3038
LA-UR-96-draft

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

TITLE: ESTIMATING HEEL RETRIEVAL COSTS FOR UNDERGROUND STORAGE TANK WASTE AT HANFORD

AUTHOR(S): Scott DeMuth

SUBMITTED TO: General Distribution

DISCLAIMER

LA-UR-96-draft

ESTIMATING HEEL RETRIEVAL COSTS FOR UNDERGROUND STORAGE TANK WASTE AT HANFORD

A Cost Study Funded by the Department of Energy
Office of Science and Technology
Tank Focus Area

August 26, 1996

Scott F. DeMuth
Los Alamos National Laboratory
Technology & Assessment Division
Energy & Environmental Analysis Group

ESTIMATING HEEL RETRIEVAL COSTS FOR UNDERGROUND STORAGE TANK WASTE AT HANFORD

Conclusions

This study was performed as a means for initiating the preparation of a comprehensive System Model for estimating costs related to the use of alternate technologies for the remediation of underground storage tank (UST) waste across the DOE complex. It was decided to begin this effort with an investigation of the cost of underground storage tank (UST) heel retrieval at Hanford. The additional cost of achieving 99% retrieval from USTs at the Hanford Site was estimated as a function of retrieval rate rather than specific retrieval technologies. Application to specific technologies can be pursued by the developer with the results of this study.

Within the range of heel retrieval rates and capital costs considered in this study, the additional cost of retrieving 99% of the UST waste at Hanford, versus the baseline effort of past practice sluicing (PPS) for single-shell tanks (SSTs) and mixer pumps (MPs) for double-shell tanks (DSTs), is $2.2- to $4.8-billion. It has been assumed for this study that PPS is capable of retrieving only 85% of the SST waste (Reference 1), and MPs are capable of retrieving only 90% of the DST waste (Reference 2). Figure 1 displays the constituents of the additional costs. The minimum rate is defined as (1/4)xPPS for SSTs and (1/2)xPPS for DSTs, and the maximum rate is defined as (1/2)xPPS for SSTs and (1)xPPS for DSTs. The minimum additional capital cost is defined as $1-million per tank and the maximum as $10-million per tank, with no additional infrastructure capital costs. The basis for these performance bounds are discussed later in this report.

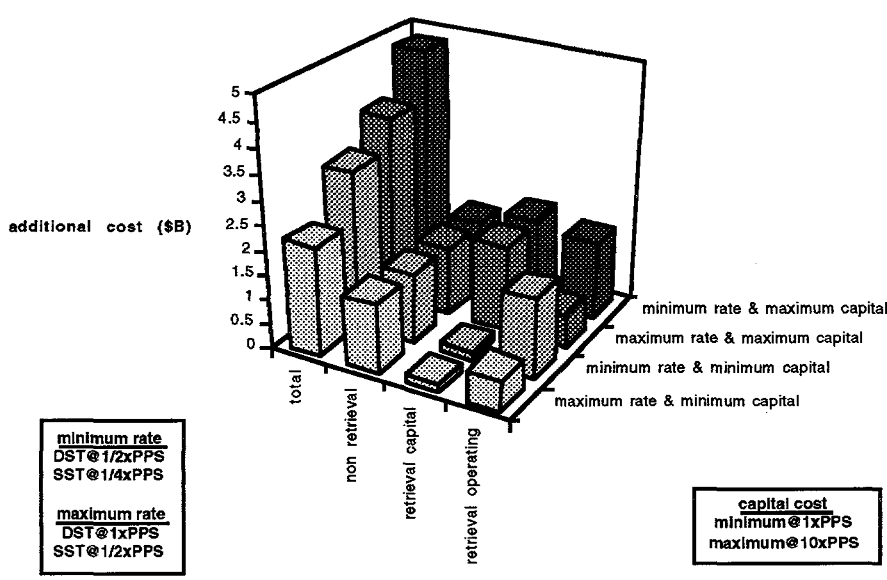

Figure 1. Beyond baseline costs for Hanford tank closure at 99% retrieval

This effort was intended to lead to further studies based on cost and performance data for specific heel retrieval technologies. Assumptions were made to greatly simplify the retrieval scenarios of this effort. These assumptions have been clearly stated so that the conclusions can be viewed in their context.

Background

Approximately 100 million gallons (~400,000 m^3) of existing U.S. Department of Energy (DOE) owned radioactive waste stored in underground tanks can not be disposed of as low-level waste (LLW). The current plan for disposal of UST waste which can not be disposed of as LLW is immobilization as glass and permanent storage in an underground repository. Disposal of LLW generally can be done sub-surface at the point of origin. Consequently, LLW is significantly less expensive to dispose of than that requiring an underground repository. Due to the lower cost for LLW disposal, it is advantageous to separate the 100 million gallons of waste into a small volume of high-level waste (HLW) and a large volume of LLW. Figure 2 shows the Sites at which this waste is located, and their relative volumes and activities (i.e. curies).

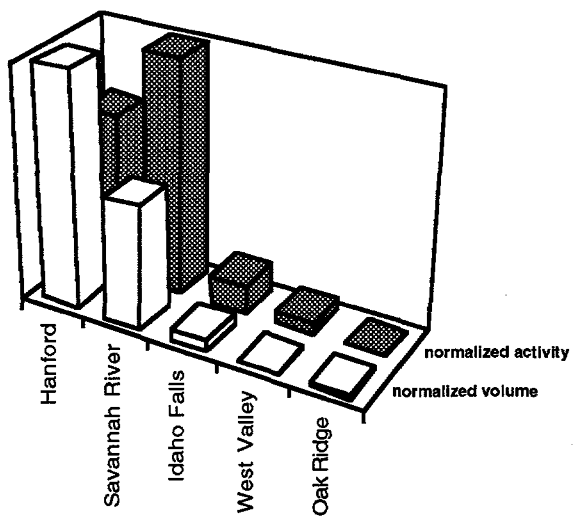

Figure 2. Underground storage tank waste volume and activity at each site (References 3 & 4)

Of the 100 million gallons of waste stored in underground tanks, approximately 65 million is located at the Hanford Site. The waste at Hanford is stored in single-shell and double-shell tanks. Neutralization was performed on the initial acidic waste to provide compatibility with the carbon steel USTs. Following neutralization, a sludge-like precipitant formed which settled on the bottom of USTs. In addition to the sludge, volume reduction of the neutralized liquid by evaporation created a crystalline-like material referred to as salt cake, and a pre-salt cake condition referred to as slurry. Most of the SST liquid waste remaining after neutralization has been pumped into the DSTs due to the SST reputation for leaking. Past-practice sluicing (PPS) is the baseline technology for retrieving the remaining sludge and salt cake from the SSTs at

Hanford. The baseline technology for retrieval of DST waste at Hanford is mixer-pumps (MPs). Figure 3 shows the distribution of waste in USTs throughout the DOE complex.

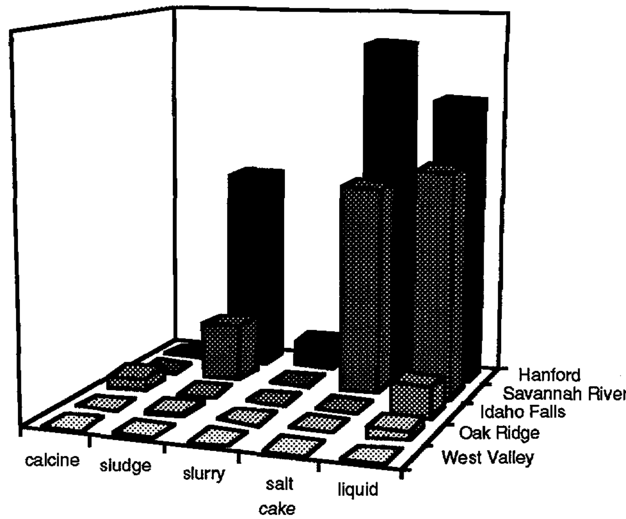

Figure 3. Underground storage tanks waste form at each site (References 3 &4)

Applicability

Significant quantities of waste in underground tanks currently exists at four DOE sites: (1) Hanford, (2) Savannah River, (3) Idaho Falls, and (4) Oak Ridge. Of these DOE sites, only the Hanford site has been considered for this cost study. However, the modeling used for this study is applicable to the other Sites as well. Due to the large portion of DOE waste which is currently located at Hanford, it was chosen as the site for this study.

Assumptions

GENERAL

- All cost figures are assumed to be in 1995 dollars.
- Pretreatment, Immobilization and Disposal unit operation costs are based on TPA Alternative Engineering Data Package for the TWRS EIS (Reference 5), Table F-36.
- Retrieval costs are based on the TPA (Reference 6), Case Beta.
- Waste processing flowsheet material balances are based on TWRS Flowsheet (Reference 1), Figure 2-3.

- Waste type and volume for each tank are based on UST-ID Site Characteristics (Reference 4), Table A-1.

<u>*SPECIFICS*</u>

Retrieval

- SSTs will be retrieved by PPS/ transfer pumps
  - the sluicing rate will average 14.4 m^3/day (TWRS Flowsheet, Appendix B)
  - the sluicing is rate limiting rather than the transfer pump rate
- DSTs will be retrieved by MPs/ transfer pumps
  - initial immobilization prior to transfer will average 200 hrs/tank (Reference 1, Section 5.2.1)
  - the transfer pump will control operating time following immobilization at 75 gal/min (rate at Savannah River Site per Reference 2)
- Capital Cost
  - total capital cost for retrieval is $5.1 billion (Reference 9, Case Beta Costs)
  - capital cost for retrieval per tank is simply the total site capital cost for retrieval divided by the number of tanks to be retrieved, since most of the retrieval cost is in infrastructure.
    - . mixer pumps cost ~ $1 million
    - . sluicing equipment is similar in cost or less than mixer pumps
    - . transfer pumps are similar in cost or less than mixer pumps
- Operating Cost
  - total operating cost for retrieval is $3.7 billion (Reference 9, Case Beta Costs)
    - . the cost per operating hour is based on yielding $3.7 billion for retrieval of all 177 tanks (SST & DST)
    - . equipment availability is 50% (similar to TWRS Flowsheet)

Pretreatment/Disposal

Radionuclide Separation
- baseline technology performance is based on the TWRS Flowsheet
- baseline costs are based Reference 5, Table F-36
- non baseline technology (CSTs) performance and cost are based on Reference 7

Non-Radionuclide Separation
- technology performance is based on TWRS Flowsheet
- costs are based on Reference 5, Table F-36

HLW & LLW Immobilization
- loading is based on TWRS Flowsheet
- costs are based on Reference 5, Table F-36

LLW Disposal
- loading is based on TWRS Flowsheet
- costs are based on Reference 5, Table F-36

HLW Interim Storage and Disposal:
- costs are combined and reported as only disposal costs (see Reference 5, Table F-36)

Caveats

This analysis has been funded by the Department of Energy, Office of Science and Technology (DOE/EM-50), specifically the Tank Focus Area (TFA). The conclusions are not necessarily endorsed by the DOE. This is a scoping study not a detailed analysis. It is not the author's intent to present this study as the only method for calculating costs. There are numerous improvements which can be made to this analysis with time.

Analyses/Results

Tank Closure

The material balances for remediation of Hanford waste are approximated in Figure 5, and are based on the TWRS Flowsheet. The masses shown in Figure 5 represent the most significant waste constituents requiring final disposal (disposed-waste), i.e. aluminum, chromium, iron and sodium. It has been assumed for this study that separation fractions occurring at each box of Figure 5 do not change significantly for small variations in the total waste processed. The stream flows of Figure 5 were determined from Reference 1 (TWRS Flowsheet) as follows.

(1) Waste into Physical Separation box
- Streams #16 plus #18 of Figure 2-3, page 22

(2) Liquid out of Physical Separation box
- Stream #205 of Sheet 4, page 233

(3) Solids out of Physical Separation box
- Item 1 minus Item 2 above

(4) 1.0 Mkg into Radionuclide Separation box
- Stream #24 of Figure 2-3

(5) Radionuclides out of Radionuclide Separation box
- Stream #26 of Figure 2-3

(6) Salts out of Radionuclide Separation box
- (Item 2 plus Item 4) minus Item 5

(7) Radionuclides out of Non Radionuclide Separation box
- Stream #20 of Figure 2-3

(8) Salts out of Non Radionuclide Separation box
- Item 3 minus Item 7

(9) Immobilized HLW for Interim Storage box
- Item 8 plus Item 5

(10) 7.9 Mkg into LLW Immobilization box
- Stream #29 of Figure 2-3

(11) Immobilized LLW for LLW Disposal box
- Item 6 plus Item 8 plus Item 10

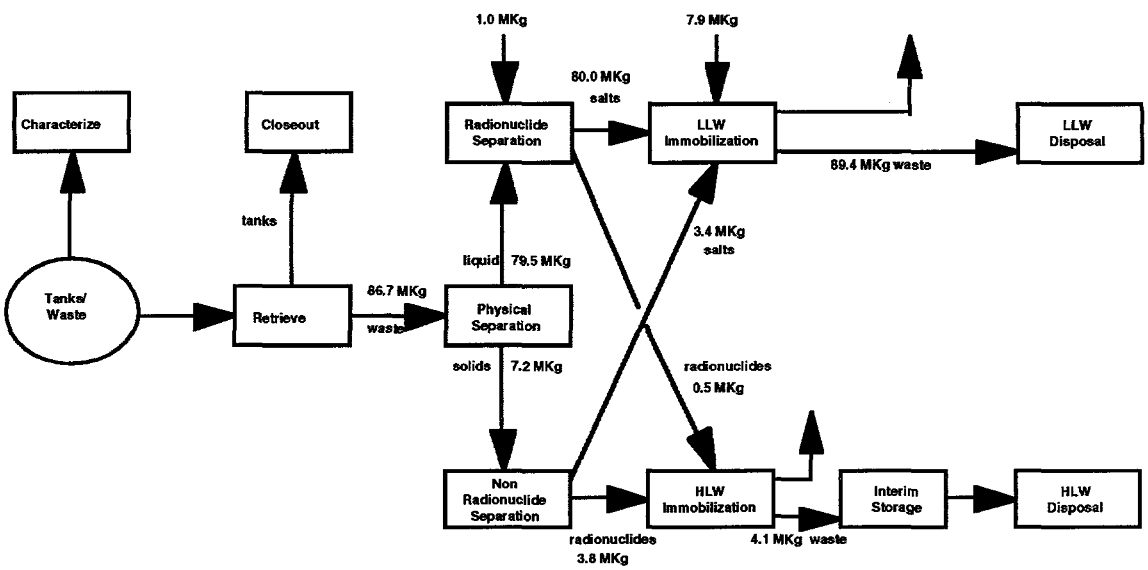

Figure 5. Material balances for Hanford TWRS

The costs shown in Figure 6 were derived from Table F-36 of the *Tri-Party Agreement Alternate Engineering Data package for the Tank Waste Remediation System Environmental Impact Statement,* Reference 5. The costs from Table F-36 are summarized below in Table 1.

	cost ($M)
Sludge Wash	207
Cesium Removal	975
Centralized Facilities	520
LLW Vitrification	2934
LLW Disposal	294
HLW Vitrification	2957
HLW Transportation	24
HLW Disposal	5858

Table 1. Hanford Remediation Costs

The costs from Table 1 were converted to those of Figure 6 as follows:

Radionuclide Separation - (Figure 6)
[cesium removal + (1/3)(central facilities)] - (Table 1)
Non Radionuclide Separation - (Figure 6)
sludge washing - (Table 1)
LLW Immobilization - (Figure 6)
[LLW vitrification + (1/3)(central facilities)] - (Table 1)
LLW Disposal - (Figure 6)
LLW disposal - (Table 1)
HLW Immobilization - (Figure 6)
[HLW vitrification + (1/3)(central facilities)] - (Table 1)

Interim Storage - (Figure 6)
included in HLW Disposal box
HLW Disposal - (Figure 6)
(HLW transportation + HLW disposal) - (Table 1)

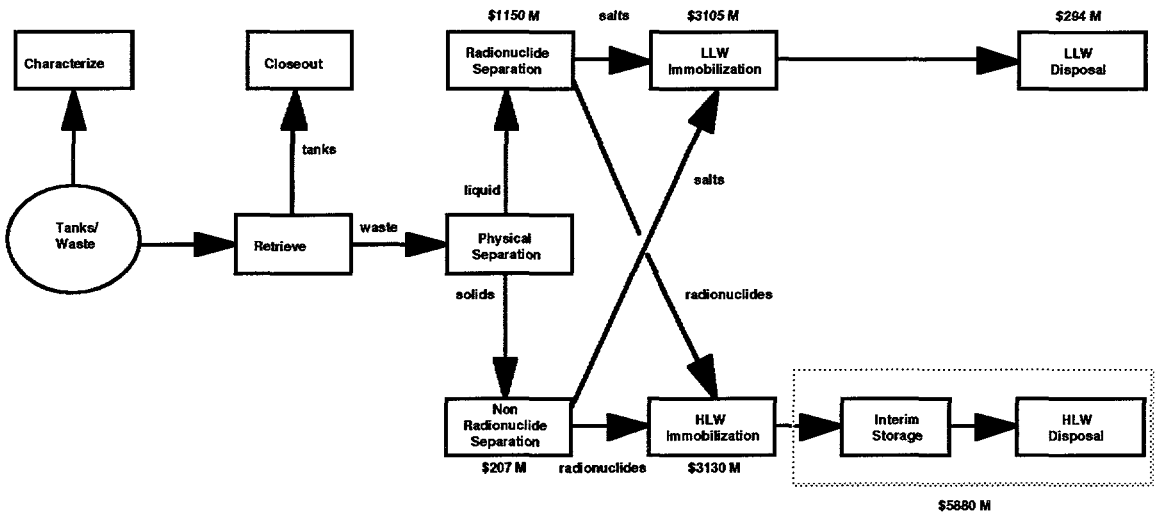

Figure 6. Costs for Hanford TWRS

Figure 7 shows the division of waste and the cost/mass of disposed-waste processed for each significant remediation step. As an example, for the Radionuclide Separation box:

radionuclide separation cost = [$975 M + (1/3)$520 M]/79.5 Mkg = $14/kg

fraction of salts from radionuclide separation = 80 Mkg/(80 Mkg + 0.5 Mkg) = 0.9937

fraction of radionuclides from radionuclide separation = 1 - 0.9937 = 0.0063

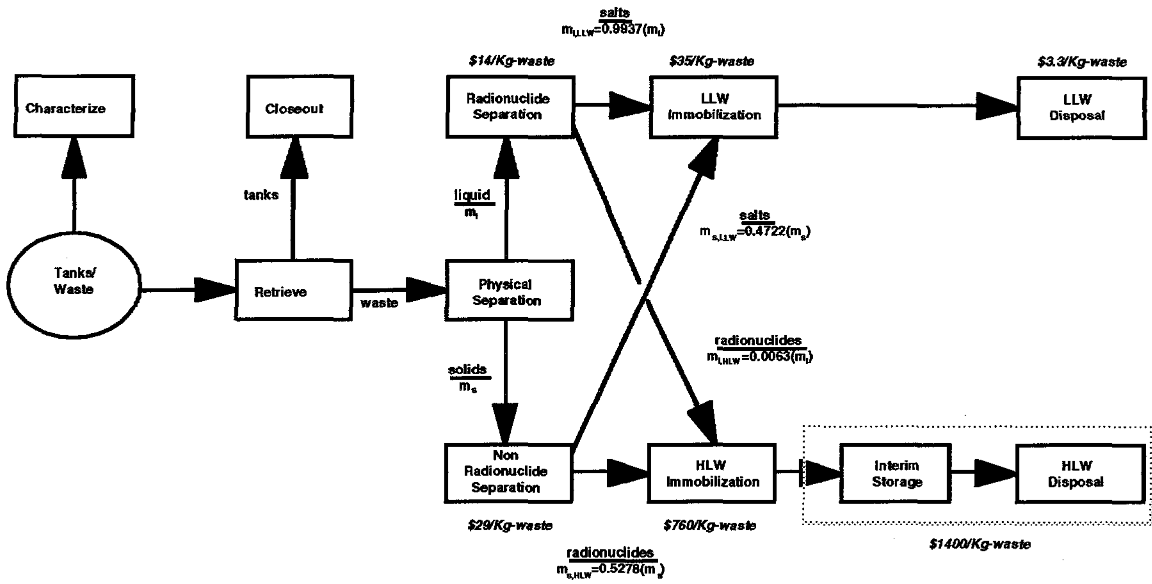

Figure 7. Simplified processing/cost model for Hanford TWRS

The method for calculating the respective remediation costs for each individual tank at Hanford is based on the type and amount of waste in each tank as determined from Table A-1 of Reference 4. The remediation cost for SST-S107 and DST-SY101 are used as examples in the following. Table A-1 defines the tank contents for each waste form as shown in Table 2 of this report.

tank	liquid (Kgal)	salt cake (Kgal)	sludge (Kgal)	slurry* (Kgal)
S107	6	69	293	0
SY101	29	560	0	530

* - slurry definition per Reference 6, liquid concentrated almost to point of precipitation/crystallization

Table 2. Waste type for Hanford tanks S107 and SY101

The following Table 3 is derived from Table 4-10 of Reference 4, and shows the average concentration of the most significant disposed-waste constituents of each waste type. Components such as Na, Al, Cr, and Fe do become part of the final waste form (FWF); whereas, components such as H_2O, NO_3, and NO_2 do not.

	liquid wt %	salt cake wt %	slurry* wt %
$NaNO_3$	20.8	81.5	14.8
- Na	***5.6***	***22.1***	***4.0***
$NaNO_2$	15.8	1.7	5.6
- Na	***5.3***	***0.6***	***1.9***
Na_2CO_3	0.6	0.5	1.9
- Na	***0.3***	***0.2***	***0.8***
NaOH	6.2	1.5	7.0
- Na	***3.6***	***0.9***	***4.0***
$NaAlO_2$	12.5	1.4	5.6
- Na	***3.5***	***0.4***	***1.6***
- Al	***1.2***	***0.1***	***0.5***
Na_3PO_4	2.3	0.6	0.8
- Na	***1.0***	***0.7***	***0.3***
- P	***0.4***	***0.1***	--
Na_2SO_4	--	1.3	0.3
- Na	--	***0.4***	***0.1***
- S	--	***0.3***	***0.1***
FeO(OH)	--	--	0.2
- Fe	--	--	***0.2***
$Al(OH)_3$	--	--	4.9
- Al	--	--	***1.7***
Na_2CrO_4	1.3	--	--
- Na	***0.4***	--	--
- Cr	***0.4***	--	--
Total FWF	***21.7***	***25.8***	***15.2***

* - see definition for Table 2

Table 3. Final waste form (FWF) components

The average density of each waste type, with regard to ***only the components present in the final waste form***, can then be calculated from the volume of each waste type listed in Reference 4 and the waste mass from the TWRS Flowsheet, as follows.

Sludge disposed-waste density
- disposed-waste mass (from Figure 5) = 7.2 Mkg
- total volume (from Reference 7) = 14.4 Mgal
- disposed-waste density (d_{sg}) = 7.2 Mkg/14.4 Mgal = 0.50 kg/gal (130 kg/m^3)
  - note: It is likely the sludge volume of Reference 4 includes a significant quantity of interstitial liquid which lowers it's FWF density.

Liquid disposed-waste density
- liquid(d_l), salt cake(d_{sc}), and slurry(d_{sl})
- $(v_l)(d_l) + (v_{sc})(d_{sc}) + (v_{sl})(d_{sl}) = 79.5$ Mkg
- from Table 3
  - $(d_{sc})/(d_l) = 25.8/21.7 = 1.19$
  - $(d_{sl})/(d_l) = 15.2/21.7 = 0.70$
  - where
    - $v_l = 19.7$ Mgal
    - $v_{sc} = 24.2$ Mgal
    - $v_{sl} = 2.0$ Mgal

rearranging and solving yields

$$d_l = 79.5\ \text{Mkg}/(v_l + 1.19v_{sc} + 0.70v_{sl})$$
$$d_l = 1.59\ \text{kg/gal}\ (410\ \text{kg/m}^3)$$
$$d_{sc} = 1.89\ \text{kg/gal}\ (479\ \text{kg/m}^3)$$
$$d_{sl} = 1.11\ \text{kg/gal}\ (283\ \text{kg/m}^3)$$

The processing and disposal costs for each tank can now be calculated based on Figure 7 of this report, and as shown for Tank S107.

disposed-waste

liquid	(6000 gal)(1.59 kg/gal) = 9540 kg
sludge	(293,000 gal)(0.50 kg/gal) = 147,000 kg
salt cake	(69,000 kg)(1.89 kg/gal) = 130,000 kg

m_l (Figure 7)
9540 kg + 130,000 kg = 140,000 kg

m_s (Figure 7)
147,000 kg

Radionuclide separation cost (Figure 7)
(140,000 kg)($14/kg) = $2.0 M

Non Radionuclide separation cost (Figure 7)
(147,000 kg)($29/kg) = $4.3 M

LLW immobilization cost (Figure 7)
$m_{l,LLW}$ = 0.9937(140,000 kg) = 139,000 kg
$m_{s,LLW}$ = 0.4722(147,000 kg) = 69,000 kg
(139,000 kg + 69,000 kg)($35/kg) = $7.3 M

LLW disposal
(139,000 kg + 69,000 kg)($3.3/kg) = $0.7 M

HLW immobilization cost
$m_{l,HLW}$ = 0.0063(140,000 kg) = 880 kg
$m_{s,HLW}$ = 0.5278(147,,000 kg) = 78,000 kg
(880 kg + 78,000 kg)($760/kg) = $60 M

LLW disposal
(880 kg + 78,000 kg)($1400/kg) = $111 M

Table 4 summarizes the processing and disposal costs for tank S107.

tank	pretreatment ($M)	immobilization ($M)	disposal ($M)
S107	2.0 + 4.3 = 6	7.3 + 60 = 67	0.7+ 111 = 112

Table 4. Summary of processing and disposal costs

The retrieval cost for each tank can be calculated from the volume of each waste type as shown in the following for SST tank S107 and DST tank SY101.

Capital (identical for both SST and DST since most of cost is in waste transfer infrastructure)
($5100 M/177 tanks) = $29 M/tank from Reference 6

Operating for SST (see Assumptions section)
S107 (SST)
14.4 m3/day or (1.3 Mgal/yr) at 50% availability
(293,000 + 69,000)gal = 362,000 gal
0.362 Mgal/[0.5(1.3 Mgal/yr)] = 0.56 yr
cost (iterative procedure)
(tank operating cost/yr)$\sum$ [tank-i operating time (yr)] = $3700 M
from Reference 6
or
(tank operating cost/yr) = $3700 M/$\sum$ [tank-i operating time (yr)]
i = 1 to 177 (total number of tanks)
tank i operating cost = 0.56 yr(tank operating cost/yr)

Operating for DST (see Assumptions section)
SY101 (DST)
200 hr + 75 gal/min or (39 Mgal/yr) at 50% availability
(29,000 + 560,000 + 530,000)gal = 1.19 Mgal
200 hr(1 yr/8760 hr) + 1.19 Mgal/[0.5(39 Mgal/yr)] = 0.08 yr
cost (same iterative procedure as for SST S107)

Figures 8-10 display the remediation cost for each tank based on the TWRS baseline. Appendix A relates tank numbers from Figures 8-10 to the actual Hanford defined tank numbers.

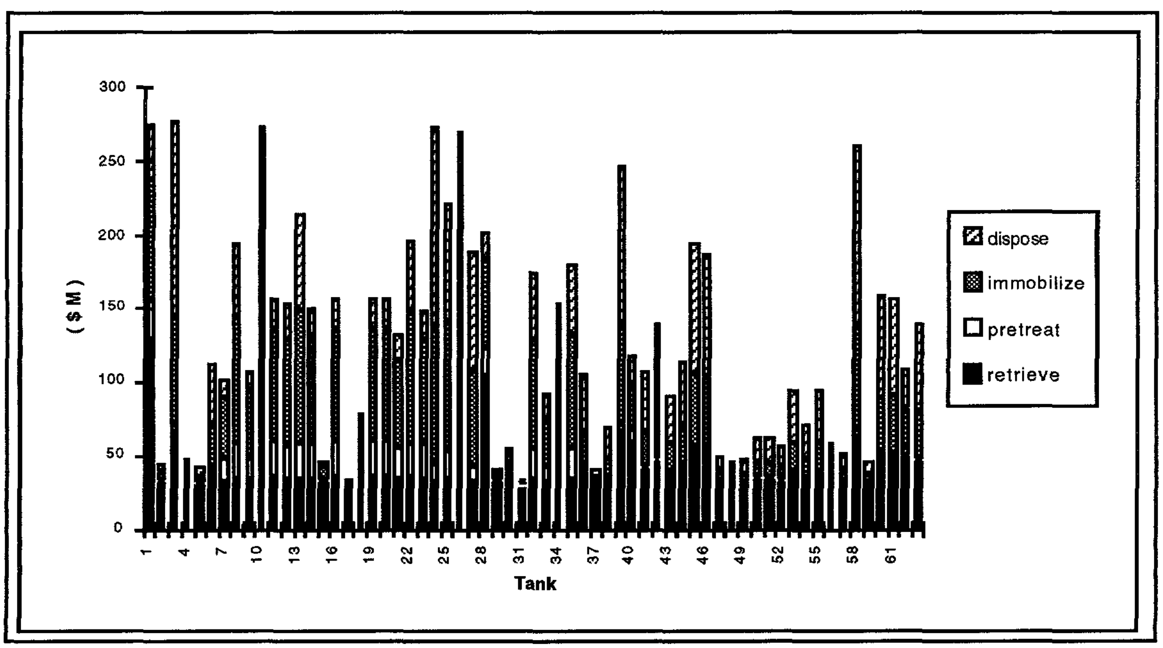

Figure 8. Remediation cost for Tanks A101-BX112

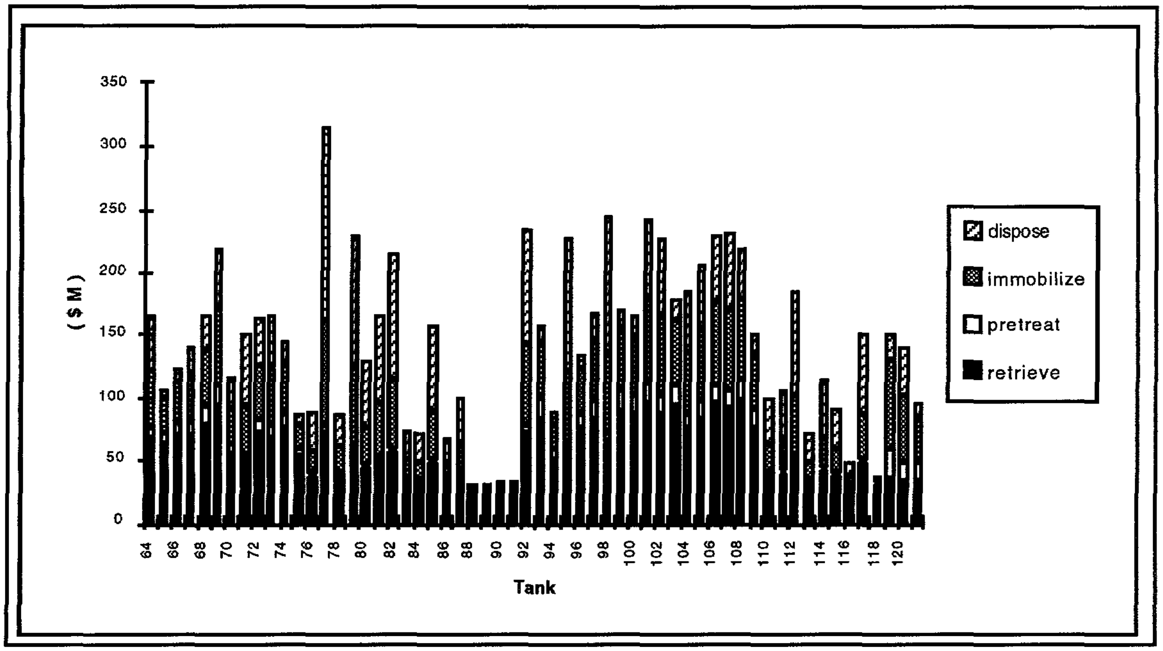

Figure 9. Remediation cost for Tanks BY101-SY103

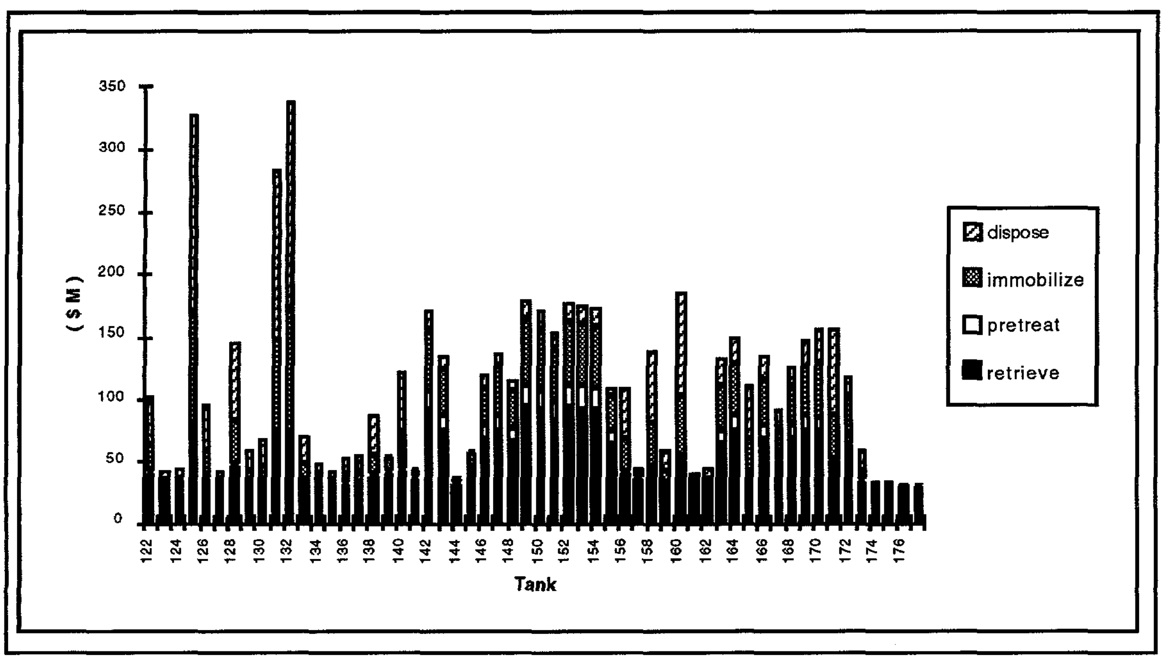

Figure 10. Remediation cost for Tanks T101-U204

The heel study was completed by similarly estimating the costs for retrieving and additional (99% - 85%) = 14% of the SST waste and (99% - 90%) = 9% of the DST waste. The additional remediation cost for the heel retrieval included the cost of processing and disposal of the additional waste.

Appendix

A101/sst	1	BX109/sst	60	SY101/dst	119
A102/sst	2	BX110/sst	61	SY102/dst	120
A103/sst	3	BX111/sst	62	SY103/dst	121
A104/sst	4	BX112/sst	63	T101/sst	122
A105/sst	5	BY101/sst	64	T102/sst	123
A106/sst	6	BY102/sst	65	T103/sst	124
AN101/dst	7	BY103/sst	66	T104/sst	125
AN102/dst	8	BY104/sst	67	T105/sst	126
AN103/dst	9	BY105/sst	68	T106/sst	127
AN104/dst	10	BY106/sst	69	T107/sst	128
AN105/dst	11	BY107/sst	70	T108/sst	129
AN106/dst	12	BY108/sst	71	T109/sst	130
AN107/dst	13	BY109/sst	72	T110/sst	131
AP101/dst	14	BY110/sst	73	T111/sst	132
AP102/dst	15	BY111/sst	74	T112/sst	133
AP103/dst	16	BY112/sst	75	T201/sst	134
AP104/dst	17	C101/sst	76	T202/sst	135
AP105/dst	18	C102/sst	77	T203/sst	136
AP106/dst	19	C103/sst	78	T204/sst	137
AP107/dst	20	C104/sst	79	TX101/sst	138
AP108/dst	21	C105/sst	80	TX102/sst	139
AW101/dst	22	C106/sst	81	TX103/sst	140
AW102/dst	23	C107/sst	82	TX104/sst	141
AW103/dst	24	C108/sst	83	TX105/sst	142
AW104/dst	25	C109/sst	84	TX106/sst	143
AW105/dst	26	C110/sst	85	TX107/sst	144
AW106/dst	27	C111/sst	86	TX108/sst	145
AX101/sst	28	C112/sst	87	TX109/sst	146
AX102/sst	29	C201/sst	88	TX110/sst	147
AX103/sst	30	C202/sst	89	TX111/sst	148
AX104/sst	31	C203/sst	90	TX112/sst	149
AY101/dst	32	C204/sst	91	TX113/sst	150
AY102/dst	33	S101/sst	92	TX114/sst	151
AZ101/dst	34	S102/sst	93	TX115/sst	152
AZ102/dst	35	S103/sst	94	TX116/sst	153
B101/sst	36	S104/sst	95	TX117/sst	154
B102/sst	37	S105/sst	96	TX118/sst	155
B103/sst	38	S106/sst	97	TY101/sst	156
B104/sst	39	S107/sst	98	TY102/sst	157
B105/sst	40	S108/sst	99	TY103/sst	158
B106/sst	41	S109/sst	100	TY104/sst	159
B107/sst	42	S110/sst	101	TY105/sst	160
B108/sst	43	S111/sst	102	TY106/sst	161
B109/sst	44	S112/sst	103	U101/sst	162
B110/sst	45	SX101/sst	104	U102/sst	163
B111/sst	46	SX102/sst	105	U103/sst	164

B112/sst	47	SX103/sst	106	U104/sst	165
B201/sst	48	SX104/sst	107	U105/sst	166
B202/sst	49	SX105/sst	108	U106/sst	167
B203/sst	50	SX106/sst	109	U107/sst	168
B204/sst	51	SX107/sst	110	U108/sst	169
BX101/sst	52	SX108/sst	111	U109/sst	170
BX102/sst	53	SX109/sst	112	U110/sst	171
BX103/sst	54	SX110/sst	113	U111/sst	172
BX104/sst	55	SX111/sst	114	U112/sst	173
BX105/sst	56	SX112/sst	115	U201/sst	174
BX106/sst	57	SX113/sst	116	U202/sst	175
BX107/sst	58	SX114/sst	117	U203/sst	176
BX108/sst	59	SX115/sst	118	U204/sst	177

References

(7) S.F. DeMuth, *Cost Benefit Analysis for Separation od Cesium from Liquid Radioactive Waste by Crystalline Silico Titanate Ion-Exchange Resin*, Los Alamos National Laboratory, Los Alamos, NM, LA-UR-96-966, March 1996.

(2) Author's discussion with Jim Lee of Sandia National Laboratory, Albuquerque, NM, May 1996.

(1) R.M. Orme, *TWRS Process Flowsheet*, Westinghouse Hanford Company, Richland, WA, WHC-SD-WM-TI-613, Rev.1, 9 August 1995.

(4) J.K. Rouse, et al., *Underground Storage Tank - Integrated Demonstration Participant Site Characteristic Summary*, Westinghouse Hanford Company, Richland, WA, WHC-EP-0566, January 1993.

(3) *Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, Oak Ridge National Laboratory, DOE/RW-0006, Rev. 7, October 1991.

(6) *Hanford Federal Facility Agreement and Consent Order - Fourth Amendment*, Washington State Department fo Ecology, United States Environmental Protection Agency, and United States Department of Energy, January 1994.

(5) E.J. Slaathaug, *Tri-Party Agreement Alternative Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement*, Westinghouse Hanford Company, Richland, WA, WHC-SD-WM-EV-104, Rev. 0, 19 July 1995.