WASTE VOLUME CHARACTERIZATION, FACILITY CONCEPTUAL DESIGN, AND ECONOMIC ANALYSIS FOR TEXAS LOW-LEVEL RADIOACTIVE WASTES

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ABSTRACT

After establishing the administrative structure of the Texas Low-Level Radioactive Waste Disposal Authority, the first technical necessities were to accurately determine Texas low-level waste volume and characteristics, project the size of operation through a conceptual design, and determine the economics of operating as a "go it alone" state. The waste volume and characteristics evaluation found that previous estimates were inaccurate and that Texas currently generates approximately 850 m^3 (30,000 ft^3) of waste per year. This is expected to grow to about 3,936 m^3 (139,000 ft^3) per year when the nuclear reactors under construction come on line in the late 1980s. The facility conceptual design was based on these projected Texas waste generation rates and specified a site of approximately 81 ha (200 acres), 20 ha (50 acres) for actual waste disposal and 61 ha (150 acres) for a buffer area. In general, the conceptual design included building requirements, trench layout and design, an equipment list, and personnel requirements. An economic analysis was then performed based on the waste evaluation and the conceptual design. Four economic scenarios were evaluated which indicated average disposal fees ranging from \$935.84 to \$1,286.87 per m^3 (\$26.50 to \$36.44 per ft^3).

INTRODUCTION

The Texas Low-Level Radioactive Waste Disposal Authority was created by the 67th Texas Legislature in response to Public Law 96-573 to develop and operate a facility for the disposal of low-level radioactive wastes produced in Texas. In November 1982, the Authority commissioned Ebasco Services Incorporated to provide assistance in preparing reports on low-level waste characterization and volume projections, a disposal facility conceptual design, an economic analysis, a regional analysis, a surface waste storage facility, and a transportation cost evaluation. This paper addresses waste characterization, the facility conceptual design, and an economic analysis for a Texas application.

WASTE CHARACTERIZATION

Over the past four years, numerous reports have attempted to characterize low-level radioactive waste generation from each state. There is wide disagreement among these reports concerning the volume and source of waste generated in Texas. Discrepancies are due in part to the nature of survey formats and techniques, failure to eliminate out-of-state wastes shipped for disposal by Texas brokers, and failure to follow up on erroneous and missing data. Estimates of Texas-generated waste volumes range from as little as 14 m^3 (500 ft^3) to amounts approaching 2,549 m^3 (90,000 ft^3) per year. The Authority elected to conduct its own evaluation to more accurately predict waste generation rates for support of the conceptual design and economic evaluation of a Texas disposal facility.

The waste characterization involved collection and evaluation of data for nonreactor sources and from 12 operating nuclear power reactors similar in design to the Comanche Peak and South Texas Project plants now under construction in Texas. Waste was categorized as institutional, industrial, federal facility, formerly used sites, and commercial nuclear power reactor. Waste streams from these sources were further characterized based on physical form, generation rate, activity level, and radionuclide content. Table I presents the Texas low-level radioactive waste volume projections.

TABLE I

Texas Low-Level Radioactive Waste Volume Projections[a]

Generator	Volume m^3	(ft^3)[b]
Institutional	651	(23,000)
Industrial	227	(8,000)
Federal Facilities and NRC Licensees	85	(3,000)
Remedial Action Sites[c]	198	(7,000)[d]
Commercial Power Reactors	2,973	(105,000)
TOTAL	3,936	(139,000)

[a]Approximately 850 m^3 (30,000 ft^3) of waste per year is currently generated in Texas.

[b]Numbers are rounded off and do not add exactly.

[c]Assumed.

[d]Not included in total.

Institutional waste is generated at academic institutions, medical research facilities, health science centers, clinics, and hospitals. Such waste is generally classified as high volume and low specific activity. Institutional waste consists primarily of dry compactible solids, biological specimens, and liquid scintillation vials containing small quantities of radioactive materials. Isotopes commonly encountered in these wastes are tritium, carbon-14, technetium-99m, iodine-131, iodine-125, phosphorus-32, and sulfur-35. Because many institutions are expected to start disposing of low levels of tritium and carbon-14 as nonradioactive waste, a steady state generation rate of 651 m^3 (23,000 ft^3) per year was projected from institutional sources. An important characteristic of institutional waste is that significant amounts can be reduced in volume and held for decay or disposed of as nonradioactive waste. Consequently, only significantly radioactive or long-lived wastes are packaged and shipped off site for disposal.

Industrial waste is generally more diversified than institutional waste in physical form, activity, and radionuclide content. These radionuclides have half-lives of years rather than days and, therefore, are not commonly stored for decay. Isotopes commonly contained include tritium, carbon-14, cobalt-60, cesium-137, iodine-125, radium-226, and americium-241. Industrial wastes are generally higher in activity per unit volume than are institutional wastes. A 1987 waste volume of 227 m^3 (8,000 ft^3) was estimated by industrial users and fabricators of radioactive materials and sources. Volume projection estimates were based on a modest two percent per year increase to compensate for economic growth and improved manufacturing processes.

Currently, four commercial reactors are under construction in Texas. The design life for each plant is 40 years. The waste stream from these pressurized water reactors may be categorized into seven distinct classes: (1) spent resins, (2) concentrated liquids, (3) filter sludges, (4) filter cartridges, (5) compactible waste, (6) noncompactible waste and irradiated components, and (7) infrequently occurring waste. Major radionuclide content of reactor wastes includes tritium, cobalt-60, strontium-90, cesium-137, manganese-54, and iron-59. Steady state waste volumes from Texas nuclear power plants after 1990 were projected at 2,973 m^3 (105,000 ft^3) per year, excluding the infrequently occurring waste. The excluded class results from cyclic maintenance operations conducted at five or ten-year intervals. This class constitutes about 198 m^3 (7,000 ft^3) of waste in applicable years, but was not included in the annual volume projection.

An estimated 70,792 m^3 (2,500,000 ft^3) of waste will be produced during decontamination and decommissioning of the four Texas nuclear power reactors. Characteristics of this type of waste were evaluated, but the amount was not included in the steady state volume projection.

Military operations such as aircraft maintenance facilities, defense research laboratories, and military health care facilities contribute approximately 42 m^3 (1,500 ft^3) per year. Veterans Administration hospitals and other radioisotope users licensed by the U.S. Nuclear Regulatory Commission produce approximately 38 m^3 (1,350 ft^3) per year. At the present time, the Pantex facility in Amarillo, Texas, a U.S. Department of Energy contractor, ships all of its radioactive waste to the Nevada Test Site. The Department of Energy predicts this will continue to be the method of disposal for this facility in the future. It was projected that federal facilities will continue producing waste at approximately 85 m^3 (3,000 ft^3) per year.

There are also 18 known Texas locations which may require some degree of remedial action. These sites are characterized by contaminated soil, building rubble, and equipment, and include formerly used sites. Most of these sites are considered to contain minimal quantities of wastes. One such site has been extensively studied by the Texas Department of Health, Bureau of Radiation Control. The Bureau recommended that 1,048 m^3 (37,000 ft^3) of material should be removed from the site and disposed of by shallow land burial. Furthermore, it is estimated that over the life of the proposed Texas disposal site, a total of 2,832 m^3 (100,000 ft^3) could be destined for disposal from such types of decontamination and decommissioning activities. These wastes also were not included in the annual volume projections.

Based on data developed by the Authority, the annual Texas low-level radioactive waste volume could exceed 4,248 m^3 (150,000 ft^3) per year. Considering the impact of improved waste management practices and implementation of volume reduction techniques, a more conservative estimate of low-level radioactive waste generation rate in Texas is approximately 3,936 m^3 (139,000 ft^3) per year.

FACILITY CONCEPTUAL DESIGN

The objective of the conceptual design was to plan a facility which is adequately sized to handle the projected waste volumes over a 30-year period; takes advantage of the state's geological and hydrological characteristics; supports efficient site operations and disposal activities; and complies with state and federal regulatory requirements and performance objectives. Finally, the design was developed in sufficient detail to support site selection, provide the necessary engineering considerations and proposed specifications to select a final facility design and contractor, and to determine the economic feasibility of the project.

The design's prime objectives were to protect the general population from releases of radioactivity and ensure the stability of the disposal facility after site closure. The conceptual design was based on a review of presently available technology and disposal practices at operating facilities, and also drew from the experience gained from presently closed disposal facilities. The conceptual design integrated specific design features with assumed site characteristics for compliance with state and federal regulatory requirements and performance objectives. The design assumed a location in an arid or semi-arid region, and these natural conditions, augmented with engineered features, provided the necessary assurance that the proposed facility would meet regulatory performance objectives.

Ideally, the disposal facility requires at least 81 ha (200 acres), of which 20 ha (50 acres) will be used for disposal of the low-level waste. Location near a major highway was assumed. The 20 ha (50 acre) disposal site is a limited access area to which entry and exit are controlled.

The conceptual design incorporates two types of waste disposal units, one for Class A wastes and the other for Class B/C wastes. Configurations of the disposal units minimize the interaction between the generally unstable Class A and stabilized Class B/C wastes. This segregation ensures that the site meets the stability performance objectives. The design specifications of both disposal units have also been standardized to simplify construction, maintenance, and repairs. The major difference in the design of the disposal units is that the Class B/C waste trenches incorporate an engineered biological intrusion barrier and can accommodate higher specific activity waste forms. Each disposal unit design incorporates a .9 m (3 ft) thick clay cap, a .6 m (2 ft) thick liner, and a total cover of 5 m (16 ft) over the buried wastes. Both trench designs also include the capability to collect, sample, and remove any water which might collect in the trenches. Water collected from the trench sumps will be tested and treated (evaporated) as necessary. No liquid effluents will be released into the environment. The controlled area of the disposal facility includes a minimum 30 m (100 ft), three-dimensional buffer zone which extends radially and downward from the disposal area. Separating the disposal area from the uncontrolled area will be a security fence and a berm to exclude outside surface waters from the trench area. A 213 m (700 ft) extended buffer zone surrounds the entire disposal complex. The conceptual design also addressed the major operational phases of the waste disposal activity such as trench construction, waste emplacement, trench backfill, closure, post-closure, and long-term care.

Support facilities include structures and systems located both inside and outside the controlled area. Facilities located inside the controlled area are the evaporation pond, maintenance building, truck wash facility, sanitary facility, and necessary site roads and parking areas. Provisions have been incorporated to include the siting of an above-ground low-level waste handling and storage facility in which incoming low-level wastes could be stored on an interim basis. Support facilities located outside the controlled area include the access control building, administration building, trucker waiting facility, water treatment facility, power distribution system, sanitary facilities, and necessary access road and parking areas.

The conceptual design also presented manpower and equipment requirements to support all anticipated site activities, including administration, security, quality assurance, health physics, operations, and maintenance. The site staff will consist of 21 individuals performing the functions noted above. The major site activities outlined as procedures are administrative, security, safety, operations, health physics, emergency, waste acceptance, and equipment.

ECONOMIC ANALYSIS

The economic analysis examined the feasibility of the low-level waste disposal facility with a custom-designed economic model using the waste characteristics and conceptual design as a basis. The scope included examination of: (1) two modes of operation, an Authority-operated disposal facility and a private contractor-operated facility; (2) two alternate financial analyses with a zero and an 8.5 percent cost of money; and (3) a parametric sensitivity study. The operation was based on an average disposal volume projection of 3,936 m^3 (139,000 ft^3) per year.

The projected waste disposal average cost was determined by finding the price that would set the present value of cash inflow equal to the present value of cash outflow. Present value is a technique for calculating an equivalent current value for a future cash flow employing the concept of the time value of money. The cash flow is usually discounted at the cost of capital. When considering a state appropriation of funds, the cost of capital is zero. On the other hand, if the Authority were to issue long-term bonds, a current 8.5 percent interest rate would be expected. The financial analysis was performed with both costs of money, zero and 8.5 percent, to consider the effect of the cost of money on the economics of the disposal facility.

The existing economic models and studies of the U.S. Nuclear Regulatory Commission, U.S. Department of Energy, and Chem-Nuclear Systems, Incorporated were reviewed for their applicability to the Texas project. The construction of a completely new Texas economic model was judged to be a more effective approach rather than modifying an existing model. The model is composed of six interrelated components: (1) capital cost, (2) operating personnel cost, (3) state administration cost, (4) facility operating cost, (5) post-operating cost, and (6) financial integration.

The capital cost component contains the itemized cost schedule of all capital equipment, buildings and support systems, property development, and licensing phases and documents required for the disposal facility. The operating personnel component contains a list of all job titles, salaries, and staffing levels over the facility lifetime. The state administration component contains the projected cost requirements of the Authority and the Texas Department of Health inspector to fulfill their duties. The facility operating cost component combines the output from the operating personnel component with all other direct operating expenses such as materials and supplies. The post-operating cost component contains the projected cost requirements for decommissioning the facility and ensuring the site's long-term stability. The financial calculation component combines the above cost data with the waste volume projection to calculate the average cost value of disposal and projected cash flows and revenues.

The economic analysis assumes a 5-year startup period, a 20-year operating period, a 5-year closure period, and a 100-year institutional care period. Although this anticipates a somewhat different operating scenario than the conceptual design, the 30-year operating period specified in the design is viewed as a safety factor and would serve to reduce costs if the time frame were extended.

The base case scenarios assumed an 8.5 percent discount rate, zero cost of money, and 4 percent inflation rate for both the Authority-operated and the contractor-operated facility. All costs were presented in 1983 dollars. Other variations assumed an 8.5 percent discount rate, an 8.5 percent cost of money, and a 4 percent inflation rate. The total was composed of an operating base price and a post-operating surcharge. The latter finances a separate fund which pays for all post-operating costs. The operating base price is an average value which includes a surcharge for Class B and C waste forms. This study assumed the contractor had a cost-plus-fixed-fee contract which included a 35 percent overhead cost, plus a profit fee of 10 percent of total operating costs. The analysis also shows that the inclusion of the cost of capital, at 8.5 percent, would increase the disposal cost. A summary of the projected average disposal cost for the Texas disposal facility is presented in Table II. The analysis showed that the Authority-operated facility was more economical than a contractor-operated facility.

TABLE II

Summary of Projected Unit Cost of the Texas Low-Level Waste Disposal Facility[a] [\$/m³ (\$/ft³)]

Category	Base Case #1 Contractor-Operated Facility	Base Case #2 Authority-Operated Facility
Average Base Price	1,035.07 (29.31)	847.91 (24.01)
Post-Operating Fund Surcharge	96.76 (2.74)	87.93 (2.49)
Total Average Disposal Cost[b]	1,131.83 (32.05)	935.84 (26.50)

Category	Variation #1 Contractor-Operated Facility	Variation #2 Authority-Operated Facility
Average Base Price	1,190.28 (33.70)	996.93 (28.23)
Post-Operating Fund Surcharge	96.76 (2.74)	87.93 (2.49)
Total Average Disposal Cost[c]	1,286.87 (36.44)	1,084.87 (30.72)

[a]Units of \$/m³ (\$/ft³) based on 3,936 m³ (139,000 ft³) per year.

[b]Base cases used a zero percent cost of money.

[c]Variations used an 8.5 percent cost of money.

Sensitivity studies indicated that a 10 percent reduction in capital cost or operating costs would reduce the average base price by \$12.36 per m³ (\$0.35 per ft³) and \$57.92 per m³ (\$1.64 per ft³), respectively. Increased waste volume also causes a substantial reduction in the average disposal cost. Projected volume variations of approximately 1,416 m³ (50,000 ft³) would result in a cost decrease of \$317.83 per m³ (\$9.00 per ft³) for the base case, an Authority-operated facility. A delay of one year in startup of the disposal facility could increase the average disposal cost by \$24.37 per m³ (\$0.69 per ft³) assuming an 8.5 percent cost of money.

CONCLUSIONS

The waste characterization evaluation determined that previous estimates of Texas low-level radioactive waste generation varied between 14-2,549 m³ (500-90,000 ft³) per year, while the actual generation rate is approximately 850 m³ (30,000 ft³) per year. It is projected that this will grow to about 3,936 m³ (139,000 ft³) per year when the Texas nuclear power reactors come on line. Deviations in previous projections were attributed to incomplete surveys, inaccurate information, duplication of data, and failure to validate data.

The conceptual design was based on the projected Texas waste stream over a 30-year period. Design considerations were based on U.S. Nuclear Regulatory Commission, Texas Department of Health, and Authority requirements. An 81 ha (200 acre) site was specified, of which approximately 20 ha (50 acres) would be used for actual disposal. The trench design, environmental monitoring system, surface water management system, road and building design and layout, equipment needs, and staffing pattern were conceptually developed.

The availability of waste generation information and the conceptual design made it possible to develop a reliable economic analysis of the Texas operation. This analysis evaluated the economics of an Authority-operated disposal facility and a private contractor-operated facility under two sets of economic conditions. The first set utilized a 4 percent inflation rate, zero cost of money, and 8.5 percent discount rate. The second set utilized a 4 percent inflation rate, 8.5 percent cost of money, and an 8.5 percent discount rate. The result of this analysis showed that an Authority-operated facility was competitive with a privately operated facility under the Texas volume generation rates. Furthermore, although Texas waste volumes are lower, a Texas facility was demonstrated to be economically competitive with other regional facilities. For these cases, average disposal fees, including closure funds, ranged from \$935.84 to \$1,286.87 per m³ (\$26.50 to \$36.44 per ft³).