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EGG-LLW-11140

Estimating Costs of Low-Level Radioactive Waste Disposal Alternatives for the Commonwealth of Massachusetts

Published February 1994

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**Prepared for the
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
Under DOE Idaho Operations Office
Contract DE-AC07-76ID01570**

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ABSTRACT

This report was prepared for the Commonwealth of Massachusetts by the Idaho National Engineering Laboratory, National Low-Level Waste Management Program. It presents planning life-cycle cost (PLCC) estimates for four sizes of in-state low-level radioactive waste (LLRW) disposal facilities. These PLCC estimates include preoperational and operational expenditures, all support facilities, materials, labor, closure costs, and long-term institutional care and monitoring costs.

It is intended that this report be used as a broad decision making tool for evaluating one of the several complex factors that must be examined when deciding between various LLRW management options - relative costs. Because the underlying assumptions of these analyses will change as the Board decides how it will manage Massachusetts's waste and the specific characteristics any disposal facility will have, the results of this study are not absolute and should only be used to compare the relative costs of the options presented.

The disposal technology selected for this analysis is aboveground earth-mounded vaults. These vaults are reinforced concrete structures where low-level waste is emplaced and later covered with a multi-layered earthen cap. The "base case" PLCC estimate was derived from a preliminary feasibility design developed for the Illinois Low-Level Radioactive Waste Disposal Facility. This PLCC report describes facility operations and details the procedure used to develop the base case PLCC estimate for each facility component and size. Sensitivity analyses were performed on the base case PLCC estimate by varying several factors to determine their influences upon the unit disposal costs. The report presents the results of the sensitivity analyses for the five most significant cost factors.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the efforts of the technical contributors to this report: Fred Feizollahi, Mike Godwin, Catherine Slater, and Bruce Stevens of Environmental Services Division, Morrison Knudsen Corporation; technical guidance provided by David Shropshire and Paul Smith of EG&G, Idaho, Inc.; and policy guidance provided by Carol Amick and Paul Mayo from the Commonwealth of Massachusetts Low-Level Radioactive Waste Management Board whose efforts made this study possible.

EXECUTIVE SUMMARY

Planning life-cycle cost (PLCC) estimates for conceptual designs of low-level radioactive waste (LLRW) disposal facilities for the Commonwealth of Massachusetts are based on the preliminary feasibility design for the Illinois Low-Level Radioactive Waste Disposal Facility for the Central Midwest Compact (the states of Illinois and Kentucky). PLCC estimates for four sizes of in-state disposal facilities were evaluated (small, medium, large, and extra-large). PLCCs were estimated for five areas of operation: (1) preoperations - including land acquisition, site selection and characterization, and initial capital improvements; (2) operations - including annual utilities, materials and labor costs; (3) closure - including decommissioning of the facility and completion of the disposal vaults; (4) post-closure - including institutional care and monitoring; and (5) community benefits and taxes. These PLCC estimates are broad-based in nature and should be used only as a decision making tool. It should be remembered that the assumptions underlying these analyses will change as the Board decides how it will manage Massachusetts' waste and the specific characteristics any disposal facility will have. Therefore, the results of this study are not absolute and should only be used to compare the relative costs of the options presented.

Sensitivity analyses were performed on PLCC estimates for each size of facility by varying several parameters. The labor rates, capital costs, staffing, preoperational costs, and material costs were selected to represent changes due to uncertainties because of their relative impact on unit and total costs. Assumptions for contingencies, maintenance, and indirect costs are based on commonly used engineering estimating practices. Because each LLRW disposal facility is unique, estimates for contingencies and indirect charges may be 5-10% higher than those used for a more "conventional" construction project, i.e., education, transportation, or industrial facilities. The unit disposal rates for the four facility sizes are as follows: small, from \$411/ft³ to \$666/ft³ with a base rate of \$499/ft³; medium, from \$369/ft³ to \$593/ft³ with a base rate of \$444/ft³; large, from \$305/ft³ to \$471/ft³ with a base rate of \$362/ft³; and extra-large, from \$178/ft³ to \$289/ft³ with a base rate of \$215/ft³. Unit disposal rates for small, medium, and large facilities were affected most by changes in the number of operations staff or by salary rates; for an extra-large facility, they were affected most by changes in capital costs. All facilities were least affected by a variation of the preoperational cost. Five percent of the annual operations cost estimate is included as operator compensation during the operational and closure periods. Interest on bonds issued for the preoperational period are 5% or less of the total cost for all sizes of disposal facilities. Community benefits and taxes during the operation of a disposal facility are about 10% of the total PLCC estimate. Unit disposal costs are most sensitive to the total disposal capacity.

PLCC estimates for each size of facility uses a 30-year operational life, a 10-year closure period, and a 300-year post-closure/institutional care period. Waste accepted at a facility will be from academia, medicine, government, industry, and utilities. The waste capacities of the disposal facilities are: small, 1,050,000 ft³; medium, 1,500,000 ft³; large, 2,400,000 ft³; extra-large, 14,000,000 ft³. The total capacity for each facility allows for future waste volumes that will be generated during decontamination and decommissioning activities by major radioactive material users. Table ES-1 is a summary of the base case PLCC estimates and unit disposal rates for the four sizes of low-level radioactive waste disposal facilities. Figure ES-1 graphs the base case costs of Table ES-1 for the four sizes of facilities.

Table ES-1. Base case cost summary for waste disposal facilities.

Work breakdown structure elements	Small	Medium	Large	Extra-large
Preoperations*	\$81,622,000	\$85,499,000	\$88,623,000	\$137,750,000
Bond interest	\$30,239,000	\$30,239,000	\$30,504,000	\$31,048,000
Operations	\$314,518,000	\$437,537,000	\$598,526,000	\$2,316,947,000
Closure	\$35,993,000	\$40,760,000	\$52,365,000	\$123,752,000
Post-closure	\$12,757,000	\$12,757,000	\$19,135,000	\$102,052,000
Community benefits	\$48,316,000	\$59,531,000	\$80,262,000	\$303,196,000
Total cost	\$523,445,000	\$666,323,000	\$869,415,000	\$3,014,745,000
Cost per cubic foot	\$499	\$444	\$362	\$215

a. Preoperations costs includes state costs of ~ \$45 M.

Figure ES-1. Total base case costs and unit costs.

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Estimating Costs of Low-Level Radioactive Waste Disposal Alternatives for the Commonwealth of Massachusetts

1. INTRODUCTION

1.1 Background

The Massachusetts Low-Level Radioactive Waste Management Board (the Board) is charged by State and Federal law to provide for the short-term management and long-term disposal of low-level radioactive waste (LLRW). LLRW is generated in the Commonwealth by various academic, health care, commercial, government, and utility users of radioactive materials. In connection with the above charge, the Board must decide whether to initiate siting activities for an LLRW disposal facility.

Options for managing LLRW out of state may be available in the future. These options may include contracts with individual states, or with a group of states (known as a "compact") bound together for the purpose of regional LLRW disposal. Currently, all states and compact regions, except for the Southeast Compact Region, that have or that are developing disposal capabilities have either adopted explicit statutory prohibitions or have communicated an unwillingness to accept LLRW from outside their state or compact. Access to the Southeast Compact regional disposal facility is due to close on July 1, 1994.

Accordingly, the Board has asked the National Low-Level Waste Management Program of the U.S. Department of Energy to develop a report on the costs of various in-state disposal options.

1.2 Purpose

The purpose of this report is to develop the planning life-cycle cost (PLCC) estimates for four sizes of in-state LLRW disposal facilities (small, medium, large, and extra-large). The PLCC estimates for all capital and operating costs expected during the site selection, characterization, licensing, construction, operation, closure, and post-closure activities are based on a preliminary feasibility design of the Illinois Low-Level Radioactive Waste Disposal Facility (ILLRWDF).

It is intended that this report be used as a broad decision making tool for evaluating one of the several complex factors that must be examined when deciding between various LLRW management options - relative costs. Because the underlying assumptions of these analyses will change as the Board decides how it will manage Massachusetts's waste and the specific characteristics the disposal facility will have, the results of this study are not absolute and should only be used to compare the relative costs of the options presented.

A separate PLCC estimate for retrieval of the long-lived waste is also being developed, but will be inserted later into this document. Since Massachusetts law M.G.L. c.111H s.46 states "...that the institutional control period shall not be less than the minimum time required for any

LLRW present at the site to decay to the maximum concentrations above natural background levels permitted to be released into the air or water in unrestricted areas under federal and state law"..., it is assumed that all long-lived LLRW will need to be retrieved at the end of the institutional control period. The PLCC contained in this report and for the retrieval insert are based on the assumption that 50% of the received wastes are short-lived and 50% are long-lived. A list of the assumptions for waste retrieval is in Appendix C. The PLCC retrieval estimate will include the construction of new waste handling facilities, excavation of disposal vaults, removal of waste containers, assaying and verification of the retrieved waste containers, onsite repacking of 5% of the retrieved waste canisters, preparation for shipment of the retrieved waste, and restoring the disturbed site. Assumptions regarding transportation and additional disposal costs will not be evaluated since these factors cannot be defined at this time.

1.3 Report Organization

This report is divided into five sections. Section 1 presents the background and purpose. Section 2 contains descriptions of the facilities that comprise the waste disposal complex. Section 3 details the PLCC estimates of each component of the facilities. Section 4 contains a discussion of the sensitivity analysis and the overall conclusions. Section 5 lists the references. The detailed cost estimate tables and the scope of work are presented in Appendices A and B, respectively. Appendix C is the discussion and the results of the PLCC estimate for retrieval of the long-lived LLRW.

2. FACILITY DESCRIPTION

2.1 Design Basis

The disposal facility cost estimates are based on the following assumptions:

- Facilities are sized for 35,000 (small); 50,000 (medium); 80,000 (large); and 466,000 ft³ (extra-large) of waste per year. Waste will be 50% short-lived and 50% long-lived.
- Minimum land allowances for small, medium, large, and extra-large facilities are 100 acres, 100 acres, 130 acres, and 420 acres, respectively.
- The preoperational phase includes construction of support buildings and disposal cells (5 cells for small, medium, and large; 15 cells for extra-large).
- Operational activities include construction of 0.9 cells/year for a small facility, 1.4 cells/year for a medium facility, 2.4 cells/year for a large facility, and 14.8 cells/year for an extra-large facility.
- The facilities will operate 16 hours/day, 5 days/week, 240 days/year.
- Solidified waste is received in approved shipping containers, placed into concrete canisters and grouted.
- The concrete canisters are 5-ft square and 7-ft high, and the walls are 0.5-ft thick.
- The facility shall operate and accept waste for 30 years.
- The closure period is 10 years.
- The institutional control period is 300 years.
- The facility shall meet the requirements of 10 CFR 61.
- The facility will have features for waste retrieval during the institutional control period.
- Long- and short-lived waste will be segregated in separate cells. The same cell design will be used for both waste types. (Massachusetts chose to separate waste as long- or short-lived waste rather than as Class A, Class B, or Class C waste.)
- Each cell is a structurally separate unit with outside dimensions of 93 by 62 by 26 ft. The cells will have 2.5-ft-thick concrete walls and a 2.5-ft-thick concrete floor and roof.
- Cells will be backfilled with dry granular material after placement of the waste canisters.
- An engineered, earthen cap will be placed over the vaults.

2.2 Facility Design Description

The conceptual LLRW disposal facility is comprised of two major components: support facilities and a disposal area. The layouts for administration, front-end and receiving, and disposal areas are provided in Figures 1 and 2.

Support facilities for the disposal cells include administration, front-end and receiving areas, and a waste packaging building. These areas will be used for site management, maintenance, and to prepare waste for disposal. Most of the buildings will be demolished during the closure period, after the facility stops accepting waste.

Earth-covered, aboveground concrete vaults are used as the basis for estimating the cost of LLRW disposal. The design concept used for this PLCC analysis is similar to that adopted by the Central Midwest Interstate Low-Level Radioactive Waste Compact for the ILLRWDF. Disposal vaults are comprised of parallel rows of cast-in-place reinforced concrete walled rooms (cells) 93 by 62 feet wide and 26 feet high. LLRW disposal in aboveground engineered vaults will provide at least three engineered barriers to prevent waste from escaping. These barriers are the shipping containers, concrete canisters, and the vault system.

The waste is received onsite, then inspected and assayed to ensure it meets the facility's waste acceptance criteria. Waste is then transferred to the waste packaging building where it is placed into concrete canisters and filled with a cement/sand grout mixture. After the grout has cured, the waste canisters are assayed, labeled, and transported to a disposal cell. Once a disposal cell is filled with canisters, any remaining void is filled with sand. A roof of concrete panels is placed to seal the cell. An engineered multi-layered earth materials cap is mounded over the disposal vaults for additional protection. The disposal cells are monitored for potential waste migration and are designed to facilitate waste canister retrieval. The system of concrete roof panels will allow for retrieval of waste at anytime during the life of the facility and for retrieval of long-lived wastes at the end of the institutional control period.

The list of assumptions and the description of the aboveground disposal system used in these PLCC estimates are based on the disposal concepts developed for the ILLRWDF. The methods and assumptions described here were used to generate detailed cost estimates. These estimates are to be used for planning-level analyses and to compare the relative costs of the options described in this study. The use of this model and the results of these analyses do not necessarily represent a preferred disposal system that may be developed by the state of Massachusetts, either now or in the future.

2.2.1 Site Development

Site development is comprised of the fundamental site preparation and infrastructure construction necessary for disposal operations. This includes site grubbing and grading, installation of a stormwater retention and treatment basin, development of a borrow/materials storage site, power services, sewage and potable water service, emergency services, fire/water systems, communications, fencing, and site access.

2.2.2 Administration Facility

The administration building includes management offices, a reception area, multi-use rooms, a computer center, a records vault, restrooms, lunchrooms, a storage area, and a mechanical and electrical equipment area. A fire alarm system is included in the cost estimate for the administration building.

2.2.3 Front-End and Receiving Facilities

The front-end and receiving facilities include the site access and guard station; a maintenance, warehouse, truck inspection and washout, and laboratory building; utility, and mechanical and machinery buildings; and an electrical distribution and control center.

The site access building is a control point for all personnel and vehicles entering or leaving the disposal area. The building is comprised of a guard station, frisk and decontamination areas, a lunchroom, a driver's lounge, a site monitoring room, and a communications support area. The maintenance/warehouse and truck inspection building houses the environmental health physics laboratory and is equipped with a dedicated air system and isolated by reinforced concrete masonry walls from the other activities in the area.

The maintenance and warehouse building contains a bay for vehicle maintenance and storage of site equipment and supplies. It will also serve as a maintenance area for smaller onsite equipment and for constructing temporary shielding supports, special test fixtures, and other site-related items. Cost estimates include all appropriate supplies and tools.

Incoming waste shipments are examined in the covered truck inspection and washout building. Inspection may include visual inspection, manifest checks, and radiological surveys. The building contains a second enclosed truck bay for washing vehicles before departure. This second bay may be used to de-ice incoming trucks during winter months. Water generated from washing and de-icing operations is collected for analysis. Contaminated water is retained in a separate holding tank for treatment by grout solidification and disposal. Clean water is recycled.

The utility, mechanical, and machinery buildings are located near the perimeter of the restricted area. These buildings house a diesel-powered emergency generator, diesel-fuel day tanks, and an emergency firewater pump system. All accessories for the generator are included.

EXPLANATION

1. ADMINISTRATIVE BLDG.
2. SITE ACCESS
3. LABORATORY
4. EQUIPMENT STORAGE
5. WAREHOUSE AND MAINTENANCE
6. TRUCK WASHING
7. TRUCK INSPECTION
8. UTILITIES & MECHANICAL
9. ELECTRICAL DISTRIBUTION & MCC
10. OPERATING AND CONTROL AREA
11. UNLOAD AND STAGE
12. TEMPORARY STORAGE
13. INSPECT AND CERTIFY
14. PLACE IN CANISTERS
15. SECONDARY WASTE TREATMENT
16. ASSAY AND INSPECT
17. ELECTRICAL ROOM
18. GROUND PLANT
19. CANISTER STORAGE

SIZE	NO. OF CELLS
SMALL	33
MEDIUM	47
LARGE	75
X-LARGE	445

FIGURE 1. DETAILED DISPOSAL FACILITY LAYOUT

FIGURE 2. DISPOSAL FACILITY LAYOUT

2.2.4 Waste Packaging Building

The waste packaging building is a separate cost item from the front-end and receiving facilities. It includes all equipment and tools for the unloading and staging areas, inspection operations, secondary waste treatment, grout plant, canister storage, and waste packaging area.

Unloading, staging, and waste packaging takes place in a covered truck bay area where the waste shipping containers are unloaded by an overhead bridge crane, and the waste is inspected and placed into concrete canisters. The truck bay has a sloped concrete floor for positive drainage. The walls are epoxy-coated for decontamination. After the waste is placed into canisters, all canisters are filled and sealed with grout. Cement for the grout is stored in a silo equipped with a pneumatic delivery pump. Sand is stored in a silo with appropriate discharge equipment. Grout is mixed and pumped to the waste packaging area.

2.2.5 Individual Disposal Cells

Each disposal cell is constructed of cast-in-place concrete forming 2.5-ft-thick walls and floors. The cells are grouped together in two parallel rows to form a disposal vault. An access aisle, 30-ft wide, separates the two parallel rows of cells. The waste canisters are transported from the waste packaging building and placed into an open disposal cell. After filling a cell to capacity, a 2.5-ft-thick reinforced-concrete wall seals the cell from the aisle. Each cell is backfilled with dry sand. The cell roof consists of tight fitting pre-cast concrete panels secured on the top of the cell in a manner to allow future retrieval of waste. Primary monitoring and leak detection systems will be installed during construction. The monitoring network may include fixed ports or remote monitoring points that can be accessed from locations outside the disposal cell. An oblique view of a disposal cell is shown in Figure 3.

Figure 3. Oblique view of an earth-mounded disposal vault.

2.3 Functional and Operational Description

The following functional and operational descriptions are based on the disposal concepts proposed to be used by the Central Midwest Compact from which the PLCC estimates were generated. The actual disposal method selected by the Commonwealth may vary from this system. The disposal facilities are separated into operational units as shown in the process functional diagram (Figure 4) which also shows the annual waste processing capacities and materials demands. Waste will be transported to the facility in approved shipping containers, such as 55-gallon drums, large cylinders, and fiberglass and metal boxes, and received at the site access station, where it is assayed and inspected. A set of criteria will be developed for the classification and acceptance of LLRW and may include considerations such as; the radiological toxicity and radioactive half-lives; radionuclides and concentrations; specific radioactivity; chemical and biological toxicity and form; chemical reactivity; and other characteristics considered necessary to determine which classes of LLRW may be stored for decay, processed for waste disposal, or require special management. The waste will be transported to the waste packaging building after it is accepted. Delivery vehicles will be readied for departure at the truck inspection and washout building.

At the waste packaging building, all accepted waste packages are placed into concrete canisters and the waste is grouted in-place in the concrete canisters. The water, sand, and cement annual use rates shown in Figure 4 assume this scenario. Secondary waste generated during operations includes decontamination waters, storm water run-off, used personal protective equipment, and damaged shipping containers. Secondary waste generation is assumed to be 2% of the annual volume. Filled waste canisters are delivered to an open disposal cell. Canister placement begins at the back of the cell and progresses toward the aisle. The canisters are placed in rows 3 high, and 11 by 17 canisters wide. A 3-foot wide void between the canisters and cell wall will be filled with sand before cell closure. Each cell is sealed with removable concrete roof panels to protect the waste until the engineered cap is placed.

2.4 Site Functions After Cell Closure

Once the cells are filled with canisters, backfilled with sand, and sealed by the concrete roof, the entire vault system is covered by an engineered cap composed of layers of sand, clay, cobbles, and topsoil. The site is then decommissioned over a 10-year closure period. Decommissioning includes the removal of services and structures not essential for long-term management, regrading the site, planting vegetation, and other preparations for transferring the site to State control for the 300-year institutional care period. The initial activities of the institutional care period will include frequent monitoring of the vaults and waste, the land surrounding the vaults; performing site groundwater and soil cleanup; conducting a performance assessment based on the inventory of disposed radionuclides; reestablishing site vegetation; restricting public access and maintaining site security; and verify the performance of the disposal system. Once these activities are complete, the remainder of the institutional care period will be used mainly to maintain site security, continue site monitoring, and perform limited site remediation and maintenance. The total time commitment for the operation of the LLRW disposal facility is 340 years.

Front End
Common
Functions

Waste Processing and Disposal

Node	1	2	3	4	5	6	7	8	9	10
Facility Size	Input	Concrete Canister	Water	Sand	Cement	Secondary Waste	Cement for Secon. Waste	Secon. Waste Output	Output to Disposal	Disposal
Flowrate	cf/yr	Canister/yr	gal/yr	cf/yr	cf/yr	cf/yr	cf/yr	cf/yr	cf/yr	cf/yr
SMALL	35,000	596	24,234	16,847	4,302	350	350	700	35,700	35,700
MEDIUM	50,000	850	34,562	24,027	6,135	500	500	1,000	51,000	51,000
LARGE	80,000	1,361	55,341	38,472	9,823	800	800	1,600	81,600	81,600
X-LARGE	466,000	7,925	322,244	224,020	57,197	4,660	4,660	9,320	475,320	475,320

3. FACILITY COST ESTIMATES

This section discusses the estimating procedure and the cost estimate summary of the work breakdown structure (WBS) shown in Table 1. Preoperational siting cost estimates provided by the Board vary slightly for different sizes of disposal facilities. The total cost for the 12 preoperational activities is about \$45 million and is detailed in Table 1, items WBS-1.1 through WBS-1.6. This is based on similar program costs or low-level waste siting activities experienced by other states or compacts. It also includes State mandated community involvement and technical support program expenses. The costs reflect the belief that the program can be accomplished in Massachusetts at a lesser cost by using experience gained from other programs. Conversely, experience by opponents in challenging LLRW disposal siting programs could increase these costs through delays or litigation.

Construction, operation, and closure cost estimates are derived from the preliminary feasibility design study of the ILLRWDF. All costs in this report are expressed in first quarter 1994 dollars. PLCC estimates are based on Morrison Knudsen Corporation's construction cost estimating program. Estimating capabilities of the program include civil engineering, concrete, earthwork, structural steel, facilities (civil/architectural/structural), electrical, mechanical, and piping and instrumentation. Standard task performance times, labor, and material unit costs are embedded in the program. For the four sizes of LLRW disposal facilities considered, the unit construction rates are applied to design parameters such as the square footage of concrete structures (disposal cells), acres of earthwork, lineal feet of utilities, and the square footage for lighting demands and emergency systems (fire or back-up power).

To yield capital cost estimates from the program, factors for the four disposal facilities were determined in the following manner. First, a scaling factor was determined for scaling each cost factor for the required facility sizes. For example, the disposal cell construction costs for the small disposal facility with 33 disposal cells has an initial factor of 0.17 ($33 \div 192$; 192 cells for the ILLRWDF). Second, by using the "6/10 rule" for all new building areas, the scaling factors are adjusted appropriately up or down depending on the complexity of construction or necessary hardware. (The 6/10 rule is a common tool for estimating the cost of machinery, equipment, buildings, or other capital improvements.) Third, these factors were escalated by 3.5% per year, or 10.5%, from the ILLRWDF 1990 dollar estimates to first quarter 1994 dollars. And fourth, the escalated scaling factor was adjusted by a dimensionless number for construction cost differences between Massachusetts and Illinois using the Means cost index¹ where Illinois = 97.6 and Massachusetts = 107.44.

The PLCC estimates are presented in current dollars without a present value analysis. Present value is best used when a disposal facility is currently in operation, or would be within a few years, and has a set of precise, well-defined assumptions. Because this is not the case for this cost study, present value was not used. This allows the estimates to better account for the tentative nature of the underlying assumptions and relative nature of the cost scaling process.

Table 1. Cost estimate summary.

PLCC Estimates for 4 Sizes of Disposal Facilities				
	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,286</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	8,707	7,457	8,388	14,896
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,076</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	85,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	<u>9,985</u>	<u>13,890</u>	<u>19,001</u>	<u>73,554</u>
2.1.7 Operator's Profit (5% of annual costs)	499	695	950	3,678
Total Operational Costs over 30 years	314,518	437,537	598,526	2,316,947
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Supplies / Utilities	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	6,922	7,838	10,070	23,790
3.8 Operator's Profit (5% x annual cost (Items 3.1-3.6))	1,384	1,568	2,014	4,750
Total Closure Costs	35,993	40,760	52,365	123,752
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,757	19,135	102,052
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	59,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	523,445	666,323	869,415	3,014,745
UNIT COSTS (\$1000 / cu ft)	0.60	0.44	0.36	0.22

3.1 WBS 1.0 — Preoperation Costs

The preoperational costs are listed by item in the cost summary, Table 1. These include direct and indirect costs for site selection, land acquisition, project/construction management, site characterization, licensing, engineering design, site improvements before construction, utility installations, and construction. These costs include all site characterization activities and studies necessary to support the environmental impact reporting process.

3.1.1 Land Acquisition

Allowances for land acquisition assumes a land purchase price of approximately \$3,000,000 to \$4,200,000. The actual cost of the land may vary depending on location or the availability of suitable State-owned land, prevailing market conditions, and community acceptability. Allowances do not include legal fees or community incentives.

3.1.2 Project Management

This cost item includes both labor and supplies, and assumes that the Board will be the overall program manager. Costs are for contractor management, labor, supplies, program plan development, federally mandated quality assurance (QA) plan development and implementation, QA consultant costs, and records management system development costs and implementation. QA plans from disposal facilities in other states are assumed to be available as models.

3.1.3 Site Selection and Characterization

Site selection, precharacterization, characterization, baseline monitoring, public involvement, and litigation are covered under this cost item. It is assumed that site selection and precharacterization will use the Commonwealth's geographic information system for initial exclusionary screening. The costs include developing site selection plans, a more comprehensive State geographic database, and technical support for public review and participation; performing criteria weighting exercises; and using other states' plans and experience. These costs include \$1,000,000 for precharacterization of five potential sites.

Full site characterization is assumed for two candidate sites. Site characterization also includes public participation in preparation and development of the site characterization plans, Community Supervisory Committee and public comment resolution, onsite data collection and baseline monitoring, and documentation of the technical and sociological results.

Baseline monitoring activities include the gathering of environmental and health data in addition to the data collected for the basic site characterization. These additional data are necessary for the proposed disposal facility because they establish a foundation for the future assessment of potential impacts upon the environment and human health.

The public involvement cost elements include comprehensive public involvement and development of a community benefits package, information documents and communication program, meeting and hearing support, consultant/contractor support, Community Supervisory

Committee and Community Advisory Committee support, and other statutorily mandated compensation programs.

Litigation costs are assumed to include contract development, request for proposal, and adjudicating legal challenges to the siting program. This cost component satisfies the need of financial support for community participation in adjudicatory proceedings on the site selection process.

3.1.4 Licensing/NEPA

The licensing and National Environmental Policy Act (NEPA) costs are for analysis, documentation, and source term study. These activities build upon the results of previous work from the site selection, characterization, and community involvement efforts. They fulfill the necessary regulatory requirements to define the disposal facility's operational functions.

Source term analyses include an inventory and identification of the characteristics and projections of total quantities of waste during the operational life of the facility. The projections include volume estimates of routine and nonroutine waste, and waste from the decommissioning of major nuclear material user facilities. The source term analyses documentation will be updated at least once during the site selection process. The information will be used for sizing and site selection, site design, disposal method selection, performance assessment, and licensing.

Analysis and documentation includes the preparation of all license support documents: draft environmental impact statement, safety analysis report, and final environmental impact statement. A major part of this task is the performance assessment. This requires complex modeling and computer work to estimate the exposure pathways, radionuclide migration, and radiological dose impacts. These studies will demonstrate the fulfillment of the final site selection, design, and licensing requirements.

3.1.5 Engineering Design

Engineering design combines elements of the source term analysis, the performance assessment, and the site selection and characterization activities to develop the disposal system. This involves the disposal method selection, evaluation of the disposal plan, a screening and qualification study, technical support for public review and participation efforts, development of critical design parameters for site selection, siting design studies, and the final design. A basic performance-based disposal facility design will provide useful information to the candidate site community for selecting the disposal technology.

3.1.6 Contingencies

Contingency factors take into consideration the highly technical, complex, and sensitive nature of the siting process, which may result in unplanned cost increases. For example, during site exploration in the site characterization phase, unanticipated site complexities may be discovered that require additional characterization work. Contingencies may also include technical assistance programs for community involvement, public meetings, and independent reviews.

3.1.6.1 Pre-operations Funding. It is assumed preoperations funds will be raised by issuing bonds. Item WBS-1.6.1 is the sum of the principal and interest on item WBS-1.6. For this report, it is assumed that the bonds are released in three equal amounts in 1996, 1997, and 1998 and due in 2016, 2017 and 2018 (20 years). A rate of 5.5% is applied using a simplified amortization function. The annual payment of approximately \$3,757,000 (for small and medium sized facilities) is multiplied by 20 (years) to yield the total bond burden.

3.1.7 Facility Construction

Facility construction includes all elements necessary to startup the disposal facility: site preparation; utility installations; site access, administration and waste support buildings; and the initial number of disposal cells. Initially, a small, medium, or large facility will have 5 disposal cells and an extra-large facility will have 15 disposal cells. The features of these facilities are described in Section 2.

A cost factor of 20% for contractor overhead is applied as an indirect costs to all construction and material costs (Subtotal Item 1.7.5, Table 1). The estimated capital costs for structures and appurtenances are the sum of the following: projected labor hours for the task completion and hourly labor rates, materials, equipment, and supplies. The components of the capital costs are then calculated on a cost item per square foot basis. Areas of specialized installations are about twice the cost of nonspecialized installations. Table 2 is a comparison of the capital cost factors for the front-end and receiving facilities of the different sized disposal sites.

3.1.8 Construction Management

Construction management is a 20% assessment on the total cost of the construction project for the startup facilities. This includes site development, and the buildings for administration, front-end/receiving, waste packaging, and the initial number of disposal cells.

3.1.9 Contingency for Construction

The contingency for construction (Item 1.9, Table 1) is a 25% assessment on the total building costs and the construction management costs. The average amount for construction and management contingencies ranges between 10% and 40%. This is expected to provide adequate funds for unforeseen problems or delays that may occur on a project of this scope.

Table 2. Capital cost factors for different front-end and receiving facilities.

Item	Cost factors (\$/ft ²)			
	Small	Medium	Large	Extra-large
Fire system	1.61	1.54	1.51	1.29
Administration/ laboratory building	142.44	136.69	134.95	122.64
Warehouse/ maintenance building	118.02	111.21	110.16	91.39
Site access building/roads	162.34	156.30	151.45	134.61
Truck inspection/ washout building	193.31	176.64	176.64	137.20
Waste packaging building	345.24	318.92	318.92	254.05
Utility/mechanical building	347.66	347.66	347.66	270.19

3.2 WBS 2.0 — Operation Costs

Operating costs include expenses for daily operations and labor, utilities, materials, cell construction costs, and maintenance over the 30-year operating life of the facility. These estimates represent expenditures for startup, environmental monitoring, equipment replacement, and supply purchases during operations. Operating cost estimates for capital expenditures are factored in the same manner as the facilities' startup construction costs in WBS-1.0. Utilities and materials costs estimates are based on calculations considering daily power, fuel, and materials demands.

3.2.1 Cell Construction

Cell construction will be ongoing during facility operations at a rate appropriate to the size of the waste processing facility. Labor and material costs are based on the ILLRWDF and assume that a constant number of cells are built per year of operation. They are: 0.9 cells per year for the small facility (28 total during 29 years); 1.4 cells per year for the medium facility (42 total during 29 years); 2.4 cells per year for the large facility (70 total during 29 years); and 14.8 cells per year for the extra-large facility (430 total during 29 years).

3.2.2 Administration

A major portion of the administration costs during operation is for personnel. The number of personnel were derived from the work force estimates from ILLRWDF. Salary rates were derived from two sources: Dames and Moore's cost study for LLRW disposal sites² and Morrison Knudsen/Chem Nuclear's design package for the ILLRWDF.³ Annual salaries listed for different

job categories are shown in Table 3. The monthly burden rate includes a 100% contingency. The labor costs for cell construction are part of the annual capital cost estimates and are not calculated with the administration labor costs.

3.2.3 Operations

The operations cost estimate is for operating labor, labor materials, and waste processing supplies. The PLCC estimates are based on the assumption that the operating life of the facility is 30 years. For the smaller sites, where two shifts per day may not be justified, a single shift per day or part-time shifts may be used. The mass flow rates for waste processing shown in Figure 4 are based on 30 years of operation.

3.2.4 Maintenance

The maintenance cost estimate includes the maintenance materials and maintenance labor costs based on the unit operations for each job. Maintenance labor is calculated as 100% of the initial equipment installation costs. Maintenance materials (including replacement parts and supplies used during repairs) are calculated at 7% of initial equipment costs.

3.2.5 Environmental Monitoring

Site environmental monitoring during facility operations comprises the majority of monitoring costs. Since the number of monitoring points are site-specific and cannot be determined at this time, the monitoring costs are based on the annual expenditures expected for the ILLRWDF. Depending on the media and analyte, environmental monitoring is performed monthly, quarterly, and annually. Monitoring includes radiological tests in soil, air, plants, animals, groundwater, and surface water. The monitoring program will be designed to satisfy regulations with the conditions of the facility license and terms of the operating contract; provide early warning of the magnitude and extent of radionuclide migration; and provide reliable environmental data throughout the development, operation, closure, post-closure and institutional control periods.

3.2.6 Utilities/Materials

The majority of material costs incurred are for the concrete overpack canisters, sand/cement grout for the canisters, sand backfill for the cells, and personal protective equipment. Utilities include fuel, lighting, and water. Fuel and electricity use is based on the type of machinery and an assumed operational efficiency of 70%. Lighting is calculated based on the square footage of each building and the square footage of outdoor areas.

Table 3. Annual salary for full-time employees.

Position	Annual salary	Monthly rate with burden ^a	Salary position used
Facility manager	\$79,800	\$13,300	— ^b
Assistant manager	\$49,800	\$9,040	Project manager ^c
Secretary	\$16,500	\$2,750	— ^b
Clerk	\$15,000	\$2,500	— ^b
Document specialist	\$34,800	\$5,800	Accountant ^b
Business manager	\$42,500	\$7,000	General support/project engineer ^c
Accountant	\$34,800	\$5,800	— ^b
Technical personnel	\$33,900	\$5,650	Field engineer ^c
Communications	\$45,000	\$7,500	QA/site engineer ^b
Quality assurance	\$45,000	\$7,500	QA/site engineer ^b
Environmental management	\$49,800	\$8,300	Radiological safety officer ^b
Laboratory manager	\$37,800	\$6,300	Senior health physics technician ^b
Laboratory technician	\$30,000	\$5,000	Health physics technician ^b
Warehouseman	\$31,000	\$5,160	— ^c
Maintenance mechanic	\$38,500	\$6,420	Mechanic/electrical ^c
Security chief	\$39,600	\$6,600	— ^b
Guard/access inspection	\$24,600	\$4,100	— ^b
Truck inspection/washout	\$19,800	\$3,300	Laborer ^b
Utility mechanic	\$38,500	\$6,420	Mechanic/electrical ^c
Disposal foreman	\$36,600	\$6,100	— ^b
Equipment operator	\$31,800	\$5,300	— ^b
Inspect/assay	\$30,000	\$5,000	Health physics technician ^b
Treat secondary waste	\$19,800	\$3,300	Laborer ^b
Grout plant operator	\$19,800	\$3,300	Laborer ^b
Personal protective equipment	\$120 each per person/day	—	— ^c

a. Monthly burden rate is a 100% markup of the monthly salary.

b. Salary information from EG&G Idaho, *Economics of Small Volume LLRW Disposal Facility*.⁴

c. Salary information from ILLRWDF study.²

3.2.7 Operator's Profit

Profit for operating the facility is based on the total annual operating costs. It excludes the annual taxes and contingencies, and includes annual capital improvements, operations, maintenance, salaries, and materials. In accordance with the regulations, the operator has the ability to set waste acceptance fees which are adequate for reimbursing all reasonable expenses for facility development and operation. A five percent profit based on the annual operating costs is therefore assumed to be a reasonable charge. The profits are costs that will not be incurred by the state or the operator, but paid by the waste generator as a part of the unit disposal rate.

3.3 WBS 3.0 — Closure Costs

Closure costs are based on closure activities during the 10-year period after the facility stops accepting waste. Costs include completion of any open disposal cells, construction of the earthen cap, environmental monitoring, decontamination, decommissioning, and demolition of buildings (except site access/control facilities), and necessary annual utilities, materials, and operational costs.

The vault completion cost is based on the (a) quantity of materials and labor needed to fill and cover any remaining cells, and (b) administration resource demands based on decommissioning projections from the ILLRWDF. Decontamination and decommissioning costs for the nonessential facilities are assumed to be 50% of the construction costs, except for the administration building. Its cost is assumed to be only 30% of the construction costs because no decontamination is expected. The annual administration cost is based on the full-time-equivalents necessary to complete all closure activities. Annual operations costs for the closure period are reduced significantly because no waste is coming into the facility and are calculated as 5% of the operating period annual operations costs. The environmental monitoring plan continues unchanged during the closure period and, therefore, its annual cost remains the same. Supplies and utilities are scaled back based on projected labor, equipment, and facility requirements. Contingency costs for the closure period are calculated as 25% of all closure costs excluding operator profit. A 5% profit is continued during the closure period.

3.4 WBS 4.0 — Post-Closure Costs

For this analysis, post-closure is the 300 year period following the closure period in which there is ongoing environmental monitoring and minor site maintenance. Costs for this period include site remediation and maintenance, site security, and environmental monitoring. Once the operator completes the closure activities and the site is returned to the Commonwealth for institutional control, it is expected that a small staff will be able to perform the necessary post-closure activities.

3.5 WBS 5.0 — Community Benefits

Community benefits are to provide incentives to communities that consider hosting a LLRW facility. They will also provide compensation for any negative impacts that may occur to the surrounding areas. Table 4 lists the monetary benefits to the state and host community(ies).

The property taxes to be paid over 40 years are based on the land purchase value and improvements, such as capital investments for the support facilities and disposal cell construction. Taxes are computed by adding the startup capital costs to an annual increment of improvements for disposal cell construction. The total cost for the cap placement is added to the final cost of capital improvements at the beginning of the closure period. The value of the cap is added in one year for small and medium disposal facilities, over two years for a large disposal facility, and over three years for the extra-large disposal facility.

The taxes are calculated only for the 30 year operating period and the 10 year closure period. Massachusetts law does require taxes to be paid by the state during the institutional control period. But, because of the difficulty in assigning values to the property and remaining structures after transfer to the state, the costs of property taxes during this period are not calculated. The amounts of the incentive payments to the community(ies) were provided by the Board and are self-explanatory. Including property tax outlays based on the capital improvements, the community benefits package is approximately 10% of the total cost of a disposal facility.

Table 4. Massachusetts community benefits and compensation.

Item	Amount ^a	Duration	Total amount ^a
Property taxes	0.018 per \$1,000/yr	40 years	\$35,870,000 – \$284,750,000
Annual payments	\$240,000/\$400,000	First 30 years	\$7,200,000/\$12,000,000
Additional payments	\$150,000/\$150,000	First three years	\$450,000/\$450,000
Community impact payment	\$3,000,000/\$3,000,000	One time	\$3,000,000/\$3,000,000
Annual neighboring community payment	\$60,000/\$100,000	First 30 years	\$1,800,000/\$3,000,000
Total community benefits and compensation	—	—	\$48,320,000 – \$303,200,000

a. Two values are expressed. The first value is for small, medium, and large disposal facilities. The second value is for the extra-large disposal facility.

3.6 Discussion of Results

PLCC estimates for four sizes of disposal facilities range between \$81,622,000 to \$137,750,000 for the initial capital costs; \$10,484,000 to \$77,232,000 for annual operating costs; \$523,445,000 to \$3,014,745,000 for total costs; and \$215/ft³ to \$499/ft³ for unit rate disposal costs (refer to Table ES-1). The PLCC estimates are based on a preliminary feasibility study of an unbuilt waste disposal facility. A preliminary feasibility study is composed of detailed architectural, civil engineering and geotechnical investigations and designs. A preliminary feasibility study can yield a cost estimate within 20% of actual expenditures.

The PLCC estimates presented here are based on these engineering estimates. However, actual cost of developing a LLRW disposal facility in Massachusetts may vary significantly from these estimates for several reasons. First, no state-of-the-art facility has been built to verify the cost bases used. Second, the assumptions in this cost study differ significantly from those embedded in the engineering estimates. Third, and most important, the underlying assumptions of this analysis are subject to change by the Board as it decides how it will manage Massachusetts's waste and the specific characteristics the actual disposal facility will have. Therefore, the results of this cost study are not absolute and should only be used to compare the relative costs of the options presented.

The PLCC estimates show that as the size of the facility increased by 43% from small to medium, 60% from medium to large, and 483% from large to extra-large, the total cost increased much less - 23%, 35%, and 278%, respectively. This difference is reflected in Table ES-1 as a decreasing unit cost (cost per cubic foot). The percentage of total cost represented by each major category also changed except for post-closure and community benefits and compensation, which stayed rather constant between 2-3% and 9-10%, respectively. The pre-operations and closure costs decreased from 21% to 6% and 7% to 4%, respectively. On the other hand, operations costs increased from 60% to 77%. These findings suggest that all broad cost categories, except for operations are relatively independent of size and that "economies of scale" help level-out or reduce their relative contribution to the total cost.

This information can be taken one step farther by standardizing cost changes to changes in volume. For example, if a cost changes 75% with a 150% change in volume, the standardized cost change to volume is computed as 75%/150% or 0.50. This means that the cost changes half as fast as the volume. When applied to this analysis, the increase in size from the small to the extra-large facility increased the total cost about 39% for each 100% increase in volume. As would be expected, pre-operations and closure costs were affected least and averaged a 5% and 20% increase, respectively, for each 100% increase in volume. This indicated, however, that post-closure costs are more sensitive than either operations or community benefits and compensation, increasing 57% compared to 52% and 43%, respectively, for each 100% increase in volume. This fact was likely masked above because of the small contribution post-closure costs make to the overall cost of the facility (2-3%).

For the assumptions used in this report, generally this means that not only is "larger cheaper" on a unit cost basis, but also that operations, post-closure, and community benefits and compensation costs increase faster than other cost categories with increases in facility size. This will be explored more fully in the sensitivity analysis section of this report.

3.7 Sensitivity Analysis

The sensitivity analysis was performed on the base case PLCC estimates by varying several different cost components. Five components were found to have the largest impact on unit and total costs. These were the staffing demands, costs incurred by the State, capital costs, materials costs (canisters, sand, and cement), and a fixed salary for all staff. The bar graphs of the five cost modifications depict the unit disposal cost information in a consistent format. From the front to the back of each graph, each set of bars illustrate the relative changes for each size facility's cost modification. For each range of modifications – 50% decrease, 50% increase, 100% increase – the positions and the shading of the bars remain constant. Modifications representing 50% cost decreases are shown first, 50% cost increases are shown second, 100% cost increases are shown third, and the base cases are shown last. For the changes in base salary (Figure 6), two bars are shown for each facility size with the base case costs at the front of the graph.

The greatest effect on the unit disposal rate was from salary and staffing changes. These changes were calculated as decreases or increases to the overall staffing demands or as a fixed salary rate to the base level staffing demands. For a 100% increase in staffing, the unit disposal rate increased by over 30% for the small, medium, and large disposal facilities, and 18% for the extra-large disposal facility (Figure 5). For all salaries fixed at the same amount, the unit disposal rate increased by 33% for the small and medium facilities, 29% for large facilities, and 19% for the extra-large facility (Figure 6).

The next largest influence in the unit disposal rates are from increases in capital costs (Figure 7). These changes decreased or increased the capital costs of the land purchase price, all operational facilities, and the cost of the disposal cells and vault caps. A 100% gain in the capital costs increases the unit disposal rates 24% for the small disposal facility and 33% for the extra-large disposal facility. A 100% increase in capital costs is the most significant impact on unit disposal rates for the extra-large and large facilities. In addition, a 50% decrease in the capital costs resulted in the largest drop in unit disposal rates for the extra-large facility, 17%. The capital cost variations also had the greatest effect on the estimated taxes. Compared to the base case, a 100% capital cost increase resulted in taxes about two times greater for all sizes of disposal facilities.

Unit disposal rates were least affected by variations in the materials costs (Figure 8) or preoperational costs (Figure 9). Materials costs modified the cost of the concrete waste canisters (\$1,500 each base price) and the sand and cement used for grouting the waste (\$0.03/lb, \$0.05/lb, respectively). The preoperational costs – funds to be raised by the State – were simply reduced by 50% (\$22 million) or increased by 100% (\$90 million). Taxes calculated for community benefits and compensation were revised accordingly. A 100% increase in the materials costs increased the unit disposal rates by 6%, 7%, and 8% for small, medium and large facilities, respectively, and by 14% for the extra-large facility. With changes in the state cost, the unit disposal costs also increased with increasing facility size. These increases costs ranged from 15% to 8% for the small, medium and large facilities, to less than 1% for the extra-large facility with a 100% increase in preoperational costs.

COST ELEMENT	SMALL FAC.	MEDIUM FAC.	LARGE FAC.	X-LARGE FAC.
50% Decrease	\$411	\$369	\$305	\$195
50% Increase	\$581	\$518	\$418	\$235
100% Increase	\$666	\$593	\$471	\$255
Base Case	\$499	\$444	\$362	\$215

Figure 5. Change in staffing.

Figure 6. Change in salary base.

COST ELEMENT	SMALL FAC.	MEDIUM FAC.	LARGE FAC.	X-LARGE FAC.
50% Decrease	\$439	\$388	\$312	\$178
50% Increase	\$560	\$501	\$413	\$252
100% Increase	\$621	\$557	\$464	\$289
Base Case	\$499	\$444	\$362	\$215

Figure 7. Change in capital costs.

COST ELEMENT	SMALL FAC.	MEDIUM FAC.	LARGE FAC.	X-LARGE FAC.
50% decrease	\$483	\$429	\$347	\$200
50% increase	\$514	\$459	\$377	\$230
100% increase	\$529	\$474	\$392	\$245
Base Case	\$499	\$444	\$362	\$215

Figure 8. Change in materials costs.

COST ELEMENT	SMALL FAC.	MEDIUM FAC.	LARGE FAC.	X-LARGE FAC.
\$22 million	\$461	\$418	\$346	\$212
\$90 million	\$572	\$496	\$394	\$216
Base Case	\$499	\$444	\$362	\$215

Figure 9. Change in state costs.

4. CONCLUSIONS

The PLCC estimates for various sizes of disposal facilities show relatively minor cost increases from the small, to the medium, and the large disposal facilities compared with the extra-large disposal facility. PLCC increases from the large to the extra-large facility is much greater because of the greater size of the facility. All areas of operations, labor, and maintenance for the extra-large disposal facility costs five to ten times more than the three smaller disposal facilities and provide a six to thirteen fold increase in disposal capacity.

The PLCC estimates indicate that the expenditures incurred during the operational period of the disposal facilities will be between 60% to 77% of the total costs. About 50% of the annual budget during the operating period will be for administrative costs due to labor and for disposal cell construction. Therefore, changes in the actual costs for these two components will have large impacts on operating costs, taxes, the total PLCC, and unit disposal rates. For all disposal facilities, the estimated taxes over 40 years (30 years for facility operations and 10 years for closure) are approximately 10% of the total facility costs. Variations in the capital costs result in similar changes in the taxes, i.e., a doubling of the capital costs doubles the tax burden. Compared to capital and labor expenditures, the total facilities costs are least affected by differences in costs of land acquisition, materials, or supplies.

In order to select the optimum disposal option, additional analyses should focus on evaluating uncertainties for operating expenditures. The sensitivity analysis shows that a change in labor or construction costs can significantly impact the total PLCC estimate. Materials and site acquisition costs comprise the smallest percentage of a facility's expenditures. The operational period is the only time of revenue generation, consequently, those revenues must apply to expenses to be incurred over the entire life of the facility. Therefore, the labor and capital cost during the 30 year operating period should be evaluated carefully during the planning and final design stages since they are the two most important factors affecting available monetary resources for long-term management during the closure and institutional control periods.

5. REFERENCES

1. R. S. Means Company, Inc., *Means Building Construction Cost Data, 50th Annual Edition for 1992*, Phillip R. Waier, editor, 1991.
2. Morrison Knudsen/Chem Nuclear Services, "Chapter 3: Illinois Low-Level Radioactive Waste Disposal Facility; Design, Construction and Capital Cost," from Illinois Low-Level Radioactive Waste Disposal Facility Application, May 1991.
3. Morrison Knudsen Corporation, *Estimating Manual*, Morrison Knudsen Environmental Services Division, two volumes, February 1993.
4. EG&G Idaho, Inc., 1993, *Economics of a Small-Volume Low-Level Radioactive Waste Disposal Facility*, prepared by Dames & Moore for Idaho National Engineering Laboratory, EG&G Idaho, Inc., DOE/LLW-170, April 1993.

Appendix A

PLCC Summary Tables

Appendix A

PLCC Summary Tables

This appendix presents summary cost tables of the PLCC estimates for the sensitivity analysis modifications. Table A-1 lists the factors that were varied for the sensitivity analysis.

Table A-1. Sensitivity analysis variations.

Case	Variables	Notes
Case A	50% decrease in staff	<ul style="list-style-type: none"> Base case staffing during the operational period is 62 FTEs for small DF; 80 FTEs for medium DF; 92 FTEs for large DF; 213 FTEs for extra-large DF.
Base B	50% increase in staff	
Case C	100% increase in staff	
		<ul style="list-style-type: none"> Base case staffing during closure period is 25 FTEs for small DF; 26 FTEs for medium DF; 34 FTEs for large DF; 53 FTEs for extra-large DF.
		<ul style="list-style-type: none"> Salary rates remain unchanged during the operational and closure periods.
Case D	\$22 M for state costs	State expenditures reduced by 50%.
Case E	\$90 M for state costs	State expenditures increased by 100%.
Case F	50% decrease capital costs	Capital costs include land purchase cost; and all construction, materials, and labor costs for support and administrative facilities, cell construction, and construction of cell cover.
Case G	50% increase capital costs	
Case H	100% increase capital costs	
Case J	Canister cost \$750 each	Cost varies from base cost of \$1,500 each. 596 canisters/year small DF; 850 canisters/year medium DF; 1,361 canisters/year DF; 7,925 canisters/year extra-large DF. Sand is \$0.03/lb; cement \$0.05/lb.
Case K	Canister cost \$2,250 each	
Case L	Canister cost \$3,000 each	
Case M	Salaries fixed at \$140 K	Salary plus burden is \$140,000/year or \$11,667/month for each FTE during operational and closure periods. Applied only to base case staffing levels.

DF — disposal facility

FTE — full time equivalent.

Data Presentation

Following are the PLCC estimate summary tables. Each cost item is listed in the format of the WBS from the scope of work. The first table is a summary of all totals of the WBS elements for each size of disposal facility and for each modified cost factor. Subtotals and totals for each WBS element are highlighted in bold-face type.

Summary of WBS Cost Totals (\$1000) for Massachusetts Disposal Facilities

CASE	WBS	SMALL DF	MED DF	LRG DF	X-LRG DF	CASE	WBS	SMALL DF	MED DF	LRG DF	X-LRG DF	DISPOSAL RATES
Base	Pre-oper	81,622	85,499	88,623	137,750	Case G	Pre-oper	101,486	107,302	111,987	185,679	Small 35,000 cu ft / yr
	Operations	314,518	437,537	598,526	2,316,947		Operations	339,510	474,991	660,904	2,633,247	1,050,000 cu ft (tot.)
	Closure	35,993	40,760	52,365	123,752		Closure	36,431	41,381	53,356	128,904	Medium 50,000 cu ft / yr
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	1,500,000 cu ft (tot.)
	Com Benefits	48,316	59,531	80,262	303,196		Com Benefits	66,249	83,072	114,169	445,568	Large 80,000 cu ft / yr
	TOTAL	523,445	666,323	869,415	3,014,745		TOTAL	587,682	750,752	991,198	3,527,912	2,400,000 cu ft (tot.)
	\$ / cu ft	\$499	\$444	\$362	\$215		\$ / cu ft	\$560	\$501	\$413	\$252	X-Large 466,000 cu ft / yr
Case A	Pre-oper	81,622	85,499	88,623	137,750	Case H	Pre-oper	121,350	129,106	135,352	233,608	14,000,000 cu ft (tot.)
	Operations	235,821	337,116	478,497	2,054,861		Operations	364,451	512,403	723,258	2,949,501	
	Closure	23,291	27,866	35,001	96,779		Closure	36,866	42,001	54,346	134,056	
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	
	Com Benefits	48,316	59,531	80,262	303,196		Com Benefits	84,182	106,612	148,075	587,941	
	TOTAL	432,048	553,009	732,022	2,725,685		TOTAL	651,866	835,139	1,112,956	4,041,034	
	\$ / cu ft	\$411	\$369	\$305	\$195		\$ / cu ft	\$621	\$557	\$464	\$289	
Case B	Pre-oper	81,622	85,499	88,623	137,750	Case J	Pre-oper	81,622	85,499	88,623	137,750	COST BASE ASSUMPTIONS
	Operations	388,458	533,201	709,043	2,559,359		Operations	298,723	415,002	562,451	2,106,859	Case A 50% decrease in staff
	Closure	48,700	55,755	69,739	152,354		Closure	35,993	40,760	52,365	123,752	Case B 50% increase in staff
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	Case C 100% increase in staff
	Com Benefits	48,316	59,531	80,262	303,196		Com Benefits	48,316	59,531	80,262	303,196	Case D State costs at \$22 M
	TOTAL	610,092	776,983	997,306	3,285,759		TOTAL	507,650	643,788	833,340	2,804,657	Case E State costs at \$90 M
	\$ / cu ft	\$581	\$518	\$416	\$235		\$ / cu ft	\$483	\$429	\$347	\$200	Case F Capital and land costs -50%
Case C	Pre-oper	81,622	85,499	88,623	137,750	Case K	Pre-oper	81,622	85,499	88,623	137,750	Case G Capital and land costs +50%
	Operations	464,777	631,244	824,316	2,811,609		Operations	330,313	460,072	634,601	2,527,035	Case H Capital and land costs +100
	Closure	61,404	69,699	87,108	180,142		Closure	35,993	40,760	52,365	123,752	Case J Canister cost \$750 ea
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	Sand \$0.015/lb
	Com Benefits	48,316	59,531	80,262	303,196		Com Benefits	48,316	59,531	80,262	303,196	Cement \$0.045/lb
	TOTAL	699,114	888,970	1,129,948	3,565,796		TOTAL	539,240	688,859	905,490	3,224,833	Case K Canister cost \$2,250 ea
	\$ / cu ft	\$666	\$593	\$471	\$255		\$ / cu ft	\$514	\$459	\$377	\$230	Sand \$0.045/lb
Case D	Pre-oper	58,729	62,606	65,337	113,657	Case L	Pre-oper	81,622	85,499	88,623	137,750	Cement \$0.075/lb
	Operations	314,518	437,537	598,526	2,316,947		Operations	346,107	482,608	670,676	2,737,123	Case L Canister cost \$3,000 ea
	Closure	35,993	40,760	52,365	123,752		Closure	35,993	40,760	52,365	123,752	Sand \$0.06/lb
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	Cement \$0.10/lb
	Com Benefits	47,263	58,478	79,072	301,721		Com Benefits	48,316	59,531	80,262	303,196	Case M Salary \$140K/FTE/yr
	TOTAL	484,079	626,957	829,254	2,972,949		TOTAL	555,034	711,394	941,565	3,434,921	
	\$ / cu ft	\$461	\$418	\$346	\$212		\$ / cu ft	\$529	\$474	\$392	\$245	
Case E	Pre-oper	126,729	130,606	133,337	181,657	Case M	Pre-oper	81,622	85,499	88,623	137,750	
	Operations	314,518	437,537	598,526	2,316,947		Operations	457,182	626,291	815,429	2,836,054	
	Closure	35,993	40,760	52,365	123,752		Closure	57,893	63,310	82,914	172,211	
	Post-Closure	12,757	12,757	19,135	102,052		Post-Closure	12,757	12,757	19,135	102,052	
	Com Benefits	50,422	61,637	82,642	306,144		Com Benefits	48,316	59,531	80,262	303,196	
	TOTAL	601,042	743,920	946,628	3,091,175		TOTAL	688,008	877,627	1,116,867	3,582,311	
	\$ / cu ft	\$572	\$496	\$394	\$216		\$ / cu ft	\$655	\$585	\$465	\$256	
Case F	Pre-oper	61,757	63,696	65,258	89,822							
	Operations	289,593	400,132	536,162	2,000,705							
	Closure	37,305	40,140	50,002	109,023							
	Post-Closure	12,757	12,757	19,135	102,052							
	Com Benefits	30,383	35,991	48,302	160,823							
	TOTAL	461,023	581,944	748,221	2,492,058							
	\$ / cu ft	\$439	\$388	\$312	\$178							

WORK BREAKDOWN STRUCTURE BASE CASES
PLCC Estimates for 4 Sizes of Disposal Facilities

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,383	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,288</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	76,132	76,132	76,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,840
1.7.5 Site Development	8,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,078</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,348	8,121	8,687	18,331
Total Pre-Operational Costs	81,622	86,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	<u>9,986</u>	<u>13,890</u>	<u>19,001</u>	<u>73,554</u>
2.1.7 Operator's Profit (5% of annual costs)	499	695	950	3,678
Total Operational Costs over 30 years	314,618	437,637	598,626	2,316,947
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	668	1,346
3.2.2 Front-End Receiving	981	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Supplies / Utilities	2,809	3,952	5,008	11,004
3.7 Contingency (for items 3.1 to 3.6)	<u>6,922</u>	<u>7,838</u>	<u>10,070</u>	<u>23,798</u>
3.8 Operator's Profit (5% x annual costs (items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	36,993	40,760	62,366	123,762
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	<u>835</u>	<u>835</u>	<u>1,252</u>	<u>6,676</u>
Total Post-Closure Costs	12,767	12,767	19,136	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,868	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	60,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	623,446	666,323	869,416	3,014,746
UNIT COSTS (\$1000 / cu ft)	0.60	0.44	0.36	0.22

WORK BREAKDOWN STRUCTURE CASE A
50% Decrease in Staff Levels

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4000	4000	4000	4000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	44,893	44,893	45,286	46,093
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,082	3,082	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	20,405	22,559	24,076	50,921
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	24,486	27,071	28,891	61,105
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	88,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	2,038	2,566	2,922	6,595
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	1,750	2,678	3,737	16,470
Subtotal Annual Operational Costs (Item 2.1)	7,488	10,702	15,190	65,234
2.1.7 Operator's Profit (5% of annual costs)	374	535	760	3,262
Total Operational Costs over 30 years	236,821	337,116	478,497	2,064,861
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	9,077	9,527	12,051	18,462
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	1,915	3,561	3,701	8,717
3.7 Contingency (for Items 3.1 to 3.6)	4,479	5,359	6,731	18,611
3.8 Operator's Profit (5% x annual cost (Items 3.1-3.6))	896	1,072	1,346	3,722
Total Closure Costs	23,291	27,866	36,001	96,779
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,757	19,136	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	59,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	432,046	563,009	732,022	2,728,686
UNIT COSTS (\$1000 / cu ft)	0.41	0.37	0.31	0.19

WORK BREAKDOWN STRUCTURE CASE B
50% Increase in Staff Levels

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4000	4000	4000	4000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,286</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,076</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,348	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	86,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	6,113	7,698	8,765	19,784
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,520	3,771	5,213	19,296
Subtotal Annual Operational Costs (Item 2.1)	<u>12,332</u>	<u>16,927</u>	<u>22,509</u>	<u>81,250</u>
2.1.7 Operator's Profit (5% of annual costs)	617	846	1,125	4,062
Total Operational Costs over 30 years	369,468	633,201	709,043	2,559,359
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	27,231	28,581	36,152	55,386
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	3,306	5,960	6,322	14,544
3.7 Contingency (for Items 3.1 to 3.6)	<u>9,385</u>	<u>10,722</u>	<u>13,411</u>	<u>29,299</u>
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,873	2,144	2,682	5,860
Total Closure Costs	48,700	66,766	69,739	162,364
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,223	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,757	19,135	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	69,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	610,092	776,983	997,306	3,286,759
UNIT COSTS (\$1000 / cu ft)	0.68	0.82	0.42	0.23

WORK BREAKDOWN STRUCTURE CASE C
100% Increase in Staff Levels

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	44,893	44,893	45,288	46,093
1.6.1 Interest and Principal on State Bonds (due 2018)	78,132	78,132	78,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	8,707	7,457	8,368	14,698
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	20,405	22,559	24,078	50,921
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	24,486	27,071	28,891	61,105
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	86,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	8,151	10,265	11,686	26,379
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,905	4,317	5,951	20,709
Subtotal Annual Operational Costs (Item 2.1)	14,755	20,039	26,169	89,257
2.1.7 Operator's Profit (5% annual costs)	738	1,002	1,308	4,463
Total Operational Costs over 30 years	464,777	631,244	824,316	2,811,609
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	36,308	38,108	48,202	73,848
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	4,002	7,159	7,632	17,457
3.7 Contingency (for Items 3.1 to 3.6)	11,808	13,404	16,752	34,643
3.8 Operator's Profit (5% x annual costs (Items 3.1-3.6))	2,362	2,681	3,350	6,929
Total Closure Costs	61,404	69,699	87,108	180,142
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,767	19,138	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,748
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,318	69,531	80,262	303,198
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	699,114	889,970	1,129,948	3,568,798
UNIT COSTS (\$1000 / cu ft)	0.67	0.69	0.47	0.25

WORK BREAKDOWN STRUCTURE CASE D

Initial State Cost \$22 M

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition				
1.2 Project Management				
1.2.1 Labor				
1.2.2 Supplies				
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization				
1.3.2 Public Involvement				
1.3.3 Characterization				
1.3.4 Litigation				
1.3.5 Baseline Monitoring				
1.4 Licensing / NEPA				
1.4.1 Source Term				
1.4.2 Analysis / Documentation				
1.5 Engineering Design				
1.6 Contingencies (for Items 1.1 to 1.5)				
Subtotal (Items 1.1 to 1.6)	22,000	22,000	22,000	22,000
1.6.1 Interest and Principal on State Bonds (due 2018)	36,819	36,819	36,819	36,819
1.7 Facility Construction				
1.7.1 Administration	1,496	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,698
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	20,405	22,559	24,076	50,921
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	24,486	27,071	28,891	61,105
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	58,729	62,606	65,337	113,657
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,859
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	9,985	13,890	19,001	73,554
2.1.7 Operator's Profit (5% of annual costs)	499	695	950	3,678
Total Operational Costs over 30 years	314,818	437,637	696,626	2,316,947
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	981	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	6,922	7,838	10,070	23,798
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	36,983	40,760	62,366	123,762
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,767	12,767	19,136	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	34,813	48,028	66,622	283,271
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	47,263	60,478	79,072	301,721
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	484,079	626,667	829,264	2,972,949
UNIT COSTS (\$1000 / cu ft)	0.48	0.42	0.38	0.21

WORK BREAKDOWN STRUCTURE CASE E

Initial State Cost \$ 90 M

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition				
1.2 Project Management				
1.2.1 Labor				
1.2.2 Supplies				
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization				
1.3.2 Public Involvement				
1.3.3 Characterization				
1.3.4 Litigation				
1.3.5 Baseline Monitoring				
1.4 Licensing / NEPA				
1.4.1 Source Term				
1.4.2 Analysis / Documentation				
1.5 Engineering Design				
1.6 Contingencies (for Items 1.1 to 1.5)				
Subtotal (Items 1.1 to 1.6)	90,000	90,000	90,000	90,000
1.6.1 Interest and Principal on State Bonds (due 2018)	160,623	160,623	160,623	160,623
1.7 Facility Construction				
1.7.1 Administration	1,496	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	20,403	22,559	24,078	50,921
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	24,484	27,071	28,891	61,105
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	128,729	130,806	133,337	181,667
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	9,886	13,890	19,001	73,554
2.1.7 Operator's Profit (5% of annual costs)	499	695	950	3,678
Total Operational Costs over 30 years	314,618	437,837	598,826	2,316,947
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	2,809	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	8,922	7,838	10,070	23,798
3.8 Operator's Profit (5% x annual cost (Items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	38,993	40,760	62,366	123,762
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,876
Total Post-Closure Costs	12,757	12,757	19,135	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	37,972	49,187	70,192	287,694
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	60,422	61,637	82,642	306,144
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	601,042	743,920	846,828	3,091,176
UNIT COSTS (\$1000 / cu ft)	0.67	0.60	0.39	0.22

WORK BREAKDOWN STRUCTURE CASE F
50% Decrease in Capital Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	1,500	1,500	1,667	2,100
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	43,393	43,393	43,590	43,993
1.6.1 Interest and Principal on State Bonds (due 2018)	72,622	72,622	72,962	73,626
1.7 Facility Construction				
1.7.1 Administration	1,496	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5) x 0.5	10,202	11,280	12,038	25,460
1.7.6 Contractor Overhead Fee (Indirect Cost)	2,040	2,256	2,408	5,092
Subtotal Facility Construction (Item 1.7)	12,243	13,536	14,446	30,552
1.8 Construction Management	2,449	2,707	2,889	6,110
1.9 Contingency for Construction (for Items 1.7 & 1.8)	3,673	4,061	4,334	9,166
Total Pre-Operational Costs	61,757	63,696	65,258	69,822
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	741	1,111	1,851	9,384
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	52	78	130	657
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	9,193	12,703	17,021	63,514
2.1.7 Operator's Profit (5% of annual costs)	460	635	851	3,176
Total Operational Costs over 30 years	289,693	400,132	536,162	2,000,706
3.0 Closure				
3.1 Cover Emplacement	336	478	762	3,648
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	3,952	3,952	3,952	3,952
3.7 Contingency (for Items 3.1 to 3.6)	7,174	7,719	9,616	20,966
3.8 Operator's Profit (5% x annual cost (Items 3.1-3.6))	1,435	1,544	1,923	4,193
Total Closure Costs	37,306	40,140	60,002	109,023
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,767	12,767	19,136	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	17,933	23,541	35,852	142,373
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	30,383	35,991	48,302	160,823
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	461,023	581,944	748,221	2,492,068
UNIT COSTS (\$1000 / cu ft)	0.44	0.39	0.31	0.18

WORK BREAKDOWN STRUCTURE CASE G
50% Increase in Capital Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	4,500	4,500	5,080	6,300
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>48,393</u>	<u>48,393</u>	<u>48,983</u>	<u>48,193</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	77,843	77,843	78,830	80,866
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,698
Subtotal Direct Costs (Items 1.7.1 to 1.7.5) x 1.5	<u>30,807</u>	<u>33,839</u>	<u>36,114</u>	<u>78,381</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	6,121	6,768	7,223	15,276
Subtotal Facility Construction (Item 1.7)	<u>36,928</u>	<u>40,608</u>	<u>43,337</u>	<u>91,657</u>
1.8 Construction Management	7,346	8,121	8,667	18,331
1.9 Contingency for Construction (for Items 1.7 & 1.8)	11,019	12,182	13,001	27,497
Total Pre-Operational Costs	101,486	107,302	111,987	186,679
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	2,222	3,332	5,552	28,151
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	156	233	389	1,971
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	<u>10,779</u>	<u>15,079</u>	<u>20,981</u>	<u>83,595</u>
2.1.7 Operators Profit (5% of annual costs)	539	754	1,049	4,180
Total Operational Costs over 30 years	339,510	474,991	660,904	2,833,247
3.0 Closure				
3.1 Cover Emplacement	1,007	1,433	2,288	11,889
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,348
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	7,008	7,958	10,281	24,789
3.8 Operator's Profit (5% x annual cost (item 3.1-3.6))	1,401	1,592	2,052	4,958
Total Closure Costs	36,431	41,381	53,366	128,904
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,757	19,135	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	53,799	70,822	101,719	427,118
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	66,249	83,072	114,169	445,568
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	587,682	750,762	991,198	3,527,912
UNIT COSTS (\$1000 / cu ft)	0.66	0.60	0.41	0.26

WORK BREAKDOWN STRUCTURE CASE H
100% Increase in Capital Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	6,000	6,000	6,786	8,400
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	47,893	47,893	48,679	50,293
1.6.1 Interest and Principal on State Bonds (due 2018)	80,183	80,183	81,469	84,170
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5) x 2	40,809	45,118	48,152	101,841
1.7.6 Contractor Overhead Fee (Indirect Cost)	8,162	9,024	9,630	20,368
Subtotal Facility Construction (Item 1.7)	48,971	54,142	57,782	122,210
1.8 Construction Management	9,794	10,828	11,558	24,442
1.9 Contingency for Construction (for items 1.7 & 1.8)	14,691	16,243	17,335	36,663
Total Pre-Operational Costs	121,360	129,106	136,362	233,608
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	2,962	4,442	7,402	37,534
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	207	311	518	2,627
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	11,570	16,267	22,961	93,635
2.1.7 Operator's Profit (5% of annual costs)	578	813	1,148	4,682
Total Operational Costs over 30 years	364,461	612,403	723,268	2,949,501
3.0 Closure				
3.1 Cover Emplacement	1,342	1,910	3,048	15,852
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	2,609	3,952	5,008	11,004
3.7 Contingency (for items 3.1 to 3.6)	7,090	8,077	10,451	25,780
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,418	1,615	2,090	5,156
Total Closure Costs	36,866	42,001	64,346	134,066
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,062	1,062	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,767	12,767	19,135	102,062
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	71,732	94,162	135,625	569,491
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	84,182	106,612	148,075	587,941
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	661,866	836,139	1,112,956	4,041,034
UNIT COSTS (\$1000 / cu ft)	0.62	0.66	0.46	0.29

WORK BREAKDOWN STRUCTURE CASE J
50% Decrease in Materials Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,286</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,082	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	8,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,076</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,348	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	85,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,787
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	1,633	2,509	3,330	11,375
Subtotal Annual Operational Costs (Item 2.1)	<u>9,483</u>	<u>13,175</u>	<u>17,856</u>	<u>66,894</u>
2.1.7 Operator's Profit (5% of annual costs)	474	659	893	3,344
Total Operational Costs over 30 years	298,723	415,002	562,451	2,106,859
3.0 Closure				
3.1 Cover Emplacement	871	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	668	1,346
3.2.2 Front-End Receiving	981	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Supplies / Utilities	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	<u>6,922</u>	<u>7,838</u>	<u>10,070</u>	<u>23,798</u>
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	35,993	40,780	52,365	123,752
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	<u>835</u>	<u>835</u>	<u>1,252</u>	<u>6,676</u>
Total Post-Closure Costs	12,757	12,757	19,135	102,052
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,868	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	<u>48,318</u>	<u>59,531</u>	<u>80,262</u>	<u>303,196</u>
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	507,650	643,788	833,340	2,804,657
UNIT COSTS (\$1000 / cu ft)	0.48	0.43	0.35	0.20

WORK BREAKDOWN STRUCTURE CASE K
50% Increase in Materials Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,286</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,076</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for items 1.7 & 1.8)	7,348	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	85,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,636	3,940	5,620	24,714
Subtotal Annual Operational Costs (Item 2.1)	<u>10,488</u>	<u>14,605</u>	<u>20,146</u>	<u>80,223</u>
2.1.7 Operator's Profit (5% of annual costs)	524	730	1,007	4,011
Total Operational Costs over 30 years	330,313	460,072	634,601	2,527,135
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Supplies / Utilities	2,609	3,952	5,008	11,004
3.7 Contingency (for items 3.1 to 3.6)	<u>6,922</u>	<u>7,838</u>	<u>10,070</u>	<u>23,798</u>
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	35,993	40,760	52,365	123,752
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	<u>835</u>	<u>835</u>	<u>1,252</u>	<u>6,676</u>
Total Post-Closure Costs	12,757	12,757	19,135	102,052
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,868	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,318	59,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	539,240	688,859	905,490	3,224,833
UNIT COSTS (\$1000 / cu ft)	0.51	0.46	0.38	0.23

WORK BREAKDOWN STRUCTURE CASE L
100% Increase in Materials Costs

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4,000	4,000	4,000	4,000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	<u>44,893</u>	<u>44,893</u>	<u>45,286</u>	<u>46,093</u>
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	<u>20,405</u>	<u>22,559</u>	<u>24,076</u>	<u>50,921</u>
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	<u>24,486</u>	<u>27,071</u>	<u>28,891</u>	<u>61,105</u>
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,346	8,121	8,667	18,331
Total Pre-Operational Costs	81,622	86,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	4,151	5,208	5,994	13,340
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	3,137	4,655	6,766	31,383
Subtotal Annual Operational Costs (Item 2.1)	<u>10,988</u>	<u>15,321</u>	<u>21,291</u>	<u>86,893</u>
2.1.7 Operator's Profit (5% of annual costs)	549	766	1,065	4,345
Total Operational Costs over 30 years	346,107	482,608	670,676	2,737,123
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	18,154	19,054	24,101	36,924
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Supplies / Utilities	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	6,922	7,838	10,070	23,798
3.8 Operator's Profit (5% x annual cost (items 3.1-3.6))	1,384	1,568	2,014	4,760
Total Closure Costs	36,993	40,760	52,366	123,752
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,757	12,767	19,135	102,052
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,746
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	59,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	555,034	711,394	941,565	3,434,921
UNIT COSTS (\$1000 / cu ft)	0.53	0.47	0.39	0.25

WORK BREAKDOWN STRUCTURE CASE M

All Salaries Fixed at \$140 K / yr

	Small (x \$1000)	Medium (x \$1000)	Large (x \$1000)	X-Large (x \$1000)
1.0 Pre-Operation				
1.1 Land Acquisition	3,000	3,000	3,393	4,200
1.2 Project Management				
1.2.1 Labor	4000	4000	4000	4000
1.2.2 Supplies	187	187	187	187
1.3 Site Selection / Characterization				
1.3.1 Site Selection / Pre-characterization	2,300	2,300	2,300	2,300
1.3.2 Public Involvement	5,000	5,000	5,000	5,000
1.3.3 Characterization	11,000	11,000	11,000	11,000
1.3.4 Litigation	1,000	1,000	1,000	1,000
1.3.5 Baseline Monitoring	1,508	1,508	1,508	1,508
1.4 Licensing / NEPA				
1.4.1 Source Term	250	250	250	250
1.4.2 Analysis / Documentation	8,377	8,377	8,377	8,377
1.5 Engineering Design	4,500	4,500	4,500	4,500
1.6 Contingencies (for Items 1.1 to 1.5)	3,771	3,771	3,771	3,771
Subtotal (Items 1.1 to 1.6)	44,893	44,893	45,286	46,093
1.6.1 Interest and Principal on State Bonds (due 2018)	75,132	75,132	75,790	77,141
1.7 Facility Construction				
1.7.1 Administration	1,498	1,732	2,221	4,487
1.7.2 Front End / Receiving	1,921	2,377	2,493	5,544
1.7.3 Waste Packaging	2,348	3,062	3,062	6,555
1.7.4 Disposal Units	7,931	7,931	7,931	19,640
1.7.5 Site Development	6,707	7,457	8,368	14,696
Subtotal Direct Costs (Items 1.7.1 to 1.7.5)	20,405	22,559	24,076	50,921
1.7.6 Contractor Overhead Fee (Indirect Cost)	4,081	4,512	4,815	10,184
Subtotal Facility Construction (Item 1.7)	24,486	27,071	28,891	61,105
1.8 Construction Management	4,897	5,414	5,778	12,221
1.9 Contingency for Construction (for Items 1.7 & 1.8)	7,348	8,121	8,687	18,331
Total Pre-Operational Costs	81,622	85,499	88,623	137,750
2.0 Operation				
2.1 Annual Costs				
2.1.1 Cell Construction	1,481	2,221	3,701	18,767
2.1.2 Administration (FTE)	8,680	11,200	12,880	29,820
2.1.3 Operations	1,840	2,807	4,159	19,889
2.1.4 Maintenance	104	155	259	1,314
2.1.5 Environmental Monitoring	275	275	413	2,200
2.1.6 Utilities / Materials	2,135	3,224	4,475	18,044
Subtotal Annual Operational Costs (Item 2.1)	14,514	19,882	25,887	90,033
2.1.7 Operator's Profit (5% of annual costs)	726	994	1,294	4,502
Total Operational Costs over 30 years	457,182	626,291	815,429	2,836,054
3.0 Closure				
3.1 Cover Emplacement	671	955	1,524	7,926
3.2 Demolition & Decontamination				
3.2.1 Administration	449	520	666	1,346
3.2.2 Front-End Receiving	961	1,189	1,247	2,772
3.2.3 Waste Packaging	1,174	1,531	1,531	3,277
3.3 Administration (FTE)	35,000	36,400	47,600	74,200
3.4 Operations	920	1,403	2,079	9,945
3.5 Environmental Monitoring	2,750	2,750	4,125	22,000
3.6 Utilities / Materials	2,609	3,952	5,008	11,004
3.7 Contingency (for Items 3.1 to 3.6)	11,133	12,175	15,945	33,117
3.8 Operator's Profit (5% x annual cost (Items 3.1-3.6))	2,227	2,435	3,189	6,623
Total Closure Costs	57,893	63,310	82,914	172,211
4.0 Post-Closure				
4.1 Environmental Monitoring	5,400	5,400	8,100	43,200
4.2 Site Remediation	5,440	5,440	8,160	43,520
4.3 Security	1,082	1,082	1,623	8,656
4.4 Maintenance	835	835	1,252	6,676
Total Post-Closure Costs	12,767	12,767	19,135	102,052
5.0 Community Benefits and Compensation				
5.1 Property Taxes (total over 40 years)	35,866	47,081	67,812	284,748
5.2 Annual Payments (total over 30 years)	7,200	7,200	7,200	12,000
5.3 Additional Payments (total over 3 years)	450	450	450	450
5.4 Community Impact Payment	3,000	3,000	3,000	3,000
5.5 Annual Neighboring Community Payments - (total over 30 years)	1,800	1,800	1,800	3,000
Total Community Benefits & Compensation Costs	48,316	59,531	80,262	303,196
TOTAL FACILITY COSTS (Items 1.0 to 5.0)	688,008	877,627	1,116,867	3,582,311
UNIT COSTS (\$1000 / cu ft)	0.66	0.69	0.47	0.26

Appendix B

Massachusetts Scope of Work Statement

Estimating Costs of Disposal Alternatives for Massachusetts

November 16, 1993

Scope of Work

A. Background

The Massachusetts Low-Level Radioactive Waste Management Board (the "Board") is charged by state and federal law to provide for the management (including disposal) of low-level radioactive waste (LLRW) generated in the Commonwealth from various academic, health care, commercial, government and utility users of radioactive materials. The Board must make decisions regarding the short-term and long-range management of this waste, including the possible determination to initiate siting for an LLRW disposal facility within the Commonwealth.

Out-of-state options for LLRW management may be available at some future date through contracts or regional compact arrangements with other states. At the present time, however, all states and compact regions with current or developing disposal capacity have adopted explicit statutory prohibitions or have communicated an unwillingness to accept LLRW from outside their state or region.

The Board has asked the National Low-Level Waste Management Program of the U.S. Department of Energy to develop a report on instate disposal facility costs and costs incurred by various states and regional compacts developing facilities outside Massachusetts. This scope document describes the tasks which will develop cost estimates to be included in the report.

B. Objectives

The objectives of this study are to:

- develop planning-level life cycle cost (PLCC) estimates (November, 1993 dollars) for four sizes of LLRW disposal facilities within Massachusetts;
- develop PLCC estimates for non-Massachusetts LLRW disposal facilities; and
- summarize the statutory provisions in compact and state law, and/or current expressed state or compact policies (i.e., votes or declarations by state LLRW management officials or Governors) regarding out-of-state access.

C. Description of Tasks

This project is divided into five tasks. They are summarized as follows:

1. Develop a draft annotated outline that reflects the format and content of the report for Task 3. Any comments concerning assumptions or tasks should be incorporated into this document.
2. Conduct a literature search of relevant available economic publications, reports, and documents, including those produced by states currently siting LLRW disposal facilities.
3. Prepare estimates of PLCCs, both in total and in unit disposal costs, for the four in-state facility sizes which incorporate the one technology option (i.e., "state-of-the-art" above-ground vaults with second engineered structure), using the assumptions in Part D, to the extent possible, as the bases for costs generated.
4. Survey all regional compact and unaffiliated host states currently developing LLRW disposal facilities. Data collected should include:
 - a. identification of PLCC estimates, both in total and in unit disposal costs, for each site. To the extent possible, these costs should be comparable with the costs identified in the Part D assumptions, or identified if not applicable or incalculable;
 - b. statutory provisions (both state and compact law) relating to the acceptance or non-acceptance of Massachusetts LLRW;
 - c. if no statutory provisions exist regarding access, identify current state/compact policy (votes, declarations, etc.) through interviews with state/compact officials, regarding existing access policies;
 - d. estimates of access costs (entry fees, annual charges, surcharges, etc.);
 - e. transportation costs; and
 - f. other identifiable charges for out-of-state disposal.
5. Develop Draft and Final versions of two reports.

D. Assumptions to be Incorporated in Analytical Tasks

The following list of assumptions should be used to the extent possible for estimating PLCCs.

1. In-state facility sizes:¹
 - #1. Massachusetts-only: 35,000 cubic feet/year;
 - #2. Massachusetts-only: 50,000 cubic feet/year;
 - #3. Small regional: 80,000 cubic feet/year; and
 - #4. Large regional: 476,000 cubic feet/year.
2. The minimum facility land area for these sizes is:
 - a. Massachusetts-only facility sizes = 100 acres;
 - b. Small regional facility = 130 acres; and

- c. Large regional facility = 420 acres.
3. The major criteria and data used for all facility sizes are:
- a. the facility would operate and accept waste for 30 years;
 - b. the waste stream would be homogeneous for the 30-year operating cycle;
 - c. total LLRW inventory is estimated based on Management Board annual surveys;
 - d. decommissioning wastes available for disposal at the facility from two commercial power reactors and other facilities are assumed to total 450,000 cubic feet of Class A, B, and C LLRW, and are included in the annualized volumes given in item D(1);
 - e. the disposal technology employed at the site for all waste classes would allow monitoring and retrieval of the waste in intact containers; and
 - f. no significant commitment of land would be required for other types of activities at the site not directly related to the disposal function. Sufficient land area would be available for office and laboratory space in connection with any affiliated activity, such as an LLRW minimization research center.
3. Annual LLRW disposal volumes:
- a. Annual LLRW disposal volumes for facility size #1 would contribute 600,000 cubic feet of Class A, B, and C LLRW to the total site inventory over 30 years; total site inventory from annual shipments and decommissioning would be 1,050,000 cubic feet.
 - b. Annual LLRW disposal volumes for facility size #2 would contribute 1,050,000 cubic feet of Class A, B, and C LLRW to the total site inventory over 30 years; total site inventory from annual shipments and decommissioning would be 1,500,000 cubic feet.
 - c. Facility size #3 would have a total site inventory from annual shipments and decommissioning of 2,400,000 cubic feet.
 - d. Facility size #4 would have a total site inventory from annual shipments and decommissioning of 14,000,000 cubic feet.
4. Facility technology is assumed to be above-ground vaults with a second engineered structure, comparable to the state-of-the-art designs under development in several compact regions.²
5. State siting costs are fixed at \$45,000,000, and assume bonding at Massachusetts bond rates for 25 years.
6. Facility location is assumed to meet the requirements of 10 CFR 61 and the Massachusetts LLRW facility siting regulations.
7. Facility design shall allow for segregation of LLRW containing short-lived and long-lived radionuclides.³
8. For the purpose of this analysis, conventional monitoring equipment is assumed to be utilized over the operating and institutional control phases of the facility.⁴

9. The facility would be operated by a private contractor according to the following conditions:
- The operational period would be 30 years;
 - The post-closure period would be 10 years;
 - The private operator would be limited to receiving reasonable expenses for facility operation;
 - Funds to cover institutional control costs (i.e., facility maintenance) would be incorporated into the fee structure for facility operation.
 - While the operator would also be expected to include in the fee structure funds to cover contingent liability during the institutional control period, political and actuarial data to estimate such costs is unknown at this time. Therefore, for the purposes of this analysis, contingent liability costs will be assumed to be a constant of zero for both in-state and out-of-state facilities. The Management Board may define these costs as part of any subsequent analysis it may perform.
10. The institutional control period would be 300 years.⁵
11. Because the insurance industry has not yet developed actuarial data to identify premiums for various types of facility insurance (e.g., All-Risk Property, General Liability, Environmental Impairment, and Nuclear Energy Liability), for the purpose of this analysis, the costs associated with the facility operator providing such financial assurance will be considered to be undefinable. Therefore, the contractor will assume said costs to be zero, and the Management Board may define these costs in any subsequent analyses.⁶
12. Community benefits and compensation:
- Payments to the "site" community⁷ would include:
 - payments of property taxes from the period commencing with the issuance of a facility license, and ending with the transfer of such license to the Management Board. For the purpose of this analysis, said payments shall assume a commercial tax rate of \$18 per thousand at full fair market (i.e., 100%) valuation of land plus improvements;
 - payments during facility operation of \$240,000 annually (during facility operation) for site sizes #1, #2, and #3; and \$400,000 annually for site size #4;
 - payments of \$150,000 per year, pro rata, for the first three years of facility operation;⁸ and
 - \$3,000,000 to fund a one-time site community "impact" payment as well as other negotiated compensation (i.e., road reconstruction, payments for emergency services, property value guarantees, etc.).⁹
 - Payments to one "neighboring" community¹⁰ would include:
 - \$60,000 annually (during facility operation) for site sizes #1, #2, and #3.
 - \$100,000 annually for site size #4.

13. Life cycle costs will include entry fees, if applicable.

14. For facility sizes #3 and #4, assume that all facility siting costs (\$45 million) would be paid by out-of-state generators from states that would be invited to join a regional compact.

E. Deliverables

Deliverables shall include the following:

1. An annotated outline reflecting the format and content of the report for Task 3 of Part C.
2. Two Draft and Final reports, one encompassing Tasks 2 and 4, and one covering Task 3 of Part C. The report for Task 3 shall, for each facility size, include cost estimating summaries and related details for the aboveground engineered disposal technology option assumed for this analysis. In addition, the Draft and Final reports shall include graphs that plot cost versus facility size. A 10-15 page narrative shall summarize the data, basis, and assumptions of the analysis for Task 3.
3. Twenty-five copies of the Draft and Final reports shall be provided to the Management Board.

F. Contract Schedule

1. The annotated outline shall be submitted on 12/1/93.
2. The Draft reports shall be delivered on or before 1/1/94.
3. The Final reports shall be submitted on or before 1/15/94.

Endnotes:

1. The last three facility sizes are discussed in the draft LLRW Management Plan, section 15.9 (attached). The first size (35,000 cubic feet) results from the Management Board's latest projection of annual volume requiring disposal in a licensed disposal facility, which reflects a 10,000 cubic feet annual reduction from earlier projections.
2. Facility life cycle costs are to some extent dependent upon the type of technology chosen for the disposal facility design. In Massachusetts, such design selection is the responsibility of the site community, not the Board. However, because facility technologies will not influence the evaluation of in-state versus out-of-state economies, for this study, the one disposal technology selected for analysis is the technology employing above-grade vaults with a second engineered structure, comparable to the state-of-the-art designs planned for Pennsylvania, Illinois, North Carolina, or Nebraska.

3. The Management Board has recommended a segregation of short- and long-lived LLRW, to enhance safety and efficiency in any retrieval activity that may later be required. In addition, segregation will aid the Board in fulfilling the requirements of state law (M.G.L. c. 111H, section 46), that stipulates: "the institutional control period shall not be less than the minimum time required for any LLRW present at the site to decay to the maximum concentrations above natural background levels permitted to be released into air or water in unrestricted areas under federal and state law."
4. Monitoring devices are required pursuant to M.G.L. c.111H that can be maintained (or replaced when necessary) in order to provide the capability to monitor waste packages throughout the life of the facility.
5. See M.G.L. c.111H, section 46 requirement referenced in Endnote 3.
6. The Management Board has recommended that the operator of any LLRW disposal facility sited in Massachusetts should be required to purchase or otherwise arrange to carry the following:
 - a. All-Risk Property Insurance to insure the facility itself (including costs of replacement of the buildings and equipment) in an amount equal to the facility's replacement cost, or the maximum amount available, whichever is less;
 - b. Comprehensive General Liability Insurance, with minimum limits of \$25 million per occurrence and \$25 million in the aggregate;
 - c. Environmental Impairment Liability Insurance, with minimum limits of \$10 million.
 - d. Nuclear Energy Liability Insurance, with minimum limits equal to \$25 million.
7. Site community compensation is referenced in two ways in state law. First, certain types of compensation are explicitly required, such as the payment of real property taxes, and annual payments during facility operation. Other forms of compensation and impact payments are left to negotiations between the site community and the facility operator, and may include property value protections, infrastructure improvements, and large, one-time community payments.
8. State law requires that in addition to the payments for property taxes, the annual operating fees, and any negotiated agreements, the operator also pay \$150,000 per year, pro rata, to the site community during the period commencing with the opening of the facility and ending five years after the issuance of a facility license. For the purpose of this analysis, it is assumed that litigation will delay the facility opening for two years.
9. See description of various community compensation and impact payments in Endnote 7.
10. A "neighboring community" is defined in state law as a community, other than a site community, which according to the most recent census, has at least 20% of its population residing within three miles of any facility site. The statute specifies the type and level of payments to such a community.

Appendix C
PLCC Estimates for the Retrieval of Long-lived LLRW

Appendix C

PLCC Estimates for the Retrieval of Long-lived LLRW

C-1 INTRODUCTION

The purpose of this appendix is to provide the PLCC estimate for retrieving long-lived radioactive waste from LLRW disposal facilities after a 300-year post-closure period. The PLCC estimates consist of the capital and operating costs for constructing a new canister receiving and packaging facility; excavating the disposal vaults and retrieving the canisters; inspecting and packaging the canisters, including repackaging 5% of the retrieved canisters; preparing the canisters for shipment; and restoring the site. Estimates are presented in first quarter 1994 dollars and use the same administration, utilities, supplies and materials rates as the operational disposal facilities. Transportation and re-disposal costs are not estimated because they cannot be defined at this time. A summary of the PLCC retrieval estimate is shown in Table C-1.

The scenario for retrieving long-lived LLRW is developed in accordance with Massachusetts law M.G.L. c.111H s.46 which requires that any disposed waste must decay to an innocuous level before the institutional control period ends. This law states:

... the institutional control period shall not be less than the minimum time required for any LLRW present at the site to decay to the maximum concentrations above natural background levels permitted to be released into the air or water in unrestricted areas under federal and state law ...

Using this criteria, it is assumed that the institutional control period is 300 years and any LLRW that has not decayed to an acceptable level must be retrieved. No assumptions have been formed for the disposition of the waste after retrieval. Accordingly, the Commonwealth of Massachusetts would use whatever technological advancements have been made during the post-closure period for disposing the retrieved LLRW.

The scenario for waste retrieval in this study is for the sole purpose of providing a basis for this cost estimate to be used as a tool in evaluating waste management options. Given the uncertainties presented by a 300-year time lapse, the actual retrieval activity might be different from that described here. Therefore, these PLCC estimates may vary significantly from actual costs and do not represent an engineering design cost analysis.

This appendix is divided into four sections. Section C-1 is the background and purpose for estimating the cost of retrieving the long-lived LLRW. Section C-2 is a description of the retrieval facilities and details the assumptions used for the waste retrieval process as a basis for the PLCC. Section C-3 describes the cost estimating method and Section C-4 discusses the conclusions.

Table C-1. PLCC Summary Costs for Retrieval.

	SMALL (x\$1000)x	MEDIUM (x\$1000	LARGE (x\$1000)	X-LARGE (x \$1000)
1.0 Vault Excavation/Retrieval				
1.1 Clear and Grub	4	5	7	42
1.2 Excavate cap	87	119	185	1,123
1.3 Remove roof panels	133	187	297	1,741
1.4 Retrieve/transport waste canisters	4,121	5,818	9,212	54,057
1.5 Utilities/Supplies	553	731	1,558	5,198
Subtotal direct costs (Items 1.1-1.5)-	4,897	6,860	11,257	62,161
1.6 Contractor overhead (field costs, Items 1.1-1.5)	979	1,372	2,251	12,432
Subtotal excavation/retrieval	5,877	8,233	13,509	74,594
1.7 Administration (FTE)	2,183	2,236	4,906	12,227
1.8 Construction management (Items 1.1-1.6)-	1,175	1,647	2,702	14,919
1.9 Contingencies (Items 1.1-1.8)	2,309	3,029	5,279	25,435
Total Excavation/Canister Removal (Item 1.0)	11,544	15,144	28,398	127,174
2.0 Facility Construction				
2.1 Canister Packaging Facilities				
2.1.1 Site Development	2,688	2,933	3,717	8,867
2.1.2 Administration	768	810	1,114	1,777
2.1.3 Canister Receive and Inspect	2,761	2,854	4,068	6,885
2.1.4 Canister Packaging and Transfer Transfer	4,840	4,840	6,150	9,223
Subtotal direct costs (Item 2.1) (Item	11,056	11,437	15,049	26,753
2.2 Contractor overhead (Field costs, Item 2.1) 2.1)	2,211	2,287	3,010	5,351
Subtotal facility construction (Items 2.1-2.2)	13,267	13,724	18,059	32,103
2.3 Administration (FTE)	735	803	911	2,553
2.4 Construction Management (Item 2.1 and 2.2) 2.2)	2,653	2,745	3,612	6,421
2.5 Contingencies (Items 2.1-2.4)	4,164	4,318	5,646	10,269
Total Facility Construction (Item 2.0)	20,820	21,589	28,228	51,347
3.0 Canister Packaging Operations				
3.1 Administration (FTE)	3,088	3,140	7,214	20,601
3.2 Materials	1,465	2,065	3,272	19,191
3.3 Utilities/Supplies	1,767	2,588	5,399	18,899
3.4 Maintenance	1,031	1,048	2,205	5,108
Total Packaging Operations (Item 3.0)	7,351	8,840	18,090	63,799
4.0 Site Closure				
4.1 Decommission Waste Packaging Facilities				
4.1.1 Administration	230	243	334	533
4.1.2 Canister Receive and Inspect	1,381	1,427	2,034	3,443
4.1.3 Canister Packaging and Transfer Transfer	1,452	1,452	1,845	2,767
4.1.4 Restore site	47	59	87	363
Subtotal Decommissioning (Item 4.1) (Item	3,110	3,181	4,300	7,106
4.2 Vault Closure				
4.2.1 Place roof panels	160	227	359	2,105
4.2.2 Cap material/cell backfill	180	253	401	2,355
4.2.3 Concrete seal	276	390	618	3,625
4.2.4 Imported material	29	38	59	304
4.2.5 Restore disturbed areas	8	11	13	126
4.2.6 Restore vegetation	13	17	26	149
Subtotal Cell Closure (Item 4.2) (Item	666	937	1,475	8,664
4.3 Contractor overhead (field costs, Items 4.1 and 4.2)	755	824	1,155	3,154
Subtotal site closure (Items 4.1-4.3) (Items	4,531	4,941	6,930	18,924
4.4 Administration (FTE)	970	1,038	1,404	1,956
4.5 Utilities/Supplies	157	181	288	1,016
4.6 Construction Management (Items 4.1- 4.3) 4.3)	906	988	1,386	3,785
4.7 Contingencies (Items 4.1-4.6)	1,641	1,787	2,502	6,420
Total Site Closure (Item 4.0)	8,205	8,935	12,510	32,101
TOTAL RETRIEVAL COSTS	47,919	54,509	85,224	274,421
UNIT COST (x \$1000 / canister)	4.95	3.98	3.93	2.16
UNIT COST (x \$1000 / cu ft)	0.09	0.07	0.07	0.04

C-2 DESCRIPTION OF RETRIEVAL FACILITY

C-2.1 Design Basis

The following assumptions are used as a guide for preparing a PLCC estimate for retrieval of long-lived waste. The conditions for the retrieval estimate, such as the vault configuration, work shifts and time-value of money, are assumed to be the same as for the disposal estimate.

- 50% of LLRW is short-lived; 50% of LLRW is long-lived and was segregated in separate disposal vaults. Therefore, half of the disposal cells are exhumed.
- Vaults containing long-lived LLRW are exhumed after a 300-year institutional control period. The canisters are retrieved, inspected, and readied for shipment. The cells are reused for disposal of onsite materials. The site is restored to its condition prior to opening the vaults.
- PLCC estimates only apply to waste retrieval and site restoration, not to re-disposal or transportation to another location.
- Waste retrieval, canister packaging, and site restoration takes a maximum of 5 years.
- Only part of the cap material is removed from the disposal vaults containing long-lived LLRW to permit entry from the top. The cap material is removed from the top of the cells, but the cap sideslope remains in place.
- Access to cells is by a 14-foot-wide perimeter haul road built on top of the cap.
- Excavated vault materials (backfill, concrete roof panels, or other cell material which is not contaminated) are stored onsite during retrieval and will be disposed of onsite.
- The concrete panels making up the cell roofs are removed by an overhead crane. Panels are placed into an adjacent evacuated cell for disposal as they are removed.
- Waste canisters in each cell are removed by an overhead crane, placed on surface transport vehicles, and sent to an onsite receiving and packaging facility.
- A packaging facility is constructed onsite to: receive, handle, inspect and assay retrieved canisters; overpack canisters as needed; and process secondary wastes.
- Waste handling capacities and equipment demands for the packaging facility assumes that 5% of the retrieved waste needs repackaging.
- All waste will remain in the original waste canisters. Canisters requiring repackaging will not be opened before being be overpacked in larger canisters.

- Overpack canisters are concentrically square with the retrieved canisters, with outside dimensions of 8.5 x 6.5 x 6.5 ft³ and 9-inch-thick concrete walls. The void and top of all canisters are sealed with grout.
- All retrieved waste canisters are labeled, manifested, and sent to the laydown area.
- Exhumed disposal cells are filled with the sand backfill remaining after the canisters are removed, concrete roof panels, and excavated cap material. Clean soil is brought to the site to fill any remaining cell volume. The top of each cell is sealed with one foot of concrete.
- The exhumed vaults will be capped with four feet of borrow material contoured with the slopes of the original cover and the vegetation will be restored to pre-excavation conditions.
- Retrieval, inspection, and repackaging activities will generate secondary waste equivalent to 2% of the retrieved waste volume. This waste will be grouted into empty concrete overpack canisters.
- No leakage of radioactivity to the outside of the cells has occurred and no environmental investigations or restoration of soil or groundwater is required at the site.
- Retrieval facilities are decontaminated and demolished after all canisters have been packaged. The overall site is restored to conditions prior to waste retrieval.

C-2.2 Description of Facility

The conceptual LLRW retrieval facility is comprised of three major components: the retrieval area, a packaging facility, and a laydown area. An oblique view of the conceptual vault excavation and retrieval area is shown in Figure C-1. The conceptual canister receiving and packaging facility layout is shown in Figure C-2.

The retrieval area consists of the area at and around the vaults that will be excavated to facilitate waste canister retrieval. The retrieval area contains the excavated vaults, working areas for removal activities and equipment, and stockpiles for temporary staging of excavated and/or borrow material. After retrieval of the waste canisters, the exhumed cells will be used for disposing of the roof and cap materials. The grout plant associated with the packaging facility can be used to supply concrete to seal the vault cells during closure.

For waste retrieval, the caps of the vaults will be removed. A perimeter road will be built around each vault to be exhumed. An overhead crane will lift off the concrete covers, and then lift out each canister. The empty vaults, used to dispose of excavated construction material, will be capped with four feet of earthen material.

FIGURE C-1. OBLIQUE VIEW OF VAULT EXCAVATION AND RETRIEVAL AREA

FIGURE C-2. PLAN VIEW OF CANISTER RECEIVING AND PACKAGING FACILITY

SCALE=1"=100'

The canister receiving and packaging facility consists of areas for administration; security; truck receiving and wash down; canister inspection and assay; canister repackaging; an analytical laboratory for engineering, health physics, and site monitoring; a grout plant; maintenance building; warehousing; parking; secondary waste treatment; canister storage; and processed canister laydown area. The administration area includes offices, a reception area, multi-use rooms, a records vault, restrooms, lunchroom, storage, and mechanical and electrical equipment area. All of the necessary facilities to support waste retrieval will need to be built. After all waste canisters have been packaged, the facilities will be decontaminated and decommissioned.

The laydown area is a temporary pad where all canisters are held prior to shipping. The area has an underlying drainage system and storm-water retention pond. Once the canisters have been removed, the laydown area will be restored and re-vegetated.

C-2.3 Description of Functions and Operations

The functions and operations described below are used as a basis for developing the PLCC estimate and do not necessarily represent a method that will be used by Massachusetts.

C-2.3.1 Canister Retrieval. The process functional diagram in Figure C-3 illustrates the vault excavation, canister retrieval, and site restoration processes, and indicates the acreage, excavation quantities, and the amount of restoration materials necessary for each facility size. The vault and stockpile areas will be cleared and grubbed. The earthen cap on the top of the vaults will be removed, and the material will be temporarily stockpiled on site. Most of the sideslope of the caps will remain intact and be used as a base for the access road on the vault.

After the cap is removed, operations will proceed cell-by-cell for canister retrieval. The roof panels will be lifted off by an overhead crane and placed in an adjacent, empty cell for disposal. Canisters also will be lifted out by an overhead crane and placed on waiting vehicles to be transported to the packaging facility. Sand formerly used as void fill will remain in the cells.

Closure of the cells and vaults will proceed contemporaneously with canister retrieval. After the roof panels have been placed on the compacted sand backfill in an emptied cell, the remaining void will be backfilled with the stockpiled cap material and with additional borrow material. Each cell will be sealed with a concrete cap. The concrete will be mixed onsite at the grout plant at the packaging facility. After the cells have been backfilled and sealed, a four-foot earthen cap will be placed over each excavated vault. The cap will be graded to the contours of the original cap and all disturbed areas will be restored.

C-2.3.2 Canister Packaging. The process functional diagram in Figure C-4 shows the canister receiving and packaging facilities process, as well as the material quantities and number of canisters for each facility size. All of the canisters will be brought from the waste retrieval area to the packaging facility and will remain unopened throughout processing. Canisters will be staged as needed at the truck receiving and washdown area and will be inspected for damage or deterioration, and assayed for radiologic integrity. It is assumed that five percent of the canisters will not pass inspection. These 5% will be placed in overpack canisters. After the smaller canister is placed into the overpack canister, any remaining void and the top will be sealed with

grout. Each canister, whether the original or the overpack, will be labelled and manifested. They will be transported to the laydown area and stacked in parallel rows, two wide and three high.

Secondary waste generated throughout the canister retrieval process and packaging includes contaminated personal protection equipment, wash water, and laboratory materials. This waste will be mixed with an equal volume of grout and placed in overpack canisters. Secondary waste canisters will be labelled, manifested and staged in the canister laydown area.

After completing retrieval operations, the packaging facility will be decontaminated and demolished, and site utilities will be decommissioned. Materials and equipment will be recycled or disposed appropriately. The site will be restored to conditions prior to waste retrieval.

C-3 RETRIEVAL COST ESTIMATES

The PLCC retrieval estimate was developed with the construction cost estimating program previously used for the operational disposal facilities. Labor, supplies, utilities, and material rates are the same as those used for the operational disposal facilities. Contractor overhead, administration, construction management, and contingencies are listed as separate items. For the applicable WBS elements, contractor's profit is 25% of the construction and materials handling costs; contractor overhead is 20% of the construction costs; construction management is 20% of construction labor and material costs; and contingencies are 25% of administration and all construction costs. Construction activities are assumed to be 240 days per year, one-shift per day for the small facility, and two shifts per day for the other three facilities. Canister retrieval and processing will operate for two shifts per day.

C-3.1 WBS-1 Vault Excavation and Canister Retrieval

WBS-1 covers activities related to excavating the vaults and retrieving the canisters. This includes site development (utilities, access roads, and water), clearing and grubbing, excavating the vault cap, removing roof panels, and retrieving the waste canisters. These include all costs for equipment, labor, maintenance, supplies, and contractor's profit. Administration (FTE) consists of engineering oversight, site and health physics monitoring, and QA/QC activities. The FTEs during excavation and retrieval are 15, 16, 24, and 34, for the small, medium, large, and extra-large facilities, respectively. The cost and time estimates for site preparation and excavation are based on current estimating factors from the construction industry. Similarly, the estimates for the removal of roof panels and canister retrieval assume present-day technologies and no unusual problems during retrieval operations. Roof panels weigh 13 tons each and are assumed to be removed and placed at 1 per hour. Canisters weigh approximately 10 tons each and it is assumed that one crew can retrieve and load 7.5 per day. For the larger facilities, more crews are needed to complete retrieval operations within the desired time frame. The small and medium facilities assume three retrieval crews and completion of retrieval operations in 1.76 years; the large facility assumes six retrieval crews and completion of retrieval operations in 2.78 years; and the extra-large facility assumes 16 retrieval crews and completion of retrieval operations in 4.08 years. Activities such as backfilling the cells are concomitant with retrieval actions.

NODE	①	②	③	
ACTIVITY	SITE DEVELOPMENT	EXCAVATE VAULT CAP	REMOVE ROOF PANELS	RE
QUANTITY	Acres	Cu. Yd.	Number Of Panels	C/N/C
SMALL	4.0	40.400	1.122	
MEDIUM	5.4	55.000	1.584	
LARGE	8.2	84.500	2.508	
EXTRA LARGE	47.8	493.000	14.718	

FIGURE C-3. PROCESS FUNCTIONAL DIAGRAM FOR VAULT

④	⑤	⑥	⑦	⑧	⑨
RETRIEVED WASTE CANISTERS	COMPACT SAND	BORROW FOR CELL BACKFILL	CONCRETE CELL COVER	RESTORE DISTURBED AREAS	RESTORE CAP VEGETATION
Number of canisters	Cu. Yd.	Cu. Yd.	Cu. Yd.	Cu. Yd.	Acres
9,537	5,040	4,794	3,170	13,200	4.0
13,464	7,110	8,808	4,470	17,650	5.4
21,318	11,260	16,527	7,070	27,038	8.2
25,103	66,060	99,888	41,480	139,860	47.8

**VAULT EXCAVATION
AND
CANISTER RETRIEVAL**

NODE	①	②	③	④	⑤
ACTIVITY	INPUT	PASS	FAIL	SAND	CEMENT
TOTAL DEMAND	Retrieved Canisters	Canisters To Laydown Area	Canisters For Packaging	Cu. Ft.	Cu. Ft.
SMALL	9,537	9,060	477	9,637	1,230
MEDIUM	13,464	12,791	673	13,605	1,737
LARGE	21,318	20,252	1,066	21,557	2,752
EXTRA LARGE	125,103	118,848	6,255	126,459	16,144

FIGURE C-4. PROCESS FUNCTIONAL DIAGRAM

CANISTER
LAYDOWN
AREA

OUT
WNT

ER
NG/
NG

PROCESSED
WASTE
CANISTERS

TO
LAYDOWN AREA

MANIFESTED
CANISTER TO
LAYDOWN AREA

⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
WATER	CANISTER	SECONDARY WASTE	CEMENT FOR SECONDARY WASTE	OUTPUT FOR SECONDARY WASTE	OVERPACK CANISTERS FOR SECONDARY WASTE	PROCESSED CANISTERS	CANISTERS FOR SHIPMENT
Gallons	Overpack Canister	Cu. Ft.	Cu. Ft.	Cu. Ft.	Canister	Canister	Canister
6.885	477	11.902	11.902	23.804	153	630	9.690
9.720	673	16.803	16.803	33.606	215	888	13.679
5.400	1.066	26.606	26.606	53.210	341	1.407	21.659
10.345	6.255	156.129	156.129	312.257	1.998	8.253	127.101

FOR CANISTER RECEIVING AND PACKAGING FACILITIES

Cost estimates for vault excavation and canister retrieval were determined in the following manner. The necessary crew and equipment demands were determined for a unit amount of work: 100 acres for clearing and grubbing; 10,000 cubic yards for cap excavation; 100 panels for the roof panel removal; 100 canisters for canister retrieval; 100 cells for cell backfill; 10,000 cubic yards for cap restoration; and 100 acres for site restoration. Once the equipment and labor demands were determined for a task, the quantity of materials to be moved were then multiplied by the hourly cost per unit of material for the equipment and crew to perform the task. For a small disposal vault, 9,537 canisters multiplied by the unit cost of canister retrieval (\$345.68) equals \$3,296,751.

C-3.2 WBS-2 Facility Construction

The estimates for constructing the receiving and packaging facility includes the costs for site development, overhead, administration, contingencies, and construction management. The items of WBS-2 are for building a new waste-packaging facility, canister receiving and packaging area, engineering and health physics laboratory, grout plant, canister laydown area, and haul road.

The cost estimates for facility construction use the same information for the operational disposal facilities. The sizes of the different components of a front-end facility were determined for the new functions with emphasis on sizing the grout plant, the canister packaging and inspection areas, and the truck receiving and wash down areas. Due to the time frame allowed for completion of the retrieval activities and number of canisters to be processed, the small and medium facilities have two truck receiving bays, the medium facility has 4 truck receiving bays and the extra-large facility has 8 truck receiving bays. Fuel and utilities demands are also increased to account for the higher processing rates. Administration (FTE) burden is for project management, engineering, QA/QC controls, and security. The FTEs for the packaging facility construction are 10, 11, 12, and 19, for the small, medium, large and extra-large facilities, respectively.

The canister laydown area is configured as a rectangular pad comprised of a polyethylene-coated geofabric, 0.5 feet of sand and 0.5 feet of aggregate. Canisters are stacked 2 wide and 3 high, with 12-foot aisles and a 20-foot perimeter road. A stormwater retention pond designed for a maximum capacity of a 10-year, 24-hour storm is included in the laydown area cost estimate. The haul road from the canister retrieval area is assumed to be one-quarter mile long for the small, medium, and large facilities and one-half mile long for the extra-large facility. The road is 40 feet wide and composed of eight inches of aggregate base and six inches of crushed gravel.

C-3.3 WBS-3 Waste Packaging Operations

The estimates for operations in WBS-3 include costs for administration, materials, utilities, supplies, and operations for processing the waste canisters after they have been retrieved. Operations expenditures include mechanical maintenance and equipment parts and are calculated at 7% of the capital costs. Administration costs are for site management and support; technical, engineering and QA/QC staff for canister processing; and labor for the handling and transfer of processed canisters. Supplies, salaries and utilities are calculated on an annual basis and are given the same annual escalation factor as the canister retrieval activities to allow enough time for

complete canister retrieval and processing. These escalation factors are 1.76 years for the small and medium facilities; 2.78 years for the large facility; and 4.08 years for the extra-large facility. Expenditures for sand, cement, and canisters are the total costs for the grout for sealing the overpack canisters, cement for processing the secondary waste, and all overpack canisters. Staffing demands are based on 2 shifts per day, 240 days per year. FTEs are 29, 30, 44, and 89, for the small, medium, large, and extra-large facilities, respectively.

C-3.4 WBS-4 Site Closure

Closure costs are for decommissioning the packaging facility, which includes the administration area, canister receiving and packaging area, and the grout plant. Closure costs for the excavated cells, disposal of the cell materials, and site restoration – although concomitant with retrieval operations – are calculated as separate costs and also presented in WBS-4. This includes compacting the sand backfill, placing roof panels into the emptied cells, filling remaining cell void, installing the concrete seal, importing additional cap materials, removing utilities, and revegetation of the site.

As with the vault excavation and canister retrieval costs, the site closure costs were developed by determining crew and equipment demands based on a unit activity of work. Since the roof panels were removed and placed as one task but considered both as a retrieval and closure activity, one-half of the cost is applied during excavation and one-half of the cost is applied during closure. Also, sand backfill remaining in the cells after canister retrieval must be levelled and compacted before placing the roof panels. The total cost for placing the roof panels is the sum of these two items. Excavated cap materials are put into the cells as backfill. An additional amount of material is required to completely fill the cells. The estimate for the backfill includes costs for moving the cap materials and imported borrow material. A one-foot-thick section of concrete is used to seal each cell. The cost of the concrete assumes that the onsite grout plant can be used for mixing concrete. Site restoration includes four feet of borrow material, and replacing the topsoil stockpiled from the cap at the beginning of the excavation phase. Restoration of site vegetation is by reseeding the area with grasses, mulch, and fertilizer. The FTE burden is for engineering oversight, technical and QA/QC controls, site monitoring and security. Construction management, contractors profit, and contingencies are the same as WBS-1 and WBS-2. The FTEs are 13, 14, 19, and 28, for the small, medium, large, and extra-large facilities, respectively.

C-4 CONCLUSIONS

The PLCC estimates are summarized in Table C-2. Total costs are from \$47,919,000 to \$274,421,000. The unit rates range from \$90 to \$40 per cubic foot based on the volume of the retrieved waste and processed secondary wastes. The line graph of Figure C-5 compares the total expenditures and the unit rates for processing the retrieved wastes. The bar graph in Figure C-5 plots the costs of each element of the PLCC estimate against the unit rate per canister (\$4,950 to \$2,160). The costs of retrieving LLRW from a disposal facility may vary significantly from these cost estimates due to a number of factors, such as markups, changes in labor or material rates, regulatory mandates, and available future technologies. Therefore, these estimates represent a broad-based analysis to be used only as guidance in evaluating LLRW management options.

The highest costs of the retrieval process is the vault excavation, canister retrieval and construction of the new canister packaging facilities. These costs are about 66% of the total estimated retrieval expenditures. As with the operational disposal facilities' PLCCs, the unit rate decreases significantly between the facility sizes due to the economy of scale for the costs distributed over the entire volume of processed materials.

Assuming institutional control ceases before the long-lived LLRW decays to desirable levels, the unit rate of disposal in 1994 dollars will increase by an average of \$68 per cubic foot for the four sizes of disposal facilities. Although the estimated unit rate for the retrieval PLCC is about one-fifth of the original disposal estimate, the total estimated unit rate for retrieval could be much higher if the cost of transportation and redisposal of the wastes were considered. However, these costs were not included in the PLCC estimate since the redisposal scenario cannot be defined at this time.

Table C-2. Summary of PLCC estimates for long-lived LLRW retrieval.

Work Breakdown Structure Element	Small	Medium	Large	Extra-large
Excavation and Canister Removal	\$11,544,000	\$15,144,000	\$26,396,000	\$127,174,000
Canister Packaging Facilities	\$20,820,000	\$21,589,000	\$28,228,000	\$51,347,000
Canister Packaging Operations	\$7,351,000	\$8,840,000	\$18,090,000	\$63,799,000
Site Closure	\$8,205,000	\$8,935,000	\$12,510,000	\$32,101,000
Total Retrieval Costs	\$47,920,000	\$54,508,000	\$85,224,000	\$274,421,000
Unit cost per canister ¹	\$4,950	\$3,980	\$3,930	\$2,160
Unit cost per ft ³ waste ²	\$90	\$70	\$70	\$40

1. Number of canisters includes retrieved canisters and processed secondary waste:
small - 9,690; medium - 13,679; large - 21,659; extra-large - 127,101

2. Waste volume includes retrieved and secondary wastes:
small - 548,804 ft³; medium - 783,606 ft³; large - 1,253,210 ft³; extra-large - 7,312,257 ft³.

Figure C-5. PLCC retrieval cost comparisons.

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