CONCEPTUAL DESIGN AND ECONOMIC ANALYSIS OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES FOR THE STATE OF TEXAS

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ABSTRACT

As part of their effort to develop a low-level radioactive waste disposal facility in the State of Texas, the Texas Low-Level Radioactive Waste Disposal Authority (the Authority) formulated a design basis, developed conceptual designs, estimated costs, and evaluated economics for three conceptual disposal facilities. All three facilities incorporate concrete as an engineered material in disposal units.

The design basis consists of the basic requirements and assumptions which govern the design of the disposal facility. The conceptual designs consist of drawings, descriptions of facilities and operations, and estimates of material, equipment, and workforce requirements. The costs were calculated from estimated resource requirements and respective unit costs for the major periods of the facility life. Unit disposal costs were found through an economic evaluation of estimated costs.

INTRODUCTION

The Texas Low-Level Radioactive Waste Disposal Authority (the Authority) has developed three conceptual designs for a waste disposal facility which will receive low-level radioactive waste (LLW) generated in the state of Texas. All three conceptual facilities incorporate additional barriers and enhanced features in order to provide alternatives to the simple shallow land disposal of the waste. This paper presents major elements of the design basis developed for the design project, describes the conceptual facilities, shows estimated costs, and discusses the economics of disposal at the facilities.

DESIGN BASIS

The design basis consists of the basic criteria, requirements, conditions, properties, and assumptions which govern the design, construction, operation, closure, and post-closure maintenance of the disposal facility. The design basis is divided into regulatory requirements, site conditions, construction materials, source term and assumptions.

General Elements of Design Basis

The disposal facility was assumed to be designed and constructed in accordance with standard engineering practices and industry standard codes and specifications.

While no specific site for the disposal facility has yet been identified, the general characteristics of western Texas were assumed where information about site conditions was necessary. Ultimately, the disposal site will be characterized in terms of its

- Location and demography
- Land use patterns
- Geomorphology
- Geology/Hydrology
- Geotechnical/Geochemical characteristics
- Meteorology
- Site stability

Regulatory Requirements

All requirements of Parts 45 and 21 of the Texas Regulations for Control of Radiation (TRCR) must be satisfied to license the facility(1). These regulations are analogous to U.S. NRC's 10 CFR Parts 61 and 20. Briefly stated, the disposal facility must be designed, constructed, operated, closed, and maintained in such a way that:

- no member of the public will receive an annual dose exceeding an equivalent of 25 millirem to the whole body.
- releases to the general environment will be as low as reasonably achievable.
- inadvertent intruders will be protected to the extent that no intruder will receive an equivalent whole body dose in excess of 500 mrem/year.
- radiation levels in unrestricted areas must not result in a dose rate in excess of 2 mrem per hour to a person continuously present in the area.
- occupational dose rates to persons in restricted areas will not exceed 5 rem per calendar year.
- operations at the disposal facility must keep exposures as low as reasonably achievable.

Numerous additional technical requirements are placed on the design, construction, operation, closure, and monitoring of the facility by TRCR Parts 45 and 21.

The conceptual designs capitalize on the opportunity to dispose of unstabilized Class A waste together with Class B and C waste if physical stability is provided by a structure. Subsequent discussions with regulatory authorities have revealed that a substantial burden of proof will be placed on any applicant who relies on long-term stability of a structure to satisfy performance objectives.

No effort was made to satisfy regulations for the disposal of hazardous waste which might apply if the LLW also exhibits hazardous characteristics or contains listed materials.

Waste Source Term

The annual disposal rate was estimated to be not more than 1.2×10^5 ft^3/yr (3.4×10^3 m^3/yr). The facility life is 30 years so that the disposal capacity is about 3.6×10^6 ft^3 (1.0×10^5 m^3). Waste volumes were estimated based on surveys of Texas LLW generators(2,3).

Radiological characteristics of individual waste streams were assumed to be those presented in the final Environmental Impact Statement (EIS) on 10CFR61(4). The distribution of volume among shipping containers was based on the data base generated in support of the draft EIS(5) and is presented in Ref. 6.

Approximately 93 percent of all waste volume was estimated to be Class A, much less than 1 percent to be Class B, and about 7 percent to be Class C. It was further estimates that less than 4 percent of the waste volume would be comprised by odd-shaped or over-sized items or containers which might require special handling and disposal.

All waste was assumed to satisfy all requirements of TRCR Parts 45 and 21. Specifically, this means that Class B and C waste will arrive at the disposal facility in a physically stable waste forms or in qualified high integrity containers. Class A waste with high gamma levels were also assumed to be in a physically stable waste form.

The waste was assumed to be free of heavy metals which might cause it to be considered mixed waste. The possibility of destroying organic waste constituents through incineration was also investigated.

CONCEPTUAL FACILITY DESCRIPTIONS

General Description

The three disposal facilities conceptually designed were:

- o below-ground modular concrete canisters, supplemented by below-ground vault.
- o above/below-ground modular concrete canisters, supplemented by below-ground vault.
- o above-ground vault.

These conceptual design are described and analyzed in detail in Ref. 6.

The conceptual below-ground and above/below-ground modular concrete canister disposal facilities rely on the disposal of most of the waste in concrete canisters. Waste received at the disposal facility will be placed in the concrete canister at a waste processing building. Although the shipping containers will be removed from shielded casks (if applicable), the waste itself will not be removed from the shipping containers. Once the waste is in the canister, void spaces between the shipping containers will be filled with grout and the canisters will be transported to the disposal area.

For the below-ground modular concrete canister disposal facility, the filled canisters will be disposed in an excavated trench below the natural grade. Canisters with high surface gamma levels, or containing Class B or C waste will be placed on the interior and bottom portions of each disposal unit. Large and odd-shaped waste items or packages will be placed in a below-ground vault.

In the above/below-ground concrete canister disposal facility, the nature of the waste will determine the disposal method. Class A waste in canisters with low surface gamma activity will be placed above-ground. Canisters of Class A waste having high surface gamma activity and canisters containing Class B and C waste will be placed in a below-ground canister vault. Large and odd-shaped waste items will be placed in a below-ground vault.

All waste is covered with earth cover systems whose composition and thickness vary with the disposal technology utilized. All cover systems are designed and constructed to minimize the potential for the infiltration of water into the disposal units.

The conceptual above-ground vault facility consists of concrete vaults constructed above natural grade. Once the waste is in the disposal cell, void spaces between the waste containers will be filled with sand. Class A waste packages which do not have high surface gamma radiation will be placed in the disposal cells without restriction. Class A waste packages with high surface gamma radiation and Class B and C waste will be constrained to the bottom 6.0 ft (1.8 m) of the interior cells of a given above-ground vault.

The above-ground vaults in this conceptual design are closed by the placement of a concrete roof over each backfilled cell. Once all cells in a vault have been provided with roofs, the vault is completely closed. No earthen cover is provided over the above-ground vaults.

In each type of disposal unit there will be at least 16.5 ft (5 m) of cover material, including Class A waste over the Class B and C waste. This configuration satisfies the requirement for inadvertent intruder protection without relying on the physical stability of the structures in which the waste is disposed.

For the two modular concrete canister facilities, all compactible waste received at the facility is assumed to be compacted. No waste compaction is assumed for the above-ground vault facility.

Physical Characteristics

For all three conceptual facilities, a 100-ft (30-m) buffer zone surrounds the disposal area. Buildings and work areas which involve very small or no amounts of radioactive material are all located in the buffer zone. These include the administration/health physics/security/change building, general warehouse, concrete batch plant, canister fabrication/holding building, guard house, truck wash, clean construction material storage area, excavation stockpile area, water tank, parking areas, access roadway, fencing, and gates. Also located in the buffer zone are areas for the receipt and inspection of waste arriving at the site. The remaining structures handle radioactive materials on a regular basis and are located in the disposal area. These include the laboratory, decontamination building, waste processing building, temporary waste storage building, equipment storage and maintenance building, disposal vaults or units, drainage retention ponds, access roadway, fencing, and gates.

A tabulation of physical characteristics is presented in Table I for all three conceptual LLW disposal facilities.

TABLE I

Physical Characteristics of Three Conceptual Disposal Facilities

Characteristic	Below-Ground Modular Concrete Canister Disposal	Above/Below-Ground Modular Concrete Canister Disposal	Above-Ground Vault Disposal
Number of disposal units (ea.)	11	15	10
Disposal Area (ac.)	30	37	29
Disposal Unit Dimensions			
Length at base (ft)	400	400	400
Width at base (ft)	75	75	75
Depth at base (ft)	28.5	9.5	3.7
Cover system thickness (ft)	6.0	6.0	3.25[a]

[a] Steel reinforced concrete roof of the vault. No earthen cover system is provided.

Where canisters are used, the cover system is a total of 6.0 ft (1.80 m) thick and consists of five layers. Beginning at the top surface, the layers of the cover system and their functions are as follows:

- o 1.0 ft (0.30 m) of riprap for wind erosion control and intrusion barrier
- o 1.0 ft (0.30 m) of cobble/gravel for water erosion control and runoff conduit
- o 0.5 ft (0.15 m) of sand for moisture wick and runoff conduit
- o 2.5 ft (0.75 m) of clay for moisture barrier
- o 1.0 ft (0.30 m) of sand as a combination of backfill and to provide a working surface for subsequent construction

For the below-ground vaults, the cover system is 14.5 ft (4.40 m) thick. Beginning at the top surface, the cover consists of the following layers:

- o 1.0 ft (0.30 m) of riprap for wind erosion control and intrusion barrier
- o 1.0 ft (0.30 m) of cobble/gravel for water erosion control and runoff conduit
- o 4.0 ft (1.20 m) of compacted natural soil for mass
- o 1.0 ft (0.30 m) of sand for moisture wick and runoff conduit
- o 3.0 ft (0.90 m) of clay for moisture barrier
- o 1.0 ft (0.30 m) of sand to minimize migration of clay into sandy gravel below
- o 3.5 ft (1.10 m) of sandy gravel for mass

Operational Characteristics

The sequence of waste handling and processing activities is summarized as shipment inspection; waste processing, if applicable; temporary waste storage, if applicable; waste disposal; and disposal unit closure.

For the modular concrete canister disposal facilities, placement of the riprap layer is delayed until it has been demonstrated through surveillance that settlement of the cover system has ceased or is not likely to occur in the foreseeable future. During the surveillance period additional cover material can be added and the cover system can be reworked as necessary to maintain it in good condition.

Once the physical stability of the disposal units has been demonstrated, the final cover system can be placed. For above/below-ground concrete canister disposal, all spaces between adjacent disposal units are filled with acceptable fill material. This produces a single mound, over which the final layers of the cover system are placed at the appropriate time.

Closure of the below-ground vaults occurs after an individual disposal cell has been filled with waste and after the voids between waste packages or items have been backfilled with sand. The roof is placed over individual cells as they are filled. The exposed face of previous construction will be prepared for the new construction by sandblasting and other appropriate processes to remove foreign material and to provide a surface to which the new concrete can bond.

Closure of the above-ground vaults occurs after an individual disposal cell has been filled with waste and after the voids between waste packages or items have been backfilled with sand. The backfill sand is the bottom form for the placement of the concrete roof. The roof is placed over individual cells as with the below-ground vaults. When all sections and cells of a given above-ground vault have been closed by the construction of the roof, the vault has been finally closed. No further closure activities are required, other than routine maintenance of concrete and soil surfaces. When disposal operations cease, the surfaces between and surrounding the vaults will be stabilized and provided with riprap cover.

Manpower and Equipment Requirements

The total workforce at the disposal facilities varies with the period of facility life. As shown in Table II, the levels range from a maximum of 50 full time equivalent persons during disposal operations to a minimum of 3 full-time equivalent persons during the last 90 years of the long-term maintenance period.

The construction equipment required to conduct all site activities also depends on the period of facility life. The equipment requirements are tabulated in Table III, together with the useful service lives assumed for this equipment.

Environmental Monitoring Plan

An extensive environmental monitoring plan has been conceptually designed for the disposal facility to comply with requirements of the Texas Department of Health(7). The type and number of samples that will be taken, and the frequency of sampling for each conceptual facility are presented in Table IV. These monitoring plans address all common types of samples which could indicate contaminant release and migration. The types of samples to be taken include groundwater, air/gas, soil, flora, fauna, sediment, and surface water (if any).

ESTIMATES AND ECONOMICS ANALYSIS

On the basis of the conceptual designs described in the foregoing section, requirements for material, equipment and workforce were estimated for all periods of facility life. These quality estimates were used with respective unit costs to estimate costs. A schedule of costs was prepared, which was used together with financial data to evaluate the economics of the project. Each of these steps are discussed below.

Major Cost Components

Cost components are broken down into four sections: pre-operational costs, operational costs, closure costs and long-term maintenance costs. The pre-operational period spans a total of 10 years, beginning in 1982 when actual costs were first incurred by the Authority and ending in 1992 when disposal operations are projected to begin. Operational costs will be incurred during the actual

TABLE II

Onsite Workforce Requirements for Conceptual Disposal Facilities

Personnel	Full-Time Equivalent Persons Required During: Operations: Below-Ground Modular Concrete Canister Disposal	Above/Below-Ground Modular Concrete Canister Disposal	Above-Ground Vault Disposal	Closure
Site Manager	1	1	1	1
Secretaries	2	2	2	-
Security Chief	1	1	1	-
Security Staff	4	4	4	3
Health Physicists	1	1	1	-
Health Physics Technicians	2	4	6	1[a]
Superintendent	1	1	1	-
Construction Foreman	1	1	1	-
Construction Crew	2	2	6	-
Batch Plant Crew	2	2	2	-
Mechanic and Warehouseman	1	1	1	-
Crane Operator	1	1	2	-
Lab Technicians	4.5	4.5	6	-
Quality Control Technicians	2	4	8	1
Disposal Foreman	1	1	1	-
Disposal Crew	3	4	4	-
Operators	2	2	2	1
Riggers	1	1	1	-
Truck Drivers	-	-	-	1
Semi-Skilled Laborer	-	-	-	3[b]
Unskilled Laborer	-	-	-	-
TOTAL	32.5	37.5	50	11

a Two for above-ground vault disposal facility.
b Six for above-ground vault disposal facility.

TABLE III

Construction Equipment Requirements for Conceptual Disposal

Description and Useful Life(a) (years)	Operations: Modular Concrete Canister Disposal	Above-Ground Vault Disposal	Closure	Long-Term Maintenance
Track Type Tractor (10)	2	1	1	-
Grader Tractor (15)	1	1	1	-
Wheel Loader (10)	2	1	-	1
Dump Truck (5)	5	2	-	-
Super Compactor (30)	1	-	-	-
Mobile Concrete Plant (30)	-	-	-	-
Wheel Scraper (10)	2	1	-	-
Wheel Tractor Backhoe (10)	2	1	1	-
Farm Tractor (15)	1	1	1	2
Bibratory Roller Compactor (15)	1	1	1	1
Water Truck (10)	2	2	-	-
Heavy Duty Forklift (5)	5	5	-	-
Forklift (3)	9	9	-	-
Trenching Machine (10)	2	2	-	-
40-Ton Crane (10)	2	2	1	-
100-Ton Crane (10)	2	2	-	-
Controls for Crane (30)	-	-	-	-
Fire Truck (30)	-	-	-	-
Sedans (5)	5	5	-	-
Pick-up Truck (5)	5	5	1	2
4 X 4 Pick-up Truck (5)	5	5	1	-
Stake Bed Truck (5)	5	5	-	-
4 X 4 Suburban Truck (5)	5	5	-	-
10 Passenger Van (5)	5	5	-	-

(a) One of each item is required during the pre-operating period, except for above-ground vault, which has no super compactor.

operation of the facility which will last for 30 years. Closure and surveillance is planned to last 5 years with post-closure activities projected for 100 years through the institutional control period. Major cost items of each component are summarized in Table V.

Material Takeoffs

Comprehensive lists of buildings, equipment, personnel, materials, environmental samples, and other cost items are presented in Ref. 6 for the three conceptual facilities. Differences between the facilities appear mainly in estimates of construction, materials and operations, payroll during operations and closure, and monitoring requirements following the pre-operational period.

TABLE IV

Summary of Environmental Monitoring Program for Conceptual Disposal Facilities

Sample Description	Number of Locations	Annual Sampling Frequency[a]
Groundwater Sampling		
Offsite: Existing wells within 6 miles	2	4
Offsite: Down-gradient, transverse to flow	10	4
Buffer Zone: Down-gradient	3	4
Buffer Zone: Up-gradient	3	4
Disposal Area: Possible leachate in trenches	2 per disposal unit[b]	12[c]
Air Monitoring		
Site Boundary	6	4[d]
Disposal Area; trench gas	1 per disposal unit[b]	4[d]
Soil Sampling		
Offsite	3	4
Buffer Zone	8	4
Disposal Area	4 per disposal unit[b]	4
Sediment	1	1
Flora and Fauna		
Buffer Zone	6	2
Disposal Area	4 per disposal unit[b]	2
Food for Herbivores	4	2
Offsite	14	2
Surface Water Sampling		
Offsite	2	2
Buffer Zone	2	12
Disposal Area	1 per disposal unit[b]	12[c]

a Stated number of locations and sampling frequency begins with site characterization and continues through the first 10 years of long-term maintenance. In the eleventh through the twenty-fifth years of long-term maintenance, the annual sampling rate reduced by 25 percent, after which it is reduced to 50 percent until the hundredth year of long-term maintenance.

b Number of trenches grows from zero at commencement of operations to final number at cessation.

c Samples taken only if and when water is present.

d Weekly for gross alpha and gross beta count.

TABLE V

Major Cost Components by Period of Facility Life

Pre-Operational Costs	Operational Costs
Site Selection	Start-up of Facilities
Environmental Impact Statement	Construction of Disposal Units
Licensing	Equipment Maintenance
Permits	Payroll
Administration	Corporate Administration
Construction Management	Legal Fees
General Supplies	Environmental Monitoring
Legal Fees	Regulatory Costs
Construction	Consumables
Construction Equipment	Office Equipment
Engineering and Design	Surety Bond
Baseline Monitoring	Institutional Transfer Payments
Contingencies	Construction Equipment
Institutional Transfer Payment	

Closure Costs	Long-Term Maintenance
Disposal Unit Closure	Personnel
Personnel Costs	Construction Equipment
Construction Equipment	Fuel, Utilities and Materials
Monitoring	Monitoring
Fuel, Utilities, and Materials	Equipment and Vehicle Maintenance
Institutional Transfer Payment	Administration Costs
Government Administration	Regulatory Costs
Regulatory Costs	Contingencies
Contingencies	Health Department Fees

Unit Material and Labor Costs

Total estimated quantities were used in conjunction with unit labor, material, and equipment costs to estimate the total costs of the project. Unit costs taken from Ref. 8 were multiplied by appropriate city cost index values for El Paso, Texas, where applicable, to more closely estimate costs in the general vicinity of the probable site. The final unit price should result in an average price that, if compared to an actual bid, would seldom be below a low bidder or above the average of all bidders. Complete listings of unit labor and material costs are presented in Ref. 6.

Many of the pre-operational costs have been developed by the Authority and represent actual or projected costs incurred or expected to be incurred by the Authority.

Summary of Cost Estimate

The complete cost estimates are presented in Ref. 6 and are summarized by period of facility life in Table VI for the three conceptual facilities. These costs are useful for identifying significant differences between cost components of the three disposal facilities.

TABLE VI

Summary of Major Cost Components for Conceptual Disposal Facilities
(millions of 1986 dollars)

Period Cost	Below-Ground Modular Concrete Canister Disposal		Above/Below-Ground Modular Concrete Canister Disposal		Above-Ground Vault Disposal	
	Millions of Dollars	Percent of Total	Millions of Dollars	Percent of Total	Millions of Dollars	Percent of Total
Pre-Operating Costs	34	19	34	15	29	10
Operating Costs	108	59	137	60	185	64
Closure Costs	9	5	9	4	11	4
Long-Term Maintenance Costs	32	18	49	21	65	22
Total Costs	182	100	230	100	289	100

As seen for these results, the major cost components for all three facilities are those associated with the operational period and account for 55 to 65 percent of the total cost. Long-term maintenance is the second most costly component, comprising 15 to 25 percent of the total, followed by costs associated with pre-operations and closure.

Total costs for the three facilities range from $182 million for below-ground modular concrete canister disposal to $289 million for above-ground vault disposal. The major source of difference in the total life cycle costs is the extreme requirements for high quality in the concrete which is used above grade. These requirements increase the costs for above/below-ground modular concrete canisters and for above-ground vaults.

Economic Evaluation

Because money has value in time, it is necessary to account for the effects of inflation, the cost of money, and income taxes. The economics evaluation takes account of these factors so that all conceptual disposal facilities can be compared on a common basis. The most straight-forward measure of this cost is the cost per unit volume of waste disposed, or unit disposal cost. The unit disposal cost is expressed in terms of 1986 dollars per cubic foot of waste delivered to the site. Implicit in this measure is the assumption that the unit disposal cost will escalate with inflation.

Inflation and the time value of money act in concert to modify the cost components, depending on the timing of each expenditure. The present value, P, of a current cost, C, expressed in constant dollars with inflation, f, and cost of money, i, is given by:

$$P = C * \left(\frac{1+f}{1+i}\right)^j \qquad (1)$$

where j is the number of years into the future when the cost is expected to be incurred.

The cost estimates summarized in earlier sections of this chapter were evaluated using Eq. (1). The detailed description of the economics methodology is presented in Ref. 6. Discussions of similar economics methodologies are presented in Refs. 9 and 10.

The effects of taxes were also considered. If the operation is publicly funded, there are no tax effects. But, if it is a private operation, revenues remaining after the deduction of operating expenses must be further reduced by the payment of taxes. In this assessment it was assumed that the private operation is a wholly independent corporation without other similar enterprises. The effect of this assumption is to force developmental costs to be capitalized and subsequently amortized or depreciated, if appropriate. The after-tax earnings of the operation is found by subtracting the income tax obligation.

The marginal income tax rate for private corporations was assumed to have a maximum value of 34 percent.

Values of key financial parameters used in the public and private base cases for the economics analyses described in the previous section are presented in Table VII.

TABLE VII

Values of Key Financial Parameters for Public and Private Base Cases

Parameter	Public	Private
Cost of Debt (percent per year)	7.5	7.5
Return on Investment (percent per year)	N/A	20
Riskless Interest Rate (percent per year)	7	7
Inflation Rate (percent per year)	5	5
Fraction of Debt Funding (percent)	100	25
Marginal Income Tax Rate (percent)	N/A	34

For a public operation, the cost of money, i, can be considered to be the opportunity cost of money committed to this project. In other words, if money is withdrawn from the state treasury to fund the development of this facility, the state would lose revenues corresponding to the interest rate at which those funds could otherwise be invested. Typically, this is similar to the interest rate of very secure government securities, which over the past 50 years has averaged about 2 percentage points in excess of the inflation rate. Currently, for funds invested in government securities, the state of Texas is earning, on average, about 7.5 percent per year.

For a private operation, the cost of money is a measure of the profit a company would earn on its investments. The value of this "return on investment" is a matter of corporate policy and therefore improbably predicted with any certainty. However, for risky ventures, such as the disposal of radioactive waste, the return on investment would probably be no less than 20 percent per year, and could be as high as 30 or 40 percent per year.

As a result of the economic analyses described above, the present values of the major cost components were determined for the public and private cases.

The total unit disposal cost was calculated as the sum of two components: a unit charge to recover all development and operating costs and a surcharge to assure that funds will be available to close and maintain the facility throughout the institutional care period. The results are presented in Table VIII for the public and private base cases. The total unit disposal costs for the private facility are much larger than those for the public facilities. This is caused by two facts: (1) the revenues in the private case are taxable whereas those in the public case are not, and (2) the cost of money for a private operation is much higher than that for the public facility.

TABLE VIII

Comparison of Total Unit Disposal Costs for Conceptual Disposal Facilities

Conceptual Disposal Facility	Public Facility	Private Facility
Below-Ground Modular Concrete Canister Disposal	55	102
Above/Below-Ground Modular Concrete Canister Disposal	65	113
Above-Ground Vault Disposal	77	120

Because the economics methodology assumes that all costs and revenues escalate with the inflation rate, the total unit costs also escalate with inflation. For the below-ground modular concrete canister disposal facility, the disposal cost escalates at 5 percent per year from about $70 per cubic foot in 1992 to about $190 per cubic foot in 2011. Over the same time period, the disposal costs for above-ground vault disposal range from about $100 to about $270 per cubic foot. The disposal costs for the above/below-ground modular concrete canister disposal facility lie midway between these extremes, ranging from about $80 to about $220 per cubic foot.

Figure 1 represents the variation of the total unit cost for a public facility with changes in the assumed cost of money (interest rate on debt). The total unit cost is highest when the cost of money is high, as seems intuitive. For all conceptual disposal facilities, the total unit cost decreases as the cost of debt declines, as shown in the figure.

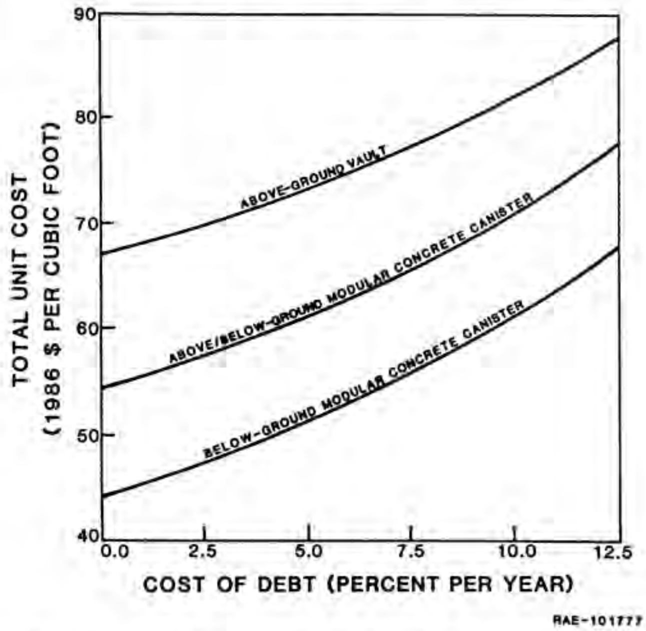

Fig. 1. Variation of Total Unit Cost with Cost of Debt for a Typical Publicly Owned Disposal Facility.

Similar variations of the total unit cost with changes in the rate of return on investment is observed for privately owned facilities. In general, the total unit cost will be lower if the cost of money is lower. Thus, assuming that the cost of debt is lower than the cost of equity (rate of return on investment), increases in the fraction of debt funding decrease the effective cost of money.

The sensitivity of the economics analysis to uncertainties and potential variations in the pre-operating and operating costs was investigated. The sensitivities of total unit costs to variations in operating costs are presented in Fig. 2 for all three publicly owned conceptual disposal facilities. If the operating costs were 10 percent higher or lower for above-ground vault disposal, the total unit cost would increase or decrease by about $5 per cubic foot. For below-ground modular concrete canister disposal, the corresponding change is only about $3 per cubic foot. The sensitivity to changes in the estimated pre-operating costs are essentially the same for all three publicly owned conceptual disposal facilities. For a 10 percent change in the estimated pre-operating costs, the predicted total unit cost would change by about $2 per cubic foot for all disposal facilities.

SUMMARY

The conceptual LLW disposal facility designs prepared by the State of Texas represent a major advance in the body of knowledge about the alternative LLW disposal technologies. An extensive design basis was prepared to facilitate the orderly development of the concepts. Drawings and descriptions convey needed information, useful in decision making. Quantity and cost estimates and economics evaluations provide a bsis for determining economic effects of design modifications.

The conceptual designs will provide input into the preliminary design of the disposal facility. While there are numerous revisions and refinements which might usefully be made, these designs contribute heavily to the process of developing a new LLW disposal facility for the State of Texas.

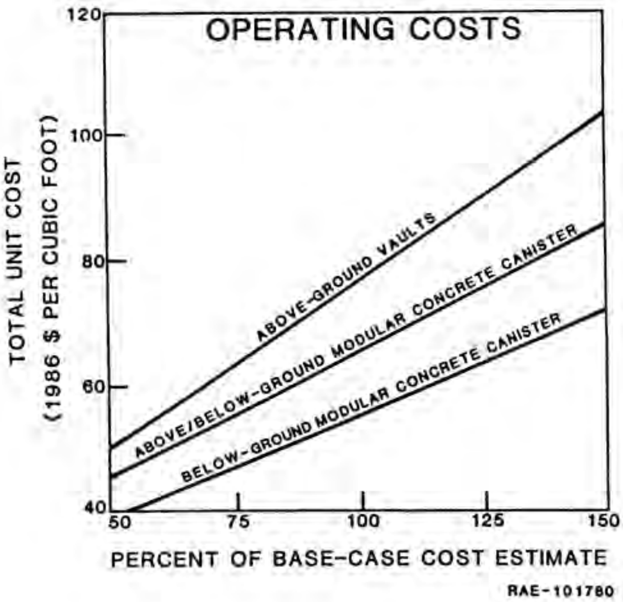

Fig. 2. Sensitivity of Total Unit Cost to Uncertainties in Cost Estimates for a Typical Publicly Owned Disposal Facility.

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