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TITLE: **Preferred Processing Options for Permanent Disposal of  
United States Department of Energy Underground Storage  
Tank Radioactive Waste**

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***Preferred Processing Options  
for Permanent Disposal of  
United States Department of Energy  
Underground Storage Tank  
Radioactive Waste***

Funding Provided by the DOE/Tank Focus Area

March 25, 1996

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## **ABSTRACT**

Underground storage tank (UST) radioactive waste is considered one of the most critical concerns for the United States Department of Energy environmental programs due to its toxicity and containment difficulty. This document has been prepared to serve as a reference for System Integration and Cost Benefit studies related to UST waste remediation. It includes a description of the proposed waste repositories, a description of the waste, the preferred processing flow sheets for each site, and a brief summary of the selected technologies for processing. It is important to note that the preferred remediation plans are still open to some debate, and that the information which follows was current as of the beginning of Fiscal Year 1996.

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## INTRODUCTION

In 1982 the United States Congress passed legislation that required the federal government to provide nuclear waste repositories. It was determined to be the responsibility of the federal government based on the large magnitude of the task. This legislation is known as the Nuclear Waste Policy Act of 1982. The Department of Energy was the natural federal agency to inherit the responsibilities of the Nuclear Waste Policy Act. Following this assignment, the Department of Energy began the creation of two underground nuclear waste repositories: (1) the Waste Isolation Pilot Plant (WIPP), and (2) Yucca Mountain.

There are two primary sources of radioactive waste in United States which will require repository storage. These are (1) spent fuel which is primarily commercial but consists of some defense related as well and (2) all other defense related wastes which includes that stored in underground tanks. The underground storage tank (UST) waste is primarily the result of past spent fuel reprocessing related to the production of nuclear materials for weapons. These two types of waste consist of short-lived radionuclides (primarily fission products) and long-lived radio nuclides (primarily transuranics). These two types of radionuclides require different types of disposal containment due to their lifetime differences. Consequently, two very different types of repositories were planned.

The Waste Isolation Pilot Plant was proposed as a repository to store long-lived radionuclides. These long-lived radionuclides are primarily transuranics (TRUs), and are often referred to as actinides due to their chemical behavior. Since long-lived radionuclides can not be guaranteed containment in their waste disposal form, the repository salt-bed geology itself is intended as secondary containment for the waste. WIPP is often referred to as a repository for defense generated TRUs. Actually the only significant amount of TRUs, not including spent fuel, have been primarily generated from defense activities.

Yucca Mountain was planned as a repository for primarily short-lived radionuclides and spent fuel. The short-lived radionuclides are primarily fission products, and due to their high radioactivity, are often referred to as high-level waste (HLW). Since the HLW is much shorter-lived than TRUs, it is believed possible to design a waste disposal form which will contain most of these radionuclides beyond their lifetimes. Consequently, Yucca Mountain is not intended to serve as secondary containment in the same sense as WIPP. While the spent fuel consists of short-lived and long-lived radionuclides, its large volume would imply an unacceptable risk for a WIPP type facility. Consequently, spent fuel will be placed in a multi-purpose canister (MPC) and stored in Yucca Mountain.

Certainly not all DOE UST HLW will end up in underground repositories. The existing UST waste will be separated into high-level and low-level radioactive portions. The low-level waste will consist of essentially the non-radioactive components of the original waste, such as sodium and aluminum, and a very small amount of the radioactive components. Once immobilized the low-level radioactive waste will be disposed of subsurface, generally at the site of origin, at a much lower cost than in an underground repository. It would be prohibitively expensive to purify all the non-radioactive components to the point where it is not classified as radioactive waste.

It has been the mission of each site possessing UST waste to minimize the final disposal volumes of both high-level and low-level waste. However, minimizing the volume of high-level takes precedent over low-level when a conflict arises. These sites include Hanford, Savannah River, Idaho Falls, West Valley and Oak Ridge. Each site has a unique set of circumstances which have governed their selection of technologies and processes for remediation. These differences have made it difficult to apply generic remediation technology across the DOE complex. For example, tank integrity varies significantly from site-to-site, which impacts whether or not in-tank processing can be done. Additionally, sites have a variety of alkaline, acid, and/or calcined waste. This dramatically affects the type of processing. Consequently, to understand the differences in remediation between sites, it is important to understand the differences in waste. This report attempts to outline most of the significant differences.

## SUMMARY AND CONCLUSIONS

Due to the diversity of waste containment (i.e. tanks) and waste type, different processing and disposal plans exist for each of the sites possessing UST radioactive waste. For instance, the storage tanks at Hanford are a mix of single and double-shell tanks where the poor integrity of the single-shell tanks limit in-tank processing. Additionally, the distances between tanks at Hanford make managing the remediation in collocated facilities difficult at best. The storage tanks at Savannah River are pseudo double-shell tanks more suited to in-tank processing than the single-shell tanks of Hanford. In-tank processing has the advantage of lower capital costs. Hanford and Savannah River possess primarily alkaline waste consisting essentially of sludge (i.e. solids), salt cake, and supernate (i.e. liquid). The waste at West Valley and Oak Ridge is alkaline-based consisting essentially of sludge and supernate; however, the volumes are significantly smaller than Hanford and Savannah River. This implies that the economics for optimizing separation technologies are not as important at West Valley and Oak Ridge than at Hanford and Savannah River. And finally, Idaho Falls has acidic-based liquid waste and calcined waste. Consequently, if waste at Idaho Falls is processed separation technologies may need to be significantly different than those at Hanford or Savannah River which have alkaline waste.

Of the existing UST waste, ~20 wt% will require solids processing and ~80 wt% liquid processing. Both the liquid-based and solids-based waste consist of more than 99 wt% nonradionuclides. Consequently, one foremost conclusion can be drawn regarding the amount of HLW requiring disposal in underground repositories. Concentration of the radionuclides in the HLW sent to the repository, based on cost effective separation technologies as compared with repository costs, can reduce the overall remediation cost. The separation processes settled to date are (1) radionuclide separation from the liquid-based waste by ion-exchange (IX) or chemical precipitation, and (2) nonradionuclide separation from the solids-based waste by caustic dissolution.



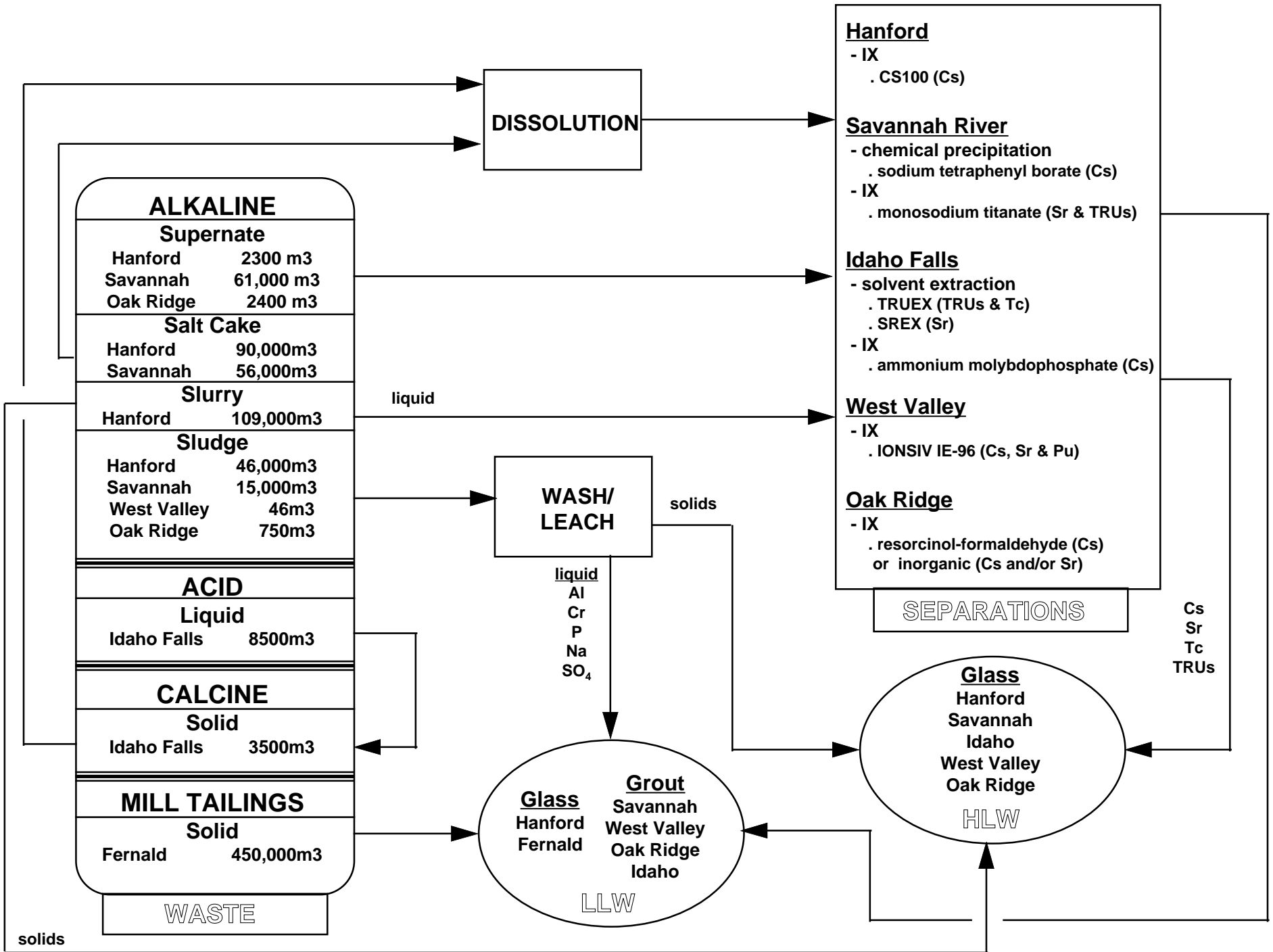


Figure S1. Integrated flowsheet

## BACKGROUND

### Repositories

#### General Description

By the late 1970s it was evident that the magnitude of nuclear waste disposal required in the United States was well beyond the capability of the private sector. Consequently, in 1982 the United States Congress passed legislation requiring the federal government to take responsibility for providing nuclear waste repositories. The natural organization of federal government to manage this effort was the Department of Energy (DOE). It was concluded two repositories were required for radioactive waste disposal as outlined in Figure R1. This conclusion was based on the existing types of radioactive waste as defined in Figure R2.

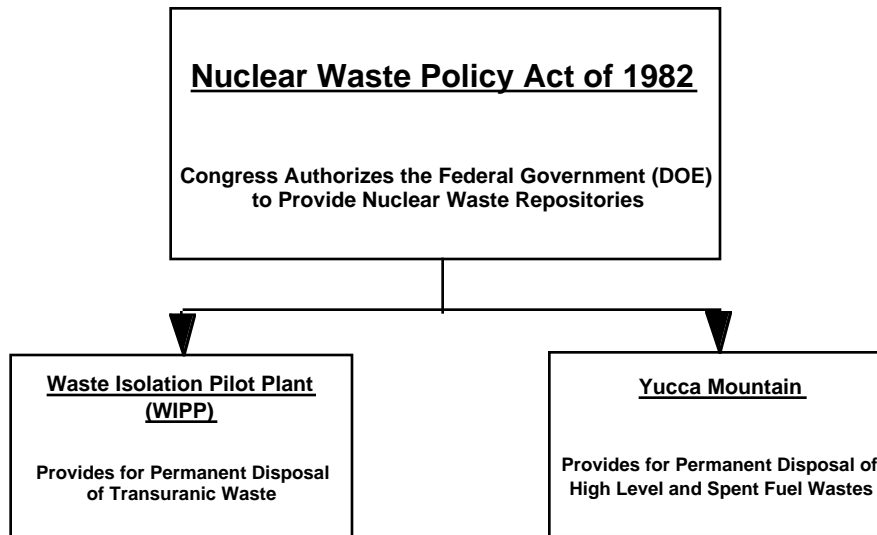


Figure R1. Nuclear Waste Policy Act of 1982

The TRU waste consists of long-lived radionuclides requiring deep underground disposal, the HLW generally consists of short-lived radionuclides requiring deep underground disposal, the spent fuel consists of TRU and HLW and consequently requires deep underground disposal as well. LLW consists of short- and long-lived radio nuclides at low concentrations which permit subsurface disposal, and mill tailings result primarily from uranium processing and consequently contain low concentrations of TRUs which can also be disposed of subsurface.

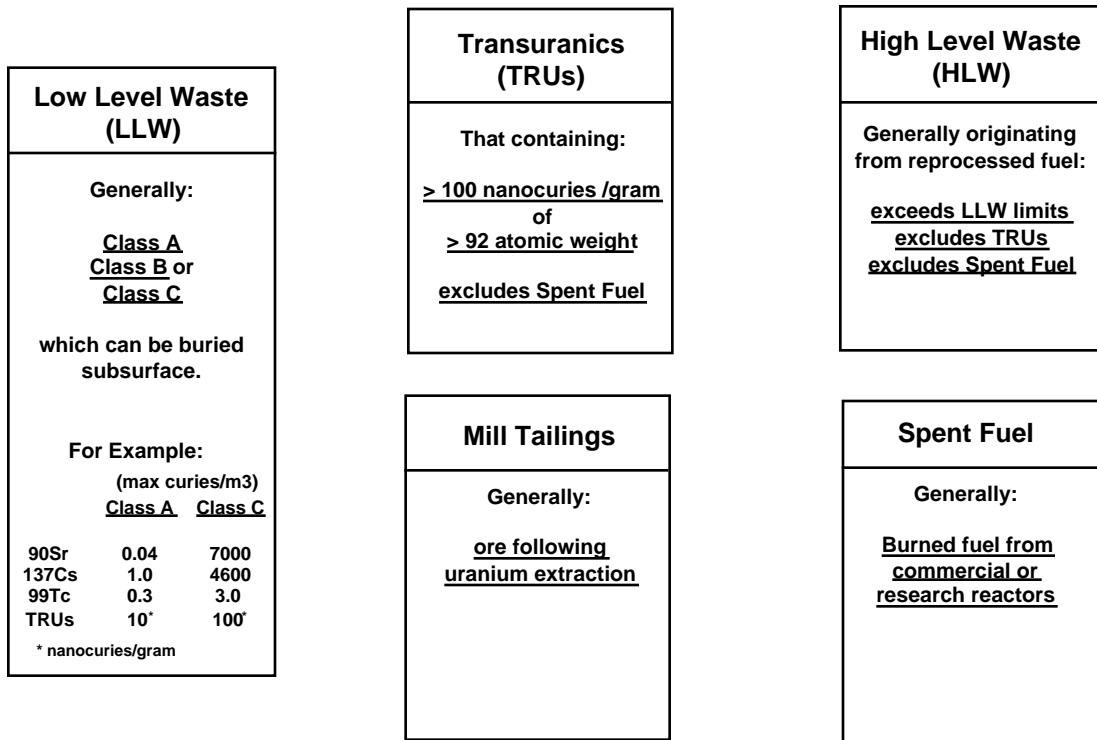


Figure R2. Waste Classification

Waste Isolation Pilot Plant

The Waste Isolation Pilot Plant was selected as a repository for long-lived radionuclides (TRUs) excluding spent fuel, for which primary waste canister containment could not be guaranteed over the life-time of the radionuclides. Waste in this category is primarily related to weapons production. Recent plans as of 1994 are for disposal of approximately 53,000 cubic meters of waste in WIPP.<sup>(WP-1)</sup> Some of these radionuclides have life-times well over ten-thousand years. Consequently, WIPP has been built within deep underground salt beds near Carlsbad, NM, which will serve as secondary containment. Recent litigation between the state of New Mexico and the federal government resulted in requiring DOE to meet all federal Environmental Protection Agency (EPA) regulations regarding this repository. This was significant since traditionally DOE regulatory requirements on federal land were left to DOE itself. While WIPP is planned as an experimental facility (i.e. Pilot Plant), the demands of EPA regulations, in particular 40 CFR-191 and -268, require that prior to any permanent disposal the DOE must demonstrate adequate containment. Consequently, the experimental activities which were originally intended to demonstrate permanent disposal with actual TRU waste, now can not be performed unless satisfactory permanent disposal is proven beforehand. Therefore, recent efforts has been focused on solving this dichotomy.

From 1986 to 1991 in-situ leaching tests were conducted at WIPP with simulated waste. In 1994 a compliance status report was prepared describing the current state of compliance toward meeting all relevant regulations.<sup>(WP-2)</sup> And finally, an experimental program has been planned for meeting the compliance requirements.<sup>(WP-3)</sup>

## Yucca Mountain

Yucca Mountain was selected as the repository for short-lived radionuclides (HLW) and spent fuel. The spent fuel will primarily originate from commercial power plants. The HLW to be disposed of at Yucca Mountain is primarily the waste from reprocessing for weapons materials and naval reactor fuel. The current plan is to reduce the HLW volume, vitrify the remaining in glass log form, and encase in steel canisters for disposal. Yucca Mountain is not intended as secondary containment in a fashion similar to WIPP. Due to the shorter life radionuclides, the HLW disposal form (i.e. glass) is intended as primary containment, and the glass log canister is intended as secondary containment..

Yucca Mountain was originally planned for disposal of approximately 62,000 metric tons of uranium, and approximately 8,000 metric tons of vitrified HLW, collectively not to exceed a thermal power density of 57 kW/acre.<sup>(YM-1)</sup> More recent estimates suggest 84,000 metric tons of uranium, and approximately 60,000 metric tons of vitrified HLW.<sup>(YM-3)</sup> Initial Licensing will be sought based on Nuclear Regulatory Commission requirements for repository development.<sup>(YM-2)</sup> Surface characterization activities for Licensing have been underway since the 1980s. Underground tunnel-based characterization is the next step and has been progressing slowly due to public controversy and budget constraints.

The final Yucca Mountain type repository may not be actually located at Yucca Mountain, Nevada. Current federal legislation limits the quantity of heavy metal in the first repository to no more than 70,000 metric tons until such time a second repository is in operation.<sup>(YM-3)</sup> However, current efforts are directed toward licensing Yucca Mountain, Nevada.

## Waste

### General Description

Approximately 100 million gallons (380,000 m<sup>3</sup>) of radioactive waste is stored in underground tanks at the Hanford, Savannah River, Idaho Falls, West Valley and Oak Ridge Sites. Figure W1 shows the relative volume and radionuclide activity at these sites.<sup>(WA-1&8)</sup> Hanford has the greatest volume of waste and Savannah River has the greatest activity. Generally speaking, this waste can not be disposed of as LLW in it's existing form. Furthermore, the volume (or mass) is much too large to be directly disposed of as HLW at Yucca Mountain. To solve this problem, it is necessary to separate the UST waste into a small volume of HLW with most of the radionuclides, and a large volume of LLW with few radionuclides.

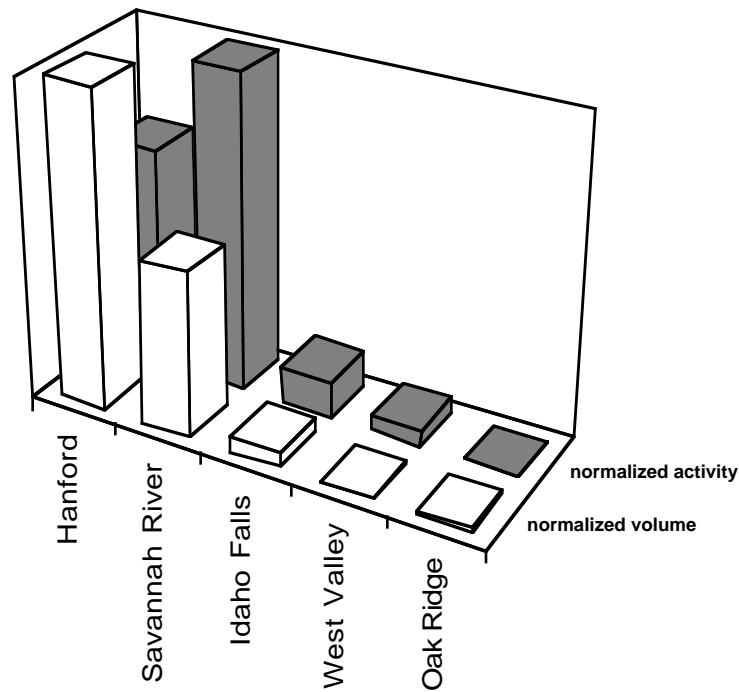


Figure W1. HLW Volume and Activity

Approximately 67-million gallons (250,000 m<sup>3</sup>) of radioactive waste is currently stored in 149 single-shell and 28 double-shell underground tanks at Hanford.<sup>(WA-8)</sup> This waste is predominantly a liquid-based high-sodium alkaline mixture. In order to minimize tank corrosion, acidic waste streams from the nuclear fuel reprocessing which formed the

source of the tank waste, were neutralized with sodium hydroxide. It has been determined that many of the single-shell tanks have or are leaking. The contents of the single-shell tanks consists of sludge (i.e. settled solids), salt cake (i.e. crystallized supernate), and supernate (i.e. liquid). To minimize leaking, an effort is underway and nearly complete to transfer the supernate from single-shell tanks to the double-shell tanks. The contents of the double-shell tanks consists of a slurry essentially composed of unsettled solids and supernate. In addition to the UST HLW, 1345 cesium capsules and 597 strontium capsules<sup>(WA-2)</sup> also exist at Hanford from prior processing of the salt cake, and will require repository disposal as well. The cesium and strontium have been immobilized as salts in the capsules.

Approximately 35-million gallons (130,000 m<sup>3</sup>) of radioactive UST waste exists at the Savannah River Site (SRS).<sup>(WA-9)</sup> This is also high-sodium alkaline waste similar to that at Hanford, and is stored in 51 underground tanks all which have some type of secondary containment, but do not all meet full RCRA requirements.<sup>(WA-3)</sup> The contents of these tanks consists of sludge, salt cake, and supernate. SRS waste differs from Hanford by it's age and chemical diversity. Hanford waste is older than SRS waste; and consequently, it's sludge will be more difficult to retrieve. Additionally, since Hanford was in operation before SRS, a greater variety of reprocessing methods were used as new technologies were developed. Therefore, the Hanford UST waste chemistry has greater variety and less characterization.

The waste at Idaho Falls consists of 2.2-million gallons (10,000 m<sup>3</sup>) of acidic liquid HLW and 3800 m<sup>3</sup> of calcine.<sup>(WA-9)</sup> The liquid waste is stored in 11 underground steel tanks (resistant to acid corrosion) with concrete vault secondary containment. These tanks do not all meet full RCRA requirements. The calcine is stored in six Calcine Solids Storage Facilities, a seventh is empty. The calcine facilities have been designed for a 500-year lifetime; however, not all meet most recent seismic requirements. The composition of the liquid and calcine waste is highly variable and is essentially either alumina, zirconia, flourinel or sodium based.

Approximately 300-thousand gallons (1200 m<sup>3</sup>) of liquid HLW existed at West Valley.<sup>(WA-6)</sup> This was predominantly high-sodium alkaline waste stored in one underground carbon steel tank. Of the 300-thousand gallons, most of the supernate (95% of original waste) has been processed for cesium removal via zeolite ion exchange. The liquid was concentrated following cesium removal to form 10,393 drums (at 71 gal/drum or 270 L/drum) of LLW grout. The remaining sludge (5% original waste) had not yet been processed at the beginning of FY-1996.<sup>(WA-7)</sup>

The Oak Ridge waste consists of approximately 200-thousand gallons (750 m<sup>3</sup>) of sludge, and 640-thousand gallons (2400 m<sup>3</sup>) of supernate stored in a variety of tanks.<sup>(WA-8)</sup>

Waste at Hanford and Savannah River is primarily the result of weapons material production. Waste at Idaho Falls is primarily due to naval nuclear fuel reprocessing. Waste at West Valley is the result of an attempt to reprocess commercial spent fuel by private industry. And finally, waste at Oak Ridge is the result of a variety of sources from weapons material research to medical radioisotope production.

The volume of each waste type for each site is shown in Figure W2.<sup>(WA-1)</sup> It can be seen that Savannah River has the greatest volume of liquid, Hanford the greatest volume of salt cake and sludge, and Idaho Falls the only calcine. Additionally, while the gunnite tanks at Oak Ridge predominantly contain only sludge, they are probably the tanks of

least integrity in the complex.<sup>(WA-9)</sup> Consequently, most of the Sites have some claim to fame.

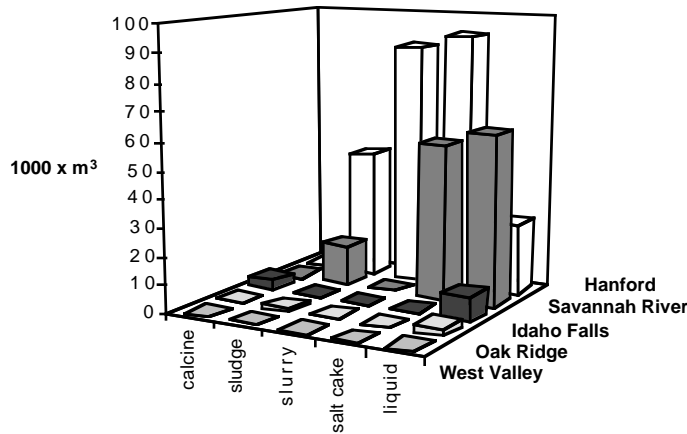


Figure W2. Volume of Waste Types

The UST waste can be divided into two categories with regard to chemical processing. These categories are liquid-based processing and solids-based processing. Essentially, all waste other than sludge will undergo liquid-based processing, if processed at all. For instance, if it is decided direct vitrification of calcine produces too much HLW, it will be dissolved in acid prior to radionuclide separation. Salt cake will be essentially dissolved in the liquid added to retrieve the waste from tanks, has similar chemistry as supernate, and consequently will be processed for radionuclide separation with liquid-based processing. Figure W3 shows the division of UST waste as that requiring liquid-based or solids-based processing.

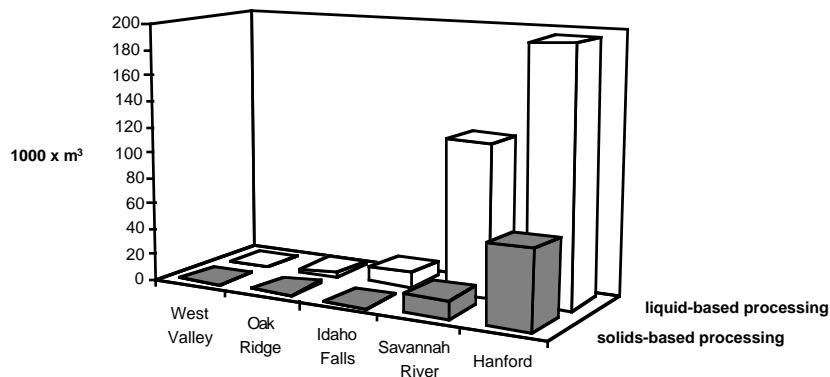


Figure W3. UST waste requiring liquid-based or solids-based waste

Generic Processing

A generic flowsheet is shown in Figure W4. The UST waste can be generally categorized as liquid or solids. The solids (primarily sludge) are precipitates of the neutralization process used to prevent acidic corrosion of carbon steel tanks. This was accomplished by adding sodium hydroxide to the original acid-based waste from nuclear fuel reprocessing. Since the sludge is difficult to handle, it is intended to limit processing to a caustic wash which partially removes chemical species such as sodium, aluminum, phosphorus and/or chromium which can dictate the amount of HLW glass if directly vitrified. It is not cost effective for the size of the repository to be excessively dictated by the amount of nonradionuclides. The liquids (including dissolved salt cake and possibly calcine) are processed such that most of their material can be disposed of as LLW. This generally involves separating cesium, strontium, technetium, and/or the TRUs.

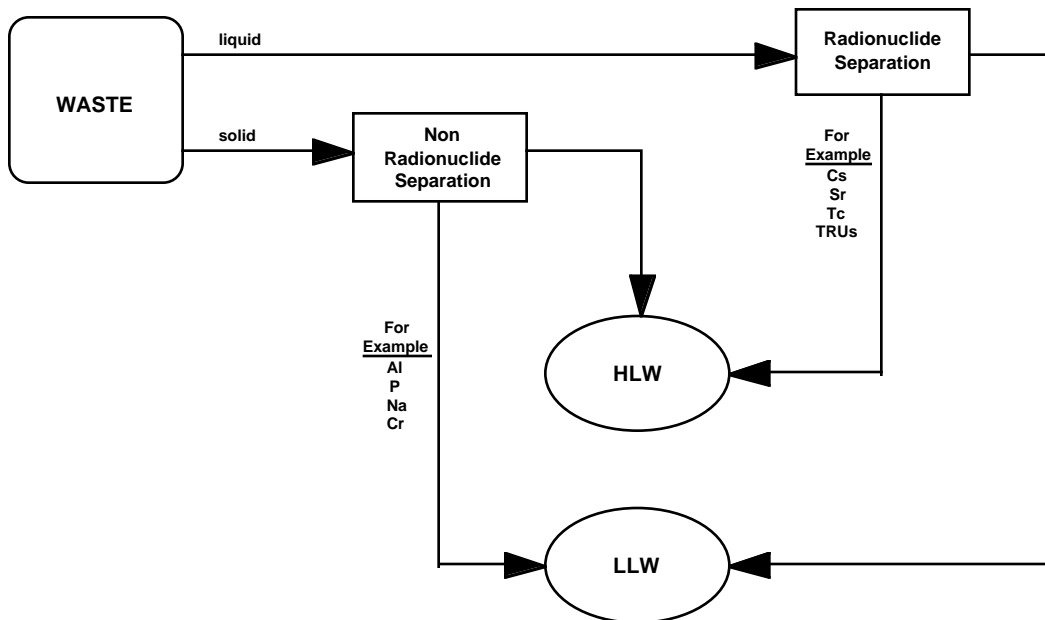


Figure W4. Generic Flowsheet



### Radionuclide Composition

The distribution of radionuclides in the alkaline UST waste for each Site is shown in Figures W5 and W6. <sup>(WA-1)</sup> Their distribution is shown for activity rather than mass or moles, because LLW limits are more directly based on activities. Activity is a measure of the number of atoms which decay per unit time. Consequently, LLW limits are actually dependent upon the decay rate and the energy of the decay products. These two characteristics affect the amount of tissue damage which a decay product can inflict. It can be seen that the cesium exists predominantly in the liquid and salt cake, and the strontium primarily in the sludge. The salt cake at Hanford has little cesium or strontium since they have already been removed and stored in capsules as a salt. The slurry at Hanford contains significant quantities of both strontium and cesium since it is a combination of liquid and solids. While TRUs are not particularly active in any of the waste, they are most prevalent in the sludges. Once again it should be noted, the liquid at West Valley has already undergone cesium separation.

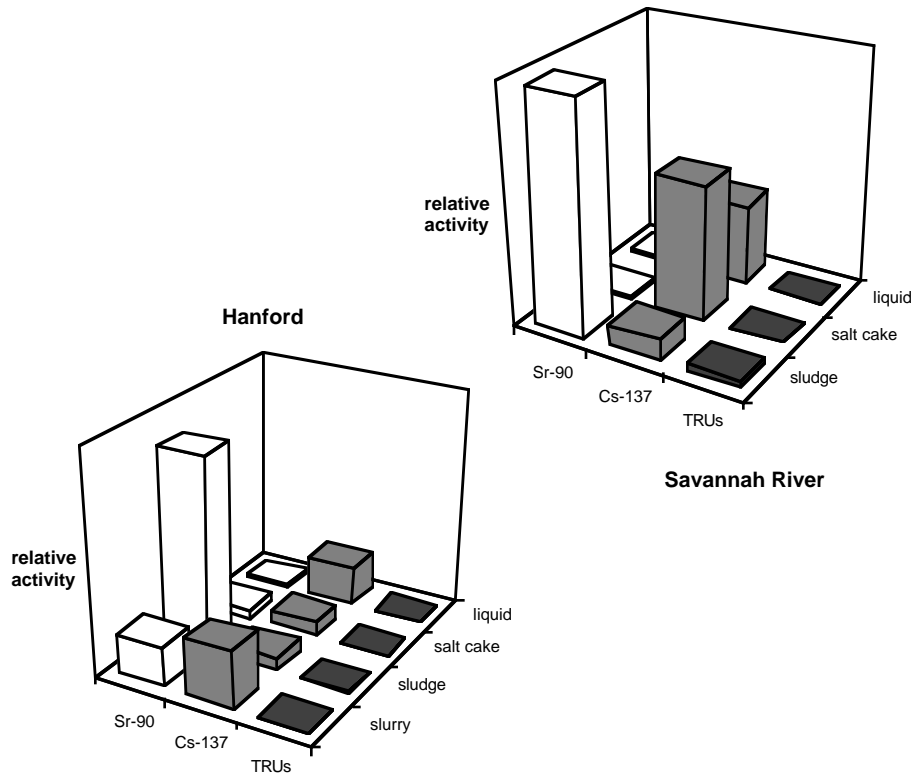


Figure W5. Radionuclide distribution at Hanford and Savannah River

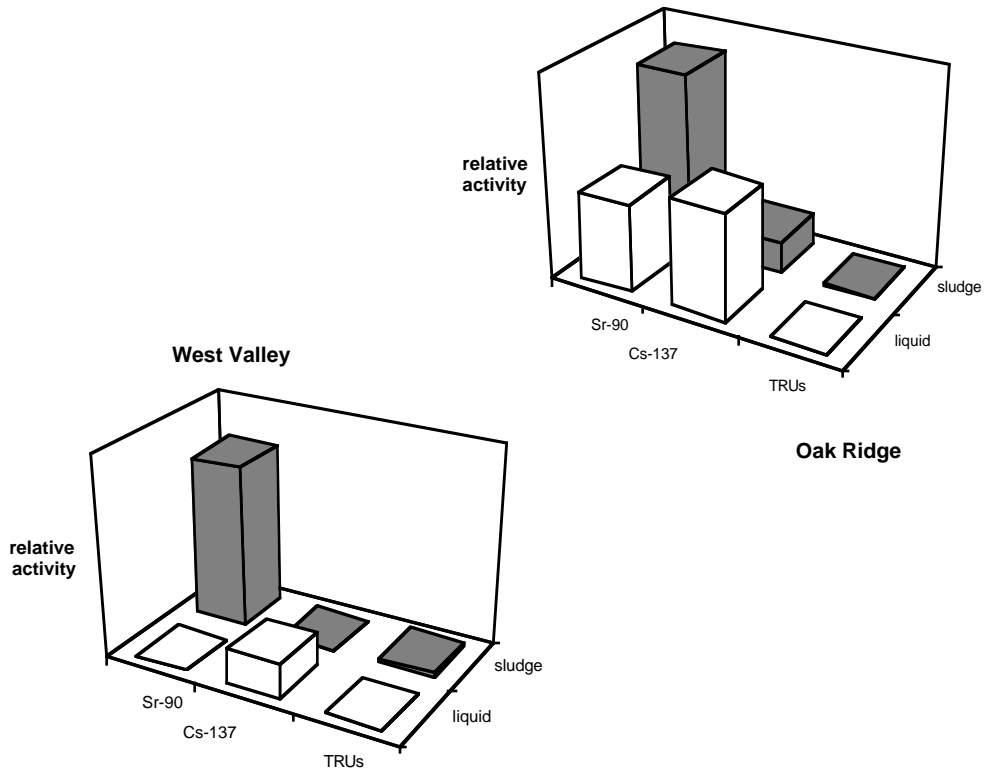


Figure W6. Radionuclide distribution at West Valley and Oak Ridge

The distribution of radionuclides in the acid and calcine UST waste at Idaho Falls, is shown in Figure W7. <sup>(WA-1)</sup> Since calcine is essentially the oxide form of liquid waste, the distribution of cesium versus strontium is the same in the liquid as in the calcine.

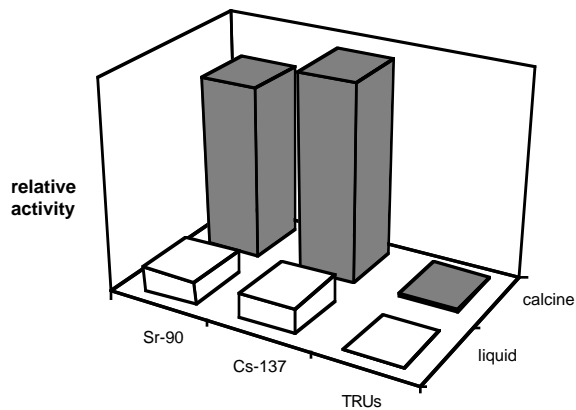


Figure W7. Radionuclide distribution at Idaho Falls

### Chemistry Composition

Figure W8 is shown to aid in demonstrating the purpose for and challenges in separating radionuclides from the liquid-based waste. It can be seen in Figure W8 that the mass of primary nonradionuclides in waste to be processed as liquid at Hanford, is between five and six orders-of-magnitude (i.e. 100,000 to 1,000,000) greater than the radionuclides. This demonstrates that if this waste were to be directly vitrified as HLW, the glass volume would be far greater than if maximum radionuclide loading were achieved based on thermal considerations. Therefore, separation of these radionuclides is critical if HLW repository costs are to be minimized. This same situation exists for the waste at other sites with their respective impacts dependent on their total UST liquid-based waste volume as shown in Figure W3.

Figure W8 can also be used to demonstrate the technical challenges regarding radionuclide separation of UST waste by liquid-based processing. If ion exchange is used to separate radionuclides the following behavior is observed.

- similarly charged ions (i.e.  $\text{Na}^+$  and  $\text{Cs}^+$ ) have similar chemical affinities for each exchange site:
  - ions with greater size may have greater difficulty entering the exchange matrix,
  - ions with smaller size may not be held within the exchange matrix as solidly,
- ions with lesser charges (i.e.  $\text{Na}^+$  versus  $\text{Sr}^{++}$ ) require multiple ions to fill an exchange site:
  - the exchange matrix may not accommodate two ions as easily,
- ions with greater charges (i.e.  $\text{Ca}^{++}$  versus  $\text{Cs}^+$ ) require two sites for each ion
  - two sites appropriately located for a single ion may not be convenient.

For chemical reaction/precipitation separations, similar rules apply as in ion exchange, with the exception that geometrical limitations are not as important. Consequently, it can be seen from Figure W6 that resin or chemical specificity for cesium or strontium, over the nonradionuclides, is the technical challenge.

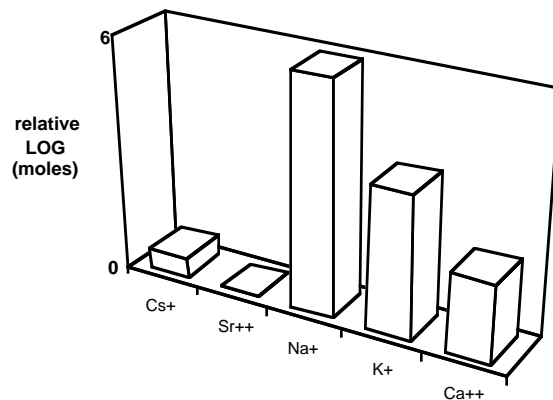


Figure W8. Primary chemical composition of waste at Hanford intended for liquid-based processing

Figure W9 is shown to aid in demonstrating the purpose for and challenges in separating nonradionuclides from the solids-based waste. Whereas the strategy for reducing the final volume of HLW due to liquid-based UST waste is separation of radionuclides from the bulk of the original waste, the strategy for reducing the final volume of HLW due to solids-based UST waste is separation of nonradionuclides from the bulk of the original waste. It can be seen in Figure W9 that the mass of primary nonradionuclides in waste to be processed as solids at Hanford, is between four and five orders-of-magnitude (i.e. 10,000 to 100,000) greater than the radionuclides. This demonstrates that if this waste were to be directly vitrified as HLW, the glass volume would be far greater than if maximum radionuclide loading were achieved based on thermal considerations. Therefore, reduction in the amount of these nonradionuclides is critical if HLW repository costs are to be minimized. The species shown in Figure W9 were selected due to their significant impact on HLW glass forming and integrity. This same situation exists for the waste at other sites, with their respective impacts dependent on their total UST solids-based waste volume as shown in Figure W3.

Separation of nonradionuclides rather than the radionuclides from the solids-based waste was chosen due to processing costs. Separation of a significant amount of nonradionuclides can be achieved with only a caustic wash to remove the more soluble species. Effective separation of the radionuclides would likely require acidic dissolution of the solids, followed by some type of ion exchange or solvent extraction process which would be considerably more expensive than a caustic wash. However, it should be noted that studies are proceeding with acid dissolution technologies to determine if they have a cost benefit.

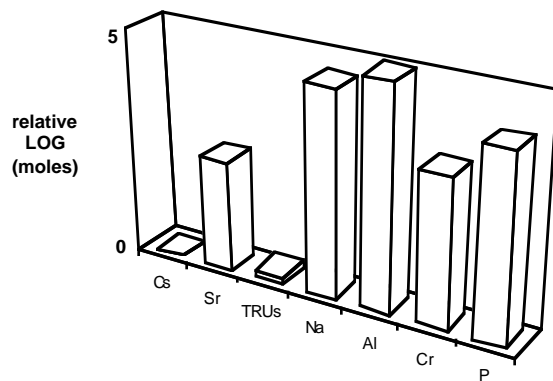


Figure W9. Primary chemical composition of waste at Hanford intended for solids-based processing

## Preferred Options

### Site Flow sheets

The baseline chemical processing flowsheet for Hanford is shown in Figure F1, and is essentially based on the Tri-Party Agreement.<sup>(FL-1)</sup> The intent at Hanford is to (1) remove cesium from the liquid-based UST waste by out-of-tank column-based ion-exchange (IX) and (2) caustic wash the sludge to partially remove species such as Na, P, Cr, and Al which would otherwise increase the HLW glass volume.<sup>(FL-2)</sup> The IX resin selected as the baseline is Duolite CS100, an phenol-formaldehyde based organic polymer. However, recent concerns over the CS100 availability and performance have forced consideration of other resins such as a resorcinol-formaldehyde based polymer and an inorganic crystalline silico-titanate resin. Following cesium separation, the liquids will be evaporated for volume reduction and disposed of with the eluted organic IX resin as LLW. The IX eluate and the washed sludge will be disposed of as HLW.

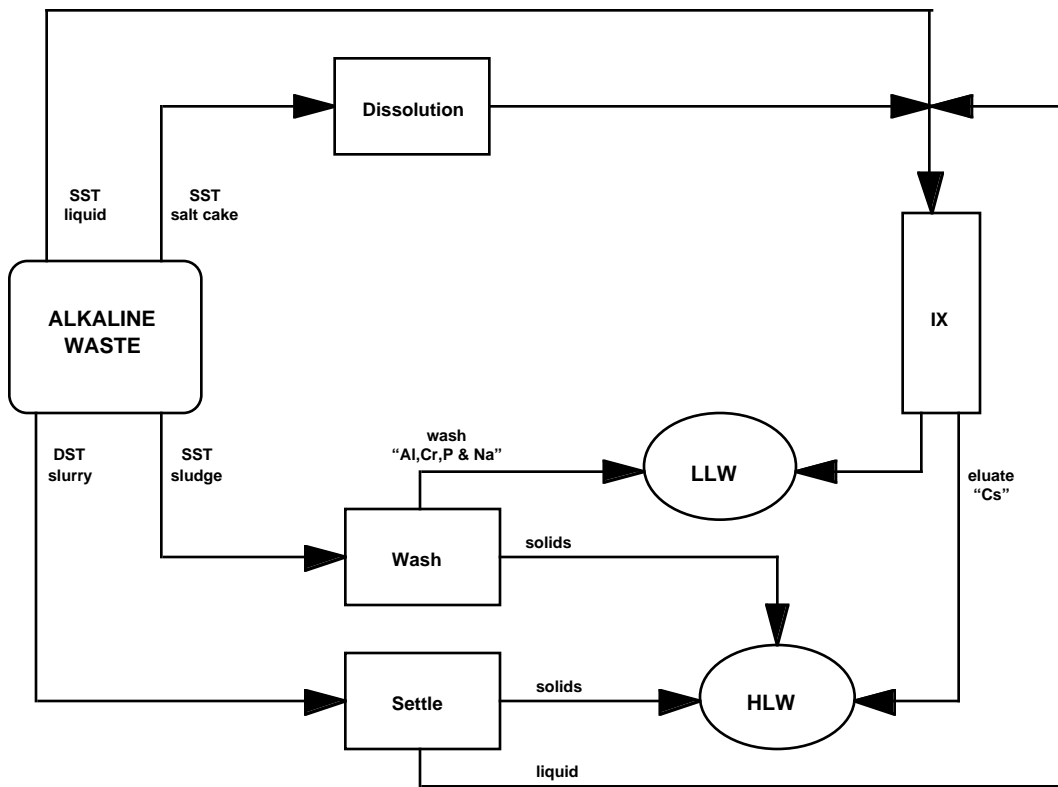


Figure F1. Hanford Preferred Processing Flowsheet

The baseline chemical processing flowsheet for Savannah River is shown in Figure F2.<sup>(FA-3)</sup> The intent at Savannah River is to (1) remove cesium from the liquid-based UST waste by in-tank chemical precipitation followed by filtration, and remove strontium and TRUs from the liquid-based UST waste by in-tank ion-exchange/adsorption followed by filtration<sup>(FA-4)</sup> and (2) caustic wash the sludge to partially remove species such as Na and Al which would otherwise increase the HLW glass volume.<sup>(FA-5)</sup> The chemical precipitate, ion-exchange/adsorption material, and dissolved sludge will be disposed of as HLW. The liquids will be evaporated for volume reduction and disposed of as LLW.

While the Savannah River chemical processing is simplified by using in-tank processing, several additional steps are required. The organic chemical used for cesium precipitation, namely sodium tetraphenylborate, will require organic destruction prior to vitrification. Additionally, an undesirable byproduct of radiolytic degradation of the sodium tetraphenylborate is benzene, which will be scrubbed from the filtrate with a nitrogen and water mixture.

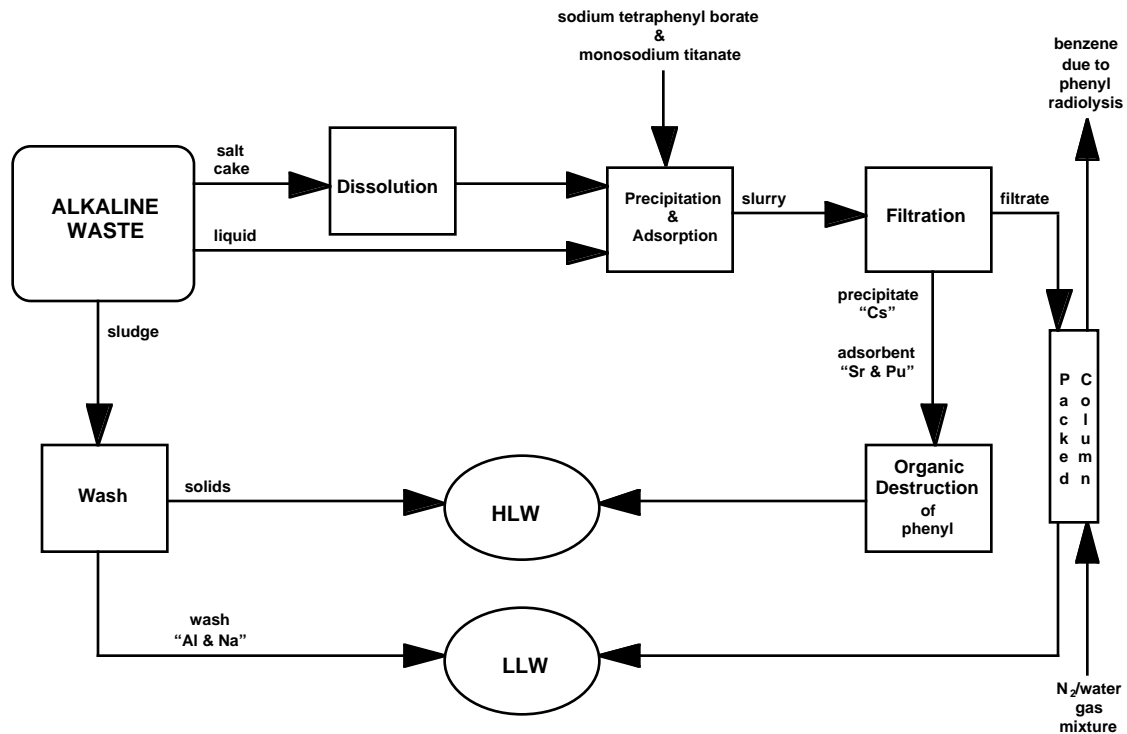


Figure F2. Savannah River Preferred Processing Flowsheet

The baseline chemical processing flowsheet for Idaho Falls is shown in Figure F3.<sup>(WA-4&5)</sup> Near-term plans at Idaho Falls involve calcination of the existing acid for interim stabilization. Even though the calcine bins have a 500-year design life, eventually the calcine will require permanent disposal. While many believe direct HLW vitrification of the calcine will be most cost effective, should the HLW repository cost become too great radionuclide concentration will significantly reduce the volume of HLW requiring disposal. Figure F3 displays the current preferred option for HLW volume reduction at Idaho Falls. Based on processing acid waste from calcine dissolution, the intent at Idaho Falls is to (1) remove uranium, TRUs, and technetium by TRUEX solvent extraction, (2) remove strontium by SREX solvent extraction, and finally (3) remove the cesium by column-based ion-exchange. A current candidate for IX separation of cesium from acidic waste is ammonium molybdophosphate (AMP). The radionuclide concentrated liquid extract from solvent extraction and the ion-exchange resin will be disposed of as HLW glass. The radionuclide depleted liquid raffinate (except cesium) from the solvent extraction will be passed through the ion-exchange column for cesium removal and then disposed of as LLW.

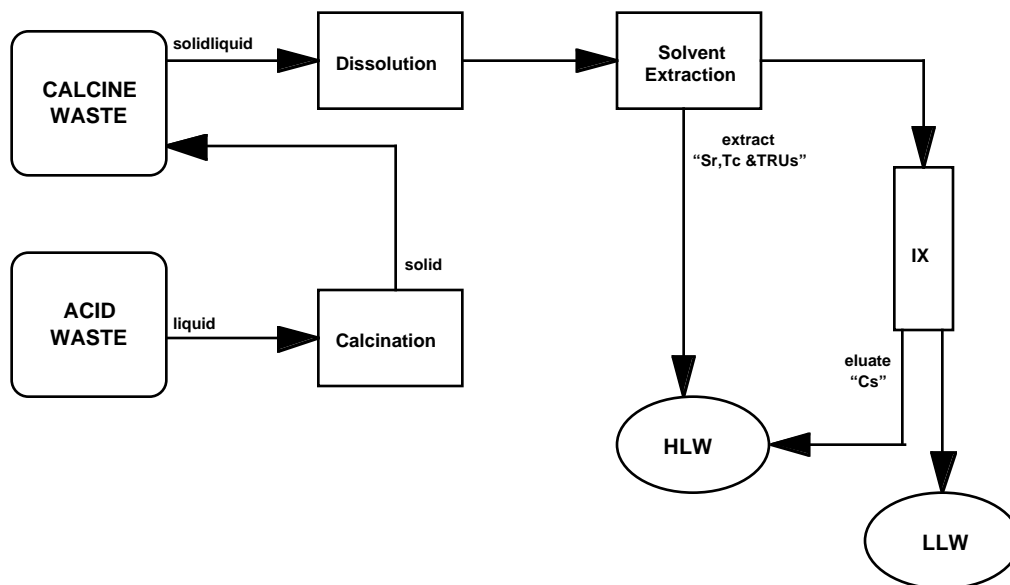


Figure F3. Idaho Falls Preferred Processing Flowsheet

The baseline chemical processing flowsheet for West Valley is shown in Figure F4.<sup>(WA-1&2)</sup> The waste at West Valley is predominantly alkaline due to neutralization. Most of the supernate has already been processed for cesium removal via out-of-tank column-based ion-exchange. This was done with a zeolite type resin. Of the sludge remaining, a wash is planned to remove the sulfate. It is expected that during the wash, some cesium, strontium and plutonium will be removed with the wash solution. Since the wash solution is destined for LLW disposal, it is planned to remove the cesium, strontium and plutonium by ion-exchange prior to disposal. This resin will be a modified form of the original resin used. The cesium separated supernate has already been evaporated and stored as LLW grout. The sludge wash liquid will be evaporated for volume reduction and disposed as LLW as well. The zeolite ion-exchange resin and washed sludge will be disposed of as HLW.

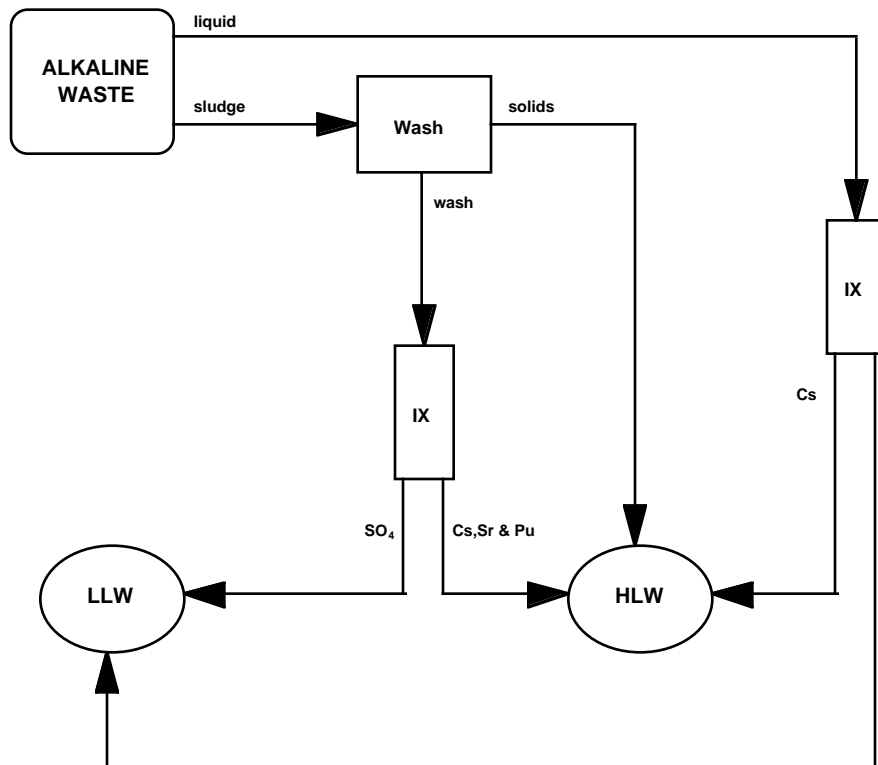


Figure F4. West Valley Preferred Processing Flowsheet



As shown in Figure F5, it is intended to reduce the amount of liquid-based UST waste at Oak Ridge by at least cesium separation and possibly strontium and TRUs as well with IX based processing.. The solids-based UST waste will simply be directly packaged for disposal as TRU waste at WIPP.<sup>(WA-8)</sup>

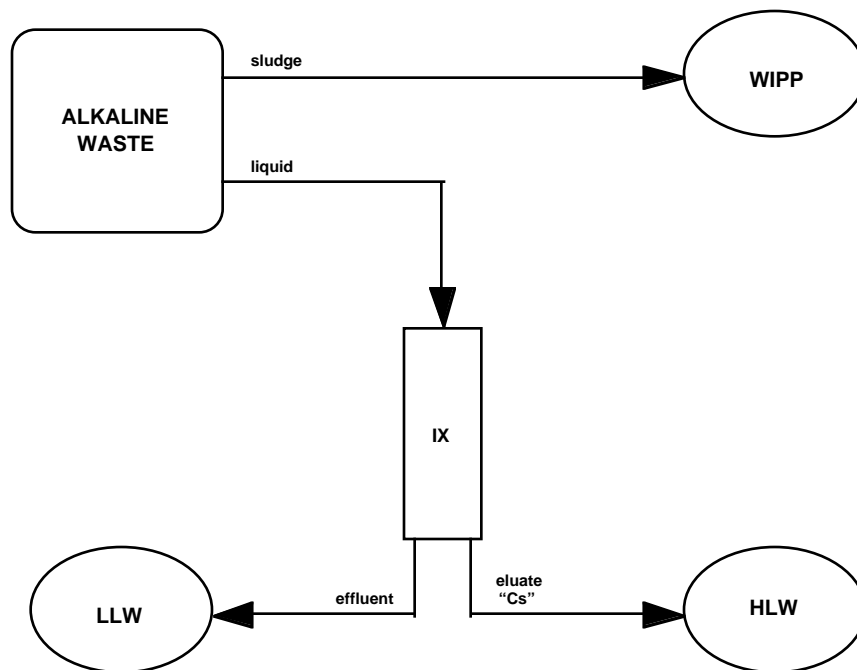


Figure F5. Oak Ridge Preferred Processing Flowsheet

Site Technologies

A summary of the preferred technologies selected for waste processing, intended to significantly reduce the HLW and LLW volume, are shown in Table T1. References have been listed in the prior section.

<u>SITE</u>	<u>Retrieval</u>	<b>TECHNOLOGIES</b>			
		<b>Pretreatment</b>		<b>Immobilization</b>	
		<u>solids</u>	<u>liquid</u>	<u>LLW</u>	<u>HLW</u>
Hanford	<ul style="list-style-type: none"> <li>• SST</li> <li>-past practice sluicing</li> <li>• DST</li> <li>-mixer pumps</li> </ul>	<ul style="list-style-type: none"> <li>• enhanced sludge wash (Na,Al,Cr,P)</li> </ul>	<ul style="list-style-type: none"> <li>• ion exchange (IX)</li> <li>-CS100 (Cs)</li> </ul>	glass/grout composite	glass
Savannah River	<ul style="list-style-type: none"> <li>• mixer pumps</li> </ul>	<ul style="list-style-type: none"> <li>• extended sludge processing (Na,Al)</li> </ul>	<ul style="list-style-type: none"> <li>• chemical precipitation</li> <li>-sodium tetraphenyl borate (Cs)</li> <li>• IX/adsorption</li> <li>-monosodium titanate (Sr,TRUs)</li> </ul>	grout "saltstone"	glass
Idaho Falls	<ul style="list-style-type: none"> <li>• calcine</li> <li>-pneumatic</li> </ul>	n/a	<ul style="list-style-type: none"> <li>• solvent extraction</li> <li>-SREX (Sr)</li> <li>-TRUEX (TRUs,Tc)</li> <li>• IX/adsorption</li> <li>-ammonium molybdophosphate (Cs)</li> </ul>	grout	glass
West Valley	<ul style="list-style-type: none"> <li>• sludge</li> <li>- past practice sluicing</li> </ul>	<ul style="list-style-type: none"> <li>• caustic wash (SO<sub>4</sub><sup>-</sup>)</li> </ul>	<ul style="list-style-type: none"> <li>• IX/adsorption</li> <li>- IONSIV IE-96 zeolite (Cs,Sr,TRUs)</li> </ul>	grout	glass
Oak Ridge	<ul style="list-style-type: none"> <li>• sludge</li> <li>- confined sluicing end effector</li> </ul>	WIPP	<ul style="list-style-type: none"> <li>• IX/adsorption</li> <li>- resorcinol/ formaldehyde (Cs)</li> <li>- or inorganic (Cs,Sr)</li> </ul>	grout	glass

Table T1. Site Preferred Technologies

## REFERENCES

FA-1 *Hanford Federal Facility Agreement and Consent Order, Fourth Amendment*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, January 1994.

FA-2 B. Rapko, *Sludge Washing and Alkaline Leaching Studies on Hanford Tank Sludges*, Tank Waste Remediation System (TWRS) Technology Demonstration Program Office (TDPO) Mid-Year Program Review, Pacific Northwest National Laboratory, Richland, WA, May 1994.

FA-3 *Decontamination of High Level Liquid Mixed Waste to Meet regulatory Compliance Issues Outlined in Federal Facilities Agreements (U)*, Westinghouse Savannah River Company, Aiken, SC, WRSC-MS-93-380, 27 February 1993.

FA-4 D.T. Hobbs and D. Walker, *Chemical Pretreatment of Savannah River Site Nuclear waste for Disposal*, Westinghouse Savannah River Company, Aiken, SC, WRSC-MS-92-144, 1992.

FA-5 C.J. Coleman, et al., *Reaction of Formic and Nitric Acid with Savannah River Site Radioactive HLW Sludge in the DWPF Pretreatment Steps*, Westinghouse Savannah River Company, Aiken, SC, WRSC-MS-93-563, 1993.

WA-1 *Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics*, U.S. Department of Energy Office of Civilian Radioactive Waste Management, DOE/RW-0006, Rev.7, October 1991.

WA-2 *Focus on Hanford: Cleanup Investment Promises Future Yields*, DOE This Month, U.S. Department of Energy, November 1994.

WA-3 *Decontamination and Treatment of High Level Liquid Mixed Waste to meet Regulatory Compliance Issues Outlined in Federal facilities Agreements (U)*, Westinghouse Savannah River Company, Aiken, SC, WSRC-MS-93-380, February 27, 1994.

WA-4 *ICPP Radioactive Liquid and Calcine Waste Technologies Evaluation Draft Technical Report*, Lockheed Idaho Technologies Company, Idaho Falls, ID, INEL-94/0119, October 1994.

WA-5 *Development of Radio nuclide Separation Technologies for Processing of Idaho Chemical Processing Plant Spent Fuel and HLW Calcine*, Westinghouse Idaho Nuclear Company, Idaho Falls, ID, WINCO-11935, 1993.

WA-6 *Status of High Level Waste Processing at West Valley*, Transactions of the American Nuclear Society, November 1991.

WA-7 *High level Waste Treatment at West Valley: Integrated Radwaste Treatment System*, Transactions of the American Nuclear Society, June 1992.

WA-8 *USTID Participant Site Characteristic Summary*, Westinghouse Hanford Company, Richland, WA, WHC-EP-0566, January 1993.

WA-9 *High-Level Waste Issues and Resolutions Document*, Westinghouse Idaho Nuclear Company, Idaho Falls, ID, WINCO-1210, May 1994.

WP-1 *Compliance Status Report for the Waste Isolation Pilot Plant*, U.S. Department of Energy, DOE/WIPP-94-019, 31 March 1994.

WP-2 *Experimental Program Plan for the Waste Isolation Pilot Plant*, U.S. Department of Energy, DOE/WIPP-94-008, January 1994.

WP-3 *Regulatory Issues for the Waste Isolation Pilot Plant Long-Term Compliance with U.S. Environmental Protection Agency 40 CFR 191B and 268*, Sandia National Laboratory, Albuquerque, NM, SAND-93-0053, October 1993.

YM-1 *A Survey of Hydrothermal Modeling Related to Yucca Mountain*, U.S. Nuclear Regulatory Agency, NUREG/CP-0040, June 1993.

YM-2 *Underground Exploration and Testing at Yucca Mountain*, Tunneling and Underground Space Technology, Vol. 9, No. 3, pgs. 353-363, 1994.

YM-3 *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program*, U.S. Department of Energy Office of Civilian Radioactive Waste Management, DOE/RW-0479, September 1995.