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LAWRENCE RADIATION LABORATORY

Elmer Nielsen

January 21, 1959

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Lawrence Radiation Laboratory
University of California
Berkeley, California

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ABSTRACT

A study has been made of comparative costs of disposal of radioactive wastes at sea and by burial, taking into account such factors as loading, storage, and transportation by various means.

Introduction

This report is a comparative cost study of radioactive waste disposal for the Lawrence Radiation Laboratory (UCRL). In particular, it compares the costs of sea disposal in depths of 1000 fathoms and of 2000 fathoms off the California coast with land burial of the wastes at the Hanford Atomic Products Operation (HAPO), Richland, Washington, at the National Reactor Testing Station (NRTS), Idaho Falls, Idaho, or at the Nevada Test Site (NTS), Nevada. In the comparison, the cost of utilizing a commercial waste-disposal firm is also shown as well as a tentative cost of using the Military Sea Transport Service (MSTS). It is understood that the commercial firm would utilize sea disposal.

In comparing sea disposal versus land disposal, it is assumed that all shipments start with a concreted 55-gallon drum containing the radioactive wastes. The purpose of the concrete is to encase and keep under safe control the radioactive materials within. With respect to sea disposal it has the additional attributes of providing the necessary weight for sinking at sea and of inhibiting, over long periods of time, the diffusion of the radioactive contents into the surrounding environment. It is assumed that this latter attribute is also desired in land burial. It should be recognized and understood that the 55-gallon drum serves only as a concrete pouring form and may be replaced by more economical forms as they are developed.

Lawrence Radiation Laboratory wastes consist occasionally of packages other than the concreted 55-gallon drum. However, for simplicity of comparison all costs have been reduced to the cost for a concreted 55-gallon drum having an average weight of 750 pounds.

To reduce the cost per 55-gallon container to costs per cubic foot of radioactive wastes or per gallon of liquid waste in the container, one can assume that about 4 cubic feet of uncompacted dry waste packages or 20 gallons of liquid waste are placed in a UCRL concreted drum. With the dry waste the added concrete fills the voids around and between the waste packages and serves to compact the wastes to some degree.

It is assumed in the survey that the concreted 55-gallon drum will have the ICC approval necessary to obviate any special Health Physics escort or services during transportation and handling. A brief examination shows that such services, if required, would add about 75 cents per drum to the cost of sea disposal. Most of this cost would arise during truck transportation. With land burial such services would add from \$2 to \$3 per drum to the cost of truck transportation to the site, and would be almost impossible for rail shipments unless arrangements for special and expeditious shipment were made.

All cost estimates have an inherent inaccuracy in that commercial costs were not based on firm bids but on estimates furnished by such concerns. In some cases there is no applicable classification for which a transportation rate has been determined. Thus transportation rates have been estimated from rates previously established for items somewhat similar in size or shape.

The best transportation rates are based on at least a given minimum quantity per shipment. For truck and rail shipments, this produces no problem, since full truckloads or railcar loads can easily be made without straining UCRL's storage capacity. For sea disposal, however, optimum rates might require making disposal trips about once or twice a year. This creates no problem so far as Livermore is concerned. However, Berkeley's

storage capacity is limited to 6 to 8 weeks' accumulation. In such cases consideration has been given to transportation from Berkeley to Livermore for interim storage pending a sea trip. Another possibility is interim storage at a commercial facility, which is quite close to a dock near the Oakland, California airport.

It is recognized that installations burying radioactive wastes within their own sites have no containment of such wastes except the plastic bags or cardboard cartons in which the wastes are collected. Other facilities shipping to these installations have their wastes buried in shipping containers such as sealed drums or specially fabricated metal boxes that can be tightly sealed.

Although it was not considered the purpose of this survey to investigate other containers for UCRL's radioactive wastes, general comments might be made. The cost of special fabricated metal containers or of sealable 55-gallon drums can amount to slightly more than \$1.00 per cubic foot of packaged wastes. The cost of materials for a 55-gallon concreted drum amounts to about \$1.00 per cubic foot of packaged wastes.

The major portion of disposal costs arises from loading and unloading operations and from rail and truck transportation between the point of origin and the disposal area. While such costs are generally quoted in terms of cost per ton handled or cost per hundred pounds transported for a given minimum loading, the basic factor is the number of packages handled and the volume occupied per package. For packages with a lower density and therefore smaller possible truckloads or carloads the transportation rates are higher per unit weight.

Savings that could be effected in some cases by palletizing loads, changing package sizes, loading barges more efficiently, or providing greater storage space in Berkeley were not examined.

Summary

The average cost estimate for commercial sea disposal at 1000 fathoms of UCRL's radioactive waste from Berkeley and Livermore ranged from \$7.48 per drum to \$8.00 per drum, assuming utilization of one of the two commercial tug and barge concern investigated. Between these two limits, prices were determined by the number of drums per sea trip and by whether Livermore or a San Leandro storage yard were used for interim storage of Berkeley's drums. Because of the need for extra transportation and storage of Berkeley drums, it is not axiomatic that the greatest number of drums per sea trip results in the lowest cost. Costs were computed for 500, 1000, and 3000 drums per sea trip.

With the second barge and tug concern, the average cost for sea disposal at 1000 fathoms ranged from \$8.53 per drum for 1850 drums per sea trip to \$20.47 per drum for a 500-drum sea trip. It is the author's belief that the latter figure is unrealistic (see discussion under Sea Disposal Section) and should probably be more like \$10 per drum for a 500-drum sea trip.

The extra cost for disposal at 2000 fathoms instead of 1000 fathoms ranged from \$0.33 per drum for a 3000-drum sea trip to \$2.00 per drum for a 500-drum sea trip, for either barge and tug concern referred to above.

The cost for disposal utilizing a commercial waste-disposal concern¹ has been given as \$14.50 per 55-gallon drum. The tentative cost for disposal via MSTTS is \$5.28 per drum.

The cost estimate for land burial at HAPO, NRTS, and NTS ranged from \$14.05 to \$15.89 per drum if rail transportation were used, and from \$14.90 to \$19.25 per drum if through truck transportation were used.

Sea Disposal

As stated in the introduction, costs of sea disposal were examined, taking into consideration various numbers of drums per sea trip. For quantities over 500 drums per sea trip provisions would be needed for interim storage of drums in excess of Berkeley's upper storage limit of approximately 200 drums. Consideration has been given to interim storage on the Livermore Site and at a commercial facility located in San Leandro, California close to a dock at the Oakland Airport.

Sea disposal costs were determined for dumping at 1000 and at 2000 fathoms. This involves barge trips of 1 and 2 days, respectively. The extra cost for 2000-fathom dumping amounts to \$1000 per trip.

In the investigation of available sea-going barging concerns in the bay area, two were found, one of which was interested only in the barge rental and sea towing aspects, while the other could handle all arrangements after disposition of UCRL's drums at a dock, including arrangements for a dock, and loading of the barge.

Docks considered were those in the East Bay Area. There are several docks in Oakland fronting on San Francisco Bay in or near the Estuary separating Oakland and Alameda. In addition there is a dock near the Oakland Airport. Any of these docks would be almost equally convenient to the Berkeley and Livermore laboratories. Docks in Richmond were not investigated but could probably be used. These would be more convenient to Berkeley than to Livermore.

Summation of the cost estimates for various combinations of the number of drums per sea trip, storage or dock facilities, tug and barge concerns, and depth of dumping are given in the Appendix, Cases A through E.

The factors that enter into sea disposal include some of the following:

1. Loading or unloading of a truck at UCRL by UCRL.
2. Transportation by commercial truck:
 - a. Berkeley to dock; unloading on dock.
 - b. Livermore to dock; unloading on dock.
 - c. Berkeley to Livermore for interim storage.
 - d. Berkeley to a commercial facility; interim storage
 - e. Commercial facility to dock; unloading on dock.
3. Dock rental.

¹ Proposal of Nuclear Engineering Co., Inc., March 25, 1957.

4. Barge rental while docked.
5. Barge loading.
6. Tug and barge charges for sea trip and dumping.

1. Truck Loading or Unloading at UCRL by UCRL

Truck loading at UCRL of radioactive waste drums has been carried on for the last 10 years. The cost of loading is about 75 cents per drum. The cost of unloading at Livermore for interim storage has been estimated as the same.

2. Transportation by Commercial Truck

Costs of transportation by commercial truck have been estimated² for the various hauls that are considered in this survey.

2a. Transportation from UCRL-Berkeley to Dock; Unloading at Dock

It has been estimated that truck transportation from UCRL-Berkeley to an Oakland dock and unloading at the dock would be \$0.25 per hundred pounds for a 40,000-pound minimum truck load. This amounts to \$1.88 for a 750-pound drum, with a 53-drum minimum truck load. The trucks to be used have space for 64 drums. Weight limitations would probably keep a load to about 55 drums. The cost of transport only (no unloading) to a Port Chicago dock has been estimated at \$1.88 per drum.

2b. Transportation from UCRL-Livermore to Dock; Unloading at Dock

The cost of transportation from UCRL-Livermore to an Oakland dock and unloading has been estimated to be \$2.25 for the 750-pound drum with the same 53-drum minimum truck load. The cost of transportation only (no unloading) to a Port Chicago dock has been estimated at \$1.88 per drum.

2c. Transportation from UCRL-Berkeley to UCRL-Livermore; Loading and Unloading by UCRL

The cost of transporting drums from UCRL-Berkeley to UCRL-Livermore has been estimated at \$1.88 per 750-pound drum, with a 53-drum minimum truck load. UCRL costs of both loading and unloading the truck would be in addition to these.

2d. Transportation from UCRL-Berkeley to Commercial Facility; Interim Storage

The cost of transportation from Berkeley to a storage yard in San Leandro, California has been estimated at \$1.50 per drum, with the same 53-drum minimum. Storage charges would be about 3 cents per square foot per month or about 12 cents per drum per month.

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Bigge Drayage Company, San Leandro, California, Mr. Doty and Mr. Brooks.

2e. Transportation from Commercial Facility to Dock; Unloading at Dock

The cost of transportation from the storage yard in San Leandro to Oakland Airport dock plus and unloading, together with the furnishing of a crane for barge loading, has been estimated at \$2.18 per drum.

3. Rental of Dock Space

The dock charges used in this survey are those obtained from Howard Terminals,³ who are located on the Oakland Estuary and who have a rail crane capable of handling up to 7.5 tons. The charges comprise a \$1.42-per-ton service charge plus a \$0.35-per-ton wharfage fee, making a total of \$1.77 per ton. This amounts to \$0.66 per 750-pound drum. One is allowed 5 days in which to make a loading.

4. Barge Rental While Docked

This was treated by one barge and tug operator⁴ as a separate item, and amounted to about \$75 per day. Assuming that 500 drums can be loaded in one day, one has a charge of \$0.15 per drum.

5. Barge Loading

An estimate of the cost of barge loading has been obtained from the California Stevedore and Ballast Co.⁵ It was estimated that 75 to 80 drums could be loaded per hour. Stevedore gang and crane charge would amount to \$3.50 per ton handled. In addition there would be a service or clerical charge of \$2.25 to \$2.50 per ton. Taking a total of \$6.00 per ton, one obtains a cost of \$2.25 per drum. There is uncertainty whether or not stevedores might require a penalty payment because of the type of cargo handled.

6. Tug and Barge Charges for Sea Trip and Dumping

One barge and tug organization⁴ in the Bay Area is acquiring a barge for the handling and dumping of sand, mud, or gravel. It has a hold shaped like a half cylinder with a radius of 15 feet and a length of 130 feet. The cargo is dumped by sinking one end of the barge and letting the cargo slide out. The load capacity is 1125 tons. In terms of UCRL's 750-pound drum, such a barge could handle about 3000 drums. Space limitations give about the same load limit.

³ Howard Terminals, Oakland, California, Mr. Jack Bentry

⁴ Seaborn Towing Service, Mr. Seaborn

⁵ California Stevedore and Ballast Co., San Francisco, California, Mr. Ebey

The estimated cost for use of the barge and tug would be \$1000 per 24-hour day. Dumping at 1000 fathoms would take 1 day, while dumping at 2000 fathoms would require 2 days. At the maximum capacity of 3000 drums, the cost of the sea trip would be \$0.33 per drum for a 1000-fathom dump and \$0.66 per drum for a 2000-fathom dump. For a load of 1000 drums, the costs would be \$1.00 and \$2.00 per drum respectively, while for a 500-drum load the costs would be \$2.00 and \$4.00 per drum respectively for the 1000-fathom and 2000-fathom dumps.

This particular organization does only barge hauling. All other steps would have to be separately negotiated.

3, 4, 5 and 6 combined (commercial barging):

All Operations and Costs from Loading of Barge in Oakland to Dumping at Sea

Another barge and tug organization⁶ has a sea-going barge located in the Seattle, Washington area and is acquiring another for use in the San Francisco Bay Area. This would be a flat-deck barge measuring 120 x 44 feet and having a load capacity of 700 tons. The barge is dumped by sinking one end and allowing the load to slide off. A single layer of drums standing upright on the deck in an area 100 feet by 40 feet would be 1000 drums or a load of about 375 tons. It is understood, however, that a barge would be loaded by stacking the drums on their sides in order to obtain a high center of gravity and make the load dumping easier. The 700-ton limitation permits a load of about 1850 drums.

The estimated cost for a trip, including all operations from loading the barge at an Oakland dock to dumping, is \$9,000 for a 1000-fathom dump and \$10,000 for a 2000-fathom dump. Although it was stated that it might be possible to share the costs of a sea dump (for a less-than-full-load drum shipment) with some other commercial dumping operation, the costs have been derived as if the concreted drums were the only cargo.

For a maximum load of 1850 drums, the cost comes to \$4.87 per drum for a 1000-fathom dump and \$5.41 per drum for a 2000-fathom dump. For a load of 1000 drums, the costs are \$9.00 and \$10.00 per drum respectively, while for a 500-drum load the costs are \$18.00 and \$20.00 per drum for the 1000-fathom and 2000-fathom dumps.

It is believed that the values per drum given above for a 1000- and a 500-drum load are not realistic. The difference between the total cost for a 1000-fathom dump and a 2000-fathom dump is \$1000, which as a charge for one day's rental of a barge and tug is comparable to other estimates obtained. Assuming that the 1000-fathom dumping is a 1-day sea trip, one has a charge of \$8000 for dock rental, barge rental during loading, and barge loading. For an 1850-drum load this amounts to \$5.32 per drum for these charges, which can be compared with the \$3.06 per drum that results from the total of the individual estimates for these factors.

However, the total charge for dock rental, barge rental during loading, and barge loading ought to be in proportion to the number of drums handled and not a fixed charge regardless of the number of drums handled; i. e., the cost per drum should remain approximately the same.

⁶ Bay Cities Transportation, Mr. Escher.

3, 4, 5, and 6 combined (MSTS):
All Operations from Truck Unloading at Concord or Port Chicago to
Dumping at Sea

The Military Sea Transport Service (MSTS) has indicated⁷ its ability to handle the sea disposal of radioactive waste from the Concord Naval Ammunition Depot. Not much is yet known about the cost of this service, but it has been indicated^{7, 8} that the charge for these operations would be \$10 per measured ton (40 cubic feet). Since a 55-gallon drum occupies a cubical space of about 12 cubic feet, one obtains a cost for these services of \$3.00 per drum.

Land Burial

For land burial, the costs were examined for three possible burial areas: (a) within the Hanford Atomic Products Operation (HAPO) at Richland, Washington, (b) within the National Reactor Testing Station (NRTS) at Idaho Falls, Idaho, and (c) within the Nevada Test Site (NTS) in Nevada. No estimates were obtained directly from any of these possible burial sites on local transportation costs, loading and unloading costs, or burial costs. Instead, estimates were made by extending local estimates or examining data available in a cost survey on radioactive waste disposal practices in the atomic energy industry.⁹

With respect to rail transportation, the nearest commercial railhead to the Hanford Atomic Products Operation is Hanford Works,¹⁰ from which carload deliveries are interchanged to a government railroad for delivery within the facility. How close the government railraod is to a possible burial site is not known, but it is assumed to be less than 10 miles.

The nearest commercial railhead to the National Reactor Testing Station is Scoville, Idaho.¹⁰ It is reported that¹¹ there is government railroad for making carload deliveries within the facility, and it is again assumed that the government railroad comes within 10 miles of a possible burial site.

The nearest commercial railhead to the Nevada Test Site is in Las Vegas, Nevada.¹⁰ There is no public crane in Las Vegas, but it is understood¹¹ that a private crane is available for \$15 per hour. The distance from Las Vegas to Camp Mercury is about 65 miles and it is assumed that the distance to a possible burial site is another 35 miles for a total trucking of 100 miles.

With respect to commercial trucking, it is assumed that such trucks will be able to go directly to the burial sites.

⁷ Memo, Robert Hughey, AEC-SAN to E. C. Shute, AEC-SAN, Dec. 15, 1958.

⁸ Personal communication, Robert Hughey to E. Nielsen.

⁹ Arnold B. Joseph, Radioactive Waste Disposal Practices in the Atomic Energy Industry--A Survey of the Costs, NYO-7830, Dec. 1955.

¹⁰ Transportation Directory, AEC Manual Chapter 5205.

¹¹ Southern Pacific Company, Oakland, California, Mr. Donald Wicks and Mr. Cliff D. Varga.

Summations of the cost estimates for land burial utilizing truck and rail transportation to the burial facility are given in the Appendix, Cases F and G.

The factors that would enter into land burial of UCRL's radioactive wastes are the following:

1. Loading of truck at UCRL by UCRL.
2. Transportation by commercial truck.
 - a. to Oakland, California rail terminal, or
 - b. directly to HAPO, NRTS, or NTS.
3. Loading of railcar in Oakland, California, and shoring of load.
4. Rail transportation to HAPO, NRTS, or NTS.
5. Unloading of railcar at railhead.
6. Transportation from railhead to burial site.
7. Unloading at burial site.
8. Direct burial costs: excavation, and cover of burial site.
9. Guarding and checking of burial site.

1. Loading of Truck at UCRL by UCRL

The cost would be same as for sea disposal operations; i. e., \$0.75 per drum.

2a, 3. Transportation by Truck to Oakland, California Rail Terminal

Transportation by commercial truck from UCRL to the Southern Pacific Railroad freight depot in Oakland, California and loading of the railcar has been estimated² to be \$0.20 per hundred pounds for a Berkeley load and \$0.25 per hundred pounds for a Livermore load, with 40,000-pound minimum load. This amounts to \$1.50 per drum from Berkeley and \$1.88 per drum from Livermore. The freight depot has a public crane that can handle up to 50 tons.

It has been estimated that the cost of shoring a load in a railcar is about \$100 per railcar for labor and materials. The particular type of railcar recommended¹¹ is the gondola car, having a bed 51 feet 6 inches long and 9 feet 2 inches wide, and an upper load limit of about 50 tons. Such a car can carry 125 drums for a total weight slightly under 47 tons. The cost of shoring would thus amount to \$0.83 per drum.

The total cost of transporting to the freight depot, loading the railcar, and shoring amounts to \$2.33 per drum for Berkeley drums and \$2.71 per drum for Livermore drums.

2b. Truck Transportation to HAPO, NRTS, or NTS

The costs of transportation by truck from UCRL directly to HAPO,¹² to NRTS,¹² or to NTS¹³ have been estimated as follows:

<u>To</u>	<u>Minimum load per truck</u>		<u>Cost</u>	
	<u>lbs.</u>	<u>Drums</u>	<u>per 100 lb.</u>	<u>per drum</u>
HAPO	24,000	32	\$2.20	\$16.50
NRTS	35,000	47	2.18	16.35
NTS	24,000	32	1.50	11.25

4. Rail Transportation to HAPO, NRTS, or NTS

The costs of rail transportation from the Southern Pacific Company freight depot in Oakland, California to the nearest railhead at HAPO, NRTS, and NTS have been estimated¹¹ from charges for somewhat similar items (metal-reinforced concrete slabs; molded cement blocks). The locations of the railheads, the minimum car loadings, and transportation costs for these items are as follows:

Estimated costs per drum of concreted wastes,
based on comparable materials

		<u>Railhead</u>		
		<u>HAPO</u>	<u>NRTS</u>	<u>NTS</u>
		<u>Richland, Wash.</u>	<u>Scoville, Utah</u>	<u>Las Vegas, Nev.</u>
Metal reinforced concrete slabs; minimum loading, 60,000 lb	per 100 lb	\$0.89	\$0.92	\$0.73
	per 750 lb	6.68	6.90	5.48
Molded cement blocks; minimum loading, 50,000 lb	per 100 lb	1.02	1.04	0.85
	per 750 lb	7.65	7.80	6.38
Average	per drum	7.17	7.35	5.93

¹¹ The cost of shuttling a carload from the commercial railhead into the facility is considered to be negligible and at least within the limits of uncertainty of other burial-site costs.

¹² Garrett Freightlines, Inc.

¹³ Wells Cargo, Inc.

5. Unloading of Railcar at Railhead

An estimate for the cost of this operation was taken as an average of UCRL cost for the loading of a truck and the estimated cost of loading a barge. This amounts to \$1.50 per drum. Demurrage charges, if incurred, are considered to be within the limits of uncertainty of this cost.

6. Truck Transportation from Railhead to Burial Site

At NTS the transportation cost is estimated at \$0.40 per hundred pounds or \$3.00 per drum. At HAPO and NRTS, this is estimated at \$0.30 per drum.

7. Unloading at Burial Site

The cost of unloading at the burial site is assumed to be \$1.00 per drum.

8. Direct Burial Costs: Excavation, and Cover of Burial Site

In a previous cost-survey report⁹ it is stated that at the National Reactor Testing Station the cost of burial is \$0.36 per cubic foot of waste. For a 55-gallon drum of approximately 7 cubic feet, this would be \$2.52 per drum. However, it is noted that charges made by the National Reactor Station to Rocky Flats for burial of wastes amounts to about \$0.10 per cubic foot, which would be equivalent to \$0.70 per 55-gallon drum. These charges to Rocky Flats must have also included truck-unloading costs.

At the Oak Ridge National Laboratory the cost-survey report⁹ shows a cost of \$0.22 per cubic foot for land burial operations. This would amount to \$1.54 per 55-gallon drum. Charges made to other installations for burial of their wastes were about \$0.17 per cubic foot, and the charge presumably included hauling 9 miles from a railhead to the dump site.

The waste-disposal service at the Oak Ridge National Laboratory available to industrial and scientific organizations is described in the 1957 edition of their Isotopes catalog. There it is stated that their disposal price for a package weighing less than 500 pounds and measuring less than 4 by 4 by 4 feet is \$10.00, and that the price for heavier or larger packages is supplied upon request. For the maximum-size package of 64 cubic feet this charge amounts to 16 cents per cubic foot. For a 1-cubic-foot package this would be \$10.00 per cubic foot, and for the 55-gallon drum \$1.43 per cubic foot. These figures imply that the major cost is in the package handling from railhead to burial ground, and that burial cost is of the order of 15 cents per cubic foot or less.

From all of the above, a value of \$1.00 per drum is taken as the burial cost.

9. Guarding and Checking of Burial Site

It is assumed that one would want to assure in perpetuity that burial sites will not be re-excavated. If burial sites are located within government-owned areas, serving other functions as well, one can be reasonably well assured that there will be adequate guarding for as long as the government exists. It is assumed that such protection, functioning as a supplementary operation, is a negligible cost per item buried.

Despite what logic may say regarding any public danger, the assuaging of public anxiety will probably require periodic sampling and testing of underground waters, lakes, and rivers in the vicinity of burial sites. Since this is a repetitive operation over many, many years and since the resultant cost per item buried is dependent upon the size of the burial area, no attempt was made to estimate the cost.

APPENDIX

Compilation of cost estimates for various assumed ways in which sea disposal or land disposal might be effected.

Sea Disposal

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Case A-1 } Case A-2 }	3000 drums per sea trip	14 15
Case B	1850 drums per sea trip	16
Case C-1 } Case C-2 } Case C-3 }	1000 drums per sea trip	17 18 19
Case D-1 } Case D-2 }	500 drums per sea trip	20 21
Case E	MSTS (Military Sea Transport Service)	21

Land Burial

Case F	Rail transportation to burial facility	22
Case G	Truck transportation to burial facility	22

Case A-1 Dumping at 1000 fathoms; 3000 drums per sea trip; 200 drums directly from Berkeley to Oakland dock; 1300 drums from Berkeley to Livermore to Oakland dock; 1500 drums from Livermore to Oakland dock; Seaborn Towing Service as the barge and tug organization. (Costs for 2000-fathom dumping, if different, shown in brackets)

Item	Cost per drum			
	Berkeley to dock	Berkeley to Livermore to dock	Livermore to dock	Average
1. UCRL truck loading and unloading	\$0.75	\$2.25	\$0.75	
2. Transportation				
a. Berkeley to dock	1.88			
b. Livermore to dock		2.25	2.25	
c. Berkeley to Livermore		1.88		
3. Dock rental	0.66	0.66	0.66	
4. Barge rental	0.15	0.15	0.15	
5. Barge loading	2.25	2.25	2.25	
Subtotal	<u>\$5.69</u>	<u>\$9.44</u>	<u>\$6.06</u>	\$7.50
6. Sea trip	<u>0.33</u> [0.66]	<u>0.33</u> [0.66]	<u>0.33</u> [0.66]	
Total	<u>\$6.02</u> [6.35]	<u>\$9.77</u> [10.10]	<u>\$6.39</u> [6.72]	\$7.83 [8.16]

Case A-2 Dumping at 1000 fathoms; 3000 drums per sea trip; 1500 drums from Berkeley to commercial facility in San Leandro for storage, 9 months average storage time, thence from San Leandro storage to Oakland airport dock; 1500 drums from Livermore to Oakland airport dock; Seaborn Towing Service as the barge and tug organization. (Costs for 2000-fathom dumping, if different, shown in brackets)

Item	Cost per drum		
	Berkeley to San Leandro to dock	Livermore to dock	Average
1. UCRL truck loading	\$0.75	\$0.75	
2. Transportation and storage			
c. Livermore to dock		2.25	
d. Berkeley to San Leandro storage	2.58		
e. San Leandro to dock	2.18		
3. Dock rental	0.66	0.66	
4. Barge rental	0.15	0.15	
5. Barge loading	2.25	2.25	
Subtotal	<u>\$8.57</u>	<u>\$6.06</u>	\$7.32
6. Sea trip	<u>0.33</u> [0.66]	<u>0.33</u> [0.66]	
Total	\$8.90 [9.23]	\$6.39 [6.72]	\$7.65[7.98]

Case B Dumping at 1000 fathoms; 1850 drums per sea trip; 200 drums directly from Berkeley to an Oakland dock; 725 drums from Berkeley to Livermore to Oakland dock; 925 drums from Livermore to Oakland dock; Bay Cities Transportation as the barge and tug organization. (Costs for 2000-fathom dumping, if different, shown in brackets)

Item	Cost per drum			
	Berkeley to dock	Berkeley to Livermore to dock	Livermore to dock	Average
1. UCRL truck loading and unloading	\$0.75	\$2.25	\$0.75	
2. Transportation				
a. Berkeley to dock	1.88			
b. Livermore to dock		2.25	2.25	
c. Berkeley to Livermore		1.88		
Subtotal	<u>\$2.63</u>	<u>\$6.38</u>	<u>\$3.00</u>	\$4.28
3. Dock rental	} 4.87 [5.41]	} 4.87 [5.41]	} 4.87 [5.41]	
4. Barge rental				
5. Barge loading				
6. Sea trip				
Total	<u>\$7.50 [8.04]</u>	<u>\$11.25 [11.79]</u>	<u>\$7.87 [8.41]</u>	\$9.15[9.69]

Case C-1 Dumping at 1000 fathoms; 1000 drums per sea trip; 200 drums directly from Berkeley to Oakland dock; 300 drums from Berkeley to Livermore to Oakland dock; 500 drums from Livermore to Oakland dock; Seaborn Towing Service as the barge and tug organization. (Costs for dumping, if different, in 2000 fathoms shown in brackets)

Item	Cost per drum			
	Berkeley to dock	Berkeley to Livermore to dock	Livermore to dock	Average to dock
1. UCRL truck loading and unloading	\$0.75	\$2.25	\$0.75	
2. Transportation				
a. Berkeley to dock	1.88			
b. Livermore to dock		2.25	2.25	
c. Berkeley to Livermore		1.88		
3. Dock rental	0.66	0.66	0.66	
4. Barge rental	0.15	0.15	0.15	
5. Barge loading	2.25	2.25	2.25	
Subtotal	<u>\$5.69</u>	<u>\$9.44</u>	<u>\$6.06</u>	\$7.00
6. Sea trip	<u>1.00 [2.00]</u>	<u>1.00 [2.00]</u>	<u>1.00 [2.00]</u>	
Total	<u>\$6.69 [7.69]</u>	<u>\$10.44 [11.44]</u>	<u>\$7.06 [8.06]</u>	\$8.00 [9.00]

Case C-2 Same as Case C-1, except using Bay Cities Transportation as the barge and tug organization.

Item	Cost per drum			
	Berkeley to dock	Berkeley to Livermore to dock	Livermore to dock	Average
1. UCRL truck loading and unloading	\$0.75	\$2.25	\$0.75	
2. Transportation				
a. Berkeley to dock	1.88			
b. Livermore to dock		2.25	2.25	
c. Berkeley to Livermore		1.88		
Subtotal	<u>\$2.63</u>	<u>\$6.38</u>	<u>\$3.00</u>	<u>\$3.94</u>
3. Dock rental	} 9.00 [10.00]	} 9.00 [10.00]	} 9.00 [10.00]	
4. Barge rental				
5. Barge loading				
6. Sea trip				
Total	<u>\$11.63</u> [12.63]	<u>\$15.38</u> [16.38]	<u>\$12.00</u> [13.00]	<u>\$12.94</u> [13.94]

Case C-3 Same as C-1, except storage of the 300 Berkeley drums is made at a San Leandro commercial facility, the dock used is the one near Oakland airport, and the average storage period is 4 months.

Item	Cost per drum			
	Berkeley to dock	Berkeley to San Leandro to dock	Livermore to dock	Average
1. UCRL truck loading	\$0.75	\$0.75	\$0.75	
2. Transportation and storage				
a. Berkeley to dock	1.50			
b. Livermore to dock			2.25	
c. Berkeley to San Leandro storage		1.98		
e. San Leandro to dock		2.18		
3. Dock rental	0.66	0.66	0.66	
4. Barge rental	0.15	0.15	0.15	
5. Barge loading	2.25	2.25	2.25	
Subtotal	<u>\$5.31</u>	<u>\$7.97</u>	<u>\$6.06</u>	\$6.48
6. Sea trip	1.00[2.00]	1.00 [2.00]	1.00 [2.00]	
Total	<u>\$6.31 [7.31]</u>	<u>\$8.97 [9.97]</u>	<u>\$7.06 [8.06]</u>	\$7.48[8.48]

Case D-1 Dumping at 1000 fathoms; 500 drums per sea trip; 250 drums from Berkeley to Oakland dock; 250 drums from Livermore to Oakland dock; Seaborn Towing Service as the barge and tug organization. (Costs for 2000-fathom dumping, if different, shown in brackets.)

<u>Item</u>	<u>Cost per drum</u>		
	<u>Berkeley to dock</u>	<u>Livermore to dock</u>	<u>Average</u>
1. UCRL truck loading	\$0.75	\$0.75	
2. Transportation			
a. Berkeley to dock	1.88		
b. Livermore to dock		2.25	
3. Dock rental	0.66	0.66	
4. Barge rental	0.15	0.15	
5. Barge loading	2.25	2.25	
Subtotal	<u>\$5.69</u>	<u>\$6.06</u>	5.88
6. Sea trip	<u>2.00</u> [4.00]	<u>2.00</u> [4.00]	
Total	<u>\$7.69</u> [9.69]	<u>\$8.06</u> [10.06]	\$7.88 [9.88]

Case D-2 Same as D-1, except utilizing Bay Cities Transportation as the barge and tug organization.

<u>Item</u>	<u>Cost per drum</u>		
	<u>Berkeley to dock</u>	<u>Livermore to dock</u>	<u>Average</u>
1. UCRL truck loading	\$0.75	\$0.75	
2. Transportation			
a. Berkeley to dock	1.88		
b. Livermore to dock		2.25	
Subtotal	\$2.63	\$3.00	2.82
3. Dock rental	} 18.00 [20.00]	} 18.00 [20.00]	
4. Barge loading			
5. Barge rental			
6. Sea trip			
Total	\$20.63 [22.63]	\$21.00 [23.00]	\$20.82 [22.82]

Case E Sea disposal through the Military Sea Transport Service; trucking from Berkeley and Livermore to storage area at Concord Naval Ammunition Depot or to Port Chicago dock.

1. UCRL truck loading	\$0.75
2. Transportation	1.88
Subtotal	\$2.63
MSTS charges*	3.00*
Total	\$5.63

* There is some question as to the amount of these charges.

Case F Trucking from UCRL to Oakland, California rail freight depot; rail transportation to burial installation railhead. (Costs are shown for Berkeley; corresponding costs for Livermore are given in brackets.)

<u>Item</u>	<u>Cost per drum</u>		
	<u>HAPO</u>	<u>NRTS</u>	<u>NTS</u>
1. UCRL truck loading	\$0.75	\$0.75	\$0.75
2a, 3. Transportation to Oakland freight depot, railcar loading, shoring	2.33 [2.71]	2.33 [2.71]	2.33 [2.71]
4. Rail to railhead	7.17	7.35	5.93
5. Unloading railcar	1.50	1.50	1.50
6. Transportation to burial site	0.30	0.30	3.00
7. Unloading at burial site	1.00	1.00	1.00
8. Burial	1.00	1.00	1.00
Total	\$14.05 [14.43]	\$14.23 [14.61]	\$15.51 [15.89]
Average, Berkeley, Livermore	14.24	14.42	15.70

Case G Trucking from UCRL at Berkeley or Livermore directly to burial site.

<u>Item</u>	<u>Cost per drum</u>		
	<u>HAPO</u>	<u>NRTS</u>	<u>NTS</u>
1. UCRL truck loading	\$0.75	\$0.75	\$0.75
2b. Transportation to burial site	16.50	16.35	11.25
7. Unloading at burial site	1.00	1.00	1.00
8. Burial	1.00	1.00	1.00
Total	\$19.25	\$19.10	\$14.90

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