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Waste Disposal Options Report

Volume 1

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ABSTRACT

This report summarizes the potential options for the processing and disposal of mixed waste generated by reprocessing spent nuclear fuel at the Idaho Chemical Processing Plant. It compares the proposed waste-immobilization processes, quantifies and characterizes the resulting waste forms, identifies potential disposal sites and their primary acceptance criteria, and addresses disposal issues for hazardous waste.

DISCLAIMER

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ACRONYMS

AEA	Atomic Energy Act
BDAT	best demonstrated available technology
CSSF	calcined solids storage facility
CFR	Code of Federal Regulations
CWO	Cementitious Waste Option
DCWO	Direct Cementitious Waste Option
DET	determination of equivalent treatment
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
FGE	fissile gram equivalents
GCD	Greater Confinement Disposal
HAW	high-activity waste
HIP	hot isostatic press
HLW	high-level radioactive waste
HWIR	hazardous waste identification rule
HOW	HIP Waste Option
ICPP	Idaho Chemical Processing Plant
INEEL	Idaho National Engineering and Environmental Laboratory
LAW	low-activity waste
LDR	land disposal restrictions
LLW	low-level radioactive waste
LWA	Land Withdrawal Act

NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act
NWPAA	Nuclear Waste Policy Amendments Act
RCRA	Resource Conservation and Recovery Act
SBW	sodium-bearing waste
TRU	transuranic
VWO	Vitrified Waste Option
WIPP	Waste Isolation Pilot Plant

Waste Disposal Options Report

1. INTRODUCTION

1.1 General

From 1953 until 1992, the Idaho Chemical Processing Plant (ICPP), located at the Idaho National Engineering and Environmental Laboratory (INEEL), reprocessed spent nuclear fuel, primarily from the U.S. Navy, to recover uranium-235. This activity produced mixed, high-level-liquid waste that was then converted to a granular, solid form of mixed, high-level waste (HLW) called calcine, which is stored in the Calcined Solids Storage Facility (CSSF, more commonly referred to as bin sets) on the INEEL Site. Routine decontamination of the calcining equipment and other activities produced a mixed, liquid waste called sodium-bearing waste (SBW). It contains sodium (from sodium hydroxide) in addition to a variety of dissolved radioactive and hazardous materials in a nitric-acid solution. The SBW is stored in the Tank Farm at ICPP. All of the wastes contain both hazardous, as defined in the Resource Conservation and Recovery Act (RCRA), and radioactive wastes that must meet stringent requirements prior to disposal. Those requirements include site-specific waste acceptance criteria, and compliance with the land disposal restrictions (LDR) for the hazardous waste components.

In 1995 the DOE signed a Settlement Agreement with the State of Idaho stating that the DOE will convert "sodium-bearing liquid high-level wastes" to calcine by the end of 2012, will finish "calcining all remaining non-sodium bearing liquid high-level wastes" by June 30, 1998, and will prepare all HLW by the end of 2035 for disposal outside of Idaho.[1] By an act of Congress,[2] the disposal of all HLW must be in a characterized, geologic repository; however, only the Yucca Mountain site in Nevada has been designated for such characterization,[3] and it might not be able to accept the ICPP's wastes when it opens. Yucca Mountain's proposed acceptance criteria require that the HLW contain no untreated, hazardous wastes, and that it be immobilized by a process called vitrification (making glass from a mixture of HLW and glass frit) or by an acceptable, equivalent process. Another geologic repository, the Waste Isolation Pilot Plant (WIPP) in New Mexico, will accept only defense-related transuranic (TRU) wastes.

In addition to the radioactive wastes, the mixed-HLW also contains two categories of RCRA-hazardous wastes, listed and characteristic, which are subject to the LDR[4,5] prior to disposal. The hazardous wastes must be treated in accordance with the methods defined in the LDR; otherwise, they must be treated by techniques approved as the equivalents to the specified treatments. Vitrification satisfies the LDR, but there are other processes evaluated in this report that may also satisfy the LDR and the repository's acceptance criteria with further development and testing. After the hazardous wastes have been treated, the State of Idaho must delist each of the listed wastes. Furthermore, the receiving State and any States through which the waste would travel, must also approve the delistings. If a particular State is not authorized by the EPA to approve the delistings, then the EPA for that region would be responsible for approving the delistings. This report assumes that all of the waste forms from the proposed processes would meet the HLW repository's acceptance criteria for radioactive wastes and would satisfy the LDR treatment standards for hazardous wastes.

The wastes at the ICPP that were considered for this report include only the following: the existing calcine in the CSSF (approximately 3,800 m^3),[9] all of the liquid wastes in the Tank Farm, and a relatively small quantity of SBW that is expected to be generated through 2012. A small volume of HLW currently stored in the Tank Farm is scheduled to be converted into calcine by mid-1998.

Three alternatives for waste disposal are being considered that include the following: (1) four separations options, (2) four nonseparations options, and (3) a no-action alternative. In the separations options, the TRU and the high-activity isotopes Cs-137 and Sr-90 would be removed from the SBW and from the dissolved, HLW-calcine for disposal in a geologic repository outside of Idaho. It is assumed that the remaining waste would be re-classified as low-level waste (LLW) and would be mixed in grout for disposal at the INEEL or at an LLW disposal site outside of Idaho, if the LDR treatment standards are met. Because the volumes of high-activity and TRU wastes are small compared to the total volume of unprocessed waste, the volume of waste sent to a repository for disposal would be minimized, thereby reducing the costs for interim storage, transportation, and disposal. In the nonseparations options, the SBW would be converted to calcine and all the calcine would be immobilized in materials like glass, pozzolan cement, or ceramic for disposal at an HLW repository. In the no-action alternative, the SBW would be calcined and stored with the existing calcine. After a few hundred years, the radiation-field strength would have been reduced to acceptable levels through radioactive decay, and the disposal of the long-lived isotopes then could begin. In all three alternatives, various amounts of mercury would be recovered and then treated for disposal as LLW.

All of the HLW forms would have to be stored until such time that space became available at a HLW repository. If the waste were to be stored at the INEEL, a new facility would have to be built.

1.2 Nomenclature

Because several different types of waste are involved, the following elementary information concerning waste classifications, regulations, and disposal requirements is presented.

1.2.1 Mixed Waste

Mixed waste is a combination of radioactive waste and RCRA-hazardous waste.

1.2.2 RCRA-Hazardous Waste

There are two categories of RCRA-hazardous waste, listed and characteristic, both of which are contained in the waste stored in the CSSF and the Tank Farm. Prior to disposal, the hazardous waste must be treated as specified in the LDR, and then delisting petitions must be granted by the State of Idaho, by the receiving State, and any States through which the waste travels (or by their regional EPA) for each listed waste. Obtaining delistings may not be easy. Between 1980 and 1995, the EPA (nationally) granted only 13% of the 809 delisting petitions sought.[8] Wichmann, et al.[7] reports 66 listed wastes covered by 43 hazardous waste codes that could be in the Tank Farm and CSSF; however, since the stored waste has never been analyzed for hazardous constituents, those numbers may be questionable. A more recent report[6] names only five hazardous chemicals covered by three hazardous waste codes. In it, K. Gilbert searched historical records and questioned laboratory personnel to determine if the listed chemicals had actually been mixed with the waste. If they had never entered the waste stream, then reducing the number of listed hazardous wastes seemed justifiable.

The following assumptions have been made: the proposed waste-treatment processes would comply with the LDR treatment standards for each hazardous waste, the listed wastes would be delisted by the appropriate authorities, and a determination of equivalent treatment (DET) would be granted by the EPA for those processes other than vitrification. The delistings and the DET would occur prior to the

construction of the waste-processing production facility, and would be based on experimental data from waste forms produced in a pilot plant.

1.2.3 High-Level Waste

HLW is defined by the Nuclear Regulatory Commission (NRC) as irradiated fuel, liquid wastes resulting from operation of first-cycle solvent extraction system, or equivalent, and the concentrated waste from subsequent extraction cycles in a facility for reprocessing irradiated reactor fuel, and solids into which such liquid wastes have been removed.[10] The DOE refers to HLW as radioactive waste in sufficient concentrations to require permanent isolation.[11] It is important to note that HLW is defined by origin and not by specific concentrations or types of isotopes.

Expressed more simply, HLW is the mixture of highly-radioactive fission products and long-lived TRU that result from the reprocessing of spent nuclear fuel, and that require permanent isolation. The process of recovering uranium-235 from spent nuclear fuel is a solvent extraction system that results in mixed-HLW.

1.2.4 Low-Level Waste Classifications

LLW contains isotopes whose activity concentrations are sufficiently low to be classified by the NRC as Class-A, B, or C radioactive waste, and whose TRU components have half-lives less than 5 years with activities of 100 nanocuries-per-gram, or less. Class-A waste is the least radioactive and Class-C is the most radioactive in the hierarchy of LLW classifications.[12]

1.2.5 Sodium-Bearing Waste

SBW is a liquid, mixed waste resulting from the decontamination of calcining equipment, using sodium hydroxide and nitric acid. The DOE does not consider it to be HLW. Based on the types of isotopes and their activity concentrations, SBW should be classified as mixed-TRU waste.

1.2.6 Transuranic Waste

TRU waste contains long-lived (half-lives of thousands to millions of years), alpha-emitting radionuclides, having atomic numbers greater than 92. To be considered a TRU waste, a material must have a half-life greater than 20 years, and an activity concentration greater than 100 nanocuries per gram.[11] It is neither LLW nor HLW; however, if it were separated from an HLW mixture, then it would be considered HLW until such time that it were re-classified as TRU waste. In this report, any waste stream evolving from a TRU-separations process that contains primarily tranuranics, shall be called TRU waste.

In two of the separations options presented in this report, the TRU wastes would be sent to the WIPP for disposal. Since the principal sources of the HLW at the ICPP are from defense-related activities, the TRU separated from that waste would meet the WIPP's acceptance criteria.[39]

1.2.7 Fission Products

Fission products are gamma-ray and beta-emitting isotopes that result from irradiating nuclear fuel and generally require massive shielding for the gamma rays. In the ICPP waste, the primary fission products are Cs-137 and Sr-90, which have half-lives of approximately 30 years. Fission products may be classified from Class-A through HLW, depending on their origin and level of activity.

1.2.8 High-Activity and Low-Activity Wastes

These waste classifications describe the status of the waste streams during the processing of HLW via the separations options. High-activity waste (HAW) refers to the mixtures of either (Cs + Sr + TRU) or (Cs + Sr) removed from the liquid SBW and dissolved calcine. Low-activity waste (LAW) refers to the much larger volume of waste remaining after the HAW have been removed. HAW will remain classified as HLW, but LAW is expected to be declassified and no longer considered HLW.

2. THE PROCESSES AND THE WASTE FORMS

The disposal options in the Separations Alternative include the Full-Separations Option, the 2006-Plan Option, TRU-Separations-Class-C-Grout Options, and TRU-Separations-Class-A-Grout Option. The 2006-Plan Option will not be discussed in this report because it is similar to the Full-Separations Option, but with a different schedule. The disposal options in the Nonseparations Alternative include Vitrified Waste (VWO) Option, Hot Isostatic Press (HIP) Waste Option (HWO), Cementitious Waste Option (CWO), and Direct Cementitious Waste Option (DCWO). More information on the processes for each of these options is available in reports,[13-18] and the bases for the processing data and the total waste volumes for each option can be found in Barnes.[9]

2.1 Assumptions

The following list of assumptions is needed to fulfill specific waste treatment and disposal requirements for the waste disposal options presented in this report.

- All waste forms produced shall meet the LDR treatment standards for the RCRA-hazardous wastes, and shall be granted DETs when necessary. This shall be accomplished prior to the construction of the waste-processing plant.
- All RCRA-listed-hazardous wastes shall be delisted by Idaho and approved by the receiving state (or regional EPA) prior to the construction of the waste-processing plant.
- The waste forms shall meet the disposal site's acceptance criteria.
- HLW-treatment processes other than vitrification shall be granted equivalence to vitrification. (Applicable to the hot-isostatic-press waste form and the cementitious-waste forms in the nonseparations options.)
- The NRC shall determine that the low-activity wastes from separations processes are no longer HLW. (Applicable to all of the separations options.)
- The NRC shall determine that TRU wastes separated from the HAWs are no longer HLW. (Applicable only to the two TRU-separations options.)
- All HLW shall be processed into a disposable form by the end of 2035, and all HLW-forms shall be stored on-site until an HLW repository is available for their disposal.
- The waste forms from the CWO and DCWO shall be disposed of at the Greater Confinement Disposal (GCD) site at the Nevada Test Site (NTS).

The processed HLW would be packaged in stainless-steel canisters (0.6-m diameter by 3-m long), the same canister design used at the Savannah River Site. In most cases, each canister would be loaded with 0.72 m^3 of processed waste. The canisters that would be sent to the WIPP for disposal would be shorter and contain from 0.1 to 0.3 m^3 of TRU waste due to limits for fissile-gram-equivalents (FGE) detailed in the acceptance criteria.[21]

The processed LLW would be used to fill the empty bin sets and SBW-storage tanks, or it would be

packaged in concrete containers, each holding 1 m^3 of waste for disposal in a near-surface facility at the INEEL or at a LLW disposal site outside of Idaho.

With the exception of the TRU-Separations-Class-C-Grout Option, all the other disposal options would require the construction of an interim storage facility for those high-level waste forms awaiting disposal at an HLW repository. Rawlins[19] documents the preliminary design study and costs associated with this facility for each option.

2.2 The Separations Alternative

Three processing options involve separating specific HAW from the HLW and the SBW to decrease or to eliminate the amount of HLW requiring disposal at an HLW repository. However, each of these three options would also produce approximately 25,000 m^3 of grouted LLW for disposal. In two of the three options, an interim-storage facility would have to be built at the INEEL to store the vitrified HLW until a repository became available for its disposal. In the TRU-Separations-Class-C-Grout Option, the TRU waste would be removed for disposal at the WIPP, and the remaining LLW waste would be grouted for disposal as Class-C waste.

For the grouted LLW, three disposal options are being considered. In one, the grouted LLW would be pumped into the empty storage tanks at the Tank Farm and into the empty storage bins at the CSSF. In the second option, the grouted LLW would be packaged in containers having 4-in.-thick concrete walls and loaded with 1 m^3 of grouted LLW, for disposal in a near-surface facility. Kiser et al.[38] provides a preliminary design study and costs associated with establishing such a disposal site at the INEEL. In the third option, the grouted LLW would be packaged and sent to the Hanford Site in Washington for disposal. It is questionable whether the processing of the LLW would satisfy the LDR treatment standards for all of the hazardous wastes present. If some of the listed wastes could not be delisted, the grouted LLW would have to be disposed of in a RCRA-Subtitle-C facility, which has not been studied.

The processing schedules for the Full-Separations Option and the TRU-Separations-Class-A-Grout Option are the same. From 2011 through 2012, the SBW would be processed to fulfill a commitment by the DOE to the State of Idaho, but the separated high-activity portion of the waste would be concentrated and stored in tanks until the start-up of the vitrification plant in 2016. Also in 2016, the retrieval and processing of the HLW calcine from the CSSF would begin; that calcine would have to be dissolved using nitric acid before the separations processes could commence. The separated HLW requiring vitrification would then be blended with glass frit and heated to approximately 1,100°C to make glass. The molten glass would then be poured into the stainless-steel canisters, which would be sealed and transferred to the interim storage facility on-site. The LLW stream would be processed, grouted, and disposed of from 2011 through 2035. All waste-processing operations would be completed by the end of 2035, although the vitrified wastes would remain in storage until such time that an HLW repository were ready to accept them for disposal.

The processing schedule for the TRU-Separations-Class-C-Grout Option is nearly the same as for the other two separations options. The SBW would be processed from 2011 through 2012, with no need for interim storage because vitrification would not be used. Instead, the separated TRU waste would be packaged and shipped to the WIPP for disposal. Similarly, the LLW would be grouted for disposal at the INEEL. The HLW calcine would be processed from 2013 through 2032, and all the waste would have been disposed by the end of 2032.

2.2.1 Full-Separations Option

In this process, depicted in Figure 1, the SBW would be processed before the calcine, because the SBW is already liquid. The calcine must be dissolved using nitric acid before it can be processed. HAW considered to remain as HLW are Cs, TRU, and Sr isotopes. During the separations processes, they are removed from the remaining low-activity wastes, which are assumed to be reclassified as LLW. The high-activity wastes would then be combined with glass-making materials, heated to 1,100°C, and poured into stainless-steel canisters. The HLW canisters would be stored at the INEEL while awaiting disposal at an HLW repository. Assuming 0.72 m^3 of vitrified waste per canister, approximately 650 canisters of vitrified HLW would be produced. However, in the Fluor Daniel study,[13] 780 HLW-canisters would be produced because a smaller waste-volume per canister was assumed. The remaining LLW stream would be concentrated by evaporation and then subjected to a denitration process at 650°C. The resulting material would then be mixed with grout for disposal as Class-A waste. Approximately 27,000 m^3 of grouted waste would be generated. Volatile materials also would be recovered during this process: mercury would be treated for disposal as LLW, some others would be grouted with the LLW, and the rest would be vitrified with the HLW.

The maturities of the technologies associated with this treatment option are given in the Fluor Daniel study.[13] One of those technologies is vitrification. It may be difficult to vitrify the varying compositions of the waste streams; several glass formulations will be necessary. Because vitrification is done at high temperatures, approximately 1,100°C, certain volatile materials, including mercury, will evolve as gases and vapors. Those volatile materials must be contained and treated, followed by disposal as LLW. Such off-gas treatment would also be required for the high-temperature denitration of the LLW stream.

The preliminary design study and costs associated with this waste-treatment option are provided in a report by Fluor Daniel.[13]

2.2.1.1 Advantages of This Option

- A relatively small number (650) of HLW canisters would be produced
- Vitrification and grouting technologies are mature.

2.2.1.2 Disadvantages of This Option

- A large volume (27,000 m^3) of Class-A waste would be produced
- The large volume (3,800 m^3) of existing calcine would have to be dissolved
- High-temperature processes would require two off-gas treatment facilities
- 650 canisters would require disposal at an HLW repository where a fee would likely be charged[20]
- HLW would be stored at the INEEL for an extended period
- Three separations processes would be needed for transuranics, cesium, and strontium.

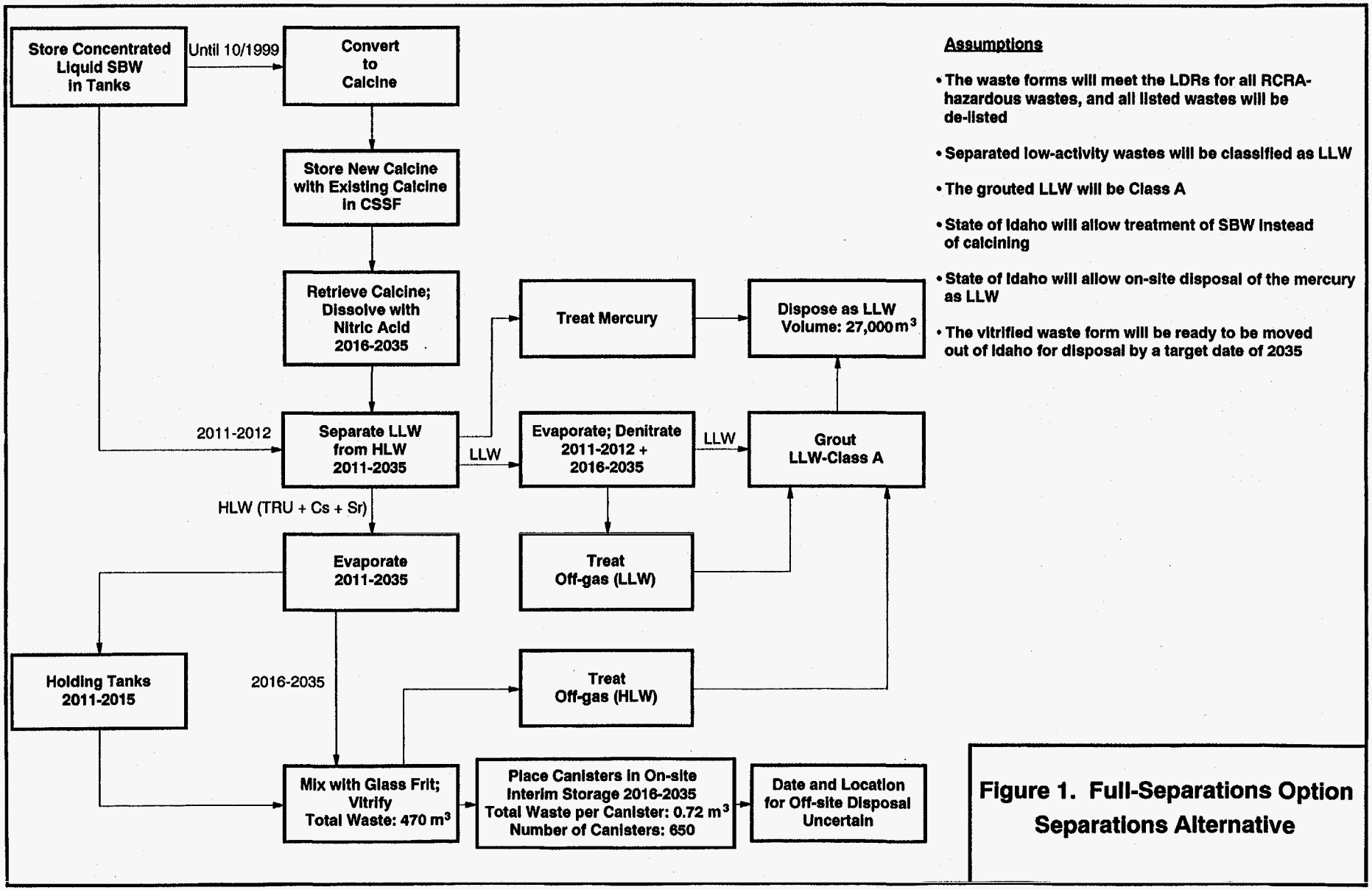


Figure 1. Full-Separations Option Separations Alternative

2.2.2 TRU-Separations-Class-C-Grout Option

Figure 2 illustrates this option, which is similar to the Full-Separations Option except that only the TRU waste is separated from the rest of the waste. Instead of being vitrified, the TRU waste stream would be dried through an evaporation process, and then packaged in smaller (0.4-m^3 capacity) stainless-steel canisters for immediate disposal at the WIPP. Because the radiation dose rate at contact would exceed 200 mrem/hr, the TRU waste would be classified as "remote-handled" according to the WIPP's waste acceptance criteria.[21] The remaining waste stream would contain the Cs and Sr isotopes in addition to the residual low-activity wastes. Following the concentration and denitration of this waste stream, it would be grouted for disposal as Class-C waste. Approximately 910 canisters of TRU waste, each containing from 0.1 to 0.3 m^3 of waste, and 22,000 m^3 of grouted LLW would be generated. The volumes of TRU waste per canister are based on FGE limits for the shipping cask used. Any mercury recovered during processing would be treated for disposal as LLW or it would be included with the TRU waste for disposal at the WIPP.

It is assumed that none of the waste-forms produced would remain classified as HLW. Because the TRU waste could be sent to the WIPP as it is processed, no interim storage facility would be needed. The WIPP would provide the shipping casks and would also be responsible for the transportation costs.[39] Another advantage of sending waste to the WIPP is that it can accept TRU wastes that contain certain listed and characteristic wastes known to be present in the waste stored in the Tank Farm and the CSSF.[21] This might eliminate the need to comply with the LDR treatment standards and the delisting requirements for TRU waste sent to the WIPP for disposal.

Landman[14] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

2.2.2.1 Advantages of This Option

- Small number of canisters (910) to ship to the WIPP for disposal
- The WIPP would provide shipping casks and transportation funding
- No interim storage facility would be needed
- All wastes would be disposed of by the end of 2032
- Many of the RCRA-hazardous wastes are acceptable at the WIPP
- Only one separations process would be required
- No vitrification plant or waste immobilization process would be needed for the TRU waste
- No HLW repository would be needed; no disposal fees would be charged
- Only one off-gas treatment facility would be needed.

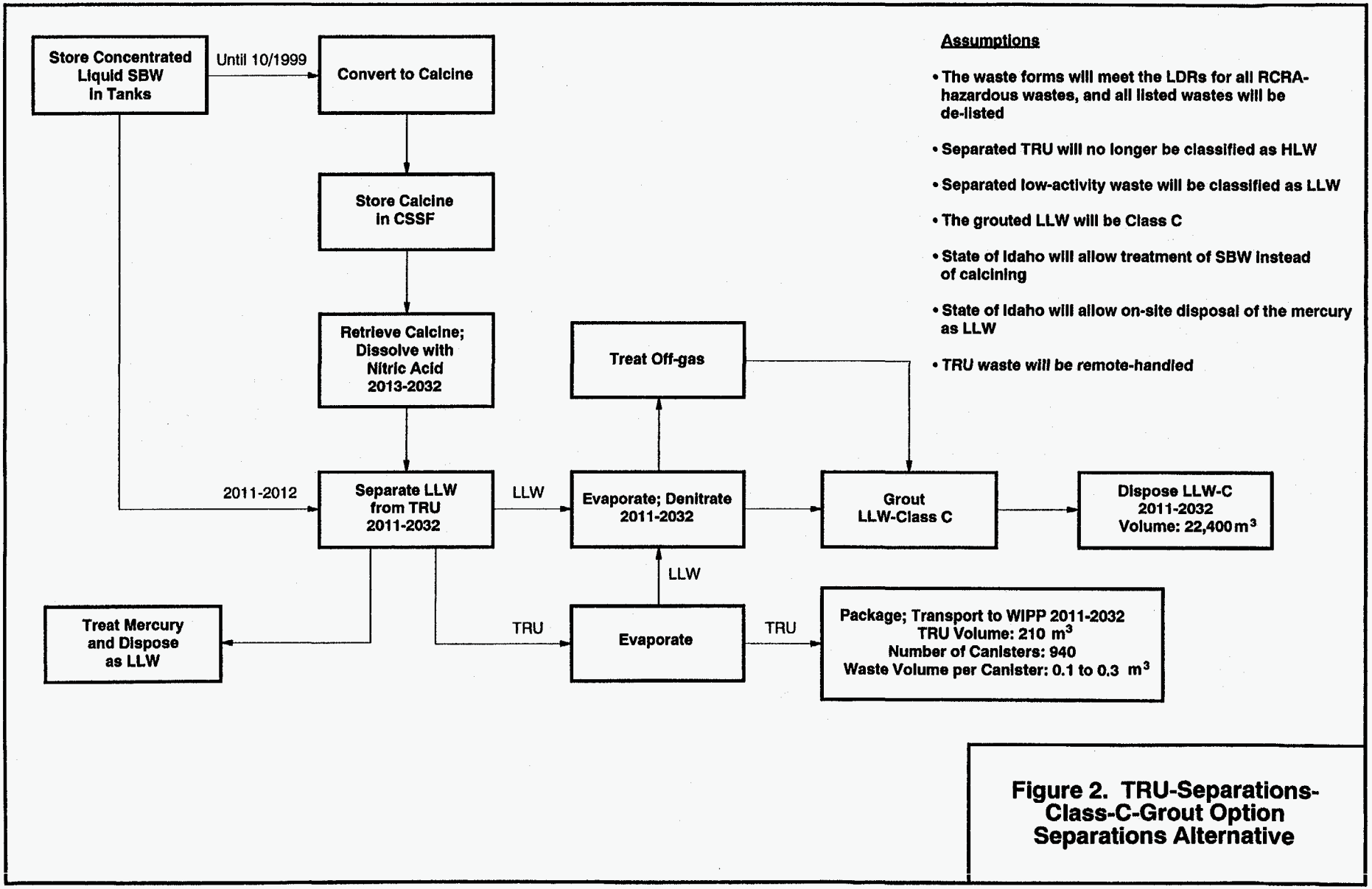


Figure 2. TRU-Separations-Class-C-Grout Option Separations Alternative

2.2.2.2 *Disadvantages of This Option*

- A large volume (22,000 m^3) of Class-C waste would be produced
- The TRU waste would have to be reclassified from HLW
- The large volume (3,800 m^3) of existing calcine would have to be dissolved.

2.2.3 TRU-Separations-Class-A-Grout Option

As depicted in Figure 3, this option is a combination of the first two separations options. The TRU waste would be separated from the rest of the waste and then dried, packaged, and sent to the WIPP in 910 of the 0.4 m^3-canisters. In a second stream, separated Cs and Sr would be combined, vitrified, and stored at the INEEL, awaiting disposal in an HLW repository. Approximately 170 canisters, each containing 0.72 m^3 of vitrified HLW, would be produced. Finally, the remaining waste stream would be denitrated and grouted for disposal as 27,000 m^3 of Class-A waste.

Landman[14] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

2.2.3.1 *Advantages of This Option*

- A small number (910) canisters would be sent to the WIPP for disposal
- Smallest number (170) of canisters would be stored and sent to an HLW repository
- The WIPP accepts many RCRA-hazardous wastes
- The WIPP would provide the shipping casks and funding for shipping the TRU waste.

2.2.3.2 *Disadvantages of This Option*

- A large volume (27,000 m^3) of Class-A waste would be produced
- The large volume (3,800 m^3) of existing calcine would have to be dissolved
- The TRU waste would have to be reclassified from HLW
- Three separations processes would be needed for transuranics, cesium, and strontium
- An interim storage facility would be needed for 170 HLW canisters
- 170 HLW canisters would have to be sent to an HLW repository where a disposal fee would likely be charged.[20]

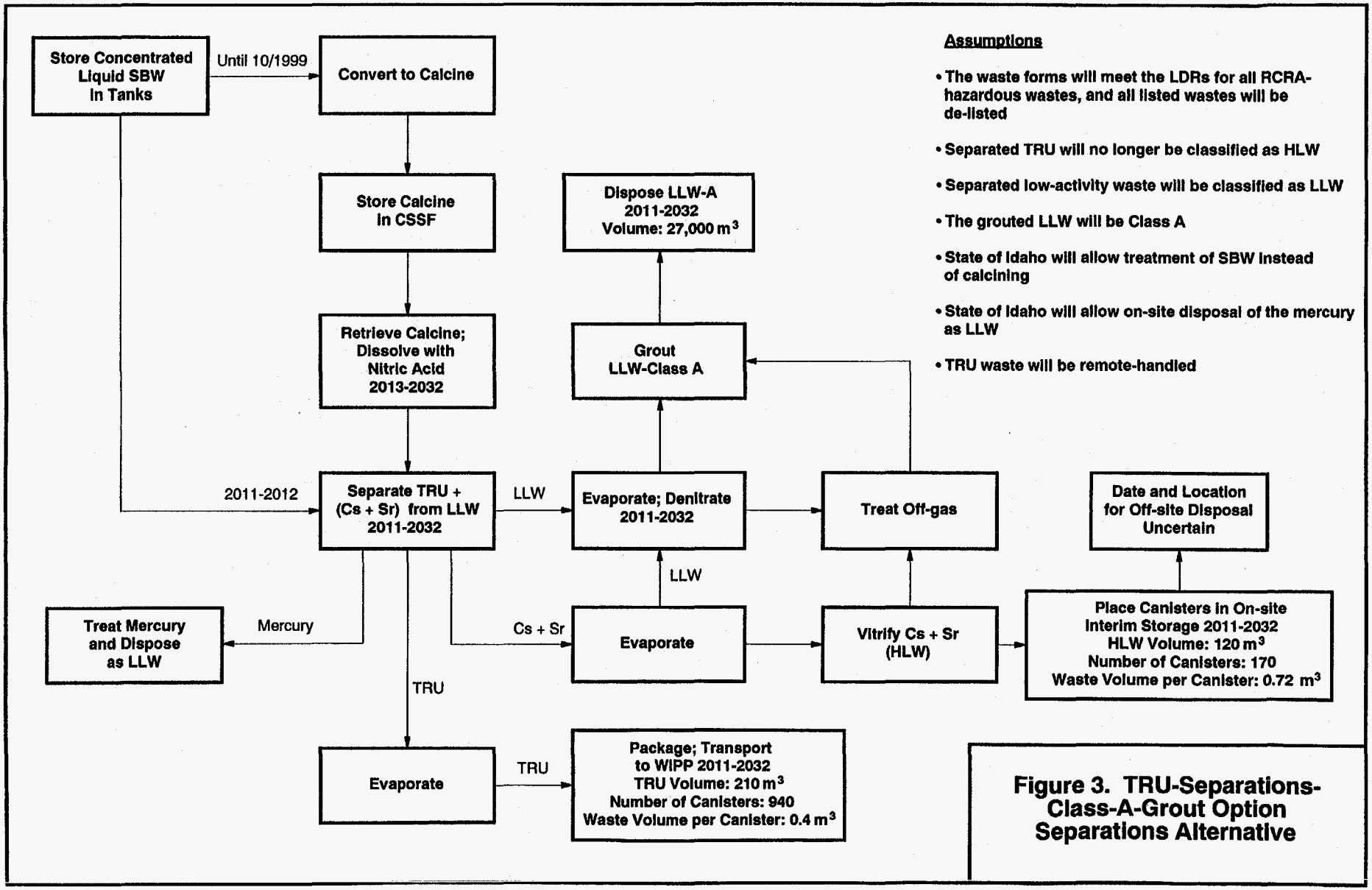


Figure 3. TRU-Separations-Class-A-Grout Option Separations Alternative

2.3 The Nonseparations Alternative

The Nonseparations Alternative includes four processing options that would immobilize calcined waste by binding it within a matrix of glass, pozzolan cement, or glass-ceramic. Each waste form would be HLW and would be contained within stainless-steel canisters, as described previously. All the remaining SBW would be converted to calcine prior to immobilization (except for the Cementitious-Waste Option, which processes the SBW directly), and the calciner's off-gas treatment system would be modified to recover mercury, which would then be treated for disposal as LLW.[24] In the Vitrified-Waste Option, the HIP-Waste Option, and the Direct-Cementitious-Waste Option, after the SBW has been calcined, the total volume of calcine stored in the CSSF would be roughly 5,400 m^3.

The HLW forms from the Vitrified-Waste Option and the HIP-Waste Option would require interim storage at the INEEL while awaiting disposal at their primary disposal site at Yucca Mountain. But the HLW forms from the Cementitious and the Direct-Cementitious-Waste Options would be sent to the GCD site, should it be approved as a disposal site. If the GCD were able to accept ICPP waste during the proposed processing schedules, then an interim storage facility would not be required.

The GCD site is a potential alternative to the proposed repository at Yucca Mountain, and is located within the NTS. It is an area where nuclear weapons tests were conducted, rendering the alluvial soil contaminated and essentially useless for anything except radioactive-waste disposal. Site characterization and waste disposal tests have been conducted there by Sandia National Laboratory[34,35] for more than ten years. Difficult political hurdles would have to be overcome before the GCD could become a disposal site for the ICPP's waste. They include changing the Nuclear Waste Policy Act Amendment to include the GCD for characterization as an HLW disposal site, and making the waste form described in the Cementitious and Direct-Cementitious-Waste Options the best demonstrated available technology (BDAT) for that site.

Waste-processing for the Cementitious Waste Option would be finished in five years, starting in 2013. The processing steps for each of the other three options would last 20 years, starting in 2013 and finishing by the end of 2032. The calcining of the SBW is assumed to be finished by the end of 2012.

2.3.1 Vitrified-Waste Option

In this process, depicted in Figure 4, batches of calcine would be transported pneumatically from the CSSF to the vitrification facility, where they would be blended and then mixed with glass-forming materials called "frit" to be fed to a melter operating at approximately 1,100°C to produce a borosilicate-glass waste form. The proposed process and equipment are very similar to those used by commercial glass makers. The chemical composition for the frit must be varied for the calcine blends to produce waste forms with optimal physical properties and acceptable leach rates. The molten glass would be poured into stainless-steel canisters for disposal at an HLW repository. Because of the high processing temperature involved, mercury would be vaporized. An off-gas treatment system would recover the mercury, which would then be treated for disposal as LLW.

Approximately 14,000 canisters, each loaded with 0.72 m^3 of vitrified waste, would be produced in this option. Lopez[15] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

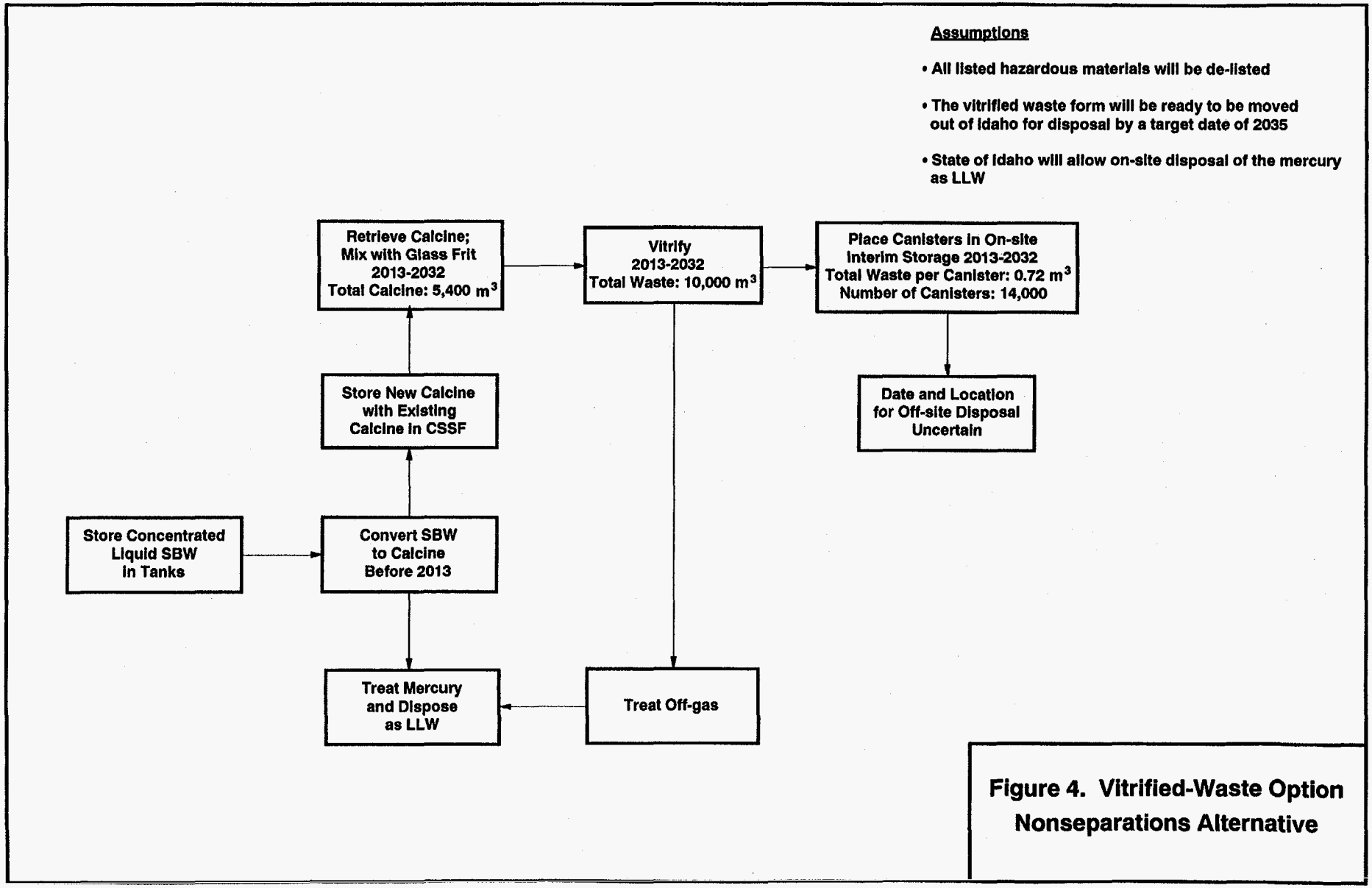


Figure 4. Vitrified-Waste Option Nonseparations Alternative

2.3.1.1 Advantages of This Option

- The vitrified waste form would satisfy the repository's acceptance criteria and the LDR
- No waste would remain in Idaho other than perhaps a small amount of treated mercury disposed as LLW.

2.3.1.2 Disadvantages of This Option

- Vitrification is a high-temperature process requiring special off-gas treatment facilities
- A large number (14,000) of HLW canisters may have to be stored for several decades in Idaho
- A large number (14,000) of HLW canisters would have to be shipped to an HLW repository where a disposal fee would likely be charged.

2.3.2 Hot-Isostatic-Press (HIP)-Waste Option

The block-flow diagram for this option is given in Figure 5. After retrieval from the CSSF, batches of calcined wastes (including the calcined SBW) would be mixed with silicates and a small amount of titanium or aluminum powder. This mixture would be placed in special cans designed to take advantage of the 50% volume reduction inherent in this process. Volatile materials would be removed at elevated temperatures prior to placing each can into the HIP apparatus and sealing the cans. Once inside the HIP chamber, the can and its contents would be exposed to high temperature (1,100°C) and pressure (20,000 psi) to produce a glass-ceramic waste form. Three of these compacted cans would then be loaded into a stainless-steel disposal canister. The high waste-loading (70 wt-% calcine) and 50% volume reduction after HIP should produce 5,700 loaded disposal canisters. Russell[16] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

2.3.2.1 Advantages of This Option

- No waste would remain in Idaho other than perhaps a small amount of mercury treated for disposal as LLW
- Represents the smallest number of canisters for disposal of the Nonseparations Alternative
- Waste form would probably satisfy the LDR and the repository's acceptance criteria.

2.3.2.2 Disadvantages of This Option

- Full-scale processing would need to be developed
- High-temperature process would require off-gas treatment facilities
- An interim storage facility may be needed in Idaho for several decades.

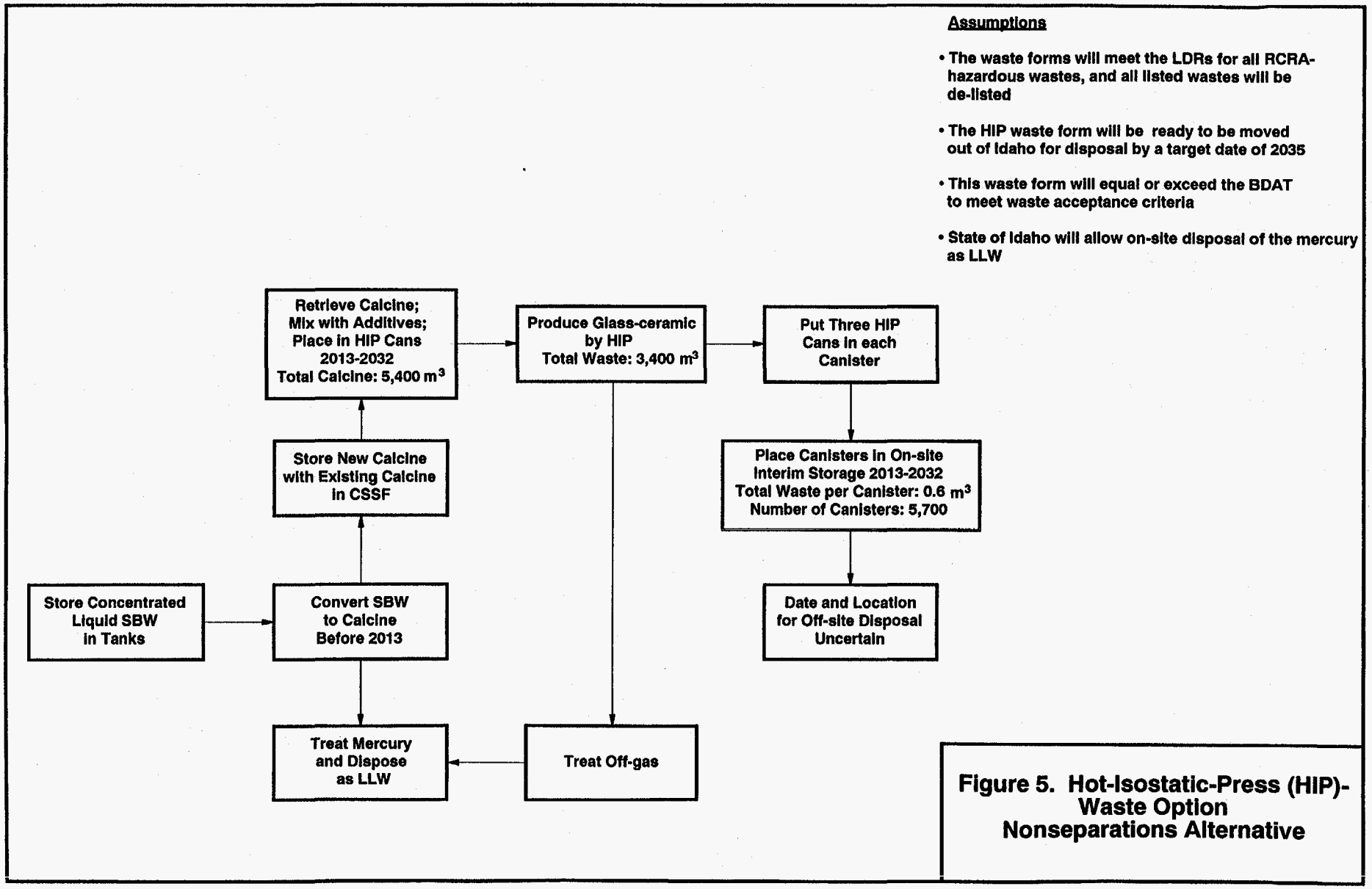


Figure 5. Hot-Isostatic-Press (HIP)-Waste Option Nonseparations Alternative

- 5,700 HLW canisters would require disposal at an HLW repository, where a fee would likely be charged.[20]

2.3.3 Cementitious-Waste Option

In this option, depicted in Figure 6, liquid SBW would be mixed with blends of existing calcines and the resulting slurries then would be re-calcined to make a more homogeneous form of calcine. The existing calcining equipment would need to be modified to accommodate the slurry feeds. An electrolytic process to recover mercury released during calcining operations would be needed also. By introducing sugar during the calcining operation, the nitrates would be reduced chemically and the amount of NO_X released would be minimized. The new calcine would then be mixed with pozzolan clay, blast furnace slag, caustic soda, and water. That mixture would be placed in stainless-steel canisters, cured at elevated temperature, and then heated under vacuum to reduce the water content to about 2 wt%. This waste-treatment option would produce approximately 16,000 loaded canisters, each containing 0.72 m^3 of processed waste. This report assumes that this treatment process will be accepted for disposal at the GCD site.

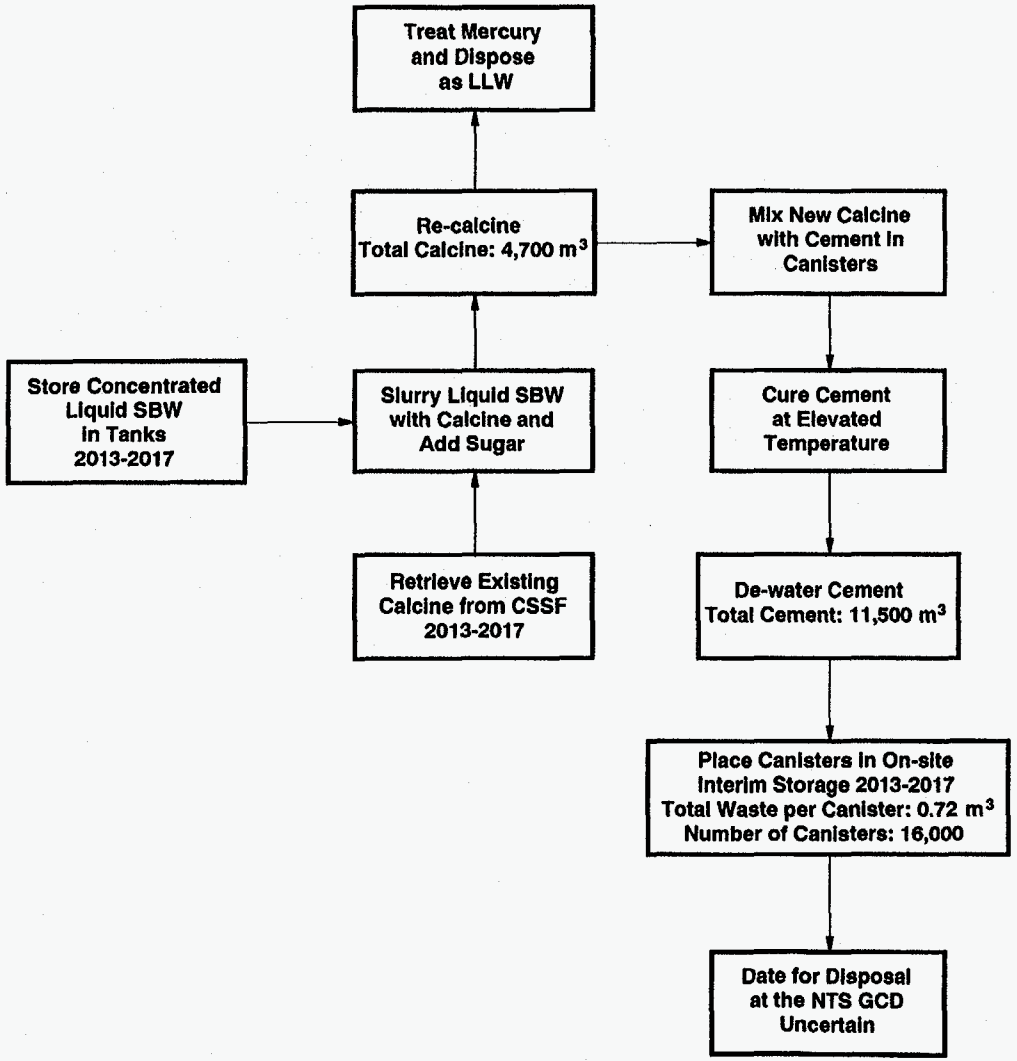
The curing and drying temperatures (250 to 300°C) are assumed to be low enough that mercury would not vaporize significantly.[17] However, during the recalcining operation, mercury would be recovered electrolytically and then treated for disposal as LLW. Oak Ridge National Laboratory and others[22,23] have performed a great deal of development work with cementitious waste forms. Lee[17] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

2.3.3.1 Advantages of This Option

- No waste would remain in Idaho other than perhaps a small amount of treated mercury for disposal as LLW
- The amount of NO_X produced during calcining would be minimal
- Virtually all nitrates would be converted to oxides
- Waste form would be compatible with the alluvial soil at the GCD site at the NTS
- Processing would be done at moderate temperatures.

2.3.3.2 Disadvantages of This Option

- A large number (16,000) of HLW canisters may have to be stored in Idaho
- Licensing the GCD as a HLW disposal site, and changing the NWPAA would be required
- Would not meet the 2012 deadline for calcining the SBW in the Settlement Agreement[1]
- The calciner would have to be modified to accept the slurry feed
- Characterization for long-term stability of the waste form may necessary.



Assumptions

- The waste forms will meet the LDRs for all RCRA-hazardous wastes, and all listed wastes will be de-listed
- Calciner will be modified to accept a slurry-feed
- Cement will be mixed with the new calcine as it is generated
- The cementitious waste form will be ready to be moved out of Idaho for disposal by a target date of 2035
- This waste form will be the BDAT for the GCD site at the NTS
- State of Idaho will allow on-site disposal of the mercury as LLW
- State of Idaho will allow liquid SBW to be treated after 2012

Figure 6. Cementitious-Waste Option Nonseparations Alternative

2.3.4 Direct-Cementitious-Waste Option

This option, shown in Figure 7, is nearly the same as the option described in the previous section, except all the liquid SBW would first be converted into calcine and then all the calcine would be retrieved from the CSSF in batches. These batches of calcine then would be mixed with pozzolan clay, blast furnace slag, caustic soda, and water, and processed thereafter as described for the previous option. The waste forms from the two options would have similar properties. During the high-temperature calcining of the SBW, mercury vapor would be recovered and treated for disposal as LLW. In the rest of the process, the temperatures would not be high enough (250 to 300°C) to release significant amounts of mercury from the waste form.[18] Approximately 18,000 canisters of HLW would be produced in this option, each containing 0.72 m^3 of processed waste.

The waste forms from this option would be sent to the GCD site for disposal. Oak Ridge National Laboratory and others[22,23] were responsible for developing this process using similar wastes. Dafoe[18] documents the preliminary design study, the maturities of the technologies employed, and the costs associated with this waste-treatment option.

2.3.4.1 Advantages of This Option

- No waste would remain in Idaho other than perhaps a small amount of treated mercury for disposal as LLW
- Waste form would be among the easiest and least expensive to produce from the options considered
- Waste form would be compatible with the alluvial soil at the GCD site at the NTS
- Processing would be done at moderate temperatures.

2.3.4.2 Disadvantages of This Option

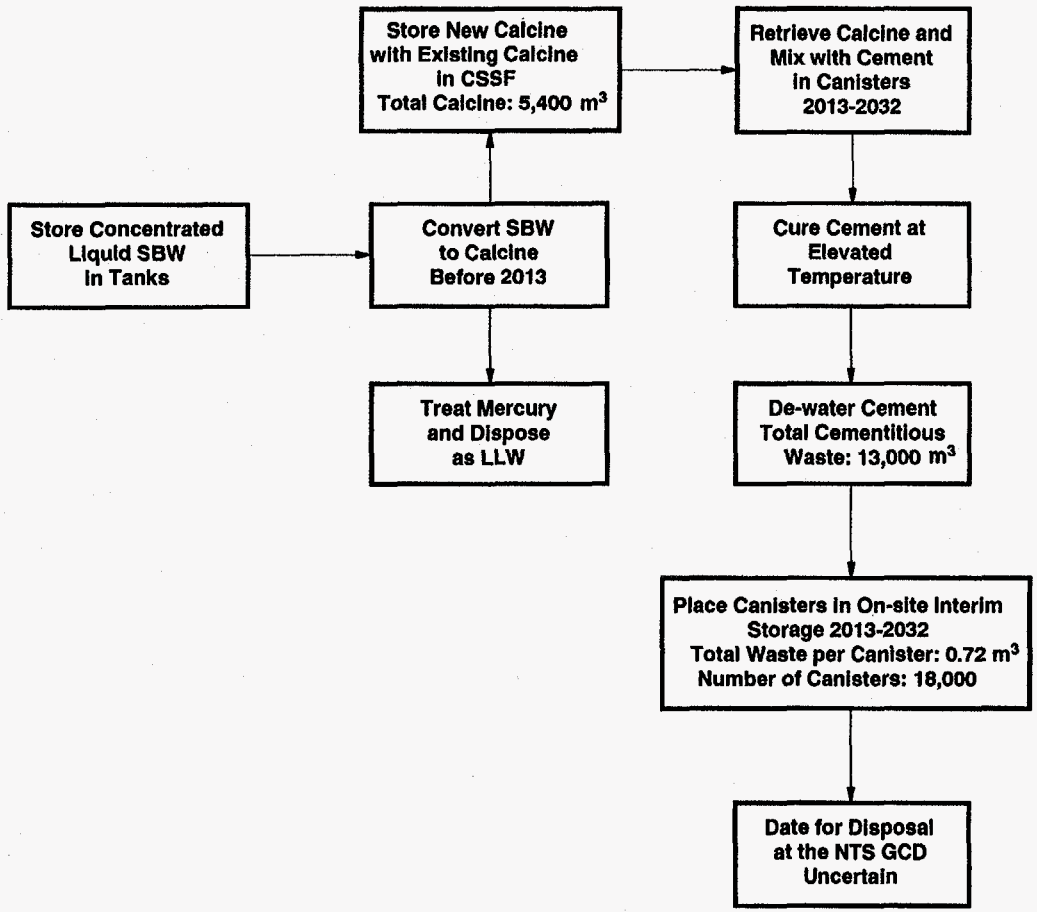
- A large number (18,000) of HLW canisters might have to be stored in Idaho
- Licensing of the GCD as an HLW disposal site and changing the NWPAA would be required
- Characterization for long-term stability of each phase of the waste form may be necessary.

2.4 Rejected Options

The seven processing options described in the previous sections are not the only ones that were considered in this study. Other processes were investigated and rejected for the reasons listed below.

2.4.1 Ceramic Silicone Foam

This material might have been considered as a material for immobilizing the calcine in a different nonseparations option, or it might have considered to replace the grout for immobilizing the LLW in the separations options. Ceramic silicone foam is polydimethyl-siloxane and is used frequently in products



Assumptions

- The waste forms will meet the LDRs for all RCRA-hazardous wastes, and all listed wastes will be de-listed
- The cementitious waste form will be ready to be moved out of Idaho for disposal by a target date of 2035
- This waste form will be the BDAT for the GCD site at the NTS
- State of Idaho will allow on-site disposal of the mercury as LLW

Figure 7. Direct-Cementitious-Waste Option Nonseparations Alternative

to seal and caulk bathroom fixtures. After a very brief investigation, it was rejected because of the lack of applicable experimental data and because of its high cost relative to grout.[25] Its resistance to radiation damage is good: it was used to patch cracks in the make-shift concrete containment at the Chernobyl site in Russia. Further research and development indicative of performance and cost advantages would be needed before this material could be considered for the immobilization of mixed waste.

2.4.2 Direct Grouting of SBW

This represents a partial solution to all of the waste disposal option because it addresses only the liquid SBW remaining in the Tank Farm. It proposes the addition of a caustic material to neutralize partially the highly acidic SBW (to a pH of 1.3) prior to immobilizing it in grout.[41] Approximately 6,000-7,300 m^3 of grouted waste[9] would be produced for on-site disposal by the end of 2012. It was thought that the grouted waste would be Class-C waste. However, the estimated concentration[9] of Pu-238 in the grouted waste exceeded the limits for Class-C waste, classifying it as TRU waste that could not be disposed of at the INEEL.

2.4.3 Disposal of Calcined SBW at the WIPP

In this proposal, the SBW stored in the Tank Farm would be converted into calcine by the end of 2012, then packaged and sent to the WIPP for disposal as remote-handled TRU waste. That could be a viable option were it not for the 7,000-m^3-volume limit for remote handled-TRU imposed by the State of New Mexico. Of that volume limitation, more than 6,000 m^3 have already been committed to TRU wastes from other DOE sites, thereby leaving space for only 1,000 m^3 of additional waste.[39] The volume of remote-handled TRU from the calcined SBW would range from 1,300 to 2,800 m^3, which would exceed the available space.[9]

2.4.4 Direct Grouting of LLW from the Separations Options

This is an alternate method to grout the LLW streams generated in the separations options. Instead of denitrating the liquid LLW, the highly acidic liquid would be neutralized partially to a pH of 1.3. The resulting volume of grout for on-site disposal would exceed 230,000 m^3, whereas the denitration method would produce approximately 25,000 m^3 (see Reference 9). This proposal was rejected because of the large difference in the final volumes of waste and the higher cost to process and dispose of the LLW by direct grouting than by denitrating prior to grouting.[41]

2.4.5 Disposal of LLW Using Polymers

In this option, the LLW would be immobilized in a polymer instead of in grout, for disposal. It was rejected because of the cost increase compared to grout, and because of the lack of experimental data[26] for disposal of LLW.

2.5 Selected Radiological Properties of Waste Forms

The ranges of radiological properties are listed in Tables 1 and 2 for each waste form and are a result of the different isotope concentrations present in the three types of waste to be processed: the alumna and zirconia calcines, and the SBW. Those ranges of radiological properties are then compared with the selected disposal sites' acceptance criteria to determine if any of the waste forms exceed the limits of the acceptance criteria.[4,21]

The sources of radiological data have various histories. The alumna and zirconia calcine data were determined by Wenzel,[27,28] primarily from analyses of calcine samples taken from two storage bins (out of a total of 43 bins) within the CSSF. He also calculated the effects of radioactive decay on the isotope concentrations to the year 2016, the approximate starting date for processing the waste. Rivard[29] provided the SBW data, but did not project the effects of decay to 2016. Barnes[9] compiled and manipulated all of those data, expressing each isotope's radiological concentration (curies/m^3) for each waste form. Peterson[30] calculated the effects of decay for the SBW data from Barnes' tables to 2016 prior to calculating the radiation dose rates and the decay heat generation for each waste canister.

For each waste form the following information was generated, as explained by McDonald[31]: radiation dose rates at contact (1 cm from the surface of the waste form), the dose rates at 1 meter, the decay heat generation expressed as watts per container of waste, the volume of waste per container, and the total number of loaded canisters for each option. For the dried TRU waste, the neutron dose rate was also calculated[32] for the vitrified HLW from the Full-Separations Option, the criticality coefficient was calculated for waste from alumna calcine.[33]

The volume of waste per container is based on the capacity for each container, except in the case of the TRU waste. In that case, the volume of waste per container was limited by the FGE of Pu-239 (a measure of criticality) that could be transported in a type 72-B shipping cask (325 FGE), as required in the WIPP's waste acceptance criteria.[21] The FGE data and plutonium-equivalent-curies per container calculations also are included by McDonald.[31]

The information indicates that the radiological properties for each waste form are within the limits of the disposal sites' criteria with one possible exception. A small number of HLW canisters (about 40) in the TRU-Separations-Class-A-Grout Option exceed the radiation field limits and the decay heat generation per canister for the proposed Yucca Mountain repository. Those few canisters represent the highest concentrations of Cs and Sr isotopes analyzed for pure alumna calcine. Likewise, the remaining 130 canisters represent much lower concentrations of those isotopes analyzed for the zirconia calcine and the SBW. However, these concentrations do not represent the way in which the wastes are actually processed. When the calcines are retrieved from the CSSF, they would be blended to form an "average" mixture prior to processing. Furthermore, several decades of storage prior to disposal would reduce the activity concentrations through radioactive decay, and the field strengths and decay heats would be more likely to be within acceptable limits.

Table 1. Properties of waste forms from the Separations Alternative.

Disposal Option & Wasteform	Disposal Site	Wasteform Property & Range	Disposal Site Limit
Full-Separations:		Contact dose rates: 2 to 2,500 R/hr	100,000 R/hr
Vitrified HLW (Cs + Sr + TRU)	Yucca Mountain	Decay heat: 25 to 220 watts/can	1,500 watts/can
		Waste volume: 0.72 m^3/canister	0.6 to 0.75 m^3/can
		Criticality coefficient, k_{eff}: 0.07	0.90
Class-A Grout	INEEL, Hanford	Contact dose rates: 0.01 to 0.02 R/hr	0.50 R/hr at 1 m
		Decay heat: 0.001 to 0.004 watt/cont	No limit defined
		Waste volume: 1.0 m^3/container	Various
TRU-Separations-Class-C-Grout:		Contact dose rates: 2 to 61 R/hr	100 R/hr
Dried, TRU Waste	WIPP	Decay heat: 1 to 6 watts/canister	300 watts/canister
		FGE: 325/canister	600 FGE/canister
		FGE: 325/cask, with 1 can/cask	325 FGE/cask
		Neutron dose rates: 10 to 80 mR/hr	270 mR/hr
		Waste volume: 0.1 to 0.3 m^3/can	0.83 m^3/canister
		Canister capacity: 0.4 m^3/canister	0.83 m^3/canister
Class-C Grout	INEEL, Hanford	Contact dose rates: 0.004 to 19 R/hr	No limit defined
		Decay heat: 0.2 to 7 watts/container	No limit defined
		Waste volume: 1.0 m^3/container	Various
TRU-Separations-Class-A-Grout:		Contact dose rates: 1,500 to 160,000 R/hr	100,000 R/hr
Vitrified HLW (Cs + Sr)	Yucca Mountain	Decay heat: 100 to 12,000 watts/canister	1,500 watts/can
		Waste volume: 0.72 m^3/canister	0.6 to 0.75 m^3/can
Class-A Grout	INEEL, Hanford	Contact dose rates: 0.01 to 0.02 R/hr	0.50 R/hr at 1 m
		Decay heat: 0.001 to 0.004 watt/cont.	No limit defined
		Waste volume: 1.0 m^3/container	Various
Dried, TRU Waste	WIPP	Contact dose rates: 2 to 61 R/hr	100 R/hr
		Decay heat: 1 to 6 watts/canister	300 watts/canister
		FGE: 325/canister	600 FGE/canister
		FGE: 325/cask, with 1 can/cask	325 FGE/cask
		Neutron dose rates: 10 to 80 mR/hr	270 mR/hr
		Waste volume: 0.1 to 0.3 m^3/can	0.83 m^3/canister
		Canister capacity: 0.4 m^3/canister	0.83 m^3/canister

Table 2. Properties of waste forms from the Nonseparations Alternative

Disposal Option & Wasteform	Disposal Site	Wasteform Property & Range	Disposal Site Limit (Yucca Mountain only)
Vitrified Waste:	Yucca Mountain	Contact dose rates: 6 to 170 R/hr	100,000 R/hr
Vitrified calcine		Decay heat: 1 to 15 watts/canister	1,500 watts/canister
		Waste volume: 0.72 m^3/canister	0.6 to 0.75 m^3/canister
HIP-Waste:	Yucca Mountain	Contact dose rates: 14 to 580 R/hr	100,000 R/hr
HIPed calcine: glass/ceramic		Decay heat: 2 to 61 watts/canister	1,500 watts/canister
		Waste volume: 0.72 m^3/canister	0.6 to 0.75 m^3/canister
Cementitious Waste:	GCD site	Contact dose rate: 140 R/hr	100,000 R/hr
Blended calcine in		Decay heat: 9 watts/canister	1,500 watts/canister
cementitious material		Waste volume: 72 m^3/canister	0.6 to 0.75 m^3/canister
Direct-Cementitious Waste:	GCD site	Contact dose rates: 7 to 290 R/hr	100,000 R/hr
Calcine in cementitious material		Decay heat: 0.5 to 16 watts/canister	1,500 watts/canister
		Waste volume: 0.72 m^3/canister	0.6 to 0.75 m^3/canister

3. THE DISPOSAL SITES

The proposed repository at Yucca Mountain is the only disposal site evaluated for the HLW forms from the following waste treatment options: Full-Separations, TRU-Separations-Class-A-Grout, Vitrified-Waste, and the HIP-Waste Options. A potential HLW disposal site at the NTS called the GCD is evaluated primarily for the HLW forms produced from the Cementitious and Direct-Cementitious-Waste Options. For the separated TRU waste, this report evaluates the WIPP in New Mexico. The grouted LLW from the separations options might be disposed of at the INEEL or at a disposal site in another State.[4]

The following LLW disposal sites and their waste acceptance criteria are discussed in detail by Banaee[4]: Envirocare of Utah, Nevada Test Site (DOE), Barnwell Waste Management Facility in South Carolina, DOE site at Hanford, INEEL (DOE), and U.S. Ecology in Richland, Washington. Currently, the Barnwell and U.S. Ecology disposal sites are not permitted to accept any DOE-generated (non-commercial) LLW due to NRC regulations and "Agreement State" legislation, and the projected radionuclide activities in the Class-A and the Class-C wastes from the proposed separations options exceed the limits specified in Envirocare's acceptance criteria. The NTS cannot accept LLW from the INEEL because the INEEL is not an approved, designated, waste generator.

Currently, the DOE's Hanford site is the only other LLW disposal site (besides the INEEL itself) to which the INEEL could send LLW. The estimated concentrations[9] of certain isotopes in the grouted, Class-A waste exceeds Hanford's waste acceptance criteria for Category-1 (Class-A) wastes, but all of the isotope concentrations for the ICPP's Class-A and Class-C grouted wastes are within Hanford's Category-3 limits.[4] However, since it is the DOE's policy to dispose of LLW where it is generated,[4] the INEEL is the only disposal site discussed in this report.

3.1 HLW Disposal Sites

The following waste forms would have to be disposed at a HLW disposal site. If the GCD site were approved for disposal of HLW, the waste forms could be sent to either the Yucca Mountain repository or the GCD site. However, the waste forms from the Cementitious and Direct-Cementitious-Waste Options are better suited than the other waste forms for disposal at the GCD site for reasons explained in Section 3.1.2.

- Vitrified HLW from the TRU-Separations-Class-A-Grout Option (Yucca Mountain)
- Vitrified HLW from the Full-Separations Option (Yucca Mountain)
- Vitrified calcine from the Vitrified-Waste Option (Yucca Mountain)
- Glass-ceramic waste forms from the HIP-Waste Option (Yucca Mountain)
- Cementitious waste forms from the Cementitious-Waste Option (GCD site only)
- Cementitious waste forms from the Direct-Cementitious-Waste Option (GCD site only).

The TRU wastes extracted during the two TRU-separations processes could be disposed in an HLW repository if they were vitrified and remained classified as HLW; however, that option has not been considered in this report.

3.1.1 Yucca Mountain Repository

Yucca Mountain is currently the only site in the U.S. designated for characterization to accept HLW, as enacted in the Nuclear Waste Policy Amendments Act of 1987. Its first commitment is the disposal of all the HLW and spent nuclear fuel from commercial reactors. It is not clear if DOE waste would be able to be disposed of at Yucca Mountain. In the meantime, the HLW from the ICPP must be immobilized within acceptable waste forms and placed in interim storage at the INEEL until such time that disposal could occur at an HLW repository, in accordance with the Settlement Agreement.[1]

The repository's waste acceptance criteria[4] are not yet final, but some of the primary requirements include the following:

- HLW shall be immobilized in borosilicate glass via the vitrification process; otherwise, the waste form shall be approved as the equivalent to vitrification and meet phase-stability and leach-rate requirements
- The waste forms shall not contain any untreated, RCRA-hazardous wastes, hazardous wastes shall meet the LDR for treatment and listed wastes shall be delisted
- The weight of a loaded canister shall not exceed 2,500 kg
- The dose rate at contact for gamma radiation shall not exceed 100,000 rem/hr per canister and the neutron dose rate shall not exceed 10 rem/hr
- The thermal power per canister shall not exceed 1,500 watts
- Canisters shall meet specifications
- The criticality coefficient, k_{eff}, shall be less than 0.90.

3.1.2 The Greater Confinement Disposal Site

The GCD is an area located within the NTS that is contaminated with radionuclides from nuclear weapons testing over an extended period. Although this area is not an approved disposal site for HLW, researchers at Sandia National Laboratory, under contract with the DOE, have conducted a study[34,35] to assess whether the GCD would comply with the disposal-site standards for HLW and TRU specified in 40 CFR 191.[4,36] The GCD performance assessment is preliminary and inconclusive at this time.

If the GCD were to be approved for disposal of the ICPP's mixed HLW, all of the waste forms destined for disposal at the proposed repository at Yucca Mountain could go there instead. But on a technical basis, it would be better to consider only the waste forms produced from the Cementitious and Direct-Cementitious-Waste Options, because they most closely resemble the GCD's alluvial soil and would be the least likely to migrate into the surrounding soil. It is very likely that the cementitious waste forms would form zeolites over an extended time and zeolites are the primary constituents in the alluvial soil at the GCD. Since the cementitious waste form and the soil would be chemically compatible, there would be no thermodynamic drivers to cause geochemical breakdown of the waste with time.[40] In a recent study,[37] Lee indicates that the waste canisters should be buried to depths of 100 to 150 feet in 12-foot-diameter boreholes that would be backfilled with native soil, and then capped with concrete.

3.2 Disposal Sites for TRU Waste

There are currently only two disposal sites for TRU wastes that would be extracted from the ICPP's HLW: the geologic repository at the WIPP and the proposed repository at Yucca Mountain described in Subsection 3.1.1.

3.2.1 The WIPP

This repository was developed exclusively for the disposal of TRU waste and mixed-TRU waste originating from defense-related activities; therefore, no HLW may be disposed of at the WIPP. It is expected that the TRU waste separated from the INEEL's HLW will be declassified as HLW and reclassified as TRU waste, thereby making it acceptable at the WIPP. Because the TRU would be slightly contaminated with fission products following the separation process, it would be classified as remote-handled TRU, according to the WIPP's contact-dose-rate criteria. Any TRU-waste canister having a contact dose rate exceeding 0.20 rem/hr would be classified as remote-handled. The following are the primary acceptance criteria for remote handled TRU at the WIPP.[21]

- Contact dose rates shall not exceed 100 rem/hr per canister (A small percentage of canisters may have contact dose rates up to 1,000 rem/hr)
- Neutron dose rates shall not exceed 0.27 rem/hr per canister
- Pu-239 FGE shall not exceed 600 per canister
- FGE per type 72-B shipping cask shall not exceed 325 (remote handled TRU must be shipped in type 72-B shipping casks)
- Plutonium-equivalent curies shall not exceed 1,000 curies per canister
- Thermal power shall not exceed 300 watts per canister
- The TRU wastes shall have originated from defense-related activities
- Total weight per loaded canister shall not exceed 8,000 lbs.

The advantages of disposing of TRU wastes at the WIPP include (a) timely disposal schedules (no need to build an interim storage facility at the INEEL), (b) removing the wastes from Idaho by the end of 2032, (c) the LDR requirements are not applicable so mixed-TRU wastes are acceptable, and (d) the WIPP provides the shipping casks and the transportation funding.

3.2.2 Yucca Mountain Repository

Disposal of the TRU waste separated from the ICPP's HLW could be at the proposed Yucca Mountain repository, when it becomes available. But, the waste must be vitrified, meet the other acceptance criteria outlined in section 3.1.1, and the separated TRU waste would have to remain classified as HLW.

3.3 LLW Disposal at the INEEL

The LLW produced from the various waste treatment options include either 27,000 m^3 of Class-A or 22,000 m^3 of Class-C grouted wastes, and varying, small quantities of treated mercury. None of the LLW contains isotope concentrations exceeding the limits for Class-C waste.[12] This was determined by comparing the isotope concentrations in each of the LLW forms[9] with their specified limits.[12]

There are two proposed, LLW-disposal plans at the INEEL, and both must meet the criteria provided in Banaee report.[4] In the first plan, the LLW would be immobilized in grout, for disposal in the empty tanks at the Tank Farm and the bins at the CSSF.[13] Recovered mercury would be treated for disposal as LLW. All of the LLW must comply with the LDR treatment standards for all of the RCRA-hazardous wastes, and each of the listed wastes must be delisted prior to disposal. Otherwise, the wastes would have to be disposed of in a RCRA-Subtitle-C, LLW facility, which has additional and more stringent design and maintenance requirements.

In the second plan, all LLW would be grouted and placed into containers made of concrete for disposal in a LLW, near-surface, facility.[38] As in the first plan, the hazardous wastes would have to comply with the LDR and each listed waste would have to be delisted prior to disposal. Treated mercury would be disposed of as LLW.

3.4 Summary of Disposal Sites and Waste Quantities

Table 3 displays the various alternatives, raw and packaged-waste quantities, and the disposal sites proposed for each waste-processing option.

Table 3. Waste form classifications, quantities, and disposal sites

Waste Disposal Alternative	Waste Form Classification and Volume		Number of Canisters	Disposal Site
No-Action Alternative				
Calcination and storage	Calcine, mixed-HLW,	5400 m^3	N/A	INEEL- CSSF
Nonseparations Alternative				
Vitrified-Waste Option	Vitrified HLW [a]	10,000 m^3	14,000	Yucca Mountain
HIP-Waste Option	Glass-ceramic HLW [a]	3,500 m^3	5,700	Yucca Mountain
Cementitious-Waste Option	Cementitious HLW [a]	11,000 m^3	16,000	GCD site
Direct-Cementitious-Waste Option	Cementitious HLW [a]	13,000 m^3	18,000	GCD site
Separations Alternative				
Full-Separations Option	Vitrified HLW[a]	50 m^3	650	Yucca Mountain
	Class-A[a] Grout	7,000 m^3	27,000	INEEL or Hanford
TRU-Separations-Class-C-Grout Option	Dried TRU waste [a]	10 m^3	910	WIPP
	Class-C [a] Grout	2,000 m^3	22,000	INEEL or Hanford
TRU-Separations-Class-A-Grout Option	Dried TRU waste [a]	10 m^3	910	WIPP
	Vitrified HLW [a]	20 m^3	170	Yucca Mountain
	Class-A [a] Grout	7,000 m^3	27,000	INEEL or Hanford

a. After compliance with the LDR treatment standards and delisting, the wastes are no longer classified as mixed wastes.

4. REGULATORY REQUIREMENTS

The radioactive wastes stored at ICPP are considered mixed-wastes, and as such are subject to the requirements of both RCRA for the hazardous waste contaminants and of the Atomic Energy Act (AEA) "Standards for Management of Radioactive Material." The AEA standards are administered by DOE RCRA as established treatment standards under the LDR for hazardous waste prior to land disposal.

The RCRA constituents in the wastes include characteristic heavy metals, and listed organic and inorganic chemicals, as defined in 40 CFR 261, Subparts C and D. Based on the regulations in 40 CFR 262.3(a)(2)(iv), "Mixture Rule," and in 40 CFR 262.3(c)(2)(i), "Derived From Rule" the ICPP wastes and the products resulting from treatment of these wastes are considered listed hazardous wastes. The only way to remove the listed waste from compliance with the RCRA regulations is to have them delisted by the EPA.

For the purpose of regulatory analysis, the waste resulting from the proposed Options are categorized into three waste classifications: HLW, TRU Waste, and LLW. The determination of the classification of the waste products is based on the waste origin, and the projected composition and estimated concentrations of the radionuclides. These wastes must be disposed of in accordance with the requirements established by the EPA, DOE, NRC, and other applicable state and local standards. In addition, the transportation of the wastes between the sites must comply with the requirements of the Department of Transportation (DOT) and NRC.

4.1 RCRA Disposal Requirements

The EPA has established treatment standards under the RCRA LDR for hazardous waste constituents prior to land disposal. The RCRA LDR requirements are implemented by the State of Idaho under the "Idaho Hazardous Waste Management Act of 1983." The LDR standards are in 40 CFR 268.40 and in 40 CFR 268.48, "Universal Treatment Standards for the Underlying Hazardous Constituents." The standards are expressed either as specified-technologies or as waste concentrations, and are based on the performance of the BDAT for a hazardous waste code.

For wastes requiring a specified treatment technology, the wastes may be land disposed after being treated using that specified technology or an equivalent treatment technology approved by the EPA Administrator under the procedures set forth in 40 CFR 268.42(b), DET.

The LDR applicability and treatment standards are determined based on hazardous chemical composition and their concentrations in the waste at the point of generation. Consistent with the cradle-to-grave mandate of the LDRs, a hazardous waste generator needs to assess what disposal prohibitions apply at different points in the waste management process (from generation to final disposal).[42] The Tank Farm has been used for storage of liquid radioactive mixed wastes that have been generated from the spent nuclear fuel reprocessing and decontamination processes. Thus, the wastes in the Tank Farm represent the point of generation. These wastes are evaluated here to assess what land disposal prohibitions apply.

The LDR analysis of the waste relies on the data from the Tank Farm and other sources.[7,9] Uncertainties exist about some of the reported data and the projected composition and estimated quantities of chemicals in the wastes. This is due to the nature of the record keeping on historical information and to the uncertainties in the waste processing alternatives being considered.

The wastes in the Tank Farm reportedly contain a variety of RCRA hazardous waste constituents. For a waste which contains various hazardous chemicals, designated by a code, the LDR require that the waste be treated for each code according to its appropriate treatment standards. Based on the existing literature, F, P, and U listed RCRA chemicals and a number of characteristic wastes are reported for the Tank Farm.[7] The reported contaminants and their concentrations are based on analytical data, process knowledge, and historical records. A more recent study of the RCRA listed wastes associated with the Tank Farm has identified only three F-listed codes.[6] The new list will require approval of the DOE and the State of Idaho to replace the existing list. The new list may also require approval of the waste receiving states and all other States through which the waste is transported. In this report, the regulatory analysis of the wastes relies on the list of RCRA chemicals as reported by Wichmann et al.[7]

4.2 Delisting

The waste can be delisted prior to or after treatment. In this study, it is assumed that up-front exclusions petitions will be granted by EPA to delist the listed waste present. Thus, the treated waste streams will no longer be considered RCRA hazardous wastes. EPA grants up-front exclusions for wastes and/or wastes from treatment that have not been generated, but will be generated in the future based on available information such as bench- or pilot-scale data. The EPA decision of up-front exclusions petition is based on an evaluation of the characteristics of the untreated waste, process description, and data from bench-scale or pilot-scale treatment system. Pursuant to EPA Rules 17B and 17B.1, the State of Idaho is authorized by the Federal EPA to grant delisting.

40 CFR 262.20 and 260.22 contain procedures and definitions whereby anyone can petition EPA to delist or exclude a listed waste. The EPA has also published a technical guidance manual[43] which contains delisting criteria and processes for preparing a delisting petition.

The candidate repositories considered in this report, with the exception of the WIPP, are not authorized to accept any hazardous waste for disposal. Therefore, the waste must be treated and delisted before shipment for disposal. The delisting by the State of Idaho requires approval of the waste receiving states and all other states through which the waste is transported. Delisting approvals can be granted either by the individual states (if authorized by the Federal EPA) or by the regional EPA administrators.

RCRA hazardous chemicals, currently identified as listed wastes in 40 CFR 261, Subpart D, are being reexamined by EPA under the proposed hazardous waste identification rule (HWIR).[44] Based on this proposal, a listed hazardous waste that meets the exit level for low-risk waste would no longer be subject to the hazardous waste management system under Subtitle C of RCRA as "listed" hazardous waste. The current EPA list of chemicals and their exit levels is incomplete at this time. The rule will be finalized on April 30, 2001. The possibility of using the HWIR for delisting listed wastes under consideration in this study will need to be investigated once the rule is finalized.

4.3 HLW Disposal Requirements

The waste processing options that are expected to generate HLW are VWO, HIP, CWO, DCWO, TRU-Separations-Class-A-Grout, and Full Separations. These options produce waste forms of borosilicate glass, glass-ceramic, and hydroceramic (pozzolan cement) that are evaluated here to determine their disposal requirements.

4.3.1 HLW forms

4.3.1.1 Vitrified HLW from VWO

The vitrified waste would be sent to an HLW repository for disposal. The hazardous components in the liquid and calcine wastes are regulated by the EPA and the management of the radioactive waste is subject to the requirements of DOE, NRC, and DOT for transportation to and disposal at an HLW repository. The reported RCRA hazardous constituents include characteristic heavy metals (D002 and D004-D011) and listed chemicals. The listed hazardous chemicals are mainly organic compounds. Vitrification is the LDR specified treatment method for HLW with waste codes D002 (corrosive) and D004–D011. Vitrification is considered BDAT by the EPA for treatment of mixed HLW containing waste codes D002 and D004–D011.[42] This decision is based on the EPA review and analysis of the specific data submitted by DOE on using borosilicate glass vitrification technology to treat mixed HLW.[42]

Some of the listed hazardous constituents require treatment other than vitrification. In this option, it is planned to calcine all the ICPP wastes prior to vitrification. Due to the operating temperature of the calciner (400 to 600°C), it is very unlikely that these chemicals could survive and be present in the existing or future calcine wastes. No analyses have been performed on the existing calcine for the RCRA contaminants.[9] The RCRA chemicals reported for the calcine are based on the calciner feed composition, and they include a few heavy metals.[9] A full characterization of the calcine wastes is necessary to determine the presence or absence of the RCRA contaminants.

The organic chemicals, if physically present, will require technology-based treatment. These include eleven listed wastes. Nine of them must be treated with combustion, chemical oxidation, or chemical reduction; and the remaining two require stabilization. For the waste codes that are subject to the LDR technology-based treatments, the wastes may also be land disposed if treated by an equivalent treatment technology approved by EPA. Under 40 CFR 268.42(b), a petition can be submitted to EPA for using vitrification as an equivalent technology to combustion, chemical oxidation, or stabilization. It is believed that vitrification at very high temperature (at least 2,000°F or 1,093°C) demonstrates the same level of performance as combustion, chemical oxidation, or stabilization.

As for inorganic chemicals requiring specified technology treatment, none is expected to be present in the calcined wastes.[9] The only contaminates that could possibly be present in the calcine wastes are vanadium pentoxide, ammonium vanadate, and potassium cyanide.[9] However, since none has been discharged in the Tank Farm since 1988,[9] it is unlikely that they will be present in any future generated calcine. It is unknown whether other chemical species are generated as a result of incomplete combustion during the calcination. A characterization study of the calcine wastes is necessary to determine the hazardous waste contents.

The remaining chemicals require concentration-based treatments if their concentrations are above the LDR limits. All the underlying hazardous constituents for characteristic wastes (e.g., corrosive) subject to the universal treatment standards must meet the limits found in 40 CFR 268.48.

Due to the high temperature vitrification process, mercury will be mostly volatilized and collected as elemental mercury in the off-gas scrub solution to be treated for disposal as LLW. All the other high-temperature treatment options will be equipped with systems for capturing and treating mercury.

4.3.1.2 Vitrified HLW from Full Separations Option

The Full Separations Option is expected to generate two separate waste streams, designated as HAW and LAW. It is planned to vitrify the HAW and to send it to an HLW repository, presumably Yucca Mountain, for disposal. The vitrified HAW is subject to the same regulatory requirements and repository criteria discussed in Subsections 4.3.1.1 and 4.3.2.

4.3.1.3 Glass-Ceramic HLW from HWO

The glass-ceramic waste form from the HIP process would be sent to the proposed repository at Yucca Mountain for disposal, requiring compliance with the RCRA regulations and the repository's acceptance criteria.

Studies[49,55,56] indicate that the HIP process (with minor variations from the option described in this report) was investigated for immobilizing HLW calcine at the ICPP. The studies included laboratory and pilot-scale tests at the ICPP to produce a glass-ceramic waste form via the HIP process.

The DOE submitted an application to EPA for an extension of LDR effective date for certain types of mixed wastes including HLW and other waste streams. The EPA proposed a decision on the DOE's request which was published in 57 Federal Register (FR) in 1992.[45] As part of the EPA requirements for granting such an extension, the DOE had to provide sufficient data and to demonstrate treatment capability for the mixed HLW. The DOE presented the EPA with laboratory and pilot-scale data on the glass-ceramic treatment process. DOE stated that the glass-ceramic process is the preferred method for INEEL HLW immobilization.[45] DOE also indicated that the glass-ceramic process meets the definition of HLW vitrification used by the EPA in 40 CFR 268.42.[45] Based on the DOE studies, and laboratory and pilot-scale tests, EPA concluded that the glass-ceramic process is more efficient than the glass process for calcine, and it is a technology that meets the definition of a BDAT.[45] The status of the EPA proposed decision in the 57 FR[45] is not clear at the present time. If the decision is finalized, a DET petition will not be needed for using the HIP technology as an alternative treatment to vitrification. DOE had previously identified borosilicate glass vitrification technology as the preferred waste form for mixed HLW. The DOE's assessment was the basis for EPA to consider vitrification a BDAT for treatment of HLW.[42] DOE has identified the glass-ceramic waste form as being similar to the Savannah River's Site glass waste product.[45] DOE's comparison of the glass-ceramic process and the corresponding waste form with borosilicate waste has shown that the glass-ceramic method meets the definition of EPA vitrification and the performance criterion (leach rates) of borosilicate waste glass.[45]

A DET petition is needed for using an alternate technology for each RCRA hazardous waste that requires LDR technology-specified treatment.

4.3.1.4 Hydroceramic HLW from CWO

It is proposed that this waste form would be suitable for disposal at the GCD site at the NTS. Disposal at the GCD consists of placing the waste in the bottom of boreholes and covering it with concrete, clay, soil, gravel, or sand. Currently, the GCD facility is not approved by the government for the disposal of HLW.

4.3.1.5 Hydroceramic HLW from DCWO

It is planned to ship this waste form to the GCD site, if approved for disposal as HLW. The hydroceramic waste is subject to the same requirements for disposal as the vitrified or glass-ceramic waste. The DCWO is not an LDR specified technology; therefore, a DET petition must be submitted to EPA for permission to use the alternate treatment method.

4.3.2 Yucca Mountain Repository

Currently, the Yucca Mountain in Nevada is the only site approved for characterization by the government as an HLW repository. The waste destined for disposal at the repository must meet certain criteria as summarized below. These criteria are preliminary at the present time.

The acceptance criteria are organized under nine major categories:

- Waste acceptance documentation
- Waste form specifications
- Radionuclide specification
- Phase stability specifications
- Leach rates
- Heat generations
- Maximum dose rates
- Canister specifications
- Quality assurance.

These criteria are described in detail in INEEL-EXT-97-01147-Rev. 1.[4] To be accepted at the potential repository, waste must be immobilized in a vitrified borosilicate glass. In addition, it must meet all other RCRA LDR requirements for disposal. Presently, the candidate repository at Yucca Mountain is not a RCRA regulated hazardous waste, Subtitle C disposal facility, and consequently does not accept any hazardous waste.[47] As a result, the waste must be delisted prior to disposal at the candidate repository. All radioactive waste must be in a solid form. Free liquids are prohibited, either internal or external to the waste package, for any packages shipped to the repository. The canistered waste form must not contain detectable amounts of explosive, pyrophoric, or combustible materials. The generator must report the inventory of radionuclides (in curies) that have half-lives longer than 10 years and that are, or will be, present in concentrations greater than 0.05% of the total radioactive inventory for each waste type, indexed to the years 2015 and 3115. The estimates of the total quantities of individual radionuclides and their upper limits to be shipped to the repository must also be reported. Leach rates must be based on comparing the total normalized release rates of matrix elements from production samples to the total normalized release of matrix elements from the benchmark glass established for the vitrified HLW form.

The rate is currently established at 1.0 gm/m^2-day.[48] At the time of shipment, the generator must certify that after the initial cool-down, the waste form temperature must not exceed 400°C.

The overall length of the canister shall be 3.000 m (+0.005 m, -0.020 m), including the neck and lifting flange. The outer diameter of the unfilled canister shall be 61.0 cm (+1.5 cm, -1.0 cm). Other type of container system proposed for HLW shipment includes an over-length (4.5 meters) canister of the standard diameter.[48] The weight of the canistered waste form shall not exceed 2,500 kg for standard canister. All deviations from the standard size canister must be approved by the repository prior to filling the canister by the shipper. Non-standard waste package shipment require producer supplied inserts to assure necessary restraint of the waste package inside the container during transport. The NRC requires that canisters used to carry vitrified HLW to the potential Yucca Mountain repository with plutonium in excess of 20 curies be doubly contained (10 CFR 71.63).

The internal gas pressure immediately after closure shall not exceed 150 kPa at 25°C. The quantities and compositions of any gases that might accumulate inside the canister from radiogenic decay, in the event that the canistered waste form temperature exceeds 400°C, must be documented. The heat generation rate for each canistered waste form shall not exceed 1,500 watts per canister at the year of shipment. The generator shall document the expected thermal output of the canistered waste forms and the range of expected variation for each waste type, indexed to the year 2015. The canistered waste form shall not exceed a maximum surface (on contact) gamma dose rate of 10^5 rem/hr and a maximum neutron dose rate of 10 rem/hr at the time of shipment. The generator must also ensure that, under normal and accident conditions, a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The calculated effective neutron multiplication factor, k_{eff}, must be shown to be less than 0.90 after allowing for bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

The generator shall establish, maintain, and execute a quality assurance program that applies to the testing and analysis activities that demonstrate compliance with all the criteria during waste form qualification, production, handling, storage, and preparation for shipment. The action plan must identify and describe the nonconformance and any action to change and correct the existing nonconformance.

4.3.3 Greater Confinement Disposal Site

The Sandia National Laboratory is conducting a study to assess the performance of the GCD site for disposal of HLW.[49] The consideration of GCD as a HLW disposal site vs. Yucca Mountain is primarily based on potential significant cost savings. The GCD performance assessment is preliminary and inconclusive at this time. If the GCD facility is approved for the disposal of HLW, the waste acceptance standards will need to be defined.

4.4 TRU Waste Disposal Requirements

4.4.1 TRU Waste from TRU Separations Options

The TRU waste stream resulting from the TRU separations options is expected to contain alpha-emitting TRU radionuclides with half-lives greater than 20 years and concentrations above 100 nCi/g. It is planned to convert the TRU waste to a solid form and to send it to the WIPP for disposal. Based on the NRC HLW definition, the TRU waste stream is actually HLW. It is assumed that a determination will be

made by the appropriate government authorities (e.g., NRC, DOE) that TRU waste will no longer be considered HLW.

4.4.2 WIPP

The waste destined for disposal at the WIPP must meet the requirements of the Land Withdrawal Act (LWA) and the WIPP's waste acceptance criteria.[21] The LWA requires that the waste destined for disposal at the WIPP meet the TRU definition, not contain HLW or spent nuclear fuel, and be generated from atomic energy defense-related activities. It appears that the TRU waste resulting from the TRU Separations Option meets the LWA requirements. The WIPP acceptance criteria contain the requirements for waste containers and disposal as well as the compliance methods for both contact-handled and remote-handled TRU waste. Based on the preliminary radionuclide analysis, the TRU waste from the separations option is considered remote handled.

The WIPP requirements are organized under container requirements, nuclear properties, chemical properties, gas generation, and data package. The remote-handled TRU criteria have not been finalized yet. The final requirements will not be available until the remote-handled TRU 72-B Cask requirements have been finalized, and remote-handled TRU 72-B Cask SARP is approved by the NRC and the WIPP SAR is updated. The remote-handled TRU 72-B Cask is intended to be used for transportation of remote-handled TRU waste canisters to the WIPP.

Canisters must meet the structural requirements and design conditions in accordance with the DOT Specification 7A, Type A. The remote-handled TRU canisters must be no larger than 0.66 m in diameter with a maximum length of 3.1 m, and weigh no more than 8,000 lbs when loaded. Removable surface contamination on remote-handled TRU canisters to be disposed in the WIPP must $\leq$ 20 dpm per 100 cm^2 for alpha-emitting radionuclides and $\leq$ 200 dpm per 100 cm^2 for beta-gamma-emitting radionuclides. Beta - Gamma contamination may be $\leq$ 1,000 dpm/100 cm^2 if it meets the requirements of the DOE RadCon Manual. The fissile or fissionable radionuclide content of RH-TRU canister must not exceed 600 g total of Pu-239 FGE. The fissile or fissionable radionuclides in an remote-handled TRU 72-B Cask must be less than 325 grams of Pu-239. The remote-handled TRU waste canisters must not exceed 1,000 plutonium-equivalent curies of activity.

The remote-handled TRU canister limit is based upon the total remote-handled TRU waste volume at the WIPP, not upon the Sites' (generator's) number of remote-handled TRU canisters. No more than 5 percent of the RH canisters received at the WIPP are allowed to have dose rates of > 100 rem/hr. Prior approval by the WIPP is required before remote-handled TRU canisters having dose rates > 100 rem/hr but $\leq$ 1,000 rem/hr may be shipped to the WIPP. All canisters must have a maximum contact dose rate at any point no greater than 1,000 rem/hr. Neutron contributions are limited to 270 mrem/hr. The external dose rate on the loaded remote-handled TRU 72-B Cask is limited to 200 mrem/hr at the surface of the cask and 10 mrem/hr at two meters distance from the cask. The thermal power generated by remote-handled TRU waste materials in any RH-TRU canister shall not exceed 300 watts.

Under the LWA, the WIPP is exempt from compliance with the LDR requirements, and both TRU waste and mixed TRU wastes are acceptable for disposal at the WIPP. However, as specified in the WIPP acceptance criteria and the WIPP Part A Permit, only a selected number of RCRA waste codes are acceptable at the WIPP. The TRU waste fraction is projected to have RCRA characteristics and listed components. The characteristic toxic metals include silver, arsenic, barium, cadmium, chromium, mercury, nickel, lead, and selenium. Fluoride compounds (corrosive) would also be present. All of the heavy metals

are acceptable at the WIPP.[21] TRU mixed waste exhibiting corrosive, reactive, or ignitable characteristics and listed codes reported in the Tank Farm are not accepted at the WIPP; therefore, the waste must be treated to remove the hazardous characteristics and delisted.

According to Craig Snider, the WIPP Office of Regulatory Compliance, (personal communication on 08/01/97), all the RCRA codes in the TRU waste, regardless of the WIPP waste acceptability status, must be reported to the WIPP prior to the waste shipment The determination of hazardous contaminants shall be based on acceptable knowledge and/or sampling and analysis data indicating that the waste is hazardous as defined in 40 CFR 261, subparts C and D. It is also required that an LDR notification be transmitted to the WIPP for each shipment of mixed waste. The notification must contains hazardous waste characterization records and records showing types and quantities of all hazardous constituents that require LDR treatments in accordance with 40 CFR 268.

4.5 LLW Disposal Requirements

4.5.1 LAW from Separations Options

The separations options would generate two classes of grouted LAW designated as Class A and Class C. These wastes are planned to be grouted and shipped to a LLW disposal facility. The LAW streams are actually HLW per NRC source-term definition; however, based on the projected activities of the radionuclides in the waste forms,[9] the grouted LAW would meet the definition of the NRC Class A and Class C LLW. The waste streams also meet the definition of incidental waste in the NRC evaluation of HLW separation processes at Hanford Site.[50] In the evaluation of the Hanford HLW separations processes, NRC concluded that residual waste generated from separation processes for removal of key radioactive elements, to the maximum extent technically and economically feasible, is classified as incidental waste. This is because the waste is incidental to the processes of separating HLW and that this waste can be disposed of at a near-surface facility. The term incidental waste is not defined by regulations, and the NRC has declined to promulgate criteria for distinguishing between and incidental waste.[51] The NRC believes that the determination for incidental waste must be made on a case-by-case basis and by way of adjudication instead of rule making.[51] It is assumed that a determination will be made by the government authorities (e.g., NRC and DOE) that the grouted LAW is not HLW because it meets the definition of NRC Class A or Class C.

The chemical constituents in the LLW may include RCRA characteristic chemicals including silver, arsenic, barium, cadmium, chromium, mercury, nickel, lead, and selenium.[7,9] Fluoride compounds are also projected to be present in the waste.[7,9] The LLW must comply with the LDR requirements and delisted prior to disposal.

4.5.2 Potential LLW Disposal Facilities

4.5.2.1 Commercial LLW Disposal Facilities

The LLW commercial disposal facilities identified in this study include the Barnwell Waste Management Facility Site in South Carolina, Envirocare of Utah, Inc. and the US Ecology facility in Washington. Currently, the Barnwell and the US Ecology facilities are not permitted to accept any DOE generated (noncommercial) LLW. This is due to the current NRC or Agreement State regulations and legislation that govern LLW waste disposal in the existing commercial facilities. The estimated activities of radionuclides in the Class A and Class C grout exceed the limits specified in the Envirocare criteria.[52]

4.5.2.2 DOE LLW Disposal Facilities

The DOE facilities that might be used for disposal of the grouted LLW are the INEEL Radioactive Waste Management Complex, the NTS, and the Hanford Site. The NTS and the Hanford Site are considered preferred disposal sites for disposal of the DOE generated LLW by the DOE Environmental Management (EM) Program.[53]

LLW and mixed LLW are accepted for disposal at the NTS from generators who are designated by the DOE Headquarters and subsequently approved by the DOE Nevada Operations Office.[35] Currently, the INEEL is neither a designated nor an approved generator. The criteria for mixed LLW disposal at the NTS from outside generators have not been finalized at this time. Based on the Hanford acceptance criteria,[54] the Hanford Site can only accept waste from offsite generators approved by the DOE EM-30. Presently, the INEEL is an approved EM generator.

4.5.3 DOE General Disposal Criteria for LLW

DOE Order 5820.2A, Chapter III provides a set of general criteria for disposal of LLW. These criteria are itemized as follows:

- Advance approval from the waste receiving facility to ship a waste package to certify prior to shipment that the waste meets the receiving facility's waste acceptance criteria.
- Waste documentation to ensure compliance with the facility disposal criteria.
- Waste must be treated so that it does not contain the RCRA listed and characteristic codes.
- Waste will not be accepted for disposal if it contains free liquid in excess of 1% of the waste volume, or 0.5% of the waste volume processed to a stable form [DOE Order 5820.2A III 3.i.(5)(b)].
- Waste capable of detonation, explosive decomposition, or reaction at normal pressures and temperature, or of explosive reaction with water will not be accepted for disposal [DOE Order 5820.2A III 3.i (5)(c)].
- Waste capable of generating toxic gases, vapors, or fumes harmful to persons handling the waste will not be accepted for disposal [DOE Order 5820.2A III 3.i.(5)(d)].
- Gaseous waste will not be accepted for disposal if it is packaged at a pressure in excess of 1.5 atmospheres [DOE Order 5820.2A III 3.i.(5)(e)].
- Pyrophoric waste will not be accepted for disposal [DOE Order 5820.2A III 3.i.(5)(f)].
- Wastes exceeding the Class C limit, as defined in 10 CFR 61.55, will not be accepted at the potential LLW disposal facilities identified in this study. Disposal of such wastes must be handled as special case, and their disposal require a case-by-case evaluation and approval by DOE.

- Waste package must meet the following DOE and DOT requirements (49 CFR 173):

  - The radiation level must not exceed 200 mrem/hr at any point on the external surface of the package. A package which exceeds the radiation level limits must be transported by exclusive use shipment, in which case the limit is 1,000 mrem/hr.

  - A package of Class 7 (radioactive) material must be designed, constructed, and loaded so that (a) the heat generated within the package by the radioactive contents will not, during conditions normally incident to transport, affect the integrity of the package; and (b) the temperature of the accessible external surfaces of the loaded package will not, assuming still air in the shade at an ambient temperature of 38°C (100°F), exceed either 50°C (122°F) in other than an exclusive use shipment; or 85°C (185°F) in an exclusive use shipment.

4.6 Waste Reclassification Issue

The HAW, LAW, and TRU waste streams resulting from the separations options would remain HLW if not reclassified. The resultant wastes do not conform to the existing classification or definition scheme for radioactive waste. Although it may be technically and economically feasible and attractive, waste reclassifications would require evaluations of the waste-treatment processes, redefinition of types of waste, and the concurrence of the competent and applicable government authorities such as NRC and DOE. If any waste-treatment option is chosen, steps should be taken to identify the mechanism by which redefinition and approval should be sought and obtained.

5. REFERENCES

1. Settlement Agreement (between the DOE and the State of Idaho), October 16, 1995.

2. National Waste Policy Act, 1982.

3. National Waste Policy Amendments Act, 1987.

4. J. Banaee, *Standard criteria of candidate repositories and environmental regulations for the treatment and disposal of ICPP radioactive mixed wastes*, INEEL/EXT-97-01147-Rev. 1, February, 1998.

5. 40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*, Office of the Federal Register.

6. K. Gilbert, *Regulatory analysis of ICPP liquid waste stream U.S. Environmental Protection Agency hazardous waste numbers*, INEEL/EXT-97-01453, January, 1998.

7. T. Wichmann, N. Brooks, and M. Heiser, *Regulatory analysis and proposed path forward for the Idaho National Engineering Laboratory High-level Waste Program*, DOE/ID-10544-Rev. 1, October, 1996.

8. Reported by Kevin Pechulis of the EPA to Jila Banaee in a telephone conversation on January 21, 1998.

9. C. M. Barnes, *Estimates of Feed and Waste Volumes, Compositions and Properties, LMITCO Engineering Design File*, EDF-FDO-001-Rev. 1, February 5, 1998.

10. 10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repository," Section 60.2, "Definitions," *Code of Federal Regulations*, Office of the Federal Register.

11. DOE Order 5820.2A, *Radioactive Waste Management*, U.S. Department of Energy, September 26, 1988.

12. 10 CFR 61.55, "Waste Classification," *Code of Federal Regulations*, Office of the Federal Register.

13. Fluor Daniel, Inc., *Idaho Chemical Processing Plant Waste Treatment Facilities Feasibility Study Report*, October, 1997.

14. W. H. Landman, and C.M. Barnes, *TRU Separations Options Scoping Study Report*, INEEL/EXT-97-01428, January, 1998.

15. D. A. Lopez, and R.R. Kimmitt, *Vitrified Waste Option Scoping Study Report*, INEEL/EXT-97-01389, January, 1998.

16. N. E. Russell, and D. D. Taylor, *Hot Isostatic Press (HIP) Waste Option Scoping Study Report*, INEEL/EXT-97-01392, January, 1998.

17. A. E. Lee, and D. D. Taylor, *Cementitious Waste Option Scoping Study Report*, INEEL/EXT-97-01400, January, 1998.

18. R. E. Dafoe, and Syl Losinski, *Direct Cementitious Waste Option Scoping Study Report*, INEEL/EXT-97-01399, January, 1998.

19. J. K. Rawlins, *Interim Storage Scoping Study Report*, INEEL/EXT-97-01393, January, 1998.

20. G. E. Stegen, *INEEL High-Level Waste Program Impacts Related to Disposal Fees and Ability of Repository to Accept Waste*, EN-RPT-001, June, 1997.

21. DOE/WIPP, *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, DOE/WIPP-069, Rev. 5, April 1996.

22. L. R. Dole, et al, *Cement-Based Radioactive Waste Hosts Formed Under Elevated Temperature and Pressures (FUETAP Concretes) for Savannah River Plant High-Level Defense Waste*, ORNL/TM-8579, March, 1983.

23. M. L. D. Gougar, D. D. Siemer, B. E. Scheetz, "Vitrifiable Concrete for Disposal of Spent Nuclear Fuel Reprocessing Waste at INEL," *Materials Res. Soc. Symp. Proc. Vol 412,* 1996, pp. 395-402.

24. H. Welland, *NWCF modification for sodium-bearing waste project conceptual design, final*, INEL/INT-97-00075, April, 1997.

25. T. G. McDonald, *Review of ceramic silicone foam for radioactive waste disposal*, EDF-FDO-005, April 17, 1997.

26. T. G. McDonald, *Epoxies for low-level radioactive waste disposal*, EDF-FDO-007, June 11, 1997.

27. D. R. Wenzel, *Evaluation of radionuclide inventory for Al calcine*, EDF-FDO-004, Oct. 14, 1997.

28. D. R. Wenzel, *Evaluation of radionuclide inventory for Zr calcine*, EDF-FDO-003, Oct. 14, 1997.

29. R. J. Rivard to J. A. Murphy, *Update of Composite Composition of Sodium Waste in Tank Farm after NWCF Campaign H-4*, RJR-06-94, July 25, 1994.

30. H. K. Peterson, *Update of radiation field definition and thermal generation rates for calcine process packages of various geometries*, Interdepartmental Communication, HKP-26-97, December 4, 1997.

31. T. G. McDonald, Background information for FGEs, dose rates, watts/canister, and PE-curies, EDF-FDO-002-Rev. 1, January 8, 1998.

32. J. W. Sterbentz, *Neutron dose rate estimates for canisters of calcine and SBW TRU-wastes*, Interdepartmental Communication, JWS-1-98, January 5, 1998.

33. L. M. Montierth, *Determination of k_{eff} for high level waste canisters in various configurations*, Interdepartmental Communication, MNT-03-97, September 23, 1997.

34. D. P. Gallegos, S. H. Conrad, and T. A. Baer, *Using Performance Assessment for Radioactive Waste Disposal Decision Making - Implementation of the Methodology into the Third Performance Assessment Iteration of the Greater Confinement Disposal Site*, SAND-93-2240C.

35. L. Price, *Disposal Configuration Options for Future Uses of Greater Confinement Disposal at the Nevada Test Site*, SAND-94-2105, September, 1994.

36. 40 CFR 191, "Environmental radiation protection standards for management of spent nuclear fuel, high-level and Transuranic wastes," *Code of Federal Regulations,* Office of the Federal Register.

37. A. E. Lee, *Preliminary design of the Nevada Test Site Greater Confinement Disposal Facility*, INEEL/EXT-97-01316, January, 1998.

38. D. M. Kiser, et al., *Low-Level, Class A/C Waste, Near Surface Land Disposal Facility Design Description*, INEEL/EXT-98-00051.

39. T. G. McDonald, "Highlights from the July 23 meeting with WIPP representative Mike Brown," Note gram from McDonald to N.E. Russell, July 30, 1997.

40. I. J. Winograd [USGS], "Radioactive Waste Disposal in Thick Unsaturated Zones," *Science, vol. 212*, No. 4502, June 26, 1981, pp. 1457-1464.

41. C. M. Barnes, "Evaluation of several neutralization cases in processing calcine and sodium-bearing wastes," EDF-TRU-005, November 25, 1997.

42. 55 Federal Register (FR), June 1, 1990, p. 22627.

43. EPA, *Petitions to Delist Hazardous Wastes: A Guidance Manual,* Second Edition, PB93-169365, March 1993.

44. 62 FR, December 21, 1995.

45. 57 FR, May 26, 1992, p. 22024.

46. Deleted.

47. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, "Waste Acceptance System Requirements Document (WASRD)," Rev. 2, DOE/RW-0351P, December 1996.

48. U.S. Department of Energy, Office of Waste Management, "Waste Acceptance Product Specifications for Vitrified High-Level Waste," DOE/EM-0093-R1, EM-WAPS, Rev. 1, May 1995.

49. U.S. Department of Energy, "Environmental Assessment, Waste Form Selection For SRP High-Level Waste," DOE/EA-0179, July 1982.

50. 58 FR, "State of Washington and Oregon, Denial for Petition for Rulemaking," U.S. Nuclear Regulatory Commission,? March 4, 1993, p. 12342.

51. DOE Manual 435.1, *Radioactive Waste Management Implementation Guide Manual*, U.S.

Department of Energy, February 28, 1997.

52. Envirocare of Utah, Inc., "*Waste Acceptance Criteria*," Utah Department of Environmental Quality, Division of Radiation Control, Radioactive Materials License (# UT 2300249).

53. EM presentation at Savannah River, November 8, 1996.

54. WHC-EP-0063-4, "Hanford Solid Waste Acceptance Criteria."

55. W. D. Bolon, et al, *Status report: the glass-ceramic processing flowsheet for ICPP high-level waste*, WINCO-1090, December, 1991.

56. B. A. Staples and H. C. Wood, *Selection Of A Glass-Ceramic Formulation To Immobilize Fluorine-Sodium Calcine*, INEL-95/0041, December, 1994.