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AN EVALUATION OF NEUTRALIZATION FOR PROCESSING SODIUM-BEARING LIQUID WASTE

N. A. Chipman
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Nuclear Waste Management

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AN EVALUATION OF NEUTRALIZATION FOR PROCESSING
SODIUM-BEARING LIQUID WASTE

N. A. Chipman
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January 1989

Westinghouse Idaho
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ABSTRACT

This report addresses an alternative concept for potentially managing the sodium-bearing liquid waste generated at the Idaho Chemical Processing Plant from the current method of calcining a blend of sodium waste and high-level liquid waste. The concept is based on removing the radioactive components from sodium-bearing waste by neutralization and grouting the resulting low-level waste for on-site near-surface disposal.

Solidifying the sodium waste as a remote-handled transuranic waste is not considered to be practical because of excessive costs and inability to dispose of the waste in a timely fashion. Although neutralization can remove most radioactive components to provide feed for a solidified low-level waste, and can reduce liquid inventories four to nine years more rapidly than the current practice of blending sodium-bearing liquid waste with first-cycle raffinate, the alternative will require major new facilities and will generate large volumes of low-level waste. Additional facility and operating costs are estimated to be at least \$500 million above the current practice of blending and calcining. On-site, low-level waste disposal may be technically difficult and conflict with national and state policies. Therefore, it is recommended that the current practice of calcining a blend of sodium-bearing liquid waste and high-level liquid waste be continued to minimize overall cost and process complexities.

SUMMARY

An alternative concept is evaluated for potentially processing existing and future sodium-bearing liquid waste separately to reduce the amount of high-level waste (HLW) and work off the sodium waste inventory faster at the Idaho Chemical Processing Plant (ICPP). The concept consists of removing the radioactive components by neutralization and solidifying the low-level waste (LLW) fraction as a grouted waste. The concept of separately solidifying the waste as remote-handled transuranic (TRU) waste is dismissed as too costly and not practical, because of inability of a potential disposal facility to accept the waste in a timely manner. Neutralization has the potential to reduce liquid sodium waste inventories more rapidly than the current practice, but is excessive with respect to cost and generation of low-level waste.

Sodium-bearing liquid waste is generated from waste evaporator bottoms and plant decontamination activities. The waste is about 1.6 M alkali (sodium plus potassium) and contains enough actinides and fission products to be classified as a remote-handled TRU waste. Sodium-bearing liquid waste is currently blended with high-level liquid waste (HLLW) and calcined. The sodium-bearing liquid waste inventory is projected to be depleted by the end of FY 2011 if blended at about a 5 mol% alkali content in the calcine.

The basis of this study for separately processing the sodium waste is that the current practice of calcining a blend of sodium-bearing liquid waste with HLLW is continued through 1997 at which time the required facilities for an alternative method are assumed to be available. The processing time to deplete the inventory of sodium waste is assumed to be either five or ten years.

This study compares the incremental life-cycle costs with current base-case ICPP operating costs. Potential savings in Calcine Storage Facility (CSSF) costs and immobilized waste disposal costs are also

considered. The life-cycle incremental costs are assumed to run from FY 1998, the year in which hot operations are assumed to begin processing sodium waste separately, through FY 2011, when the sodium waste is projected to be depleted under current base-case operations of blending sodium waste with HLLW prior to calcination.

The concept of directly solidifying the sodium-bearing liquid waste as a grout and disposing of it as a remote-handled TRU waste results in the generation of about 16170 m³ of waste by the end of 2011. The Waste Isolation Pilot Plant (WIPP) is the only facility designed to dispose of remote-handled TRU waste. The process is very costly. Thus, this management concept is not considered to be feasible, and no further evaluation is shown in this report.

The alternative method to separately process the sodium waste evaluated in this report is:

"Neutralization" in which the acidic sodium-bearing liquid waste is made basic to pH 13.5 to precipitate and separate the radioactive fraction from most of the inert (non-radioactive) components of the waste. The precipitated radionuclides are dissolved and combined with radionuclides removed by ion exchange from the neutralized solution, then returned to the HLLW tanks. The low-level liquid stream created by this process is then directly solidified by grouting and disposed on-site in a near-surface, LLW disposal facility.

For HLLW calcination it is estimated that New Waste Calcining Facility (NWCF) operating costs would decrease by less than 5% from the current operating cost for blended waste. Savings are realized, however, from the reduced volume of calcine produced, thus requiring about two-thirds of a CSSF less over the 14 year period of this study. Other facilities, such as a neutralization facility, grouting, and near-surface disposal facility, would have to be built specifically for a sodium-bearing liquid waste treatment method.

Currently under the assumed base-case, sodium-bearing liquid waste is calcined at an average rate of 55 m³/month and is generated at about 17 m³/month. Processing of sodium-bearing liquid waste separately under the alternative methods beginning in FY 1998 would result in processing 1180 m³ of sodium waste per year for the five-year schedule, or 720 m³ per year for the ten-year schedule. Once the inventory is depleted the new facilities would process annually generated sodium waste.

Presented in Table S.1 are the major new facilities required for the alternative method.

Table S.1
Additional Facility Requirements for Processing Sodium Waste Separately

Facility	Additional Facilities Needed	
	Base-Case (Current Operations)	Neutralization w/Liquid Grouting
Neutralization	N/A	X
Ion Exchange	N/A	X
LLW Grouting	N/A	X

N/A = Not applicable

Over the life-cycle of the facility about 8200 m³ of sodium-bearing liquid waste will be processed. If the LLW is directly grouted, 16,170 m³ of solid LLW would be produced by the end of 2011. Volumes of liquid waste processed and low-level grout produced are summarized in Table S.2. Low-level waste disposal on-site may be technically difficult and conflict with national and state policies.

Estimated incremental life-cycle rough-order-of-magnitude (ROM) costs above current base-case life-cycle costs for the alternative method are presented in Table S.3. Included are ROM estimates for additional facilities and separate sodium waste operating costs. Also included are

Table S.2
Liquid Sodium Waste Processed and Solid Low-Level Waste Generated
for the 5 and 10 Year Inventory Depletion Schedule

	Time Period ^a	Volume of Liquid Sodium Waste Processed	Volume of Neutralized Liquid Sodium Waste	Volume of Grouted Low-Level Waste Generated
Five Year Inventory Depletion Schedule	1998-2002	1181 m ³ /yr	8535 m ³ /yr	2325 m ³ /yr
	2003-2011	255 m ³ /yr	1845 m ³ /yr	505 m ³ /yr
	Total Volumes (14 year period ^a)	8200 m ³	59,280 m ³	16,170 m ³
Ten Year Inventory Depletion Schedule	1998-2007	718 m ³ /yr	5190 m ³ /yr	1415
	2008-2011	255 m ³ /yr	1845 m ³ /yr	505
	Total Volumes (14 year period ^a)	8200 m ³	59,280 m ³	16,170 m ³

a This study is carried out through 2011, the year in which the liquid sodium waste inventory is projected to be depleted under the current practice of calcining a blend of sodium bearing liquid waste with HLLW.

Table S.3

Additional Life-Cycle Costs for Processing
Sodium Waste Separately^a by Neutralization

Life-Cycle Process Facility and Operating Costs and Reduced HLW Disposal Costs, (\$Millions)							
5-year Schedule				10-year Schedule			
Total Facility Cost ^c	Total Operating Cost	Reduced ^b HLW Disp. Cost	Net Incremental Cost	Total Facility Cost ^c	Total Operating Cost	Reduced ^b HLW Disp. Cost	Net Incremental Cost
203	575	(265)	513	203	660	(265)	598

a - Life-cycle costs cover the period FY 1998-2011 and are incremental costs above the life-cycle costs for base-case operation

b - Reduced HLW disposal costs include: \$17 million for reduced CSSF requirements and \$248 million for reduced amounts of immobilized HLW disposal in a federal repository.

c - Facilities include: neutralization, ion exchange and grouting of slurried liquid waste.

incremental cost savings of \$17 million for reduced CSSF requirements and \$248 million for reduced disposal costs of immobilized high-level waste in a federal repository. Costs are shown for the 5-year and 10-year inventory depletion times.

If geometrically favorable dissolvers (GFD) are incorporated into the existing fuel dissolution facility, up to 30% less HLLW will be generated. The annual depletion rate of the sodium-bearing liquid waste would correspondingly be reduced requiring up to five additional years until FY 2016 to blend and calcine the sodium waste inventory. The effect on additional costs for solidifying the backlog of sodium waste inventory separately is minimal, because the work off inventory is the same for both cases.

Although neutralization could potentially deplete the sodium-bearing liquid waste five to ten years sooner than the current practice, and some savings in HLW calcine storage and immobilized HLW disposal could be realized, overriding unfavorable factors of additional facility and operating costs exist. The generation of LLW requires the opening of a new LLW disposal area, and the life-cycle cost above the base-case for neutralization is greater than \$500 million. Thus, based on the analyses in this report, it is recommended that the current practice of calcining a blend of sodium-bearing liquid waste and HLLW be continued to minimize overall cost, avoid increased process complexity, avoid potential conflict with national and state policies, and minimize public concern. Additionally, it is recommended that neutralization to process sodium-bearing liquid waste separately not be implemented.

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1. INTRODUCTION

1.1 PURPOSE

Currently there are about 5144 m³ of sodium-bearing liquid waste stored at the Idaho Chemical Process Plant (ICPP) tank farm. This sodium waste is currently solidified by blending with first-cycle raffinate high-level liquid waste (HLLW) and calcining the blend in the New Waste Calcining Facility (NWCF) to produce a granular solid material. During operation of the NWCF, about 55 m³ per month of sodium waste is solidified.^{1,2} Sodium-bearing liquid waste is generated at about 17 m³ per month.^{1,2} Based on current projections, the inventory of sodium waste will be depleted by the end of FY 2011 using the current method of blending and calcining.³ This report addresses a concept for managing sodium-bearing liquid waste separately from the first-cycle raffinate waste. The concept is removing the radioactive components by neutralization such that the bulk of the waste can be grouted for disposal as a low-level waste (LLW). A second concept of solidifying the waste as a remote-handled transuranic (TRU) waste is dismissed as too costly and impractical, because a disposal facility is not available to accept the waste in a timely manner.

1.2 CURRENT WASTE MANAGEMENT PRACTICES

Sodium-bearing liquid waste is generated primarily as process equipment waste (PEW) evaporator bottoms and plant decontamination solutions.⁴ These solutions are generated at a rate of about 17 m³ per month, with a nominal 1.6 M alkali (sodium plus potassium) content. The rate is variable depending upon plant operations and decontamination efforts. The sodium-bearing liquid wastes are stored in six 1136 m³ tanks located in the ICPP tank farm (WM tanks 180, 181, 183, 184, 185 and 186). At the end of FY 1988, about 5144 m³ of sodium-bearing liquid waste was contained in these tanks. This liquid waste volume constitutes about 79% of the working volume available in these six tanks.

Currently, sodium-bearing liquid waste is blended with the Fluorinel HLLW just prior to solidification in the NWCF. Blend ratios for various waste compositions are based on limiting the alkali content in the calcine product to less than 5.3 mol percent. Although the blend ratios vary, they are typically about 4-5 volumes of HLLW to 1 volume sodium waste. Calcine produced in the NWCF from blended HLLW and sodium-bearing liquid waste exhibits a volume reduction factor of about 7 and has a bulk density of about 1.4 g/cc. As the calcine is produced, it is pneumatically transported to the Calcine Solids Storage Facilities (CSSF) where it is stored pending future decisions on its disposition.⁵

1.3 ALTERNATIVE CONCEPTS FOR PROCESSING SODIUM-BEARING LIQUID WASTES

Other than the current practice of blending sodium-bearing liquid waste with HLW and calcining the blend, the concept for processing existing and future sodium waste by neutralization has been identified. The concept consists of removing the radioactive components by precipitation with sodium hydroxide, separating soluble radionuclides from the supernate, concentrating the liquid fraction by evaporation, then solidifying the resulting slurry as a grout for on-site, near-surface disposal. A second concept of solidifying the waste as a remote-handled TRU waste is not considered to be practical.

1.3.1 Solidification and Disposal as a Remote-Handled Transuranic Waste

Because of its actinide content, mostly americium (Am) and plutonium (Pu), the sodium-bearing liquid waste stored at the ICPP is in reality a TRU waste. But because of the high cesium (Cs) and strontium (Sr) content, the waste is very radioactive, requiring shielded facilities for storage and handling. The radioactivity content of future generated sodium waste is expected to increase. Thus, future generated sodium waste will continue to be a TRU waste at minimum, and possibly a HLW

based on Cs and Sr content. Sodium-bearing liquid waste could possibly be concentrated by evaporation then neutralized and solidified as a grout for disposal as a remote handled TRU waste in the Waste Isolation Pilot Plant (WIPP). Solidification of the waste by calcination is not practical because of operational problems including excessive fines generation and agglomeration. Shielded facilities to neutralize and grout the waste would be required.

The only facility designed to accept remote-handled TRU waste is WIPP. It is designed to receive up to 7080 m³ of remote-handled transuranic waste over a 25-year operating period.⁷ Waste generated through FY 2011 by this concept would require about twice the total capacity of the WIPP, or 16,170 m³ of grouted waste. Thus, the option of neutralizing sodium waste directly does not appear to be feasible because of the amount of repository volume required, the rate at which it would have to be received, and the high cost for facilities and disposal. If calcining could be used, an additional calcining facility, approximately twice the size of the NWCF, would be required. Therefore, this concept is not evaluated further in this report.

1.3.2 Solidification and Disposal of Sodium Waste as a Low-Level Waste

Removal of the actinides and fission products, followed by solidification has been proposed as a means to produce a solid LLW from the sodium-bearing liquid waste.⁸ A neutralization method for this management concept is evaluated in this report.

In the neutralization method, the acidic sodium waste is made basic to about pH 13.5 to precipitate and separate most of the radioactive components from the inert (non-radioactive) components of the waste. The liquid stream is further decontaminated to remove Cs, Sr and possibly technetium (Tc) by ion exchange. The radioactive precipitate is redissolved with nitric acid, combined with the radioactive materials elutriated from the ion exchange system, and returned to the HLLW tanks. The LLW is used as a component to produce a grout. The grout is disposed

as LLW in a separate on-site near-surface disposal area. This alternative process is very similar to a process previously evaluated for the reduction of HLW volumes⁹ and is similar in chemistry to the neutralization process practiced at the Savannah River¹⁰ plant, and interim in-tank storage of HLW at Hanford.¹¹ This alternative method for processing sodium-bearing liquid waste is discussed in further detail in Section 3 of this report.

2. BASES AND ASSUMPTIONS

2.1 SODIUM WASTE VOLUMES AND COMPOSITIONS

Currently there are about 5144 m³ of sodium-bearing liquid waste stored in tanks WM-180, WM-181, WM-183, WM-184, WM-185, and WM-186.¹ The volume of sodium waste currently stored in each tank is given in Table 2.1.

TABLE 2.1
Current (End FY-88) Volumes of Sodium Waste Solutions

<u>Tank#</u>	<u>Volume (m³)</u>
WM 180	516
WM 181	847
WM 183	1071
WM 184	1071
WM 185	1073
WM 186	<u>566</u>
Total	5144

Sodium-bearing liquid waste, nominally 1.6 M alkali (sodium plus potassium), is generated at about 17 m³/month.^{1,2} During the past year of NWCF operation, sodium waste from WM-186 has been depleted at an average rate of 55 m³/month.^{1,2} The volume of liquid sodium waste projected to be generated between FY 1989 and the start of a separate sodium waste treatment facility is 1873 m³. An estimated volume of 2310 m³ will be calcined by blending to leave a starting volume of sodium waste for separate treatment in FY 1998 of 4707 m³. Projected generation rates of sodium-bearing liquid waste for the years FY 1998 to 2011 are given in Table 2.2.³ To deplete the sodium waste inventory present at FY 1998 by continued calcining of a blend will take until FY 2011. Therefore the years FY 1998 to FY 2011 are used for comparison purposes to develop comparative total life-cycle costs for processing sodium waste separately. Also shown in Table 2.2 is the rate at which the sodium waste inventory is depleted by continued calcining of a blend.

TABLE 2.2

Projected Sodium Waste Generation and Year End Inventory
for Continued Calcination

End of FY	Sodium-Bearing Liquid Waste Inventory (m ³)	Volume of Sodium-Bearing Liquid Waste Generated ^a (m ³)	Volume of Sodium-Bearing Waste Calcined (m ³)
1988	5144	-	-
1989			
to	4707	1873	2310
1997			
1998	4707	186	186
1999	4402	248	553
2000	3962	255	696
2001	3521	255	696
2002	3078	253	696
2003	2724	234	588
2004	2266	238	696
2005	1729	238	775
2006	1192	238	775
2007	1525	333	0
2008	1858	333	0
2009	1277	144	775
2010	333	267	1161
2011	0	<u>269</u>	<u>602</u>
	TOTAL	3491	8199

a - Projected sodium waste generation rate is greater than the current generation rate of 17 m³/month.

The chemical and radionuclide compositions present in the sodium waste tanks are not well defined. While tanks WM-180, WM-181, WM-184 and WM-186 were sampled and analyzed in 1984, some of the liquid in WM-180 was concentrated in a process evaporator with the bottoms going to WM-181. WM-186 was sampled during the most recent NWCF campaign. Thus, only the analyses of tanks WM-184 and WM-186 are reasonably accurate. A sampling plan for the sodium waste tanks has been prepared, and sampling

should take place in 1989.¹ The chemical and radionuclide compositions of solution and solids in WM-184 and WM-186 are given in Table 2.3 and Table 2.4.

For the purpose of this report, the chemical and radionuclide composition of the existing sodium waste is assumed to be the average of the compositions of tanks WM-184 and WM-186. Future generated sodium waste compositions are anticipated to be less concentrated.⁵ These compositions are given in Table 2.5.

2.2 POTENTIAL SCHEDULE FOR DESIGN, CONSTRUCTION AND START UP OF A SODIUM WASTE PROCESSING FACILITY

A potential schedule for design, construction and startup of a sodium waste processing facility is presented in this section. For the purposes of this study, conceptual design starts in FY 1990. A Schedule 44-budget request is submitted in February 1990 and funding for the project is assumed to be authorized at the start of FY 1992.

Verification of the proposed processes and the development of the conceptual design criteria would be completed on operating funds starting as soon as possible, perhaps during FY 1989. Other major activities, including the start of conceptual design, notice to the public of the intent to prepare an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA), and the preparation of required EIS documentation and permits must also be started before the project is fully funded by line item authorization in order to maintain the assumed schedule. Funding for these activities would also come from operating sources.

The preparation of NEPA documentation and permits is considered to require a 3 year or longer period. All required permits must be secured before major construction can start. Preparation of the documentation

TABLE 2.3
Chemical Compositions of Current Sodium Waste Solutions

Solution Composition				Undissolved Solids Composition		
Component	Tank			Component	Tank	
	WM-184 (1984)	WM-186 (1984)	WM-186 (1987)		WM-184	WM-186 ^a
Sp. G.	1.259	1.221	1.224	Sp.G ^d	1.13	1.176
H ⁺ (N ^b)	0.38	1.81	1.69			
NO ₃ (M)	4.83	4.73	4.96			
Al (M)	0.77	0.42	0.45	Al (mg/g)	35.05	0.65
Na (M)	2.28	1.39	1.46	Na (mg/g)	74.75	1.48
K (M)	0.151	0.220	0.21	K (mg/g)	3.11	2.97
Zr (M)	0.00002	0.00009		Zr (mg/g)	40.80	4.317
F (M)	0.032	0.039				
B (M)	0.005	0.008	0.049	B (mg/g)	53.10	<0.74
Fe (M)	0.019	0.024	0.024	Fe (mg/g)	10.90	2.27
Hg (M)	0.003	0.002		Hg (mg/g)	13.38	<0.00
Mn (M)	0.014	0.014		Mn (mg/g)	<0.47	<0.74
Cr (M)	0.002	0.005		Cr (mg/g)	0.76	0.52
Ni (M)	0.001	0.003		Ni (mg/g)	6.65	1.49
Ca (M)	0.006	0.062		Ca (mg/g)	10.20	0.85
Cl (M)	0.045	0.028	0.023			
SO ₄ (M)	0.074	0.065	0.03			
PO ₄ (M)	0.025	0.007	0.05	PO ₄ (mg/g)	60.0	8.2
Np (μg/L)	642	391		Np (mg/g)	0.004	0.00008
Pu (μg/L)	1487	679		Pu (mg/g)	0.13	0.003
U (g/L)	0.056	0.158		U (mg/g)	1.09	0.014
UDS ^c (g/L)	0.65	.75	0.90	UDS ^c (g/L)	0.65	9.53

a - Solids analysis of WM-186 appears to be lower than WM-184 by about a factor of 10, but no analytical errors were found. The UDS of the WM-186 sample is higher than WM-184 by about a factor of 10.

b - N = normal

c - UDS = Undissolved solids

d - Specific gravity of redissolved solids solutions.

TABLE 2.4
Radionuclide Compositions of Current Sodium Waste Solutions

Component	Solution Radioactivities, disintegrations ($\frac{\text{sec-mL}}{\text{Tank}}$)		Undissolved Solids Radioactivities, disintegrations ($\frac{\text{sec-mL}}{\text{Tank}}$)	
	WM-184	WM-186	WM-184	WM-186 ^a
Sr-90	5.80 E5	1.17 E6	3.02 E6	1.39 E5
Ce-144	2.24 E4	1.33 E4	5.61 E5	1.51 E4
Co-60	-N-	5.16 E2	1.73 E4	1.00 E3
Cs-134	7.73 E3	8.89 E3	2.15 E5	4.75 E3
Cs-137	6.96 E5	1.31 E6	3.23 E6	1.62 E5
Eu-154	1.34 E3	3.80 E3	-N-	-N-
Ru-106	-N-	-N-	1.34 E7	1.28 E6
Sb-125	-N-	1.15 E4	1.21 E7	4.90 E5
Zr-95	-N-	1.93 E3	4.94 E6	2.39 E5
Am-241 ^b	1.75 E4	5.11 E2	<2.60 E4	<6.20 E3
Tc-99	1.00 E2	1.89 E2	-N-	-N-
Sn-126	1.60	3.01	-N-	-N-
U (g/L)	0.056	0.158	1.09 ^d	0.014 ^d
Pu (μg/L)	1487	679	0.13 ^d	0.003 ^d

a - Solids analysis of WM-186 appears to be low, but no analytical error was found.

b - Am-241 analyses were performed with a limited amount of sample left and may not be too accurate.

c - Values were below detectable limits.

d - mg/g

-N- Not analyzed.

requires that significant details of the facility size and performance be known. These data may come from pilot-plant verification and conceptual design studies. The preparation of the draft EIS is often coordinated to coincide with conceptual and Title I design. A preliminary Safety Analysis Report (PSAR) is completed usually at or near the start of Title II design. This ensures that the Title Design accounts for all safety

TABLE 2.5

Average Composition of Projected Sodium Waste Solutions

<u>Chemical Composition</u>		<u>Solution Radioactivity</u>	
<u>Component</u>		<u>Component</u>	disintegrations (<u>sec-mL</u>)
Sp.G.	1.24	Am-241	5.0 E3
H ⁺	1.1 M	Co-60	2.07 E3
NO ₃ ⁻	4.0 M	Zr-95	2.05 E3
Al	0.5 M	Tc-99	2.46 E2
Na	1.4 M	Sr-90	1.49 E6
K	0.2 M	Sb-125	1.16 E4
Zr	0.0 M	Sn-126	3.91 E0
F	0.03 M	Cs-134	1.83 E4
B	0.03 M	Cs-137	1.70 E6
Fe	0.02 M	Ce-144	7.27 E4
Cl	0.03 M	Eu-154	4.71 E3
SO ₄	0.05 M		
U	0.1 g/L		
Pu	0.7 mg/L		
Np	0.3 mg/L		
UDS	0.05 g/L		

issues identified. The final EIS (FEIS) and Record of Decision (ROD) must be prepared before major construction starts. The preparation of NEPA documentation and the permitting process has required increased resources in recent construction of major facilities at the ICPP and cannot be completed until Title II is complete or nearly so. Thus, this portion of the schedule may be unduly optimistic by 1 or 2 years.

Title design which is assumed to take about 2 1/2 years, starts in FY 1992 and is completed by the end of FY 1994. Information from Title I design is used in the preparation of NEPA documentation and the PSAR. The more costly and complete Title II design is started only after the PSAR has been completed and approved. Title I and II designs are estimated to take 1 and 1-1/2 years, respectively.

Construction of the facility is considered to occur on a fast track basis coinciding with the completion of the FEIS, ROD, permitting approvals, and is estimated to take at least 3 years. Additional time may be required depending on required tie-ins to other operating facilities and the possibility of hampered winter construction efforts. After construction is completed, 1 year is allowed for cold testing and startup. Thus, the schedule estimates that 9 years at the very best are required to design, construct and bring to hot operations by the start of FY 1998 a facility to independently process and solidify sodium-bearing liquid wastes.

The overall time required to design and construct a several hundred million dollar facility, as is required in this case, is consistent with times required to obtain other major facilities at the ICPP, but may be optimistic based on recent additional permitting requirements to construct such facilities. Figure 2.1 presents the major activities involved.

2.3 POTENTIAL SCHEDULES FOR SEPARATELY PROCESSING SODIUM WASTE

For the purpose of this study, calcining of blended waste continues until the end of FY 1997 when a separate sodium waste processing facility is assumed to be available for hot operation. At that time the calcining of blended waste operations cease. Sodium waste is generated at the rate given in Table 2.2. Two schedules, one of 5-years and one of 10-years, are assumed to separately process the sodium waste. At the end of the 5- or 10-year period, the sodium waste facility would have processed all of the sodium waste inventories and would continue to process the annually generated sodium waste.

Sodium waste process schedules are presented in Table 2.6. Included are facility throughput rates, and cumulative volumes of sodium waste processed. A starting sodium waste liquid inventory of 4707 m³ will exist at the end of FY 1997 and about 255 m³ of sodium is projected to

Figure 2-1. Potential Schedule for Design, Construction, and Start Up of a Sodium Waste Processing Facility

TABLE 2.6

Sodium Waste Processing Rates for a Separate Processing Facility

End of FY	Na Waste Produced, m ³	5 Year Processing Schedule			10 Year Processing Schedule		
		Liquid Na Waste Processed, m ³	Cumulative Na Waste Processed, m ³	Liquid Na Waste Inventory, m ³	Liquid Na Waste Processed, m ³	Cumulative Na Waste Processed, m ³	Liquid Na Waste Inventory, m ³
1997	-	-	-	4707	-	-	4707
1998	186	1181	1181	3713	719	719	4175
1999	248	1181	2362	2780	719	1438	3704
2000	255	1181	3543	1854	719	2157	3240
2001	255	1181	4724	928	719	2876	2776
2002	253	1181	5905	0	719	3595	2310
2003	234	234	6139	0	719	4314	1825
2004	238	238	6377	0	719	5033	1344
2005	238	238	6615	0	719	5752	863
2006	238	238	6853	0	719	6471	382
2007	333	333	7186	0	715	7186	331
2008	333	333	7519	0	333	7519	0
2009	144	144	7663	0	144	7663	0
2010	267	267	7930	0	268	7930	0
2011	269	269	8199	0	269	8199	0
Total	3491	8199			8199		

be generated annually. If a processing time of 5 years is assumed, the sodium waste facility must process about 1180 m³ of sodium waste per year for the five years. If a processing time of 10 years is assumed, the sodium waste facility would operate at a lower rate of about 720 m³ of sodium waste per year for the ten years. Thereafter for either process schedule the facility would operate at a rate equal to the annual sodium waste generation rate.

2.4 INCREMENTAL PROCESSING COSTS

Processing the sodium waste separately only significantly effects the operation of the NWCF. For HLLW calcination and storage it is estimated that operating costs would be at least 95% of the current operating cost for blended waste. Savings are only realized in the quantity of HLW calcine produced, which results in reduced calcine storage space requirements and the reduced number of canisters of immobilized waste for disposal in a federal repository. Therefore for cost comparisons, this study evaluates the life-cycle costs incremental to current ICPP costs for each alternative based on the additional facility and operating costs required, and potential savings in calcine storage and immobilized waste disposal costs. The life-cycle costs cover a time frame from FY 1998, the year in which hot operations begin processing sodium waste separately, through FY 2011, when the sodium waste is projected to be depleted under current operations of blending sodium waste with HLLW prior to calcination. For purposes of cost comparisons, the calcination of blended waste as currently practiced is considered to be the base-case.

The cost for constructing the 7th CSSF, completed in 1988, was \$25 million. It has a design capacity of 1780 m³. Thus, any reduction in calcine produced from HLLW provides a cost savings of \$14,000/m³ of calcine. If the immobilization of the HLW calcine is considered additional savings can be realized in processing sodium waste separately. Estimated cost savings per canister of waste saved are assumed to be \$250,000 per canister.¹²

3. DESCRIPTION OF NEUTRALIZATION FOR PROCESSING SODIUM WASTE

This section describes the neutralization method and major facility and equipment needs for separately processing sodium-bearing liquid waste. Figure 3-1 compares the processing steps assumed to be included in the base-case and the neutralization method to process sodium waste through to disposal. The current practice involves blending sodium-bearing liquid waste with HLLW prior to calcination at about a 5:1 volume ratio with the sodium-bearing liquid waste. Neutralization to remove radioactive components and treatment for disposal is considered in this study. A flowsheet with liquid and solid flow rates is given for a 5-year and 10-year processing schedule.

Section 2.2 of this report presents a fast-track schedule to fund, design and construct a facility to process sodium-bearing liquid wastes. This schedule indicates that a 9-year period at minimum is required to design and construct a separate sodium waste treatment facility.

3.1 BASE-CASE

3.1.1 Base-Case for Blending and Calcining Sodium Waste

The base-case method for solidifying the sodium-bearing liquid waste is to continue the practice of blending this waste with the HLW and calcining it for storage and eventual repository disposal. If blending and calcining continues at the rate projected in Table 2.2 the sodium inventory will be depleted by the end of FY 2011. The peak inventory of sodium waste occurs in FY 1989 and decreases thereafter. Thus, no additional tanks are required for storage of sodium waste. In addition, no new facilities or processes are required. Also, improvements in calcining methods under investigation have the potential to increase the sodium waste concentration of the blended feed by up to 50%, which would significantly reduce the time required to work off the sodium waste inventory.

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Figure 3-1. Steps Assumed for the Base-Case and Neutralization Method for Processing Sodium Waste.

3.1.2 Base-Case for Geometrically Favorable Dissolver

A secondary base-case for disposal of sodium-bearing liquid wastes is the inclusion of geometrically favorable dissolvers (GFD). The addition of GFD to the fuel dissolution process eliminates the use of a soluble neutron poison which in turn reduces the amount of fluoride required for fuel dissolution. Thus, up to 30% less HLW is generated from fuel dissolution. For this case, sodium-bearing liquid waste inventories cannot be depleted as rapidly. About five additional years, until about 2016, are required to blend and calcine the sodium-bearing liquid waste inventory (see Table 3.1).

TABLE 3.1

Projected Sodium Waste Inventories for Geometrically Favorable Fuel Dissolution Operations			
End of FY	Volume of Sodium-Bearing Liquid Waste Generated (m ³)	Volume of Sodium-Bearing Liquid Waste Calcined (m ³)	Sodium-Bearing Liquid Waste Inventory (m ³)
1998	186	0	4893
1999	248	216	4821
2000	255	480	4589
2001	255	607	4237
2002	253	537	3953
2003	234	463	3724
2004	238	503	3458
2005	238	551	3145
2006	238	738	2645
2007	333	0	2978
2008	333	0	3311
2009	144	115	3341
2010	267	554	3054
2011	269	878	2444
2012	270	901	1813
2013	259	819	1253
2014	260	796	716
2015	262	791	187
2016	259	381	65
TOTAL	4801	9330	

Although the analyses contained in this report are based on continued HLW waste solidification as currently practiced, waste volume estimates for separately solidifying sodium waste with the GFD process are presented in Section 4 and cost estimates are presented in Section 5.

3.2 NEUTRALIZATION METHOD

3.2.1 Description

The neutralization process involves the addition of sodium hydroxide to the sodium-bearing liquid waste to precipitate most of the radionuclides.⁹ The precipitate is filtered from the supernate, redissolved in nitric acid, and returned to the HLLW tanks for eventual calcination and disposal as HLW. The supernate is decontaminated of remaining Cs, Sr, and possibly Tc, by an ion exchange system. These radionuclides are also returned to the HLLW tanks. The low fluoride content (~0.04 M) of the sodium waste may require precipitation by calcium nitrate, but is not anticipated as would be required for HLLW. The resulting LLW fraction is either concentrated and solidified directly as a grout for disposal, or calcined with ANN and incorporated into a grout for disposal. If the LLW stream is directly grouted, the supernate is sent through an evaporator to increase the solids content to about 30 wt%. The chemical composition of this concentrated neutralized solution (Table 3.2) is similar to the LLW being generated at the Savannah River Plant.¹³ This solution is assumed to compose 38 wt% of the solidified grout. Potential grout additives for this salt solution would be Portland Cement, fly ash, soil or clay. A large volume of grouted LLW is generated by direct liquid grouting; 2,325 m³/yr for the 5-year schedule and 1,415 m³/yr for the 10-year schedule, both producing a total of 16,170 m³ of grouted LLW by the end of FY 2011. Schematic flowsheets for both the 5-year and 10-year liquid grouting processing schedules are shown in Figures 3-2 and 3-3, respectively.

Table 3.2

Chemical Composition of Concentrated, Neutralized LLW Stream

Chemical Component	Composition (wt%)
H ₂ O	70.0
NaNO ₃	21.6
NaAl(OH) ₄	3.5
NaOH	2.8
KOH	0.7
Na ₂ SO ₄	0.4
Ca(OH) ₂	0.3
Fe(OH) ₃	0.2
Cr(OH) ₃	0.2
NaBF ₄	0.1
Ni(OH) ₂	0.1
Mn(OH) ₂	<u>0.1</u>
	100.0

3.2.2 Feasibility Status and R&D Required

While the neutralization process has been applied at the Savannah River Plant (SRP)¹⁰ and Hanford during interim in-tank storage of HLW,¹¹ the feasibility of an on-line process as conceived for this study needs to be established. Methods for separating the precipitate from the supernate must be developed. Existing processes for separation of Cs, Sr, or Tc from the supernate, as may be required, need to be evaluated for the ICPP waste. Other process aspects such as the required precipitate digestion times and precipitate washing requirements have not been examined. How to best handle the precipitate at full-scale has not been determined, although the process concept proposes to redissolve the precipitate and

transfer the solution to the HLLW tanks for eventual calcination. Neutralization of the sodium-bearing liquid waste with sodium hydroxide releases a considerable amount of heat (over 700 kcal per liter of sodium waste) and, therefore, would require special in-process neutralization vessels with extreme cooling capacity. Grouting studies for the specific ICPP LLW stream must be done. Fluorides, for example, hinder the setting of grouts.

3.2.3 Impact

The process for neutralizing sodium-bearing liquid waste requires major new facilities for precipitation, solids separation, supernatant decontamination, LLW grouting, and LLW disposal. Major development is required to bring these technologies to an operational stage. Although the process appears to be technically feasible, it generates an undesirable large volume of LLW. On-site disposal of LLW may be technically difficult, conflict with national and state policies, and also potentially increase public concern.

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Figure 3-2. Simplified Conceptual Flowsheet for Neutralization and Grouting of the Waste Based on a 5-year Schedule.

Figure 3-3. Simplified Conceptual Flowsheet for Neutralization and Grouting of the Waste Based on a 10-year Schedule.

4. IMPACT ON ICPP OPERATIONS FROM SEPARATE SODIUM WASTE PROCESSING

4.1 NWCF PROCESSING RATES

A sodium-bearing liquid waste processing facility would reduce both the volumetric liquid feed to the NWCF and the volume and mass of calcine produced, starting in FY 1998. Also, some of the solids producing constituents of the processed sodium waste, i.e. actinides, Sr, Cs and inert compounds, such as Fe, Cr, Mn, and Ni, would be returned to the HLLW tanks upon removal from the sodium waste. These solids contribute approximately 7 kg of calcine per cubic meter of sodium waste produced.

The major solids producing constituents in the sodium-bearing liquid waste are Al, Na, and K. When sodium waste is blended with HLLW, calcium nitrate is added at a ratio of 0.70 mol calcium per mol fluoride. If HLLW is calcined separately, calcium nitrate is added at a ratio of 0.55 mol calcium per mol fluoride.⁵ Calcining the HLLW alone would result in about a 17% decrease in calcine volume and mass over that of blending. Table 4.1 shows the calcine production for continued calcining of the blended sodium wastes. Also shown is the volume of HLW calcine generated if the sodium waste is separately processed as a LLW. About 1220 m³ can be saved by processing the sodium waste separately, which results in a savings of about \$17 million for calcine bin storage. Also, the schedule for construction of an additional CSSF could be delayed a few months to nearly 1 year.

4.2 LOW-LEVEL WASTE DISPOSAL

The LLW stream is directly grouted from the liquid for on-site disposal, a large volume of LLW is generated by each processing schedule; 2,325 m³ of LLW grout per year for the 5-year schedule and 1,415 m³ of LLW grout per year for the 10-year schedule, each producing a total of 16,170 m³ of LLW grout by the end of FY 2011. Disposal of the grout would

Table 4.1
Estimated Calcined HLW Volumes For Blended Waste and Without Blending
Sodium Waste for the Base-Case

FY	- Base-Case - Continued Calcining of a Sodium Waste Blend			- Alternative - Calcined HLW Without Blending		
	Volume of Blended HLLW (m ³)	Volume of Calcine Produced (m ³)	Equivalent Canisters of Immobilized ^a Waste	Volume of HLLW only (m ³)	Volume of Calcine Produced (m ³)	Equivalent Canisters of Immobilized ^a Waste
1998	1074	123	135	888	98	116
1999	2799	446	489	2246	357	422
2000	3523	561	632	2827	449	530
2001	3523	561	632	2827	449	530
2002	3523	561	632	2827	449	530
2003	2977	475	521	2389	380	449
2004	3523	561	632	2748	449	530
2005	3523	536	588	2748	429	507
2006	3523	536	588	2748	429	507
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	3523	536	588	2748	429	507
2010	5284	804	882	4123	643	759
2011	<u>2739</u>	<u>409</u>	<u>448</u>	<u>2137</u>	<u>327</u>	<u>386</u>
Total	39,534	6109	6767	31,256	4888	5773

a - Assumes the calcined waste is immobilized as a glass-ceramic.

require engineered disposal vaults to be built on-site.¹⁴ An area for actual disposal of 2-5 acres would be required; the exclusion area could be about 50 acres. A new LLW disposal area might be in conflict with national and state policies.

4.3 IMPACT ON IMMOBILIZED WASTE VOLUME FOR DISPOSAL

Processing the sodium waste separately reduces the volume of immobilized HLW (glass-ceramic canisters) requiring disposal in a federal repository. For the purposes of this evaluation it is assumed that

calcine is mixed with a glass-ceramic additive and hot isostatic pressed (HIPed) at high temperatures and pressures to produce an immobilized waste for repository disposal.¹⁵ The glass-ceramic additive chemical makeup depends on the composition of the calcine to be immobilized. Alkalies and SiO₂ are major constituents required to produce the glass phase of the product. The waste loading of the product is dependent on the required additive to produce the waste form.

The current practice of blending HLLW and sodium waste allows about a 70 wt% waste loading of calcine. The equivalent number of canisters which will be generated from the calcine produced during FY 1998 to FY 2011 are shown in Table 4.1. The equivalent of 6767 canisters of immobilized waste are projected to be produced by the current process of blending during the fourteen year period of this study.

When sodium waste is processed separately, the alkali content in the calcine is reduced, thereby allowing only about a 65 wt% waste loading of calcine in the glass-ceramic. The volume of calcine without blending and equivalent number of canisters which would be generated during FY 1998 to FY 2011 are also shown in Table 4.1. If the sodium waste is processed separately a total of 5773 canisters are produced for the fourteen year period of this study. This results in about a 15% reduction in the number of canisters produced. A savings of about \$248 million results at a cost of \$250,000 per canister of repository disposal.¹²

4.4 IMPACTS FOR GFD BASE-CASE

Implementation of the GFD process would reduce the amount of HLLW available for blending with sodium-bearing liquid waste. Therefore, the sodium-bearing liquid waste is projected to be depleted by the end of FY 2016. By Separately processing the sodium waste, calcined HLW production would be reduced by about 11% in both volume and mass. A savings would result of about 40 HLW canisters per year, or about a total of about 764 canisters over the 19 year lifetime of the study. Table 4.2

Table 4.2
Estimated Calcined HLW Volumes For Blended Waste and Without Blending
Sodium Waste for the GFD Base-Case

FY	- GFD Base-Case - Volumes for Continued Calcining of a Sodium Waste Blend			- Alternative - Volumes for Calcined HLW Without Blending		
	Volume of Blended HLLW (m ³)	Volume of Calcine Produced (m ³)	Equivalent Canisters of Immobilized ^a Waste	Volume of HLLW (m ³)	Volume of Calcine Produced (m ³)	Equivalent Canisters of Immobilized ^a Waste
1998	0	0	0	0	0	0
1999	1235	146	160	1019	121	143
2000	2785	389	427	2305	322	380
2001	3523	492	539	2916	407	481
2002	3115	436	478	2578	361	426
2003	2687	376	412	2224	311	367
2004	2919	408	447	2416	338	399
2005	3632	353	387	2081	292	345
2006	3523	473	519	2785	391	462
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	547	74	81	432	61	72
2010	2642	355	389	2088	294	347
2011	4191	551	604	3313	456	538
2012	2497	566	621	3398	468	553
2013	3908	524	575	3089	434	512
2014	3799	510	559	3003	422	498
2015	3774	507	556	2983	420	496
2016	<u>1817</u>	<u>244</u>	<u>268</u>	<u>1436</u>	<u>202</u>	<u>239</u>
Total	46,594	6404	7022	38,066	5300	6258

a - Assumes the calcine waste is immobilized as a glass-ceramic.

shows the liquid volumes calcined, calcine produced and the equivalent number of HLW canisters filled for the GFD process. About 18,400 m³ of low level grouted waste would be generated through FY 2016.

5. COSTS FOR IMPLEMENTING NEUTRALIZATION

5.1 INCREMENTAL COSTS FOR NEUTRALIZATION

This section evaluates the incremental costs for separately processing the sodium-bearing liquid waste. The estimates are rough order-of-magnitude (ROM) costs reported in FY 1988 dollars.

Estimated ROM costs for facilities and estimated average annual operating costs during full capacity operations for neutralization is shown in Table 5.1. These costs are based on a recent cost study and adjusted for flowrates used herein.^{16,17} The operating costs for the 5-year processing schedule are higher than for the 10-year processing schedule, because of higher flowrate requirements. Once the sodium-bearing liquid waste has been depleted, operating costs are reduced to reflect the reduced processing rate for the annually generated sodium-bearing liquid waste, (see Table 5.1). Total life-cycle costs are compared for the alternative method from start of hot operations in FY 1988, through FY 2011, when the sodium waste inventory is projected to be depleted under the current method of calcining the blended wastes.

Total projected incremental facility costs and total projected incremental operating costs for the alternative method for the 5 and 10-year processing schedules are provided in Table 5.2. The costs are adjusted for savings incurred by reduced calcine generation and repository disposal costs.

The projected incremental facilities costs are \$203 million. The total incremental operating plus facility costs are \$513 million. These incremental costs reflect a 14 year operating period (FY 1998 - FY 2011). However, other additional costs which may be associated with potential regulatory requirements of near-surface LLW disposal have not been estimated.

Table 5.1
Estimated Operating and Sodium Waste
Processing Facility Costs

Facility	Facility Costs (FY-1988 \$Millions)	Annual Average Operating Costs (\$ Million, FY 1988)	
		During Inventory Depletion ^a	After Inventory Depletion ^b
Neutralization	100	27	18
Ion Exchange	60	11	8
Liquid LLW Grouting	<u>43</u>	<u>14</u>	<u>9</u>
Total	203	52	35

a - Included are average annual operating and capital equipment costs during the 5-year or 10-year waste inventory depletion schedule.

b - Included are average annual operating and capital equipment costs for processing sodium waste on an as generated basis after inventory has been depleted.

5.2 INCREMENTAL COSTS FOR THE GFD BASE-CASE

Estimated facility costs for separately managing sodium waste assuming a base-case with geometrically favorable fuel dissolution are given in Table 5.1. Incremental operating costs for processing the sodium waste for the 5- and 10-year processing schedules are provided in Table 5.3. The projected incremental operating and facility costs are \$757 million for the 5-year processing schedule and \$842 million for the 10-year processing schedule. The total incremental costs reflect a 19 year operating period (FY 1998 - FY 2016). As previously noted, GFD per-se reduces HLW generation by about 30% resulting in a very significant savings in HLW disposal costs. The processing rate to deplete the sodium waste inventory is identical for either the GFD base-case or the base-case. In either case, a 5-year or 10-year depletion schedule is used. However, the GFD base-case life-cycle operating costs are larger than the base-case life-cycle operating costs as the GFD base-case requires an additional 5-year to deplete the sodium waste inventory. If both the base-case and GFD base-case were continued through FY 2016, the total volume of sodium waste and the life-cycle operating costs would be about the same for either case.

Table 5.2

Total Incremental Life-Cycle Costs for the 5-year and 10-year
Processing Schedule for the Base-Case
(FY-1988 \$Millions)

	Total Cost			
	5-Year Sodium Waste Inventory Depletion Schedule ^a		10-Year Sodium Waste Inventory Depletion Schedule ^a	
	<u>Facility</u>	<u>Operating</u>	<u>Facility</u>	<u>Operating</u>
Neutralization	100	297	100	342
Ion Exchange	60	127	60	142
LLW Grouting	<u>43</u>	<u>151</u>	<u>43</u>	<u>176</u>
Total	203	575	203	660
<hr/>				
System Cost	778		863	
Less HLW Savings				
CSSF	(17)		(17)	
Immobilizeed Waste Canisters	<u>(248)</u>		<u>(248)</u>	
Net Incremental Life-Cycle Costs	513		598	

a - Costs are for 14 year operating period from 1998 through 2011.

Table 5.3

Total Incremental Life-Cycle Costs for the 5-year and 10-year
Processing Schedule for the GFD Base-Case
(FY-1988 \$Millions)

	Total Cost			
	5-Year Sodium Waste Inventory Depletion Schedule ^a		10-Year Sodium Waste Inventory Depletion Schedule ^a	
	<u>Facility</u>	<u>Operating</u>	<u>Facility</u>	<u>Operating</u>
Neutralization	100	387	100	432
Ion Exchange	60	167	60	182
LLW Grouting	<u>43</u>	<u>196</u>	<u>43</u>	<u>221</u>
Total	203	750	203	835
<hr/>				
System Cost	953		1038	
Less HLW Savings				
CSSF	(15)		(15)	
Immobilized Waste Canisters	<u>(181)</u>		<u>(181)</u>	
Net Incremental Life-Cycle Costs	757		842	

a - Costs are for 19 year operating period from 1998 through 2016.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

For the alternative of neutralization, the time required to design and construct the necessary facilities is nine years, from FY 1989 through FY 1997. Thereafter, a five-year or a ten-year processing time (until the end of FY 2002 or FY 2007) is assumed to deplete all existing and annually generated sodium-bearing liquid waste. For cost comparison purposes a time period through the end of FY 2011 is used, at which time the current practice of calcining a blend of wastes will also have depleted the sodium-bearing liquid waste inventory.

Processing sodium-bearing liquid waste separately decreases the volume of high-level calcine generated by about 1220 m³, or about two thirds of a CSSF. The volume of the immobilized HLW saved is about 15%. This results in a savings of about 71 HLW canisters per year, or about a total of 994 canisters for the 14 year lifetime of this study.

Neutralization generates a LLW stream that requires solidification and disposal. About 16,170 m³ of low-level grout is made over the 14 year lifetime of this study. The properties of the grout have not been established. However, the grout will contain large quantities of nitrates, which present a potential leaching hazard as previously identified in tests of grouted waste to be produced at the Savannah River Defense Waste Processing Facility.¹³ The disposal facilities are assumed to consist of concrete bunkers covered with earthen materials to reduce infiltration of water. Collection points to sample any water transported through the waste are included in the facilities. Regulatory and permitting requirements for on-site disposal of a LLW must be addressed.

The ROM additional costs of implementing sodium waste neutralization are based on a previous evaluation requiring the same or similar facilities¹⁶ and range from about \$500 million for the 5-year depletion schedule to about \$600 million for the 10-year depletion schedule.

For the geometrically favorable dissolver base-case, the sodium-bearing liquid waste is not projected to be depleted until FY 2016. By separately processing the sodium waste, calcine production would be reduced by about 11% in both volume and mass. A savings would result of about 40 HLW canisters per year, or about a total of about 764 canisters over the 19 year lifetime of the study. About 18,400 m³ of grouted low-level waste would be generated.

A new on-site, low-level waste disposal area covering 2 to 5 acres with an isolation area of at least 50 acres would have to be opened. Obtaining regulatory and permitting approvals for the LLW disposal site may be problematic and increase public concern with regard to INEL operations.

6.2 RECOMMENDATIONS

Based on the analyses of this report, it is recommended that the current practice of calcining a blend of sodium-bearing liquid waste with high-level waste be continued to minimize overall cost and process complexity. Additionally, it is recommended that the alternative of processing sodium-bearing liquid waste separately not be implemented. Although neutralization could potentially deplete the sodium-bearing liquid waste four to nine years sooner than the current practice and that some savings in HLW calcine storage and immobilized waste disposal costs could be realized, overriding factors of additional facility and operating costs plus the undesirable generation of LLW requiring the opening of a new disposal area preclude the recommendation of neutralization to solidify sodium waste. Additional life-cycle costs above the base-case of \$513 million and the generation of about 16,170 m³ of solidified LLW are estimated for neutralization. Also, the disposal of LLW on-site may be technically difficult and conflict with national and state policies as well as increase public concern for continued safe operations of the ICPP and the INEL.

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