THE SUBOPTIMUM OPTIMIZATION OF LLRW TREATMENT/DISPOSAL

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ABSTRACT

The decision to volume reduce, as a step in LLRW Disposal, has historically been based on the generators comparison of disposal price vs. their own volume reduction costs. This, relatively straight forward, engineering economics analysis does not adequately deal with the complete system on an incremental costing basis. Incremental costing is particularly important because of the high fixed annual costs which make up a large fraction of the disposal charges.

Utilizing a typical distribution of LLRW, costs are calculated for several sizes of disposal facilities 200,000 - 1,000,000 ft^3/yr (prior to volume reduction) and for three disposal technologies, enhanced shallow land burial, concrete containerization and above/below grade vaults. Total costs for this spectrum of conditions ranged from 22 to 135 \$/ft^3 of original wastes. These data are used as an input to demonstrate the effects of volume reduction . For SLB, volume reduction adds about 3 \$/ft^3 but for concrete containerization and vault systems there is a cost saving of 3 \$/ft^3 and 7 \$/ft^3 respectively.

With the trend toward the greater confinement disposal technology, possible interim storage requirements, the surcharges and penalties of the LLRW Act-1985, greater volume reduction is clearly the prudent approach.

BACKGROUND

An individual generator's decision on how much LLRW volume reduction to implement has historically been based on straightforward engineering economics and cost and price data that is a comparison of his own cost and the disposal price. It was not possible or perhaps even useful to determine if volume reduction was economically desirable in the total system, or global sense. Dames & Moore did evaluate the total systemwide impacts as part of the Management Plan recommendations developed for the Southeast Compact Commission(1). The effect of such decisions in relation to current pricing and surcharge conditions is summarized here.

As implied above, an analysis which uses disposal price and concludes that if volume reduction can be accomplished at a lower cost in dollars/ft^3 it should be done, misses some of the basic principles of incremental costing. In so doing, the "optimization", from the generator's view may be "suboptimum" (more costly) from a total expenditure standpoint. To penetrate, and illustrate, this question requires a detailed understanding of the realistic costs and charges which make up the total disposal price so that the changes in cost can be assessed under different waste volume conditions. There are two key words in this paragraph - "incremental" and "realistic".

COST DEVELOPMENT

TABLE I compares costs of low-level waste disposal developed by various organizations over the last several years. The range of costs in this table indicates that past estimates have not reflected very well the real world. The California LLRW site development proposal data (7) (8) which incorporated the experience of actual site operation and further represents a firm business commitment is the most realistic. This information has been interpreted and used as the basic blueprint for the components of cost developed in this paper.

TABLE I
Disposal Cost Estimates

Reference Studies	Cost \$/ft^3	Year	Size 10^3 ft^3/yr
Ford, Bacon & Davis (2)	4-5	1979	1,000
NRC-EIS-10CFR61 (3)	6-12	1981	1,300-850
Argonne Nat. Lab. (4)	23	1984	350 total *
EPRI(5)	10	1984	500
Current Operations			
Operating Site (6)	30	1985	1,000
Projected			
California Proposal (7) (8)	32-35	1984	400

* "B", "C" wastes as a fraction of the total facility. Costs are for Greater-Confinement Disposal and do not compare directly with the shallow land burial estimates of the other studies.

Unit costs (\$/ft^3) are developed by determining total annual expenditures at the facility and dividing by the volume of waste received during the year. The unit disposal charge will vary as a function of facility size because the total cost is a combination of fixed annual costs (constant regardless of how much waste is received) and variable costs (proportional to throughput). There are four major categories of charges, three of which are principally independent of annual capacity. These are:

Preoperational Costs - which are treated as a capital investment and are therefore fixed as an annual cost at the start of operation. A large fraction of these costs relate to the site selection, characterization and licensing, all of which are virtually independent of site size. This annual charge is highly dependent upon the corporate structure or financing policies which would affect the amount of the annual fixed charge, but is not related to facility size. The pre-op value also varies to some modest degree with the waste disposal technology utilized.

Closure Costs - once a closure plan is adopted, (prior to operation) the annual cost would be fixed and essentially independent of throughput. Also these costs are related to the projected requirements of the waste disposal technology.

State/Local Taxes and Assessments - this cost, not technically related to the thoughput, may be identified as a dollars per ft^3 charge but its principal purpose is to generate a given number of dollars/year to pay for incurred state/local costs.

Operating Costs - these costs are a combination of fixed and variable components and are highly dependent upon the waste technology utilized.

Preoperational Costs

TABLE II summarizes the estimated $20 million dollars in preoperational costs by category of charges. TABLE III illustrates the annual, preoperational cash flow over the preoperational period. These data are necessary to determine total capital investment including accrued interest and/or return on corporate equity.

$20 million dollars may seem like a lot of money but this total and the distribution is typical of firm business proposals submitted in response to the State of California request for proposals for LLRW Site Development in 1984[6].

TABLE II
Pre-Operational Disposal Site* Development Cost (10^3 Dollars)

Cost Distribution	
Preliminary Charges	$ 300
Site Development	1,500
Administration	1,500
Licensing/Engineering	11,500
Buildings	2,000
Equipment	3,200
Cumulative Total	$20,000

TABLE III
Cash Flow Requirements

Year of Preoperational Period	10^3 Dollars/Year
1	$ 800
2	2,400
3	3,000
4	3,200
5	3,400
6	7,200
Total	$20,000

The cost data summarized in TABLES II and III is for an enhanced shallow land burial system and therefore does not represent one of the more capital intensive systems such as above grade vaults. Most of the costs, except perhaps for buildings and to some degree equipment, are independent of disposal site size and disposal technology. The costs for greater containment systems are more reflected in subsequent operating charges as construction is ongoing during the operational period. The subsequent comparative analysis addresses the different pre-op and operating costs for the greater containment systems.

The annual charge for this $20 million pre operational expenditure can vary over a large range from a minimum of about $3.2 million per year for a State Authority (100% debt @ 11%/year rate) to a "typical" $8.8 million per year for a large corporation (30% debt @ 11%/year, 70% equity with an after tax return rate of 20%/year). It is easily possible to have a range of 50% or more around this nominal rate depending upon the corporate structure and the company's business risk view.

Closure Costs

Closure and post-closure activities for a licensable system are relatively small and are designed to be more passive than active - more surveillance than repair-for a licensable system. Hence the funding for these future costs are relatively independent of volume in the repository. The value used in this study, typical of current site operations, is 2 $/ft^3$ at the one million ft^3/year operating level. It is further assumed that $1.5/$ft^3$ (or $1.5 million per year) is fixed and $0.5/$ft^3$ is proportional to throughput.

State/Local Assessments

State and Local taxes or assessments are classically collected on the basis of $/$ft^3$ of disposal and therefore might be thought of as proportional to annual throughput. However, the rationale for such charges is to reimburse the local government for costs *incurred as a result* of the operation of the disposal facility. These costs are not particularly related to the size of the facility. The charge (assessment), although implemented on a $/$ft^3$ basis, is designed to produce a given total revenue per year. This paper has been therefore considered this cost to be fixed at a level of $4 million dollars per year.

Operating Cost

Operating costs are a mix of fixed and variable (incremental) charges. Analyzing the operating cost distributed to given tasks or categories of service, a fixed and variable fraction can be assigned to each component and the total can then be summed. The summary in TABLE IV, utilizes the California proposal information (7) (8) with some interpretation of the data to average the differences. The size of this disposal facility was approximately 400,000 ft^3/year. The estimate and the allocations is subject to personal interpretation, but we believe the values shown are within 5% or so of the appropriate distribution.

TABLE IV
Annual Operating Expenses
Thousands of Dollars/Year
400,000 ft^3/year disposal faciltiy

Expense Category	Percent Fixed	Fixed	Variable
Travel	100	$ 100	
Insurance	100	200	
Training	100	40	
Relicensing	100	250	
Professional Services	100	60	
Corp. Administration	100	300	
Local Office Support	100	50	
Public Information	100	150	
Subtotal		$1,150	
Salary Fringes	75	$ 750	$250
Supplies	80	32	8
Utilities	70	98	42
Communications	70	56	24
Repairs & Maintenance	80	72	18
Trench Construction	20	66	264
Equipment Rental	60	12	8
Office & Finance	90	207	23
Miscellaneous	90	54	6
Engineering Services	80	160	40
Environ Monitor	90	144	16
Subtotal		$1,651	$698
Total	$3,500	$2,801	$699
Distribution	100%	80%	20%

These data are for an enhanced Shallow Land Burial Facility rather than the more capital intensive disposal systems, eg. above/below ground vaults. The majority of the fixed components in TABLE IV will not change significantly for the more capital intensive disposal systems. The incremental additions are in two areas - more extensive engineering, construction and equipment (for the first modules) during the pre-op phase of facility development and new construction costs directly related to the ft^3 of disposal volume during the operating phase. The incremental costs for two examples, concrete containerization and above/below ground vaults, are developed to illustrate the full spectrum of total disposal costs as influenced by volume reduction treatment. For this analysis the reference disposal capacity prior to volume reduction is about 400,000 ft^3/year, approximately the middle of the range for the compact regions of US.

Concrete Containerization

The pre-operational costs for concrete containerization would not be much different than for enhanced SLB. There would be some additional facilities for handling and loading containers for which engineering and construction could add on the order of $500,000 to the pre-op charges. This converts to an additional fixed charge of about $ 0.2 million/year.

For post operational cost of concrete-containerization systems it could be assumed that both closure and post closure would be substantially less because of the long-term system stability. Half of the reference SLB charges have been estimated and used in this analysis.

The principal operating cost difference is that of purchase or contruction of the concrete containers, a direct $/$ft^3$ charge. Without volume reduction this direct incremental cost is on the order of $15/$ft^3$ with this cost depending on the ratio of waste drums to LSA boxes.

Above/Below Ground Vaults

Pre-operational costs for this technology would involve both additional engineering for the vault design plus the construction of the first modules of vaults prior to operation. This cost has been estimated at a relatively low $8 million level. A wide range can result from differences in how costs are defined and allocated to the pre-op or operational phase. This $8 million dollars results in an annual fixed charge addition of $3.5 million per year, for a total of $12.3 million.

Closure and maintenance charges are assumed similar to that of concrete containerization. Although there is "structure" which could be considered to require more maintenance and repair than in SLB, if such maintenance were required, this disposal system would probably be unacceptable. High maintenance during the institutional control phase would also imply even a greater need after the 100 year point which, under current regulations, could not be guaranteed. Table V summarizes the fixed costs including state/local assessments, in millions of dollars per year for each of the three technologies.

TABLE V

Summary of Fixed* Annual Costs

10^6 \$/year

Fixed Cost	Enhanced SLB	Concrete Containerization	Above/Below Ground Vaults
Pre-op Charges	\$8.8	\$9.0	\$12.3
Closure & Maintenance	1.5	0.7	0.7
State/Local Taxes	4.0	4.0	4.0
Fixed Operating	2.8	2.8	2.8
Total	\$19.9	\$19.3	\$22.6

* Charges which are independent of disposal facility capacity

The major incremental charge for a vault disposal system is that of the direct cost of new vault construction each year. Unfortunately there have been no designs approved by NRC. On the contrary no designs have been developed to the point that the licensing issues have been defined and "solved". Hence, there are no hard data on the cost of such facilities. As an approximation to those costs, data on interim LLRW facilities have been reviewed and interpreted(10) (11) (12) (13).

The capacity of these interim storage facilities ranges from 50,000 ft^3 to 500,000 ft^3. Technology varies from the most simple of designs to elaborate computer controlled crane systems with shielded areas and shielded roof. It is not surprising then that costs vary from 17 \$/ft^3 to 89 \$/ft^3. Some of the designs develop the costs of the first module which is generally on the order of twice the costs of the extensions. One of the studies (10) separately identifies the storage structure per se. A "disposal" vault structure could result in both higher costs (long life concrete, QA/QC, unique design) and lower costs (no H&V, temporary electrical, less convenient storage and/or retrieval) cost so that on balance interim facilities cost would be indicative of disposal vaults.

The Dames & Moore interpretation of the above designs indicates an incremental cost of on the order of 25 \$/ft^3, the value used in this analysis.

Volume Reduction

To determine the costs of disposal with and without volume reduction a spectrum of wastes was assumed similar to that generated by the S.E. Compact States. Simply stated approximately 45% of the total waste generated in this region is "A" compactable/incineratable. In the subsequent analysis a volume reduction of 40% has been assumed (60% of the original volume is disposed of). The cost of this volume reduction has been estimated to be 10 \$/ft^3 of original waste to be so treated, high for compaction but low for incineration. We have *elected to use* these typical values, rather than paramaterizing the ranges so as to explicitly focus on probable results, not an array of possible conclusions.

SUMMARY OF COSTS

The disposal costs in \$/year and \$/ft^3 are summarized for enhanced shallow low land burial, concrete containerized, and above/below ground vaults in TABLES VIa, b and c respectively. For each disposal system costs for three annual capacities (200,000, 400,000 and 1,000,000 ft^3/year,) are calculated with and without volume reduction.

TABLE VIa

Enhanced Shallow Land Burial

Summary of Cost Distribution

(Millions of Dollars/Year)

	Original Waste Volume-10^3 ft^3 200	400	1000
Incremental Cost			
Closure	0.10	0.20	0.50
Operating	0.35	0.70	1.75
Total	0.45	0.90	2.25
Fixed Cost	19.9	19.9	19.9
Total Cost	20.35	20.80	22.15
\$/ft^3	101.8	52.0	22.2
Volume Reduction	0.8	1.6	4.0
Disposal*	20.17	20.44	21.25
Total with VR	20.97	22.04	25.25
\$/ft^3	194.9	55.1	25.3

* Developed as above for disposal volumes of 120, 240 and 600 ft^3, respectively, the volume after VR.

TABLE VIb

Concrete Containerized

Summary of Cost Distribution

(Millions of Dollars/Year)

	Original Waste Volume-10^3 ft^3 200	400	1000
Incremental Cost			
Closure	0.06	0.12	0.30
Operating	3.35	6.70	16.75
Total	3.41	6.82	17.05
Fixed Cost	19.3	19.3	19.3
Total Cost	22.71	26.12	36.35
\$/ft^3	113.6	65.3	36.4
Volume Reduction	0.8	1.6	4.0
Disposal*	21.35	23.39	29.53
Total with VR	22.15	24.99	33.53
\$/ft^3	110.8	62.5	33.5

* Developed as above for disposal volumes of 120, 240 and 600 ft^3, respectively, the volume after VR.

TABLE VIc

Above/Below Ground Vaults
Summary of Cost Distribution
(Millions of Dollars/Year)

	Original Waste Volume-10^3 ft^3 200	400	1000
Incremental Cost			
Closure	0.06	0.12	0.30
Operating	5.35	10.70	26.75
Total	5.41	10.82	27.05
Fixed Cost	22.6	22.6	22.6
Total Cost	27.01	32.42	48.65
$/ft^3	135.1	81.1	48.7
Volume Reductionion	0.8	1.6	4.0
Disposal*	24.85	28.09	37.83
Total with VR	25.65	29.69	41.83
$/ft^3	128.3	74.2	41.8

* Developed as above for disposal volumes of 120, 240 and 600 ft^3, respectively, the volume after VR.

CONCLUSIONS

Can this "less than optimum" result be controlled or influenced by the waste generator; and even further "should it be?". Assume a given generator, and others, are disposing to a 400,000 disposal would be $/ft^3 (see TABLE III) and further assume we can reduce his wastes to 60% of original volume at a cost of 10 $/ft^3 for that 40% fraction of the wastes so treated. If all generators went through the same logic the new volume of wastes going to this facility would be 240,000 ft^3/yr at an average unit cost of 85.20 $/ft^3. The generators would now view their volume reduction savings at $75.20/ft^3 (the difference between disposal cost and volume reduction) indicating an even better decision than originally estimated. However, on original volume basis total costs including VR, would be 55.10 $/ft^3 up from 52.00 $/ft^3 for disposal only. This decision on "optimization" results in a "suboptimum" total system.

The situation is even more complicated if the "what if" game is played. Consider the consequences if, recognizing the above, you did not volume reduce and all other generators did. The cost for disposal would now be 85.20 $/ft^3 for all of your wastes rather than for 60% of that volume. This is clearly a risk which cannot be taken.

The numeric results of this study are summarized and compared in TABLE VII. It is first important to note the very wide range in disposal costs, primarily related to annual capacity of the disposal site, but also importantly influenced by the disposal system selected. The total spread ranges from 22 to 135 $/ft^3.

TABLE VII

Summary Comparison of Total Costs - $/ft^3

Original Volume (10^3 ft^3/yr)	Enhanced SLB No Vol Red	Enhanced SLB Vol Red	Concrete Contain No Vol Red	Concrete Contain Vol Red	Above/Below Ground Vaults No Vol Red	Above/Below Ground Vaults Vol Red
200	101.8	104.9	113.6	110.8	135.1	128.3
400	52.0	55.1	65.3	62.5	81.1	74.2
1000	22.2	25.3	36.4	33.5	48.7	41.8
Advantage to Volume Reduction	-3.1$/ft^3		+2.8$/ft^3		+6.9$/f^3	

The next observation is total volume reduction, under the incremental costing conditions defined, results in an increase of total costs for enhanced SLB. The increase is not large, on the order of 3 $/ft^3, with this delta being independent of disposal capacity. As this result seems counter to the conventional wisdom, it might be useful to explore the logic of this conclusion. The result comes about from the relatively low incremental cost of disposal, significantly lower than the incremental cost of VR; hence "excess" volume reduction results in higher annual cost to the generator if all generators similarly volume reduced.

On a technical basis when greater containment systems are in place their incremental costs are greater than the volume reduction charges. Volume reduction in a concrete containerization system would result in a $3/ft^3 saving and for vault structures the advantage would be $7/ft^3 (see TABLE VII). If interim storage were required maximum volume reduction is even more justified.

There is in addition an "external" economic incentive for volume reduction in the surcharges and possible penalties legislated in the LLRW Act of 1985. The possible need for interim storage to meet the Act's limits, and a trending toward greater containment disposal systems with their higher costs, both total and incremental, all suggest that maximum volume reduction is the prudent decision.

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