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BARNWELL LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY; CONCEPTUAL DESIGN FOR LOW-VOLUME OPERATIONS

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EXECUTIVE SUMMARY

As of June 2008 the Barnwell LLRW disposal facility will restrict acceptance of waste to three states: South Carolina, Connecticut and New Jersey, the member states of the Atlantic Interstate Low-Level Radioactive Waste Compact (the Compact). The acceptance of waste from only the Compact states will decrease the volume of waste requiring disposal and raises concern about the economic viability of the facility's continued operation.

Regulatory requirements particularly relevant to consideration of the viability of a new disposal configuration and operating concept in clued:

- Performance Objectives (RHA 7.17 through 7.21)
- Facility Design Requirements (RHA 7.23)
- Operations and Closure Requirements (RHA 7.24)

An alternative disposal unit configuration conceptual and operating mode might be developed to reduce operating costs and bolster the economic viability of the Barnwell facility. The alternative configuration evaluated in this document includes the following characteristics:

- LLRW is accomplished within reinforced concrete vaults.
- A surface water drainage system will preclude surface water from adjacent areas from entering the excavation and drain any runoff from the disposal area away at velocities that limit erosion.
- Vaults are pre-placed in a single layer within the shallow excavation with top of each vault wall is at or near the grade at its location.
- A leachate collection and removal system ensures that any water that appears at the bottom of the excavation will flow away from vaults and be removed by pumping during active operations.
- Voids between adjacent vaults are backfilled with cohesionless soils (dry sand) prior to LLRW placement within vaults.
- A low-permeability cover layer is constructed between the top of the backfill and the top of each vault wall. This layer is gently sloped from the centerline of the disposal unit to encourage runoff of precipitation and minimize infiltration.
- Once placed, vaults remain temporarily covered and unused until needed for disposal of LLRW received during current operations.

It is projected that 12,000 cubic feet might be received for disposal at the Barnwell facility beginning July 1, 2008. Of this total, 77, 11, and 12 percent are projected to be Class A, Class B, and Class C waste, respectively. Assuming historical vault utilization, approximately 67 cylindrical and 9 rectangular vaults will be required annually at this disposal rate. Assuming that this conceptual facility were located in Area 1 at the Barnwell facility, sufficient disposal capacity exists to sustain facility operation for about 40 years at this rate.

Waste receipt and disposal operations will occur only on a part-time basis throughout the year. Part-time operation could be accomplished either by scheduling waste deliveries to the facility only:

- On one day every second week (i.e., receiving bi-weekly).
- During annual disposal campaigns of nominally five weeks' duration (i.e., receiving annually).

Once LLRW is received at the facility, the delivery vehicle drives from the receiving area to the active disposal area. The delivery vehicle drives onto the structural cover layer until it is correctly positioned. A pre-positioned mobile crane transfers the waste containers from the delivery vehicles to the pre-placed vaults. Permanent vault lids are placed on each vault that has just received waste. As a rank of pre-placed vaults is filled with waste, the structural cover layer is extended to allow ongoing waste delivery and transfer operations to occur as close as possible to pre-placed vaults.

Radiation exposures to members of the general public and to facility workers are projected to be smaller than those produced by the current facility configuration and operating mode.

An operating staff of approximately 22 persons is estimated to be required to fully accomplish all receipt and disposal functions and comply with applicable regulatory requirements and license conditions. The annual level of effort required to receive and dispose of waste and provide all support functions for year-round bi-weekly and annual campaign receipt of waste are estimated to be 2.9 and 3.2 full-time equivalents (FTE), respectively.

Operating costs are estimated to total $1.2 and $1.5 million per year for year-round bi-weekly and annual campaign receipt of waste, respectively. The effective annual costs of vaults required to support disposal of 12,000 cubic feet per year was estimated to be less than $460,000 per year.

1. INTRODUCTION

1.1 BACKGROUND

The Low-Level Radioactive Waste Policy Act, 1980 (LLRWPA), and Low-Level Radioactive Waste Policy Amendments Act, 1985 (LLRWPAA) authorized the formation of regional compacts to facilitate the disposal of LLRW. Currently, South Carolina is part of the Atlantic Interstate Low-Level Radioactive Waste Management Compact (the Atlantic Compact). The Atlantic Compact consists of the states of South Carolina, Connecticut, and New Jersey. The Barnwell facility is the Compact's regional LLRW disposal facility. As provided by the LLRWPAA, a compact can limit or restrict LLRW importation from sources or exportation to destinations not located within the Atlantic Compact member states.

In 2000, South Carolina enacted the Atlantic Interstate Low-Level Radioactive Waste Compact Implementation Act (the Atlantic Compact Act) specifying the maximum volumes acceptable for disposal at the Barnwell facility. Under the schedule enacted, no more than 35,000 cubic feet of LLRW might be disposed of at the Barnwell facility in FY 2008 (July 1, 2007 through June 30, 2008). The law also restricts acceptance of waste from generators located outside the Atlantic Compact beginning July 1, 2008. This restriction will have a national impact, since the Barnwell facility has, for several years, been the only commercial LLRW disposal facility available to most of the nation for disposal of all classes of commercial LLRW.

Chem-Nuclear Systems, LLC (CNS), presently a subsidiary of EnergySolutions LLC (ES), operates the Barnwell low-level radioactive waste (LLRW) disposal facility. In the late 1970's, the Barnwell site was one of only three commercially operated disposal sites receiving more than three-fourths of the nation's waste. The increased waste receipt led to the establishment of limits on the annual volume of waste allowed to be received at the site.

As of June 2008 the Barnwell LLRW disposal facility will restrict acceptance of waste to three states: South Carolina, Connecticut and New Jersey, the member states of the Atlantic Interstate Low-Level Radioactive Waste Compact (the Compact). The acceptance of waste from only the Compact states will decrease the volume of waste requiring disposal and raises concern about the economic viability of the facility's continued operation.

The purpose of this report is to characterize and evaluate an alternative disposal unit configuration and operating mode as an approach to addressing the concerns over economic viability of the facility's continued operations

Three major documents govern the Barnwell site and its operation, namely:

1) The Lease Agreement, and its amendments, between CNS and the SC B&CB;
2) South Carolina Radioactive Material License 097 (License 097) issued by the South Carolina Department of Health and Environmental Control (DHEC); and
3) The Decommissioning Trust Agreement of 1981 between CNS and the state of South Carolina.

1.2 OVERVIEW OF BARNWELL LLRW DISPOSAL FACILITY

The Barnwell LLRW disposal facility (the Barnwell facility) is a 235-acre tract of land owned by the state of South Carolina. The facility is located between the DOE Savannah River Site (SRS) and the hamlet of Snelling, as shown in Figure1. The layout of the Barnwell facility is shown in Figure 2.

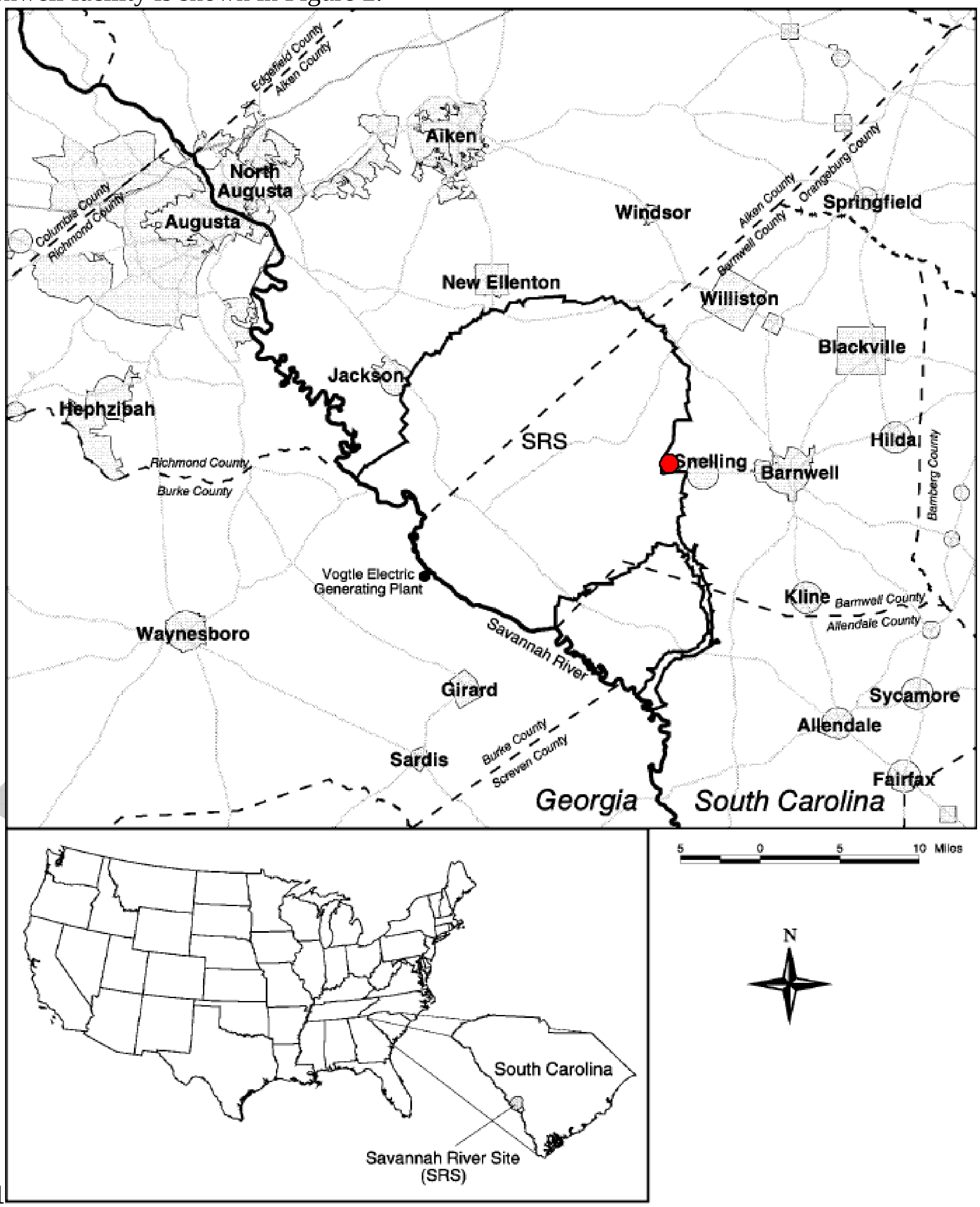

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Figure 1. Location of the Barnwell LLRW Disposal Facility

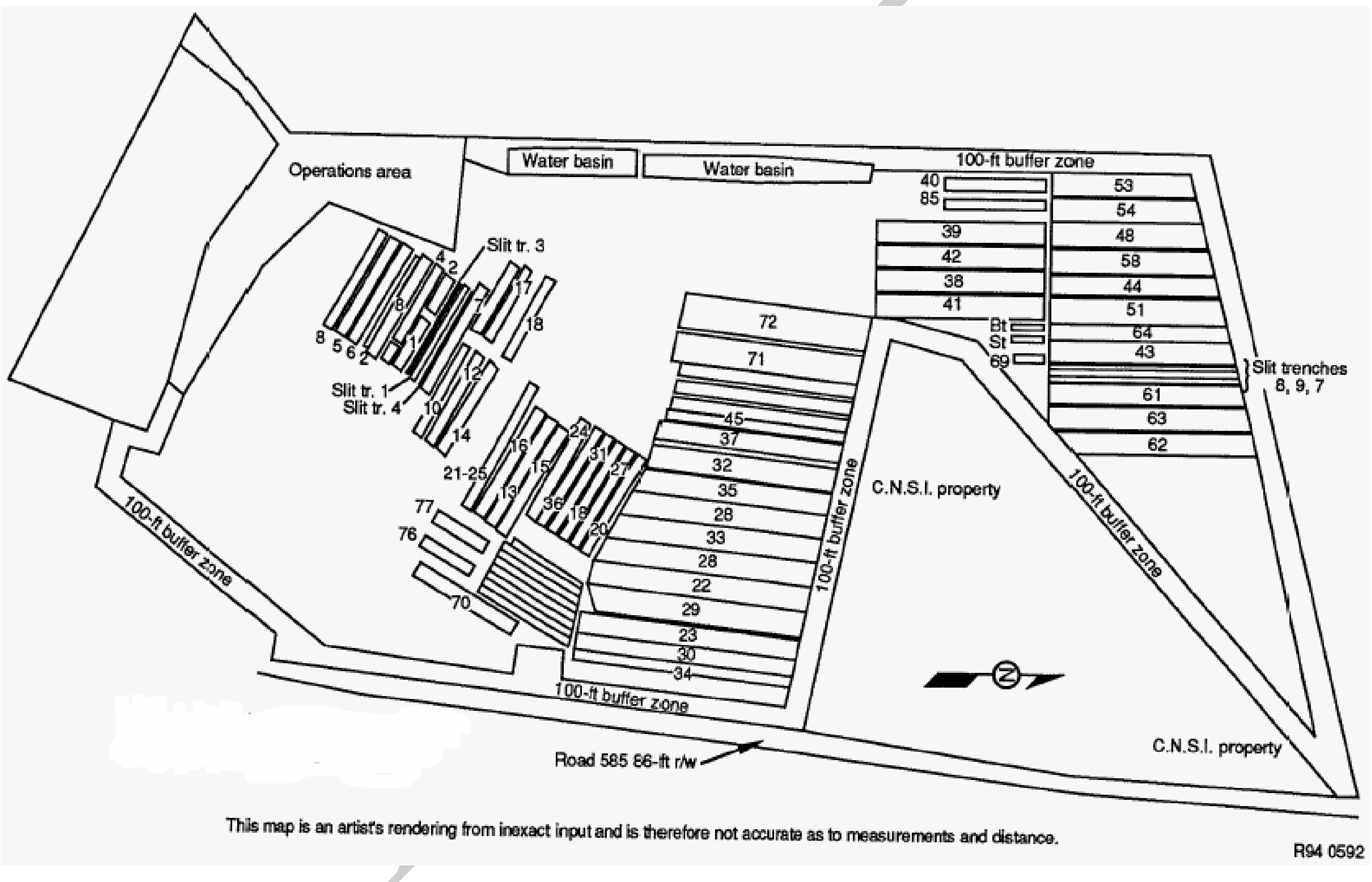

Figure 2. Layout of Barnwell LLRW Disposal Facility

1.3 SCOPE

This document addresses the topics requested by the Atlantic Compact Commission as follows:

- Project the minimum and the maximum number of rectangular and cylindrical vaults that would be needed each year for disposal of Atlantic Compact waste. The minimum number assumes acceptance of Class B and C wastes only. The maximum assumes acceptance of all Atlantic Compact waste, excluding large components and irradiated hardware. The estimate may be based upon waste data provided by the South Carolina State Energy Office for recent years and other information.
- Show through illustrations how vaults might be arrayed in "Area 1" of the Barnwell site so that they are pre-staged to facilitate easy off-load and emplacement of high integrity containers and other waste packages from arriving trucks. The size and shape of Area 1 can be estimated from the Barnwell Site Remaining Waste Disposal Capacity Evaluation, December 2006.
- Consideration should be given to the placement of arriving trucks with respect to the vaults, exposure dose assessment, dose rates to the fenceline and the safe operating range of any crane that might be available for moving the waste packages.
- Estimate the total number of rectangular vaults and cylindrical vaults that might fit into Area 1, based on the hypothetical array. Making conservative assumptions about the volume of waste that can be placed into vaults, estimate the total volume of waste that might be accommodated in this manner in Area 1. It is important to distinguish between waste volume and disposal volume when developing these assumptions.
- Provide a conceptual design for disposal trenches that might be used to accommodate the vault arrays. Provide summary procedures for:
  - ✓ Conceptual disposal trench design and operations
  - ✓ Trench maintenance during non-disposal operations
  - ✓ Active trench water management.
- Consult with DHEC staff on any features that they would consider desirable or necessary in any such design.
- Estimate the costs of offloading waste from Atlantic Compact generators during a single campaign period each year. As a starting point, assume that a crew properly trained in radiation protection is brought in from outside the State, which requires salary, per diem, housing, and transportation. Use fully burdened labor rates, as applicable, to account for corporate overhead (G&A) associated with the campaign. Account for the salaries of two full-time equivalent employees year round to plan for the waste campaign, and provide a customer contact. Also, account for a Radiation Safety Officer (RSO) to be onsite during operations and to oversee planning for the disposal site. Account for rental of a crane and other equipment that is not already available at the disposal site.

- Prepare a project report final report documenting all project activities, including definition of the desired concept and results of required evaluations.

2. DESIGN BASIS

All activities involving the licensing, construction, operation, closure, and post-closure maintenance of the Barnwell LLRW disposal facility are governed under South Carolina the Atomic Energy and Radiation Control Act (Statutory Authority: Section 13-7-40 et seq., as amended, of the 1976 Code). LLRW disposal is specifically controlled by the regulations contained in the South Carolina Code of Regulations, Chapter 61 "Department of Health and Environmental Control", Part 63 "Radioactive Materials," Part VII "Licensing Requirements for Land Disposal of Radioactive Waste." Individual sections are referred to using the "RHA" citation.

Numerous regulatory requirements exist beyond those summarized in this document. However, those particularly relevant to consideration of the viability of a new disposal configuration and operating concept in clued:

- Performance Objectives (RHA 7.17 through 7.21)
- Facility Design Requirements (RHA 7.23)
- Operations and Closure Requirements (RHA 7.24)

The Atlantic Compact Commission specified additional requirements that relate more to economic viability.

These requirements are summarized in the following sections.

2.1 PERFORMANCE OBJECTIVES

The performance objectives that must be met by the design, construction, operation, closure, and long-term maintenance of the LLRW disposal facility (RHA 7.17 through 7.21) are the following:

- Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems (0.25 mSv) to the whole body, 75 millirems (0.75 mSv) to the thyroid, and 25 millirems (0.25 mSv) to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.
- Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.
- Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in Part III of these regulations, except for releases of radioactivity in effluents from the land disposal facility, which must be

governed by 7.18. Every reasonable effort should be made to maintain radiation exposures as low as is reasonably achievable.

- The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required. Engineered barriers must be used to ensure that the stability requirements are met.

2.2 FACILITY DESIGN REQUIREMENTS

Facility design requirements (RHA 7.23) consist of the following:

- Provide long-term isolation of disposed waste
- Avoid the need for continuing active maintenance after site closure .
- Be compatible with the disposal site closure and stabilization plan.
- Lead to disposal site closure that provides reasonable assurance that the performance objectives will be met.
- Complement and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives will be met.
- Minimize, to the extent practicable, water infiltration.
- Direct percolating or surface water away from the disposed waste.
- Resist degradation by surface geologic processes and biotic activity.
- Direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require ongoing active maintenance in the future.
- Minimize, to the extent practicable, the contact of water with waste during storage.
- Minimize, to the extent practicable, the contact of standing water with waste during disposal.
- Minimize, to the extent practicable, the contact of percolating or standing water with wastes after disposal.

2.3 FACILITY OPERATIONS AND CLOSURE REQUIREMENTS

Facility operations and closure requirements (RHA 7.24) consist of the following:

- Wastes designated as Class A pursuant to 3.25.1 of these regulations must be segregated from other wastes by placing in disposal units which are sufficiently separated from disposal units for the other waste classes so that any interaction between Class A wastes and other wastes will not result in the failure to meet the performance objectives of this part. This segregation is not necessary for Class A wastes if they meet the stability requirements stated in these regulations.

- Waste designated as Class C must be disposed of so that the top of the waste is a minimum of 5 meters below the top surface of the cover or must be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years.
- Only waste classified as Class A, B, or C must be acceptable for near-surface disposal.
- Wastes must be emplaced in a manner that maintains the container integrity during emplacement, minimizes the void spaces between containers, and permits the void spaces to be filled.
- Void spaces between waste containers must be filled with earth or other material to reduce future subsidence within the fill.
- Waste must be placed and covered in a manner that limits the radiation dose rate at the surface of the cover to levels that at a minimum will permit the licensee to comply with all provisions of these regulations at the time the license is transferred to the site owner.
- The boundaries and locations of each disposal unit must be accurately located and mapped by means of a land survey. Near surface disposal units must be marked in such a way that the boundaries of each unit can be easily defined. Three (3) permanent survey marker control points, referenced to U.S. Geological Survey (USGS) or National Geodetic Survey (NGS) survey control stations, must be established on the site to facilitate surveys. The USGS or NGS control stations must provide horizontal and vertical controls as checked against USGS or NGS record files.
- A buffer zone of land must be maintained between any buried waste and the disposal site boundary and beneath the disposed waste. The buffer zone must be of adequate dimensions to carry out environmental monitoring activities and take mitigative measures if needed.
- Closure and stabilization measures as set forth in the approved site closure plan must be carried out as each disposal unit is filled and covered.
- Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.
- Only wastes containing or contaminated with radioactive material must be disposed of at the disposal site.

2.4 COMMISSION SPECIFICATIONS

In addition to regulatory requirements summarized above, the Atlantic Compact Commission (the Commission) has specified several additional objectives of design and operation. These include:

- Accommodating the disposal of normal operational Class A, Class B, and Class C LLRW after June 30, 2008.

- Limiting operating costs to allow economically viable disposal charges to waste generators that rely upon the facility's disposal services.
- Minimizing the generation of contact water prior to final facility closure.
- Minimizing the need for trench maintenance prior to final facility closure.

Notice that the Commission has specified no requirement for disposal of large components (such as steam generators or reactor pressure vessels), or for disposal of waste with very high levels of radiation (such as has historically been disposed of in the so-called "slit trench"). Disposal of these types of LLRW is not addressed in this report.

2.5 TECHNICAL INFORMATION AND CONSTRAINTS

Data provided by the SC State Energy Office (Newberry, 2007) is summarized in Table 1, together with results of intermediate calculations:

Table 1. Summary of Selected Barnwell Waste Disposal History

	FY2001 (12 Months Data)	FY2002 (12 Months Data)	FY2003 (3 Months Data)	FY2004 (12 Months Data)	Totals
Rectanglar Vaults					
Volume of Waste Disposed (cf)	15,159	20,396	4,101	6,600	46,256
Number of Vaults Used	58	73	15	24	170
Waste Volume per Vault Used (cf/Vault)	261	279	273	275	272
Vault Space Utilization (% of Interior Vault Space)	38%	41%	40%	40%	40%
Cylindrical Vaults					
Volume of Waste Disposed (cf)	87,912	44,362	6,999	40,894	180,167
Number of Vaults Used	616	352	48	322	1,338
Waste Volume per Vault Used (cf/Vault)	143	126	146	127	135
Vault Space Utilization (% of Interior Vault Space)	52%	46%	53%	46%	49%

Information about how vault utilization differs between Class A, Class B, and Class C LLRW was not available. However, experience suggests that rectangular vaults are used primarily for Class A LLRW.

These figures show that over the four-year period summarized by the data available, 20 percent of the volume was disposed of in rectangular and 80 percent in cylindrical vaults. On average over this time, 272 cubic feet of waste were disposed of in each rectangular and 135 cubic feet were disposed of in cylindrical vault.

Volumes of operational LLRW (other than large components and waste carried over from previous years) to be received at the Barnwell facility beginning in FY 2009, when only Compact LLRW will be accepted, are projected as shown in Table 2 (Latham 2007).

Table 2. Summary of Barnwell Waste Distribution by Waste Class

	Projected Volume (cf)	Percent of Projected Volume
Class A LLRW	8,763	77 %
Class B LLRW	1,265	11 %
Class C LLRW	1,316	12 %
All LLRW	11,344	100 %

In projecting the number of vaults expected for disposal after FY 2008, it was assumed that 20 percent of all LLRW volume received is disposed of in rectangular vaults (the balance in cylindrical vaults), irrespective of waste class. URS also considered two sets of vault volume utilization values:

- Four-year average utilization (i.e., 272 cubic feet per rectangular and 135 cubic feet per cylindrical vault; these values correspond to 40 and 50 percent utilization, respectively).

- Efficient vault utilization (i.e., 408 cubic feet per rectangular and 193 cubic feet per cylindrical vault; these values correspond to 60 and 70 percent utilization, respectively).

Based on these conditions, it was estimated that the numbers of vaults shown in Table 3 will be required annually for operational LLRW delivered to the Barnwell disposal facility after FY 2008:

Assuming historical vault utilization as shown above, it was estimated that 9 and 67 rectangular and cylindrical vaults annually, respectively, would be required to dispose of all classes of LLRW received. Assuming efficient vault utilization, it was estimated that 7 and 49 rectangular and cylindrical vaults annually, respectively, would be required to dispose of all classes of LLRW received.

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Table 3. Projected Numbers of Vaults Required for Disposal of Barnwell LLRW after FY2007

		Class A	Class B	Class C	Total
	Volume in Rectanglar Vaults (20 percent)	1,753	253	263	2,269
	Volume in Cylindrical Vaults (80 percent)	7,010	1,012	1,053	9,075
Historical Vault Utilization	Number of Rectangular Vaults	7	1	1	9
	Number of Cylindrical Vaults	51	8	8	67
Efficient Vault Utilization	Number of Rectangular Vaults	5	1	1	7
	Number of Cylindrical Vaults	37	6	6	49

If only Class B and Class C LLRW were disposed of at the Barnwell facility, the vaults shown under the column above headed “Class A” would not be required. Obviously, if only Class B and C waste were received at the Barnwell facility, many fewer vaults would be required. Again, referring to the table immediately above, assuming historical vault utilization as shown above, it was estimated that only 2 and 16 rectangular and cylindrical vaults annually, respectively, would be required to dispose of Class B and C waste received. Assuming efficient vault utilization, it was estimated that only 2 and 12 rectangular and cylindrical vaults annually, respectively, would be required to dispose of Class B and C waste received.

Were only “Area 1” to be utilized for the disposal of operational LLRW that is considered in this evaluation, sufficient area would exist to support disposing of all classes of LLRW for up to 40 years at the currently projected annual delivery rate of 12,000 cubic feet per year. Capacity would be available for more than 100 years, if only Class B and C LLRW were received at the facility at the currently projected annual rate.

3. GENERAL FACILITY DESCRIPTION

This conceptual design report defines and evaluates a method by which Barnwell LLRW disposal facility may be operated part-time. Figure 1 is an illustration of the Barnwell Disposal Facility and Area 1 in which the proposed Compact Waste will be placed. Area 1 is an 8 acre tract of land out of the 235 acres leased to CNS. Area 1 will be developed such that one layer of concrete vaults will be pre-placed (or buried) before waste operations begin. The vaults are placed so that the top is near existing grade and accessible for placement of delivered LLRW. The layout of the conceptual facility also minimizes the generation of contact water requiring management. Storm water is diverted from contacting the waste and therefore remains clean water, free of contamination.

At this conceptual stage, numerous technical issues must necessarily remain unresolved since the concept is only now emerging. As better definition is prepared, additional detail can be provided to ensure that all technical, safety, and regulatory issues are resolved. At this stage, however, it is sufficient to acknowledge that much additional technical justification must be prepared and to observe that almost any issue can be resolved, provided willingness exists to commit the required resources. Of course, determining whether that willingness exists is exactly the objective of conceptual and subsequent evaluations and design activity – to determine whether the concept can meet all applicable requirements at a cost that is acceptable to the interested parties.

3.1 CONCEPTUAL FACILITY CONFIGURATION

The prominent features of the conceptual facility described and evaluated in this document are illustrated graphically in Figures 2 through 4. Figure 2 is a perspective illustration of the conceptual disposal unit located in Area 1. Figure 3 shows a plan layout of the disposal unit with pre-placed vaults. Figure 4 shows typical cross sections lengthwise and crosswise through the disposal trench, respectively.

Disposal of LLRW will take place in Area 1 of the Barnwell Disposal Facility. Area 1 is approximately 250 feet wide by 1,300 feet long. The area will be developed to enable disposal of all classes of LLRW suitable for near-surface disposal. With the configuration described herein, approximately 40 years of disposal capacity exists in Area 1.

The conceptual facility possesses the following general characteristics:

- As required by South Carolina regulations, disposal of LLRW is accomplished within reinforced concrete vaults. The rectangular and cylindrical vaults that have been used at the Barnwell facility since 1995 are assumed to continue being used in this conceptual design configuration and operating concept
- A surface water drainage system will be constructed to preclude surface water from adjacent areas from entering the excavation and to drain any runoff from the disposal area away at velocities that do not cause erosion that would compromise the function of any component of the disposal system.

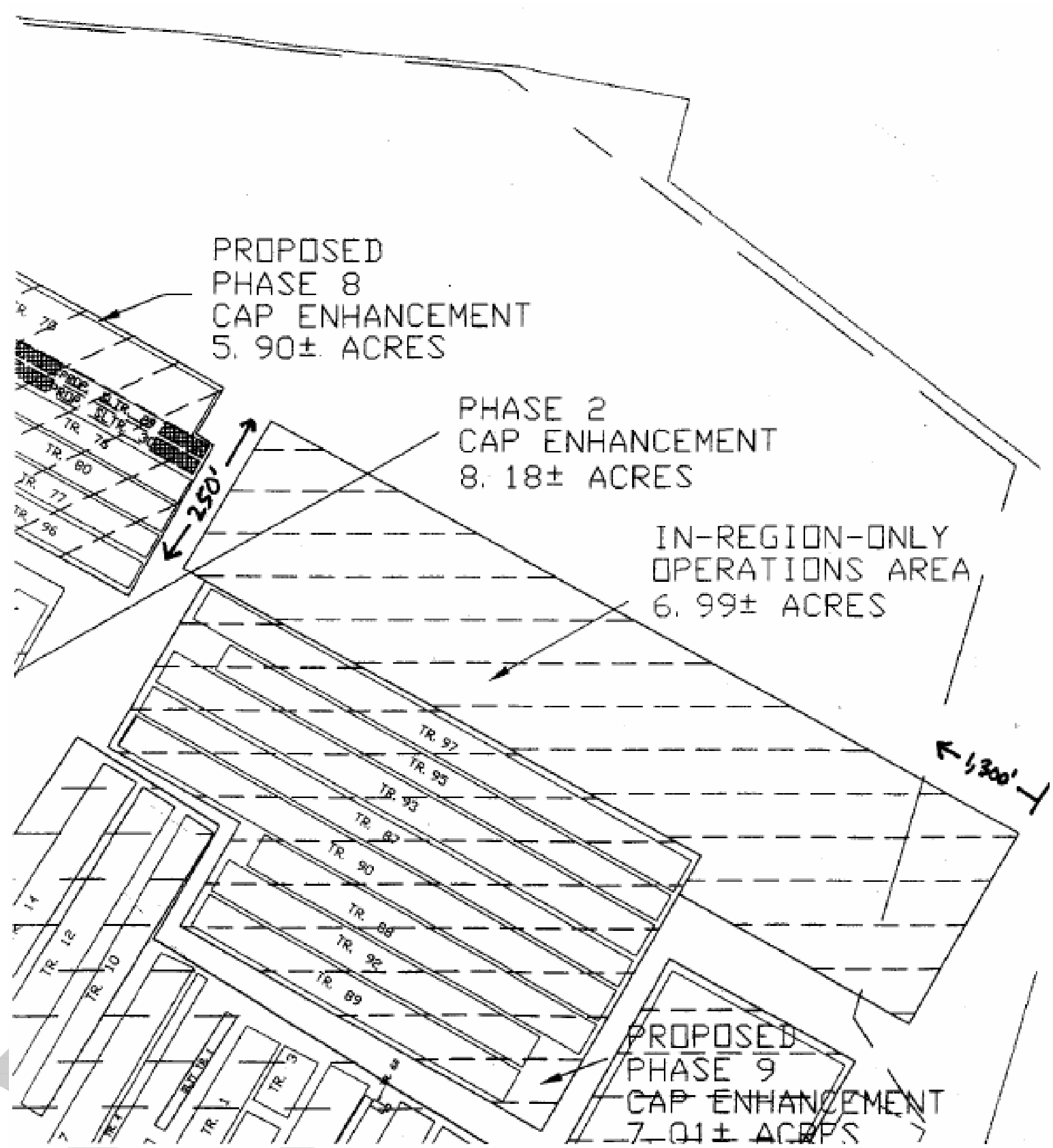

Figure 3. Location of Area 1 on Barnwell LLRW Disposal Facility *(REPLACE WITH BETTER)*.

- Vaults are pre-placed in a single layer within the shallow excavation.
- Trenches are excavated with side slopes as steep as the existing soils will allow.
- The top of each vault wall is at or near the grade at its location. Cylindrical vaults are placed on a triangular pattern, while rectangular vaults are placed adjacent to each other.
- The bottom of the excavation is gently sloped from the excavation center line to the sides.

- A leachate collection and removal system is provided in the bottom of the excavation to ensure that any water that appears at the bottom of the excavation will flow away from vaults and be removed by pumping during active operations.
- Spacing between adjacent vaults is no less than 12 inches to allow for effective backfilling of voids between vaults and to cushion and distribute lateral loadings on vault walls during any seismic event.
- Pre-placed vaults are provided with weather shield (temporary or permanent lid) whose purpose is to exclude precipitation from entering the vaults prior to waste placement within them.
- Voids between adjacent vaults are backfilled with cohesionless soils (dry sand) prior to LLRW placement within vaults.
- A low-permeability cover layer is constructed between the top of the backfill and the top of each vault wall. This layer is gently sloped from the centerline of the disposal unit to encourage runoff of precipitation and minimize infiltration.
- Once placed, vaults remain temporarily covered and unused until needed for disposal of LLRW received during current operations.

The disposal unit will be constructed in a phased approach. Each phase will involve the following activities:

- Extending the surface water drainage system.
- Extending the excavation to enable pre-placement of the pre-determined number of vaults.
- Constructing the trench floor and leachate collection and removal system.
- Pre-placing the selected number of vaults, in number sufficient to support disposal operations for five to ten years.
- Placing a weather shield on each pre-placed vault.
- Backfilling voids between adjacent vaults.
- Constructing the low-permeability cover layer on top of backfill.
- Extending the structural cover layer and final cover system as appropriate.

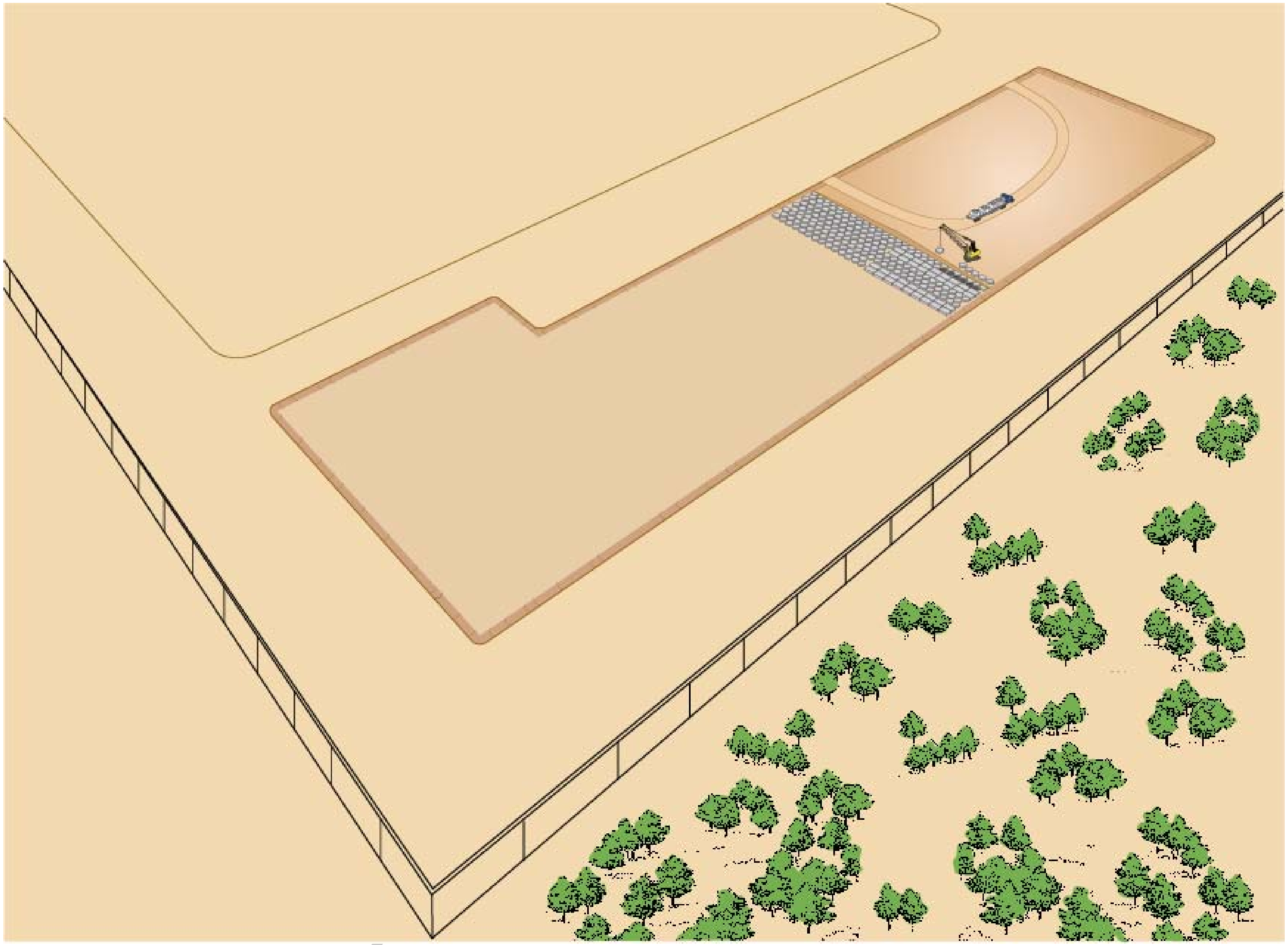

Figure 4. Perspective View of Conceptual Facility

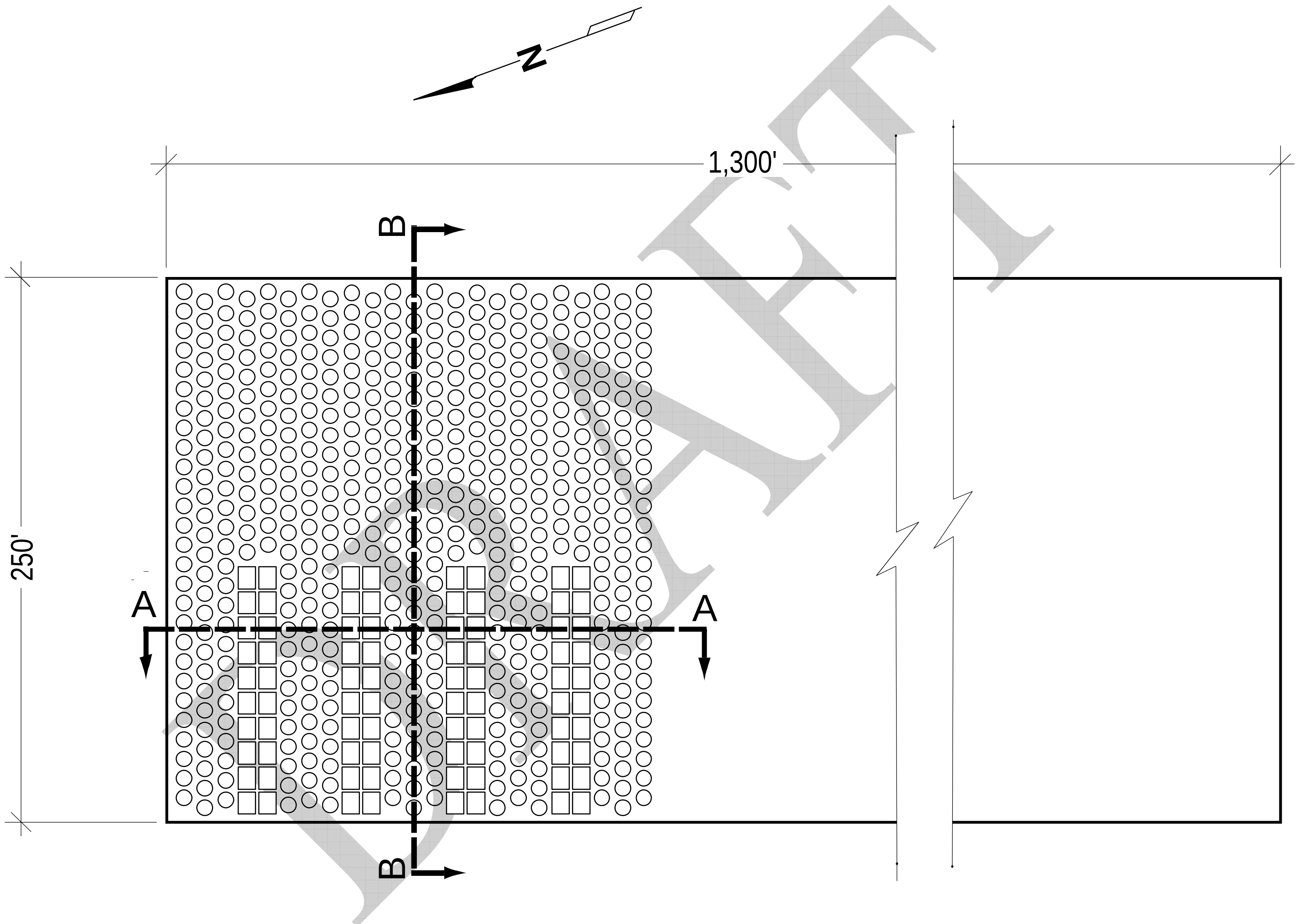

Figure 5. Plan View of Conceptual Disposal Unit

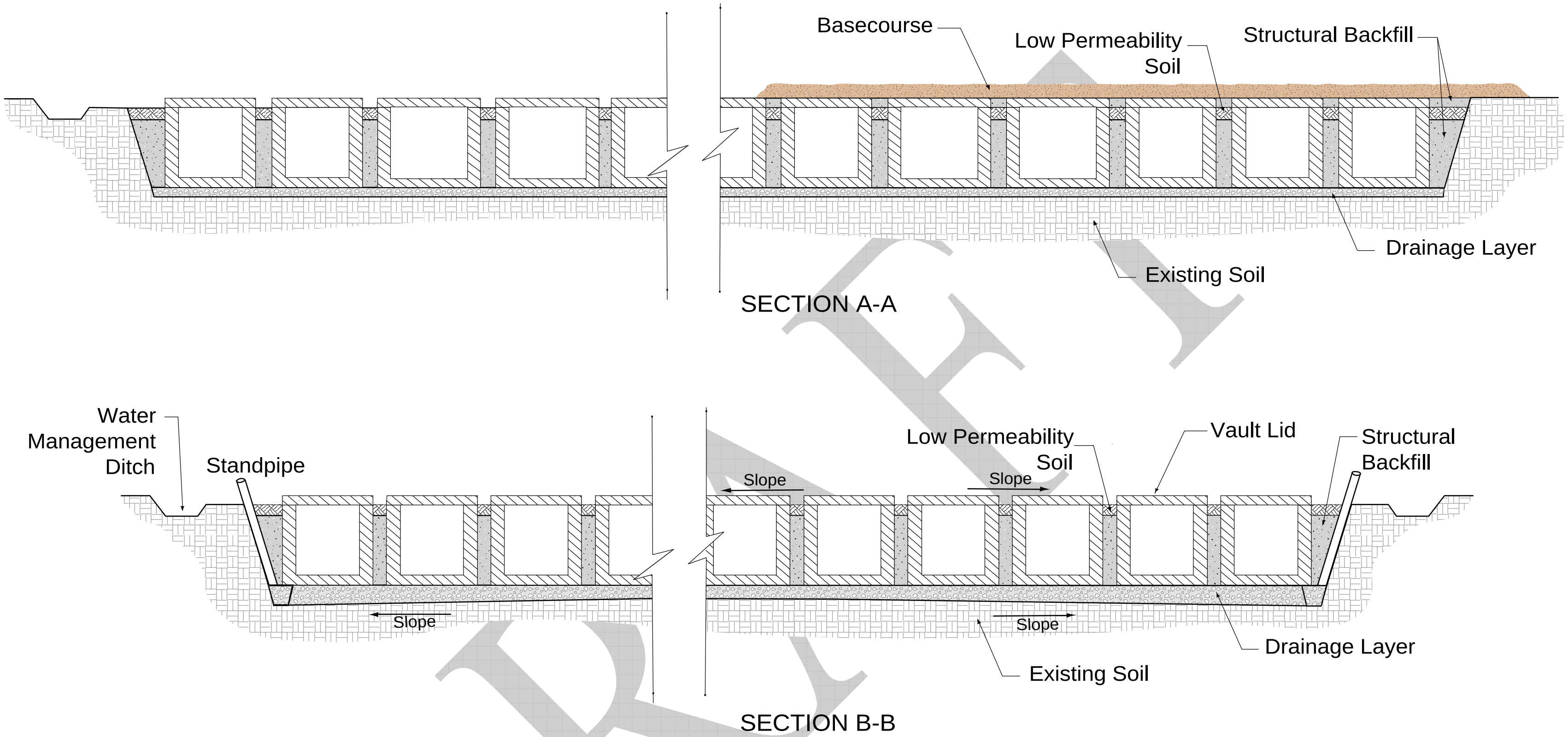

Figure 6. Cross Sections of Conceptual Disposal Unit

3.2 CONCEPTUAL FACILITY OPERATION

Receiving Schedule

Waste receipt and disposal operations will occur only on a part-time basis throughout the year. Part-time operation could be accomplished either by scheduling waste deliveries to the facility only:

- On one day every second week (i.e., receiving bi-weekly).
- During annual disposal campaigns of nominally five weeks' duration (i.e., receiving annually).

The bi-weekly operating mode has the advantages of:

- Minimally impacting generators' current waste shipping practices.
- Being more attractive to potential part-time employees than part-time employment for several weeks once annually.

Waste receipt rate under either of these receiving schedules are small and be easily received and disposed of. Assuming an annual disposal rate of about 12,000 cubic feet per year, the effective daily receipt rate would lie between 400 and 500 cubic feet. This effective daily receipt rate is about the same magnitude as receipt and disposal operations during 2000. This effective daily receipt rate is well lass than the much larger daily rates that prevailed from 1995 to 1999 (more than 1,800 cubic feet declining to less than 700 cubic feet per day), during which time essentially identical receipt and disposal procedures were followed.

Waste received at the facility will be inspected, administratively processed, and received following essentially the same procedures as are currently authorized for those activities.

Disposal and Associated Operations

Delivery vehicles will travel on and a transfer crane be pre-positioned on the structural cover layer. The structural cover layer must be designed to accommodate all loads expected and likely during delivery and transfer operations. These loads are considered live loads and include:

- Weight of the heaviest LLRW container
- Weight of the heaviest delivery vehicle
- Weight of the heaviest crane expected to be used for transfer operations
- Weight of the structural cover layer, assuming it is saturated with water

Design variables of the structural cover layer include particle size distribution, density, and angle of influence. The design variables for the loading conditions include bearing area for loads and live load limitations.

Once LLRW is received at the facility, the delivery vehicle drives from the receiving area to the (radiologically clean portions of the) active disposal area. The delivery vehicle drives onto the structural cover layer until it is correctly positioned. The driver removes himself from the active disposal area to limit his exposure to potentially elevated radiation levels while waste is transferred from the delivery vehicle to the pre-placed vaults. Necessary and appropriate physical preparations are made to the waste shipment.

A mobile crane is pre-positioned on the structural cover layer. Before the truck arrives at the active disposal area, the crane removes the weather shields from the designated pre-placed vaults to receive the arriving waste.

When the delivery vehicle has been properly positioned and appropriate physical preparations of the shipment have been made, the waste containers are transferred from the delivery vehicles to the pre-placed vaults. The permanent vault lids are placed on each vault that has just received waste.

The delivery vehicle driver returns and drives the vehicle from the active disposal area to the area designated for surveying and decontaminating the vehicle as needed prior to its release for travel on uncontrolled roadways.

As a rank of pre-placed vaults is filled with waste, the structural cover layer is extended. This allows ongoing waste delivery and transfer operations to occur as close as possible to pre-placed vaults. The final cover system can also be periodically extended as dictated by license conditions and operating procedures.

The exact ratio of the numbers of rectangular and cylindrical vaults must be the subject of substantial additional evaluation. To be sure, once the vaults are placed and voids between them backfilled, some operational flexibility will be lost. If a need for additional rectangular vaults arises when such are not available at a convenient location, then management/administrative controls might be required to delay the delivery of such LLRW or accelerate the delivery of other LLRW to the Barnwell facility until it can be timely received and dispatched.

An alternative disposal unit configuration could involve placing cylindrical vaults on one end of Area 1 and rectangular vaults on the opposite end. In this manner, the constraint created by projecting the ratio of number of cylinders to the number of rectangles can be eliminated, without appreciable costs. The excavations associated with each type of vault would be extended as need to match their use.

3.3 STRUCTURAL COVER LAYER DESIGN

As noted in Section 3.2, the design of the structural cover layer is critical to the success of this concept as configured. The design must protect the structural stability of the underlying components, namely vault lids and vaults. To the extent that the structural stability of the vaults and lids cannot be protected, the concept would have to be revised. A design revision that would limit loads from the structural cover layer would be to leave aisles on the excavation floor from which waste delivery and transfer operations could be conducted.

However, preliminary evaluations indicate the concept can be adequately design under the following conditions:

- Voids between canisters must be filled with compacted backfill or a flowable material to prevent differential settling between the canisters and the backfill material.
- Canister lids are 16" thick and constructed with a minimum strength 4000 psi concrete. Two layers of reinforcement exist in each lid. Both top and bottom layers consist of #5 bars placed at 6"o.c. in each direction.
- Canister lid capacity is based on 100-ton (capacity) crane for which the maximum gross weight of crane plus load must not exceed 150,000 lb.
- Canister lid capacity is based also on HS 25 Truck loading from AASHTO (American Association of State Highway and Transportation Officials) 17th edition.
- One to three feet of structural cover soils should be placed over canisters after they have been filled. This condition will provide a level surface for delivery vehicle and crane operations and will prevent any damage to the vaults and lids.
- Crane outrigger support (cribbing) is required to be 100 square feet minimum at each outrigger. Cribbing shall be determined by the crane operator/supplier to distribute the load of the crane evenly over the specified area. The area of cribbing specified above is only limits load to the canisters. Other operating considerations must also be addressed to provide adequate cribbing to ensure safe crane operations.
- Once truck and crane operations in a given area are complete, additional cover material can be placed over the canisters. Preliminary evaluations indicate that the canisters can accommodate up to 10 feet of total cover material.

3.4 CONSTRUCTION SPECIFICATIONS

The engineered drawings of Area 1 must show the locations and layout of the vaults and other principal design features, including subsurface drainage layers, leachate removal components, backfill, cover layers, and surface drainage components. The drawings will indicate the quantities of the materials while specifications will indicate the quality of materials.

Construction specifications will cover the excavation of the disposal unit, installation of clay liner, and placement of drainage layers, vaults, structural fill between vaults, and interim clay cover. These specifications will generally include at least the following details:

Surface Water Drainage and Management Features

Surface features, such as ditches and berms, will be constructed around Area 1 to control storm water flows. The features will be installed at gentle slopes to reduce the risk of erosion and the need for ongoing active maintenance.

Storm water accumulation from areas off-site will not run on to Area 1. However, to protect against the unlikely possibility that run on might occur, a ditch or berm will be constructed to divert the storm water away from Area 1.

In much the same way as an engineered cover, all components of the cover layers over closed areas will be crowned to promote water drainage away from the disposal area. Storm water run off from the disposal area will flow into ditches and eventually into the existing detention ponds. This water is considered non-contact (not radiologically contaminated) water since all waste is containerized and disposed of in reinforced concrete vaults.

Disposal Unit Excavation

The disposal unit will be excavated to the lines and grades shown in Figures 5 and 6. This concept differs from current operations in that its depth is sufficient for only a single layer of concrete vaults, whereas current excavations accommodate three layers of vaults below grade. Excavation depth will allow:

- Installation of a clay barrier layer
- Installation of a subsurface drainage and leachate collection system
- Placement of only one layer of concrete vaults
- Construction of an interim clay cover designed to tie directly into existing ground elevation.
- The top of the concrete vaults and interim clay cover will generally coincide with the existing local ground elevation.

Disposal unit side slopes will be cut at the same slopes as is done currently. The steep side slope allows more area to be used for waste disposal. No maintenance of slopes is required since the time between excavation and construction of the low-permeability layer is expected to be short (on the order of weeks).

The bottom or floor of the disposal unit will be excavated and graded to promote drainage of any leachate to the long edge of the disposal unit. The disposal unit will be crowned in the center, along a line parallel to the major axis of the trench. Any subsurface water (leachate) will flow first to the side (or long edge) and then along the long trench edge where it is collected in a sump or sumps and removed by pumping.

Clay Barrier

Excavation of the disposal unit at Area 1 is into the natural clay stratum. In order to reinforce the ability of the clay soil to perform as a hydraulic barrier, the clay at the bottom of the disposal unit will be scarified and compacted. The scarification and compaction of the bottom layer of existing clay will help reduce the permeability of the soils, thereby to impede the flow of water through the soils. This hydraulic barrier will help divert water along the leachate collection system and impede its entry into underlying soils.

Installation of Leachate Collection and Removal System

A leachate collection and removal system will be installed along the disposal unit floor where potential water will drain to the outer edges of the disposal unit to be collected. The disposal unit floor drains water away from the center of the disposal unit in both directions, towards the long edges of Area 1. The leachate collection system consists of a gravel drainage layer sloped toward a gravel sump. The general layout of this system is shown in Figure 7.

Along the outer edges of the disposal unit, on the disposal unit floor, sumps will be provided with standpipes to facilitate pumping of any leachate that might appear. Standpipes will be large and strong enough to allow a pump to be lowered and retrieved. Collected water in the leachate sumps will be mechanically removed for testing and discharge.

Whatever trench water accumulates with the pre-placed vault concept will be less than presently accumulates in the current design configuration and operating mode. The permeability of the low-permeability cover in the pre-placed vault concept, even with defects that might develop (and that could easily be mitigated), would allow substantially

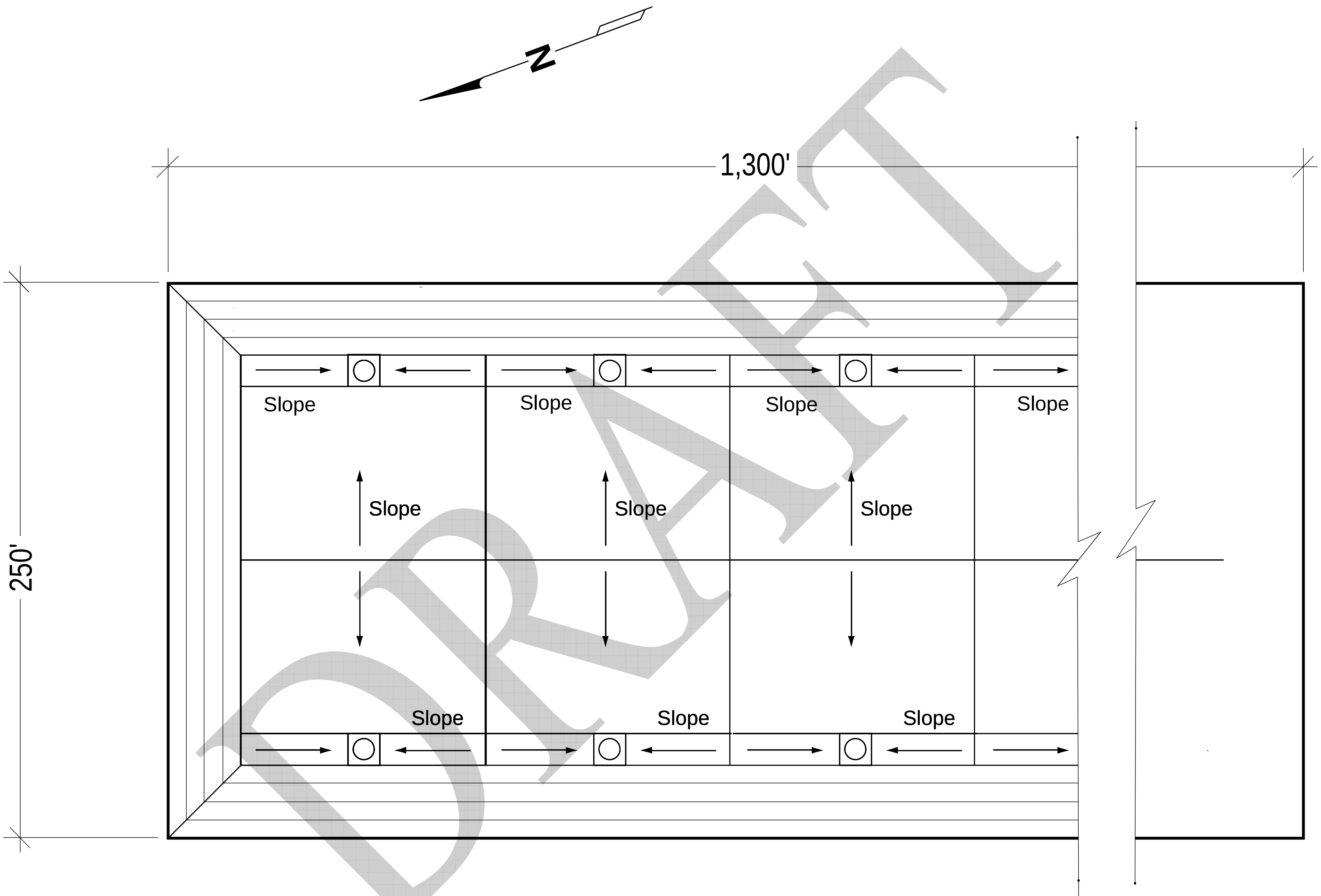

Figure 7, Layout of Leachate Collection and Removal System

less water into the trench than is allowed with the current design configuration and operating mode.

Vault and Weather Shield Placement

As with current operations, both cylindrical and rectangular steel-reinforced concrete vaults will be used for disposal of waste containers delivered to and accepted at the Barnwell facility. The choice of vault depends upon the geometries and sizes of waste containers received.

In general, the objectives in determining the use of vaults will be to use available disposal capacity (volume) as efficiently as possible and to maintain radiation exposure to disposal workers as low as be reasonably achievable (ALARA). While improvements in disposal efficiency might be possible by modifying the dimensions of the two vaults, evaluating this possibility is beyond the scope of this investigation.

Vaults are placed into the disposal unit in one layer only. The top of the vault (not including weather shield or lid) will generally be at the same elevation as the existing local grade. Once placed, a weather shield will be placed to prevent rainfall, other precipitation, and windblown particles from entering the vaults prior to waste placement.

Each vault must be placed at an appropriate elevation, allowing reasonable tolerance (or deviation from specified conditions). Such placement is easily achievable with modern computer-aided earthmoving and material handling equipment, hardware, and software. Moreover, because only one layer of vaults must be placed, the need to ensure that each vault is situated exactly vertically is minimized. The need for precision is less with the pre-placed vault concept than with the current design configuration and operating mode.

Vaults will be placed with enough space between adjacent vaults to allow structural fill to be placed between them (12 inches). This separation is much greater than is provided in current Barnwell operations. Thus, backfilling of voids in the pre-placed vault concept will be achieved at least as effectively as backfilling using the current design configuration and operating mode.

Fill between vaults will contribute to the stability of the vaults and the disposal unit cover system. Vaults are set and structural fill installed so that disposal unit construction is essentially completed (with the exception of the structural cover layer and final cover system) before waste disposal operations begin.

The configuration of vaults will maximize the capacity of Area 1 for waste disposal. Vaults will be set at elevations that promote the drainage of the site during operations. The top of the interim cover (low permeable layer of soil above the structural fill and vault lids) and vaults is in the shape of a mansard roof; similar in contour to that of a cover system crowned at the middle, over a rectangular shaped disposal unit. Placing the vaults and interim cover in this manner will provide a means for the disposal unit to shed any water that runs off during operations.

Construction of Initial Cover Layers

Voids between vaults are backfilled with structural fill in order to promote structural stability of the disposal unit cover system. Between the top of the backfill and the top vault walls is constructed a layer of low-permeable soil. This initial, interim cover layer will discourage water from entering the disposal unit during operations by encouraging it to drain laterally away from the disposed waste. The soil will be placed between vaults, graded to shed water from the center of the disposal unit toward the outer edges and compacted to the specified permeability.

Construction of the low-permeability layer on top of backfilled soils admittedly will not be accomplished with large machinery because of the small working areas available. Although placing and compacting the clayey soils will indeed be labor intensive, the required permeabilities will easily be achieved using manual methods and small equipment. Moreover, relying on manual labor in these tight spaces will not produce increased radiation exposures since the vaults are placed before any LLRW is placed in the disposal unit or only after previously placed LLRW has been covered with vault lids and structural and final cover layers.

Construction of Structural Cover

Waste is loaded into vaults using a crane situated atop the structural cover layer (structural base course). This structural cover layer distributes dead and live loads so that the integrity of the closed vaults is maintained. As vaults are filled and lids placed, waste delivery and transfer operations move back and forth across the width of the disposal unit filling ranks of pre-placed vaults in the process. When a row rank of pre-placed vaults has been filled and lids placed, the structural cover layer is extended so that subsequently delivered waste can placed into the next rank of pre-placed vaults. Thus, disposal proceeds along the major axis of the disposal unit.

The structural cover layer will have characteristics that enable an adequately sized crane and delivery vehicles to operate atop the structural cover layer without compromising the structural integrity of underlying components (namely vaults, lids, backfill, leachate collection/removal system, and clay barrier). This structural platform will also be slightly crowned to promote controlled runoff of storm water away from the disposal unit.

Low-Permeability Cover

Once disposal operations have been completed in a given area of the disposal unit and the structural cover system is no longer required in support of current operations, a low-permeability cover system can be constructed. As with other cover components, the low-permeability cover system is crowned to encourage run off of water at velocities that will not cause erosion and to minimize infiltration. The characteristics of the entire cover system will be such that radiation levels at the top surface of the final cover system (top of the low-permeability cover system) will not exceed limits stated in the regulations.

The low-permeability cover system will be stable under climatic and other conditions likely to prevail at the Barnwell disposal facility. The potential for settlement and subsidence will be minimized by the design and construction, not only of the low-permeability cover system, but also of all underlying components (namely vaults, backfill, leachate collection/removal system, and clay barrier).

3.5 OPERATIONS

Operational procedures are provided to define the placement of waste into vaults and vault closure. Operational procedure may include:

General Operations

Waste will be isolated in an engineered trench that is provided with a water management system, structural backfill, reinforced concrete vaults, structural cover, and low-permeability cover. Traditional trench excavation of the 250- by 1,300-foot area will have side slopes as steep as the existing soils will allow. Bottom floor drains perpendicular to the long side of the trench will be sloped at 2 percent. Drainage layer parallel to the major axis of the trench floor leads to the drain standpipe system that supports leachate monitoring and removal.

Vaults are set with structural backfill in one layer with the top of lid elevation set to match local grade. Vaults and structural backfill are placed so that the final top elevation of the vaults and interstitial low-permeable soil (top 1 ft only, refer to sketches) are contoured in the shape of a mansard roof (similar to a typical contoured cover over a rectangular disposal unit). This shape will cause run off water to drain away from Area 1 in a controlled manner as the vaults await waste placement.

Vaults are loaded by crane starting along the short side of the excavation and proceeding along the length of the trench as allowed by the extension of the structural cover. Previously filled vaults will have lids in place and 1 to 2 ft of structural cover. Disposal operations will progress with the crane stationed on top of the structural cover system constructed on previously filled vaults. Trucks offloading waste will also use the cover over filled vaults as a traffic route.

Waste Receipt

In much the same way as presently done, waste will arrive at the main gate where paperwork and the physical shipment will be examined to ensure safety and internal consistency. Radiation dose rates will be surveyed, the shipping vehicle examined to ensure no leaks have occurred, the delivery vehicle inspected to ensure roadworthiness, and shipping documentation examined in detail to ensure that waste acceptance criteria are satisfied.

Once found acceptable, a disposition of the received waste into rectangular or cylindrical vaults will be determined. The shipment will then be directed to the active disposal area, where the delivery vehicle drives onto the structural cover system. When in proper position, the delivery vehicle will await offloading operations to commence. The driver will relocate away from waste handling operations to minimize his exposure to radiation.

A major difference between the current operating mode and that of this concept is that the shipments will be scheduled to occur only during limited times when disposal operations are actively conducted. Depending on operating choices yet to be made, deliveries could be accepted only one day every other week or during a few-week period that occurs once each year.

Waste Placement in Vaults

The delivery of waste to the conceptual disposal unit and its transfer to pre-placed vaults is depicted graphically in Figure 8. Waste delivery vehicles are directed to the disposal unit and staged, eventually, atop the previously filled and closed vaults and the structural cover layer. A crane stationed on the structural cover system will remove the vault weather shield from the designated pre-placed vault. The crane will remove any shielding or other vehicle apparatus to allow access to the received waste. The crane will transfer the waste from the truck into the selected vault and place a permanent lid on the vault. The crane will then replace any shielding or apparatus removed from the delivery vehicle.

Any special handling operations or constraints required will be developed prior to acceptance. Radiation protection staff will monitor all waste handling operations.

Vault Closure

Once waste has been placed in a vault and the permanent vault lid is installed, the vault will be covered with structural fill. The vault lid, structural fill, and structural cover system provide radiation shielding from previously disposed waste.

3.6 MAINTENANCE

Maintenance procedures address active water management within the conceptual facility. There will be no active trench maintenance since vaults are pre-placed and voids in the trench backfilled soon after excavation. Maintenance procedures are described below.

Leachate Water Monitoring

Leachate from the disposal unit leachate sump will be sampled and removed through the collection standpipes. Leachate will be sampled and tested periodically to document its characteristics and quantity and to limit its accumulation.

Surface Water Controls

Surface water ditches and berms will periodically be inspected and maintained. Special attention will be given following large storm events. Surface water controls divert storm water in a controlled manner and are designed with slopes to minimize the generation of erosive forces. These controls may require occasional maintenance during the operating life of the facility to preserve proper function of drainage features.

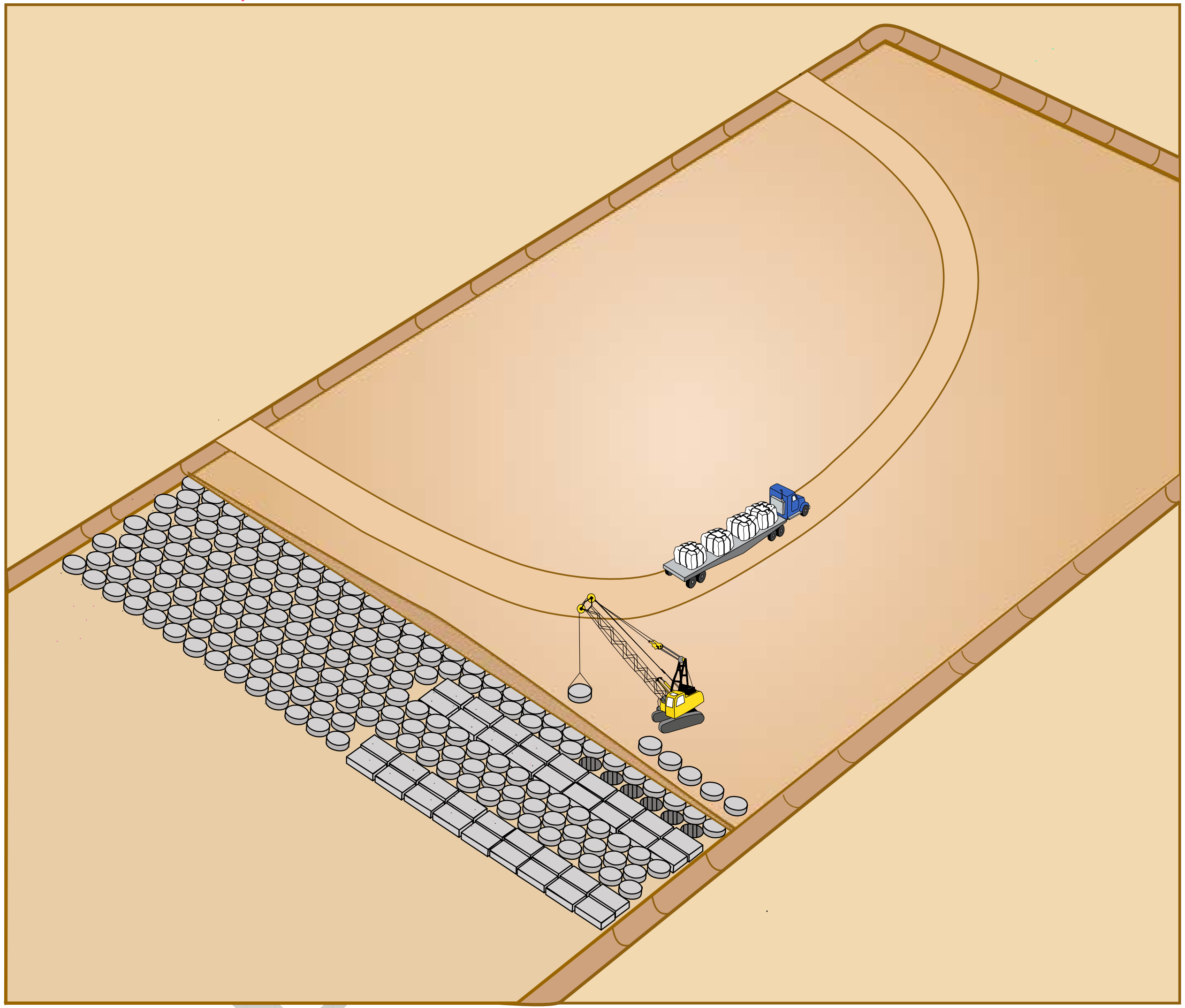

Figure 8. Perspective View of Waste Delivery to and Transfer at Conceptual Disposal Unit

4. RADIATION PROTECTION: GENERAL PUBLIC

The potential for doses to the public at the fenceline or beyond can be separated into doses from normal operations and doses from accidents or unusual conditions. In either case, experience has shown there is little possibility of exceeding the regulatory dose limits for members of the public.

4.1 NORMAL OPERATIONS

Under normal operating conditions, no radionuclide releases will occur. The waste will arrive in containers that will be placed in the disposal vaults. Voids inside the disposal vaults will be filled to the extent practicable and the lids will be placed on the vaults. There should be no radionuclide releases to air, surface water, groundwater, or soil. The only potential pathway for doses to the public is through direct radiation from the waste containers.

Radiation levels of individual waste containers are likely to vary greatly. Most waste containers are expected to have low external dose rates and will be handled without the need for additional shielding. There will likely be a small fraction of high activity waste containers that will require special handling and additional portable shielding to protect workers. High activity waste containers will be handled only after appropriate procedures have been developed and approved that protect the workers and site personnel. The same procedures that provide protection to workers will also protect offsite individuals at the fenceline and beyond.

Radiation exposures to offsite individuals will be mitigated by several factors, which include:

- Waste acceptance criteria
- Waste packaging
- Disposal below grade
- Geometrical attenuation
- Shielding by air
- Operational procedures

The waste acceptance criteria are the most important requirements that will limit the exposures from radioactive waste. Only Class A, B, or C low-level radioactive wastes will be accepted for disposal. The waste must meet several physical and chemical characteristics that ensure that it can be safely handled and disposed of (refer to RHA 3.56).

The waste packaging will limit the surface radiation doses to levels that are required for shipping the waste from the generator. For all wastes, the waste container will be disposed with the waste. Some wastes will require extra shielding for radiation protection during transport over the highways. In these cases, the waste container will be removed from the shielded transport container before disposal.

Disposal below grade ensures that all radiation levels are attenuated as they pass through backfill soils, the low-permeability cover soils and the concrete vault lids. Given the geometry facing a person standing at the fenceline, the soils and concrete effectively eliminate direct gamms radiation exposure.

Radiation exposures at the fenceline will be reduced by geometrical factors. At distances much greater than the dimensions of the waste container, radiation is attenuated generally according to the inverse square of the distance from the waste. For example, if a waste container had an exposure rate of 100 R/hr at a distance of one meter, the geometrical factor would reduce the exposure rate at 100 meters to only 0.01 R/hr ($[1m / 100 m]^2$).

In addition to the geometrical attenuation of radiation, exposure rates are reduced by the shielding effect of the air between the waste container and the facility fenceline. The effect of shielding by air is generally less important than the geometrical factors, but it also helps reduce offsite exposure rates.

Operational procedures will minimize offsite radiation exposures by minimizing the time that waste containers are handled prior to placement in the disposal vaults. Waste will be handled as quickly and efficiently as possible to maintain all doses (onsite and offsite) as low as reasonable achievable.

In addition to direct gamma radiation, sky shine is another possible exposure pathway at the facility fenceline. Sky shine refers to gamma radiation that is scattered by the air. When high activity waste containers are handled, radiation emitted from the container is scattered by the air and could cause a dose at the fenceline, even if there is no direct line of sight from the waste container to the fenceline. Sky shine doses should be minimal and not a concern at the fenceline, because the doses are approximately three orders of magnitude lower than direct line of sight doses. As is the case with direct radiation exposure, sky shine exposure will also be minimized by geometrical factors, air shielding, and efficient operational procedures. The same factors that limit direct radiation exposure to acceptable levels will also be effective for limiting sky shine exposures.

4.2 ACCIDENTS AND UNUSUAL CONDITIONS

While accidents and unusual conditions are impossible to predict, the most likely scenarios include:

- Dropped waste container with possible radionuclide releases
- Crane malfunction that temporarily suspends a high activity waste container
- Onsite truck accident with possible radionuclide releases
- Extreme weather conditions

In general, doses from accidents and unusual conditions would be mitigated by the facility's emergency management plan. In the event of an accident or unusual conditions, the response would typically include evacuation of workers from the affected area and evacuation of visitors, non-radiological workers and members of the public near the fenceline.

Under extreme weather conditions, surface water would be contained onsite. Accidental radiological releases, if any, would not leave the site unless they were airborne. The buffer zone around the disposal units would allow airborne releases to disperse before leaving the site, thus reducing offsite doses to members of the public. If required, radiological cleanup would proceed in a manner that controls or prevents further offsite releases.

4.3 SUMMARY

Doses to the public at the fenceline or beyond can be controlled and mitigated by a variety of factors. Under normal operations, design features, waste acceptance criteria, and operational procedures will ensure that doses to the public are kept within the prescribed regulatory limits. For accident or unusual conditions, doses to the public will be limited primarily by the buffer zone around the disposal units. Responses to accidents will be dictated by the emergency action plan and radiological cleanups, if required, will be conducted in a way that prevents offsite doses to members of the public.

5. RADIATION SAFETY: FACILITY WORKERS

This section qualitatively addresses the impact to worker doses based on the conceptual facility and its operation summarized in Section 3 of this report.

Information about how vault utilization differs between Class A, Class B, and Class C LLRW was not available. However, experience suggests that rectangular vaults are used primarily for Class A LLRW, and high integrity containers (HIC) and similar containers are often disposed within cylindrical vaults. Also, information regarding expected changes to the specific activity and the anticipated dose rates of received materials will change over time was not available.

If the specific activity and dose rates of inbound material do increase in future years, accepted health physics techniques can be applied to control individual and collective worker doses. The analysis below anticipates that the specific activity and dose rates of future inbound wastes will be the same as those of current receipts, except that less waste is delivered for disposal. If the average dose rate for the inbound waste increases, the potential exists for higher individual doses. The ALARA principles of time, distance and shielding can reduce worker time in proximity to containers through the use of material handling and extended reach tools, and the judicious installation of temporary shielding.

External collective and individual doses from ionizing radiation were considered qualitatively. External doses are the result of source-receptor interactions. The sources are inbound waste containers and previously emplaced waste, while the workforce is the receptor.

In parallel, there is an expected decrease in both the number of inbound waste containers and in staffing. If the staffing and waste container decreases are proportional, the collective dose is expected to decrease, and the individual doses are expected to remain approximately constant for pre-emplacement activities.

The geometry for disposal will change as described above. Many of the source-receptor interactions will remain the same during disposal employing both the current and proposed methods. A significant disposal difference is that the vaults will be one layer deep in comparison to earlier disposal methods where vaults were stacked in up to three layers.

Individual and collective doses to workers during vault installation are expected to decrease as there will no longer be waste below the new vaults, and installation will be completed less frequently.

Collective doses to workers during waste emplacement will be reduced in proportion to the reduced influx of waste containers. It is reasonable to assume that cycle time for waste emplacement into a vault will decrease as it will be less technically challenging to place waste in vaults at a shallower depth. The reduction in cycle time may not be significant enough to result in a demonstrable reduction in crane operator doses.

As with the current method of waste emplacement, line-of-sight exposure to the waste containers is lost upon emplacement. For the short period until the vault lid is emplaced, there is a possibility of skyshine. As all of the vaults will be close to the surface, the average skyshine contribution to individual and collective doses may increase. Note that the skyshine contribution is anticipated to be a minor component of the individual and collective doses.

Dose rates to workers from emplaced waste will be similar to current operations or slightly lower. Waste from the bottom two layers of vaults is effectively shielded by the uppermost layer; therefore the doses to workers on top of three layers of vaults or one layer of vaults will be similar, or slightly less in the one vault layer scenario. An additional technique to reduce the dose rate to the workforce is filling vault voids with grout, sand or soil after emplacing the waste. This would provide additional shielding and enhance the structural stability of the vaults.

In summary, the individual occupational doses to radiation workers as part of the new engineered trench design are manageable and are expected to remain approximately in line with historic doses, or to decrease. The collective dose across the pool of qualified radiation workers is expected to decrease due to a lower rate of waste receipts and potentially reduced staffing.

Characteristics of the pre-placed vault concept and its operating mode are expected to decrease radiation doses to facility workers below those being produced with the current design configuration and operating mode. Those handling LLRW packages in the pre-placed vault disposal unit will receive lower doses they would have than received with the current design configuration and operating mode because:

- The "working face" of vaults filled with LLRW (and creating radiation field in the disposal unit) is eliminated.
- All LLRW previously placed is below grade and shielded at least by soil and vault lids. All LLRW disposed in previous campaigns (or that has been placed several months ago) will also be shielded by the structural cover and possibly by the final cover.

It is a reasonable assumption that relative risk of a damaged container resulting in the opportunity for a contamination or inhalation incident is a function of the total number of incoming waste containers. Assuming the rate of damaged containers remains constant, the forecasted number of damaged containers, potential contamination and potential inhalation events would decrease as the total number of incoming waste containers decreases.

6. COST ESTIMATE

This section presents the costs of operating the conceptual facility described and evaluated in this report. Capital costs required to for initial construction and periodic extensions of the disposal unit are not addressed in this report.

6.1 BASIS OF COST ESTIMATE

The following conditions and assumptions comprise the important elements of the basis of cost estimate:

- Labor rates represent those of various labor categories in the Barnwell vicinity in 2007 dollars.
- Labor costs were estimated for two operating modes:
  - ✓ Bi-weekly receipts – waste deliveries received one day every other week
  - ✓ Annual receipts – waste deliveries received for three weeks once a year.
- Operational staff include the following:

Table 4. Operational Staffing Requirements

Position/Function	Crew Size	Position/Function	Crew Size
Project Manager	1	Accounting Manager	2
Secretary/Clerk	2	Health and Safety Manager	1
Engineer	2	Operations Manager	1
Technician (Health Physicist, Radiation Worker, Laboratory)	2	Field Technician (Environmental monitoring, Quality Assurance)	2
Equipment Operator	6	General Laborer	2
Mechanic	1		
		Estimated Total Crew Size	22

- No allowance was made for training of the disposal operations staff.
- Support staffing requirements were assumed to be met from employees of the parent company involved other than disposal operations in the Barnwell vicinity. Their cost to disposal operations were taken as a fraction of their total annual costs, as shown ion Table 2. Staffing requirements were estimated to include the following:

Table 5. Support Staffing Requirements	
Position/Function	**Basis for Time Sharing**
Security Guard	10 percent, lump sum
Program Coordinator	Bi-weekly: 1 day in 10; 28 of 100 employees Annually: 7 of 52 weeks; 28 of 100 employees
Administrative	Bi-weekly: 1 day in 10; 28 of 100 employees Annually: 7 of 52 weeks; 28 of 100 employees
Radiation Safety Officer	50 percent during disposal operations 10 percent during balance of the year.

- During the annual disposal campaign, major functions are carried out as follows:
  - ✓ Total campaign duration: 7 weeks
  - ✓ Preparation: 1 week
  - ✓ Waste receipt: 2 weeks
  - ✓ Waste disposal 2.5 weeks
  - ✓ Cover placement and monitoring:1.5 weeks
- Operational labor for the annual campaign must travel from a remote location. Airfares, lodging, subsistence, and local travel expenses are paid during the annual campaign as follows:
  - ✓ Air fares: $800 each
  - ✓ Lodging: $100 per worker-day
  - ✓ Per Diem: $70 per worker-day
  - ✓ Rental Car: Two or three workers per vehicle at $50 per vehicle-day
- Equipment rental costs were estimated as follows:
  - ✓ Crane, Biweekly: $6,500 per month
  - ✓ Crane, Annually: $17,500 lump sum
  - ✓ Other Equipment, Biweekly: $30,000 lump sum
  - ✓ Other Equipment, Annually: $10,000 lump sum

- Material costs were estimated as follows:
  - ✓ Structural Cover Soil 1,500 cubic yards at $30 per yard
  - ✓ Vault Lids 76 each at $1,500
- No allowance was made for extending the final cover system
- Workman's comp and fixed overhead costs are estimated to be 32.5 percent of labor, travel, equipment, and materials costs.
- Overhead costs are estimated to be 10 percent of labor, travel, equipment, materials and workman's comp/fixed overhead costs.
- Margin payable to the facility operator was estimated to be 29 percent of all direct and indirect operating costs.
- Contingency allowance of 15 percent of all direct and indirect operating costs plus margin was provided.

6.2 ESTIMATE

Using the basis of estimate presented in Section 6.1, the costs were estimated. The estimated costs for the bi-weekly operating mode are presented in Table 6. The estimated costs for the annual operating mode are presented in Table 7

Table 6. Part-Time Year-Round Operations.

Status	Category Description	Piggy-Back Factor	Number	Hours	Unit Cost (hour + fringe)	Total Labor
Full-time	Security Guard	0.1	1	8760	$21.00	$18,396
	Program Coordinator	0.03	1	2080	$85.00	$4,950
	Administrative	0.03	1	2080	$28.00	$1,631
	RSO	0.18	1	2080	$65.00	$24,336
As required	HR Manager	0.03	1	2080	$54.00	$3,145
	Information Systems	0.03	1	2080	$34.00	$1,980
Part-time*	Project Manager	1	1	208	$74.00	$15,392
	Manager (Acct./Fin.)	1	2	208	$85.00	$35,360
	Secretary	1	2	208	$24.00	$9,984
	Health & Safety Manager	1	1	208	$65.00	$13,520
	Engineer	1	2	208	$70.00	$29,120
	Operations Manager	1	1	208	$48.00	$9,984
	Technician (HP, Rad, Lab)	1	2	208	$41.00	$17,056
	Field Technician (Mon, QA)	1	2	208	$38.00	$15,808
	Equipment Operator	1	6	208	$33.00	$41,184
	General Laborer	1	2	208	$32.00	$13,312
	Mechanic	1	1	208	$33.00	$6,864

Training			?	
Total Labor Cost	**2.91**	**FTE**		**$262,022**
	28	persons		

*Year round operation. 1 day every other week, 52 weeks per year.

Travel	**Quantity**	**Unit**	**Unit Cost**	**Total**
Round Trip Air	0	Each	$800	$0
Lodging -- 7 weeks	0	day	$100	$0
Per diem -- 7 weeks	0	day	$70	$0
Rental Car -- 7 weeks	0	veh-day	$50	$0
Lodging -- 5 weeks	0	day	$100	$0
Per diem -- 5 weeks	0	day	$70	$0
Rental Car -- 5 weeks	0	veh-day	$50	$0
Miscellaneous	1	Lump	$10,000	$10,000
Total Travel				**$10,000**

Equipment and Materials	**Quantity**	**Unit**	**Unit Cost**	**Total**
Crane Rental	12	Month	$6,500	$78,000
Other Equipment	1	Lump	$30,000	$30,000
Import Structural Soil Cover	1,500	CY	$30	$45,000
Vault Lids	76	Each	$1,500	$114,000
Final Enhanced Cover	2,500	CY		
Total Equipment/Materials				**$267,000**

Subtotal (Labor, Equip., ODC)	$539,022
Worker Comp & Fixed Overhead (32.5%)	$175,182
Overhead (10%)	$71,420
Margin (29%)	$227,831
Total	$1,013,456
Contingency (15%)	$152,018
Annual Total	**$1,165,475**

.

Table 7. Part-Time Annual Campaign Operations

Status	**Category Description**	**Piggy-Back Factor**	**Number**	**Hours**	**Unit Cost (hour + fringe)**	**Total Labor**
Full-time	Security Guard	0.1	1	8760	$21.00	$18,396
	Program Coordinator	0.04	1	2080	$85.00	$6,664

	Administrative	0.04	1	2080	$28.00	$2,195
	RSO	0.15	1	2080	$65.00	$20,800
As required	HR Manager	0.04	1	2080	$54.00	$4,234
	Information Systems	0.04	1	2080	$34.00	$2,666
Campaign*	Project Manager	1	1	280	$74.00	$20,720
	Manager (Acct./Fin.)	1	2	210	$85.00	$35,700
	Secretary	1	2	280	$24.00	$13,440
	Health & Safety Manager	1	1	280	$65.00	$18,200
	Engineer	1	2	210	$70.00	$29,400
	Operations Manager	1	1	280	$48.00	$13,440
	Technician (HP, Rad, Lab)	1	2	280	$41.00	$22,960
	Field Technician (Mon, QA)	1	2	280	$38.00	$21,280
	Equipment Operator	1	6	200	$33.00	$39,600
	General Laborer	1	2	200	$32.00	$12,800
	Mechanic	1	1	200	$33.00	$6,600
	Training			?		
	Total Labor Cost		**3.21**	**FTE**		**$289,094**
			28	persons		

*Campaign is 7 week period. 1 week preparation, 2 weeks waste receipt, 2.5 weeks disposal, 1.5 week cover placement and monitoring

Travel	**Quantity**	**Unit**	**Unit Cost**	**Total**
Round Trip Air	22	Each	$800	$17,600
Lodging -- 7 weeks	637	day	$100	$63,700
Per diem -- 7 weeks	637	day	$70	$44,590
Rental Car -- 7 weeks	245	veh-day	$50	$12,250
Lodging -- 5 weeks	315	day	$100	$31,500
Per diem -- 5 weeks	315	day	$70	$22,050
Rental Car -- 5 weeks	175	veh-day	$50	$8,750
Miscellaneous	1	Lump	$10,000	$10,000
Total Travel				**$210,440**

Equipment and Materials	**Quantity**	**Unit**	**Unit Cost**	**Total**
Crane Rental	1	Each	$17,500	$17,500
Other Equipment	1	Lump	$10,000	$10,000
Import Structural Soil Cover	1,500	CY	$30	$45,000
Vault Lids	76	Each	$1,500	$114,000
Final Enhanced Cover	2,500	CY		
Total Equipment/Materials				**$186,500**

Subtotal (Labor, Equip., ODC)	$686,034
Worker Comp & Fixed Overhead (32.5%)	$222,961

Overhead (10%)	$90,900
Margin (29%)	$289,970
Total	$1,289,865
Contingency (15%)	$193,480
Annual Total	**$1,483,344**

6.3 EVALUATION OF COST ESTIMATE

As shown in Tables 6 and 7, the operating costs of part-time year-round operations were estimated to be about $1.2 million per year, whereas the operating costs of part-time annual campaign operations were estimated to be about $1.5 million per year.

The costs of preparing submittals required in support of a license amendment request, obtaining a license amendment, initial construction, and vault procurement are not included as operating costs. These would be considered capital costs for the conceptual facility that is the topic of this report and are not estimated under the authorized scope of work.

As shown in Table 3, it was estimated that 67 cylindrical and 9 rectangular vaults would be required annually to dispose of 12,000 cubic feet of LLRW. Vault prices were stated during the 2005 Public Service Commission hearings on Barnwell operating costs (Newberry, 2006) to be nearly $4,800 for cylindrical and nearly $10,400 for rectangular vaults. In order to allow comparison with operating costs for the current configuration and operating mode, an effective annual vault purchase costs has been determined. Allowing for two years of cost escalation and 5 percent per year, the effective annual vault cost was estimated to be nearly $460,000 per year.

The cost of vaults required for the initial construction of a five-year phase of conceptual facility was estimated. Using these escalated vault prices and distribution of cylindrical and rectangular vaults mentioned in the preceding paragraph, the initial cost of vaults required for a five-year phase would be nearly $2.3 million.

7. RECOMMENDATIONS

Several activities might be useful to follow-up the issues addressed in this document. These include:

- Assess the appropriateness or suitability of current vault dimensions in consideration of the waste expected to be delivered to the Barnwell facility beginning July 1, 2008.
- Identify weaknesses in the concept discussed in this document and evaluate alternatives that nevertheless accomplish the objective of ensuring economic viability of the Barnwell facility.
- Estimate the capital costs to develop the pre-placed vault disposal concept.

REFERENCES

Latham, 2007 — James W. Latham, Chem-Nuclear Systems, "Reference: B&CB Letter dated April 24, 2007, White to Latham," letter to Henry J. White, Executive Director, South Carolina State Budget & Control Board, July 30, 2007.

Newberry, 2006 — William, F. Newberry, South Carolina State Energy Board, "RE: Barnwell Cylindrical Canister Cost," personal communication via e-mail to Robert Baird of URS Corporation, March 29, 2006.

Newberry, 2007 — William, F. Newberry, South Carolina State Energy Board, "Vault Loading Data," personal communication via e-mail to Robert Baird of URS Corporation, August 17, 2007.