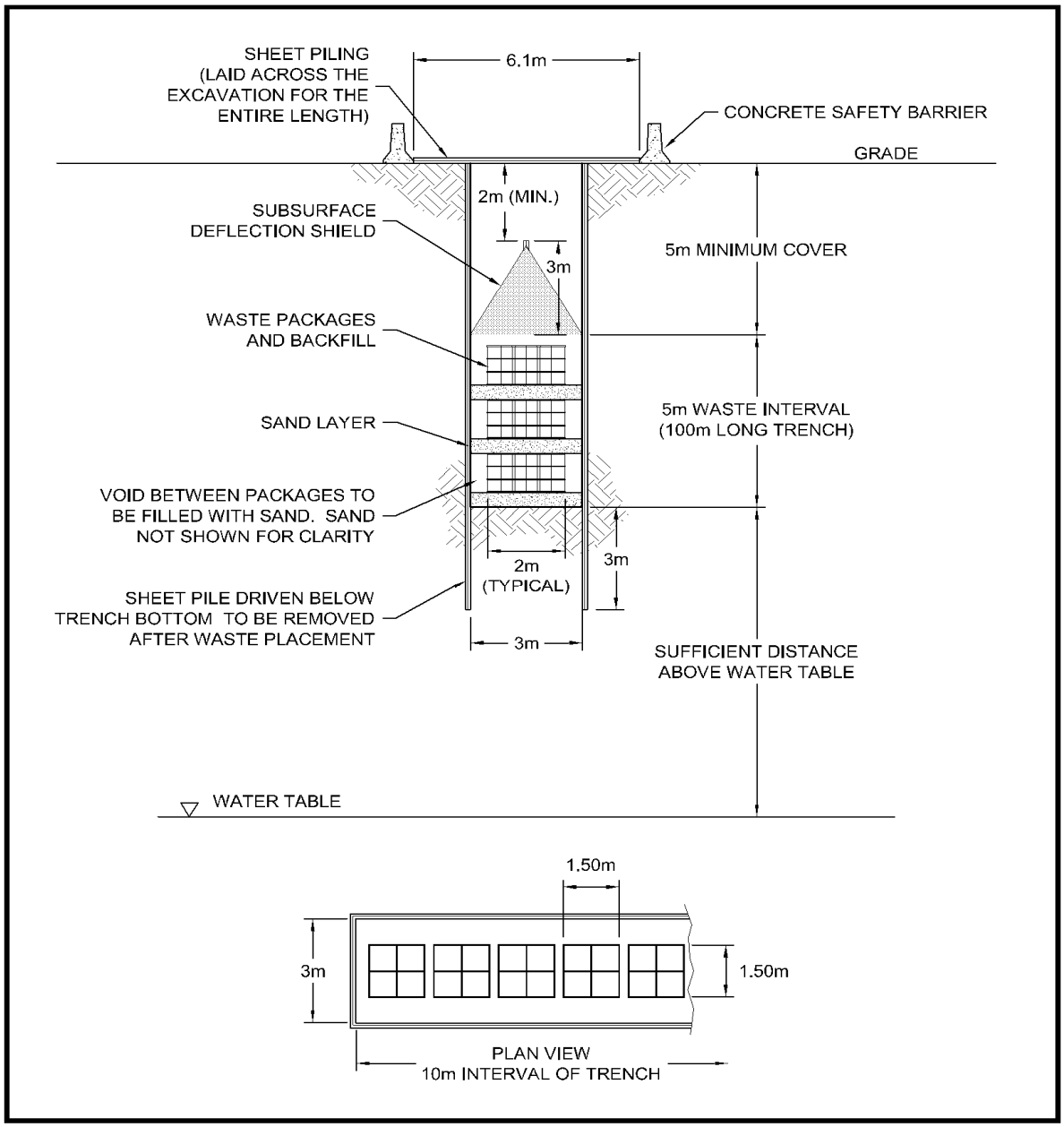


Figure 6. Emplacement of $^{137}$Cs irradiators in an ENSD Facility Trench

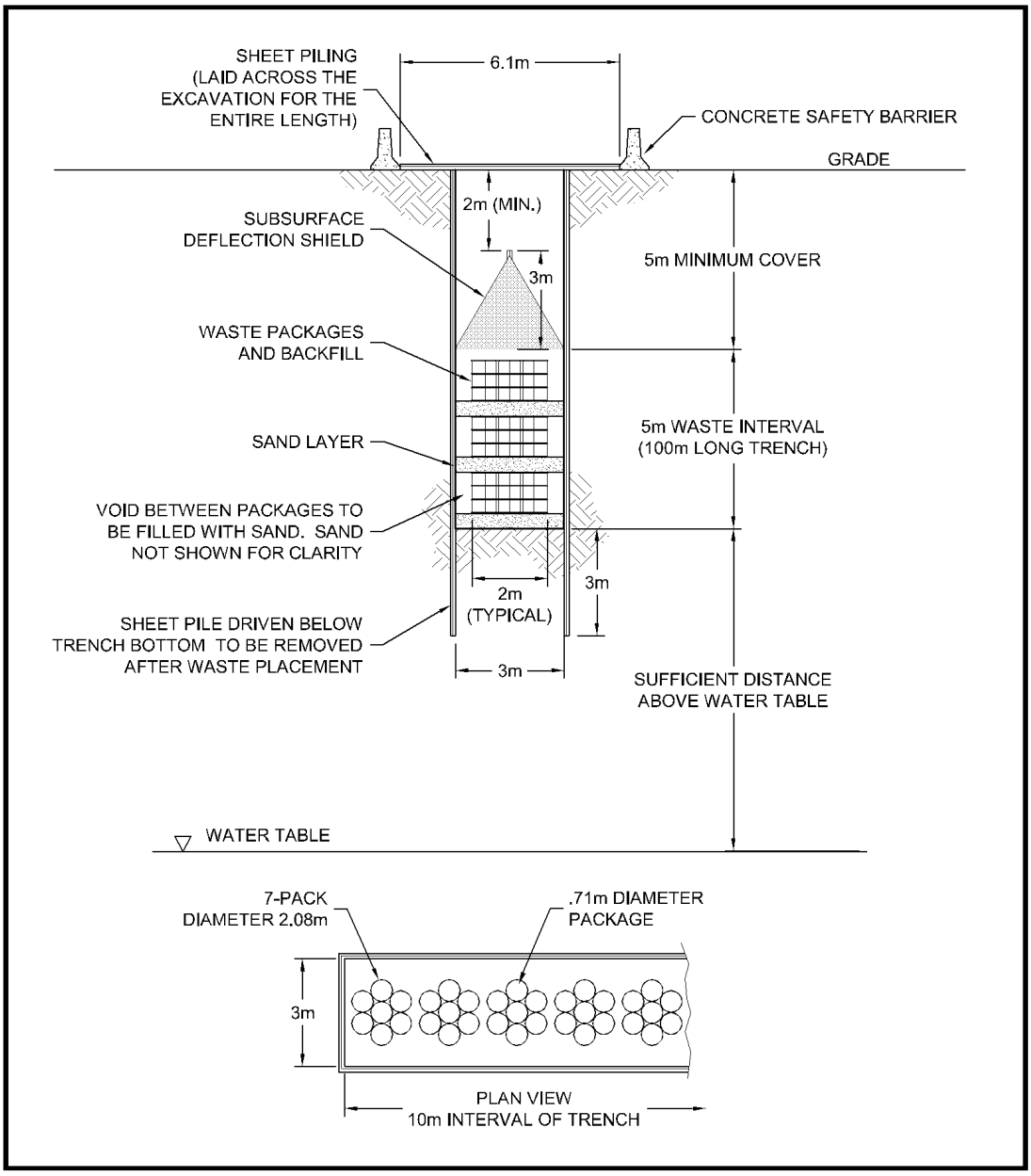


Figure 7. Emplacement of half-SAMCs in an ENSD Facility Trench

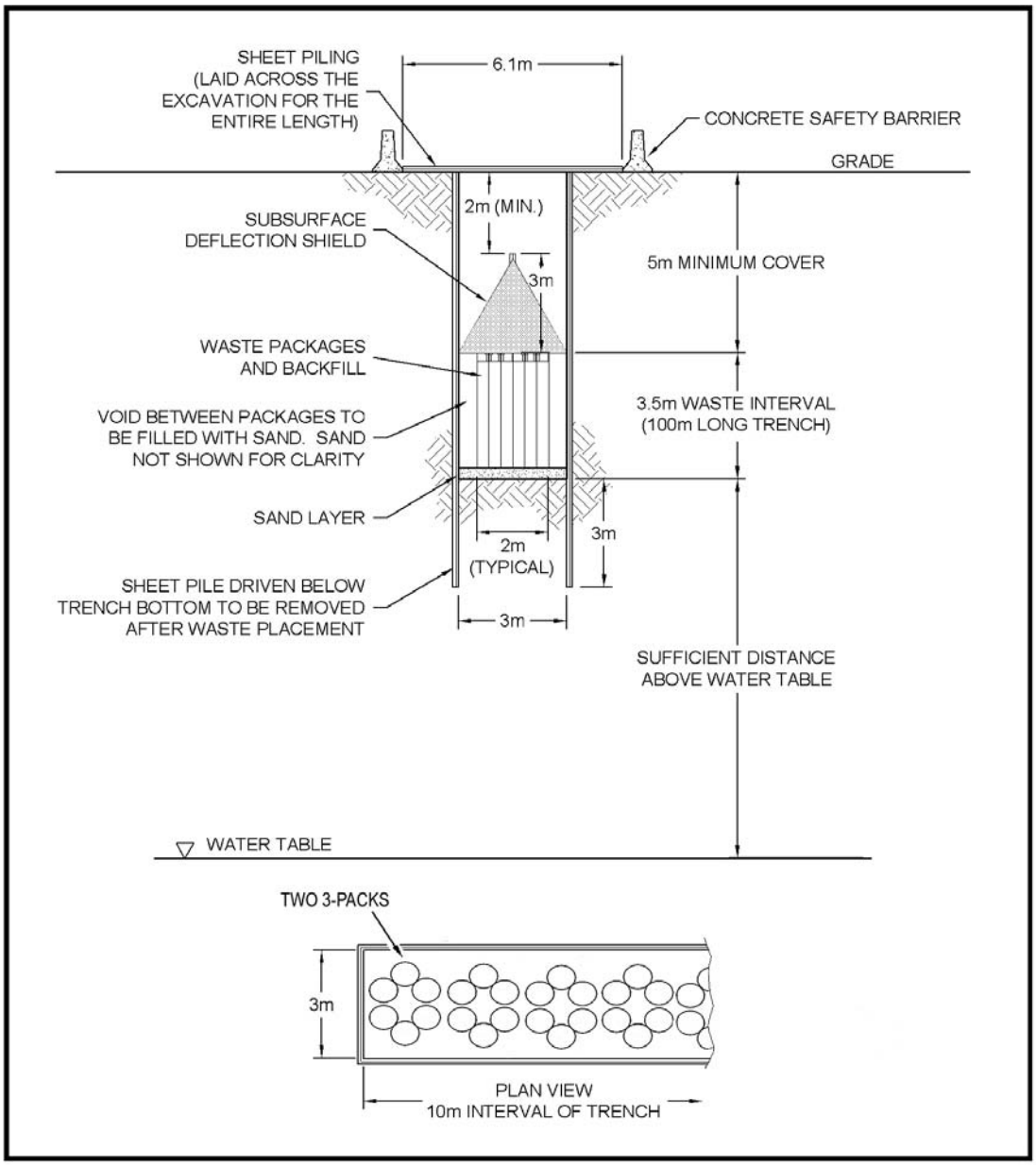


Figure 8. Emplacement of AMCs, SAMCs, and RH Canisters in an ENSD Facility Trench

# 4. INTERMEDIATE DEPTH BOREHOLE DISPOSAL CONCEPTUAL DESIGN

One basic conceptual design and two variations have been developed for the IDBD facility. Based on site specific conditions, including subsurface geology and depth to groundwater, one of the design variations would be pared with individual land disposal sites for evaluation in the EIS. The design variations are intended to allow implementation of the IDBD facility in either consolidated or unconsolidated environments. In general, the land disposal sites considered for this technology should have a depth to water greater than the total borehole completion depth.

## 4.1 BASIC DESIGN

The basic design for the IDBD facility utilizes boreholes that are 2.44 meters in diameter and 70 meters deep. The borehole diameter was selected to allow disposal packages described in Section 2.2. Borehole depths depend primarily on the subsurface geology and were chosen to optimize disposal capacity per borehole within the practical limits of commercially available drilling equipment. The maximum borehole depth would be optimized for such factors as site hydrogeology, cost and performance considerations. The conceptual design of the basic borehole (Figure 9) depicts the borehole design features, dimensions, and the layers of the future waste placement.

A surface completion (six meters in diameter, one and a half meters deep) would be placed around the borehole. The first 0.75 m of the surface completion would include a concrete collar around corrugated metal pipe. The metal pipe would be secured using a bentonite grout below the concrete collar. The surface completion would also include a lockable steel lid. Figure 10 shows the drilling of a large diameter borehole with a corrugated metal surface casing.

Approximately 0.3 meters of sand or gravel would be placed in the bottom of the borehole in order to provide a smooth foundation to place the initial layer of waste containers. Once the initial waste containers are placed into the borehole, sand would be placed around the waste packages to fill void spaces. An additional 0.3 meters of sand would be placed over the waste packages prior to the placement of the next layer of waste packages. A final layer of sand would be emplaced on top of the waste packages prior to the installation of the subsurface deflection shield. A subsurface deflection shield as described in Appendix A would be placed in each borehole. It is anticipated that clean fill from the borehole construction would be used to backfill the borehole above the subsurface deflection shield. The backfill would be screened to remove large diameter rock and vegetative materials, as required, brought to an appropriate moisture content, placed in lifts, and compacted.

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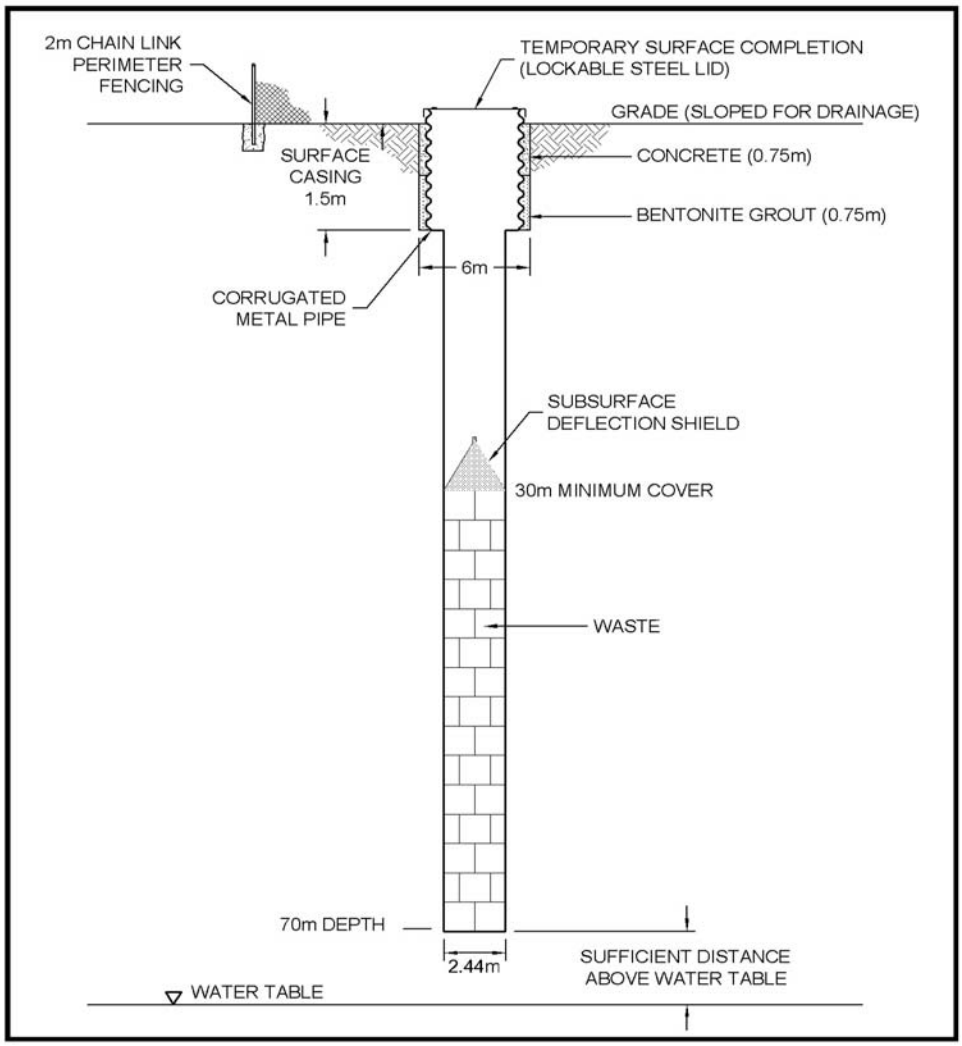


Figure 9. Conceptual Drawing of the IDBD Facility Borehole Basic Design

Figure 10. Drilling a Large Diameter Borehole with a Corrugated Metal Surface Casing

The borehole would be advanced to the pre-determined depth and all materials (cuttings) obtained during borehole installation are assumed to be clean and available for re-use. Soils generated during borehole installation would be stored within the project site. Soils would be stockpiled for re-use as clean fill material in stockpiles that are no greater than seven meters tall. Stockpiled soil would not be stored on liner or other synthetic material, as it would be clean materials. In arid climates, where wind may be a factor, dust suppression would be conducted on an as needed basis.

In the basic design, a 70-meter borehole would be completed in semi-consolidated sediments which can be accomplished using commercially available drilling equipment and advancement of a smooth, steel casing to depth is not required. Figure 11 is a photograph looking down on uncased, 36 m deep, large diameter borehole. The surface casing would be installed, but a smooth, steel casing would not be installed.

## 4.2 DESIGN VARIATIONS

### 4.2.1 Variation A

It is anticipated that the Basic Design (Figure 9) would be completed in semi-consolidated soil. For unconsolidated soil (Variation A, Figure 12), 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. The upper 30 m of smooth steel casing would be removed upon closure of the borehole.

Figure 11. Photograph of an Uncased, 3-m in Diameter Borehole Drilled 36 m Deep in Weakly-Cemented Gravelly Sand (monitoring devices are embedded in the three instrument strings)

### 4.2.2 Variation B

It is anticipated that 40-meter boreholes would be completed in consolidated material / hard rock (Variation B, Figure 13). Coring equipment is required for borehole construction in consolidated material. Based on information from drilling companies with equipment capable of coring large-diameter boreholes in hard rock, the borehole depth for Variation B was selected to be 40 meters.

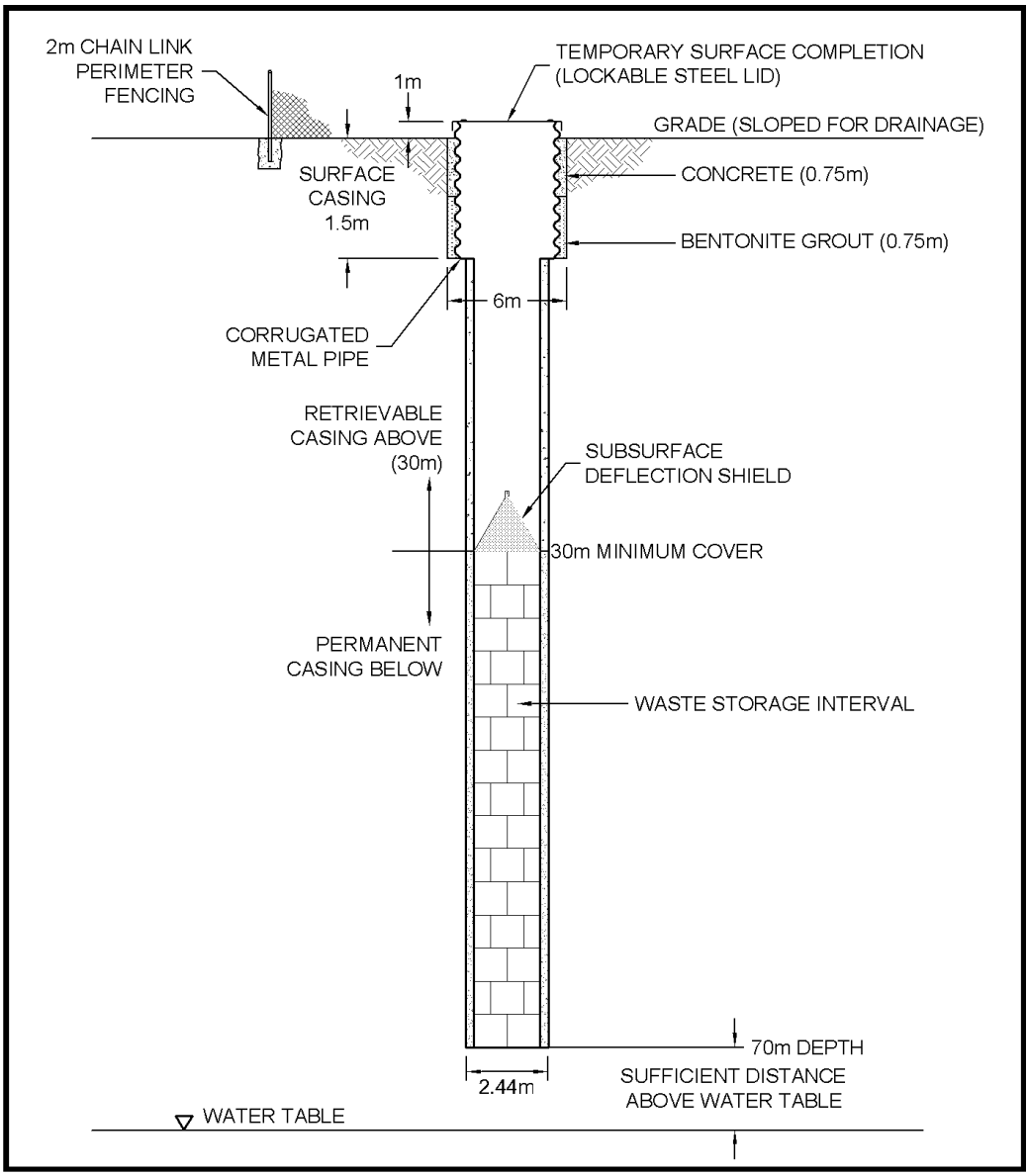


Figure 12. Conceptual Drawing of the IDBD Facility Borehole Variation A

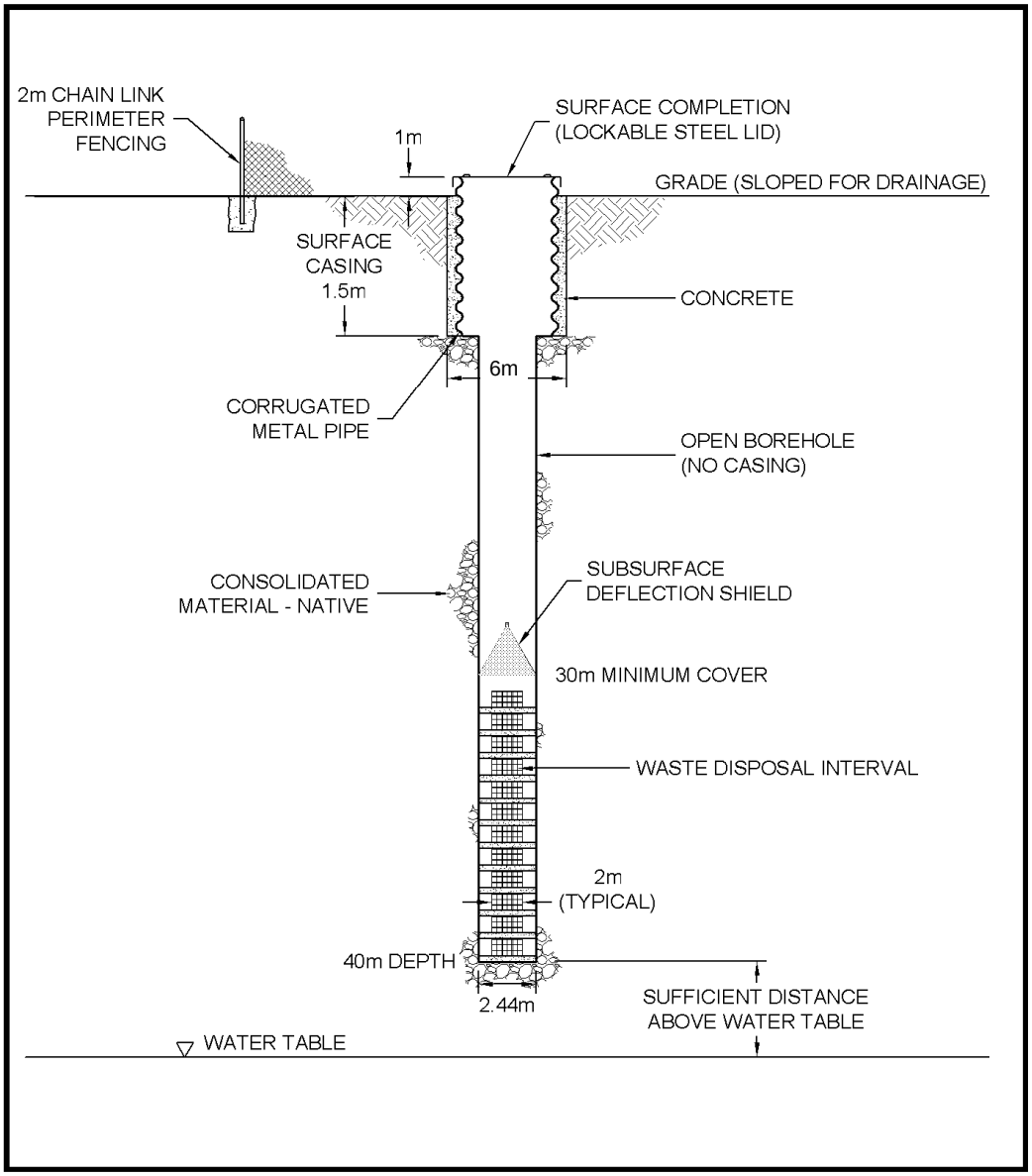


Figure 13. Conceptual Drawing of the IDBD Facility Borehole Variation B

## 4.3 DISPOSAL CAPACITY

The emplacement configuration for seven-packs of 55-gallon drums is shown in Figure 14. The emplacement configuration for four-packs of $^{137}$Cs irradiators is shown in Figure 15. The emplacement configuration for seven-packs of half-SAMCs is shown in Figure 16. The RH canister emplacement configuration is shown in Figure 17, and the emplacement configuration for bundles of AMCs/SAMCs is shown in Figure 18.

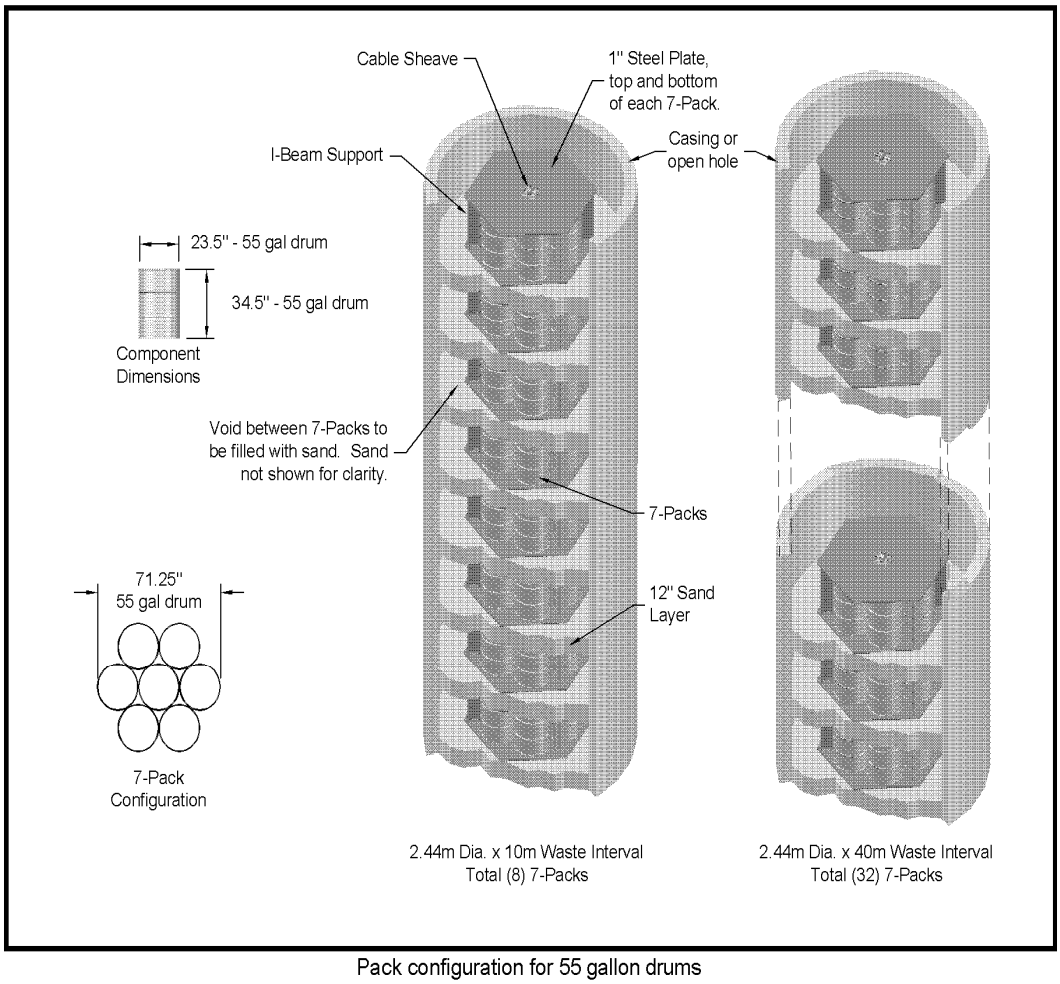


Figure 14. Emplacement of 55-Gallon Drums in a 40 m IDBD Borehole (center) and a 70 m IDBD Borehole (right)

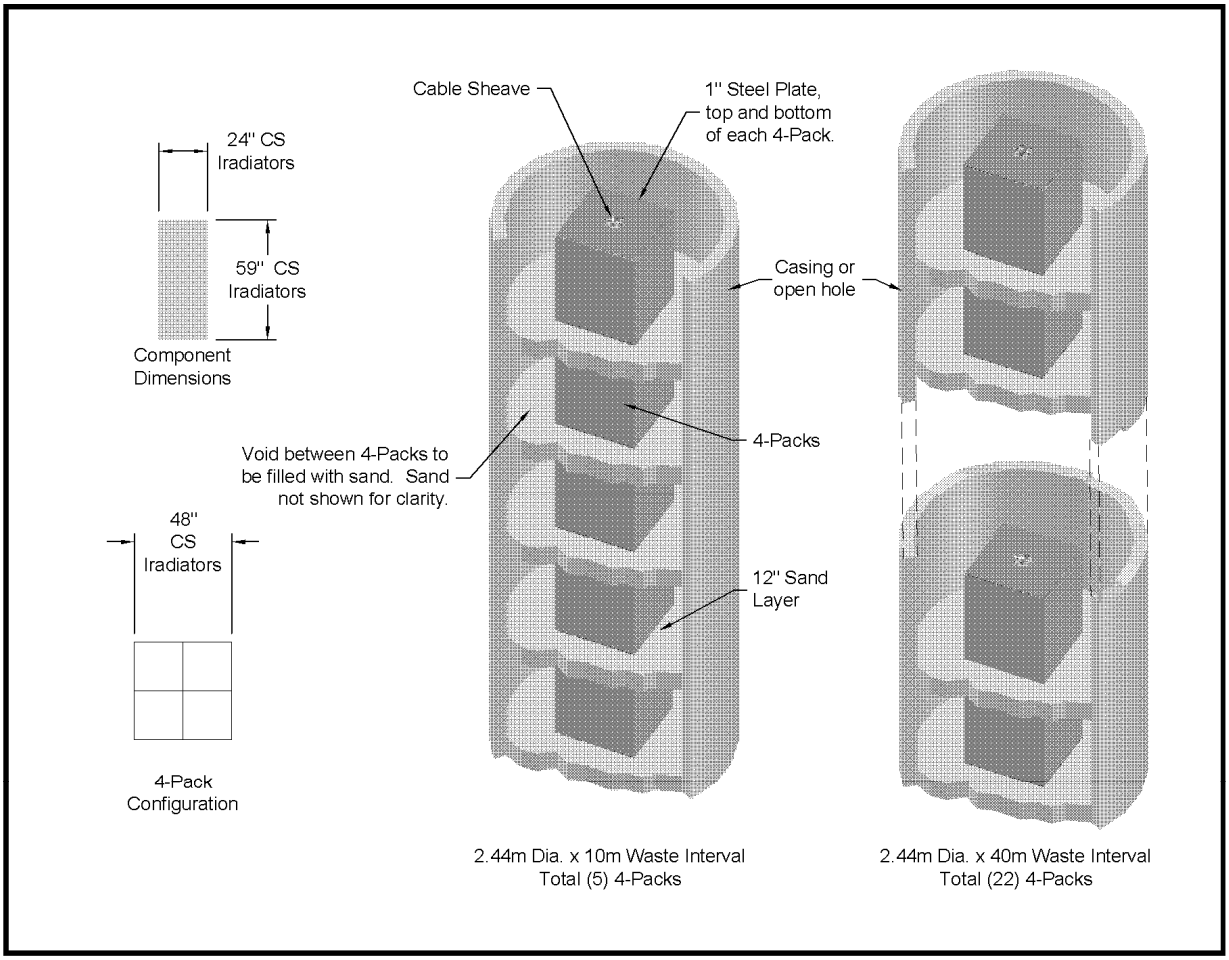


Figure 15. Emplacement of $^{137}$Cs irradiators in an a 40 m IDBD Borehole (center) and a 70 m IDBD Borehole (right)

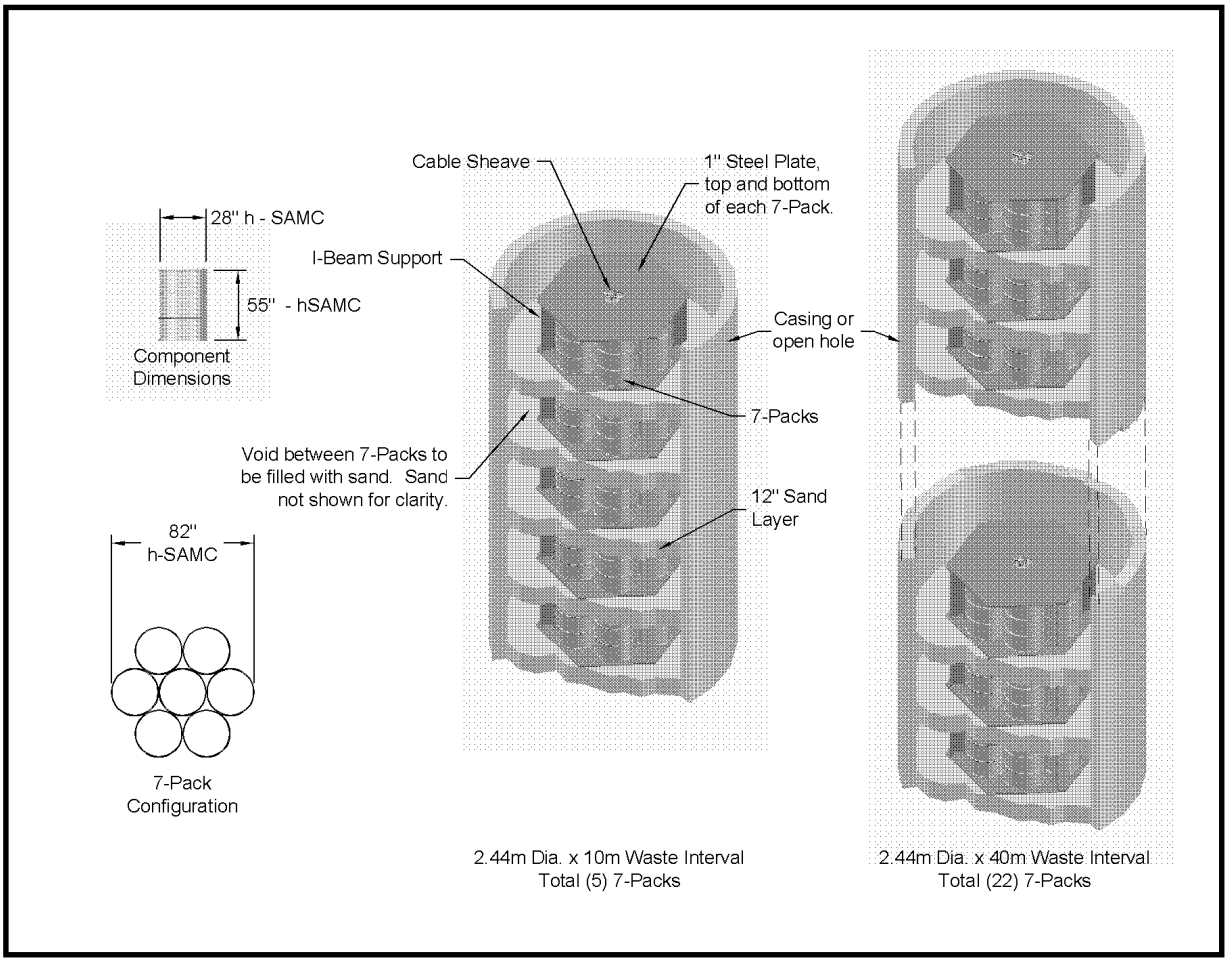


Figure 16. Emplacement of Half-SAMCs in a 40 m IDBD Borehole (center) and a 70 m IDBD Borehole (right)

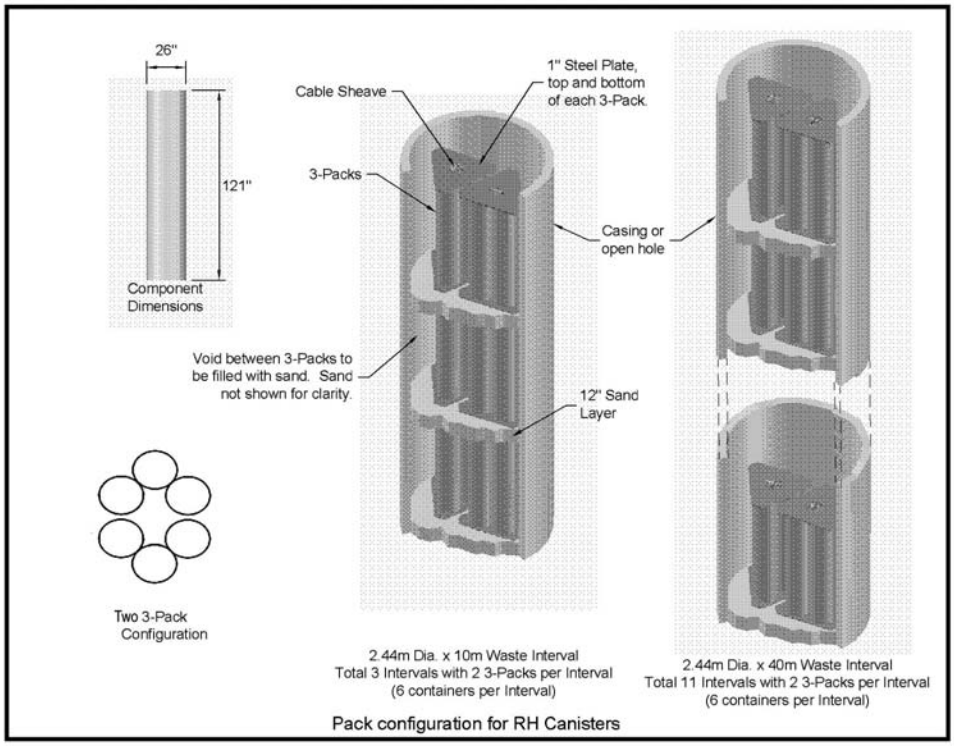


Figure 17. Emplacement of RH Canisters in a 40 m IDBD Borehole (center) and a 70 m IDBD Borehole (right)

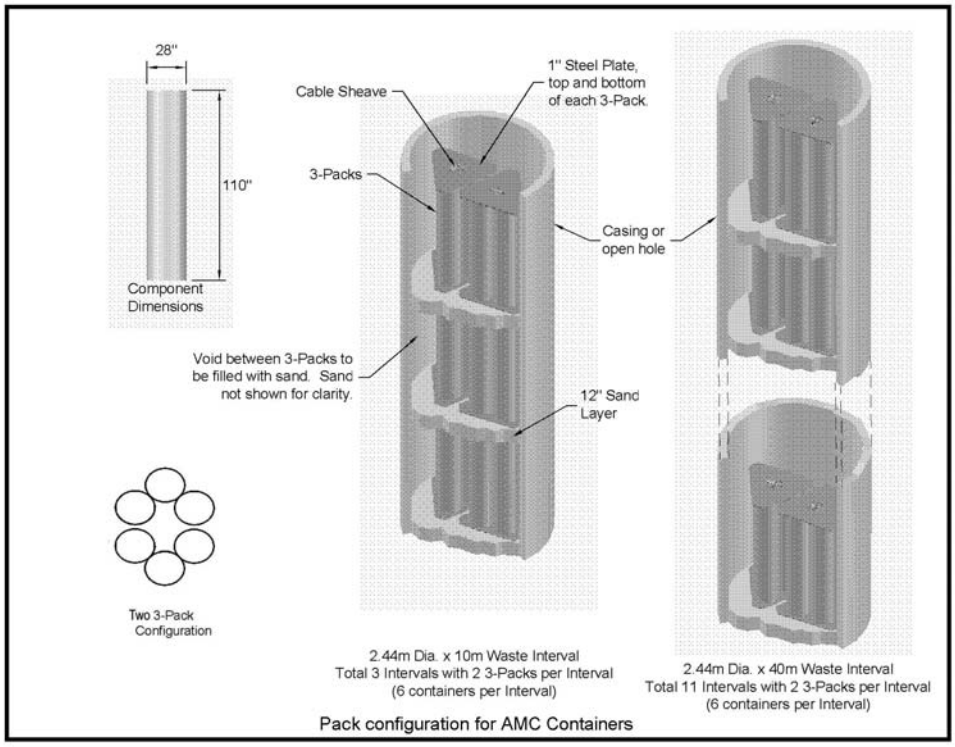


Figure 18. Emplacement of AMC and SAMC Canisters in a 40 m IDBD Borehole (center) and a 70 m IDBD Borehole (right)

The basic IDBD facility borehole design accommodates the package types discussed in Section 2.2 as shown in Table 3. A borehole with a 70-meter depth would be able to accommodate a 40-meter-thick disposal zone. Given the dimensions of the GTCC LLW containers, a 70-m borehole can accommodate 32 waste intervals of 55-gallon drums, 11 waste intervals of AMCs/SAMCs or RH canisters, and 22 waste intervals of half-SAMCs and $^{137}$Cs irradiators. A 40-meter borehole (Table 4) would accommodate a 10-meter-thick disposal zone. Given the dimensions of the GTCC LLW containers, a 40-m borehole can accommodate 8 waste intervals of 55-gallon drums, 3 waste intervals of AMCs/SAMCs or RH canisters, and 5 waste intervals of half-SAMCs and $^{137}$Cs irradiators.

Table 3. Per Borehole Disposal Capacity for the IDBD Facility – 70 m Boreholes

| Package Type | Disposal Configuration | # waste intervals | packs per interval | # container per interval | # container per borehole | Packs per borehole |
|---|---|---|---|---|---|---|
| 55-gallon drums | 7-pack | 32 | 1 | 7 | 224 | 32 |
| AMCs/SAMCs | Two 3-packs | 11 | 1 | 6 | 66 | 11 |
| Half-SAMCs | 7-pack | 22 | 1 | 7 | 154 | 22 |
| RH Canisters | Two 3-packs | 11 | 1 | 6 | 66 | 11 |
| $^{137}$Cs Irradiators | 4-pack | 22 | 1 | 4 | 88 | 22 |

Table 4. Per Borehole Disposal Capacity for the IDBD Facility – 40 m Boreholes

| Package Type | Disposal Configuration | # waste intervals | packs per interval | # container per interval | # container per borehole | Packs per borehole |
|---|---|---|---|---|---|---|
| 55-gallon drums | 7-pack | 8 | 1 | 7 | 56 | 8 |
| AMCs/SAMCs | Two 3-packs | 3 | 1 | 6 | 18 | 3 |
| Half-SAMCs | 7-pack | 5 | 1 | 7 | 35 | 5 |
| RH Canisters | Two 3-packs | 3 | 1 | 6 | 18 | 3 |
| $^{137}$Cs Irradiators | 4-pack | 5 | 1 | 4 | 20 | 5 |

# 5. SUBSURFACE CONSTRUCTION DATA FOR THE ENSD AND IDBD FACILITIES

This report presents information on two specific disposal technology conceptual designs that may be used to dispose of GTCC LLW, the ENSD and the IDBD designs. The focus of the report is the subsurface construction phase for the disposal facilities. For an ENSD facility, subsurface construction is construction of the trenches for waste disposal. It does not include construction of permanent surface facilities or operations during waste disposal. Similarly, for an IDBD facility, subsurface construction is construction of the boreholes for waste disposal and does not include construction of permanent surface facilities or operations during waste disposal. These ENSD and IDBD conceptual designs provide the building blocks that will be used to conceptually assemble entire disposal facilities in the Task 3.6 reports.

The ENSD conceptual design builds on the current practice for disposal of LLW, but is enhanced in two ways. First, the ENSD technology conceptual design places wastes between 5 and 10 m below the land surface. Second, a subsurface deflection shield that will limit biotic transport, hydraulic transport, and manual transport (via drilling) of material is recommended. The trenches will be approximately 3 m wide which will accommodate the expected package types and configurations. Development of corresponding construction data for the trench option is detailed in Appendix B. To derive appropriate per unit values (resources, wastes, emissions, costs, durations, and man-hours) for construction of an ENSD facility, the one-time values (e.g. mobilization costs and costs to build a temporary access road) are averaged across five ENSD trenches that are 100 m long. The five, 100 m long ENSD trenches are not linked to the volume of GTCC LLW and five trenches were selected only to derive appropriate per unit values; the actual cost to construct and operate an ENSD facility will be developed in Task 3.6. Five trenches were selected because the one-time costs (on a per-trench basis) do not change significantly when averaged over more than five trenches (see Figure 19). Operational details, e.g., operational practices for managing high-exposure rate waste packages, are also presented in the Task 3.6 reports.

The IDBD conceptual design builds on a design that has been used to dispose waste much like GTCC LLW (Cochran et al. 2001), but is enhanced in three ways. First, waste is placed a minimum of 30 m below the land surface. Second, a subsurface deflection shield will limit biotic transport, hydraulic transport, and manual transport (via drill cuttings). Third, the waste acceptance criteria and the method of waste and backfill emplacement will prevent future subsidence. The boreholes will be approximately 2.44 m in diameter which will accommodate the expected package types and configurations. The maximum depth of the IDBD conceptual design will depend on the lithology and the depth to the groundwater. Development of corresponding construction data for the borehole option is detailed in Appendix C. To derive appropriate per unit values

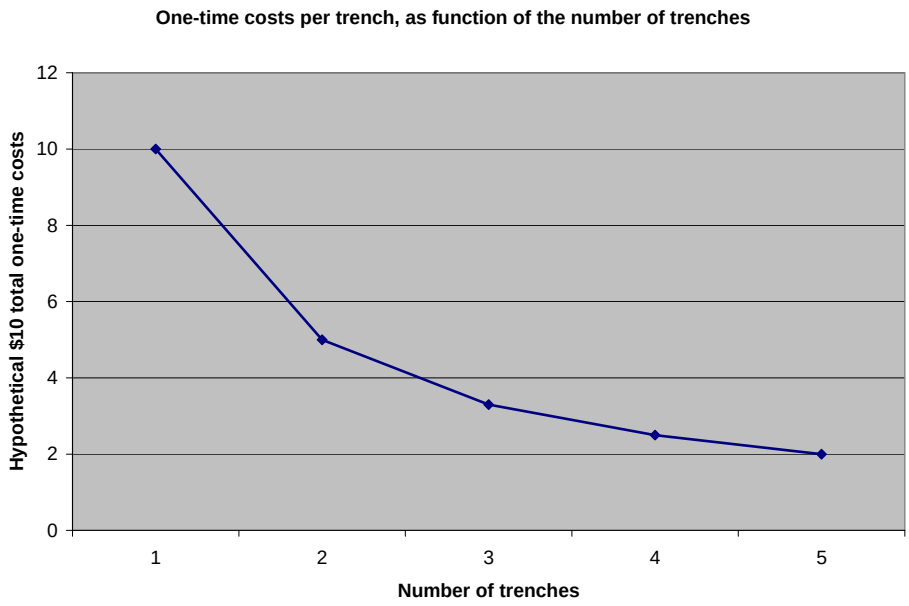


Figure 19. One-Time Costs per Trench as a Function of the Number of Trenches

(resources, wastes, emissions, costs, durations, and man-hours) for construction of an IDBD facility, the one-time values (e.g. mobilization costs and costs to build a temporary access road) are averaged across fifty IDBD boreholes that are either 70 m or 40 m deep. The fifty boreholes are not linked to the volume of GTCC LLW and fifty boreholes were selected only to derive appropriate per unit values; the actual cost to construct and operate an IDBD facility will be developed in Task 3.6. Fifty boreholes were selected because the one-time costs (on a per-borehole basis) do not change significantly when averaged over more than fifty boreholes. Operational details, e.g., operational practices for managing high-exposure rate waste packages, are also presented in the Task 3.6 reports.

## 5.1 LAND USE

Table 5 is a summary of the land use information from Appendix B and Appendix C.

Table 5. Average Land Area Needed for Construction of an Individual Trench or an Individual Borehole[a]

| | Total Land Area (hectares) | Disturbed Land Area (hectares) | Fenced Area (hectares) | Paved Area (hectares) |
|---|---|---|---|---|
| **Per Trench[b]** | 0.94 | 0.68 | 0.84 | 0 |
| **Per Borehole[c]** | 0.094 | 0.068 | 0.084 | 0 |

[a]Total land area needed for the hypothetical five-trench or fifty-borehole facility, divided by either five or 50. For example, 4.7 hectares is needed for the five trenches and supporting construction activities, and

therefore the land area per trench is 0.94 hectares (4.7 divided by 5). Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]For either 40 m or 70 m boreholes. Summary of information from Appendix C

## 5.2 CONSTRUCTION EQUIPMENT, RESOURCE AND MATERIAL REQUIREMENTS

Table 6 is a summary of the heavy equipment inventory from Appendix B and Appendix C. Table 7 is a summary of the resource requirements from Appendix B and Appendix C. Table 8 is a summary of the material requirements from Appendix B and Appendix C.

Table 6. Heavy Equipment Required for Construction of Individual Trenches and Boreholes[a]

| | ENSD Facility[b] | | IDBD Facility[c] | |
|---|---|---|---|---|
| **Equipment** | **Quantity** | **Horsepower (hp)** | **Quantity** | **Horsepower (hp)** |
| Excavator | 2 | 330 | 0 | NA |
| Loader | 1 | 197 | 1 | 197 |
| Dozer | 1 | 200 | 1 | 200 |
| Grader | 1 | 220 | 1 | 220 |
| Water Truck | 1 | 280 | 1 | 280 |
| Vibratory Roller | 1 | 60 | 1 | 60 |
| Dump Truck | 1 | 280 | 1 | 280 |
| Driller/Auger | 0 | NA | 1 | 220 |
| Driller/Coring | 0 | NA | 1 | 650 |
| Generator | 2 | 100 | 2 | 100 |
| Crane | 1 | 300 | 1 | 300 |
| Crane/Pile Driver | 1 | 300 | 0 | NA |
| Cement Truck | 1 | 280 | 1 | 280 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

Table 7. Resource Requirements for Construction of Individual Trenches and Boreholes[a]

| **Technology** | **Diesel[a]** | **Water[b]** |
|---|---|---|
| | (liters/trench) | (liters/trench) |
| ENSD- Basic Design[b] | **41,631.66** | 320,200 |
| ENSD- Variation A[b] | **50,575.11** | 320,200 |
| **Technology** | (liters/borehole) | (liters/borehole) |
| IDBD -Basic Design[c] | **36,142.19** | 36,000 |
| IDBD Variation A[c] | **36,142.19** | 365,000 |
| IDBD Variation B[c] | **71,706.15** | 26,100 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

Table 8. Material Requirements for Construction of Individual Trenches and Boreholes[a]

| Technology | Steel | Concrete |
|---|---|---|
| | (tons/trench) | ($m^3$/trench) |
| ENSD- Basic Design[b] | 700 | 370 |
| ENSD- Variation A[b] | 220 | 370 |
| **Technology** | **(tons/borehole)** | **($m^3$/borehole)** |
| IDBD -Basic Design[c] | 10 | 20 |
| IDBD Variation A[c] | 40 | 20 |
| IDBD Variation B[c] | 10 | 20 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

Figure 20 shows the resource requirements for the construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 20 is waste that is packaged in 55-gallon drums.

The two trench options, ENSD basic design and Variation A, are less resource intensive than the IDBD designs. ENSD basic design, a shored trench, requires 46.4 liters of diesel and 110 deciliters of water per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). The ENSD Variation A, an unshored trench, requires 60 liters of diesel and 110 deciliters of water per cubic meter of waste that can be disposed (for waste package in 55-gallon drums). The IDBD designs range from 247 liters of diesel (basic design and Variation A) to 1876 liters of diesel (Variation B) per cubic meter of waste that can be disposed (for waste package in 55-gallon drums). The IDBD designs range from 77 deciliters of water (basic design and Variation A) to 224 deciliters of water (Variation B) per cubic meter of waste that can be disposed (for waste package in 55-gallon drums).

Figure 21 shows the material requirements for the construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 21 is waste that is packaged in 55-gallon drums. The unshored trench and uncased borehole, ENSD Variation A and IDBD basic design, require less steel than the other designs. ENSD Variation A, an unshored trench, requires 0.64 tons of steel per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). The IDBD basic design, a 70 meter borehole that is not cased to depth, requires 0.2 tons of steel per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). The other designs range from 2.30 tons of steel (ENSD basic design) to 0.8 tons of steel (IDBD Variation B) per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums).

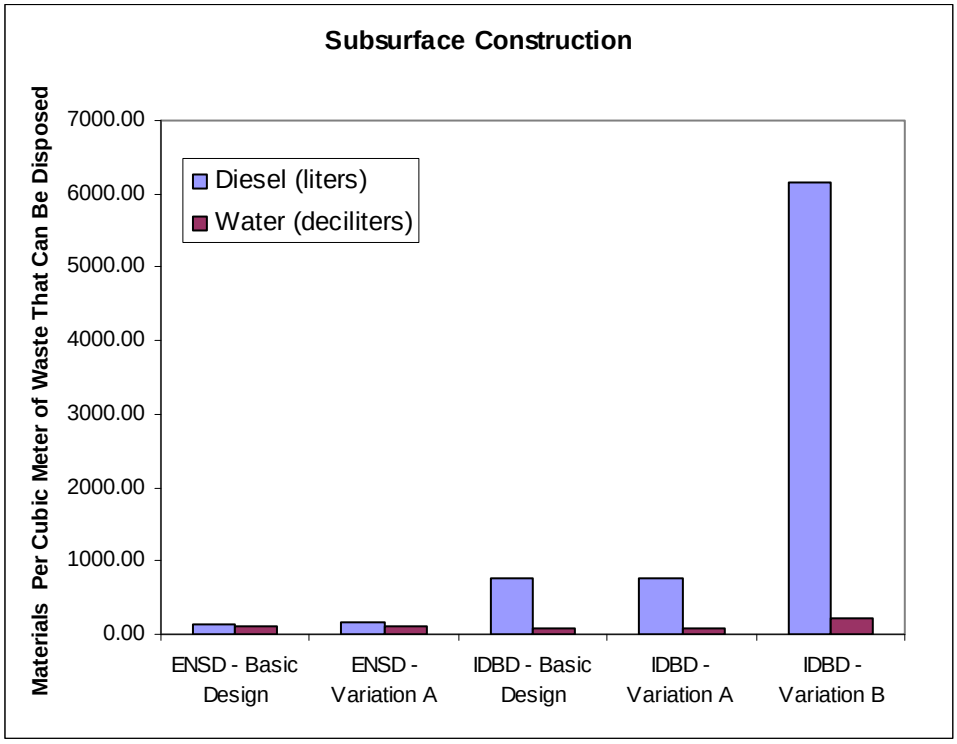


Figure 20. Resource Requirements for Construction of Individual Trenches and Boreholes

The trench designs require very little concrete; 1.3 cubic meters of concrete are needed per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). The only place that concrete is used in the trench designs is in the subsurface deflection shield. The concrete requirements for the IDBD designs range from 0.35 cubic meters of concrete (IDBD basic design) to 1.4 cubic meters of concrete (IDBD Variation B) per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums).

## 5.3 CONSTRUCTION WASTES AND EMISSIONS

Table 9 is a summary of the wastes produced during subsurface construction from Appendix B and Appendix C. Table 10 is a summary of the emissions produced during subsurface construction from Appendix B and Appendix C.

Figure 22 shows the waste produced during subsurface construction for the construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 22 is waste that is packaged in 55-gallon drums.

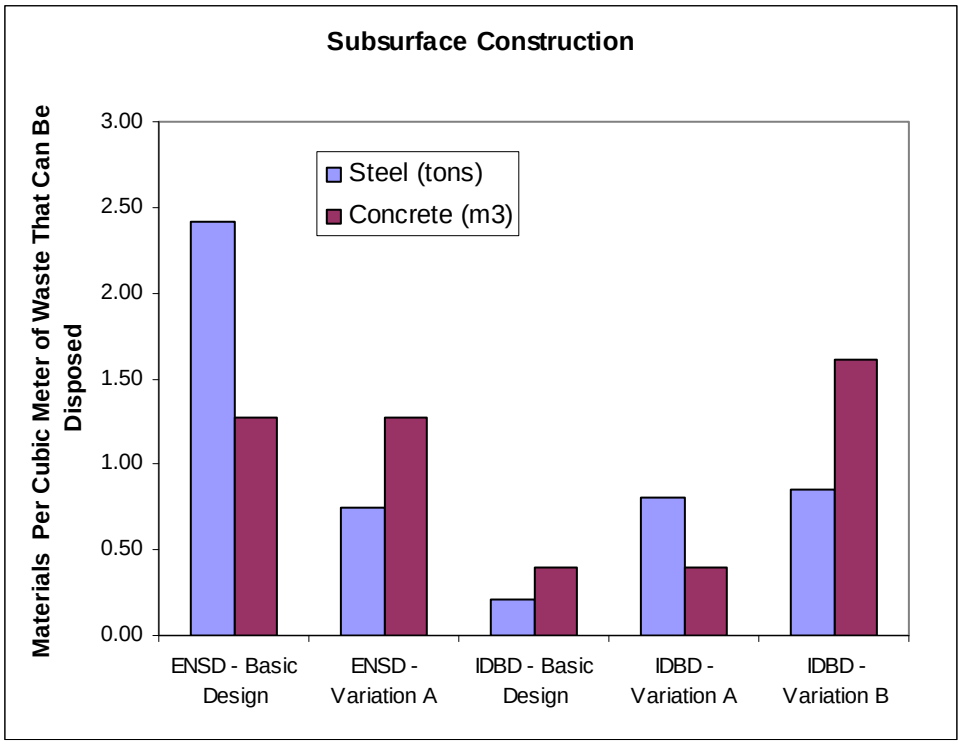


Figure 21. Material Requirements for Construction of Individual Trenches and Boreholes

Table 9. Wastes Produced During Construction of Individual Trenches and Boreholes[a]

| Technology | Construction Debris | Refuse | Excavated Material |
|---|---|---|---|
| | ($m^3$/trench) | ($m^3$/trench) | ($m^3$/trench) |
| ENSD- Basic Design[b] | 18 | 9 | 3108 |
| ENSD- Variation A[b] | 18 | 9 | 3108 |
| **Technology** | ($m^3$/borehole) | ($m^3$/borehole) | ($m^3$/borehole) |
| IDBD –Basic Design[c] | 1.8 | 0.9 | 375 |
| IDBD Variation A[c] | 1.8 | 0.9 | 375 |
| IDBD Variation B[c] | 1.8 | 0.9 | 214 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

Table 10. Emissions Produced During Construction of Individual Trenches and Boreholes[a]

| Technology | CO | NOx | PM |
|---|---|---|---|
| | (lb/trench) | (lb/trench) | (lb/trench) |
| ENSD- Basic Design[b] | 472 | 3255 | 191 |
| ENSD- Variation A[b] | 610 | 4211 | 246 |
| | (lb/borehole) | (lb/borehole) | (lb/borehole) |
| IDBD -Basic Design[c] | 401 | 2,770 | 161 |
| IDBD Variation A[c] | 401 | 2,770 | 161 |
| IDBD Variation B[c] | 762 | 5,256 | 305 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

There is very little waste produced as a result of the subsurface construction of individual trenches or boreholes. The excavated material can be reused as can the steel that is pulled from either the trench or the borehole. Refuse and construction debris together range from 0.06 cubic meters per cubic meter of waste that can be disposed (IDBD basic design and Variation A) to 0.23 cubic meters per cubic meter of waste that can be disposed (IDBD Variation B).

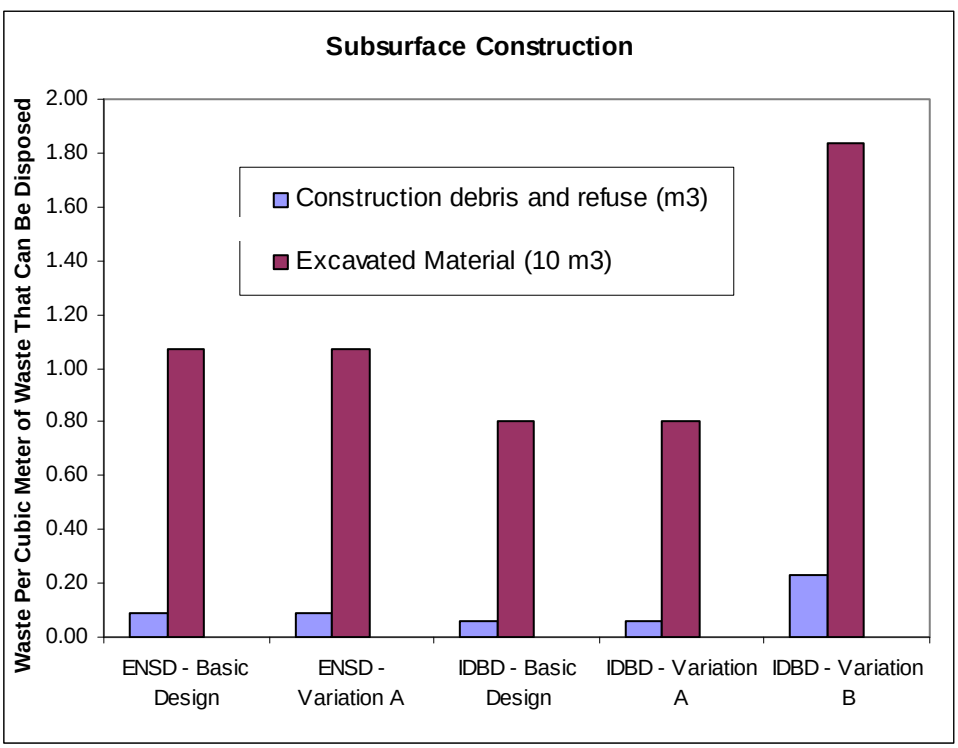


Figure 22. Wastes Produced During Construction of Individual Trenches and Boreholes

Figure 23 shows the emissions produced during subsurface construction for the construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 23 is waste that is packaged in 55-gallon drums.

ENSD basic design, construction of a shored trench, produces the smallest amount of emissions per cubic meter of waste that can be disposed (1.62 lbs CO; 11.2 lbs $NO_X$; 0.65 lbs PM). The ENSD Variation A, an unshored trench, produces 2.10 lbs CO, 14.5 lbs $NO_X$, and 0.84 lbs PM per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). These two options have roughly equivalent emissions per cubic meter of waste that can be disposed. The IDBD basic design and Variation A, produce 8.62 lbs CO, 59.5 lbs $NO_X$, and 3.45 lbs PM per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums), and the IDBD Variation B, produces 65.43 lbs CO, 451.3 lbs $NO_X$, and 26.18 lbs PM per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums).

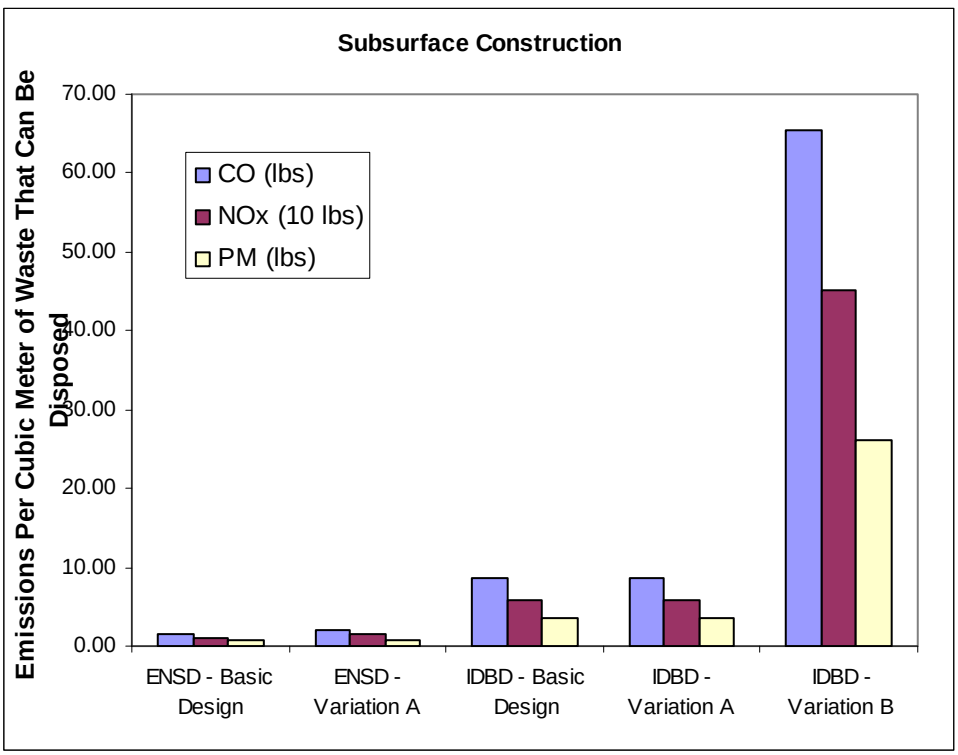


Figure 23. Emissions Produced During Construction of Individual Trenches and Boreholes

## 5.4 CONSTRUCTION COSTS, DURATIONS, AND PERSONNEL

Table 11 is a summary of the cost, duration, and man-hours for subsurface construction from Appendix B and Appendix C.

Table 11. Costs, Durations, and Man-hours for Construction of Individual Trenches and Boreholes[a]

| Technology | Costs | Duration | Man-Hours |
|---|---|---|---|
| | (K dollars/trench) | (days/trench) | (hours/trench) |
| ENSD- Basic Design[b] | 3,121 | 63 | 802 |
| ENSD- Variation A[b] | 2,638 | 59 | 672 |
| | (K dollars/borehole) | (days/borehole) | (hours/borehole) |
| IDBD -Basic Design[c] | 463 | 15 | 776 |
| IDBD Variation A[c] | 560 | 21 | 776 |
| IDBD Variation B[c] | 1,121 | 40 | 936 |

[a]Based on a hypothetical five-trench or fifty-borehole facility. Does not include construction of permanent surface facilities for operation; [b]Summary of information from Appendix B; [c]Summary of information from Appendix C

Figure 24 shows the cost of construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 24 is waste that is packaged in 55-gallon drums.

ENSD Variation A, construction of an unshored trench, is the least expensive of all the options at 9.1 K dollars per cubic meter of waste that can be disposed (for waste package in 55-gallon drums). Construction of basic IDBD design, a 70 meter borehole without casing to depth, costs 9.9 K dollars per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums). These two options have roughly equivalent costs per cubic meter of waste that can be disposed. The ENSD basic design, a shored trench, costs 10.7 K dollars per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums), and the IDBD Variation A, a 70 meter borehole that is cased to depth, costs 12.0 K dollars per cubic meter of waste that can be disposed. The most expensive option is the IDBD Variation B, a 40 meter borehole in consolidated material, which costs 96.2 K dollars per cubic meter of waste that can be disposed (for waste packaged in 55-gallon drums).

Figure 25 shows the durations for the construction of individual trenches and boreholes normalized to the volume of waste that can be disposed in the trench or borehole. The amount of waste that was used to normalize the data shown in Figure 25 is waste that is packaged in 55-gallon drums.

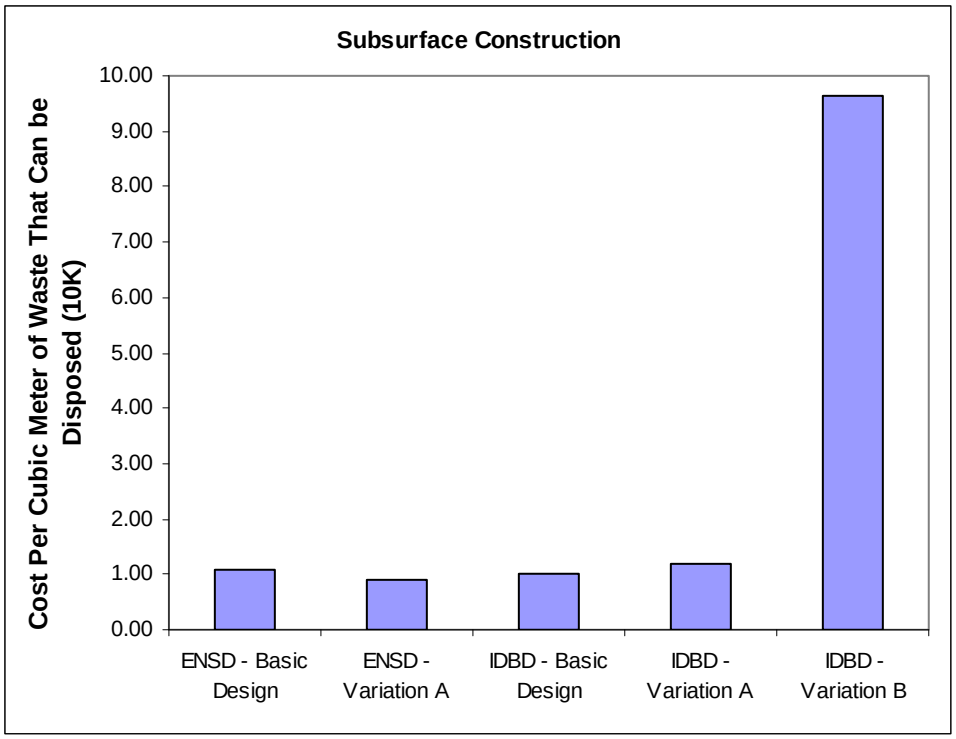


Figure 24. Costs For Construction of Individual Trenches and Boreholes

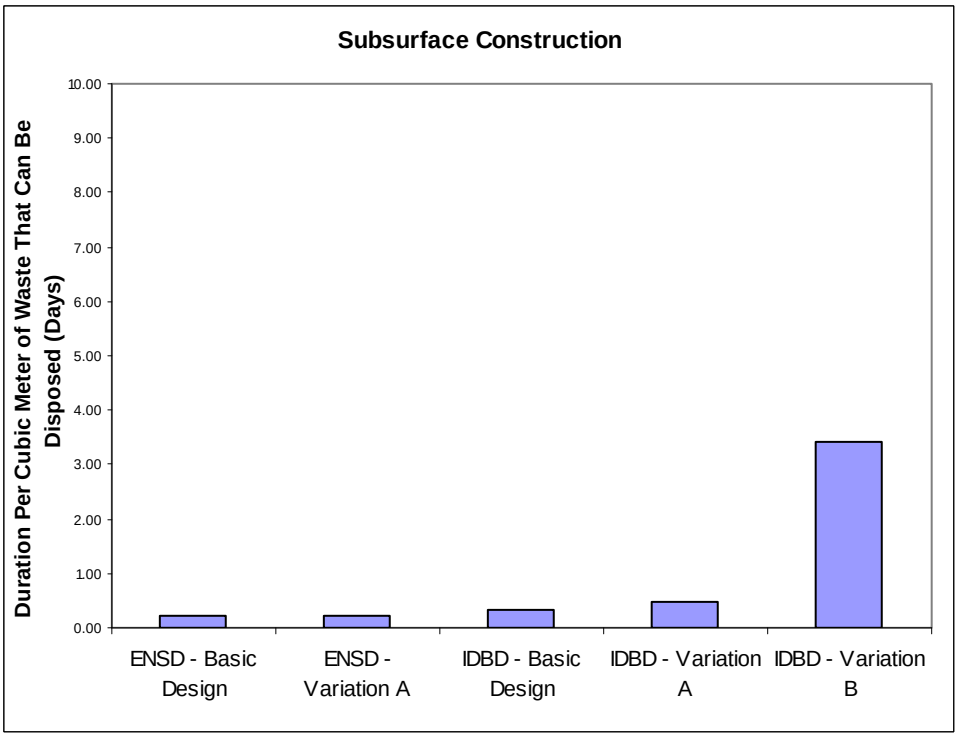


Figure 25. Durations for Construction of Individual Trenches and Boreholes

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# Appendix A
# Conceptual Design for the ENSD and IDBD Facilities Subsurface Deflection Shields

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## A1. INTRODUCTION

The conceptual design proposed as a buried barrier for both disposal configurations is a subsurface deflection shield (SDS). A subsurface barrier is deemed preferable to an above-grade barrier to avoid above-surface environmental weathering and to minimize the potential for vandalism and scavenging.

The SDS is aligned at an angle of 30 degrees from vertical, providing a surface that should deflect an incoming drill bit. As additional defense the shield includes four layers of abrasion-resistant steel, each of which is expected to effectively stop a bit if for some reason it were to penetrate the shield instead of deflecting. Two of the steel layers are plate and two are rebar encased in high-strength concrete. The design provides for redundancy to enhance the likelihood of preventing an intrusion into the waste.

A deflection angle of 30 degrees from vertical is specified based on interviews with individuals experienced in drilling water wells, R. Keith of West Texas Well Services, and designing drill bits, G. McKown of Smith International. When a drill bit encounters a naturally dipping (or angled) bedded geologic rock formation, the drill bit tends to deviate toward the formation (i.e., perpendicular to the bed) if the dip of the geologic rock formation is about 45 degrees from horizontal or less. If the dip angle of the rock formation is greater than 45 degrees from horizontal, the bit tends to deflect parallel to the bedding plane. This is particularly the case when the dipping geologic formation is significantly harder than the overlying material. Based on this industry experience and the very hard surface of the abrasion-resistant steel shield, it is believed that a deflection barrier placed 30 degrees from vertical will deflect an intruding drill bit.

## A2. BOREHOLE DISPOSAL

For the IDBD configuration, the SDS is in the shape of a cone (Figure A.1). The diameter of the base of the cone is nominally the same as the diameter of the borehole and the sides are aligned at 30 degrees from vertical, resulting in a height of 2.6 m.

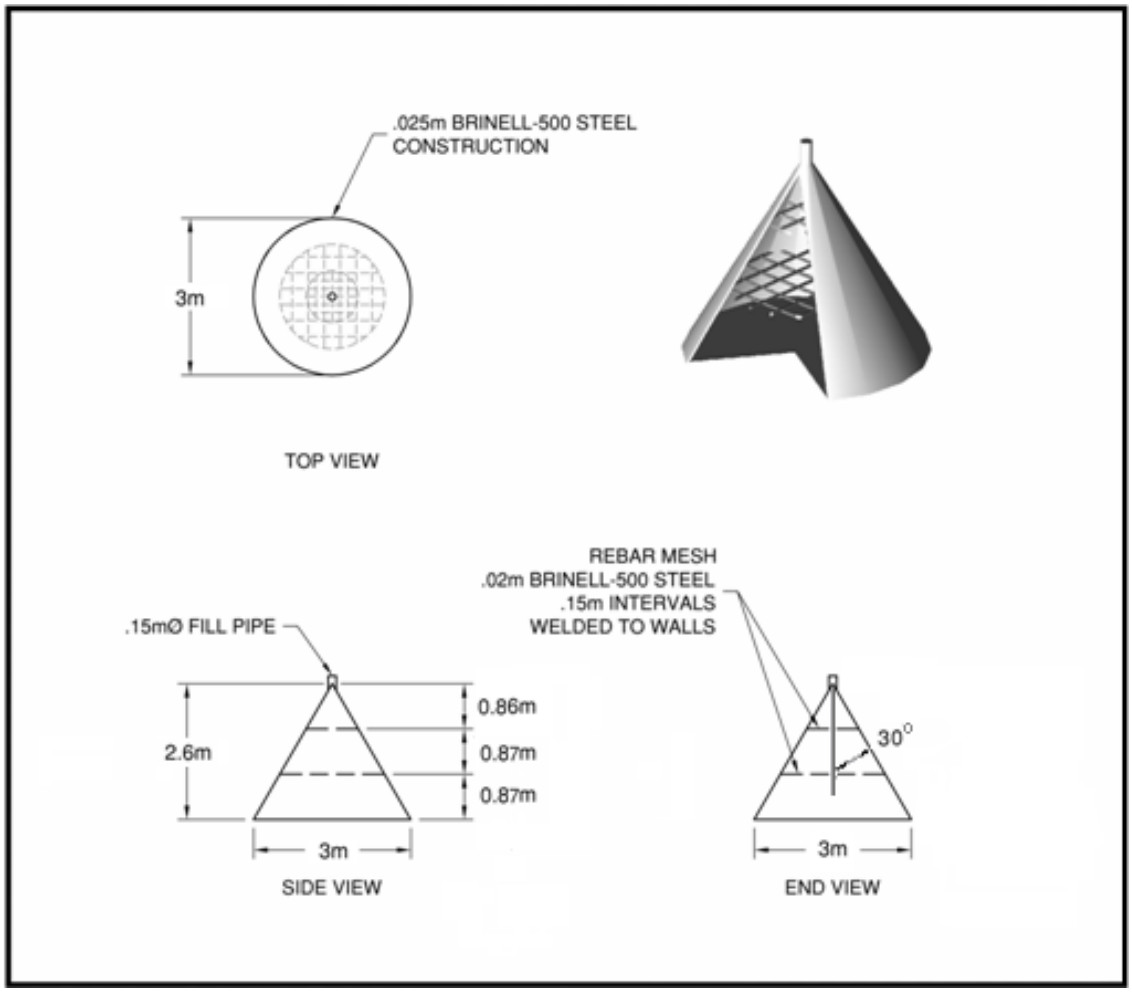


Figure A.1. Conceptual Design of the Deflection Shield for the IDBD Design

The bottom and sides of the cone are fabricated from 2.5-centimeter-thick Brinnell-500 abrasion resistant steel, welded together at the seams. Within the cone are two layers of rebar mesh, also of Brinnell-500 steel, and welded to the inside surfaces of the cone. The rebar is 2-centimeter thick at 15.2-centimeter intervals. A 15.2-centimeter-diameter stainless steel fill pipe extends several inches upward from the top of the cone.

When a disposal borehole has been completely filled with waste, the steel cone would be lowered into the borehole. The cone would then be filled (through the fill pipe) with high-volume fly ash (HVFA) concrete. A HVFA concrete mix is more durable that normal concretes, because it eliminates cracking during curing. The HVFA concrete would consist of ASTM Class F fly ash as the pozzolanic material that will substitute for a portion of the Portland cement in the mix. The aggregates should be selected to be as stable and non-reactive as possible.

With this design, the steel cone serves as the concrete form, providing essentially indefinite cure time within the form, which in turn maximizes the strength of the concrete. The inclusion of four separate layers of steel (two of plate and two of rebar) provides multiple metal barriers, each of which would likely stop a drill bit should it tend to penetrate the barrier rather than be deflected.

The primary cost elements for this conceptual design are the fabrication of the Brinnell-500 steel cone and the concrete. Fabrication cost for each unit (based on a borehole diameter of 3.4 meters) is estimated at $53,600. The concrete requirement for each unit is about 5.8 cubic meters, for a total concrete cost of approximately $1050. This totals to a cost of about $54,750 for the fabrication and filling of each unit. Additional costs to transport the fabricated steel cone and the concrete to the site would depend on the site location.

## A3. TRENCH DISPOSAL

For the ENSD configuration, the SDS is in the shape of a wedge (Figure A. 2). Similar to the borehole cone, the width of the base of the wedge is nominally the same as the width of the trench and the sides will be aligned at 30 degrees from vertical, which results in a height of 2.6 m. The wedge will be five meters long and with closed ends.

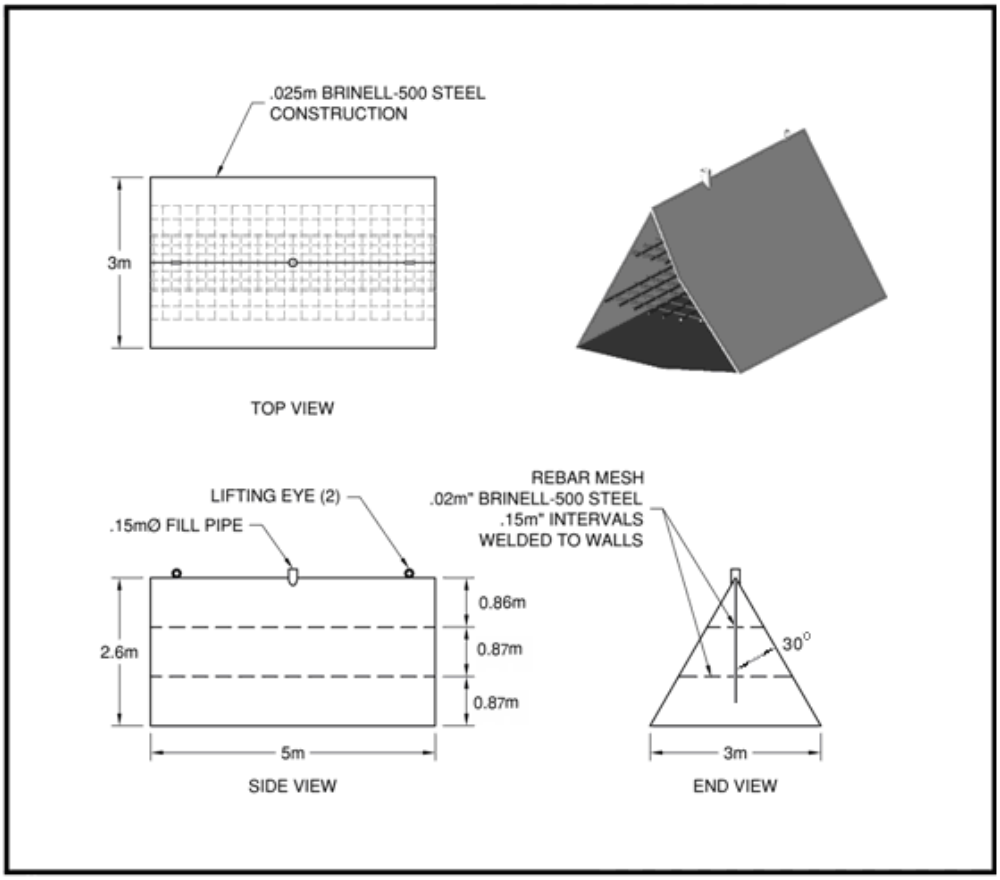


Figure A.2. Conceptual Design of the Deflection Shield for the ENSD Design

Materials of construction and construction configuration are the same as those of the borehole cone, including Brinnell-500 steel, rebar layers, and fill pipe. Once a disposal trench is filled with waste, the deflection wedges would be placed end-to-end above the waste and below the land surface. They would then be filled with HVFA concrete.

Fabrication cost for each unit is estimated at $83,850. The concrete requirement for each unit would be about 18.6 cubic meters for a total concrete cost of approximately $3250. This totals to a cost of about $87,100 for the fabrication and filling of each unit. Additional costs would include transportation of the fabricated steel wedges and the concrete.

# Appendix B
# ENSD Associated Construction Data for Use in Task 3.6

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# ACRONYMS

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| CQP | Construction Quality Plan |
| DOE | Department of Energy |
| EIS | Environmental Impact Statement |
| ENSD | Enhanced Near Surface Disposal |
| EPP | Environmental Protection Plan |
| HASP | Health and Safety Plan |
| OSHA | Occupational Safety and Health Administration |
| QAP | Quality Assurance Plan |
| RPPP | Radiation Protection Program Plan |
| SWPPP | Storm Water Pollution Prevention Plan |
| WP | Work Plan |

## B 1. INTRODUCTION

This appendix provides the construction data for building the subsurface component of an Enhanced Near Surface Disposal (ENSD) facility. Conceptual designs for the ENSD facility were presented in Section 3. Two variations, a Basic Design and Variation A, are presented in Section 3. The Enhanced Near Surface Disposal (ENSD) facility conceptual design and

associated construction data discussed in this document have been formulated solely for use in preparing the Environmental Impact Statement (EIS). Of necessity, a number of assumptions, which are documented in this appendix, have been made. The construction data discussed in this document is for construction of five trenches and does not include construction of surface facilities for operation. A five-trench configuration was chosen for the purposes of spreading one-time values for application in the Task 3.6 data packages. Defining the number of trenches to use as a basis for spreading one-time values was iterative, starting with one trench, calculating the per trench cost, and then increasing the number of trenches. At five trenches, increasing the number of trenches no longer produced a significant change in the per trench cost. Therefore, a five trench configuration was chosen as a basis for spreading the one time costs.

A flow diagram for construction of the ENSD facility is shown in Figure B.1. Construction occurs in several phases starting with planning and permitting and ending in clearing of all construction-specific equipment (demobilization). Planning, geotechnical investigations, mobilization, surface preparation, trench excavation, auxiliary installations, and demobilization are the phases identified in Figure B.1.

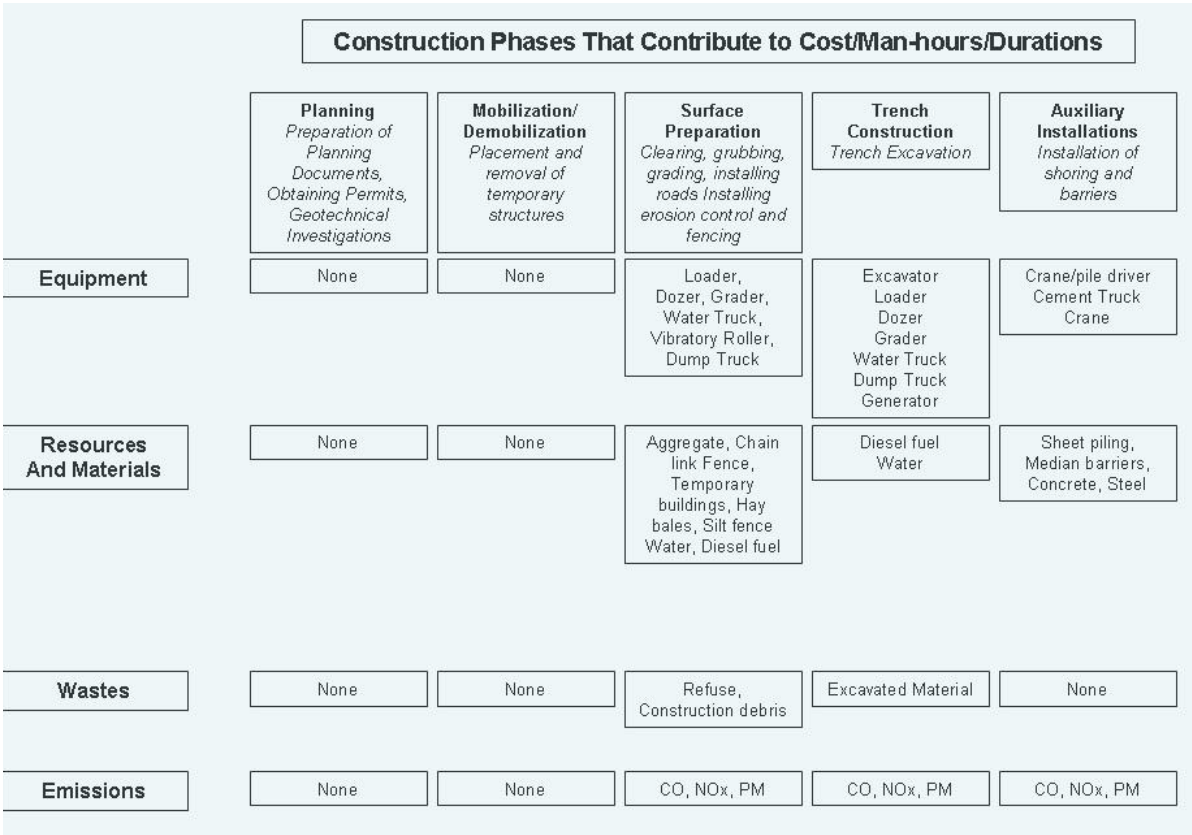


Figure B.1. Process Flow Diagram for Construction of an ENSD Facility

The methods and assumptions used to prepare the information presented in this appendix are discussed separately below for each of the construction phases identified in Figure B.1. Section B.2 describes the work that is required before breaking ground. Section B.3 describes the surface preparation phase of construction identifying land use and giving site maps. Section B.4 describes the equipment, resources, and materials needed to build the facility. Section B.5 describes the wastes and emissions that one can expect to be produced while constructing the facility. Section B.6 describes the costs, durations, and man-hours associated with facility construction.

## B 2. PLANNING, GEOTECHNICAL INVESTIGATIONS, AND MOBILIZATION

The first three phases of ENSD facility construction (planning, geotechnical investigations, and mobilization) have bearing on costs and durations for the project and as such have bearing on the information presented in Section B.6.

### B 2.1 PLANNING

Actual construction will require time and funding for construction planning and permitting. It is assumed that all construction activities will be “clean construction” requiring the use of modified

level D personal protection. Preparation of a Radiation Protection Program Plan (RPPP) or participation in such plan is not included in this document or associated cost estimate. DOE planning documents include the preparation of the following planning documents to support facilities construction:

- Design drawings and specifications;
- Construction Quality Plan (CQP);
- Work Plan (WP);
- Project-specific Quality Assurance Plan (QAP);
- Health and Safety Plan (HASP), which includes activity hazard analyses for work activities;
- Environmental Protection Plan (EPP);
- Project-specific Security Plan;
- Accident Prevention Plan;
- Project Management Project Control Plan (PMPC);
- Geotechnical Investigation Plan;
- Sampling and Analysis Plan;
- Field Implementation Plan; and
- As-built drawings.

A Storm Water Pollution Prevention Plan (SWPPP) for construction activities will have to be prepared, which will include submission of construction notice of intent to discharge. Should an air quality mobile source permit be required for construction equipment, one will be prepared and submitted. The planning and permitting activities are for construction only and do not include operational permitting and public outreach. Regulatory interaction or notification is not included in construction related activities. This analysis only addresses construction costs. After planning documents are complete, a readiness review will be conducted prior to site mobilization.

## B 2.2 GEOTECHNICAL INVESTIGATIONS

Soil borings will be installed to determine subsurface conditions at each project site. Sufficient data will be collected to assure that the supporting soil or rock has sufficient capacity to provide adequate safety factor against foundation failure and adequate stiffness to minimize settlements under design loads. Actual boring locations will be dependent on field conditions. The actual number of borings will be adequate to fill data gaps for the final geotechnical investigation and to allow the Professional Engineer to make final geotechnical recommendations for foundation design, slab support, trench design, and related earthwork.

During drilling activities, samples will be collected at selected depths from the surface to total boring depths to obtain geotechnical data. Core samples will be placed on plastic sheeting

during logging. The borings will be logged in the field using the Unified Soil Classification System in accordance with ASTM D2487. A soil boring log will be recorded in the field by the geotechnical engineer. The boring log will contain a graphical log of soil/rock type encountered, sample location, blows per foot, unified soil classification code, remarks of the field engineer, and a detailed visual classification.

Geotechnical samples will be obtained from the test borings installed as part of this final geotechnical investigation activity. Borings will be installed to sufficient depth to provide geotechnical information to assist with final design of the proposed ENSD. Samples sent to the materials testing laboratory will be collected from the area within the zone of influence of the stresses for the proposed building walls and foundations. Samples will be collected throughout the depth of the boring for testing. Tests will consist of unconfined compression, direct shear, consolidation, expansion, moisture content, density sieve analysis, and Atterberg Limits. Additional testing, based on field conditions encountered during drilling may be conducted.

Samples will be collected for laboratory geotechnical analysis to verify visual classification made in the field and to evaluate engineering properties that may impact the project performance. Actual types and quantities of samples and geotechnical analysis performed may be based on conditions encountered in the field during investigation activities.

## B 2.3 MOBILIZATION

Once operational readiness has been established, the equipment materials and personnel required to construct the ENSD facility would be mobilized to the site. Heavy equipment required to construct the ENSD such as front end loaders, excavators, dump trucks and graders would be required to prepare the site surface for construction of the facility. For the purpose of facility infrastructure construction it is assumed that utilities would not be available at the ENSD facility construction site. Water, sanitation and power (generators) would be required to provide the required utilities to the ENSD facility site. In addition, a bulk fuel storage tank would be required to store diesel fuel onsite to re-fuel construction equipment during facility construction.

Once the facility is constructed, all equipment required to construct the facility would be demobilized from the project site. Temporary structures would be removed and transported off-site during demobilization efforts.

## B 3. SURFACE PREPARATION

This section discusses the fourth phase of construction which is surface preparation. Before trench excavation can begin, the land area that encompasses the site must be prepared. For the purposes of this analysis, the ENSD facility is assumed to require at least 4.2 hectares[1] of land to allow for the installation of five trenches, support facilities (storage for heavy equipment; staging areas for soils generated) and infrastructure (temporary roads and parking). This assumption is being made for the purposes of spreading one time values (i.e., costs, wastes, resources) across multiple trenches to derive appropriate per trench values for application in the Task 3.6 data

[1] One hectare is equivalent to 2.471 acres.

packages. A hypothetical ENSD facility layout used to derive per trench values is shown in Figure B.2.

For the five-trench configuration, the proposed facility would be approximately 217 meters long by 217 meters wide, covering approximately 4.7 hectares of land. The total disturbed site area would be approximately 3.4 hectares. A security perimeter fence with three strands of barbed wire installed at the top to prevent unauthorized entry and rodent barrier along the bottom three feet would be required making the total fenced area 4.2 hectares. Parking areas and site roads would be constructed of base-coarse or gravel. Roads and parking areas would not be paved with asphalt. All materials excavated during construction would be stored within the project boundary, within one mile from the point of generation. These site land parameters are shown in Table B.1. Both total values and per trench values based on the five-trench configuration are shown in Table B.1.

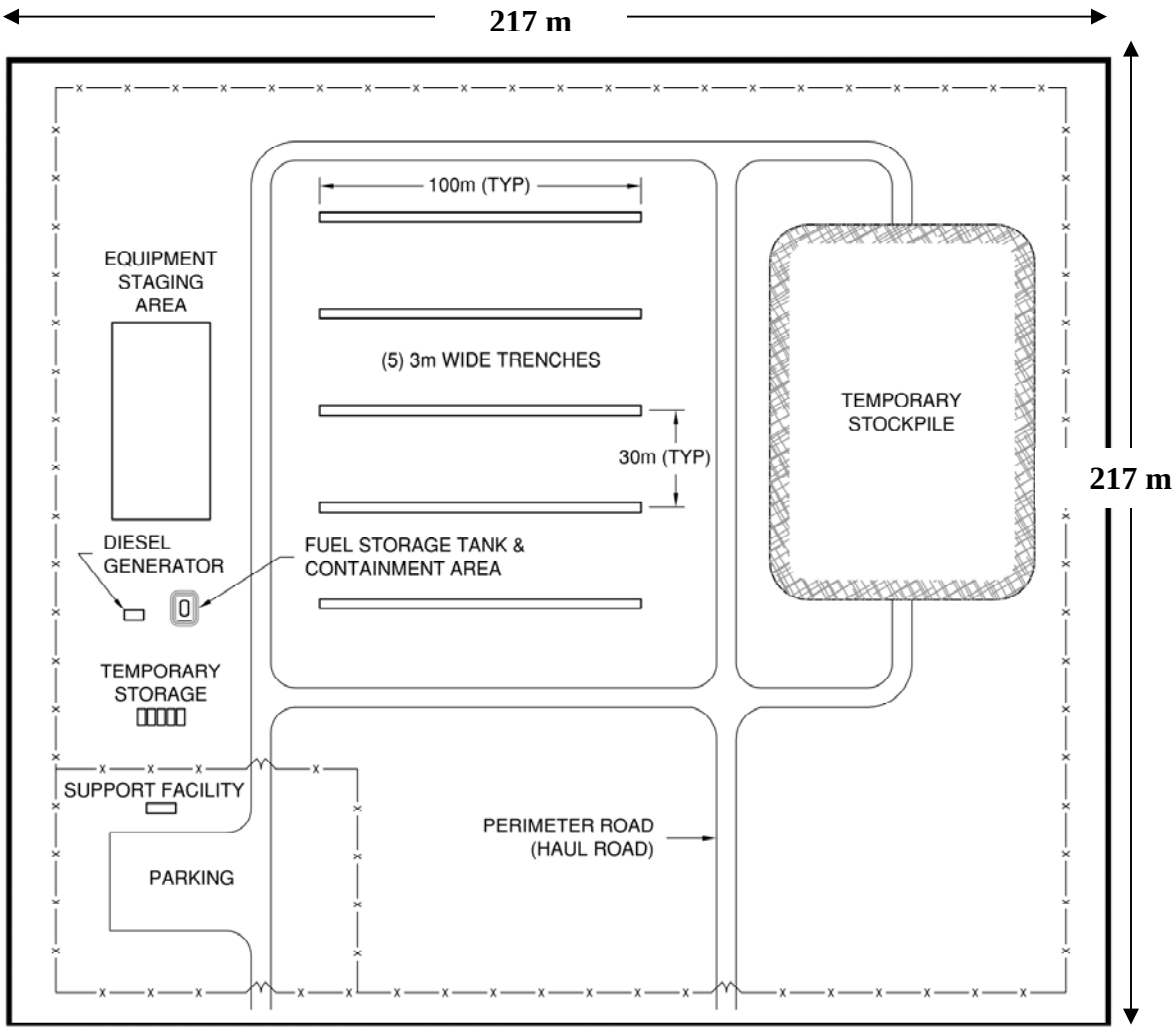


Figure B.2. Hypothetical Facility Layout for Purposes of Deriving Normalized Per Unit Costs

Table B.1. Land Use Parameters Based on the Five-trench ENSD Facility Design[a,b]

| | Site Land Area (hectares) | Disturbed Land Area (hectares) | Fenced Area (hectares) | Paved Area (hectares) |
|---|---|---|---|---|
| **Total** | 4.7 | 3.4 | 4.2 | 0 |
| **Per Trench** | 0.94 | 0.68 | 0.84 | 0 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

## B 4. CONSTRUCTION EQUIPMENT, RESOURCE AND MATERIAL REQUIREMENTS

Construction of the ENSD will require construction materials, use of heavy equipment, site vehicles and utilities. It was assumed that utilities, water, sanitation and electricity would not be

available at the selected site. Generators will be utilized to provide power to the site, portable sanitation facilities (portable toilets) will be used for site personnel and visitors. Equipment utilized will include heavy construction equipment, support trucks, site personnel vehicles, and generators.

This section presents the equipment, resources, and materials needed for construction of an ENSD facility comprised of five trenches as described in Section B.3. As stated in Section B.1, three phases of construction have equipment, resource and material demands: surface preparation, trench excavation, and auxiliary installations. The equipment, resource, and material requirements are identified below for these phases of construction.

## B 4.1 CONSTRUCTION EQUIPMENT

The overall heavy equipment list includes: excavators, loaders, dozers, graders, water trucks, dump trucks, cement trucks, cranes, crane/pile drivers, generators, and vibratory rollers. Total inventory for this equipment is shown in Table B.2.

Table B.2. Heavy Equipment Required for Construction of ENSD Facility[a]

| Equipment | Quantity | Horsepower (hp) |
|---|---|---|
| Cement Truck[c] | 1 | 280 |
| Crane[c] | 1 | 300 |
| Crane/Pile driver[b] | 1 | 300 |
| Dozer[b] | 1 | 200 |
| Dump Truck[b] | 1 | 280 |
| Excavator[b] | 2 | 330 |
| Generator[b] | 2 | 100 |
| Grader[b] | 1 | 220 |
| Loader[b] | 1 | 197 |
| Vibratory Roller[b] | 1 | 60 |
| Water Truck[b] | 1 | 280 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]While not called out in AMEC (2007), this equipment is required for construction of the subsurface deflection shield.

### *B 4.1.1 Surface Preparation*

The heavy equipment required for surface preparation is shown in Table B.3.

Table B.3. Heavy Equipment Required for Surface Preparation[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) |
|---|---|---|---|
| Dozer | 1 | 200 | 220 |
| Dump Truck | 1 | 280 | 110 |
| Grader | 1 | 220 | 220 |
| Loader | 1 | 197 | 110 |
| Vibratory Roller | 1 | 60 | 220 |
| Water Truck | 1 | 280 | 220 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

The loader is used for loading excavated soils generated during surface preparation activities into dump trucks for transport to the staging area. The loader is a 197 hp machine and it is estimated that 110 hours are required for surface preparation. The dozer is used for several purposes including, assisting with site preparation activities, moving soils during the loading process and moving soils that are stored in the on-site staging area. The dozer is a 200 hp machine and it is estimated that 220 hours are needed for surface preparation. The grader is used for grading the surface in preparation for construction activities. The grader is a 220 hp machine and it is estimated that 220 hours are needed for surface preparation. The water truck is used for dust suppression during surface preparation activities. In arid environments, daily watering of roadways and areas under construction will be required to suppress dust generated during these activities. The water truck is a 280 hp machine and it is estimated that 220 hours are needed for surface preparation. The vibratory roller is used for compaction of roadways and parking areas. The vibratory roller is a 60 hp machine and it is estimated that 220 hours are needed for surface preparation. The dump truck is used for transporting soils generated during the site preparation phase to the onsite staging area. The dump truck is a 280 hp machine and it is estimated that 110 hours are needed for surface preparation.

#### *B 4.1.2 Trench Excavation*

The heavy equipment required for trench excavation is shown in Table B.4.

Table B.4. Heavy Equipment Required for Trench Excavation[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration for Five Trenches (hr/unit) | |
|---|---|---|---|---|
| | | | Basic Design | Variation A |
| Dozer | 1 | 200 | 250 | 500 |
| Dump Truck | 1 | 280 | 250 | 500 |
| Excavator | 2 | 330 | 250 | 500 |
| Generator | 2 | 100 | 250 | 500 |
| Grader | 1 | 220 | 250 | 500 |
| Loader | 1 | 197 | 250 | 500 |
| Water Truck | 1 | 280 | 250 | 500 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

The loader is used for loading excavated soils generated during trench construction into the dump truck for transportation to the onsite storage area. The loader is a 197 hp machine and it is estimated that 250 hours are required for trench excavation. The dozer is used for several purposes including assisting with trench construction, and assisting with soil management at the onsite staging area. The dozer is a 200 hp machine and it is estimated that 250 hours are needed for trench excavation. The grader is used for grading surfaces such as roadways receiving heavy truck traffic and assisting with trench excavation and soil staging activities. The grader is a 250 hp machine and it is estimated that 250 hours are needed for trench excavation. The water truck is used for dust suppression. The water truck is a 280 hp machine and it is estimated that 250 hours are needed for trench excavation. The dump truck is used for transporting soils generated during trench construction to the onsite storage area. The dump truck is a 280 hp machine and it is estimated that 250 hours are needed for trench excavation. The excavator is used for trench excavation. The excavator is a 330 hp machine and it is estimated that 2 excavators will be required to conduct trench excavation activities each day. A total of 250 hours for each excavator is needed for five trenches. The generators are used for power to small hand tools and, if needed, site lighting (light towers) for work activities conducted during periods of low natural light. The generators are 100 hp machines and it is estimated that 2 generators will be required for 250 hours each during trench excavation activities. For Variation A, since excavation is in consolidated material, equipment usage is twice that of the basic design.

### *B 4.1.3 Auxiliary Installations*

The heavy equipment required for the auxiliary installations is shown in Table B.5. The crane/pile driver is used for installation of trench shoring when shoring is required for trench construction. The crane/pile driver is a 300 hp machine and it is estimated that 750 hours are required for shoring placement in five trenches. This includes 100 hours for placing sheet piling across the trench. For variation A, the crane/pile driver is use solely for placing sheet piling across the trench.

When a disposal trench has been completely filled with waste, the steel SDS would be lowered into the trench. The SDS would then be filled with concrete. The crane is used for lowering the SDS pieces into the trench (20 pieces per trench). The crane is a 300 hp machine and it is estimated that 200 hours are required for placing SDSs in five trenches. The cement truck is used to fill the SDSs with concrete. The cement truck is a 280 hp machine and it is estimated that 200 hours are required to fill the SDSs in five trenches.

Table B.5. Heavy Equipment Required for Auxiliary Installations[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration for Five Trenches (hr) | |
|---|---|---|---|---|
| | | | Basic Design | Variation A |
| Crane/pile driver | 1 | 300 | 750 | 100 |
| Crane | 1 | 300 | 200 | 200 |
| Cement Truck | 1 | 280 | 200 | 200 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007) except for the crane and cement truck which are required for construction of the subsurface deflection shield; [c]Equipment duration is based on a 10-hour work day.

## B 4.2 CONSTRUCTION RESOURCES

Principal resources for the construction of the ENSD facility include:

- Diesel
- Water

The per trench values for these resources based on the five-trench design discussed in Section B.3 are summarized in Table B.6. Calculation of the per trench values is discussed in Sections B 4.2.1 through B 4.2.3.

Table B.6. Per Trench Resource Requirements for Construction of an Enhanced Near Surface Disposal Facility[a]

| Activity | Diesel (liters/trench) | Diesel (gallons/trench) | Water (liters/trench) | Water (gallons/trench) |
|---|---|---|---|---|
| **Surface Preparation[b]** | 9,502.33 | 2510.51 | 130,148.48 | 34,385.23 |
| **Trench Excavation[c]** | | | | |
| Basic Design | 17,378.61 | 4591.43 | 190,085.28 | 50,220.53 |
| Variation A | 34,757.22 | 9182.86 | 190,085.28 | 50,220.53 |
| **Auxiliary Installations[d]** | | | | |
| Basic Design | 14,750.73 | 3897.14 | 0 | 0 |
| Variation A | 6,315.56 | 1668.57 | 0 | 0 |
| **Total[e]** | | | | |
| Basic Design | 41,631.66 | 11,004.91 | 320,233.76 | 84,605.76 |
| Variation A | 50,575.11 | 13,369.02 | 320,233.76 | 84,605.76 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section B 4.2.1; [c]Calculated from data given in Section B 4.2.2.; [d]Calculated from data given in Section B 4.2.3; [e]Calculated as the total of surface preparation, trench excavation, and auxiliary installations

### *B 4.2.1 Surface Preparation*

The diesel fuel consumption presented in this section is derived from the equipment horsepower and hours of operation data provided in AMEC (2007). AMEC (2007) indicates that the total horsepower-hours during the surface preparation phase of construction to be approximately 219,670 horsepower-hours (see also Section B 5.2.1). Standard Specific Fuel Consumption (SFC) for diesel engines is assumed to be 0.4 lbs / hp-hr . Using the following conversions:

- 1 gallon of diesel weighs 7 lbs (U. S. BOT 2007)
- 264.34 gallons/$m^3$
- 1000 liters/$m^3$
- 2.205 lbs/kg,

and allocating the surface preparation resources over five trenches yields 9,502.33 liters (2,510.51 gallons) of diesel fuel per trench.

The primary water use is for dust suppression during surface preparation. The water requirements presented here are derived from the data given in AMEC (2007). AMEC (2007) indicates that during surface preparation, 10,640 cubic yards of soil are excavated. Assuming that the soil is processed for a resulting eight percent water content, 851.20 cubic yards of water would be used. This translates to 650,742.40 liters (171,942.40 gallons) of water utilized during surface preparation, or 130,148.48 liters of water per trench (34,388.23 gallons per trench).

### *B 4.2.2 Trench Excavation*

AMEC (2007) indicates that the total horsepower-hours during trench excavation for the basic design is 401,750 horespower-hours. Converting as described above indicates that it takes

86,893.05 liters (22,957.14 gallons) of diesel fuel for excavation of five trenches, or 17,378.61 liters per trench (4,591.43 gallons per trench).

AMEC (2007) indicates that the total horsepower-hours during trench excavation for Variation A is 803,500 horsepower-hours. Converting as described above indicates that it takes 173,786.09 liters (45,914.29 gallons) of diesel fuel for excavation of five trenches, or 34,757.22 liters per trench (9,182.86 gallons per trench).

A 6,000 gallon water truck would be utilized for dust suppression during trench excavation activities. AMEC (2007) determined that during trench excavation, 15,540 cubic yards of soil will be excavated. Assuming that the soil is processed for a resulting eight percent water content, 1243.20 cubic yards of water would be used. This translates to 950,426.40 liters (251,102.65 gallons) of water used during surface preparation, or 190,085.28 liters per trench (50,223.53 gallons per trench).

#### *B 4.2.3 Auxiliary Installations*

Auxiliary installations for the basic design include installing the shoring, sheet pilling across the trench, and the subsurface deflection shield. The horsepower-hours during auxiliary installations for the Basic Design is 341,000 horsepower-hours(see Table B.15). Converting as described above indicates that it takes 73,753.65 liters (19,485.71 gallons) of diesel fuel for the auxiliary installations for five trenches, or 14,750.73 liters per trench (3,897.14 gallons per trench).

The horesepower-hours during auxiliary installations for Variation A is 146,000 horsepower-hours (see Table B.16). Converting as described above indicates that it takes 31,577.81 liters (8,342.86 gallons) of diesel fuel for the auxiliary installations for five trenches, or 6,315.56 liters per trench (1,668.57 gallons per trench).

## B 4.3 CONSTRUCTION MATERIALS

Principal construction materials for the ENSD facility include:

- Steel
- Concrete

The per trench values for these resources based on the five-trench design discussed in Section B.3 are summarized in Table B.7. Calculation of the per trench values is discussed in Sections B 4.3.1 through B 4.3.3.

Table B.7. Per Trench Material Requirements for Construction of an Enhanced Near Surface Disposal Facility[a]

| Activity | Steel (pounds/trench | Steel (tons/trench) | Concrete (C.Y./trench) | Concrete ($m^3$/trench) |
|---|---|---|---|---|
| **Surface Preparation[b]** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Trench Excavation[c]** | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | |
|---|---|---|---|---|
| Basic Design **Auxiliary Installations**[d] | 1,406,000 | 703.00 | 486.27 | 372 |
| Variation A | 438,000 | 219.00 | 486.27 | 372 |
| Basic Design **Total**[e] | 1,406,000 | 703.00 | 486.27 | 372 |
| Variation A | 438,000 | 219.00 | 486.27 | 372 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Individual materials listed in Table B.8; [c]Calculated from data given in Section B 4.3.2.; [d]Calculated from data given in Section B 4.3.3. Materials other than steel and concrete listed in Table B.9; [e]Calculated as the total of surface preparation, trench excavation, and auxiliary installations

### *B 4.3.1 Surface Preparation*

Construction materials used during the surface preparation phase of construction are listed in Table B.8.

The office trailer will be used for administrative support for all project activities. This trailer will be used for project meetings, a break room for the field staff, and other related meetings to support GTCC field activities. Storage boxes are used for storage of small tools and supplies required to support field operations. The storage boxes will be located in the laydown area. Top soil is used for site restoration activities. Fine/medium/coarse grade aggregate is used for road base and base coarse in the parking lot and vehicle and equipment staging areas. The silt fences and hay bales are used to control impacts to storm water run-off and erosion control.

### *B 4.3.2 Trench Excavation*

There are no materials used during the trench excavation phase of construction.

### *B 4.3.3 Auxiliary Installations*

Construction materials used during the auxiliary installations phase of construction are listed in Table B.9.

Steel is used in the ENSD conceptual design in three ways: sheet piling used to hold the trench open while waste is being emplaced, sheet piling that is laid across the excavation for the entire length of the trench, and steel in the barrier/cover. AMEC (2007) determined that the weight of steel used to hold the trench open during waste emplacement is 324 tons per trench (1,620 tons for five trenches) for the sheet piling and 160 tons per trench (800 tons for five trenches) for wales, connections, and struts. The weight of steel piling used to cover the top of each trench to prevent unintentional entry into the trench is 58 tons per trench. Hillesheim (2007) indicates that the steel in the subsurface SDS is 8.05 tons per section. Since there are 20 sections per trench, the weight of steel per trench is 161 tons, or 805 tons for five trenches.

The total weight of steel for the Basic design is 703 tons per trench or 3,515 tons for five trenches. For Variation A, no shoring is used, but sheet piling across the trench and the subsurface SDS are emplaced. The total steel for variation A is 219 tons per trench or 1,095 tons for five trenches.

Concrete is used in the ENSD conceptual design as part of the subsurface SDS. Hillesheim (2007) indicates that the volume of concrete in each segment of the SDS for a trench is 18.6 $m^3$. Since there are twenty segments to the SDS for each trench, the volume of concrete per trench is 372 $m^3$ or 486.27 cubic yards per trench (2,431.35 cubic yards for five trenches).

Table B.8. Material Requirements for the Surface Preparation Phase of Construction for an Enhanced Near Surface Disposal Facility[a,b]

| Material | Unit[c] | Amount |
|---|---|---|
| Office Trailer, furnished, buy, 32' x 8', excl. hookups | Ea | 1.00 |
| Storage Boxes, buy, 20' x 8' | Ea | 20.00 |
| Top Soil | C.Y. | 10,640 |
| Fine Grade Aggregate | S.Y. | 13,629 |
| Medium Grade Aggregate | B.C.Y. | 2,800 |
| Course Grade Aggregate | S.Y. | 9,520 |
| Silt Fence | L.F. | 3,080 |
| Hay Bales | L.F. | 700 |
| Chain Link Fence | L.F. | 3,080 |
| Chain Link Gates (5' x 20') | Opng. | 3 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Abbreviations are: Ea for each, C.Y. for cubic yards, S.Y. for square yards, B.C.Y for Bulk Cubic Yard, L.F. for linear foot, and Opng for opening.

Table B.9. Material Requirements for the Auxiliary Installations Phase of Construction for an Enhanced Near Surface Disposal Facility[a]

| Material | Unit[d] | Amount |
|---|---|---|
| Median barrier, precast concrete, double face, 3' - 6" high, 2' wide, 10 ' long[b] | L.F. | 680 |
| Sheet Piling – Basic Design Only[b] | Ton | 1,620 |
| Sheet Piling – All Variations[b] | Ton | 290 |
| Wales, connections and struts – Basic design Only[b] | Ton | 800 |
| Steel in Subsurface Deflection Shield[c] | Ton | 805 |
| Concrete in Buried Deflection Shield[c] | C.Y. | 2,567 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]From Hillesheim (2007); [d]Abbreviations are: C.Y. for cubic yards and L.F. for linear foot.

## B 5. CONSTRUCTION WASTES AND EMISSIONS

Construction activities will result in air emissions from equipment used during construction. Construction activities also generate dust and impact storm water. Dust will be controlled with dust suppression by spraying water during excavation activities. Impacts to storm water will be controlled with utilization of best management practices including silt fences, hay bales, and berming.

This section presents the wastes and emissions produced as a result of construction of an ENSD facility comprised of five trenches as described in Section B.3. As stated in Section B.1, three phases of construction produce wastes and emissions: surface preparation, trench excavation, and

auxiliary installations. Wastes and emissions are identified below for these phases of construction.

## B 5.1 CONSTRUCTION WASTES

Principal wastes for the construction of the ENSD facility include:

- Construction debris and
- Refuse (non-hazardous solid waste).

Generation of RCRA hazardous and TSCA waste are not anticipated.

Although soil will be generated during the construction activities, the ENSD facility construction is assumed to be clean construction. As a result of the construction being conducted in an uncontaminated environment, the excess soils generated would be stockpiled for re-use and are not considered a waste requiring disposal.

The per trench values for these wastes based on the five-trench design discussed in Section B.3 are summarized in Table B.10. Calculation of the per trench values is discussed in Sections B 5.1.1 through B 5.1.3.

Table B.10. Per Trench Wastes Produced During Construction of an Enhanced Near Surface Disposal Facility[a]

| Activity | Construction Debris (C.Y/trench) | Refuse (C.Y/trench) | Excavated Material (C.Y./trench)[f] |
|---|---|---|---|
| **Surface Preparation[b]** | 23.54 (18 $m^3$/trench) | 11.77 (9 $m^3$/trench) | 0.00 |
| **Trench Excavation[c]** | 0.00 | 0.00 | 4,065 (3,108 $m^3$/trench) |
| **Auxiliary Installations[d]** | | | |
| Basic Design | 0.00 | 0.00 | 0.00 |
| Variation A | 0.00 | 0.00 | 0.00 |
| **Total[e]** | | | |
| Basic Design | 23.54 (18 $m^3$/trench) | 11.77 (9 $m^3$/trench) | 4,065 (3,108 $m^3$/trench) |
| Variation A | 23.54 (18 $m^3$/trench) | 11.77 (9 $m^3$/trench) | 4,065 (3,108 $m^3$/trench) |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section B 5.1.1; [c]Calculated from data given in Section B 5.1.2.; [d]Calculated from data given in Section B 5.1.3; [e]Calculated as the total of surface preparation, trench excavation, and auxiliary installations; [f]Excess soils generated would be stockpiled for re-use and are not considered a waste requiring disposal

#### *B 5.1.1 Surface Preparation*

AMEC (2007) determined that surface preparation generates 90 $m^3$ of construction debris for five trenches, or 18 $m^3$/trench (23.54 C.Y./trench). Similarly, surface preparation generates 45 $m^3$ of refuse for five trenches, or 9 $m^3$/trench (11.77 C.Y./trench).

#### *B 5.1.2 Trench Excavation*

AMEC (2007) determined that trench excavation generates 15,540 $m^3$ of excavated material for five trenches, or 3,108 $m^3$/trench (4,065 C.Y./trench). All soil generated from the trench installation is assumed to be clean fill and will be stored on site pending re-use. The soils will be stock piled within one mile of the excavation location. Soils will not be placed on secondary containment since they are assumed to be clean.

#### *B 5.1.3 Auxiliary Installations*

There are no wastes produced during the auxiliary installations. However, pulling the shoring when the trench is closed is recommended. Leaving the shoring in place can create a preferential flow path for plant roots, gases and moisture, which are adverse to post-closure performance.. It is believed that the steel shoring can be recycled for two reasons. First, loose surface contamination on the waste containers will be absolutely minimal in order to meet licensing and OSHA requirements for the facility. Second, the waste forms that will be placed in the trenches do not emit neutrons in activities that could possibly activate the steel shoring. Small neutron-generating GTCC sealed sources will be disposed, but the disposal packages will incorporate long-lived neutron shielding materials.

### B 5.2 CONSTRUCTION EMISSIONS

Principal emissions for the construction of the ENSD facility include:

- CO
- NOx
- PM

To estimate emissions generated during construction of the ENSD, the equipment required for the construction was determined. Based on the equipment used, emissions were calculated. To calculate emissions, emission factors were utilized. An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors are generally expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. Such factors facilitate estimation of emissions from various sources of air pollution. Emission factors are averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category. The general equation for emissions estimation is:

$$\mathbf{E = A \times EF \times (1-ER/100)}$$

where:

E = emissions;
A = activity rate;
EF = emission factor, and
ER =overall emission reduction efficiency, %

The overall emission reduction efficiency (ER) is the weight per unit time of pollutant removed by a control device divided by the weight per unit time of pollutant emitted by an emission source expressed as a percentage. A control device is equipment used to reduce, by destruction or removal, the amount of air pollutant(s) in an exhaust stream prior to discharge to the ambient air. Examples of control devices include filters, scrubbers, low NOx burners or scrubbers, catalytic converters, fuel additives, and thermal and catalytic oxidizers.

Emissions factors are the fundamental tool in developing emissions inventories. More recently, emissions factors have been applied in determining emissions limitations in operating permits by federal, state, local, and tribal agencies, consultants, and industry.

Construction activities will result in air emissions from equipment used during construction. Using emissions factors obtained from EPA, anticipated equipment horsepower, and estimated equipment usage (duration in time) air emission estimates were calculated for construction.

The per trench values for these emissions based on the five-trench design discussed in Section B.3 are summarized in Table B.11. Calculation of the per trench values is discussed in Sections B 5.2.1 through B 5.2.3.

Table B.11. Per Trench Emissions Produced During Construction of an Enhanced Near Surface Disposal Facility[a]

| Activity | CO (lb/trench) | NOx (lb/trench) | PM (lb/trench) |
|---|---|---|---|
| **Surface Preparation[b]** | 96.87 | 668.43 | 40.61 |
| **Trench Excavation[c]** | | | |
| Basic Design | 224.54 | 1549.31 | 89.81 |
| Variation A | 449.07 | 3098.61 | 179.63 |
| **Auxiliary Installations[d]** | | | |
| Basic Design | 150.35 | 1037.43 | 60.14 |
| Variation A | 64.37 | 444.18 | 25.75 |
| **Total[e]** | | | |
| Basic Design | 471.76 | 3255.17 | 190.57 |
| Variation A | 610.32 | 4211.22 | 245.99 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section B 5.2.1; [c]Calculated from data given in Section B 5.2.2.; [d]Calculated from data given in Section B 5.2.3; [e]Calculated as the total of surface preparation, trench excavation, and auxiliary installations

### *B 5.2.1 Surface Preparation*

Emissions produced during the surface preparation phase of construction are listed in Table B.12.

Table B.12. Emissions Produced During Surface Preparation for an Enhanced Near Surface Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Loader | 1 | 197 | 110 | 1.00 | 0.43 | 47.78 |
| Dozer | 1 | 200 | 220 | 1.00 | 0.44 | 97.02 |
| Grader | 1 | 220 | 220 | 1.00 | 0.49 | 106.72 |
| Water Truck | 1 | 280 | 220 | 1.00 | 0.62 | 135.83 |
| Vibratory Roller | 1 | 60 | 220 | 1.00 | 0.13 | 29.11 |
| Dump Truck | 1 | 280 | 110 | 1.00 | 0.62 | 67.91 |
| **Total Duration and Emission** | | | 1100 | | | 484.37 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Loader | 6.9 | 3.00 | 329.70 | 0.4 | 0.17 | 19.11 |
| Dozer | 6.9 | 3.04 | 669.44 | 0.4 | 0.18 | 38.81 |
| Grader | 6.9 | 3.35 | 736.38 | 0.4 | 0.19 | 42.69 |
| Water Truck | 6.9 | 4.26 | 937.21 | 0.4 | 0.25 | 54.33 |
| Vibratory Roller | 6.9 | 0.91 | 200.83 | 0.72 | 0.10 | 20.96 |
| Dump Truck | 6.9 | 4.26 | 468.61 | 0.4 | 0.25 | 27.17 |
| **Total Duration and Emission** | | | 3342.17 | | | 203.06 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

### *B 5.2.2 Trench Excavation*

Emissions produced during the trench excavation phase of construction are listed in Table B.13.

Table B.13. Emissions Produced During Trench Excavation (Basic Design) for an Enhanced Near Surface Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Excavator | 2 | 330 | 250 | 1.00 | 0.73 | 363.76 |
| Loader | 1 | 197 | 250 | 1.00 | 0.43 | 108.58 |
| Dozer | 1 | 200 | 250 | 1.00 | 0.44 | 110.23 |
| Grader | 1 | 220 | 250 | 1.00 | 0.49 | 121.25 |
| Water Truck | 1 | 280 | 250 | 1.00 | 0.62 | 154.32 |
| Dump Truck | 1 | 280 | 250 | 1.00 | 0.62 | 154.32 |
| Generator | 2 | 100 | 250 | 1.00 | 0.22 | 110.23 |
| **Total Duration and Emission** | | | 1750 | | | 1122.69 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Excavator | 6.9 | 5.02 | 2509.92 | 0.4 | 0.29 | 145.50 |
| Loader | 6.9 | 3.00 | 749.17 | 0.4 | 0.17 | 43.43 |
| Dozer | 6.9 | 3.04 | 760.58 | 0.4 | 0.18 | 44.09 |
| Grader | 6.9 | 3.35 | 836.64 | 0.4 | 0.19 | 48.50 |
| Water Truck | 6.9 | 4.26 | 1064.81 | 0.4 | 0.25 | 61.73 |
| Dump Truck | 6.9 | 4.26 | 1064.81 | 0.4 | 0.25 | 61.73 |
| Generator | 6.9 | 1.52 | 760.58 | 0.4 | 0.09 | 44.09 |
| **Total Duration and Emission** | | | 7746.53 | | | 449.07 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

Table B.14. Emissions Produced During Trench Excavation (Variation A) for an Enhanced Near Surface Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Excavator | 2 | 330 | 500 | 1.00 | 0.73 | 727.51 |
| Loader | 1 | 197 | 500 | 1.00 | 0.43 | 217.15 |
| Dozer | 1 | 200 | 500 | 1.00 | 0.44 | 220.46 |
| Grader | 1 | 220 | 500 | 1.00 | 0.49 | 242.50 |
| Water Truck | 1 | 280 | 500 | 1.00 | 0.62 | 308.64 |
| Dump Truck | 1 | 280 | 500 | 1.00 | 0.62 | 308.64 |
| Generator | 2 | 100 | 500 | 1.00 | 0.22 | 220.46 |
| **Total Duration and Emission** | | | 3500 | | | 2245.37 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Excavator | 6.9 | 5.02 | 5019.84 | 0.4 | 0.29 | 291.01 |
| Loader | 6.9 | 3.00 | 1498.35 | 0.4 | 0.17 | 86.86 |
| Dozer | 6.9 | 3.04 | 1521.16 | 0.4 | 0.18 | 88.18 |
| Grader | 6.9 | 3.35 | 1673.28 | 0.4 | 0.19 | 97.00 |
| Water Truck | 6.9 | 4.26 | 2129.63 | 0.4 | 0.25 | 123.46 |
| Dump Truck | 6.9 | 4.26 | 2129.63 | 0.4 | 0.25 | 123.46 |
| Generator | 6.9 | 1.52 | 1521.16 | 0.4 | 0.09 | 88.18 |
| **Total Duration and Emission** | | | 15493.06 | | | 898.15 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

### *B 5.2.3 Auxiliary Installations*

Emissions produced during the auxiliary installation phase of construction are listed in Tables B.15 and B.16.

Table B.15. Emissions Produced During Auxiliary Installations for an Enhanced Near Surface Disposal Facility the Basic Design[a,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Crane/pile driver[b] | 1 | 300 | 750 | 1.00 | 0.66 | 496.03 |
| Crane[d] | 1 | 300 | 200 | 1.00 | 0.66 | 132.28 |
| Cement Truck[d] | 1 | 280 | 200 | 1.00 | 0.62 | 123.46 |
| **Total Duration and Emission** | | | | | | 751.76 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Crane/pile driver[b] | 6.9 | 4.56 | 3422.62 | 0.4 | 0.26 | 198.41 |
| Crane[d] | 6.9 | 4.56 | 912.70 | 0.4 | 0.26 | 52.91 |
| Cement Truck[d] | 6.9 | 4.26 | 851.85 | 0.4 | 0.25 | 49.38 |
| **Total Duration and Emission** | | | 5187.17 | | | 300.71 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day; [d]AMEC (2007) did not include the emissions for placement of the SDS. Values here added to account for placement of the SDS.

Table B.16. Emissions Produced During Auxiliary Installations for an Enhanced Near Surface Disposal Facility Variation A[a,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Crane[b] | 1 | 300 | 100 | 1.00 | 0.66 | 66.14 |
| Crane[d] | 1 | 300 | 200 | 1.00 | 0.66 | 132.28 |
| Cement Truck[d] | 1 | 280 | 200 | 1.00 | 0.62 | 123.46 |
| **Total Duration and Emission** | | | | | | 321.87 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission for Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Crane[b] | 6.9 | 4.56 | 456.35 | 0.4 | 0.26 | 26.46 |
| Crane[d] | 6.9 | 4.56 | 912.70 | 0.4 | 0.26 | 52.91 |
| Cement Truck[d] | 6.9 | 4.26 | 851.85 | 0.4 | 0.25 | 49.38 |
| **Total Duration and Emission** | | | 2220.90 | | | 128.75 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day; [d]AMEC (2007) did not include the emissions for placement of the SDS. Values here added to account for placement of the SDS.

## B 6. CONSTRUCTION COSTS, DURATIONS, AND PERSONNEL

This section presents the costs, durations, and personnel required for construction of an ENSD facility comprised of five trenches as described in Section B.3. The first three phases of ENSD facility construction (planning, geotechnical investigations, and mobilization) have bearing on costs, durations, and personnel for the project. Construction, consisting of three phases, surface preparation, trench excavation, and auxiliary installations also affect the costs, durations, and personnel as identified below.

Cost estimates were prepared for this project by AMEC (2007). To develop the construction cost estimates for the conceptual design of ENSD, *RSMeans* Construction Estimating Software was utilized. *RSMeans* is a product line of Reed Construction Data, which provides accurate and up-to-date cost information which is used in *RSMeans* to assist construction cost estimators in the development of cost estimates for a wide range of construction projects, including environmental and clean construction activities. *RSMeans* contains a collection of annual construction cost data books, and is the most used, quoted, and respected construction and facility management cost guides in the construction industry. The 23 Means Construction Cost Data Guides contain unit and assemblies costs for almost 100,000 building components. These completely-updated costs are carefully prepared from the experience of thousands of building owners, facilities managers, engineers, contractors and suppliers in the months just before the guides are published. The cost data is arranged in the 16 CSI MasterFormat95 divisions, allowing for fast, accurate referencing. In addition to the use of *RSMeans*, specialty subcontractors, such as drilling contractors and material suppliers were contacted to verify input parameters into construction spreadsheets. All of the data used in *RSMeans* was verified by AMEC (2007).

### B 6.1 COSTS

Principal costs for the construction of the ENSD facility include:

- Project Management Labor Costs (P)
- Subcontractor Costs (S)
- Engineering Design Fees (E)
- Direct Costs (O)

Direct costs include temporary site facilities, consumables, airfare, car rental, and lodging/per diem and are small compared to the other costs involved. Therefore, while the direct costs were included in AMEC (2007), they are neglected in this document.

The per trench values for these costs based on the five-trench design discussed in Section B.3 are summarized in Table B.16. Calculation of the per trench values is discussed in Sections B 6.1.1 through B 6.1.4.

Table B.17. Per Trench Costs for Construction of an Enhanced Near Surface Disposal Facility[a]

| Activity | Project Management Labor Costs[b] (dollars/trench) | Subcontractor Costs[c] (dollars/trench) | Engineering Design Fees[d] (dollars/trench) | Direct Costs[e] (dollars/trench) | Total Costs[f] (dollars/trench) |
|---|---|---|---|---|---|
| Basic Design | $137,760 | $2,491,900 | $52,030 | $9,257 | $3,121,373 |
| Variation A | $125,287 | $2,095,800 | $43,859 | $8,475 | $2,637,928 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section B 6.1.1; [c]Calculated from data given in Section B 6.1.2.; [d]Calculated from data given in Section B 6.1.3; [e] Calculated from data given in Section B 6.1.4.; [f]Calculated as described in Section B 6.1.

The total cost is calculated as:

$$(S + E + O)*1.15 + P*1.25 + E*0.25$$

This includes a 15% markup on the subtotal of the subcontractor costs, the engineering design fees, and the direct costs as well as a professional services contingency mark up on the subtotal of the project management labor costs and the engineering design fees.

### *B 6.1.1 Project Management Labor Costs*

Project management labor costs are listed in Table B.17. Project Management cost would include man hours expended to coordinate field activities and ensure that all activities related to the construction are conducted on time and within the allotted budget.

Table B.18. Project Management Labor Costs for Construction of an ENSD Facility[a]

| Project Management Labor Costs | | | | Planning Documents | | Geotechnical Investigation | | Support Facilities Construction | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 0 | $0.00 | 3.2 | $151.55 | 198 | $9,377.28 |
| 1 | Program Manager | ST | $182.48 | 12 | $2,189.76 | 3.2 | $583.94 | 4.4 | $802.91 |
| 1 | Project Manager | ST | $170.83 | 144 | $24,599.52 | 12.8 | $2,186.62 | 35.2 | $6,013.22 |
| 1 | Program QA/QC Manager | ST | $112.19 | 144 | $16,155.36 | 1.28 | $143.60 | 8.8 | $987.27 |
| 1 | Construction Manager | ST | $103.25 | 0 | $0.00 | 64 | $6,608.00 | 198 | $20,443.50 |
| 1 | Project QA Inspector | ST | $72.14 | 0 | $0.00 | 19.2 | $1,385.09 | 99 | $7,141.86 |
| 1 | Health & Safety Manager | ST | $103.25 | 144 | $14,868.00 | 12.8 | $1,321.60 | 19.8 | $2,044.35 |
| 1 | Project Engineer-Senior | ST | $141.17 | 57.6 | $8,131.39 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Mid | ST | $131.69 | 57.6 | $7,585.34 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Junior | ST | $121.28 | 57.6 | $6,985.73 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Senior | ST | $141.17 | 0 | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Mid | ST | $131.69 | 0 | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Administrative Assistant | ST | $54.25 | 259.2 | $14,061.60 | 19.2 | $1,041.60 | 29.7 | $1,611.23 |
| 1 | Cost Scheduler | ST | $77.56 | 76.8 | $5,956.61 | 0 | $0.00 | 0 | $0.00 |
| 1 | CAD/GIS Operator | ST | $67.82 | 57.6 | $3,906.43 | 0 | $0.00 | 0 | $0.00 |
| 1 | Technical Writer/Editor | ST | $72.14 | 480 | $34,627.20 | 0 | $0.00 | 0 | $0.00 |
| 1 | Accounting Clerk | ST | $45.00 | 36 | $1,620.00 | 25.6 | $1,152.00 | 39.6 | $1,782.00 |
| **SUBTOTAL LABOR** | | | | **1526.4** | **$140,686.94** | **161.3** | **$14,574.00** | **632.5** | **$50,203.62** |

| Project Management Labor Costs | | | | ENSD Mobilization & Demobilization | | Trench Excavation Basic Design | | Trench Excavation Variation A | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 45 | $2,131.20 | 225 | $10,656.00 | 450 | $21,312.00 |
| 1 | Program Manager | ST | $182.48 | 1 | $182.48 | 5 | $912.40 | 10 | $1,824.80 |
| 1 | Project Manager | ST | $170.83 | 8 | $1,366.64 | 40 | $6,833.20 | 80 | $13,666.40 |
| 1 | Program QA/QC Manager | ST | $112.19 | 2 | $224.38 | 10 | $1,121.90 | 20 | $2,243.80 |
| 1 | Construction Manager | ST | $103.25 | 45 | $4,646.25 | 225 | $23,231.25 | 450 | $46,462.50 |
| 1 | Project QA Inspector | ST | $72.14 | 22.5 | $1,623.15 | 112.5 | $8,115.75 | 225 | $16,231.50 |
| 1 | Health & Safety Manager | ST | $103.25 | 45 | $4,646.25 | 225 | $23,231.25 | 450 | $46,462.50 |
| 1 | Project Engineer-Senior | ST | $141.17 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Project Engineer-Mid | ST | $131.69 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Project Engineer-Junior | ST | $121.28 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Scientist-Senior | ST | $141.17 | | $0.00 | | $0.00 | | $0.00 |
| 1 | Scientist-Mid | ST | $131.69 | | $0.00 | | $0.00 | | $0.00 |
| 1 | Administrative Assistant | ST | $54.25 | 6.75 | $366.19 | 33.75 | $1,830.94 | 67.5 | $3,661.88 |
| 1 | Cost Scheduler | ST | $77.56 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | CAD/GIS Operator | ST | $67.82 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Technical Writer/Editor | ST | $72.14 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Accounting Clerk | ST | $45.00 | 9 | $405.00 | 45 | $2,025.00 | 90 | $4,050.00 |
| **SUBTOTAL LABOR** | | | | **184.3** | **$15,591.54** | **921.3** | **$77,957.69** | **1842.5** | **$155,915.38** |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table B.17 Project Management Labor Costs for Construction of an Enhanced Near Surface Disposal Facility[a,b] (continued)

| Project Management Labor Costs | | | | Basic Design Shoring Placement | | Variation A Sheet Piling Placement | | Construct Engineered Barrier | |
|---|---|---|---|---|---|---|---|---|---|
| Classification | | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 450 | $21,312.00 | 45 | $2,131.20 | 675 | $31,968.00 |
| 1 | Program Manager | ST | $182.48 | 10 | $1,824.80 | 1 | $182.48 | 15 | $2,737.20 |
| 1 | Project Manager | ST | $170.83 | 80 | $13,666.40 | 8 | $1,366.64 | 120 | $20,499.60 |
| 1 | Program QA/QC Manager | ST | $112.19 | 20 | $2,243.80 | 2 | $224.38 | 30 | $3,365.70 |
| 1 | Construction Manager | ST | $103.25 | 450 | $46,462.50 | 45 | $4,646.25 | 675 | $69,693.75 |
| 1 | Project QA Inspector | ST | $72.14 | 225 | $16,231.50 | 22.5 | $1,623.15 | 338 | $24,347.25 |
| 1 | Health & Safety Manager | ST | $103.25 | 450 | $46,462.50 | 45 | $4,646.25 | 675 | $69,693.75 |
| 1 | Project Engineer-Senior | ST | $141.17 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Mid | ST | $131.69 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Junior | ST | $121.28 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Senior | ST | $141.17 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Mid | ST | $131.69 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Administrative Assistant | ST | $54.25 | 67.5 | $3,661.88 | 6.75 | $366.19 | 101 | $5,492.81 |
| 1 | Cost Scheduler | ST | $77.56 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | CAD/GIS Operator | ST | $67.82 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Technical Writer/Editor | ST | $72.14 | | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Accounting Clerk | ST | $45.00 | 90 | $4,050.00 | 9 | $405.00 | 135 | $6,075.00 |
| **SUBTOTAL LABOR** | | | | **1842.5** | **$155,915.38** | **184.3** | **$15,591.54** | **2763.8** | **$233,873.06** |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

All costs are included in the basic design. The total project management labor costs for the basic design is $688,802 for five trenches, or $137,760 per trench. Costs for trench excavation for the basic design are lower than those for Variation A because the trenches are being dug in unconsolidated media.

All costs except the shoring placement costs are included for Variation A. Sheet piling emplacement costs are included in Variation A. The total project management labor costs for Variation A is $626,436 for five trenches or $125,287 per trench. The costs for trench excavation for Variation A are higher than those for the basic design because the trenches are being dug in consolidated media, but there are no shoring costs for Variation A.

### *B 6.1.2 Subcontractor Costs*

Subcontractor costs are listed in Table B.18. Subcontractor cost would include the cost incurred to conduct the actual construct related activities associate with the ENSD facility construction. Subcontractors, for example, would also include rental of equipment such as portable toilets and the cost to service such materials.

Table B.19. Subcontractor Costs for Construction of an Enhanced Near Surface Disposal Facility[a,b]

| ENSD – Subcontractor Costs | | | Geotechnical Investigation | | Support Facilities Construction | |
|---|---|---|---|---|---|---|
| Subcontractor Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Geotechnical Services, RSM | LS | $48,000.00 | 1 | $48,000.00 | | |
| 1 General Contractor, RSM | LS | $373,000.00 | | | 1 | $373,000.00 |
| 5 Excavation Contractor, RSM | LS | $180,125.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $257,500.00 | | | | |
| 1 Mobilization & Demobilization | LS | $9,875.00 | | | | |
| 1 Sheet Piling Contractor, RSM | LS | $518,000.00 | | | | |
| 1 Mobilization & Demobilization | LS | $38,000.00 | | | | |
| 5 Intrusion Barrier Construction | | $85,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | **1** | **$48,000.00** | **1** | **$373,000.00** |
| **ENSD - Subcontractor Costs** | | | **ENSD Mobilization & Demobilization Basic Design** | | **ENSD Mobilization & Demobilization Variation A** | |
| Subcontractor Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 General Contractor, RSM | LS | $373,000.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $180,125.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $257,500.00 | | | | |
| 1 Mobilization & Demobilization | LS | $9,875.00 | 1 | $9,875.00 | 1 | $11,500.00 |
| 1 Sheet Piling Contractor, RSM | LS | $518,000.00 | | | | |
| 1 Mobilization & Demobilization | LS | $38,000.00 | 1 | $38,000.00 | | |
| 5 Intrusion Barrier Construction | | $85,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | **1** | **$47,875.00** | **1** | **$11,500.00** |
| **ENSD - Subcontractor Costs** | | | **Trench Excavation Basic Design** | | **Trench Excavation Variation A** | |
| Subcontractor Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 General Contractor, RSM | LS | $373,000.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $180,125.00 | 1 | $900,625.00 | | |
| 5 Excavation Contractor, RSM | LS | $257,500.00 | | | 1 | $1,287,500.00 |
| 1 Mobilization & Demobilization | LS | $9,875.00 | | | | |
| 1 Sheet Piling Contractor, RSM | LS | $518,000.00 | | | | |
| 1 Mobilization & Demobilization | LS | $38,000.00 | | | | |
| 5 Intrusion Barrier Construction | | $85,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | **1** | **$900,625.00** | **1** | **$1,287,500.00** |
| **ENSD - Subcontractor Costs** | | | **Shoring Placement[c]** | | **Construct Engineered Barrier** | |
| Subcontractor Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 General Contractor, RSM | LS | $373,000.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $180,125.00 | | | | |
| 5 Excavation Contractor, RSM | LS | $257,500.00 | | | | |
| 1 Mobilization & Demobilization | LS | $9,875.00 | | | | |
| 1 Sheet Piling Contractor, RSM | LS | $518,000.00 | 1 | $2,590,000.00 | | |
| 1 Mobilization & Demobilization | LS | $38,000.00 | | | | |
| 5 Intrusion Barrier Construction | | $85,000.00 | | | 20 | $8,500,000.00 |
| **SUBTOTAL SUBCONTRACTOR** | | | **1** | **$2,590,000.00** | **20** | **$8,500,000.00** |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]For Variation A, placing the sheet piling is 10% of the shoring cost.

All costs are included in the basic design. The total subcontractor costs for the basic design is $12,459,500 for five trenches, or $2,491,900 per trench. Costs for trench excavation for the basic design are lower than those for Variation A because the trenches are being dug in unconsolidated media.

All costs except the shoring placement costs are included for Variation A. Variation A does include costs for placing the sheet piling which are ten percent of the shoring costs. The total subcontractor costs for Variation A are $10,479,000 for five trenches or $2,095,800 per trench. The costs for trench excavation for Variation A are higher than those for the basic design because the trenches are being dug in consolidated media, but there are no shoring costs for Variation A.

### *B 6.1.3 Engineering and Design Fees*

Engineering and design fees are listed in Table B.19. Engineering design fees would include the cost incurred to conduct the actual design of the facility. The design would be based on the conceptual design presented in this document.

Table B. 20. Engineering Design Fees for Construction of an Enhanced Near Surface Disposal Facility[a,b]

| **ENSD – Direct Costs** | | | **Geotechnical Investigation** | | **Support Facilities Construction** | |
|---|---|---|---|---|---|---|
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Engineering Design Fees – Basic Design | | | 1 | $1,251.00 | 1 | $8,464.07 |
| 1 Engineering Design Fees - Variation A | | | 1 | $1,251.00 | 1 | $8,464.07 |
| **ENSD – Direct Costs** | | | **ENSD Mobilization & Demobilization** | | **Trench Excavation** | |
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Engineering Design Fees – Basic Design | | | 1 | $1,269.33 | 1 | $19,571.65 |
| 1 Engineering Design Fees - Variation A | | | 1 | $541.83 | 1 | $28,868.31 |
| **ENSD – Direct Costs** | | | **Shoring Placement[c]** | | **Construct Engineered Barrier** | |
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Engineering Design Fees – Basic Design | | | 1 | $54,918.31 | 1 | $174,677.46 |
| 1 Engineering Design Fees - Variation A | | | 1 | $5,491.83 | 1 | $174,677.46 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]For Variation A, placing the sheet piling.

All costs are included in the basic design. The total engineering and design fees in the basic design is $260,152 for five trenches, or $52,030 per trench. Costs for trench excavation for the basic design are lower than those for Variation A because the trenches are being dug in unconsolidated media.

All costs except the shoring placement costs are included for Variation A. Variation A does include costs for placing the sheet piling which are ten percent of the shoring costs. The total

engineering and design fees for Variation A are $219,294.98 for five trenches or $43,859 per trench. The costs for trench excavation for Variation A are higher than those for the basic design because the trenches are being dug in consolidated media, but there are no shoring costs for Variation A.

### *B 6.1.4 Direct Costs*

Direct costs are listed in Table B.20.

Table B.21. Direct Costs for Construction of an Enhanced Near Surface Disposal Facility[a,b]

| **ENSD – Engineering & Design Costs** | | | **Geotechnical Investigation** | | **Support Facilities Construction** | |
|---|---|---|---|---|---|---|
| Professional Consultant | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $6,940.96 | 1 | $15,184.84 |
| 1 Direct Costs - Variation A | | | 1 | $6,790.48 | 1 | $14,771.02 |
| **ENSD - Engineering & Design Costs** | | | **ENSD Mobilization & Demobilization** | | **Trench Excavation** | |
| Professional Consultant | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $3,451.10 | 1 | $3,451.10 |
| 1 Direct Costs - Variation A | | | 1 | $3,357.05 | 1 | $6,714.10 |
| **ENSD - Engineering & Design Costs** | | | **Shoring Placement[c]** | | **Construct Engineered Barrier** | |
| Professional Consultant | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $6,902.20 | 1 | $10,353.30 |
| 1 Direct Costs - Variation A | | | 1 | $671.41 | 1 | $10,071.15 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]For placing the sheet piling in Variation A.

All costs are included in the basic design. The total direct costs in the basic design are $46,284 for five trenches, or $9,257 per trench. Costs for trench excavation for the basic design are lower than those for Variation A because the trenches are being dug in unconsolidated media.

All costs except the shoring placement costs are included for Variation A. Variation A does include costs for placing the sheet piling which are ten percent of the shoring costs. The total engineering and design fees for Variation A are $42,375 for five trenches or $8,475 per trench. The costs for trench excavation for Variation A are higher than those for the basic design because the trenches are being dug in consolidated media, but there are no shoring costs for Variation A.

## B 6.2 DURATIONS

Durations for construction are listed in Table B.21.

Table B.22. Durations for Construction of an Enhanced Near Surface Disposal Facility[a,b]

| | | Basic Design | | Variation A | |
|---|---|---|---|---|---|
| **ENSD – Construction Phases** | Unit | Per Trench | For Five Trenches | Per Trench | For Five Trenches |
| Planning Documents | Days | 24 | 120 | 24 | 120 |
| Geotechnical Investigation | Days | 3.2 | 16 | 3.2 | 16 |
| Support Facilities Construction | Days | 4.4 | 22 | 4.4 | 22 |
| IDBD Mobilization & Demobilization | Days | 1 | 5 | 1 | 5 |
| Trench Excavation | Days | 5 | 25 | 10 | 50 |
| Shoring Placement | Days | 10 | 50 | 1 | 5 |
| Place Subsurface Deflection Shield | Days | 15 | 75 | 15 | 75 |
| Total | Days | 63 | 313 | 59 | 293 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

The planning stage takes about 120 days. The total duration required to conduct the geotechnical investigation activities, prior to construction is 16 days. Support facility construction is 22 days and mobilization and demobilization would take 5 days.

Excavation of five trenches would take 25 days for the basic design and 50 days for Variation A. Shoring placement requires about 50 days. Placement of the sheet piling across the trenches requires about 5 days. Finally, placement of the subsurface SDSs requires 75 days for five trenches.

The resulting total durations for the basic design and Variation A, respectively are 313 days and 293 days for five trenches, or 63 and 59 days per trench.

## B 6.3 MAN-HOURS

Man hours are from:

- Project management
- Heavy equipment operations

The per trench values for the man hours based on the five-trench design discussed in Section B.3 are summarized in Table B.22.

Table B.23. Man-hours for Construction of an Enhanced Near Surface Disposal Facility[a,b]

| | Classification | Man-hours | | Man-Hours Per Trench | |
|---|---|---|---|---|---|
| | | Basic Design | Variation A | Basic Design | Variation A |
| 1 | Field Tech | 1596 | 1416 | 319 | 283 |
| 1 | Program Manager | 51 | 47 | 10 | 9 |
| 1 | Project Manager | 440 | 408 | 88 | 82 |
| 1 | Program QA/QC Manager | 216 | 208 | 43 | 42 |
| 1 | Construction Manager | 1657 | 1477 | 331 | 295 |
| 1 | Project QA Inspector | 816 | 726 | 163 | 145 |
| 1 | Health & Safety Manager | 1572 | 1392 | 314 | 278 |
| 1 | Project Engineer-Senior | 58 | 58 | 12 | 12 |
| 1 | Project Engineer-Mid | 58 | 58 | 12 | 12 |
| 1 | Project Engineer-Junior | 58 | 58 | 12 | 12 |
| 1 | Scientist-Senior | 0 | 0 | 0 | 0 |
| 1 | Scientist-Mid | 0 | 0 | 0 | 0 |
| 1 | Administrative Assistant | 517 | 490 | 103 | 98 |
| 1 | Cost Scheduler | 77 | 77 | 15 | 15 |
| 1 | CAD/GIS Operator | 58 | 58 | 12 | 12 |
| 1 | Technical Writer/Editor | 480 | 480 | 96 | 96 |
| 1 | Accounting Clerk | 380 | 344 | 76 | 69 |
| 1 | Heavy Equipment Operator | 4,010 | 3,360 | 802 | 672 |

[a]Construction of five trenches. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

## B 7. REFERENCES

AMEC (2007). Summary of Input Parameters for Conceptual Facility Designs for Greater-Than-Class C Low-Level Waste Disposal Options, Task 3.4, Revision 1. ERMS 547141. AMEC.

Hart, J. and M. Hillesheim (2007). Selection of Barrier Designs and Barrier Materials for Intermediate-Depth Borehole Disposal and Enhanced Near-Surface Disposal Systems, Revison 0. ERMS 547135. Sandia National Laboratories. Carlsbad, NM.

U. S. BOT (2007). Table 4-6: Energy Consumption by Mode of Transportation (Trillion BTU). Available at:www.bts.gov/publications/national_transportation_statistics/2002/html/table_04_06.html. ERMS 545735. U. S. Bureau of Transportation. Washington, DC.

# Appendix C
# IDBD Associated Construction Data for Use in Task 3.6

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ASTM | American Society for testing and materials |
| CQP | Construction Quality Plan |
| DOE | Department of Energy |
| EIS | Environmental Impact Statement |
| EPP | Environmental Protection Plan |
| HASP | Health and Safety Plan |
| IDBD | Intermediate Depth Borehole Disposal |
| OSHA | Occupational Safety and Health Administration |
| QAP | Quality Assurance Plan |
| RPPP | Radiation Protection Program Plan |
| SWPPP | Storm Water Pollution Prevention Plan |
| WP | Work Plan |

## C1. INTRODUCTION

This appendix provides the construction data for building the subsurface component of an Intermediate Depth Borehole Disposal (IDBD) facility. Conceptual designs for the IDBD facility were presented in Section 4. Three variations, a Basic Design, Variation A and Variation B were presented in Section 4. The Intermediate Depth Borehole Disposal Facility (IDBD) conceptual design and associated construction data discussed in this document have been formulated solely for use in preparing the Environmental Impact Statement (EIS). Of necessity, a number of assumptions, which are documented in this appendix, have been made. The construction data set discussed in this document is for construction of fifty boreholes and does not include construction of surface facilities for operation. A fifty-borehole configuration was chosen for the purposes of spreading one-time values for application in the Task 3.6 data packages. Defining the number of boreholes to use as a basis for spreading one-time values was iterative, starting with one borehole, calculating the per borehole cost, and then increasing the number of boreholes. At fifty boreholes, increasing the number of boreholes no longer produced a significant change in the per borehole cost. Therefore, a fifty borehole configuration was chosen as a basis for spreading one time costs.

A flow diagram for construction of the IDBD facility is shown in Figure C.1. Construction occurs in several phases starting with planning and permitting and ending in clearing of all construction-specific equipment (demobilization). Planning, mobilization/demobilization, surface preparation, borehole drilling, and auxiliary installations are the phases identified in Figure C.1. These phases of construction contribute to the costs, durations and man-hours required to build an IDBD facility.

Figure C.1 is a conceptualization of the construction process. The IDBD facility design presented in this report is conceptual and was created solely to support the EIS evaluations. The facility designs are not intended to be used for licensing or construction purposes. The methods and assumptions used to prepare the information presented in this report are discussed separately below for each of the construction phases identified in Figure C.1. Section C.2 describes the work that is required before breaking ground. Section C.3 describes the surface preparation phase of construction identifying land use and giving site maps. Section C.4 describes the equipment, resources, and materials needed to build the facility. Section C.5 describes the wastes and emissions that one can expect to be produced while constructing the facility. Section C.6 describes the costs, durations, and man-hours associated with facility construction.

**Construction Phases That Contribute to Cost/Man-hours/Durations**

| | **Planning** *Preparation of Planning Documents, Obtaining Permits, Geotechnical Investigations* | **Mobilization/ Demobilization** *Placement and removal of temporary structures* | **Surface Preparation** *Clearing, grubbing, grading, installing roads Installing erosion control and fencing* | **Borehole Construction** *Borehole drilling with augering or coring equipment* | **Auxiliary Installations** *Installing borehole casings, subsurface barrier* |
|---|---|---|---|---|---|
| **Equipment** | None | None | Loader, Dozer, Grader, Water Truck, Vibratory Roller, Dump Truck | Drill Rig, Loader, Water Truck, Generator Dump Truck | Crane Cement Truck |
| **Resources & Materials** | None | None | Aggregate, Chain link Fence, Temporary buildings, Hay bales, Silt fence Water, Diesel fuel | Diesel Fuel Water | Concrete, Grout, Steel Casing, Corrugated Metal, Steel Borehole Cover |
| **Wastes** | None | None | Refuse, Construction debris | Excavated Material | None |
| **Emissions** | None | None | CO, NOx, PM | CO, NOx, PM | CO, NOx, PM |

Figure C.1. Construction Phases for an IDBD Facility

## C2. PLANNING, MOBILIZATION, DEMOBILIZATION

The first phases of IDBD facility construction would be planning and mobilization. The last phase would be demobilization after the facility has been built. The phases have bearing on costs, durations and man-hours for the project and are included in the Section C.6 discussions.

### C 2.1 Planning

Actual construction would require time and funding for construction planning, permitting, and geotechnical investigations. It is assumed that all construction activities would be "clean construction" requiring the use of modified level D personal protection. Hence, preparation of a Radiation Protection Program Plan (RPPP) or participation in such plan is not included in this document or the associated cost estimate. DOE planning documents include the preparation of the following to support facilities construction:

- Design drawings and specifications;

- Construction Quality Plan (CQP);
- Work Plan (WP);
- Project-specific Quality Assurance Plan (QAP);
- Health and Safety Plan (HASP), which includes activity hazard analyses for work activities;
- Environmental Protection Plan (EPP);
- Project-specific Security Plan;
- Accident Prevention Plan;
- Project Management Project Control Plan (PMPC);
- Sampling and Analysis Plan;
- Field Implementation Plan;
- Geotechnical Investigation Plan; and
- As-built drawings.

A *Storm Water Pollution Prevention Plan (SWPPP) for Construction* activities would also have to be prepared. The SWPPP would include submission of a construction notice of intent to discharge. Should an air quality mobile source permit be required for construction equipment, one would be prepared and submitted. The planning and permitting activities are for construction only and do not include operational permitting and public outreach. Regulatory interaction or notification is not included in construction related activities. This analysis only addresses construction costs. After planning documents are complete, a readiness review would be conducted prior to site mobilization.

## C 2.2 Geotechnical Investigations

Soil borings will be installed to determine subsurface conditions at each project site. Sufficient data will be collected to assure that the supporting soil or rock has sufficient capacity to provide adequate safety factor against foundation failure and adequate stiffness to minimize settlements under design loads. Actual boring locations will be dependent on field conditions. The actual number of borings will be adequate to fill data gaps for the final geotechnical investigation and to allow the Professional Engineer to make final geotechnical recommendations for foundation design, slab support, borehole design, and related earthwork.

During drilling activities, samples will be collected at selected depths from the surface to total boring depths to obtain geotechnical data. Core samples will be placed on plastic sheeting during logging. The borings will be logged in the field using the Unified Soil Classification System in accordance with ASTM D2487. A soil boring log will be recorded in the field by the geotechnical engineer. The boring log will contain a graphical log of soil/rock type encountered, sample location, blows per foot, unified soil classification code, remarks of the field engineer, and a detailed visual classification.

Geotechnical samples will be obtained from the test borings installed as part of this final geotechnical investigation activity. Borings will be installed to sufficient depth to provide geotechnical information to assist with final design of the proposed IDBD. Samples sent to the materials testing laboratory will be collected from the area within the zone of influence of the stresses for the proposed building walls and foundations. Samples will be collected throughout the depth of the boring for testing. Tests will consist of unconfined compression, direct shear, consolidation, expansion, moisture content, density sieve analysis, and Atterberg Limits. Additional testing, based on field conditions encountered during drilling may be conducted.

Samples will be collected for laboratory geotechnical analysis to verify visual classification made in the field and to evaluate engineering properties that may impact the project performance. Actual types and quantities of samples and geotechnical analysis performed may be based on conditions encountered in the field during investigation activities.

### C 2.3 Mobilization/Demobilization

Once operational readiness has been established, the equipment materials and personnel required to construct the IDBD facility would be mobilized to the site. Heavy equipment required to construct the IDBD such as front end loaders, excavators, dump trucks and graders would be required to prepare the site surface for construction of the facility. For the purpose of facility infrastructure construction it is assumed that utilities would not be available at the IDBD facility construction site. Water, sanitation and power (generators) would be required to provide the required utilities to the IDBD facility site. In addition, a bulk fuel storage tank would be required to store diesel fuel onsite to re-fuel construction equipment during facility construction.

Once the facility is constructed, all equipment required to construct the facility would be demobilized from the project site. Temporary structures would be removed and transported off-site during demobilization efforts.

## C3. SURFACE PREPARATION

This section discusses the fourth phase of construction which is surface preparation. Before borehole drilling can begin, the land area that encompasses the site must be prepared. For the purposes of this analysis, the IDBD facility is assumed to require at least 4.7 hectares[1] of land to allow for the installation of fifty boreholes, support facilities (storage for heavy equipment; set up and operation of drilling pad, staging areas for soils generated) and infrastructure (temporary roads and parking). This assumption is being made for the purposes of spreading one time values (i.e., costs, wastes, resources) across multiple boreholes to derive appropriate per borehole values for application in the Task 3.6 data packages. A hypothetical IDBD facility layout used to derive per borehole values is shown in Figure C.2.

For the fifty-borehole facility configuration, the facility would be approximately 217 meters long by 217 meters wide, covering approximately 4.7 hectares of land. The total disturbed site area would be approximately 3.4 hectares. A security perimeter fence with three strands of barbed wire installed at the top to prevent unauthorized entry and a three foot rodent barrier along the

[1] One hectare is equivalent to 2.471 acres.

bottom would be required. The total fenced area of the fifty-borehole facility would be approximately 4.2 hectares. Parking areas and site roads would be constructed of base-coarse or

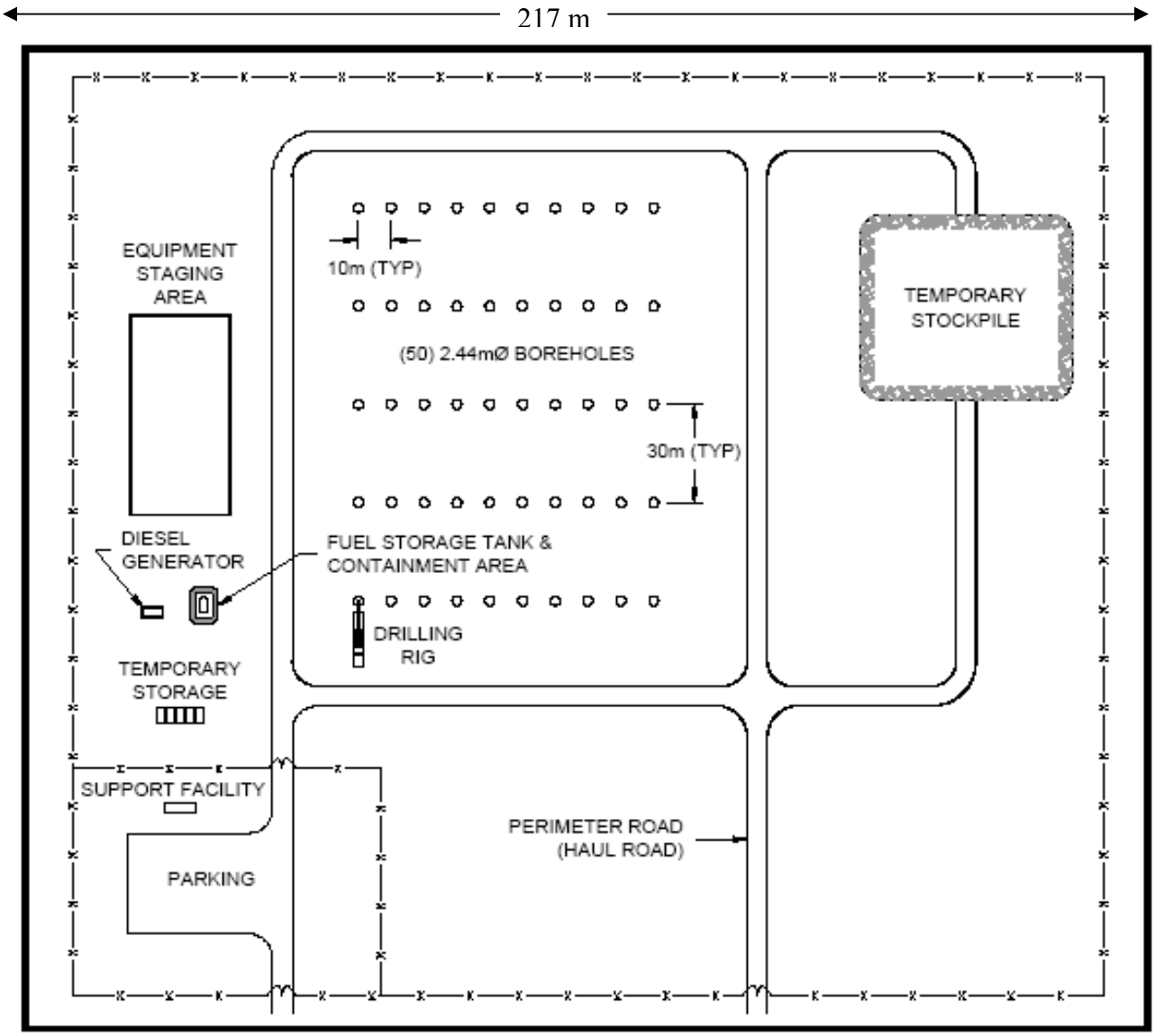


Figure C.2. Hypothetical Facility Layout for Purposes of Deriving Normalized Per Unit Costs

Table C.1. Land Use Parameters Based on the Fifty-Borehole IDBD Facility Design[a]

| | Site Land Area (hectares) | Disturbed Land Area (hectares) | Fenced Area (hectares) | Paved Area (hectares) |
|---|---|---|---|---|
| **Total** | 4.7 | 3.4 | 4.2 | 0 |
| **Per Borehole** | 0.094 | 0.068 | 0.084 | 0 |

[a]Source is AMEC (2007)

gravel. Roads and parking areas would not be paved with asphalt. All materials excavated during construction would be stored within the project boundary, within one mile from the point of generation. The site land parameters are shown in Table C.1. Both the total values and the per borehole values, based on the fifty-borehole configuration shown in Figure C.2, are shown in the table.

## C4. CONSTRUCTION EQUIPMENT, RESOURCE AND MATERIAL REQUIREMENTS

Construction of the IDBD facility will require construction materials, use of heavy equipment, site vehicles and utilities. It was assumed that utilities, water, sanitation and electricity would not be available at the selected site. Generators will be utilized to provide power to the site, portable sanitation facilities (portable toilets) will be used for site personnel and visitors. Equipment utilized will include heavy construction equipment, support trucks, site personnel vehicles, and generators.

This section presents the equipment, resources, and materials needed for construction of an IDBD facility comprised of fifty boreholes as described in Section C.3. As shown in Figure C.1, three phases of construction have equipment, resource and material demands: surface preparation, borehole drilling, and auxiliary installations. The equipment, resource, and material requirements are identified below for these phases of construction.

### C 4.1 Construction Equipment

The overall heavy equipment list includes: loaders, dozers, graders, water trucks, dump trucks, cement trucks, vibratory rollers, drilling equipment, cranes, and generators. Total inventory for this equipment is shown in Table C.2.

Table C.2. Heavy Equipment Required for Construction of IDBD Facility[a]

| Equipment | Quantity | Horsepower (hp) |
|---|---|---|
| Loader[b] | 1 | 197 |
| Dozer[b] | 1 | 200 |
| Grader[b] | 1 | 220 |
| Water Truck[b] | 1 | 280 |
| Vibratory Roller[b] | 1 | 60 |
| Dump Truck[b] | 2 | 280 |
| Driller/Auger[b] | 1 | 220 |
| Driller/Coring[b] | 1 | 650 |
| Generator[b] | 2 | 100 |
| Crane[c] | 1 | 300 |
| Cement Truck[c] | 1 | 280 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]While not called out in AMEC (2007), this equipment is required for construction of the subsurface deflection shield.

### *C 4.1.1 Surface Preparation*

The heavy equipment required for surface preparation is shown in Table C.3.

Table C.3. Heavy Equipment Required for Surface Preparation[a,b]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) |
|---|---|---|---|
| Dozer | 1 | 200 | 220 |
| Dump Truck | 1 | 280 | 110 |
| Grader | 1 | 220 | 220 |
| Loader | 1 | 197 | 110 |
| Vibratory Roller | 1 | 60 | 220 |
| Water Truck | 1 | 280 | 220 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

The loader is used for moving soil generated during construction. The loader is a 197 hp machine and it is estimated that 110 hours are required for surface preparation. The dozer is used to move soil. The dozer is a 200 hp machine and it is estimated that 220 hours are needed for surface preparation. The grader is used for site preparation to grade and level to surface of the site. The grader is a 220 hp machine and it is estimated that 220 hours are needed for surface preparation. The water truck is used for dust suppression during construction activities. The water truck is a 280 hp machine and it is estimated that 220 hours are needed for surface preparation. The vibratory roller is used for compaction of surfaces such as roadways and

parking areas. The vibratory roller is a 60 hp machine and it is estimated that 220 hours are needed for surface preparation. The dump truck is used to transport soils from excavated areas to the storage location. The dump truck is a 280 hp machine and it is estimated that 110 hours are needed for surface preparation.

### *C 4.1.2 Borehole Drilling*

The heavy equipment required for borehole drilling is shown in Table C.4

Table C.4. Heavy Equipment Required for Borehole Drilling[a,b]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration for Fifty Boreholes (hr) | |
|---|---|---|---|---|
| | | | 70-meter Boreholes | 40-meter Boreholes |
| Drill Rig (auger) | 1 | 220[c] | 7,500 | 2,500 |
| Drill Rig (corer) | 1 | 650[c] | 0 | 15,000 |
| Dump Truck | 1 | 280 | 7,500 | 7,000 |
| Generator | 2 | 100 | 7,500 | 7,000 |
| Loader | 1 | 197 | 7,500 | 7,000 |
| Water Truck | 1 | 280 | 7,500 | 7,000 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Auger technology is utilized to install 70 m boreholes (220 hp) in unconsolidated material. Auger technology is used for the first 20 meters of the 40 meter boreholes. Coring technology is used to complete the 40 meter consolidated borings (650 hp).

Auger technology will be utilized to drill the 70 m boreholes The auger rig is 220 hp and it is estimated that 7500 hours are needed to install the 70 meter unconsolidated boreholes. The drilling operation will require continuous operation of support equipment.

Both the augering drill rig and the coring drill rig will be utilized to install the 40 m consolidated boreholes. The augering drill rig (220 hp) will be used for 2,500 hours for 50 boreholes. The coring drill rig proposed is a 650 hp machine and it is estimated that 15,000 hours are needed to drill fifty 40-meter boreholes in consolidated rock. The coring operation will require intermittent (forty percent) operation of equipment to remove the core cuttings.

The loader is used for removing drill cuttings from the immediate vicinity of the bore hole. Drill cuttings will be loaded into the bucket of the loader and transferred to a dump truck which will haul the drill cuttings for storage. The loader is a 197 hp machine and it is estimated that 7,500 hours are required during drilling activities for fifty 70-meter boreholes in unconsolidated rock material. The dump truck is used to transport soils from excavated areas to the storage location. The dump truck is a 280 hp machine and it is estimated that 7,500 hours are required during drilling activities for fifty 70-meter boreholes in unconsolidated material.

The coring operation requires intermittent operation of equipment to remove the core cuttings, and it is estimated that 7,000 hours for the loader and dump truck are required during drilling activities for fifty 40-meter boreholes in consolidated rock.

The water truck is used for dust suppression. The water truck is a 280 hp machine and it is estimated that 7,500 hours are needed for dust suppression activities while drilling fifty 70-meter boreholes in unconsolidated material. It is estimated that 7,000 hours are needed for drilling fifty 40-meter boreholes in consolidated rock.

Two generators are needed. They are used to supply power to small power tools utilized during drilling and to supply power for any lights required to conduct night time activities. It is estimated that each will be operated 7,500 hours while drilling fifty 70-meter boreholes in unconsolidated material. It is estimated that each will be operated 7,000 hours while drilling fifty 40-meter boreholes in consolidated rock.

#### *C 4.1.3 Auxiliary Installations*

The heavy equipment required for auxiliary installations is shown in Table C.5.

Table C.5. Heavy Equipment Required For Auxiliary Installations[a,b]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration for Fifty Boreholes (hr) | | |
|---|---|---|---|---|---|
| | | | Basic Design | Variation A | Variation B |
| Crane for Subsurface Deflection Shield Emplacement | 1 | 300 | 100 | 100 | 100 |
| Cement Truck | 1 | 280 | 100 | 100 | 100 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]This equipment is required for construction of the subsurface deflection shield.

When a disposal borehole has been completely filled with waste, the steel frame for the subsurface deflection shield would be lowered into the borehole using a crane. The crane is a 300 hp machine and it is estimated that 100 hours are required to install the subsurface deflection shields. The subsurface deflection shield would then be filled with concrete. The cement truck is used to fill the subsurface deflection shields with concrete. The cement truck is a 280 hp machine and it is estimated that 100 hours are required to fill the subsurface deflection shields in fifty boreholes.

### C 4.2 Construction Resources

Principal resources for the construction of the IDBD facility include:

- Diesel
- Water

The per borehole values for these resources based on the fifty-borehole design discussed in Section C 3.0 are summarized in Table C.6. Calculation of the per borehole values is discussed in Sections C 4.2.1 through C 4.2.4.

Table C.6. Per Borehole Resource Requirements for Construction of an IDBD Facility[a]

| Activity | Diesel (liters/borehole) | Diesel (gallons/borehole | Water (liters/borehole) | Water (gallons/borehole) |
|---|---|---|---|---|
| **Surface Preparation[b]** | 950.23 | 251.05 | 13,014.85 | 3,438.85 |
| **Borehole Construction[c]** | | | | |
| Basic Design | 34,941.06 | 9,231.43 | 22,935.00 | 6,060.00 |
| Variation A | 34,941.06 | 9,231.43 | 22,935.00 | 6,060.00 |
| Variation B | 70,505.03 | 18,627.43 | 13,105.71 | 3,462.86 |
| **Auxiliary Installations[d]** | | | | |
| Basic Design | 250.89 | 66.29 | 0.0 | 0.0 |
| Variation A | 250.89 | 66.29 | 0.0 | 0.0 |
| Variation B | 250.89 | 66.29 | 0.0 | 0.0 |
| **Total[e]** | | | | |
| Basic Design | 36,142.19 | 9,553.83 | 35,949.85 | 9,498.85 |
| Variation A | 36,142.19 | 9,553.83 | 35,949.85 | 9,498.85 |
| Variation B | 71,706.15 | 18,954.80 | 26,120.56 | 6,901.71 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section C 4.2.1; [c]Calculated from data given in Section C 4.2.2.; [d]Calculated from data given in Section C 4.2.3; [e]Calculated as the total of surface preparation, borehole drilling, and auxiliary installations

### *C 4.2.1 Surface Preparation*

The diesel fuel consumption presented in this section is derived from the equipment horsepower and hours of operation data provided in AMEC (2007). AMEC (2007) indicates that the total horsepower-hours during the surface preparation phase of construction to be approximately 219,670 horsepower-hours (see also Section B 5.2.1). Standard Specific Fuel Consumption (SFC) for diesel engines is assumed to be 0.4 lbs / hp-hr . Using the following conversions:

- 1 gallon of diesel weighs 7 lbs (U. S. BOT 2007)
- 264.34 gallons/$m^3$
- 1000 liters/$m^3$
- 2.205 lbs/kg,

and allocating the surface preparation resources over fifty boreholes yields 950.23 liters (251.05 gallons) of diesel fuel per borehole.

The primary water use is for dust suppression during surface preparation. The water requirements presented here are derived from the data given in AMEC (2007). AMEC (2007) indicates that during surface preparation, 10,640 cubic yards of soil are excavated. Assuming that the soil is processed for a resulting eight percent water content, 851.20 cubic yards of water would be used. This translates to 650,742.40 liters (171,942.40 gallons) of water utilized during surface preparation, or 13,014.85 liters of water per borehole (3,438.85 gallons per borehole).

### *C 4.2.2 Borehole Drilling*

The basic design is a 70 m uncased borehole. For the basic design, AMEC (2007) indicates that the horsepower-hours during construction of fifty boreholes is 8,077,500. Converting as described above indicates that it takes 1,747,053.10 liters (461,571.43 gallons) of diesel fuel to drill fifty boreholes, or 34,941.06 liters/borehole (9,231.43 gallons per borehole). This also applies to Variation A.

Variation B is a 40 m uncased borehole in consolidated material. For Variation B, AMEC (2007) indicates that the horesepower-hours during construction of fifty boreholes is 16,299,000 horsepower-hours. converting as described above indicates that it takes 3,525,251.43 liters (931,371.43 gallons) of diesel fuel to drill fifty boreholes, or 70,505.03 liters per borehole (18,627.43 gallons per borehole).

A 6,000 gallon water truck would be utilized for dust suppression during borehole drilling activities. AMEC (2007) determined that during borehole drilling, 18,750 cubic yards of soil will be excavated in the Basic Design and Variation A. Assuming that the soil is processed for a resulting eight percent water content, 1500 cubic yards of water would be used. This translates to 1,146,750.00 liters (302,971.35 gallons) of water used during borehole drilling, or 22,935.00 liters per borehole (6,059.43 gallons per borehole).

AMEC (2007) determined that during borehole drilling, 10,714 cubic yards of soil will be excavated in Variation B. Assuming that the soil is processed for a resulting eight percent water content, 857 cubic yards of water would be used. This translates to 655,268.24 liters (173,121.87 gallons) of water used during borehole drilling, or 13,105.36 liters per borehole (3,462.44 gallons per borehole).

#### *C 4.2.3 Auxiliary Installations*

Auxiliary installations include installing the surface completion and the subsurface deflection shield. The horsepower-hours during auxiliary installations for the Basic Design and Variation B is 58,000 horsepower-hours (see Table C.15). Converting as described above indicates that it takes 12,544.61 liters (3,314.29 gallons) of diesel fuel for the auxiliary installations for fifty boreholes, or 250.89 liters per borehole (66.29 gallons per borehole).

### C 4.3 Construction Materials

Principal materials for the construction of the IDBD facility include:

- Steel
- Concrete

The per borehole values for these resources based on the fifty-borehole design discussed in Section C 3.0 are summarized in Table C.7. Calculation of the per borehole values is discussed in Sections C 4.3.1 through C 4.3.4.

Table C. 7. Borehole Material Requirements for Construction of an IDBD Facility[a]

| Activity | Steel (tons/borehole) | Steel (lbs/borehole | Concrete[f] (C.Y./borehole) | Concrete[f] ($m^3$/borehole) |
|---|---|---|---|---|
| **Surface Preparation[b]** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Borehole Drilling[c]** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Auxiliary Installations[d]** | | | | |
| Basic Design | 9.9 | 19,800 | 24.54 | 18.77 |
| Variation A | 37.71 | 75,420 | 24.54 | 18.77 |
| Variation B | 9.9 | 19,800 | 24.54 | 18.77 |
| **Total[e]** | | | | |
| Basic Design | 9.9 | 19,800 | 24.54 | 18.77 |
| Variation A | 37.71 | 75,420 | 24.54 | 18.77 |
| Variation B | 9.9 | 19,800 | 24.54 | 18.77 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Individual materials listed in Table C.8; [c]Calculated from data given in Section C 4.3.2.; [d]Calculated from data given in Section C 4.3.3. Materials other than steel and concrete listed in Table C.8; [e]Calculated as the total of surface preparation, borehole drilling, and auxiliary installations; [f]Includes bentonite grout for surface casing.

### *C 4.3.1 Surface Preparation*

Construction materials used during the surface preparation phase of construction are listed in Table C.8.

Table C. 8. Material Requirements for the Surface Preparation Phase of Construction for an Intermediate Depth Borehole Disposal Facility[a,b]

| Material | Unit[b] | Amount |
|---|---|---|
| Office Trailer, furnished, buy, 32' x 8', excl. hookups | Ea | 1.00 |
| Storage Boxes (connex), buy, 20' x 8' | Ea | 2 |
| Top Soil | C.Y. | 10640 |
| Fine Grade Aggregate | S.Y. | 13629 |
| Medium Grade Aggregate | B.C.Y. | 2800 |
| Course Grade Aggregate | S.Y. | 9520 |
| Silt Fence | L.F. | 3080 |
| Hay Bales | L.F. | 700 |
| Chain Link Fence | L.F. | 3080 |
| Chain Link Gates (5’ x 20’) | Opng. | 3 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Abbreviations include: Ea for each, C.Y. for cubic yards, S.Y. for square yards, B.C.Y for Bulk Cubic Yards, L.F. for linear feet, and Opng for opening.

The office trailer will be used for administrative support for all project activities. This trailer will be used for project meetings, a break room for the field staff, and other related meetings to support GTCC field activities. Storage boxes are used for storage of small tools and supplies required to support field operations. The storage boxes will be located in the laydown area. Top soil is used for site restoration activities. Fine/medium/coarse grade aggregate is used for road base and base coarse in the parking lot and vehicle and equipment staging areas. The silt fences and hay bales are used to control impacts to storm water run-off and erosion control.

### *C 4.3.2 Borehole Drilling*

There are no materials used during the borehole drilling phase of construction.

### *C 4.3.3 Auxiliary Installations*

Construction materials used during the auxiliary installations phase of construction are listed in Table C.9.

Table C. 9. Material Requirements for the Auxiliary Installations Phase of Construction for an Intermediate Depth Borehole Disposal Facility[a,b]

| Material | Unit[b] | Amount | Unit[c] | Amount |
|---|---|---|---|---|
| Steel lockable surface lid | Ton | 282.5 | lb | 564,856.75 |
| Steel surface casing | Ton | 69.44 | lb | 138,879.15 |
| Steel casing to depth | Ton | 1,390.42 | lb | 2,780,846.49 |
| Steel in subsurface deflection shield | Ton | 143.00 | lb | 286,000.00 |
| Concrete in subsurface deflection shield | $m^3$ | 289.90 | C.Y. | 378.95 |
| Concrete in surface casing | $m^3$ | 323.97 | C.Y. | 423.76 |
| Bentonite grout in Surface Casing | $m^3$ | 323.97 | C.Y. | 423.76 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Abbreviations include: C.Y. for cubic yard.

Steel is used in the IDBD conceptual design in four ways: the lockable steel lid that is part of the surface completion, corrugated metal pipe that is part of the surface casing, steel used to case to depth in Variation A, and steel in the subsurface deflection shield.

It is assumed that the lockable steel lid is 2 inches (0.0508 m) thick with a 4 m diameter. The resulting area of the lid ($a = \pi \cdot r^2$) is 12.57 $m^2$ and the volume of the lid is 0.64 $m^3$. If the density of steel is 8044 kg/$m^3$, then the weight of steel is 5,135 kg (11,297.10 pounds) or 5.65 tons per borehole, 282.5 tons (564,856.75 pounds) for fifty boreholes.

The borehole design uses 2.5 m of corrugated metal pipe for the surface casing. The outer diameter of the pipe is 5 m. If the pipe thickness is 0.004 m, the volume of steel in the pipe is 0.157 $m^3$. If the density of steel is 8,044 kg/$m^3$, the weight of steel in the corrugated metal pipe

is 1,262.54 kg (2,783.90 pounds) or 1.39 tons per borehole, 69.44 tons (138,879.15 pounds) for fifty boreholes.

If the borehole is cased to depth (Variation A), the height of the casing is 68.5 m. The outer radius is 1.22 m. If the casing thickness is 0.006 m, the volume of the casing is 3.14 $m^3$. Assuming the density of steel is 8,044 $kg/m^3$, the weight of steel in the casing is 25,280 kg (55,733.79 pounds) or 27.81 tons per borehole, 1,390.42 tons (2,780,846.49 pounds) for fifty boreholes.

Hillesheim (2007) calculated the weight of steel in the subsurface deflection shield as 2.86 tons per shield. Since there are 50 boreholes, the total weight of steel is 143 tons.

Concrete is used in the IDBD conceptual design in two ways: as part of the subsurface deflection shield, and to secure the casings.

In the surface casing, the height of concrete is 0.75 m and the outer radius of the concrete is 3.0 meters. Assuming a concrete thickness of 0.5 meters, the volume of concrete is 6.48 $m^3$ or 8.48 cubic yard per borehole. For fifty boreholes this is 423.76 cubic yards or 323.97 $m^3$. The same amount of bentonite grout is used in the design.

Hillesheim (2007) calculated the volume of concrete in the subsurface deflection shield as 5.798 $m^3$ or 7.579 cubic yards. Since there are 50 boreholes, the total volume of concrete is 378.95 cubic yards or 289.90 cubic meters.

## C5. CONSTRUCTION WASTES AND EMISSIONS

Construction activities will result in air emissions from equipment used during construction. Construction activities also generate dust and impact storm water. Dust will be controlled with dust suppression by spraying water during excavation and drilling activities. Impacts to storm water will be controlled with utilization of best management practices including silt fences, hay bales, and berming.

This section presents the wastes and emissions produced as a result of construction of an IDBD facility comprised of fifty boreholes as described in Section C.3. As shown in Figure C.1, three phases of construction produce wastes and emissions: surface preparation, borehole drilling, and auxiliary installations. The wastes and emissions are identified below for these phases of construction.

### C 5.1 Construction Wastes

Principal waste streams generated for the construction of the IDBD facility would include:

- Construction debris and
- Refuse (non-hazardous solid waste).

Generation of RCRA hazardous and TSCA waste is not anticipated.

Although soil will be generated during the construction activities, the IDBD facility construction is assumed to be clean construction. As a result of the construction being conducted in an uncontaminated environment, the excess soils generated would be stockpiled for re-use and are not considered a waste necessarily requiring disposal.

The per borehole values for these wastes based on the fifty-borehole design discussed in Section C.3 are summarized in Table C.10. Calculation of the per borehole values is discussed in Sections C 5.1.1 through C 5.1.3.

Table C.10. Per Borehole Wastes Produced During Construction of an IDBD Facility[a]

| Activity | Construction Debris (C.Y./borehole) | Refuse (C.Y./borehole) | Excavated Material (C.Y./borehole) [f] |
|---|---|---|---|
| **Surface Preparation[b]** | 2.35 (1.8 $m^3$/borehole) | 1.18 (0.9 $m^3$/borehole) | 0.00 |
| **Borehole Drilling[c]** | | | |
| Basic Design | 0.00 | 0.00 | 490.5 (375 $m^3$/borehole) |
| Variation A | 0.00 | 0.00 | 490.5 (375 $m^3$/borehole) |
| Variation B | 0.00 | 0.00 | 279.9 (214 $m^3$/borehole) |
| **Auxiliary Installations[d]** | | | |
| Basic Design | 0.00 | 0.00 | 0.00 |
| Variation A | 0.00 | 0.00 | 0.00 |
| Variation B | 0.00 | 0.00 | 0.00 |
| **Total[e]** | | | |
| Basic Design | 2.35 (1.8 $m^3$/borehole) | 1.18 (0.9 $m^3$/borehole) | 490.5 (375 $m^3$/borehole) |
| Variation A | 2.35 (1.8 $m^3$/borehole) | 1.18 (0.9 $m^3$/borehole) | 490.5 (375 $m^3$/borehole) |
| Variation B | 2.35 (1.8 $m^3$/borehole) | 1.18 (0.9 $m^3$/borehole) | 279.9 (214 $m^3$/borehole) |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section C 5.1.1; [c]Calculated from data given in Section C 5.1.2.; [d]Calculated from data given in Section C 5.1.3; [e]Calculated as the total of surface preparation, borehole drilling, and auxiliary installations; [f]Excess soils generated would be stockpiled for re-use and are not considered a waste requiring disposal

### *C 5.1.1 Surface Preparation*

AMEC (2007) indicates that surface preparation generates 90 $m^3$ of construction debris, or 1.8 $m^3$/borehole (2.35 C.Y./borehole). Similarly, surface preparation generates 45 $m^3$ of refuse, or 0.9 $m^3$/borehole (1.18 C.Y./borehole).

### *C 5.1.2 Borehole Drilling*

AMEC (2007) indicates that borehole drilling generates 18,750 $m^3$ of excavated material for 70 meter boreholes or 10,714 $m^3$ for 40 meter boreholes. This would be 375 $m^3$/borehole for 70 meter boreholes and 214 $m^3$/borehole for 40 meter boreholes. All soil generated from the borehole installation is assumed to be clean fill and will be stored on site pending re-use. The soils will be stock piled within in one mile of the drilling location. Soils will not be placed on secondary containment since they are assumed to be clean.

### *C 5.1.3 Auxiliary Installations*

There are no wastes produced during the auxiliary installations. However, if the casing is pulled upon closure of a borehole, the casing material may be considered a waste. The steel casing would require screening for the presence of radiological constituents. Should it be determined by others that the casing materials are free from contaminants, the steel casing could be recycled as scrap steel.

## C 5.2 Construction Emissions

Principal emissions for the construction of the IDBD facility include:

- CO
- NOx
- PM

To estimate emissions generated during construction of the IDBD facility, the equipment required for the construction was determined. Based on the equipment used, emissions were calculated. To calculate emissions, emission factors were utilized. An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors are generally expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. Such factors facilitate estimation of emissions from various sources of air pollution. Emission factors are averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category. The general equation for emissions estimation is:

$$\mathbf{E = A \times EF \times (1\text{-}ER/100)}$$

where:

E = emissions;
A = activity rate;
EF = emission factor, and
ER =overall emission reduction efficiency, %

The overall emission reduction efficiency (ER) is the weight per unit time of pollutant removed by a control device divided by the weight per unit time of pollutant emitted by an emission source expressed as a percentage. A control device is equipment used to reduce, by destruction or removal, the amount of air pollutant(s) in an exhaust stream prior to discharge to the ambient air. Examples of control devices include filters, scrubbers, low NOx burners or scrubbers, catalytic converters, fuel additives, and thermal and catalytic oxidizers.

Emissions factors are the fundamental tool in developing emissions inventories. More recently, emissions factors have been applied in determining emissions limitations in operating permits by federal, state, local, and tribal agencies, consultants, and industry.

Construction activities will result in air emissions from equipment used during construction. Using emissions factors obtained from EPA, anticipated equipment horsepower, and estimated equipment usage (duration in time) air emission estimates were calculated for construction.

The per borehole values for these emissions based on the fifty-borehole design discussed in Section C.3 are summarized in Table C.11. Calculation of the per borehole values is discussed in Sections C 5.2.1 through C 5.2.3.

Table C.11. Per Borehole Emissions Produced During Construction of an IDBD Facility[a]

| Activity | CO (lb/borehole) | NOx (lb/borehole) | PM (lb/borehole) |
|---|---|---|---|
| **Surface Preparation[b]** | 9.69 | 66.84 | 4.06 |
| **Borehole Drilling[c]** | | | |
| Basic Design | 389.22 | 2,685.62 | 155.69 |
| Variation A | 389.22 | 2,685.62 | 155.69 |
| Variation B | 749.90 | 5,171.77 | 299.81 |
| **Auxiliary Installations[d]** | | | |
| Basic Design | 2.56 | 17.65 | 1.02 |
| Variation A | 2.56 | 17.65 | 1.02 |
| Variation B | 2.56 | 17.65 | 1.02 |
| **Total[e]** | | | |
| Basic Design | 401.46 | 2,770.10 | 160.77 |
| Variation A | 401.46 | 2,770.10 | 160.77 |
| Variation B | 762.14 | 5,256.25 | 304.90 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section C 5.2.1; [c]Calculated from data given in Section C5.2.2.; [d]Calculated from data given in Section C5.2.3; [e]Calculated as the total of surface preparation, borehole drilling, and auxiliary installations

### *C 5.2.1 Surface Preparation*

Emissions produced during the surface preparation phase of construction are listed in Table C.12.

### *C 5.2.2 Borehole Drilling*

Emissions produced during the borehole drilling phase of construction are listed in Tables C.13 and C.14.

### *C 5.2.3 Auxiliary Installations*

Emissions produced during the auxiliary installations phase of construction are listed in Table C.15.

Table C.12. Emissions Produced During Surface Preparation for an Intermediate Depth Borehole Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Loader | 1 | 197 | 110 | 1.00 | 0.43 | 47.78 |
| Dozer | 1 | 200 | 220 | 1.00 | 0.44 | 97.02 |
| Grader | 1 | 220 | 220 | 1.00 | 0.49 | 106.72 |
| Water Truck | 1 | 280 | 220 | 1.00 | 0.62 | 135.83 |
| Vibratory Roller | 1 | 60 | 220 | 1.00 | 0.13 | 29.11 |
| Dump Truck | 1 | 280 | 110 | 1.00 | 0.62 | 67.91 |
| **Total Duration and Emission** | | | 1100 | | | 484.37 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Loader | 6.9 | 3.00 | 329.70 | 0.4 | 0.17 | 19.11 |
| Dozer | 6.9 | 3.04 | 669.44 | 0.4 | 0.18 | 38.81 |
| Grader | 6.9 | 3.35 | 736.38 | 0.4 | 0.19 | 42.69 |
| Water Truck | 6.9 | 4.26 | 937.21 | 0.4 | 0.25 | 54.33 |
| Vibratory Roller | 6.9 | 0.91 | 200.83 | 0.72 | 0.10 | 20.96 |
| Dump Truck | 6.9 | 4.26 | 468.61 | 0.4 | 0.25 | 27.17 |
| **Total Duration and Emission** | | | 3342.17 | | | 203.06 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

Table C. 13. Emissions Produced During Borehole Drilling (70 m) for an Intermediate Depth Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Drill Rig | 1 | 220 | 7500 | 1.00 | 0.49 | 3637.57 |
| Dump Truck | 1 | 280 | 7500 | 1.00 | 0.62 | 4629.63 |
| Generator | 2 | 100 | 7500 | 1.00 | 0.22 | 3306.88 |
| Loader | 1 | 197 | 7500 | 1.00 | 0.43 | 3257.28 |
| Water Truck | 1 | 280 | 7500 | 1.00 | 0.62 | 4629.63 |
| **Total Duration and Emission** | | | 37500 | | | 19460.98 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Drill Rig | 6.9 | 3.35 | 25099.21 | 0.4 | 0.19 | 1455.03 |
| Dump Truck | 6.9 | 4.26 | 31944.44 | 0.4 | 0.25 | 1851.85 |
| Generator | 6.9 | 1.52 | 22817.46 | 0.4 | 0.09 | 1322.75 |
| Loader | 6.9 | 3.00 | 22475.20 | 0.4 | 0.17 | 1302.91 |
| Water Truck | 6.9 | 4.26 | 31944.44 | 0.4 | 0.25 | 1851.85 |
| **Total Duration and Emission** | | | 134280.75 | | | 7784.39 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

Table C.14. Emissions Produced During Borehole Drilling (40 m) for an Intermediate Depth Disposal Facility[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Drill Rig (Coring) | 1 | 650 | 15000 | 1.00 | 1.43 | 21494.71 |
| HAS Drill Rig | 1 | 220 | 17500 | 1.00 | 0.49 | 1212.52 |
| Dump Truck | 1 | 280 | 17500 | 1.00 | 0.62 | 4340.00 |
| Generator | 2 | 100 | 17500 | 1.00 | 0.22 | 3086.42 |
| Loader | 1 | 197 | 17500 | 1.00 | 0.43 | 3040.12 |
| Water Truck | 1 | 280 | 17500 | 1.00 | 0.62 | 4320.99 |
| **Total Duration and Emission** | | | 45500 | | | 37494.76 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Drill Rig (Coring) | 6.9 | 9.89 | 148313.49 | 0.4 | 0.57 | 8597.88 |
| HAS Drill Rig | 6.9 | 3.35 | 8366.40 | 0.4 | 0.19 | 485.01 |
| Dump Truck | 6.9 | 4.26 | 29820.42 | 0.4 | 0.25 | 1728.72 |
| Generator | 6.9 | 1.52 | 21296.30 | 0.4 | 0.09 | 1234.57 |
| Loader | 6.9 | 3.00 | 20976.85 | 0.4 | 0.17 | 1216.05 |
| Water Truck | 6.9 | 4.26 | 29814.81 | 0.4 | 0.25 | 1728.40 |
| **Total Duration and Emission** | | | 258588.28 | | | 14990.62 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007); [c]Equipment duration is based on a 10-hour work day.

Table C. 15. Emissions Produced During Auxiliary Installations for an Intermediate Depth Disposal Facility Basic Design, Variation A, and Variation B[a,b,c]

| Equipment | Quantity | Horsepower (hp) | Est. Equipment Usage Duration (hr) | Emission Factor CO (g/hp-hr) | Emission Rate CO (lb/hr) | Est. CO Emission for Duration (lbs) |
|---|---|---|---|---|---|---|
| Crane - Subsurface Deflection Shield | 1 | 300 | 100 | 1.00 | 0.66 | 66.14 |
| Cement Truck | 1 | 280 | 100 | 1.00 | 0.62 | 61.73 |
| **Total Duration and Emission** | | | | | | 127.87 |
| **Equipment** | **Emission Factor NOx (g/hp-hr)** | **Emission Rate NOx (lb/hr)** | **Est. NOx Emission For Duration (lbs)** | **Emission Factor PM (g/hp-hr)** | **Emission Rate PM (lb/hr)** | **Est. PM Emission for Duration (lbs)** |
| Crane Subsurface Deflection Shield | 6.9 | 4.56 | 456.35 | 0.4 | 0.26 | 26.46 |
| Cement Truck | 6.9 | 4.26 | 425.93 | 0.4 | 0.25 | 24.69 |
| **Total Duration and Emission** | | | 882.28 | | | 51.15 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b] AMEC (2007) did not include emissions from placement of the SDS. Added to account for placement of the SDS; [c]Equipment duration is based on a 10-hour work day.

## C6. CONSTRUCTION COSTS, DURATIONS, AND PERSONNEL

This section presents the costs, durations, and personnel required for construction of an IDBD facility comprised of fifty boreholes as described in Section C.3. The first three phases of IDBD facility construction (planning, geotechnical investigations, and mobilization) have bearing on costs, durations, and personnel for the project. Construction, consisting of three phases, surface preparation, borehole drilling, and auxiliary installations also affect the costs, durations, and personnel as identified below.

Cost estimates were prepared for this project by AMEC (2007). To develop the construction cost estimates for the conceptual design of IDBD, *RSMeans* Construction Estimating Software was utilized. *RSMeans* is a product line of Reed Construction Data, which provides accurate and up-to-date cost information which is used in *RSMeans* to assist construction cost estimators in the development of cost estimates for a wide range of construction projects, including environmental and clean construction activities. *RSMeans* contains a collection of annual construction cost data books, and is the most used, quoted, and respected construction and facility management cost guides in the construction industry. The 23 Means Construction Cost Data Guides contain unit and assemblies costs for almost 100,000 building components. These completely-updated costs are carefully prepared from the experience of thousands of building owners, facilities managers, engineers, contractors and suppliers in the months just before the guides are published. The cost data is arranged in the 16 CSI MasterFormat95 divisions, allowing for fast, accurate referencing.

In addition to the use of *RSMeans*, specialty subcontractors, such as drilling contractors and material suppliers were contacted to verify input parameters into construction spreadsheets. Data used in *RSMeans* was verified by AMEC (2007).

## C 6.1 Costs

Principal costs for the construction of the IDBD facility include:

- Project Management Labor Costs (P)
- Subcontractor Costs (S)
- Engineering Design Fees (E)
- Direct Costs (O)

Direct costs include temporary site facilities, consumables, airfare, car rental, and lodging/per diem and are small compared to the other costs involved. Therefore, while the direct costs were included in AMEC (2007), they are neglected in this document.

The per borehole values for these costs based on the fifty-borehole design discussed in Section C.3 are summarized in Table C.16. Calculation of the per borehole values is discussed in Sections C 6.1.1 through C 6.1.4. The total costs shown in Table C.16 are calculated as follows:

$$(S + E + O)*1.15 + P*1.25 + E*0.25$$

This includes a 15% markup on the subtotal of the subcontractor costs, the engineering design fees, and the direct costs as well as a professional services contingency mark up on the subtotal of the project management labor costs and the engineering design fees.

Table C.16. Per Borehole Costs for Construction of an IDBD Facility[a]

| Activity | Project Management Labor Costs[b] (dollars/borehole) | Subcontractor Costs[c] (dollars/borehole) | Engineering Design Fees[d] (dollars/borehole) | Direct Costs[e] (dollars/borehole) | Total Costs[f] (dollars/borehole) |
|---|---|---|---|---|---|
| Basic Design | $33,603.23 | $355,870.00 | $7,733.18 | $695.45 | $462,880.76 |
| Variation A | $46,076.43 | $424,220.00 | $9,349.64 | $913.40 | $559,588.45 |
| Variation B | $90,652.79 | $852,345.00 | $18,803.67 | $1,051.68 | $1,121,047.31 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Calculated from data given in Section C 6.1.1; [c]Calculated from data given in Section C 6.1.2.; [d]Calculated from data given in Section C 6.1.3; [e] Calculated as described in Section C 6.1.4; [f]Calculated as described in Section C 6.1.

### *C 6.1.1 Project Management Labor Costs*

Project management labor costs are listed in Table C.17. Project Management cost would include manhours expended to coordinate field activities and ensure that all activities related to the construction are conducted on time and within the allotted budget.

The total project management labor costs for the basic design is $1,680,161.42 for fifty boreholes, or $33,603.23 per borehole. The total project management labor costs for Variation A is $2,303,821.57 for fifty boreholes, or $46,076.43 per borehole. The total project management labor costs for Variation B is $4,532,639.55 for fifty boreholes, or $90,652.79 per borehole.

### *C 6.1.2 Subcontractor Costs*

Subcontractor costs are listed in Table C.18. Subcontractor cost would include the cost incurred to conduct the actual construct related activities associate with the IBDB facility construction. Subcontractors, for example, would also include rental of equipment such as portable toilets and the cost to service such materials.

The total subcontractor costs for the basic design is $17,793,500.00 for fifty boreholes, or $355,870.00 per borehole. The total subcontractor costs for Variation A is $21,211,000.00 for fifty boreholes, or $424,220.00 per borehole. The total subcontractor costs for Variation B is $42,617,250.00 for fifty boreholes, or $852,345.00 per borehole.

### *C 6.1.3 Engineering Design Fees*

Engineering and design fees are listed in Table C.19. Engineering design fees would include the cost incurred to produce the actual design of the facility. The design would be based on the conceptual design presented in this document.

The total engineering and design fees for the basic design are $386,659.24 for fifty boreholes, or $7,733.18 per borehole. The total engineering and design fees for Variation A are $467,482.18 for fifty boreholes, or $9,349.64 per borehole. The total engineering and design fees for Variation B are $940,183.53 for fifty boreholes, or $18,803.67 per borehole.

### *C 6.1.4 Direct Costs*

Direct costs are listed in Table C.20. Direct costs would include temporary site facilities, consumables, airfare, car rentals, and lodging.

The total direct costs for the basic design are $34,772.64 for fifty boreholes, or $695.45 per borehole. The total direct costs for Variation A are $45,670.08 for fifty boreholes, or $913.40 per borehole. The total direct costs for Variation B are $52,584.16 for fifty boreholes, or $1,051.68 per borehole.

Table C. 17. Project Management Labor Costs for Construction of an IDBD Facility[a,b]

| Project Management Labor Costs | | | | Planning Documents | | Geotechnical Investigation | | Support Facilities Construction | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 0 | $0.00 | 3.2 | $151.55 | 198 | $9,377.28 |
| 1 | Program Manager | ST | $182.48 | 12 | $2,189.76 | 3.2 | $583.94 | 4.4 | $802.91 |
| 1 | Project Manager | ST | $170.83 | 144 | $24,599.52 | 12.8 | $2,186.62 | 35.2 | $6,013.22 |
| 1 | Program QA/QC Manager | ST | $112.19 | 144 | $16,155.36 | 1.3 | $145.85 | 8.8 | $987.27 |
| 1 | Construction Manager | ST | $103.25 | 0 | $0.00 | 64 | $6,608.00 | 198 | $20,443.50 |
| 1 | Project QA Inspector | ST | $72.14 | 0 | $0.00 | 19.2 | $1,385.09 | 99 | $7,141.86 |
| 1 | Health & Safety Manager | ST | $103.25 | 144 | $14,868.00 | 12.8 | $1,321.60 | 19.8 | $2,044.35 |
| 1 | Project Engineer-Senior | ST | $141.17 | 57.6 | $8,131.39 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Mid | ST | $131.69 | 57.6 | $7,585.34 | 0 | $0.00 | 0 | $0.00 |
| 1 | Project Engineer-Junior | ST | $121.28 | 57.6 | $6,985.73 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Senior | ST | $141.17 | 0 | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Scientist-Mid | ST | $131.69 | 0 | $0.00 | 0 | $0.00 | 0 | $0.00 |
| 1 | Administrative Assistant | ST | $54.25 | 259.2 | $14,061.60 | 19.2 | $1,041.60 | 29.7 | $1,611.23 |
| 1 | Cost Scheduler | ST | $77.56 | 76.8 | $5,956.61 | 0 | $0.00 | 0 | $0.00 |
| 1 | CAD/GIS Operator | ST | $67.82 | 57.6 | $3,906.43 | 0 | $0.00 | 0 | $0.00 |
| 1 | Technical Writer/Editor | ST | $72.14 | 480 | $34,627.20 | 0 | $0.00 | 0 | $0.00 |
| 1 | Accounting Clerk | ST | $45.00 | 36 | $1,620.00 | 25.6 | $1,152.00 | 39.6 | $1,782.00 |
| **SUBTOTAL LABOR** | | | | **1526** | **$140,686.94** | **161** | **$14,574.00** | **633** | **$50,203.62** |

| Project Management Labor Costs | | | | IDBD Mobilization & Demobilization | | Drilling Basic Design and Variation A | | Drilling Variation B | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 16 | $757.76 | 4500 | $213,120.00 | 15750 | $745,920.00 |
| 1 | Program Manager | ST | $182.48 | 16 | $2,919.68 | 100 | $18,248.00 | 350 | $63,868.00 |
| 1 | Project Manager | ST | $170.83 | 16 | $2,733.28 | 800 | $136,664.00 | 2800 | $478,324.00 |
| 1 | Program QA/QC Manager | ST | $112.19 | 4 | $448.76 | 200 | $22,438.00 | 700 | $78,533.00 |
| 1 | Construction Manager | ST | $103.25 | 90 | $9,292.50 | 4500 | $464,625.00 | 15750 | $1,626,187.50 |
| 1 | Project QA Inspector | ST | $72.14 | 45 | $3,246.30 | 2250 | $162,315.00 | 7875 | $568,102.50 |
| 1 | Health & Safety Manager | ST | $103.25 | 9 | $929.25 | 450 | $46,462.50 | 1575 | $162,618.75 |
| 1 | Project Engineer-Senior | ST | $141.17 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Project Engineer-Mid | ST | $131.69 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Project Engineer-Junior | ST | $121.28 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Scientist-Senior | ST | $141.17 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Scientist-Mid | ST | $131.69 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Administrative Assistant | ST | $54.25 | 13.5 | $732.38 | 675 | $36,618.75 | 2362.5 | $128,165.63 |
| 1 | Cost Scheduler | ST | $77.56 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | CAD/GIS Operator | ST | $67.82 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Technical Writer/Editor | ST | $72.14 | 0 | $0.00 | | $0.00 | | $0.00 |
| 1 | Accounting Clerk | ST | $45.00 | 18 | $810.00 | 900 | $40,500.00 | 3150 | $141,750.00 |
| **SUBTOTAL LABOR** | | | | **228** | **$21,869.91** | **14,375** | **$1,140,991.25** | **50312.5** | **$3,993,469.38** |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table C.17. Project Management Labor Costs for Construction of an IDBD Facility[a,b] (continued)

| **Project Management Labor Costs** | | | | **Basic Design and Variation B Case Boreholes** | | **Variation A Case Boreholes** | | **Construct Subsurface Deflection Shields** | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | Unit | Hourly Cost | Hrs | Ext | Hrs | Ext | Hrs | Ext |
| 1 | Field Tech | ST | $47.36 | 450 | $21,312.00 | 2250 | $106,560.00 | 450 | $21,312.00 |
| 1 | Program Manager | ST | $182.48 | 10 | $1,824.80 | 50 | $9,124.00 | 10 | $1,824.80 |
| 1 | Project Manager | ST | $170.83 | 80 | $13,666.40 | 400 | $68,332.00 | 80 | $13,666.40 |
| 1 | Program QA/QC Manager | ST | $112.19 | 20 | $2,243.80 | 100 | $11,219.00 | 20 | $2,243.80 |
| 1 | Construction Manager | ST | $103.25 | 450 | $46,462.50 | 2250 | $232,312.50 | 450 | $46,462.50 |
| 1 | Project QA Inspector | ST | $72.14 | 225 | $16,231.50 | 1125 | $81,157.50 | 225 | $16,231.50 |
| 1 | Health & Safety Manager | ST | $103.25 | 450 | $46,462.50 | 2250 | $232,312.50 | 450 | $46,462.50 |
| 1 | Project Engineer-Senior | ST | $141.17 | | | | $0.00 | 0 | |
| 1 | Project Engineer-Mid | ST | $131.69 | | | | $0.00 | 0 | |
| 1 | Project Engineer-Junior | ST | $121.28 | | | | $0.00 | 0 | |
| 1 | Scientist-Senior | ST | $141.17 | | | | $0.00 | 0 | |
| 1 | Scientist-Mid | ST | $131.69 | | | | $0.00 | 0 | |
| 1 | Administrative Assistant | ST | $54.25 | 68 | $3,689.00 | 338 | $18,309.38 | 68 | $3,661.88 |
| 1 | Cost Scheduler | ST | $77.56 | | | | $0.00 | 0 | |
| 1 | CAD/GIS Operator | ST | $67.82 | | | | $0.00 | 0 | |
| 1 | Technical Writer/Editor | ST | $72.14 | | | | $0.00 | 0 | |
| 1 | Accounting Clerk | ST | $45.00 | 90 | $4,050.00 | 450 | $20,250.00 | 90 | $4,050.00 |
| **SUBTOTAL LABOR** | | | | **1843** | **$155,915.38** | **9212.5** | **$779,576.88** | **1843** | **$155,915.38** |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table C.18. Subcontractor Costs for Construction of an IDBD Facility[a,b]

| IDBD - Subcontractor Costs | | | | Planning Documents | | Geotechnical Investigation | |
|---|---|---|---|---|---|---|---|
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | 1 | $48,000.00 |
| 1 | General Contractor, RSM | LS | $373,000.00 | | | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | | | | |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | | | | |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | | | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | | | | |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | | | | | **$48,000.00** |

| IDBD - Subcontractor Costs | | | | Support Facilities Construction | | IDBD Mobilization & Demobilization Basic Design | |
|---|---|---|---|---|---|---|---|
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 | General Contractor, RSM | LS | $373,000.00 | 1 | $373,000.00 | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | | | 2.3 | $172,500.00 |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | | | | |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | | | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | | | | |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | | | **$373,000.00** | | **$172,500.00** |

| IDBD - Subcontractor Costs | | | | IDBD Mobilization & Demobilization Variation A | | IDBD Mobilization & Demobilization Variation B | |
|---|---|---|---|---|---|---|---|
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 | General Contractor, RSM | LS | $373,000.00 | | | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | 22 | $165,000.00 | 12 | $90,000.00 |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | | | | |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | | | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | | | | |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | | | **$165,000.00** | | **$90,000.00** |

| IDBD - Subcontractor Costs | | | | Drilling Basic Design | | Drilling Variation A | |
|---|---|---|---|---|---|---|---|
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 | General Contractor, RSM | LS | $373,000.00 | | | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | | | | |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | 200 | $13,000,000.00 | 130 | $8,450,000.00 |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | | | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | | | | |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | | | **$13,000,000.00** | | **$8,450,000.00** |

Table C.18. Subcontractor Costs for Construction of an IDBD Facility (continued)[a,b]

| IDBD - Subcontractor Costs | | | | Drilling Variation B | | Basic Design and Variation B Case Boreholes | |
|---|---|---|---|---|---|---|---|
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 | General Contractor, RSM | LS | $373,000.00 | | | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | | | | |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | 62.5 | $4,062,500.00 | | |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | 62.5 | $33,843,750.00 | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | | | 20 | $1,450,000.00 |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | | |
| **SUBTOTAL SUBCONTRACTOR** | | | | | **$37,906,250.00** | | **$1,450,000.00** |
| **IDBD - Subcontractor Costs** | | | | **Variation A Case Boreholes** | | **Construct Subsurface Deflection Shields** | |
| Subcontractor Costs | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Geotechnical Services, RSM | LS | $48,000.00 | | | | |
| 1 | General Contractor, RSM | LS | $373,000.00 | | | | |
| 1 | Drilling, Transport x 500 mi | LS | $75,000.00 | | | | |
| 50 | Drilling, excludes groundwater | VLF | $1,300.00 | | | | |
| 50 | Drilling excludes groundwater | VLF | $10,830.00 | | | | |
| 50 | Place & Grout Casing | VLF | $1,450.00 | 130 | $9,425,000.00 | | |
| 50 | Construct Subsurface Deflection Shields | LS | $55,000.00 | | | 50 | $2,750,000.00 |
| **SUBTOTAL SUBCONTRACTOR** | | | | | **$9,425,000.00** | | **$2,750,000.00** |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table C.19. Engineering and Design Fees for Construction of an Intermediate Depth Borehole Disposal Facility

| IDBD – Engineering & Design Costs | | | | Geotechnical Investigation | | Support Facilities Construction | |
|---|---|---|---|---|---|---|---|
| Professional Consultant | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Engineering Design Fees – Basic Design | | | 1 | $1,251.48 | 1 | $8,464.04 |
| 1 | Engineering Design Fees - Variation A | | | 1 | $1,251.00 | 1 | $8,464.04 |
| 1 | Engineering Design Fees - Variation B | | | 1 | $1,251.00 | 1 | $8,464.04 |
| **IDBD - Engineering & Design Costs** | | | | **IDBD Mobilization & Demobilization** | | **Borehole Drilling** | |
| Professional Consultant | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Engineering Design Fees – Basic Design | | | 1 | $3,887.40 | 1 | $282,819.83 |
| 1 | Engineering Design Fees - Variation A | | | 1 | $3,737.40 | 1 | $191,819.83 |
| 1 | Engineering Design Fees - Variation B | | | 1 | $2,237.40 | 1 | $837,994.39 |
| **EIDBD - Engineering & Design Costs** | | | | **Case Boreholes** | | **Construct Subsurface Deflection Shield** | |
| Professional Consultant | | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 | Engineering Design Fees – Basic Design | | | 1 | $32,118.31 | 1 | $58,118.31 |
| 1 | Engineering Design Fees - Variation A | | | 1 | $204,091.54 | 1 | $58,118.33 |
| 1 | Engineering Design Fees - Variation B | | | 1 | $32,118.33 | 1 | $58,118.33 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table C.20. Direct Costs for Construction of an IDBD Facility[a,b]

| IDBD – Direct Costs | | | Geotechnical Investigation | | Support Facilities Construction | |
|---|---|---|---|---|---|---|
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $6,264.16 | 1 | $14,254.24 |
| 1 Direct Costs - Variation A | | | 1 | $8,237.44 | 1 | $17,199.96 |
| 1 Direct Costs - Variation B | | | 1 | $6,735.04 | 1 | $14,618.56 |
| **IDBD – Direct Costs** | | | **IDBD Mobilization & Demobilization** | | **Borehole Drilling** | |
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $6,479.20 | 1 | $6,479.20 |
| 1 Direct Costs - Variation A | | | 1 | $7,781.80 | 1 | $7,781.80 |
| 1 Direct Costs - Variation B | | | 1 | $6,644.80 | 1 | $23,256.80 |
| **IDBD - Direct Costs** | | | **Case Boreholes** | | **Construct Subsurface Deflection Shield** | |
| Other Direct Costs | Unit | Cost | Qty | Ext | Qty | Ext |
| 1 Direct Costs – Basic Design | | | 1 | $647.92 | 1 | $647.92 |
| 1 Direct Costs - Variation A | | | 1 | $3,890.90 | 1 | $778.18 |
| 1 Direct Costs - Variation B | | | 1 | $664.48 | 1 | $664.48 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

## C 6.2 Durations

Durations for construction are listed in Table C.21.

The planning stage takes about 120 days. The total duration required to conduct the geotechnical investigation activities, prior to construction is 16 days. Support facility construction is 22 days and mobilization and demobilization would take 10 days.

Drilling fifty boreholes would take 500 days for 70 m boreholes and 1750 days for the 40 m boreholes which have to be both augered and cored. Surface casing placement requires about 50 days and casing to depth (Variation A) for fifty boreholes requires 250 days. Finally, placement of the subsurface deflection shield requires 50 days for fifty boreholes.

The resulting total durations for the Basic Design, Variation A and Variation B, respectively are 768 days, 1018 days, and 2018 days for fifty boreholes, or 15, 21, and 40 days per borehole.

## C 6.3 Man-Hours

Man-hours for construction are listed in Table C.22.

Table C.21. Durations for Construction of an Intermediate Depth Borehole Disposal Facility

| | | Basic Design | | Variation A | | Variation B | |
|---|---|---|---|---|---|---|---|
| **IDBD – Construction Phases** | Unit | Per Borehole | For Fifty Boreholes | Per Borehole | For Fifty Boreholes | Per Borehole | For Fifty Boreholes |
| Planning Documents | Days | 2 | 120 | 2 | 120 | 2 | 120 |
| Geotechnical Investigation | Days | <1 | 16 | <1 | 16 | <1 | 16 |
| Support Facilities Construction | Days | <1 | 22 | <1 | 22 | <1 | 22 |
| IDBD Mobilization & Demobilization | Days | <1 | 10 | <1 | 10 | <1 | 10 |
| Borehole Drilling | Days | 10 | 500 | 10 | 500 | 35 | 1750 |
| Casing Placement | Days | 1 | 50 | 5 | 250 | 1 | 50 |
| Place Engineered Barrier | Days | 1 | 50 | 1 | 50 | 1 | 50 |
| Total | Days | 15 | 768 | 21 | 1018 | 40 | 2018 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

Table C. 22. Man-Hours for Construction of an Intermediate Depth Borehole Disposal Facility

| | | Man-hours[a] | | | Man-Hours Per Borehole | | |
|---|---|---|---|---|---|---|---|
| | | Basic Design | Variation A | Variation B | Basic Design | Variation A | Variation B |
| 1 | Field Tech | 5617.2 | 7417.2 | 16867.2 | 112 | 148 | 337 |
| 1 | Program Manager | 155.6 | 195.6 | 405.6 | 3 | 4 | 8 |
| 1 | Project Manager | 1168 | 1488 | 3168 | 23 | 30 | 63 |
| 1 | Program QA/QC Manager | 398.1 | 478.1 | 898.1 | 8 | 10 | 18 |
| 1 | Construction Manager | 5752 | 7552 | 17002 | 115 | 151 | 340 |
| 1 | Project QA Inspector | 2863.2 | 3763.2 | 8488.2 | 57 | 75 | 170 |
| 1 | Health & Safety Manager | 1535.6 | 3335.6 | 2660.6 | 31 | 67 | 53 |
| 1 | Project Engineer-Senior | 57.6 | 57.6 | 57.6 | 1 | 1 | 1 |
| 1 | Project Engineer-Mid | 57.6 | 57.6 | 57.6 | 1 | 1 | 1 |
| 1 | Project Engineer-Junior | 57.6 | 57.6 | 57.6 | 1 | 1 | 1 |
| 1 | Scientist-Senior | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | Scientist-Mid | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | Administrative Assistant | 1132.1 | 1401.6 | 2819.6 | 23 | 28 | 56 |
| 1 | Cost Scheduler | 76.8 | 76.8 | 76.8 | 2 | 2 | 2 |
| 1 | CAD/GIS Operator | 57.6 | 57.6 | 57.6 | 1 | 1 | 1 |
| 1 | Technical Writer/Editor | 480 | 480 | 480 | 10 | 10 | 10 |
| 1 | Accounting Clerk | 1199.2 | 1559.2 | 3449.2 | 24 | 31 | 69 |
| 1 | Heavy Equipment Operator | 38,800 | 38,800 | 46,800 | 776 | 776 | 936 |

[a]Construction of fifty boreholes. Does not include construction of surface facilities for operation; [b]Source is AMEC (2007)

## C7. REFERENCES

AMEC (2007). Summary of Input Parameters for Conceptual Facility Designs for Greater-Than-Class C Low-Level Waste Disposal Options, Task 3.4, Revision 1. ERMS 547141. AMEC.

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