Savannah River Site

High Level Waste Salt Disposition
Systems Engineering Team

Final Report (U)

WSRC-RP-98-00170
Revision: 0

October 29, 1998

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HLW Salt Disposition Systems Engineering Team
Final Report

Approved By: ______________________________ ______________
S. F. Piccolo, HLW Salt Disposition Systems Engineering Team Leader **Date**

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REVISION SUMMARY

Rev. No.	Rev. Date	Affected Sections	Description of Revision
0	10/29/98	N/A	Initial Draft

Abstract

This report describes the process used and results obtained by the High Level Waste (HLW) Salt Disposition Systems Engineering Team (Team) to select a primary and backup alternative salt disposition method for the Savannah River Site (SRS). The Executive Summary located in Section 1.0 provides a high level summary of the selection process. The Team activities leading to the selection of the recommended alternatives are described in the remaining sections of this report. The selection of an alternative salt disposition technology is necessary as the existing In Tank Precipitation (ITP) process cannot simultaneously meet the HLW flow sheet production and safety requirements. To fulfill the mission need SRS HLW salt must be immobilized for final disposition in support of environmental protection, safety, and current and planned missions. The Team selected Small Tank Tetraphenylborate (TPB) Precipitation as the recommended alternative to the currently configured In Tank Precipitation (ITP) process for HLW salt disposition, with Crystalline Silicotitanate (CST) Non-Elutable Ion Exchange as the backup technology.

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1.0 Executive Summary

The purpose of this section is to provide a high level summary of the activities leading to the selection of the recommended alternatives to the ITP process. This summary describes the HLW mission, the ITP process suspension, the Team Charter, the selection process, and the recommendation.

1.1 Charter

The Savannah River Site (SRS) Site Treatment Plan (STP) and Federal Facilities Agreement (FFA) call for closing the HLW Tanks through vitrification of both the long-lived and short-lived radioisotopes in the Defense Waste Processing Facility (DWPF) in preparation for transport to the national high level waste repository. To make this program economically feasible, it is necessary to limit the volume of HLW glass produced by removing much of the non-radioactive salts and incidental wastes for disposal as saltstone. The ITP facility was designed and constructed to separate the cesium isotopes from the non-radioactive salts so the decontaminated salts could be disposed in a grouted wasteform at the Saltstone facility at SRS.

The ITP process was successfully piloted both on a moderate and full-scale basis with actual SRS waste in the 1980s. During the facility radioactive startup, higher than predicted benzene releases were observed. Additional laboratory and facility tests were initiated to further investigate process chemistry issues. In January 1998, conclusions were drawn from the test program that the benzene release rates associated with facility operation could exceed the capability of the current plant hardware/systems. On January 22, 1998, Westinghouse Savannah River Company (WSRC) informed DOE that ITP chemistry testing demonstrated that the present system configuration could not cost-effectively meet the safety and production requirements for the ITP facility and recommended that a study of alternatives to the current system configuration be conducted by a systems engineering team.

On February 6, 1998, the Assistant Secretary for Environmental Management approved a DOE-Savannah River (DOE-SR) plan of action to suspend startup-related activities and undertake a systems engineering study of alternatives to ITP. On February 20, 1998, DOE-SR concurred with the WSRC evaluation of the ITP chemistry data, instructed WSRC to suspend ITP startup preparations, and directed WSRC to perform an evaluation of alternatives to the current system configuration for HLW salt removal, treatment, and disposal.

On March 13, 1998, the WSRC High Level Waste Management Division chartered the Team to systematically develop and recommend an alternative method and/or technology for disposition of HLW Salt. The selected Team members were approved by DOE on March 31, 1998.

1.2 Selection

At the start of the selection process, the Team had concluded that the four Short List alternatives were implementable, and that project and life cycle cost should be the prime driver in the selection process. As overall cost and uncertainty data were developed, it was recognized that costs were similar enough to not be the prime discretionary driver in selection, so the Team considered technical maturity, risk management, safety and Team member expertise in the selection.

The Team's recommended alternative is Small Tank TPB Precipitation. Although it did not have the lowest life cycle cost, it has the lowest project cost, the highest scientific maturity, the most-manageable risks, and is judged to have the highest likelihood of success because the open issues for this technology affect mechanical sizing more than chemical processing or chemistry solutions. The issues raised regarding TPB in the ITP process have been definitively addressed in the pre-conceptual design to answer concerns regarding benzene flammability. The process includes positive pressure nitrogen inerting and secondary confinement of the process vessels. In addition, the stainless steel small tank design, with its shorter processing time, minimizes the product stability issues while achieving desired decontamination.

As a backup technology, the Team selected CST Non-Elutable Ion Exchange. As well as having a lower project cost and life cycle cost than solvent extraction, its scientific maturity is higher and it has greater opportunity for recovery from process performance problems. Solvent Extraction offers benefits because of its desirable interface with DWPF, better inherent safety and greatest potential for production improvements through further R&D and value added engineering efforts. However, with the Team's Charter requirement for "assured success", CST was the preferred backup.

Some of the key selection parameters are listed below in Table 1-1:

Table 1-1: Key Selection Parameters

Selection Parameter	TPB	CST
Project Capital Cost (TEC), including contingency $M	692	768
Other Project Costs (OPC), including contingency $M	378	418
Life Cycle Cost Point Estimate, including contingency $M (This includes TEC and OPC)	3,453	2,877
Baseline Date for Radioactive Operation	May 2006	March 2007
Date for Radioactive Operation, including uncertainty	May 2010	January 2012
Baseline Date for Tank Emptying	Oct. 2020	April 2019
Date for Tank Emptying, including uncertainty	July 2025	January 2025

The Team evaluation was based on an exhaustive review of potential technologies at the pre-conceptual level for disposition of salt contained in the SRS HLW Tanks. Technologies that appeared to have a significant chance of success in this application were developed to the flowsheet level and were studied with visits to facilities and laboratories involved in their development and use. Then, the handful of technologies that emerged as leading contenders were subjected to a more rigorous flowsheet and layout analysis and were targeted in specific Research and Development programs to more precisely understand their strengths and weaknesses. The preferred and backup alternatives finally selected are technically sound and have been shown to be capable of successful implementation on the required schedule .

Additionally, the Team focused a great deal of attention on the inherent safety of the proposed technologies. During the early phases of Team activities, inherent human and environmental safety were key criteria used in distinguishing among alternatives. In the final stages, a hazards evaluation was performed of the final candidates. The preferred choice has minimal inherent hazards and has a clear safety strategy to address the residual hazards.

Finally, technology alternatives under consideration were subjected to increasingly detailed cost analyses to support pre-conceptual level estimates. The analyses addressed project cost, operating cost, and total life cycle cost, taking into account the identified uncertainties for each technology. For the final candidates, cost estimates included contingency analysis. The final choice of a preferred alternative was based on cost, with identified residual uncertainties taken into account, technical maturity, risk management, safety, the professional judgement of the Team, historical experience, and SRS and DOE Complex needs.

In its deliberations, the Team was impressed with the technical benefits of the Direct Disposal in Grout alternative. This alternative clearly had the lowest technical risk of the Short List alternatives. The grouting process is widely used for immobilization of radioactive waste. While a new formulation of grout may be necessary to optimize the wasteform for this particular mixture, it is noteworthy that the existing Saltstone formulation which contains very similar chemical components, appears to give satisfactory results as demonstrated in the performance assessment. The process itself has a lengthy track record for waste containing much higher levels of radioactivity than would be experienced at SRS.

The project cost, including technical uncertainties is lower than that of any of the other alternatives under consideration. The baseline schedules, without uncertainties, to place the facility into operation and to empty the SRS HLW Tanks are shortest for this alternative.

The grouting process provides a high level of protection for the health and safety of the public and the environment. The reduction in cesium 137 loading of the DWPF canisters reduces the heat load on the HLW repository over the first few hundred years an impact recognized by the NRC as assisting in limiting the potential migration of HLW from the repository. Even with the loading of cesium 137 in the grouted material, the final wasteform left at SRS is only at 5% of the Class C limit. Additionally, even if the cesium 137 were to leach from the grout, cesium does not migrate to any great extent through the SRS type soil. Finally, the half-life of cesium 137 is thirty years. By about the time the grouting process is completed, half of the cesium resulting from SRS reactor operation existing at the time of K-Reactor shutdown will have decayed. After three hundred years, a short time compared to the migration speed of the cesium, over 99.9% of the cesium will have decayed. The grouted cesium will present no hazard to people or the environment after it has been placed in the grout matrix.

In spite of these advantages, the Team felt the Direct Disposal in Grout could not be selected as either the primary or backup recommendation. The reason for this is the non-technical programmatic risks. The recommended alternative must have a sure path to operation by 2010 and the closure of the SRS HLW Tanks in accordance with the FFA and STP commitments. The Team knows of no mitigation strategy that would assure that the facility could be commissioned, NRC, SCDHEC, and EPA approvals could be obtained, and likely court cases resolved in a manner compatible with this schedule. In addition, tests demonstrated that the cesium could leach. Although acceptably passing the performance assessment requirements, the Team felt that public acceptance would be more difficult than originally anticipated. The three sequential risks of regulatory approval, political approval, and judicial approval, all of which have been seen in similar instances, could not be guaranteed to be resolved on the necessary schedule with any mitigation strategy the Team could devise. If such a strategy were available, Direct Disposal in Grout would have been the Team's recommendation.

It should also be noted that Solvent Extraction ranked favorably by the Team when compared to CST Non-Elutable Ion Exchange as a backup selection. The relative immaturity of the calixarene crown ether extractant was the major deciding factor. Positive attributes associated with this technology were operational, mission and operating schedule flexibility. However, Team judgement was that CST could be more readily implemented today and solvent extraction would require approximately two years of favorable scientific development to influence the decision.

1.3 Systems Engineering

The Systems Engineering approach was both required by the Charter and recognized by the Team as the most appropriate tool for accomplishing its assigned task.

The Systems Engineering Management Plan (SEMP) provides a high level description of the methodology, tools, deliverables, and schedules required to implement the systems engineering approach for Team activities. The Initial Design Input provides the Team Mission Need and Problem Statement and the highest level functions and requirements applicable to the eventual preferred alternative(s). The SEMP is the parent document to the position papers and desktop procedures written by the Team to control its activities in choosing a preferred alternative(s). The Initial Design Input provides the basis for criteria developed to distinguish among potential technologies for recommendation.

The Team activities were pursued in three distinct phases referred to as the Identification, Investigation and Selection Phases. The Identification Phase resulted in the "Initial List" of eighteen alternatives. The Investigation Phase resulted in the "Short List" of four alternatives. The Selection Phase resulted in Small Tank TPB Precipitation as the primary alternative and CST Non-Elutable Ion Exchange as the backup alternative.

The Team implementation of the SE process was predicated on a consensus philosophy. If consensus was not reached by the Team members during any decision or phase of Team activities, a formal Dissenting Opinion vehicle existed to document the opposing view(s). The Team procedure for this process requires that all Dissenting Opinions be made part of the Final Report. There were three Dissenting Opinions generated during the Team's activities and are listed below by title.

DO98001: Solvent Extraction O&M Duration - Section 7.0

DO98002: Solvent Extraction Contingency Value - Section 7.0

DO98003: Backup Alternative Technology Selection – Section 9.0

All the Team members concurred that DO98001 and DO98002 had no effect on the recommendations. The Team did not achieve consensus on the backup alternative selection. The response to the dissenting opinion was accepted by all Team members

1.4 Team Members and External Input

Team members were chosen to provide expertise in Systems Engineering, Process Engineering, Operations, Waste Processing, Science, Safety and Regulatory Engineering, Chemistry, and Chemical Processes. Members were also chosen to provide viewpoints from other DOE Complex facilities with large radioactive waste disposal programs, international radioactive waste disposal programs, the National Labs, industry, and academia. Significant WSRC engineering resources were dedicated to and managed by the Team, as was an administrative support staff. Research and Development support and management was provided by the Savannah River Technology Center (SRTC). Additional Research and Development (R&D) support was provided by the Oak Ridge and Argonne National Laboratories and several universities (Texas A&M University, University of South Carolina, and Purdue University).

1.5 Risk Management

Throughout the process, risk identification and management was a common theme of Team activities.

During the Identification Phase, risk identification and management was implemented by conducting a coarse screening of technical categories and the alternatives within each category. The technical categories were evaluated against two broad risk areas, i.e., Technical Maturity and a Reasonable Chance of

Deployment. If the Team lacked sufficient knowledge to assess the category, then it was accepted for screening of the individual alternatives.

The Team then proceeded to screen and rank the individual alternatives within each technical category. The Safety, Schedule, Cost, Science, and Process screening criteria were derived from the Initial Design Input. Alternatives failing any one of these screening criteria were considered as having unacceptable risk and were dropped from further consideration. The result of the Identification Phase was an Initial List of eighteen accepted alternatives.

During the Investigation Phase, the Team developed additional information on the Initial List of alternatives. This facilitated a more rigorous Preliminary Risk Assessment of the alternatives. A detailed checklist of risk screening questions in the areas of Technology, Interfaces, Safety, Design, Resources/Conditions, Cost/Schedule, Procurement, and Regulatory/Environmental was developed and applied to each of the alternatives. Statements of risk applicable to each of the alternatives were documented, and relative estimates of probability and consequence for these risks were generated. Significant risks were assigned risk-handling strategies. The quantified risks, along with qualitative information, were used in the selection from the Initial List to a Short List of four alternatives.

In the Selection Phase the Team reviewed risks identified in previous phases of its activities for applicability. National and international experts and stakeholders were convened for a five-day period of risk assessment of both technical and programmatic risks associated with the Short List alternatives. From these activities, the Team developed a consolidated list of risks to be considered during the Selection Phase.

The risks were reviewed and quantified as to potential cost and schedule impacts (uncertainties) to the implementation of the alternative. After consideration of the identified risks, the uncertainties were reviewed to see which could be considered to fall within normal project contingency and which had to be considered in addition to normal project contingency.

Positive as well as negative uncertainties in terms of both Cost and Schedule impacts were used by the Team to facilitate the final selection process.

1.6 Flowsheet

A Flowsheet Team was formed to provide process and layout information to the Team during the pre-conceptual design process. Flowsheets were first developed as part of the Investigation Phase of pre-conceptual design. During the Identification Phase of Team activities, the alternative technologies were reviewed at a very high technical level for reasonable chance of deployment. Only those that did not meet minimum requirements were eliminated. However, during the Investigation Phase, a more rigorous process was used. This process involved the technical development of the alternatives composing the Initial List. These efforts included the generation of flowsheets, including material balances, for the alternatives; observation of related waste management processes at West Valley, Oak Ridge, Hanford, Idaho National Engineering and Environmental Laboratory (INEEL) and Sellafield (BNFL) by Team members; preliminary cost and schedule evaluations; and preliminary risk/mitigation assessments.

The Selection Phase of Team activities provided the basis for the Team recommendation of the preferred alternative(s). The focus of this phase was to develop, at a pre-conceptual level, the baseline cost and schedule for implementation of each of the Short List alternatives and to evaluate the potential impacts of identified risks as uncertainties in project cost and schedule. The Team initiated a number of activities during the Selection Phase to support the evaluation of these alternatives. These activities included continuing refinement of the flowsheets and models to provide preliminary equipment sizing, facility layout/siting and material/energy balances; specific Research and Development activities at SRTC, Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL) and the University of South Carolina, and Purdue and Texas A&M Universities on aspects key to the selection process; a hazards evaluation of the processes to better define potential safety concerns; and detailed pre-conceptual cost and schedule estimates for the Total Project and Life Cycle Costs of the alternatives.

The Team recognized commitments existed to close the SRS HLW Tanks by the FFA/STP schedule and to begin emptying the HLW Tanks by 2010 to avoid “waterlogging” in the Tank Farm. The mission requires that the recommended alternative(s) have a high confidence of success. Therefore, the selection process had to develop each alternative to a level that would provide a clear vision of the technical implementation of the alternative, identify credible risks and quantify resulting uncertainties. The cost of resolving problems arising from the identified risks was included in the Team evaluation.

1.7 Cost

The Team evaluation of cost became more detailed as the technical definition of alternative technologies became more refined. Initially, broad estimates of cost were used to see if alternatives were credible. No alternative technologies were eliminated on this basis. During the Investigation Phase, rough estimates were established based on previous experience, but were given lower weight than technical and safety criteria. During the Selection Phase, more detailed pre-conceptual estimates were established for the Short List alternatives. TEC, OPC and LCC estimates were produced, and contingency analyses were performed using Monte Carlo techniques to produce contingency estimates. Technical and programmatic risks carried forward in the selection process were then evaluated for impact on cost and schedule. The estimated cost of addressing the uncertainty and the cost of schedule change or delay was applied to the LCC estimates where it was considered not to be within the already calculated LCC contingency. This value reflected the potential total cost of the project, including the cost to address problems arising from the identified project risks.

1.8 Deliverables

The final deliverables defined in the Team Charter are a completed pre-conceptual design, initial cost estimate, a final report on Team activities and a recommendation on a preferred alternative(s).

The Pre-Conceptual Design Package and Facility Design Description (Chapter 1) satisfy the pre-conceptual design deliverable and are shown in Enclosures 1, 2, 4 and 5.

The "Life Cycle Cost Estimate Bases, Assumptions, and Results" document satisfies the initial cost estimate deliverable and is shown in Enclosure 7.

This Report satisfies the final report deliverable on Team activities.

The Team recommends the use of Small Tank TPB Precipitation as the method for disposition of SRS high level waste salt. CST Non-Elutable Ion Exchange is recommended as a backup technology.

Submittal of this report completes chartered Team activities.

2.0 Introduction and Purpose

The SRS STP and FFA call for closing the HLW Tanks through vitrification of both the long-lived and short-lived radioisotopes in DWPF in preparation for transport to the national high level waste repository. To make this program economically feasible, it is necessary to limit the volume of HLW glass produced by removing much of the non-radioactive salts and incidental wastes for disposal as saltstone. The ITP facility was designed and constructed to separate the cesium isotopes from the non-radioactive salts so the decontaminated salts could be disposed in a grouted wasteform at the Saltstone facility at SRS.

The ITP process was successfully piloted both on a moderate and full-scale basis with actual SRS waste in the 1980s. During the facility radioactive startup, higher than predicted benzene releases were observed. Additional laboratory and facility tests were initiated to further investigate process chemistry issues. In January 1998, conclusions were drawn from the test program that the benzene release rates associated with facility operation could exceed the capability of the current plant hardware/systems. On January 22, 1998, WSRC informed DOE that ITP chemistry testing demonstrated that the present system configuration could not cost-effectively meet the safety and production requirements for the ITP facility and recommended that a study of alternatives to the current system configuration be conducted by a systems engineering team.

On February 6, 1998, the Assistant Secretary for Environmental Management approved a DOE-SR plan of action to suspend startup-related activities and undertake a systems engineering study of alternatives to ITP. On February 20, 1998, DOE-SR concurred with the WSRC evaluation of the ITP chemistry data, instructed WSRC to suspend ITP startup preparations, and directed WSRC to perform an evaluation of alternatives to the current system configuration for HLW salt removal, treatment, and disposal.

In March 1998, a WSRC-sponsored High Level Waste Systems Engineering Team (Team) was formed to study alternatives to the ITP processes as well as methods to enhance the current process. The multi-disciplined Team was chartered with the task of "systematically developing and recommending an alternative method and/or technology

The Charter also identified the following deliverables:

- Systems Engineering Team Selection
- System Engineering Management Plan
- Report Summarizing Activities Leading to the Initial List of Alternatives
- Report Summarizing Activities Leading to the Short List of Alternatives

- Interim Progress Report
- Detailed Evaluation Criteria for the Short List
- Preliminary Risk Assessments
- Programmatic Risk Assessments and Mid-Course Correction
- Pre-conceptual Design and Initial Cost Estimate
- Final Report

This report constitutes the "Final Report" required by the Team Charter.

2.1 Background

High Level Waste has been produced at the Savannah River Site since 1951. This waste was stored in Interim Waste Tanks. In the early 1980s, a concept was developed to no longer construct additional Interim Waste Tanks, but to process the waste into a safer storage form, reduce risk, and ready the waste for permanent storage. This led to an initial design concept for DWPF and an Ion Exchange Facility.

The cost for both facilities was high, and technical uncertainties for Ion Exchange posed too high a risk. Alternatives to the Ion Exchange Process were evaluated and the ITP process was selected due to lower projected cost and technical risk.

The Savannah River Site currently stores 34 million gallons of HLW in Interim Storage Tanks. This activity is considered to be one of the higher risk activities on the Site. The FFA requires removing the waste from the high level waste tanks to resolve several safety and regulatory concerns. Tanks have leaked observable quantities of waste from primary to secondary containment. Other tanks have known penetrations above the liquid level, although no waste has been observed to leak through these penetrations. The "old style" tanks do not meet EPA secondary containment standards for storage of hazardous waste, (effective January 12, 1987). The 34 million gallons of liquid waste stored in the HLW tanks are composed of 31 million gallons of "Salt" and 3 million gallons of sludge. The Sludge process is fully operational. The ITP process was the baseline method intended for handling Salt.

During the facility radioactive startup, higher-than-predicted benzene releases were observed, and a program was initiated to further investigate process chemistry issues. The program concluded that the benzene release rates associated with facility operation could exceed the capability of the current plant hardware/systems. WSRC informed DOE that the present system configuration could not cost-effectively meet the safety and production requirements for the ITP facility and recommended that a study of alternatives to the current system configuration be conducted by a Systems Engineering team.

With the formation of the Team, a DOE-sponsored charter was issued to guide the systems engineering process for determination of a preferred salt disposition technology. The need for a timely decision was identified from impacts to the following: Limited Tank Farm storage capacity, additional DWPF glass canister production, incurred Life Cycle Cost (LCC) and prolonged environmental risk for liquid waste storage.

2.2 High Level Waste System Overview

Any new salt processing system will interface with existing facilities, and the ease or difficulty of the successful implementation of an alternative technology is governed by how well it will integrate into the existing HLW System.

The HLW System is a set of seven different interconnected processes (Figure 2-1) operated by the High Level Waste and Solid Waste Divisions. These processes function as one large treatment plant that receives, stores, and treats high level wastes at SRS and converts these wastes into forms suitable for final disposal. The three major permitted disposal forms are borosilicate glass, planned for disposal at a Federal Repository; saltstone grout, disposed in vaults on the SRS site; and treated water effluent, released to the environment.

These processes currently include:

- High Level Waste Storage and Evaporation (F and H Area Tank Farms)
- Salt Processing (In Tank Precipitation and Late Wash Facilities)
- Sludge Processing (Extended Sludge Processing Facility)
- Vitrification (DWPF)
- Wastewater Treatment (Effluent Treatment Facility)
- Solidification (Saltstone Facility)
- Organic Destruction (Consolidated Incineration Facility)

F and H Area Tank Farm, Extended Sludge Processing, DWPF, Effluent Treatment Facility, Saltstone Facility, and the Consolidated Incineration Facility are all operational. ITP Facility operations are limited to safe storage and transfer of materials. The Late Wash Facility has been tested and is in a dry lay-up status.

The mission of the HLW System is to receive and store SRS high level wastes in a safe and environmentally sound manner and to convert these wastes into forms suitable for final disposal. The planned forms are:

- borosilicate glass to be sent to a Federal Repository
- saltstone to be disposed of on site
- treated wastewater to be released to the environment.

Also, the storage tanks and facilities used to process the high level waste must be left in a state such that they can be decommissioned and closed in a cost-effective manner and in accordance with appropriate regulations and regulatory agreements.

All high level wastes in storage at SRS are Land Disposal Restrictions (LDR) wastes, which are prohibited from permanent storage. Since the planned processing of these wastes will require considerable time and therefore continued storage of the waste, DOE has entered into a compliance agreement with the EPA and SCDHEC. This compliance agreement is implemented through the STP, which requires processing of all the high level waste at SRS according to a schedule negotiated between the parties.

Figure 2-1 schematically illustrates the routine flow of wastes through the HLW System. The various processes within the system and external processes are shown in rectangles. The numbered streams identified in italics are the interface streams between the various processes. The discussion below represents the HLW System configuration as of January 1998.

Incoming high level wastes are received into HLW Storage and Evaporation (F and H Area Tank Farms) (Stream 1). The function of HLW Storage and Evaporation is to safely concentrate and to store these wastes until downstream processes are available for further processing. The decontaminated liquid from the evaporators are sent to Wastewater Treatment (ETF) (Stream 13).

The insoluble sludges that settle to the bottom of waste receipt tanks in HLW Storage and Evaporation are slurried using hydraulic slurrying techniques and sent to Extended Sludge Processing (ESP) (Stream 2). In ESP, sludges high in aluminum are processed to remove some of the insoluble aluminum compounds. All sludges, including those that have been processed to remove aluminum, are washed with water to reduce their soluble salt content. The spent washwater from this process is sent back to the HLW Storage and Evaporation (Stream 3). The washed sludge is sent to Vitrification (DWPF) for feed pretreatment and vitrification (Stream 4).

Saltcake is redissolved using hydraulic slurrying techniques similar to sludge slurrying. As currently designed, the salt solutions from this operation, and other salt solutions from HLW Storage and Evaporation, were intended for feed to Salt Processing (Stream 5). In ITP, the salt solution would be processed to remove radionuclides, which are concentrated into an organic precipitate. The decontaminated filtrate would then be sent to Tank 50. A concentrated organic precipitate, containing most of the radionuclides, is produced by the process. This precipitate is washed with water to remove soluble salts. However, some soluble corrosion inhibitors that interfere with DWPF processing must be left in the precipitate after washing because the precipitate is stored in carbon steel tanks, which are susceptible to corrosive attack by uninhibited precipitate wastes.

The precipitate is transferred to Late Wash for further washing in stainless steel tanks to reduce the level of soluble corrosion inhibitors to acceptable levels for the DWPF process (Stream 7). The washwater from this process is returned to ITP to be reused in the ITP process (Stream 8).

The washed precipitate from Late Wash is then sent to the DWPF vitrification building (221-S). In the vitrification building, the precipitate is catalytically decomposed and separated into two streams: a mildly contaminated organic stream and an aqueous stream containing virtually all of the radionuclides. The mildly contaminated organics are stored at DWPF and eventually transferred to Organic Destruction (CIF) (Stream 11). The aqueous stream is combined with the washed sludge from ESP, which has undergone further processing and the mixture vitrified.

The washed sludge from ESP (Stream 4) is chemically adjusted in the DWPF to prepare the sludge for feed to the glass melter. As part of this process, mercury is stripped out, purified, and sent to mercury receivers (Stream 12). The aqueous product from organic decomposition is added to the chemically adjusted sludge. The mixture is then combined with glass frit and sent to the glass melter. The glass melter drives off the water and melts the wastes into a borosilicate glass matrix, which is poured into a canister. The canistered glass wasteform is sent to site interim storage, and will eventually be disposed of in a Federal Repository (Stream 9).

The water vapor driven off from the melter along with other aqueous streams generated throughout the DWPF vitrification building is recycled to HLW Storage and Evaporation for processing (Stream 10).

Overheads from the HLW Storage and Evaporation evaporators are combined with overheads from evaporators in the F and H Area Separations processes and other low-level streams from various waste generators. This mixture of low-level wastes is sent to the ETF (Stream 13).

In the ETF, these low-level wastes are decontaminated by a series of cleaning processes. The decontaminated water effluent is sent to the H Area outfall and eventually flows to local creeks and the Savannah River (Stream 14). The contaminants removed from the water are concentrated and sent to Tank 50 (Stream 15).

In Tank 50, the concentrate from the ETF is combined with the decontaminated filtrate from the ITP and sent to Saltstone (Stream 6). In the Saltstone Facility, the liquid waste is combined with cement formers and pumped as a wet grout to a vault (Stream 16). In the vault, the cement formers hydrate and cure, forming a saltstone monolith. The Saltstone Facility vaults will eventually be closed as a landfill

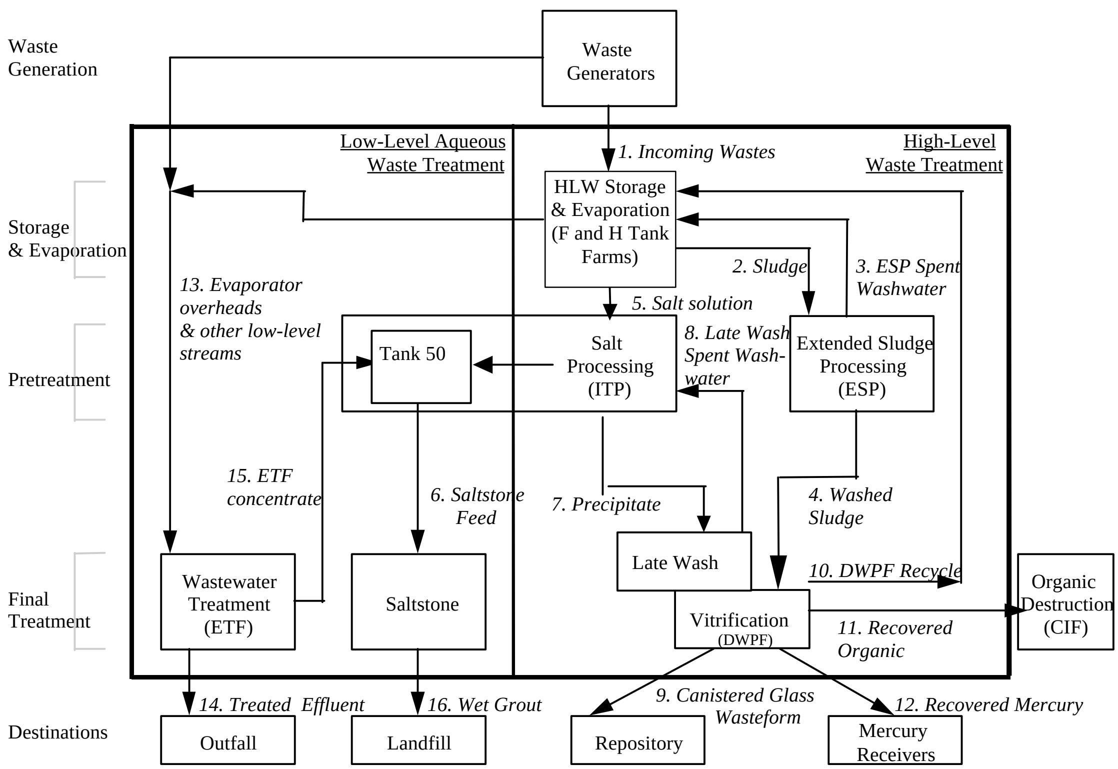


Figure 2-1: HLW System Major Interfaces

2.3 Team Activities

The Team was formed with the following members, representing national labs, academia, waste processing, science and technology, operations, process chemical engineering, systems engineering, and integrated safety management.

NAME	AREA OF CONTRIBUTION
Steve Piccolo	Team Leader
Gary Abell	Systems Engineering
Ken Rueter	Process Engineering
Jeff Barnes	Operations
Peter Hudson	Waste Process
Lucien Papouchado	Science
Ed Murphy	Safety and Regulatory Engineering
Jack Watson	Science
Ed Cussler	Chemical
Gene Kosiancic	Chemical Process

The Team was chartered to recommend a technology for the salt disposition process. In the Identification Phase, the Team collected input on diverse possible technologies from around the DOE Complex and the world, and completed an initial screening process to develop the best combination of alternatives that would be further evaluated. This resulted in the Initial List of eighteen processing alternatives.

In the Investigation Phase, the Initial List alternatives were evaluated by the Team to determine the probability of success for the individual alternatives along with the identification of preliminary risks for each process. Based on this evaluation the Team selected the Short List of four alternatives. This process has been independently reviewed by the WSRC Review Panel, SRS Citizen's Advisory Board (CAB), DOE-SR, and DOE Headquarters Independent Evaluation (DOE-HQ IPE) Team. Each of these reviews supported the four selected alternatives as technically workable, capable of being implemented in the field and as representing the most promising alternatives to be included in the final selection process.

The purpose of the Selection Phase was to analyze the four alternatives at a more detailed level and recommend the preferred alternative(s) for salt disposition. This process included:

- Identifying and completing R&D activities that would minimize the level of uncertainty associated with each process that had been identified in the Investigation Phase
- Improving the alternative flowsheet interfaces with HLW System interfaces
- Defining the processing plant preliminary specifications (equipment size, bounding feed cases, facility layout, siting, etc.)
- Developing the preliminary construction/project/operation schedule
- Developing both the Salt Disposition Facility TPC and Life Cycle Cost estimates including respective contingencies
- Identifying, evaluating and quantifying the uncertainties for each process in terms of potential cost and schedule impact
- Evaluating the qualitative and quantitative information to select the preferred alternative(s)

3.0 Systems Engineering Process

The purpose of this section is to describe the structured process the Team used to objectively and efficiently complete its chartered activities. The process provided steps to develop the relevant information and activities needed for Team decisions during the course of the pre-conceptual phase.

The Team commenced its chartered activities utilizing a structured Systems Engineering (SE) process. The process was effectively applied to identify, investigate, and select the preferred alternative. The SE approach is instrumental in managing large and technically complex projects and is recognized by both the DOE and DNFSB as an effective methodology for project development. DOE Order 430.1 (Life Cycle Asset Management LCAM) and the associated Good Practice Guides outline the principles and practices of Systems Engineering.

The Team developed and approved a Systems Engineering Management Plan (SEMP) at the beginning of the pre-conceptual activities in order to document the SE activities, resources, and tools that the Team would apply. The principles and practices identified in the SEMP were implemented by the Team. Procedures, position papers, and results reports were developed to document the structured controls, inputs, support resources needed, and outputs obtained during the Teams activities.

The SE process is a “top down” approach and requires the identification of appropriate personnel and resources to perform mission definitions and analysis, functions and requirements analysis, alternative evaluation, selection, validation, and verification. In addition, the disciplined application of risk management, interface control, technical planning and integration to successfully execute the work activities are required to satisfy the SE process.

The structured process was applied in the three phases of the pre-conceptual activities. These phases are referred to as the Identification, Investigation, and Selection phases. During the initial phase, referred to as “identification”, the Team’s application of the process resulted in several outputs. These included the mission analysis and definition, development of necessary and sufficient functions and requirements that any alternative solution must satisfy, and the identification and initial screening of potential solutions (alternatives).

The functions developed defined “what” the selected alternative must do to fulfill the mission. The associated requirements identified specify “how well” the functions must be performed.

The mission and supporting top-level functions, which must be satisfied by the preferred alternative(s), are identified in Figure 3-1 and defined in the Initial Design Input.

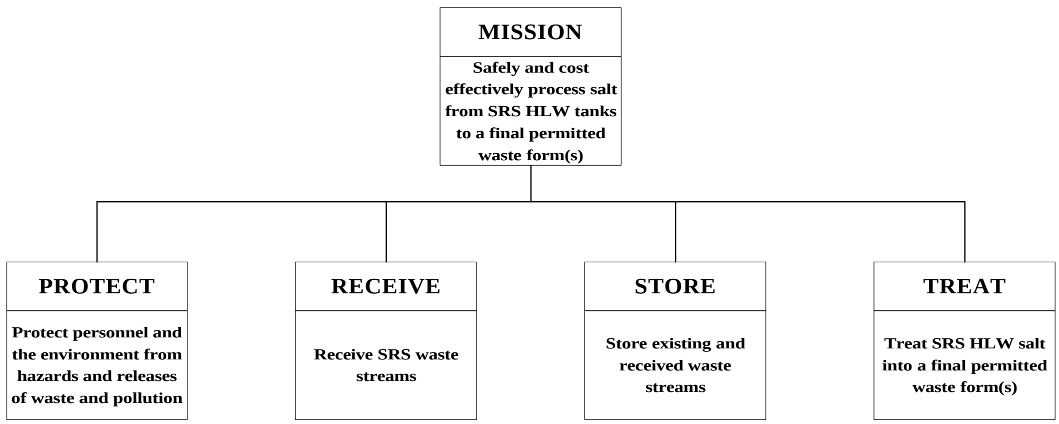


Figure 3-1: Mission and Top-Level Functions

Several systems engineering process tools were employed to systematically identify a broad and comprehensive list of diverse technologies for subsequent investigation (evaluation) and selection. The methods used included brainstorming by DOE Complex subject matter experts/stakeholders, literature/patent searches, and solicitation of SRS employee input. The results of the Identification Phase culminated in the Initial List of identified alternatives and are discussed in detail in Section 4.0 (Technology Identification). Identified technologies were recorded on a “pro-forma”.

The application of the SE process continued into the Investigation Phase, in which basic engineering flowsheets and models were developed to facilitate preliminary risk assessments and develop preliminary schedule and cost estimates for each of the Initial List alternatives. Significant risks were assigned risk handling strategies for subsequent evaluation. These strategies were addressed through specific engineering, research, testing or operational analysis, studies, and tasks. These activities are discussed further in Section 6.0 (Flowsheet Development). In addition, the Team conducted several field trips at both DOE and commercial facilities with similar/same technologies for the purpose of validating the risks identified and process applied. The details and results of the preliminary risk assessment activities are discussed in Section 5.0 (Risk Management).

The Investigation Phase continued with an evaluation of the Initial List to further downselect to a Short List. This systematic evaluation consisted of defining key evaluation criteria with assigned weights. Each weighted criterion was supplemented by “utility functions”. The utility functions provide a means of consistently evaluating the alternatives against each criterion to yield numerical scores for comparison purposes.

To complete the Investigation Phase, the Team considered the weighted scores, technical information, and risk results to derive the Short List of alternatives.

The SE process in the third and final phase (i.e., Selection Phase) was structured to facilitate the Team's selection of a preferred alternative(s). The Selection Phase was heavily focused on LCC, schedule, and the various aspects that feed LCC, including risk and associated uncertainties. Project (OPC and TEC), Operating and Maintenance (O&M), and Decontamination and Decommission (D&D) costs were developed as components of each alternative's LCC. Risks identified in the Investigation Phase were key drivers for much of the engineering, research, and testing pursued in the Selection Phase. The applied research and engineering activities completed during the Selection Phase provided the Team with needed information to define the magnitude of uncertainties in terms of schedule impacts, process equipment/material considerations, and additional research or testing to be factored into the decision making process. The results of these technical activities were used as input to the identification and quantification of risks and uncertainties in terms of schedule and cost impacts. The specific LCC, schedule information, and results are presented in Section 7.0 (Cost/ Schedule and Systems Integration).

The Team defined uncertainties in terms of positive or negative cost impacts in addition to LCC. The quantified uncertainties defined, as a result of applying the SE risk process, are discussed in Section 8.0 (Uncertainties).

This information was augmented by a qualitative evaluation based on Team expertise and judgement of each of the Short List alternatives. The qualitative evaluation considered the strengths and weakness of each alternative in the areas of mission, technical maturity, environment, engineering/design, operations, regulatory, stakeholder, safety, and radiological.

The final activity to complete the Selection Phase involved the Team review and discussion of technical, cost, schedule, risk, and uncertainty information. The individual and collective expertise of the Team resulted in selection of the Small Tank TPB Precipitation process as the recommended alternative and CST Non-Elutable Ion Exchange as a backup alternative. The details of the selection process are discussed in Section 9.0 (Selection).

4.0 Technology Identification

The purpose of this section is to describe how technologies were identified using an extensive search process and how, throughout the Investigation and Selection Phases, the process allowed the consideration of new alternatives, updated technologies, and developments both within the DOE Complex and world-wide.

4.1 Technology Search Phase

In the early 1980s, SRS chose In-Tank TPB precipitation to separate cesium from the non-radioactive salts that reside in the HLW Tanks. The TPB precipitation process was chosen from several precipitation and ion exchange processes at that time. During subsequent years, considerable technology development had taken place worldwide, thus the first phase in establishing a new process for SRS was to establish a comprehensive list of alternative technologies and identify a working list of the technologies that, at a high level, appeared capable of being successfully deployed on the required time scale. In this phase, the emphasis was on completeness. All decisions were structured to avoid premature technology elimination and to err on the side of over-inclusion.

This phase began with a Team effort to establish and communicate the functions and requirements to be accomplished by the eventual preferred technology(ies). Based on the defined functions and requirements, a request for proposed technologies was spread widely across the Savannah River Site, the DOE Complex, academia, and industry. In particular, the Team sought input and participation from the Tanks Focus Area and the Efficient Separations Crosscutting Program. This request was supplemented by brainstorming sessions with invited experts.

A detailed literature search was conducted utilizing the resources of the SRTC, ORNL, and the Pacific Northwest National Laboratory (PNNL) to assure that potentially successful technologies were not overlooked. The search was conducted utilizing the search patterns of cesium removal, cesium separation, and associated separation processes and technologies. The resulting list of over 1700 references to cesium removal was categorized into sixteen process technologies for ease of information review. The source documents were identified in the United States and 37 other countries. Of the 1700 references, ion exchange, solvent extraction, adsorption, and precipitation technologies represented over 90%. ORNL, PNNL, and SRTC reviewed the findings against the original list of alternatives and determined that one additional proposal was needed to capture a unique variation. This review demonstrated that the pro-forma process adequately captured the breadth of technologies for cesium removal.

In addition to the technologies identified and assessed during the Identification Phase activities, the Team continued to accept and assess technologies that were suggested via pro-forma submissions up to the selection of the preferred alternative(s).

The Identification Phase decision-making process was designed to act as a coarse sieve to eliminate concepts that could clearly not be relied on to be successful on the required time scale. It also provided an opportunity to combine parts of different technology concepts to create processes with the potential to meet the functions and requirements earlier defined. The Team developed a number of suggestions reflecting combinations of submitted ideas as a result of this process.

The majority of pro-forma concepts were considered as alternatives, variations of an alternative, or pro-forma hybrids. Suggestions were only eliminated from further consideration if they could clearly not meet the functions and requirements, were insufficiently mature to be reliably deployed on the required time scale, or were clearly inferior to similar technologies (e.g., if multiple ion exchange resins were available that could remove cesium, only the best ones would be carried forward).

The product of this phase was a list of eighteen alternatives, with a textual description, a high level flowsheet, and identified variations. These alternatives were carried forward for further consideration in the Investigation Phase.

Table 4-1 compares the options considered by the Team to a high level survey of those identified in recent similar DOE Complex programs (West Valley, INEEL, Oak Ridge, and Hanford). While the outcomes vary from site to site depending on waste composition, site-specific legislation and other unique site considerations, it is clear that the Team has not overlooked technologies considered important at other sites and that options considered important in those studies have been given strong consideration by the Team. Members of the Team visited several DOE sites for face-to-face discussions of technologies used or tested at those sites and their experience with those technologies. The sites visited are shown in Table 4-1. While not shown in the table, the Team also reviewed technologies in use or under development in other countries, (e.g., grout application by BNFL).

Table 4-1: DOE Complex Technology Review Comparison

Alternative	SRS	WVNS	ORNL	INEEL	Hanford
Fractional Crystallization	A				X
Crystalline Silicotitanate (CST)	A		X	X	X
Zeolite (Non-elutable Ion Exchange)	A K2CoFe[CN]6 Durasil	X	K2CoFe[CN]6	K2CoFe[CN]6	
Elutable Ion Exchange	A	CS-100 (Duolite)	RF SuperLig CS-100	AMP-PAN	X SuperLig Duolite, RF
Acid Side Ion Exchange	A			AMP-PAN	
Tetraphenylborate Precipitation	A	X			X
Caustic Side Solvent Extraction	A				X
Acid Side Solvent Extraction	A			X	
Electrochemical	A	X Electrodialysis		X	
Direct Vitrification	A	Reject-WVDA			X
Direct Disposal in Grout	A	Reject-WVDA	Prohibited by State		X Not Allowed per Tri-Party Agreement
Supernate Separation	A				Saltwell Pumping Utilized
Hyperfiltration	R	X			
Other Precipitation		K2CoFe[CN]6 Na2NiFe[CN]6 PTA			K2CoFe[CN]6 Na2NiFe[CN]6 PTA
Biosorbants	R	X		X	X
Chelating Agents (Devoe – Holbein)	R	X			X

A = Accepted as an alternative
R = Rejected
X = Addressed
WVDA = West Valley Demonstration Act
PTA = Phosphotungstic Acid
RF = Resorcinol Formaldehyde
AMP-PAN = Ammonium molybdophosphate – Polyacrylonitrile

4.2 Technology Categories

Alternatives were organized by technology category. Broad screening was performed on the technology categories.

The technology categories are as follows:

- **Crystallization –** Separation of the cesium from non-radioactive salts by fractional crystallization
- **Electrochemical** – Electrochemical processes that achieve separation/ destruction of different ionic components in the system
- **Elutable Ion Exchange** – Separation of cesium from HLW salt by regenerable ion exchange
- **Non-elutable Ion Exchange –** Separation of cesium from HLW salt by non-regenerable ion exchange
- **Geological –** Alternatives more dependent on geology than processing
- **Inorganic Precipitation –** Separation of the desired substance by addition of an inorganic precipitant
- **Organic Precipitation/Modify ITP –** Separation of cesium by addition of an organic precipitant with extensive use of the existing ITP Facility
- **Organic Precipitation/New Process** – Separation of cesium using a facility substantially different from the existing ITP Facility
- **Solvent Extraction –** The use of a solvent for separating cesium based on either an alkaline or acidic feed stream
- **Vitrification –** Disposition of the salt by vitrifying it either in DWPF or using new equipment or facilities
- **Miscellaneous –** Approaches not covered by the other categories

Each technology category passed the screening process.

4.3 Initial List Alternatives

The Team screened the approximately 140 pro-formas and established an Initial List of eighteen for further evaluation. The list of eighteen alternatives represents portions, combinations, modifications or hybrids of the original pro-formas.

The alternatives selected for further evaluation are described briefly below:

Fractional Crystallization - DWPF Vitrification
The process would selectively remove sodium salts from acidified salt solution as sodium nitrate crystals leaving behind a liquid containing most of the cesium for vitrification at DWPF. The decontaminated crystals would be dissolved, neutralized, and made into a Class A waste (grout) at the Saltstone Facility.

Electrochemical Separation and Destruction – DWPF Vitrification
The process would utilize an electrochemical cell through which filtered supernate would be transferred to convert nitrates and nitrites to hydroxides. The resultant liquid would be pumped through an electro-chemical membrane to produce two streams. The first stream is a small volume of alkaline solution enriched in cesium for feed to DWPF, and the second is a large volume of caustic solution for recycle to the tank farm and/or saltstone disposal.

Elutable Ion Exchange - DWPF Vitrification
The process uses an elutable ion exchange resin (e.g., crown ether on the substrate) to remove cesium and a second elutable resin for strontium, plutonium, and uranium removal. The radionuclides would be eluted with nitric acid and vitrified at DWPF. The decontaminated salt solution would be made into a Class A waste (grout) at the Saltstone Facility.

Potassium Removal followed by TPB Precipitation
The process would use a potassium-specific resin to remove most (~90%) of the potassium from salt solution prior to precipitation with sodium tetraphenyl borate (TPB). This would dramatically reduce the use of TPB and resulting benzene production. The cesium precipitate would be vitrified in DWPF, together with the monosodium titanate (MST) used for removal of the strontium, plutonium, and uranium. The potassium and decontaminated salt solution would be made into a Class A waste (grout) at the Saltstone Facility.

Acid Side Ion Exchange - DWPF Vitrification
The process would employ one of several effective cesium removal resins in an acidic flowsheet such as ammonium molybdophosphate on polyacrylonitrile resin (AMP-PAN). If elutable, the eluate containing cesium would be fed to DWPF. If non-elutable, the loaded resin would be vitrified at DWPF. The decontamination salt solution would be made into Class A waste (grout) at the Saltstone Facility.

Crystalline Silicotitanate (CST) Ion Exchange – DWPF Vitrification
The process would employ CST resin for cesium removal coupled with MST addition for strontium, plutonium, and uranium removal. The loaded CST resin

and MST would be vitrified at DWPF. The decontaminated salt solution would be made into Class A waste (grout) at the Saltstone Facility.

Crystalline Silicotitanate (CST) Ion Exchange – New Facility Vitrification
The process would employ CST resin for cesium removal coupled with MST addition for strontium, plutonium, and uranium removal. The loaded CST resin and MST would be vitrified at a new dedicated vitrification facility. The decontaminated salt solution would be made into Class A waste (grout) at the Saltstone Facility.

Zeolite Ion Exchange - DWPF Vitrification
The process would utilize zeolite resin to remove cesium and a second zeolite resin to remove strontium, plutonium, and uranium. The loaded resins would be vitrified at DWPF. The decontaminated salt solution would be made into Class A waste (grout) at the Saltstone Facility.

Crystalline Silicotitanate (CST) Ion Exchange – Ceramic Wasteform
The process would employ CST resin for cesium removal coupled with MST addition for strontium, plutonium, and uranium removal. The loaded CST resin would be converted to a ceramic wasteform. The ceramic would be stored on site until the cesium activity was negligible (~300 years).

Reduced Temperature ITP
The process is a variation on the current ITP flowsheet. The flowsheet process would be the same but modifications would be required to maintain TPB slurry and filtrate temperatures below 25°C. This would increase precipitate stability and reduce benzene generation.

Catalyst Removal ITP
The process is a variation on the current ITP flowsheet. This process requires an additional process step to remove both solid catalyst (entrained sludge) and soluble catalyst (metal ions in the salt solution). This would increase precipitate stability and reduce benzene generation.

ITP with Enhanced Safety Features
The process is similar to the current ITP flowsheet. The modifications would compensate for Authorization Basis safety issues with Engineered Safety Features.

Small Tank TPB Precipitation
The process would be a series of Continuous Stirred Tank Reactors to conduct a TPB precipitation. This is followed by a chilled concentrate tank for storage of the precipitate. This reduces cycle time and total inventory, thereby reducing the

hazardous material source term. The downstream process would be similar to the current ITP flowsheet.

Caustic Side Solvent Extraction - DWPF Vitrification
The process would encompass multiple extraction, scrub, and strip stages with a diluent and an extractant such as a crown ether for cesium removal. The cesium would then be stripped from the solvent with dilute acid and vitrified at DWPF. The decontaminated salt solution would be made into a Class A waste (grout) at the Saltstone Facility.

Acid Side Solvent Extraction - DWPF Vitrification
The process would first acidify the salt solution with nitric acid and would then encompass multiple extraction, scrub, and strip stages with appropriate diluent and an extractant such as cobalt dicarbolide for cesium removal. The cesium would then be stripped from the solvent with acid and vitrified at DWPF. The decontaminated salt solution would be made into a Class A waste (grout) at the Saltstone Facility.

Direct Vitrification
The process would treat all of the salt solution in a new vitrification facility. A high throughput melter(s) would be required to meet the production requirements.

Supernate Separation – DWPF Vitrification
The process would feed concentrated supernate liquid directly to DWPF to be mixed with sludge for vitrification. Dissolved saltcake would be treated with MST for strontium, plutonium, and uranium removal. The loaded MST would be vitrified in DWPF. The partially decontaminated salt solution would be made into a Class C waste (grout) in a modified Saltstone or new facility.

Direct Disposal in Grout
The process would treat the salt solution with MST for strontium, plutonium, and uranium removal. The loaded MST would be vitrified at DWPF. The treated salt solution would be grouted in a new facility to meet Class C waste limits.

Figure 4-1 shows the progression of the selection for the recommended alternatives.

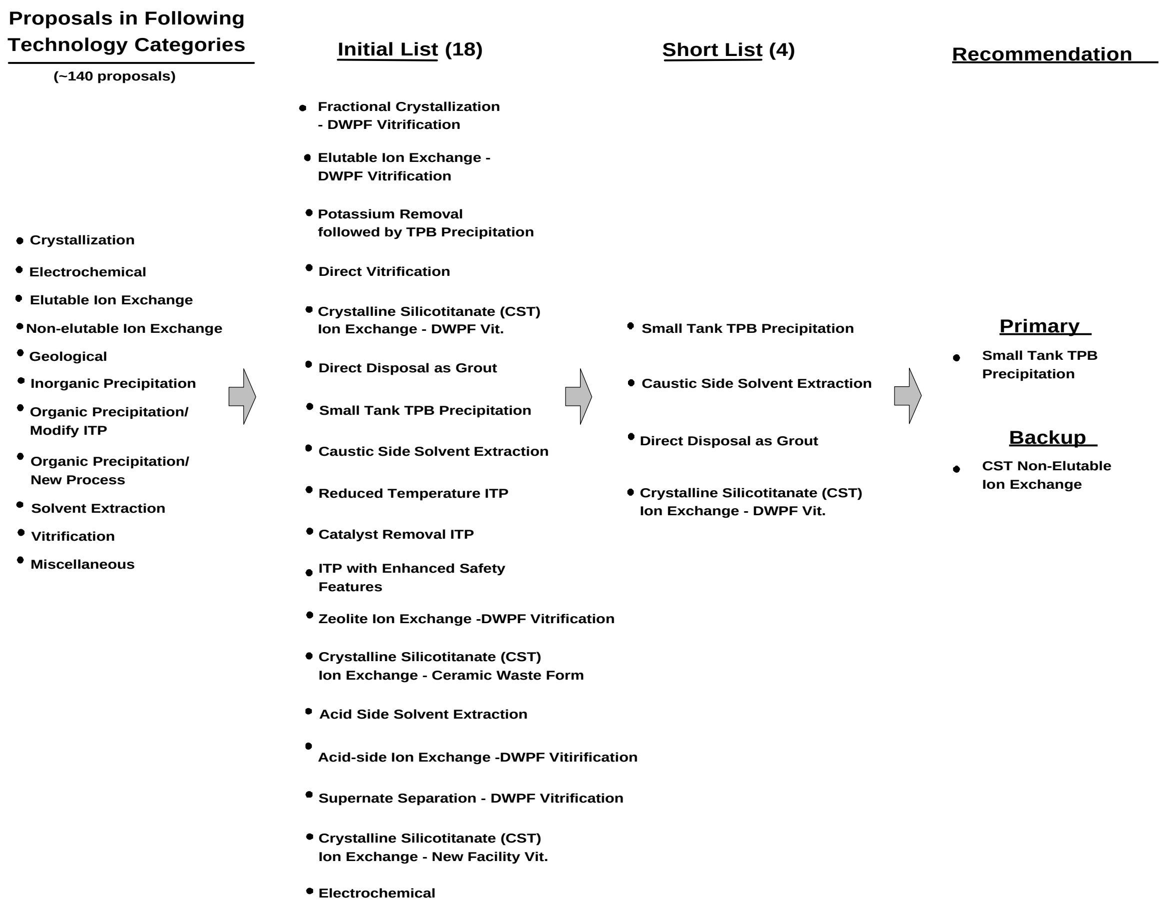


Figure 4-1: Salt Disposition Technologies

4.4 Process Description of the Four Short List Alternatives

4.4.1 Caustic Side Solvent Extraction

The basic principle of solvent extraction is to use an insoluble diluent material that carries an extractant that will complex with the cesium ions in the caustic solution. The clean aqueous stream (raffinate) is sent to saltstone for disposal. The cesium contained in the organic phase (solvent) is stripped back into an aqueous phase ready for transfer to DWPF. The solvent is recycled. The strontium, plutonium, and uranium in the salt solution feed would first be removed by MST along with filtration to remove the solids for transfer to DWPF. For a more detailed description refer to Section 9.2.1.

4.4.2 CST Non-Elutable Ion Exchange

The proposed process would employ CST resin to remove cesium from the salt solution. The strontium, plutonium, and uranium would first be removed by MST addition along with filtration to remove the solids for transfer to DWPF. The cesium-loaded resin would be transferred to the DWPF to be combined with sludge and frit to produce borosilicate glass. The decontaminated salt solution would go to the Saltstone Facility to be made into a Class A grout. For a more detailed description refer to Section 9.2.2.

4.4.3 Direct Disposal in Grout

In the proposed process, soluble waste, including cesium, is sent to the Saltstone facility. The strontium, plutonium, and uranium would first be removed by MST addition along with filtration to remove the solids for transfer to DWPF. The saltstone wasteform generated from the salt solution must meet NRC Class C LLW disposal requirements for near-surface disposal. The vaults presently used in the Saltstone facility meet current regulations for NRC Class C disposal, although the current permit restricts the average curie content in a disposal unit (cell) to be within NRC Class A limits for disposed saltstone. At the projected maximum concentration of cesium 137, a new grout production facility within a new shielded cell with grout production equipment modified to enable remote maintenance capability will need to be constructed. For a more detailed description refer to Section 9.2.3.

4.4.4 Small Tank TPB Precipitation

The strategy that drives this option is to eliminate the issues associated with the current ITP process using engineered solutions while preserving the cesium decontamination that has been demonstrated by sodium tetraphenylborate (NaTPB) precipitation process. The problems identified with benzene generation, retention, and release are resolved by engineered features such as temperature control, adequate mixing, and positive pressure nitrogen blankets on the processing tanks. The effects of lower temperature and shorter residence times on NaTPB decomposition are addressed in the Excess Sodium Tetraphenylborate and Intermediates Decomposition Studies.

This option replaces batch precipitation in Tank 48 with continuous precipitation. This continuous precipitation unit operation would be a Continuous Stirred Tank Reactor(s) (CSTR) sized to provide enough holdup to allow for adequate cesium decontamination with NaTPB and for adequate plutonium, uranium, and strontium decontamination with MST, simultaneously. The slurry is passed through crossflow filters to separate the radioactive solids from the decontaminated salt solution. The slurry is concentrated to ten weight percent solids. A washing facility would then wash the salts from the slurry to meet DWPF salt requirements using crossflow filters. For a more detailed description refer to Section 9.2.4.

4.5 Technologies Not Carried Forward to the Short List

In selecting the Short List alternatives during the Investigation Phase, the remaining alternatives were dropped from further consideration. The technologies not carried forward into the Selection Phase and the principal reasons for not carrying them forward are listed below:

- Large Tank Precipitation – Technology mature, but process controls and operations are difficult to achieve in 1.3 million gallon tank. (Three alternatives: Catalyst Removal, Reduced Temperature, Enhanced Safety Features)

- Potassium Removal followed by In Tank Precipitation – Technology immature, sufficiently selective resin for potassium removal in the presence of sodium and cesium is not available.

- Direct Vitrification – Vitrification is a mature technology, however massive increase in the throughput requirement and the number of canisters produced will be required. Melter and offgas design for salt processing is still under development. The process is expensive due to the requirement for approximately five melt cells each about twice the diameter of the DWPF melter.

- Separate Supernate and Vitrify – Same issues as direct vitrification, and feed to Saltstone would contain a significant amount of cesium 137.

- Acid Side Ion Exchange – Technology immature, processing large amounts of acid and lack of demonstrated industrial resin performance poses too much risk.

- Acid Side Solvent Extraction – Technology mature, but safety issues with the use of nitrobenzene as a solvent and large volume caustic/acid interactions pose too much risk.

- Elutable Ion Exchange – Technology mature, but resin performance for predictable regenerative capability has not been demonstrated.

- Fractional Crystallization – Technology mature in non-nuclear applications, but remote operation of nine evaporative stages and multiple tens of crystallizers could not reasonably be accomplished.

- Electrochemical Separation – Technology immature, and safety issues involve hydrogen, oxygen, and ammonia gas generation near spark sources.

5.0 Risk Management

Risk Management is vital to the success of any program or project. In order to credibly claim an expectation of success in any activity, it is necessary to investigate potential risk, devise strategies to minimize threats to success, and assess the residual risk. Risk Management was also prescribed as a Team activity in the Charter.

While the Team recognized that Risk Management was a necessary component of all its activities, it also recognized that the detail in which Risk Management could be applied varied with the depth of knowledge available on the alternative technologies. Accordingly, Risk Management was performed in increasing detail as the application of the technologies became better defined. In order to assure objective and uniform assignment of risk, risks were always based on the perceived capability of the technologies to meet the defined Initial Design Input.

The Risk Management techniques applied by the Team were documented in position papers and desktop procedures in order to assure uniformity of application. These techniques were based on the level of detail available in the different phases of Team activity and are best considered by phase. The purpose of this section is to describe the application of risk management to the Identification, Investigation and Selection Phases.

5.1 Identification Phase

The Identification Phase was distinguished as a concentrated effort to identify technologies that could plausibly be considered as alternatives for dispositioning the salt in the SRS HLW Tanks, followed by a screening process to separate those technologies which were either impractical or inferior to closely related alternatives. The two vital components of Risk Management at this point were: (1) screening each alternative methodology or technology for fundamental flaws which would impair its prospects for successful application; and, (2) ranking screened alternative methodologies and technologies within groupings to establish those candidates with the highest likelihood of success within the grouping. The result of the process was to identify a diverse grouping of technologies with clear potential for successful application.

Approximately 140 ideas were submitted to or developed by the Team for initial consideration. As a coarse risk screening, the Team first grouped these ideas into eleven technology categories and examined the categories for obvious disqualifying risks. The screening criteria applied were Technical Maturity (Is the category based on conjecture or founded on proven nuclear applications?) and Practicality (Is it reasonable to believe that a facility based on this technology category can be successfully fielded within both the technical and schedule constraints of the Initial Design Input?). The Team rules for performing this screening were that no category could be eliminated because the Team lacked information (i.e., if there was not enough knowledge to disqualify a category it was accepted) and if any technology within a category was acceptable, the entire category was acceptable. No categories were dropped from further consideration by this screening.

The Team then screened the individual alternative methodologies and technologies. To prepare for this screening the various proposals were individually reviewed for content. Based on this review, proposals based on the same concept were consolidated, as were specific cases of more general proposals.

Five primary criteria, based on the Initial Design Input document, were then prepared. These Criteria were Safety, Schedule, Cost, Science, and Process. The Safety criterion was broken out into subcriteria relating to inherent safety, "licensability," and emissions/wasteforms. The Schedule subcriteria were based on the ability to meet committed tank closure dates. The Science subcriteria addressed scientific maturity and ability to successfully address DNFSB Recommendation 96-1 considerations. The Process subcriteria addressed engineering maturity and the ability to maintain external interfaces (i.e., receive and store existing waste streams and emit acceptable waste streams of its own), meet required attainment rates, and be constructable and maintainable.

The Cost criterion was established at the conceptual level, but the Team had difficulty in establishing a screening cost value. The Team decided to defer establishing a value until the need for such a value became apparent in the screening process. Such a value was not required. The alternative methodologies and technologies which the Team felt could be affected by the Cost criterion had difficulty with other criteria (which were the drivers for the higher cost) and were eliminated without application of the Cost criterion.

Each pro-forma was assigned one of four results based on this screening: Accept, Reject, Included (redundant to or a subset of another alternative), or Hybrid (not successful on its own, but modified or combined with another alternative to create an additional proposal for screening). The "Accepted" alternatives were then ranked within their respective categories and the highest ranked "Accepted" alternatives within each category were carried forward to the Initial List of alternatives for review in the Investigation Phase.

5.2 Investigation Phase

The Investigation Phase was primarily a review of alternatives on the Initial List to establish a grouping of alternatives that were viewed by the Team as fully capable of successful deployment. The focus of this phase was primarily on the scientific/technical and safety attributes of Initial List alternatives although consideration was also given to cost, schedule, and interface issues.

The foundation of Risk Management efforts in this phase was an effort to identify risks. This identification effort included literature surveys, the development of flowsheets for each alternative, including material balances, visits to operating facilities in the United States and abroad which used similar processes (West Valley, Oak Ridge, Hanford, INEEL, Sellafield [BNFL]).

A Preliminary Risk Assessment was then performed based on this foundation and other information available to the Team. The Preliminary Risk Assessment started with the development of detailed checklists from standard Systems Engineering templates. The available templates were reviewed by the Team and modified to reflect risk areas and questions that the Team felt applicable to the mission. The identified risk areas were Technology, Interfaces, Safety, Design, Resources/Conditions, Cost/Schedule, Procurement and Regulatory/ Environmental. Each area had between two and eleven detailed questions to help develop appropriate risks.

Each alternative was then analyzed by the Team. Each area and question on the checklist was applied to the alternative. Where application of the questions revealed a potential risk for an alternative, a Statement of Risk was defined. An "Identification Form" was created for each risk statement. This form contained subjective evaluations of probability and consequence for the risk. Probability and consequence were rated on a scale from zero to one with one being the most probable or highest consequence. Statements of probability and consequence drivers were documented on the form. After the checklist areas and questions were completed for an alternative, the Team reviewed the forms for the alternative to assure that probabilities and consequences were uniformly valued and consistently stated. After the alternatives were completed, the Team performed a consistency review across each of the forms. This review assured that risks were applied to each applicable alternative and that consistent values were used for comparable risks.

Risk handling strategies were then developed for significant risks. Significant risks were defined as those with a product of probability and consequence values of 0.3 or above. Risks found not to be significant were Team reviewed to assure that risk handling strategies were not necessary. The risk handling strategy developed was documented on the identification form and, where applicable, the impacts of the handling strategy on risk probability and consequence were estimated and documented.

The Preliminary Risk Assessment and development of risk handling strategies were primarily useful to the Team as a means of identifying risks associated with the alternatives, understanding the nature of the risks, and developing means to address the risks. This information was used as the basis of the performance of a qualitative assessment of the merits and issues associated with the alternatives and a quantitative Multi-Attribute Utility Analysis (MAUA) of the alternatives used in the selection process.

5.3 Selection Phase

The Selection Phase emphasized the translation of program risk into cost impact. This required that risks be identified to some level of detail, risk handling strategies be developed and costed, and consequences be quantified. Risks, strategies, and consequences were viewed from both a quantitative and qualitative perspective. The quantitative review addressed project and life cycle cost contingency analysis, project and life cycle cost overrun probabilities and unique uncertainties deriving from the nature of the individual Short List alternatives. The Team drew upon its own expertise, the resources of SRTC, ORNL, ANL, Texas A&M University, Purdue University, and the University of South Carolina; the expertise of technical and programmatic Subject Matter Experts from SRS, the DOE Complex, and BNFL; and the skills of experienced project estimators and SRS HLW System financial analysts during this phase.

The foundation of Team activities was the further detailed development of information concerning the perceived program risks and the definition of the programmatic baseline. R&D activities were commissioned to obtain the data necessary to clarify identified risks and determine the likelihood of success for proposed risk handling strategies. The Flowsheet Team refined its Investigation Phase products regarding the Short List alternatives and advanced to pre-conceptual layouts for the alternatives. These layouts were used by project estimators to arrive at facility TEC and OPC estimates. Additionally, the pre-conceptual information and Team-generated operating cost information was used by SRS HLW financial analysts to assess the life cycle costs for the proposed facilities and the impact of the alternatives on the cost of operation of the SRS HLW System.

In parallel with these activities, the Team reviewed risks identified in earlier phases and worked with a variety of experts to identify additional risks. In the technical arena, the Team met to identify technical risk from its knowledge of the Short List alternatives, the risks identified in the Investigation Phase, a review of the trip reports of visits to facilities involved with the technologies, and the Work Scope Task Definition document. In addition, the Team convened four days of technical Subject Matter Expert meetings to individually review the four alternatives for potential additional risks. Following these meetings, the Team met to review issues identified by the Team and the technical Subject Matter Experts to confirm that the risks were real and relevant to the selection process. The risks emerging from this confirmation were then categorized into project uncertainties, design considerations and filed items. The evaluation of project uncertainties is discussed further in this section and in detail within Section 8.0 (Uncertainties). Design considerations were captured as design input to assure that the design process resolved any concerns associated with the issue. Filed items were concerns that were either redundant or did not rise to the level of a significant uncertainty for an alternative that were captured and documented for future reference to assure that the item did not impact the project.

In parallel with the work on technical risks, a meeting of programmatic Subject Matter Experts was convened to review the Short List alternatives from a programmatic perspective. Issues were raised in this review that impacted both individual alternatives and groups of alternatives. The risks emerging from this review were then categorized into project uncertainties, design considerations, and filed issues.

A Monte Carlo analysis was also performed to determine the Life Cycle Cost contingency estimate for each Short List alternative. The same methodology was used for this analysis as was used for the TEC and OPC contingency estimates. Since contingency estimates are not normally made for life cycle cost analyses, the estimators performed more of an advisory role for the estimate. The estimators and financial analysts proposed parameters for use in the analysis and advised the Team as it made the final parameter selection and prepared the parameter probability distributions. The Monte Carlo analyses provided a range of contingency estimates with “probability of exceeding” values associated with the values. The Team chose to use the 50% (probability of project cost exceeding the estimate if this contingency value is used) value to define the “point” values for TEC, OPC, and Life Cycle Cost estimates for the Short List alternatives. A cost estimate “box” was defined for each alternative from the Monte Carlo data. The box indicated the range of costs for which the probability of exceeding the estimates was less than 60% and more than 20%. The 20% upper-bound value was chosen because of the known aggressive nature of the project with regard to funding and contracting within government system. The lower bound value was selected based on the pre-conceptual nature of the information used to prepare the estimate and is typical of commercial practice. The cost and schedule estimating process is described in detail within Section 7.0 (Cost/Schedule and Systems Integration).

Technical and programmatic uncertainties carried forward in the selection process were then evaluated for impact on program cost and schedule. The Team reviewed each of the risks and estimated the potential cost and schedule impact of the uncertainties. Typically, a risk would be assumed to result in an unfavorable outcome, which required a change or delay in the program. The cost of the change and the duration of the delay were estimated and documented for each of the identified uncertainties. It should be noted that some favorable uncertainties were also identified, cases in which a possible cost and/or schedule improvement could occur. Favorable uncertainties were tracked separately from unfavorable uncertainties.

The schedule impacts of uncertainties were then individually analyzed for impact on the project schedule. This individual analysis was required in order to account for uncertainties that did not affect the critical path (or impacted the critical path for less than the full amount of its uncertainty) and for schedule uncertainties that impacted the critical path in a parallel rather than a series fashion. After the total impact on project schedule was established for each alternative, the schedule uncertainty was converted into a cost uncertainty based on life cycle cost analysis. The conversion factors were in millions of constant dollars per year operating system life:

Direct Disposal as Grout	$395 M/year delay
Caustic Side Solvent Extraction	$420 M/year delay
Small Tank TPB Precipitation	$415 M/year delay
CST Non-elutable Ion Exchange	$410 M/year delay

The monetary value of the positive and negative schedule impacts were then applied to the point estimates for the alternative life cycle costs to establish the quantitative measure of project risk for each alternative. The cost uncertainties, without schedule impact, were small compared to the life cycle cost contingencies and the defined limits of the point estimates, represented by the “box”. Application of these uncertainty components separately was considered “double-counting”. The application of uncertainty is described in detail within Section 8.0 (Uncertainties).

The Team then reviewed each alternative qualitatively with regard to the information gathered during the Team activities. The qualitative assessment was important in assuring that each alternative was evaluated as a whole and not merely as a summary of individual components. The qualitative review allowed each of the alternatives to be viewed in full perspective, permitting a subjective ranking and comparison to the ITP baseline flowsheet. This activity was considered vital to avoid the selection process being driven by individual details rather than holistic views of the alternatives. This qualitative review is described in detail within Section 9.0 (Selection).

The results of both the quantitative evaluation of project TEC, OPC, and Life Cycle Cost and the qualitative evaluation of the alternatives was carried into the final selection process. The final selection process is described in detail within Section 9.0 (Selection).

6.0 Flowsheet Development

The purpose of this section is to discuss the Team approach to the preparation of flowheets and the supporting research and development effort. This discussion is significant because the flowsheets formed the basis for technical viability of the Initial List alternatives and were the foundation for the cost and schedule estimates to implement the Short List alternatives.

6.1 Identification Phase

During the Identification Phase, approximately 140 salt disposition concepts were received by the Team. Many of these concepts were supported with some level of technical detail from the authors. Based on this information and expertise of the Team, and particularly that of the Flowsheet Team, simple process diagrams were prepared for the Initial List alternatives. These diagrams served as the basis of later flowsheet development.

6.2 Investigation Phase

To evaluate the technical aspects of the Initial List alternatives, a preliminary flowsheet for each alternative was completed and used to ensure alternatives were compared in a consistent technical manner.

The flowsheets were developed utilizing a structured method of analysis and assessment. They provide information on a specific process system and integration of that system with existing interfaces. Each process flow diagram (PFD) depicts the various flow paths of the process system, material balances, tabular data (such as flow rates, cycle time, etc.) and major pieces of equipment.

In order to provide the flowsheets for the Initial List alternatives during the Investigation Phase, global and specific bases and assumptions were defined and documented for each alternative. These assumptions were based on the technical information/data available for the various processes as well as the expertise of the Flowsheet Team. In addition, information gathered on site trips was used as input. Table 6-1 identifies the sequence of site visits and the technologies reviewed.

Table 6-1: Field Confirmation Trips

Site Visited	Technology Reviewed
British Nuclear Fuels plc (BNFL) – Sellafield – Salford Quays (Engineering)	Non-elutable Ion Exchange Solvent Extraction HLW Vitrification Immobilization in Grout Precipitation and Filtration
Hanford	Fractional Crystallization Non-elutable Ion Exchange Elutable Ion Exchange Precipitation Solid – Liquid Separation
Idaho National Engineering and Environmental Laboratory (INEEL)	Acid Side Solvent Extraction Acid Side Ion Exchange
West Valley Nuclear Services (WVNS)	Zeolite Non-Elutable Ion Exchange HLW Vitrification
Oak Ridge National Laboratory (ORNL)	CST Non-Elutable Ion Exchange Elutable Ion Exchange Resin Slurry Management and Handling

Due to the complexity of the alternatives and details required, the Flowsheet Team developed mathematical models and PFDs to provide a level of material balance and flow stream analysis that supported the Investigation Phase evaluation process. The engineering calculations and models were developed from consistent bases, assumptions, and constraints with as many common unit operations as possible.

During the Investigation Phase, the calculated variables were limited to material balances such as cycle times, mass and volumetric flow rates entering and exiting each alternative, emission levels, waste work-off schedules, and final wasteform production rates. This defined approach to modeling met the requirements documented for the Investigation Phase and ensured the models developed could be used as a starting point for Selection Phase flowsheet efforts.

6.2 Selection Phase

The flowsheets for the Short List alternatives were initially developed from the basis established by the Investigation Phase flowsheet efforts. The Selection Phase model and engineering calculation results were used to produce equipment lists, equipment sizing, and building layout requirements. These pre-conceptual equipment lists and sizing and building layout information were used to estimate the project and life cycle costs for each Short List alternative. The Selection Phase revised material balances were used to verify that the equipment sizing, layouts, and cost for each of the options was accurately reflected for bounding waste stream conditions.

The material balances, and any required energy balances for determining expected flowsheet performance, incorporated additional data obtained from Selection Phase research efforts to reduce uncertainties and substantiate assumptions defined in the Identification Phase. The process equipment identified in the Selection Phase flowsheets, such as tanks and ion exchange columns, were defined to a greater level of detail. Where feasible, actual dimensions, based on existing equipment characteristics and thermodynamic values, were considered in the development of the models.

The additional experimental data was developed at SRTC, ORNL, ANL, Texas A&M University, Purdue University, and other facilities as defined in the Work Scope Task Definition document (e.g. Figure 6-1).

The models, developed in the Selection Phase, describe the alternative processes mathematically by way of differential and algebraic equations used to represent system components and performance. The models were developed from consistent bases, assumptions, and constraints with as many common unit operations as possible. Engineering calculations and the Aspen Corporation SPEEDUP™ dynamic modeling product were used to execute the models and generate the performance results and material balances for the alternatives.

Completion of the flowsheet effort during the Selection Phase required additional information. The Work Scope Task Definition document was developed and distributed by the Team to identify specific work activities for the Engineering, Research and Development, and Safety Management support organizations. Each work activity was directly related to information needed by the Team to assess the alternative layout, cost estimates, schedules, and application of uncertainty for each alternative.

Through the use of a “Road Mapping” approach (e.g. Figure 6-2), a logical and consistent plan of action was applied to the scope of work activities for each of the alternatives and an Engineering Integrated Commitment Matrix (e.g. Figure 6-3) was developed for managing outstanding items, work activities, deliverables, and plans.

GROUP	***ITEM***	***TYPE***	***SOURCE***	***REQ'D? for Phase III***	***CONSIDERATIONS***	***PATH FORWARD***	***RESPONSIBLE ORGANIZATION***
Non-Elutable IX							
Engineering	1. Slurry handling particle degradation column sluicing fines generation & capture slurry rheology/change with particle size settling/resuspension/ min transfer velocity samplin erosion	Risk; Facility Design	6.D.4-1 & 6.A.3-2	Yes	All aspects of CST/water slurry handling must be understood prior to final facility design. High risk of expensive and complex design (R/A 6.D.4-1) is mitigated by equipment design based on cold full-scale testing. Tests at ORNL funded by TFA are planned to investigate slurry handling for using CST to treat DWPF recycle.	*Preliminary studies using the CST loop at Oak Ridge and/or existing facilities at TNX will be performed to provide guidance on the difficulty of handling CST slurries.* Long term flow testing will be started at risk.	SRTC
Chemistry	2. CST equilibrium curve solution/CST equilibrium data at low [Cs] effect of [K], [Na], [OH], [NO_3], temp effect of feed comp Δ's	Assumption: 1) 75% of max from McCabe tests, 2) only Cs is adsorb-ed on CST	Bases, Assumptions & Results document	Yes	Equilibrium curve provides driving force term for mass transfer. Have data for SRS waste as f([Cs]) at high concentrations but not at low. Data is needed for mass transfer coefficient, column sizing, material balance, tank retrieval scheduling. Estimates of effects of [K], [Na], etc., on equilibrium curve can be estimated from SNL/TAM model.	Use existing data to estimate non-linear equilibrium curve at low [Cs] concentration. Obtain equilibrium data at low [Cs] for SRS-type waste. Determine if TAM model can be used to estimate effects of other parameters. Obtain new test data at low [Cs] concentration	Flowsheet Team SRTC SRTC
Chemistry	3. Adsorption kinetics/ column sizing velocity & effect of Δ's length Cs loading in lead column guard column length/DF particle size, resin density pressure drop control strategy	Assumption: at 2.6 cm/ min –75% of max in lead colm; guard colm long enough for DF of 20,000	Bases, Assumptions & Results document	Yes	Continuing concern regarding long breakthru curve at relatively low velocities –may have poor kinetics/mass transfer. Dynamic model (with equilibrium curve) can be used to evaluate mass transfer coefficients from column data and then to determine approximate column dimensions, CST loading, etc., for FDD and flowsheet evaluations	Immediately begin evaluation of mass transfer and column sizing with existing data using Beck's dynamic model with non-linear equilibrium curve (in preparation). In parallel, pursue use of existing models (TAM or Purdue) for post-Phase III use. Set up meeting with Wang and/or Anthony to discuss models, existing data sets, and immediate data needs. Perform column tests on SRS-type waste to provide data for models and evaluate mass transfer coefficients.	Flowsheet Team SRTC

Figure 6-1: Example of a Work Scope Task Definition Document

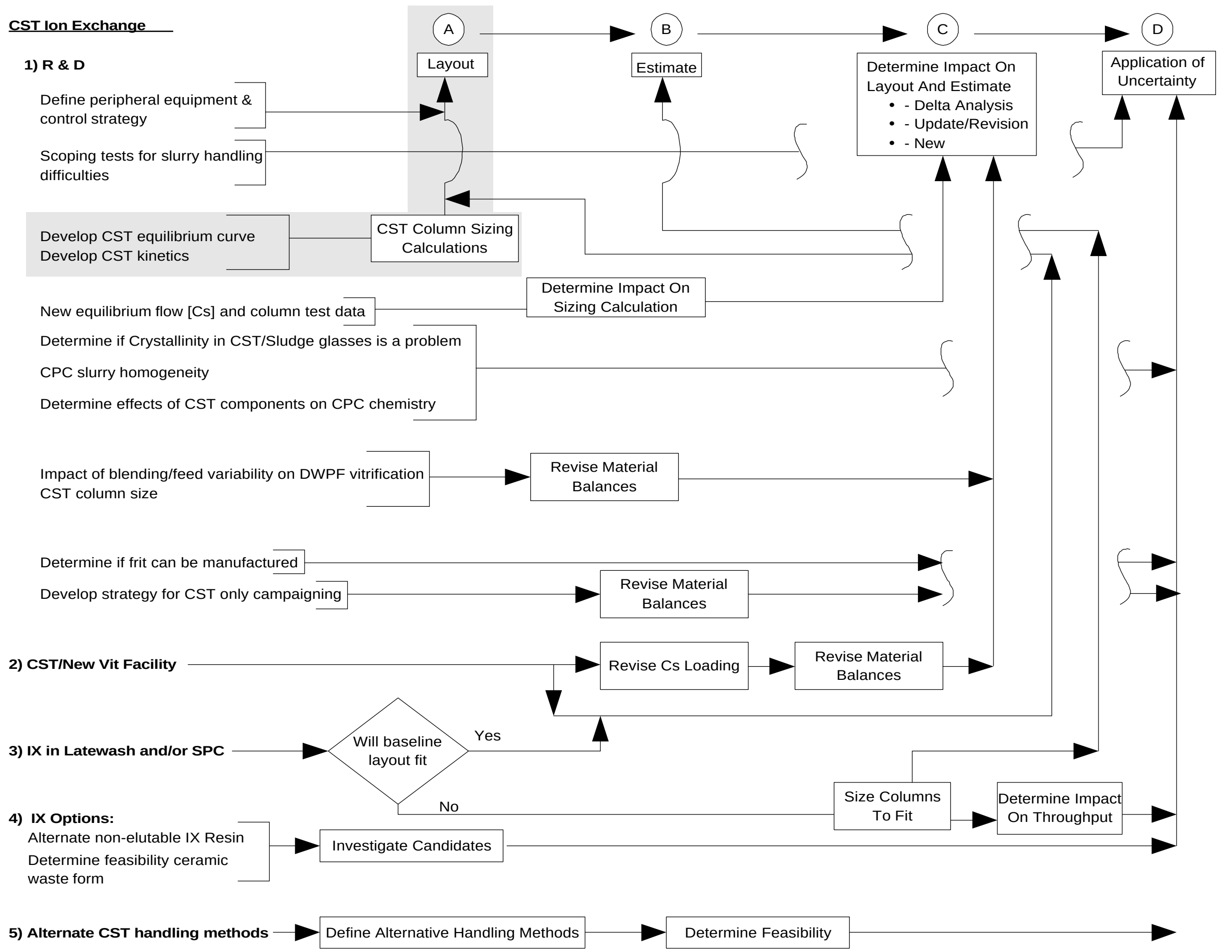


Figure 6-2: CST Non-Elutable Ion Exchange

GROUP	*ITEM*	*REQ'D? for Phase III*		*DELIVERABLES*	*RESPONSIBLE ORGANIZATION*	*TASK SHEET APPROVED?*	*TEST PLAN DOCUMENT NUMBER*	*Comments*	*Completed R & D Reports*	*Section of B,A,&,R which incorporates ICM commitments*
Non-Elutable IX										
Engineering	1. Slurry handling particle degradation column sluicing fines generation & capture slurry rheology/change with particle size settling/resuspension/ min transfer velocity samplin erosion	Yes	–	– SRTC Report.	SRTC	Not Received		Information per Roy Jacobs received 8/26/98	SRT-WHM-98-0019	None
Chemistry	2. CST equilibrium curve solution/CST equilibrium data at low [Cs] effect of [K], [Na], [OH], [NO_3], temp effect of feed comp Δ's	Yes	–	– BA&R Document – BA&R Document – SRTC Report	Flowsheet Team SRTC SRTC	NA Yes Yes	NA WSRC-RP-98-00732 WSRC-RP-98-00732	- Information per Roy Jacobs received 8/26/98 Information per Roy Jacobs received 8/26/98	WSRC-RP-98-01051, Rev 0 WSRC-TR-98-00344, Rev 0 WSRC-TR-98-00344, Rev 0	3.4.2.2
Chemistry	3. Adsorption kinetics/ column sizing velocity & effect of Δ's length Cs loading in lead column guard column length/DF particle size, resin density pressure drop control strategy	Yes	–	– BA&R Document – SRTC Report	Flowsheet Team SRTC	NA Yes	NA WSRC-RP-98-00732		WSRC-RP-01053, Rev 0 WSRC-TR-98-00343, Rev 0 . Includes reports from TAN and Purdue WSRC-TR-98-0344, Rev.0	3.4.2.3

Note: Columns "Considerations" and " Path Forward" are not shown in this example to accommodate for paper size. However these columns are presented in Figure 6-1.

Figure 6-3: Example of Engineering Integrated Commitment Matrix

The Engineering Integrated Commitment Matrix (ICM) is a modified version of the Work Scope Task Definition document used by the Team. The ICM serves as a tracking tool for management of the work scope tasks/road map items.

For example, Item 3 of Figure 6-1 defines the work activity for identifying the adsorption kinetics (column sizing velocity) and effects of varying column lengths on the cesium loading onto the CST resin. A concern established by the Flowsheet Team was that a long breakthrough curve at low velocities may produce a poor mass transfer.

As shown in Figure 6-2, a logic path exists on the "Road Map" for the application of the CST equilibrium curve and kinetics data to drive column sizing and, ultimately, CST process layout (Area "A" on Figure 6-2). The "Road Map" thereby served the Team by illustrating the application of work scope tasks to the selection process.

The path forward approach taken by the Flowsheet Team was to develop a column sizing model and resulting calculation to address this issue. An evaluation of the mass transfer and column sizing effects was established in conjunction with models produced at Texas A&M University and Purdue University. The appropriate fields of the ICM were completed to track the progression of work activities.

The disciplined approach for the development of flowsheets within the framework of approved procedures permits the products of the effort to be used as a starting point for the conceptual design process. These products include:

- The Bases, Assumptions and Results of the Flowsheet Calculations for the Short List Salt Disposition Alternatives (report)
- R&D reports
- Pre-Conceptual Design Package
- Facility Design Description, Chapter One

7.0 Cost/Schedule and Systems Integration

The purpose of this section is to integrate the final four salt disposition alternatives into the HLW System and provide cost estimates for each salt disposition alternative. This Section will provide:

- Cost Estimates Overview
- Technical Integration of the Alternatives into the HLW System
- Total Project Cost Estimates and Contingency Analysis
- Project Schedules
- Required Cash Flows for the Total Project Cost to Attain the Schedules
- Operating and Maintenance Cost for the Alternatives
- D&D Cost for the Alternatives
- Life Cycle Cost for the Alternatives
- Production Model Analysis
- Life Cycle Cost for the HLW System
- Application of Contingency to the Alternatives Life Cycle Cost
- Development of the LCC Point Estimate and Contingency

7.1 Evolution of Cost Estimates

During the Identification Phase, approximately 140 alternatives were screened to produce the Initial List of eighteen alternatives to be carried forward to the Investigation Phase. Cost was considered as a screening criterion, but a specific value was difficult to establish and did not have to be applied. However, screening criteria relating to schedule were used to identify those alternatives that could not meet the schedule requirements.

During the Investigation Phase, a coarse preliminary LCC analysis was performed. The cost figures generated for the eighteen alternatives were not of budgetary or pre-conceptual cost study quality and were used as a selection criterion. A preliminary LCC estimate was developed for each Initial List alternative. The estimate permitted the comparison of the alternatives on an equivalent cost basis. Future projected costs were discounted to their present worth.

Investigation Phase estimating techniques included scaling from existing facilities such as DWPF, use of prior estimates (from DWPF studies and Hanford) for Ion Exchange Facilities, and expert opinion. Major operating cost variants from the baseline amount (such as the amount of grout to be produced at the Saltstone Facility and the number of canisters to be produced at DWPF) were also considered. Engineering definition was limited to flowsheet parameters developed during the Investigation Phase.

The Investigation Phase LCC estimates are summarized in Table 7-1.

Table 7-1: Preliminary Life Cycle Cost Estimate Summary

Alternative	**Less than $ 2 billion**	**$2 billion to $ 4 billion**	**$4 billion to $8 billion**	**$8 billion to $16 billion**	**Excess of $16 billion**
Vitrification			X		
Electrochemical Separation and Destruction – DWPF Vitrification				X	
Elutable Ion Exchange – DWPF Vitrification		X			
Potassium Removal followed by TPB Precipitation		X			
Acid-side Ion Exchange – DWPF Vitrification		X			
Crystalline Silicotitanate (CST) Ion Exchange – DWPF Vitrification		X			
Crystalline Silicotitanate (CST) Ion – New Facility Vitrification			X		
Zeolite Ion Exchange – DWPF Vitrification			X		
Crystalline Silicotitanate (CST) Ion Exchange – Ceramic Wasteform		X			
Reduced Temperature ITP	X				
Catalyst Removal ITP	X				
ITP with Enhanced Safety Features		X			
Small Tank TPB Precipitation	X				
Caustic Side Solvent Extraction – DWPF Vitrification		X			
Acid Side Solvent Extraction – DWPF Vitrification			X		
Direct Vitrification					X
Supernate Separation – DWPF Vitrification				X	
Direct Disposal as Grout	X				

During the Selection Phase the Team was focused on cost and schedule as bases for the comparison of alternatives and the selection of the preferred alternatives. Figure 7-1 shows the process of cost and schedule development and integration during the Selection Phase.

Sections 7.2 through 7.11 describe in detail how cost and schedule information was developed for subsequent use in the selection process.

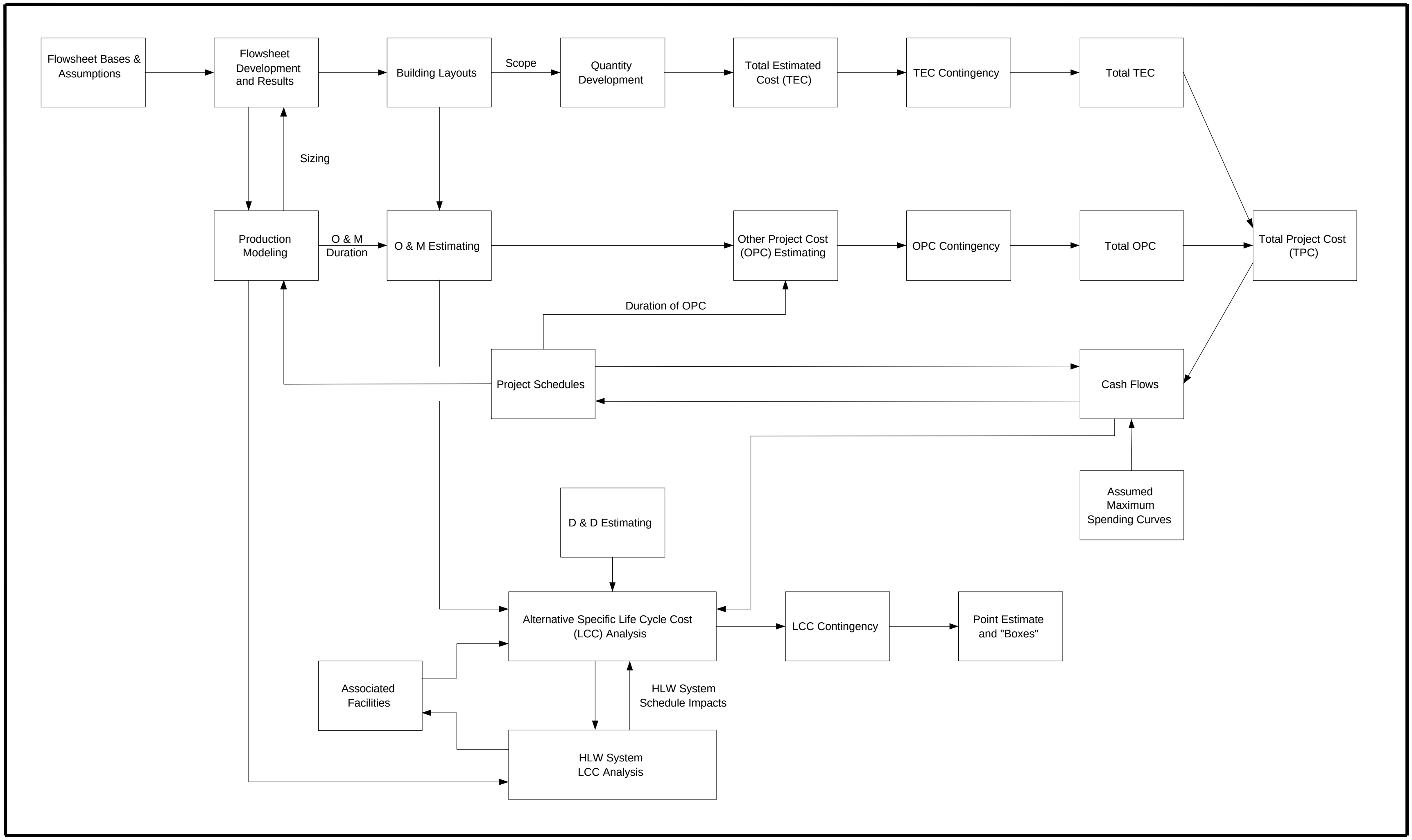


Figure 7-1: Scope and Cost Integration Method

7.2 Technical Integration of the Alternatives into the High Level Waste System

At the beginning of the Selection Phase, each Short List alternative flowsheet was reviewed and modified to ensure the optimum integration into the HLW System.

7.2.1 High Level Waste System Flowsheet

The HLW System at SRS is a highly integrated group of facilities designed to:

- Safely store existing HLW as well as receive newly generated HLW
- Evaporate influents to reduce volume and maximize tank storage capacity
- Remove both sludge and salt HLW from tanks and pre-treat it prior to disposal
- Vitrify the HLW component into borosilicate glass at the DWPF facility
- Dispose of the low level waste component at the Saltstone Facility
- Store vitrified glass canisters pending the opening of a Federal Repository
- Close waste storage tanks once they have been emptied of waste

Since the salt processing alternatives being evaluated in this report are intended to be an integral part of this system, the impact of the various alternatives on the rest of the system, especially the impact on the waste removal schedule, is important.

7.2.2 Planning Methodology

To ensure proper integration and planning of the HLW System, WSRC uses a family of computer simulations to model the operation of the entire system. Each computer simulation is designed to address different aspects of long range production planning. For each of the four salt processing alternatives being analyzed, these computer simulations were used to model the operation of the HLW System including the proposed salt processing alternative.

- The Waste Characterization System (WCS) documents the chemical and nuclear composition of the waste in each of the 51 HLW tanks. For each of the four salt processing alternatives being analyzed, the analysis used WCS data as of August 3, 1998.
- The Chemical Process Evaluation System (CPES) and Product Composition Control System (PCCS) are used to ensure that sludge batches are of a proper composition to produce glass that meets quality specifications. For each of the four salt processing alternatives being analyzed, this analysis used data from an early FY98 run of these models. While data from this run was not fully consistent with the August 3, 1998

WCS, an analysis confirmed that the results of the previous CPES and PCCS results were not significantly impacted.

- The Production Model (ProdMod) is a linear equation model that uses SPEEDUP™ software to calculate material transfers and HLW System processing by year through the end of program. For each salt processing alternative, ProdMod was modified to reflect the operating parameters and was used to predict operations of the HLW System, by process and by year through the end of the program including material balances by tank.

7.2.3 Integration of Alternative Flowsheets

In the Selection Phase, the flowsheets from the Investigation Phase were analyzed to ensure that each flowsheet and technical basis met the following:

- The Technical constraints of the HLW System
- The Technical constraints of each individual alternative
- The Life cycle cost of the HLW System

Based on this analysis, each flowsheet and technical basis was modified to provide the best opportunity for success.

7.2.3.1 High Level Waste System Technical Constraints

There are five HLW System Technical Constraints in the HLW System that must be considered to optimize each flowsheet:

- *Vitrification Processing Schedule* - A melter failure is projected to occur after two years of operation in the Vitrification Facility and expected to require a six-month outage for removal and replacement of the melter.
- *Vitrification Maximum Processing Rate* -The maximum vitrification processing rate is estimated to be 320 canisters per year during a full operating year. Based on the vitrification processing schedule that includes a six-month outage after every two years of operations, a 320-canister rate for a full operating year equates to an average of 256 canisters per year over the life of the program. The 320-canister rate is based on the sustainable melt rate at the facility in FY98.
- *Vitrification Minimum Processing Rate* - The minimum vitrification processing rate is 200 canisters per year based on the STP regulatory requirement that the Vitrification Facility produce an average of 200 canisters per year.

- *Salt Processing Cell Rate* - The Salt Processing Cell (SPC) processing rate constraint is based on batch processing times. This constraint applies only to the Small Tank TPB alternative (which is the only alternative that uses the SPC). The time required to process precipitate in the SPC essentially limits the precipitate feed to the Vitrification Facility to a maximum of 406,000 gallons per operating year (or 325,000 gallons per average year, including the six-month melter outages). The average annual canister production rate is 210 canisters per average year.

- *Tank Farm Feed Production Rate* - The salt solution feed rate from the Tank Farms is limited to an average of six million gallons per year (6.44 M Na). This limit is determined by the number of waste transfers that can be supported by the transfer lines and diversion boxes which interconnect the tanks.

  The six million gallons maximum feed per year effectively limits the production capacity of three of the four salt alternatives. Based on the differing production schedules of the four salt alternatives, this feed rate translates into a salt work off rate during an operating year of the following:

  - **Caustic Side Solvent Extraction and CST Ion Exchange:** 6.9 million gallons of salt feed can be worked off per operating year for the Caustic Side Solvent Extraction and CST Ion Exchange alternatives which both operate for two months during the melter outages. (In thirty months there will be fifteen million gallons of feed available which these alternatives will work off in 26 months, at a rate of 577,000 gallons per month or the equivalent of 6.9 million gallons per operating year).
  - **Direct Disposal in Grout:** six million gallons of salt feed can be worked off per operating year for the Direct Disposal in Grout alternative, which operates during melter outages. This alternative works off the six million gallons as it becomes available regardless of any melter outages.
  - **Small Tank TPB Precipitation:** 7.5 million gallons of salt feed per operating year can be provided to the Small Tank TPB alternative, which does not operate during melter outages. (In thirty months this alternative would have to work off fifteen million gallons of feed in 24 operating months, a rate of 625,000 gallons per month or the equivalent of 7.5 million gallons per twelve-month operating year in order to process the available feed.) However, the production capacity for this alternative is limited to 6.5 million gallons of salt solution per operating year by the SPC rates.

7.2.3.2 HLW System Life Cycle Cost

The lowest Life Cycle Cost for the system results when the system is operated at its maximum capacity, reducing the total number of years of the program. Therefore, each flowsheet was sized at its maximum rate consistent with the HLW System constraints for that alternative, as depicted in Table 7-2.

Table 7-2: Flowsheet Throughputs

Salt Workoff @6.44 M [Na+]		**Design Basis**		
Alternative	**75% Attainment**	**Annualized Rate** **(12 months of operations)**	**Na Molarity**	**Flowrate**
Caustic Side Solvent Extraction	17.5 gpm	6,900,000	6.44	17.5gpm
CST Non-Elutable Ion Exchange	17.5 gpm	6,900,000	5.6	20.1gpm
Direct Disposal in Grout	15.2 gpm	6,000,000	6.0	100 gpm
Small Tank TPB Precipitation	16.5 gpm	6,500,000	6.44	16.5gpm

7.3 Total Project Cost and Contingency Analysis

Total Project Cost (TPC) is defined as the sum of the Total Estimated Costs (TEC) and the Other Project Costs (OPC) for a facility. This section discusses the TPC estimating processes and results. Additional details are documented in the “Estimate Preparation, Pre-Conceptual Scheduling and Life Cycle Cost Analysis Procedure” and the “Life Cycle Cost Estimate Bases, Assumptions, and Results”.

Table 7-3 displays the results of the TPC estimates for the Short List alternatives in constant year dollars*:*

Table 7-3: TPC Estimates
(Millions of FY99 Constant Year Dollars)

Alternative	TEC	OPC	TPC
Caustic Side Solvent Extraction	872	490	1,362
CST Non-Elutable Ion Exchange	768	418	1,186
Direct Disposal in Grout	634	274	908
Small Tank TPB Precipitation	692	378	1,070

7.3.1 Total Estimated Costs (TEC)

Total Estimated Costs (TEC) are comprised of engineering, construction, project management, Savannah River Site (SRS) markups, and other support services costs. Engineering costs include design and systems engineering activities following conceptual design. Construction costs include labor, materials (permanent and consumable), construction equipment, and other items typically considered as "direct" construction costs. Project management costs include project management, project controls, quality assurance, and other services required for management of the engineering and construction activities.

The estimating process for the TEC is comprised of the following steps:

- Obtain initial pricing data and estimate structure
- Load cost estimating software
- Review/adjust unit pricing and rates
- Develop quantities
- Review

7.3.1.1 Obtaining Initial Pricing Data and Estimate Structure

The initial pricing data and estimating structure used to evaluate alternatives was developed from a structure previously generated for the Tank Waste Remediation System (TWRS) at Hanford. The TWRS pricing data included assumptions and calculations for quantity development based on given parameters such as quantity of HVAC materials per cubic foot of building volume and quantities of rebar per cubic yard of concrete. The TWRS estimate structure provided the basis to identify common cost components to facilitate comparison of the alternatives.

7.3.1.2 Loading Cost Estimating Software

In order to ensure correct application of SRS estimating practices and markups, the initial pricing data and estimate structure were entered into the "Success" cost estimating system which is the standard cost estimating software used at SRS. Quality checks were performed on the software to ensure that results were accurate and reasonable based on the input used.

7.3.1.3 Review/Adjustment of Unit Pricing and Rates

In addition to using the "Success" cost estimating software to assure consistency with SRS estimating practices and markups, input was obtained relative to SRS unit pricing, labor rates, and productivity assumptions from other SRS organizations.

7.3.1.4 Quantity Development

Quantity development was performed based on flowsheets and pre-conceptual building layout drawings. Allowances were made for common engineered systems not appearing on the pre-conceptual flowsheets. Additionally, meetings were conducted with Team personnel to define the scope for each alternative. Scope descriptions were generated that defined the facilities and associated process equipment in general terms. Using the structure previously generated for TWRS, further quantity development was performed based on these scope descriptions. The estimating structure was used for parameters, such as the amount of lighting per square foot and other semi-detailed parametric estimating approaches. Scope descriptions and associated quantity development data for each alternative were routed to the Team for concurrence.

The estimates for engineering, project management, and other "soft" costs within the TEC were developed using a parametric approach due to the limited design information expected at this stage of a project schedule. The parametric approach uses data from other projects adjusted for each alternative. Data were obtained from other estimated and actual projects at SRS similar in nature to each of the alternatives. Further, input was received from WSMS for items typically under their work scope.

7.3.1.5 Review

Following the quality check of the estimating software and the generation of the estimates based on the pricing and quantity development steps, the Team reviewed the estimates in detail to assure that technical and business changes had been incorporated to their satisfaction. Such estimate review included review of pricing factors, material take-offs, pricing, and labor productivity assumptions.

7.3.2 Contingency Analysis on TEC

Contingency is that portion of a cost estimate used to cover uncertainties associated with the level of design completion, unit price variations, productivity variations and quantities. Cost contingency is planned to be expended during the course of the project and is not intended to cover costs associated with major scope changes or fluctuations in predicted escalation rates.

Following the review and acceptance of the estimate for a particular alternative by the Team, a contingency analysis was performed using “Rac-8”, a Bechtel-developed program for contingency analysis which has been successfully used for over 30 years. The program uses Monte Carlo simulation to produce risk analysis curves for use by management in the decision process to establish the amount of contingency to include in a cost estimate. Quality checks were performed on the software to ensure that results were accurate and reasonable based on the input used.

The contingency analysis included such factors as scope definition (including safety and functional classification complexities and safety strategy assumptions), labor productivity (including consideration of complexities), and potential changes in actual versus estimated pricing of materials.

Figure 7-2 below, provides an example of the output from the Monte Carlo simulation and displays the results of the “Rac-8” analysis for the Caustic Side Solvent Extraction alternative.

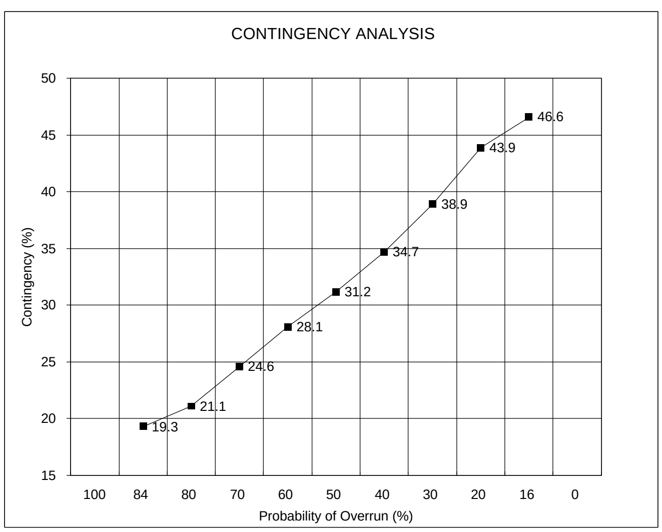


Figure 7-2: Monte Carlo Analysis for Caustic Side Solvent Extraction

As part of the contingency analysis process, the Team determined that the 50% probability point from the Monte Carlo analysis would be applied to the TEC estimate prior to input to the LCC. The reason to use the 50% probability point can be stated in common terminology as "To ensure a fifty percent probability that the project cost will not be overrun, apply the contingency percentage from that point on the curve to the TEC". Additionally, SRS uses the 50% confidence level in most TEC estimates.

Table 7-4 below, shows the TEC with the amount of contingency required to achieve a 50% probability that the project TEC will not be overrun.

Table 7-4: Total Estimated Cost
(Millions of FY99 Constant Year Dollars)

Alternative	Contingency for 50% Probability	TEC w/ Contingency
Caustic Side Solvent Extraction	31.2%	872
CST Non-Elutable Ion Exchange	30.7%	768
Direct Disposal in Grout	31.9%	634
Small Tank TPB Precipitation	33.0%	692

7.3.3 Other Project Costs (OPC)

Other Project Costs (OPC) are primarily comprised of operations activities prior to completion of construction as well as laboratory process development costs including research and development, bench-scale testing, and prototype testing. Other activities that are funded under OPC include conceptual design, preparation of required documentation (performance/design/hazard assessment reports and operating procedures), Operational Readiness Review (ORR) and other activities not funded under the TEC.

The OPC costs for the Short List alternatives were estimated using ratios of OPC versus operating and maintenance costs from other SRS facilities and then adding allowances for R&D activities. This approach recognized that there is insufficient design detail to perform an estimate of these costs using a task analysis basis. Using a ratio from O&M costs and then adding R&D allowances was appropriate because the primary cost drivers for OPC are the number of operational personnel and the cost of R&D activities.

7.3.4 Contingency Analysis on OPC

The contingency analysis was performed using the "Rac-8" Monte Carlo analysis as described in Section 7.3.2.

Table 7-5 displays the summary OPC including contingency (in millions of FY99 constant year dollars) for each of the alternatives. As was the case for the TEC contingency analysis, the contingency percent to achieve a 50% probability that the project OPC will not be overrun was applied to the OPC estimate prior to input into the LCC analysis.

Table 7-5: Other Project Costs
(Millions of FY99 Constant Year Dollars)

Alternative	Contingency for 50% Probability of no Cost Overrun	OPC w/ Contingency
Caustic Side Solvent Extraction	38.5%	506
CST Non-Elutable Ion Exchange	38.9%	437
Direct Disposal in Grout	38.1%	284
Small Tank TPB Precipitation	38.9%	402

7.4 Schedule

Project schedules for each alternative were developed to ensure that the alternative would be available for operation to support both tank farm operational requirements as well as the schedule of the Federal Facility Agreement for closing waste tanks.

The project schedules for each alternative were developed using activities and key milestones in a generic schedule logic. A generic approach was used because the building footprint for each alternative is similar. This generic schedule logic was developed by using the Key Activities for the Successful Execution of Projects "KASE" software program and consulting with the groups which will perform the work. These groups include Design Engineering, Systems Engineering, SRS Construction, WSMS and startup specialists. The schedules were then given final review and approval by the Team.

All of the schedules share these assumptions:

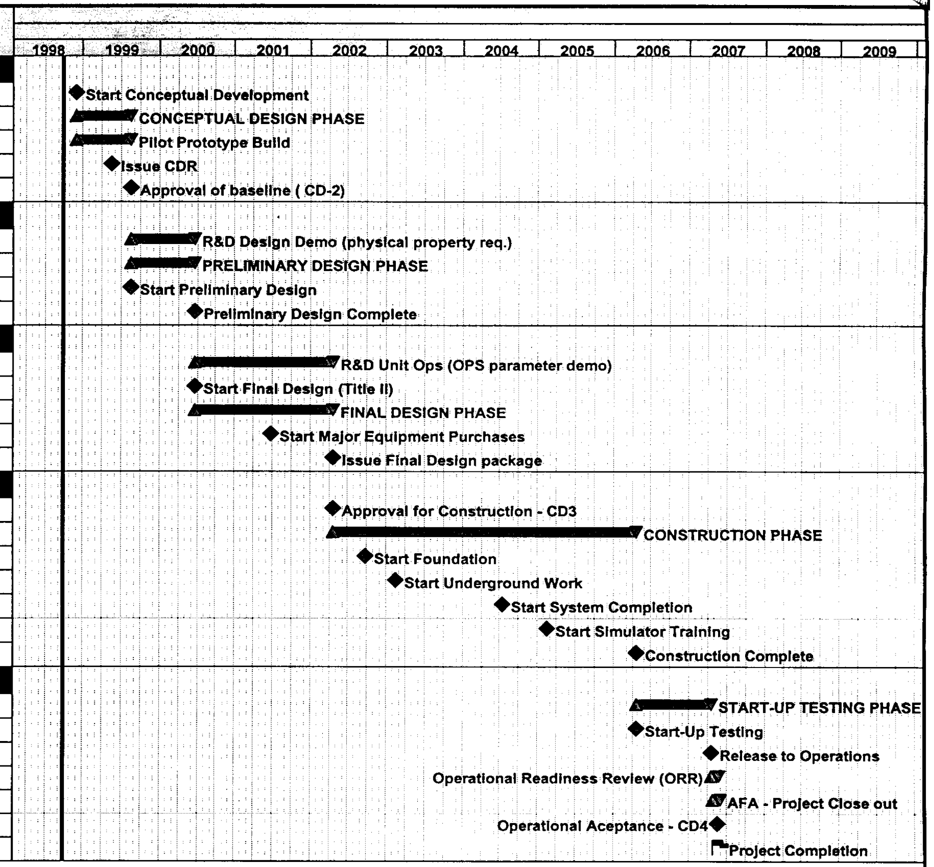
- Work will be done in phases, with each phase ending before the start of the following phase. Thus design will be complete prior to the start of construction.
- The work week during the design phases will be five days.

- During the construction and startup testing phases, work will be performed on a rolling schedule with no breaks for holidays or weekends. A rolling four-day, ten-hours per day, single shift work schedule is projected.
- R&D pilot/prototype development will be done in parallel with engineering activities.
- Preliminary Safety Analysis Report (PSAR) will be completed during the Conceptual Design Phase to the “Safety Strategy” level.
- Necessary reviews and approvals will occur in parallel with other activities, resulting in no delays.

No contingency has been built into the schedule durations.

Summary schedules for each of the alternatives are given in Figures 7-3 through 7-6.

Activity Description	Early Start	Early Finish
CONCEPTUAL PHASE		
Start Conceptual Development	30NOV98*	
CONCEPTUAL DESIGN PHASE	30NOV98	16AUG99
Pilot Prototype Build	30NOV98	16AUG99
Issue CDR		14MAY99
Approval of baseline (CD-2)		16AUG99
PRELIMINARY DESIGN PHASE		
R&D Design Demo (physical property req.)	17AUG99	16JUN00
PRELIMINARY DESIGN PHASE	17AUG99	16JUN00
Start Preliminary Design	17AUG99	
Preliminary Design Complete		16JUN00
FINAL DESIGN PHASE		
R&D Unit Ops (OPS parameter demo)	19JUN00	19APR02
Start Final Design (Title II)	19JUN00	
FINAL DESIGN PHASE	19JUN00	19APR02
Start Major Equipment Purchases	22JUN01	
Issue Final Design package		19APR02
CONSTRUCTION PHASE		
Approval for Construction - CD3	20APR02	
CONSTRUCTION PHASE	20APR02	17APR06
Start Foundation	20SEP02	
Start Underground Work	13FEB03	
Start System Completion	15JUL04	
Start Simulator Training	15FEB05	
Construction Complete		17APR06
START-UP TESTING AND ACCEPTANCE PHASE		
START-UP TESTING PHASE	18APR06	15APR07
Start-Up Testing	18APR06	
Release to Operations		15APR07
Operational Readiness Review (ORR)	16APR07	25MAY07
AFA - Project Close out	21APR07	31MAY07
Operational Aceptance - CD4		20MAY07
Project Completion		31MAY07



Project Start	01AUG97
Project Finish	05SEP07
Data Date	01OCT98
Run Date	14OCT98

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Early Bar
Progress Bar
Critical Activity

EO03

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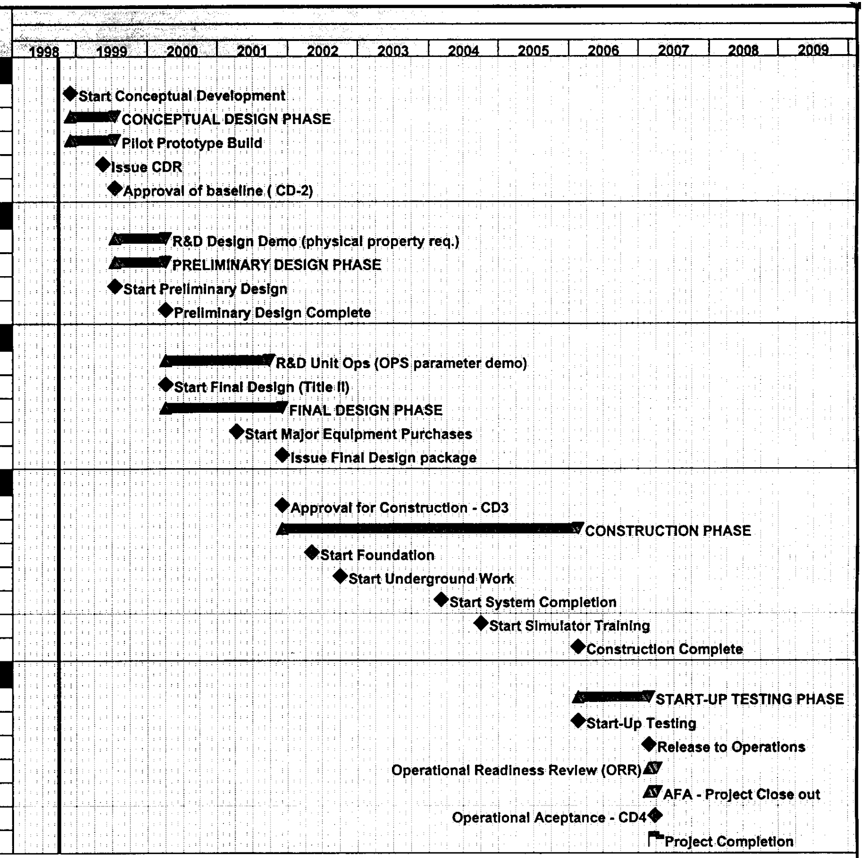
Westinghouse Savannah River Company
SALT REMOVAL PROJECT
SOLVENT EXTRACTION OPTION Summary

Figure 7-3: Caustic Side Solvent Extraction Summary Schedule

Activity Description	Early Start	Early Finish
CONCEPTUAL DESIGN PHASE		
Start Conceptual Development	30NOV98*	
CONCEPTUAL DESIGN PHASE	30NOV98	15JUL99
Pilot Prototype Build	30NOV98	15JUL99
Issue CDR		14MAY99
Approval of baseline (CD-2)		15JUL99
PRELIMINARY DESIGN PHASE		
R&D Design Demo (physical property req.)	16JUL99	31MAR00
PRELIMINARY DESIGN PHASE	16JUL99	31MAR00
Start Preliminary Design	16JUL99	
Preliminary Design Complete		31MAR00
FINAL DESIGN PHASE		
R&D Unit Ops (OPS parameter demo)	03APR00	20SEP01
Start Final Design (Title II)	03APR00	
FINAL DESIGN PHASE	03APR00	03DEC01
Start Major Equipment Purchases	06APR01	
Issue Final Design package		03DEC01
CONSTRUCTION PHASE		
Approval for Construction - CD3	04DEC01	
CONSTRUCTION PHASE	04DEC01	19FEB06
Start Foundation	08MAY02	
Start Underground Work	28SEP02	
Start System Completion	02MAR04	
Start Simulator Training	30SEP04	
Construction Complete		19FEB06
START-UP TESTING AND ACCEPTANCE PHASE		
START-UP TESTING PHASE	21FEB06	18FEB07
Start-Up Testing	21FEB06	
Release to Operations		18FEB07
Operational Readiness Review (ORR)	20FEB07	31MAR07
AFA - Project Close out	25FEB07	31MAR07
Operational Aceptance - CD4		26MAR07
Project Completion		31MAR07



Project Start 01AUG97
Project Finish 12JUL07
Data Date 01OCT98
Run Date 14OCT98
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Early Bar
Progress Bar
Critical Activity

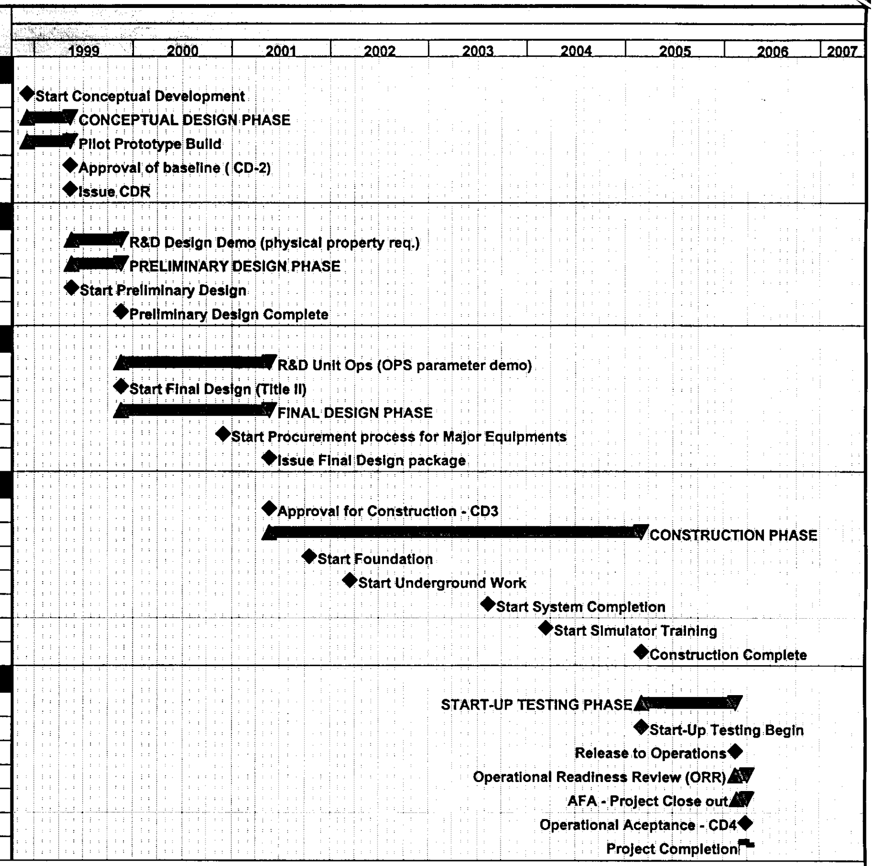
E004

Sheet 1 of 1

Westinghouse Savannah River Company
SALT REMOVAL PROJECT
ION EXCHANGE OPTION Summary Schedule

Figure 7-4: CST Non-Elutable Ion Exchange Summary Schedule

Activity Description	Early Start	Early Finish
CONCEPTUAL DESIGN PHASE		
Start Conceptual Development	30NOV98*	
CONCEPTUAL DESIGN PHASE	30NOV98	14MAY99
Pilot Prototype Build	30NOV98	14MAY99
Approval of baseline (CD-2)		14MAY99
Issue CDR		14MAY99
PRELIMINARY DESIGN PHASE		
R&D Design Demo (physical property req.)	17MAY99	17NOV99
PRELIMINARY DESIGN PHASE	17MAY99	17NOV99
Start Preliminary Design	17MAY99	
Preliminary Design Complete		17NOV99
FINAL DESIGN PHASE		
R&D Unit Ops (OPS parameter demo)	18NOV99	17MAY01
Start Final Design (Title II)	18NOV99	
FINAL DESIGN PHASE	18NOV99	17MAY01
Start Procurement process for Major Equipments	27NOV00	
Issue Final Design package		17MAY01
CONSTRUCTION PHASE		
Approval for Construction - CD3	18MAY01	
CONSTRUCTION PHASE	18MAY01	03MAR05
Start Foundation	18OCT01	
Start Underground Work	14MAR02	
Start System Completion	12AUG03	
Start Simulator Training	16MAR04	
Construction Complete		03MAR05
START-UP TESTING AND ACCEPTANCE PHASE		
START-UP TESTING PHASE	04MAR05	18FEB06
Start-Up Testing Begin	04MAR05	
Release to Operations		18FEB06
Operational Readiness Review (ORR)	19FEB06	31MAR06
AFA - Project Close out	25FEB06	31MAR06
Operational Aceptance - CD4		26MAR06
Project Completion		31MAR06



Project Start 01AUG97
Project Finish 12JUL06
Data Date 01OCT98
Run Date 14OCT98
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Early Bar
Progress Bar
Critical Activity

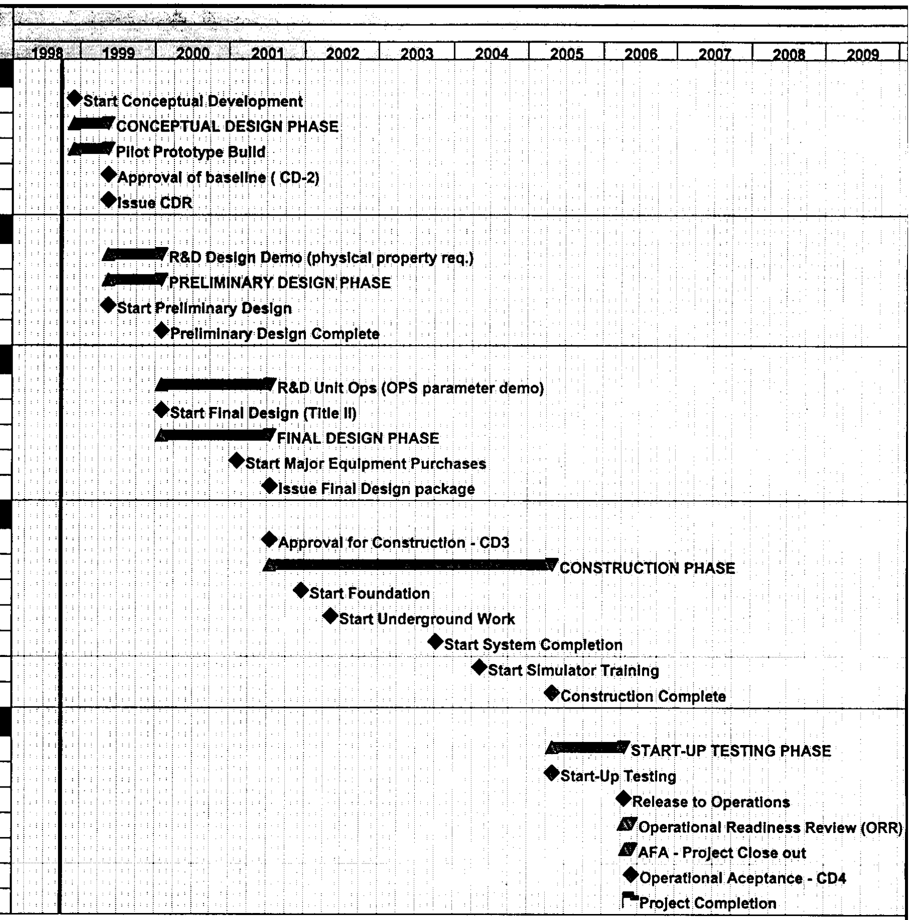
E001

Sheet 1 of 1

Westinghouse Savannah River Company
SALT REMOVAL PROJECT
GROUT OPTION Summary Schedule

Figure 7-5: Direct Disposal in Grout Summary Schedule

Activity Description	Early Start	Early Finish
CONCEPTUAL PHASE		
Start Conceptual Development	30NOV98*	
CONCEPTUAL DESIGN PHASE	30NOV98	14MAY99
Pilot Prototype Build	30NOV98	14MAY99
Approval of baseline (CD-2)		14MAY99
Issue CDR		14MAY99
PRELIMINARY DESIGN PHASE		
R&D Design Demo (physical property req.)	17MAY99	31JAN00
PRELIMINARY DESIGN PHASE	17MAY99	31JAN00
Start Preliminary Design	17MAY99	
Preliminary Design Complete		31JAN00
FINAL DESIGN PHASE		
R&D Unit Ops (OPS parameter demo)	01FEB00	16JUL01
Start Final Design (Title II)	01FEB00	
FINAL DESIGN PHASE	01FEB00	16JUL01
Start Major Equipment Purchases	06FEB01	
Issue Final Design package		16JUL01
CONSTRUCTION PHASE		
Approval for Construction - CD3	17JUL01	
CONSTRUCTION PHASE	17JUL01	01MAY05
Start Foundation	18DEC01	
Start Underground Work	12MAY02	
Start System Completion	13OCT03	
Start Simulator Training	15MAY04	
Construction Complete		01MAY05
START-UP TESTING AND ACCEPTANCE PHASE		
START-UP TESTING PHASE	02MAY05	20APR06
Start-Up Testing	02MAY05	
Release to Operations		20APR06
Operational Readiness Review (ORR)	21APR06	31MAY06
AFA - Project Close out	26APR06	31MAY06
Operational Aceptance - CD4		25MAY06
Project Completion		31MAY06



Project Start	01AUG97	Early Bar
Project Finish	09SEP06	Progress Bar
Data Date	01OCT98	Critical Activity
Run Date	14OCT98	

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EC0B

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SALT REMOVAL PROJECT
SMALL TANK OPTION Summary Schedule

Figure 7-6: Small Tank TPB Precipitation Summary Schedule

7.5 Cash Flow

Cash flows were developed for each alternative to evaluate fiscal year funding requirements. The cash flow for each alternative was prepared on both Budget Outlay and Budget Authorization basis, reflecting the funding provided by Congress each year for the alternative. The project cash flows were prepared following Team approval of the project estimates for each alternative. The early procurement of major engineered equipment and training simulators were factored into the development of each alternative cash flow.

Budget Authorization cash flow was projected using the requirement that all funding for purchase orders (e.g. engineered equipment) or subcontracts (e.g. engineering services) be in hand when the orders and subcontracts are awarded.

Tables 7-6 through 7-9 give a summary cash flow for each alternative.

In Thousands of Constant Dollars

Project Cash Flow Caustic Side Solvent Extraction	*Budget Authority (BA)*			*Budget Outlay (BO)*		
	Total Estimated Cost (TEC)	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*	*Total Estimated Cost (TEC)*	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*
FY 1999	39,284	26,384	*65,668*	0	26,384	*26,384*
FY 2000	90,146	49,386	*139,531*	50,860	49,386	*100,246*
FY 2001	99,526	86,760	*186,286*	50,860	86,760	*137,620*
FY 2002	132,528	42,267	*174,795*	95,357	42,267	*137,624*
FY 2003	166,383	42,694	*209,077*	225,610	42,694	*268,304*
FY 2004	187,673	43,974	*231,647*	236,769	43,974	*280,743*
FY 2005	121,949	62,311	*184,260*	177,824	62,311	*240,135*
FY 2006	31,022	88,304	*119,326*	31,232	88,304	*119,535*
FY 2007	2,485	49,305	*51,791*	2,485	49,305	*51,791*
FY 2008			*0*			*0*
Total	*870,996*	*491,384*	*1,362,380*	*870,996*	*491,384*	*1,362,380*

Table 7-6: Caustic Side Solvent Extraction Summary Cash Flow

In Thousands of Constant Dollars

Project Cash Flow CST - Non Elutable Ion Exchange	*Budget Authority (BA)*			*Budget Outlay (BO)*		
	Total Estimated Cost (TEC)	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*	*Total Estimated Cost (TEC)*	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*
FY 1999	33,503	25,700	*59,203*	7,925	25,700	*33,625*
FY 2000	76,784	48,094	*124,878*	47,551	48,094	*95,645*
FY 2001	97,034	85,576	*182,610*	44,263	85,576	*129,838*
FY 2002	137,296	40,954	*178,250*	90,740	40,954	*131,695*
FY 2003	147,011	41,332	*188,343*	199,613	41,332	*240,945*
FY 2004	158,033	43,651	*201,684*	205,967	43,651	*249,619*
FY 2005	91,625	58,830	*150,455*	145,226	58,830	*204,056*
FY 2006	24,569	58,405	*82,974*	24,568	58,405	*82,973*
FY 2007	1,606	15,949	*17,555*	1,606	15,949	*17,555*
FY 2008			*0*			*0*
Total	*767,460*	*418,491*	*1,185,951*	*767,460*	*418,491*	*1,185,951*

Table 7-7: CST Non-Elutable Ion Exchange Summary Cash Flow

In Thousands of Constant Dollars

Project Cash Flow	*Budget Authority (BA)*			*Budget Outlay (BO)*		
Disposal in Grout	*Total Estimated Cost (TEC)*	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*	*Total Estimated Cost (TEC)*	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*
FY 1999	22,148	26,440	*48,587*	11,465	26,440	*37,905*
FY 2000	67,226	47,896	*115,121*	45,859	47,896	*93,755*
FY 2001	83,350	35,474	*118,824*	62,695	35,474	*98,168*
FY 2002	138,914	33,699	*172,613*	133,937	33,699	*167,636*
FY 2003	153,715	33,699	*187,414*	161,808	33,699	*195,507*
FY 2004	133,964	24,849	*158,813*	172,719	24,849	*197,568*
FY 2005	32,489	44,652	*77,141*	43,323	44,652	*87,975*
FY 2006	1,620	27,430	*29,050*	1,620	27,430	*29,050*
FY 2007	0	0	*0*	0	0	*0*
FY 2008			*0*			*0*
Total	*633,426*	*274,138*	*907,564*	*633,426*	*274,138*	*907,564*

Table 7-8: Direct Disposal in Grout Summary Cash Flow

In Thousands of Constant Dollars

Project Cash Flow Small Tank TPB Precipitation	*Budget Authority (BA)*			*Budget Outlay (BO)*		
	Total Estimated Cost (TEC)	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*	*Total Estimated Cost (TEC)*	*Other Project Cost (OPC)*	*Total Project Costs (TPC)*
FY 1999	32,558	26,436	*58,993*	11,551	26,436	*37,986*
FY 2000	67,211	65,817	*133,027*	46,202	65,817	*112,019*
FY 2001	111,445	51,538	*162,983*	60,269	51,538	*111,807*
FY 2002	148,940	37,259	*186,199*	155,064	37,259	*192,323*
FY 2003	180,761	37,902	*218,663*	194,217	37,902	*232,119*
FY 2004	112,202	46,614	*158,816*	169,688	46,614	*216,302*
FY 2005	35,490	62,106	*97,596*	51,616	62,106	*113,722*
FY 2006	2,452	51,051	*53,503*	2,452	51,051	*53,503*
FY 2007	0	0	*0*	0	0	*0*
FY 2008			*0*			*0*
Total	*691,059*	*378,722*	*1,069,781*	*691,059*	*378,722*	*1,069,781*

Table 7-9: Small Tank TPB Precipitation Summary Cash Flow

7.6 Operation and Maintenance Cost

The Operating and Maintenance (O&M) costs for each Short List alternative were developed using a process which included using a "Tailored Benchmark Model" developed by the Team using the DWPF O&M staffing as a benchmark from which to scale costs. As an initial step, the Team used the pre-conceptual project layouts and flowsheets for each alternative to estimate the following:

- Operators
- Maintenance mechanics
- Laboratory technicians
- Process area square footage
- Capital equipment replacements
- Consumable materials
- Essential materials

The "Tailored Benchmark Model" then used this data and the DWPF staffing levels and support services costs to scale the remaining elements of O&M costs. These estimates were then reviewed by the Team and specific adjustments were made in areas where the Team felt that direct scaling from DWPF was not representative of the O&M cost for each alternative. The resulting O&M cost for each alternative are shown below in Table 7-10. In addition, the O&M costs for Saltstone are shown where applicable.

Table 7-10: Average Yearly O&M Costs
(thousands of FY99 constant year dollars)

Cost Element	Caustic Side Solvent Extraction	CST Non-Elutable Ion Exchange	Direct Disposal In Grout	Small Tank TPB Precipitation
HLW Labor & Subcontracts	19,627	11,906	13,063	15,844
Consumable Materials	728	485	485	485
Support Group Services	12,033	9,651	7,853	10,307
CE & GPP	3,503	3,877	3,123	3,314
Average Essential Materials*	28,808	6,404	3,178	12,893
Vault Construction **			*16,532*	
Site Overhead & Fee	17,612	8,297	11,870	11,428
Average O&M Cost per Year - Alternative Specific	*82,310*	*40,620*	*56,104*	*54,271*
Saltstone O&M Cost w/ SOH***	28,218	41,560	0	30,919
Average O&M Cost per Year including supporting Facilities	110,528	82,180	56,104	85,190

* The annual cost for essential materials is based on the production schedule. However, for comparison purposes, an average cost per year is shown.
** Vault Construction Cost is shown only for Direct Disposal in Grout alternative. The vaults used in the other alternatives are included in the Saltstone O&M Cost.
*** Saltstone O&M cost is shown for three of the alternatives, since Saltstone processes the decontaminated stream into grout.

7.7 Decontamination and Decommissioning (D&D) Cost

Each of the alternatives will be decontaminated and decommissioned at the end of the production cycle. The estimate for the D&D cost for each alternative has been scaled from the DWPF D&D cost estimate, which is based on engineering judgement and brief discussions with SRS Environmental Restoration personnel. D&D costs for each alternative are shown in Table 7-11.

Table 7-11: D&D Costs
(millions of FY99 constant year dollars)

Alternative	D&D Cost
Caustic Side Solvent Extraction	124
CST Non-Elutable Ion Exchange	135
Direct Disposal in Grout	87
Small Tank TPB Precipitation	117

7.8 Life Cycle Cost

Using the methods described in Sections 7.3 through 7.7, the Life Cycle Costs of each alternative were developed. Life Cycle Costs include cost components from the inception of the project through production and D&D. The LCCs also include the O&M and D&D costs for the Saltstone Facility, which is a part of the overall salt processing mission.

7.9 Production Model Analysis

After the Selection Phase flowsheets were defined, the Production Model (ProdMod) was run for each alternative. By incorporating the operating parameters of each alternative, ProdMod was able to predict how the facilities in the HLW System, including the specific salt alternative facility, would operate. Prior to running the model, a number of generic assumptions were defined and used for the alternatives.

7.9.1 Generic ProdMod Assumptions

The major assumptions were:

- Influent streams will be as currently forecast. No new or additional Canyon or DWPF missions are assumed.
- The HLW facilities can support a significant increase in intra- and inter-area transfers in order to support a salt solution feed of six million gallons per year.
- Concentrated supernate can be stored in “old style tanks” (Tanks 4-8) if space in Type III tanks is not available.
- The current contents of Tank 49 will be transferred to Tank 48 or processed to Saltstone. Once de-inventoried, Tank 49 will be returned to Tank Farm waste storage service.

- Tank 50 will continue to be used to receive Effluent Treatment Facility (ETF) concentrate until the startup of salt processing. The Saltstone facility will be in a "partial lay-up" mode except when it must be operated to process Tank 50 material.
- No long, unplanned outages are assumed anywhere in the HLW System. The evaporators (2F, 2H and the Replacement High Level Waste Evaporator), ESP, and DWPF are expected to operate continuously throughout the period, except during planned outages.
- Existing FFA and STP commitments remain in effect.

7.9.2 ProdMod Results

In addition to the generic assumptions listed above, ProdMod used the startup dates, processing rates, and other flowsheet information for each alternative as inputs. Annual feed from the tank farms to the salt and sludge processing facilities was selected to allow the HLW System to maximize processing capabilities while operating within the bounds of set volume, waste composition and other system constraints.

ProdMod calculates material flows throughout the HLW System on a year-by-year basis and ensures that material balances do not exceed any of the HLW System constraints (e.g., Tank Farm storage capacity based on physical and administrative limits). ProdMod generates the following types of information:

- Tank Farm material balances
- Salt and sludge removal and processing schedules and volumes
- Waste Removal project schedules
- Tank closure schedules
- DWPF recycle stream volume
- Evaporation requirements
- Inter-area transfers (to maximize tank space usage between the two tank farms)
- Saltstone processing schedules, including vault usage
- Canister storage, including the schedules which show when additional canister storage space must be constructed

These results are used as the basis for planning and operation throughout the HLW System. The individual facilities in the HLW System use these results to determine what scope to accomplish in each fiscal year to support the needs of the HLW System. This information is further refined by facility and division planners to determine what specific month or week a facility can take outages or when individual transfers should occur. The HLW Financial Model uses the ProdMod results in its budget preparations to ensure that adequate funding is requested for each fiscal year to fund the integrated scope requirements of the HLW system. A summary of key results of the ProdMod runs for each salt processing alternative is shown in Table 7-12.

Table 7-12: Key Results Summary Information

Key Results	Caustic Side Solvent Extraction	CST Non-Elutable Ion Exchange	Direct Disposal in Grout	Small Tank TBP Precipitation
Salt Processing Plant Operations Initiated	5/07	3/07	3/06	5/06
Number of Years of Salt Plant Operations	13	13	13	15
Meets Regulatory Commitments (FFA /STP)	Yes	Yes	Yes	Yes
Planned Canister Production Rate Per Year	225	225	235	210
Number of Old Style Tanks Utilized for Temporary Storage of Additional Waste	2	2	2	2
Year the 24 "Old Style" Tanks are Closed	2016	2016	2015	2016
Salt and Sludge Processing Operations Completed	6/19	3/19	4/18	9/20
Processing and Storage Facilities Closed	6/21	3/21	4/20	9/22
Canisters Produced	5084	5084	5084	5084
Year Canister Shipments Complete	2025	2025	2025	2025
Class A Vaults – Onsite Disposal	14	15	2	18
Class C Vaults – Onsite Disposal	0	0	13	0

The ProdMod annual canister production rate for each alternative is driven by the need to minimize costs through completion of sludge processing at the same time as salt processing. This is due to the blending of the salt solution feed stream with sludge material to avoid the production of additional canisters.

The ProdMod runs for each alternative meet Federal Facility Agreements and STP regulatory requirements. These requirements include closure of the "old style" tanks, commitments regarding DWPF canister production (average of 200 cans per year) and removal of waste inventory from the HLW tanks by FY2028.

7.10 HLW System LCC

In addition to the differences of construction and operating costs of the specific Salt Disposition Facility, each alternative also differs in its effect on the HLW System schedule and costs. Differences can include: the year salt processing can begin; the schedule for waste tank closure (ending tank operating costs); the schedule for waste tank waste removal; and, most importantly, the schedule for completion of the waste removal program. Given the high annual fixed costs of operating the entire HLW System, there are significant cost benefits for completing waste removal as soon as possible ending these costs. To quantify the LCC impacts on the HLW System, the HLW Financial Model was used. This model is used routinely to estimate the HLW System LCC of various funding scenarios.

The Financial Model uses FY99 as the base operating year. For each subsequent year the cost of continuing scope is escalated and the cost impact of major, programmed scope changes is factored into the analysis. Major scope changes can include such items as facility construction and startup, tank closures, essential materials, melter replacements, vault construction, tank waste removal, and canister shipments. Line item projects, including D&D, are included according to their project schedules. Waste removal and tank closure are shown tank-by-tank. The scope changes are based on the ProdMod detailed results described in Section 7.9.

The results of the model are shown in Tables 7-13 through Table 7-15, which show HLW System LCC in constant, escalated, and discounted dollars.

Table 7-13: HLW Total System LCC (Escalated Dollars)

(Budget Authority millions of escalated dollars)

Work Scope	Caustic Side Solvent Extraction	CST Non-Elutable Ion Exchange	Direct Disposal in Grout	Small Tank TPB Precipitation
H Tank Farm				
H Tank Farm Operations	1,834	1,815	1,699	1,994
LI: Replacement Evap	7	7	7	7
LI: Tk Fm Service Upgds I	1	1	1	1
LI: E Hill Piping	34	34	34	34
LI: StormWater	10	10	10	10
Sub-Total	**1,886**	**1,867**	**1,751**	**2,046**
F Tank Farm				
F Tank Farm Operations	1,179	1,173	1,085	1,245
LI: Tk Fm Service Upgds II	26	26	26	26
Sub-Total	**1,205**	**1,199**	**1,111**	**1,270**
Waste Removal & Tank Closures				
WR Ops w/ Demo Projs	197	194	191	218
LI: WR from Tanks	813	813	796	830
WR: Tank Closure	721	725	705	740
Sub-Total	**1,731**	**1,732**	**1,692**	**1,788**
Feed Prep. & Sludge Ops	**1,888**	**1,856**	**1,732**	**2,051**
Salt Alternative				
LI: Salt Alternative	1,511	1,307	991	1,169
LI: Salt Alternative Upgrades	179	153	127	142
Salt Alternative Ops	1,522	789	1,026	1,201
Saltstone Operations	565	594	37	703
Salt Alternative & Saltstone D&D	228	248	154	225
Sub-Total	**4,004**	**3,091**	**2,335**	**3,440**
Vitrification				
Vitrification Ops	4,115	4,054	3,821	4,479
Failed Equip. Stor. Vaults	16	16	16	16
LI: Vit Upgrades	186	186	186	186
Sub-Total	**4,317**	**4,257**	**4,023**	**4,682**
Glass Waste Storage	**272**	**272**	**281**	**264**
Support Facilities				
CIF Operations	803	803	803	803
ETF Operations	537	528	495	584
Sub-Total	**1,340**	**1,331**	**1,298**	**1,387**
Facility D&D	**420**	**417**	**401**	**434**
GRAND TOTAL	**17,064**	**16,023**	**14,625**	**17,362**

Table 7-14: HLW Total System LCC (Constant FY99 Dollars)

(Budget Authority in millions of constant FY99 dollars)

Work Scope	Caustic Side Solvent Extraction	CST Non-Elutable Ion Exchange	Direct Disposal in Grout	Small Tank TPB Precipitation
H Tank Farm				
H Tank Farm Operations	1,311	1,303	1,236	1,392
LI: Replacement Evap	7	7	7	7
LI: Tk Fm Service Upgds I	1	1	1	1
LI: E Hill Piping	32	32	32	32
LI: StormWater	10	10	10	10
Sub-Total	**1,361**	**1,353**	**1,286**	**1,442**
F Tank Farm				
F Tank Farm Operations	843	841	794	878
LI: Tk Fm Service Upgds II	26	26	26	26
Sub-Total	**869**	**867**	**820**	**904**
Waste Removal & Tank Closures				
WR Ops w/ Demo Projs	143	142	142	155
LI: WR from Tanks	616	618	615	617
WR: Tank Closure	470	470	470	470
Sub-Total	**1,229**	**1,230**	**1,227**	**1,242**
Feed Prep. & Sludge Ops	**1,296**	**1,281**	**1,219**	**1,374**
Salt Alternative				
LI: Salt Alternative	1,362	1,186	908	1,070
LI: Salt Alternative Upgrades	123	108	89	97
Salt Alternative Ops	989	500	678	750
Saltstone Operations	379	402	32	468
Salt Alternative D&D	129	141	92	122
Sub-Total	**2,982**	**2,337**	**1,799**	**2,508**
Vitrification				
Vitrification Ops	2,854	2,826	2,711	3,029
Failed Equip. Stor. Vaults	14	14	14	14
LI: Vit Upgrades	148	148	148	148
Sub-Total	**3,016**	**2,987**	**2,872**	**3,190**
Glass Waste Storage	**214**	**214**	**222**	**203**
Support Facilities				
CIF Operations	557	557	557	557
ETF Operations	370	366	349	393
Sub-Total	**927**	**923**	**906**	**950**
Facility D&D	**236**	**236**	**236**	**236**
GRAND TOTAL	**12,130**	**11,427**	**10,587**	**12,048**

Table 7-15: HLW Total System LCC (Discounted Dollars)

(Budget Authority in millions of discounted dollars)

Work Scope	Caustic Side Solvent Extraction	CST Non-Elutable Ion Exchange	Direct Disposal in Grout	Small Tank TPB Precipitation
H Tank Farm				
H Tank Farm Operations	1,126	1,121	1,073	1,182
LI: Replacement Evap	7	7	7	7
LI: Tk Fm Service Upgds I	1	1	1	1
LI: E Hill Piping	30	30	30	30
LI: StormWater	10	10	10	10
Sub-Total	**1,173**	**1,168**	**1,121**	**1,229**
F Tank Farm				
F Tank Farm Operations	723	721	689	752
LI: Tk Fm Service Upgds II	23	23	23	23
Sub-Total	**747**	**744**	**712**	**775**
Waste Removal & Tank Closures				
WR Ops w/ Demo Projs	110	109	112	120
LI: WR from Tanks	454	457	464	447
WR: Tank Closure	295	293	302	287
Sub-Total	**860**	**859**	**877**	**854**
Feed Prep. & Sludge Ops	**1,038**	**1,029**	**989**	**1,086**
Salt Alternative				
LI: Salt Alternative	1,197	1,050	811	956
LI: Salt Alternative Upgrades	78	71	59	62
Salt Alternative Ops	656	344	482	504
Saltstone Operations	259	276	29	317
Salt Alternative & Saltstone D&D	67	72	51	60
Sub-Total	**2,257**	**1,814**	**1,432**	**1,900**
Vitrification				
Vitrification Ops	2,278	2,259	2,188	2,383
Failed Equip. Stor. Vaults	10	10	10	10
LI: Vit Upgrades	113	113	113	113
Sub-Total	**2,402**	**2,383**	**2,311**	**2,507**
Glass Waste Storage	**171**	**171**	**177**	**157**
Support Facilities				
CIF Operations	428	428	428	428
ETF Operations	296	293	282	309
Sub-Total	**724**	**721**	**711**	**738**
Facility D&D	**120**	**121**	**127**	**116**
GRAND TOTAL	**9,491**	**9,010**	**8,457**	**9,361**

7.11 Application of Contingency to Life Cycle Cost

This section discusses contingency analysis of the LCC, impacts of the alternatives on HLW System schedules, calculation of the LCC point estimates, and calculation of the upper/lower limit of the "boxes".

7.11.1 Contingency Analysis of the Life Cycle Cost

The LCC contingency analysis was performed applying the same methodology used for TEC and OPC. Since the LCC variables are not as recognized as those used in the TEC and OPC analysis, the Team developed appropriate terms and variables for the LCC analysis considering SME advice.

Table 7-16 displays the Monte Carlo contingency percentage at the 50% probability point for cost overruns. As was done for the TEC and OPC estimates, the contingency percent at the 50% probability of cost overrun was applied to the LCC estimates.

Table 7-16: Contingency Percentage (50% Probability Point)

Alternative	Contingency @ 50% Prob.
Caustic Side Solvent Extraction	4.2%
CST Non-Elutable Ion Exchange	10.2%
Direct Disposal in Grout	8.4%
Small Tank TPB Precipitation	7.7%

The contingency is notably lower on the Caustic Side Solvent Extraction alternative. This is due to the favorable probability ranges applied by the Team to the TEC Design Complexity variable.

7.11.2 HLW System Schedule Impacts

Each alternative has different impacts on the operating cycle of the HLW System. The LCC "point" estimate for each alternative was defined by the Team to include the LCC (including the 50% probability of overrun contingency from the Monte Carlo analysis) plus the HLW System schedule impacts. In order to calculate the HLW System schedule impact for each alternative, the LCC was subtracted from the LCC of the entire HLW System for that alternative. The result was termed the "Systems Impacts on LCC".

The important factor is the differences in how the alternatives impact the total HLW System. Therefore, the Systems Impact on LCC for Direct Disposal in Grout was set at zero. The Systems Impact for the other three alternatives was then set as the delta from Direct Disposal in Grout.

7.11.3 LCC Point Estimate

The LCC point estimate for each alternative can be calculated by using the following:

- Total LCC
- The 50% probability of overrun contingency
- The HLW System Schedule Impacts

Since the HLW System Schedule Impacts were not part of the Monte Carlo analysis, contingency was applied to the LCC prior to adding the HLW System Schedule Impacts. The formula for calculating the LCC point estimates at the 50% probability of overrun point from the Monte Carlo analysis is:

Total LCC Point Estimate = (LCC x [1 + Contingency Percentage]) + HLW System Impacts

The LCC point estimates for each of the alternatives are shown in Table 7-17 below:

Table 7-17: Total LCC Point Estimates (Millions of FY99 constant year dollars)

Alternative	Total LCC Estimate	Contigency @ 50% Confidence Interval	HLW Overall System Impacts	Total LCC Point Estimate
Caustic Side Solvent Extraction	2,983	125	360	3,468
CST Non-Elutable Ion Exchange	2,336	238	303	2,877
Direct Disposal in Grout	1,799	151	0	1,950
Small Tank TPB Precipitation	2,507	193	753	3,453

7.11.4 LCC Upper/Lower Limits

In order to determine the upper limits of the LCC Point Estimate "box", the Team decided to use the contingency from the Monte Carlo analysis at the 20% probability of overrun point (i.e. 80% confidence that the LCC costs will not overrun). As an example of the process, the calculation for the Small Tank TPB Precipitation alternative is shown below:

Example: Small Tank TPB Precipitation Alternative (in thousands of FY99 constant year dollars)

TEC
Total TEC w/o contingency = 520,044
Contingency percent at 20% probability of overrun = 47.5%
Difference between 50% probability and 20% probability = 47.5 – 33.0 = 14.5%
Additional TEC contingency = 520,044 x 14.5% = 75,406

OPC
Total OPC w/o contingency = 272,226
Contingency percent at 20% probability of overrun = 64.5% Difference between 50% probability and 20% probability = 64.5 – 38.9 = 25.6%
Additional OPC contingency = 272,226 x 25.6% = 69,690

LCC
Total LCC w/o contingency = 2,507,646
Contingency percent at 20% probability of overrun = 14.3%
LCC Contingency = 2,507,646 x 14.3% = 358,593

Upper Limit of Box
Therefore, the upper limit of the box is calculated by adding the additional TEC contingency, the additional OPC contingency, the LCC contingency, the LCC total and the HLW System Schedule Impact:

75,406 + 69,690 + 358,593 + 2,507,646 + 752,667 = 3,764,003

The Team determined that the lower limit of the LCC point estimate "box" should be based on the contingency from the Monte Carlo analysis at the 60% probability of overrun. The calculation process shown in the example above is applied to calculate the lower limit results. The results of these calculations are summarized in Table 7-18 below:

Table 7-18: Upper/Lower Box Limits
(Millions of FY99 constant year dollars)

Alternative	Lower Limit of Boxes	Upper Limit of Boxes
Caustic Side Solvent Extraction	3,354	3,888
CST Non-Elutable Ion Exchange	2,782	3,236
Direct Disposal in Grout	1,866	2,259
Small Tank TPB Precipitation	3,374	3,764

8.0 Uncertainties

The purpose of this section is to discuss the specific use of uncertainties by the Team and to report the uncertainties associated with each alternative for the selection process.

The Team defined uncertainties as potential variances in the cost or schedule of an alternative. In turn, risks were defined as issues that could cause uncertainties. The major concern of the selection process was identifying, assessing and minimizing issues that could increase the cost associated with or prevent the success of an alternative in meeting the Mission Need. Since tools have been used in the cost estimating process to accommodate "normal" project cost and schedule variations within the estimates, the Team limited the potential cost and schedule impacts that could lead to "uncertainties" to those arising from specific attributes of the alternative under consideration. Uncertainties may result in either increases or decreases in cost and/or schedule estimates. No schedule impacts were allowed to be greater than five years, as that was assumed to be the greatest time period required to resolve any issue. Only the regulatory uncertainty related to approval of the grout waste as "other than HLW" was assigned a value of five years.

Uncertainties are the Team quantification of the potential impact of identified issues. In order to be useful, each uncertainty used in the selection process was required to be assigned a value in dollars, months or both. For the same reason, uncertainties with cost and schedule impacts too small to significantly contribute to the discrimination of the alternatives were not carried into the selection process. These potential impacts were assumed to be within the contingency estimates, within the stated value range of the Life Cycle Cost Point Estimate or within the baseline schedule for each alternative.

Two functions are provided by the use of uncertainties. First, as described in the Risk Management section, uncertainties play a key role in the evaluation of risks and the generation of risk handling strategies. Second, uncertainties permit the Short List alternatives to be evaluated on a consistent basis. The need for the use of uncertainties in the evaluation process is derived from the Team decision to compare the alternatives on the basis of cost to achieve assured success. Assured success means that credible risk handling strategies have been established and appropriate cost and schedule impacts evaluated and attributed to the alternative for each identified uncertainty. The value of the cost of assured success is the Team estimate of the cost of implementing an alternative assuming an unfavorable outcome of the identified uncertainties.

After cost and schedule impacts for each uncertainty used in the selection process were established a combination method was required to provide the total impact on the cost of the alternative. While the cost uncertainties for a given alternative could simply be added, schedule uncertainties could not be handled as simply. Since the schedule impacts of the uncertainties for an alternative were not necessarily on critical path or sequential, the Team had to analyze the individual impacts of each schedule uncertainty on the overall implementation schedule of the alternative. The results of this analysis are discussed in Section 9.0 (Selection). Each alternative had an overall schedule impact established, representing the contribution of all schedule uncertainties.

In order to provide a useful comparison of the alternatives, it was necessary to convert these overall schedule impacts into cost impacts. The financial model of the SRS HLW System generated estimates of the cost of operating the HLW System for the length of time required by each alternative to de-inventory the HLW Tanks. The three highest cost alternatives were assessed with their difference in cost from the lowest cost alternative.

Table 8-1 is a list of the uncertainties used for each of the Short List alternatives in the selection process with the cost and/or schedule impact assigned to the uncertainty by the Team.

Table 8-1: Quantified Uncertainties

Caustic Side Solvent Extraction	
Uncertainty Statement	**Explanatory Note**
Decomposition/Degradation products may negatively affect downstream operations.	$1 million cost increase for 2 carbon bed filters.
Crud formation in the system at the organic to aqueous interface.	$500,000 cost increase for crud separation tanks.
Insufficient understanding of the operating window with respect to feed impurities. (DNFSB 96-1)	14 month delay in completing preliminary design.
Difficulty in filtration of sludge and/or MST will produce low filtrate flow rates and require frequent cleaning	$1.5 million cost increase for the larger filters. $5 million cost increase for the larger pumps.
TRU decontamination with MST is not adequate with the design residence time.	$50 million cost increase (based on one half the estimate for cost savings for moving the MST strike to the Tank Farm).
Public acceptability may not be achieved.	$500,000 cost increase for public relations and analysis

Table 8-1: Quantified Uncertainties (continued)

Caustic Side Solvent Extraction	
Uncertainty Statement	**Explanatory Note**
DOE independent project review and acceptance may impact project milestones.	Schedule impact of 1 month at end of conceptual design, 1 month at the end of preliminary design, 2 month at the end of final design and 1 month prior to radioactive operations.
The requirement for NRC licensing may impact the cost and schedule.	18 month delay to radioactive operations. Additional $1 million cost. SAR may cause 4 month delay in completing preliminary design.
DOE lack of support of required budget and schedule may delay new facility startup.	6 month schedule impact in the first year. 7 month schedule impact in the second year. 7 month schedule impact in the third year.
SRS infrastructure may not support the project needs.	$31 million cost increase for overtime resulting from staffing delays.
Pressure on ‘old’ infrastructure will increase, endangering schedule due to three fold increase in flow requirements from HTF and FTF. This would endanger performance of infrastructure.	9 month delay in completing salt removal from a production schedule delay to reach salt solution feed rate assumption. Basis: 50% material movement in the first year results in 6 months and 75% material movement in the second year results in 3 months.
Improper contract strategy for design work may impact the schedule.	6 month delay in completing conceptual design.
Research and development work performed must be coordinated with the design effort.	3 month delay in completing preliminary design.
Geotechnical problems with siting locations may cause schedule delays.	12 month delay in start of Final design. $126 million cost increase (based on 10% of TEC + $34 million for substructure grout + contingency percentage).
A clearly defined safety strategy should be agreed to by the end of conceptual design to preclude schedule impacts.	2 month delay in start of preliminary design.

Table 8-1: Quantified Uncertainties (continued)

Caustic Side Solvent Extraction	
Uncertainty Statement	**Explanatory Note**
Solvent estimated unit cost rate may be reduced.	Solvent extractant cost bases decreases from $500 to $175 per gram, resulting in a $190 million life cycle cost decrease.
Solvent estimated consumption cost may be reduced.	Change cost bases to complete replacement of solvent every 2 years and solvent extractant cost bases to $175 per gram resulting in a $51 million cost decrease.
The interfacing facilities operational schedules may impact completion of tie-ins to the new facility.	2 month production delay for DWPF to install new transfer line.
GT-73 unit operations may not be required.	$25 million cost decrease.
CST Non-Elutable Ion Exchange	
Uncertainty Statement	**Explanatory Note**
Resin bed temperature control during operational conditions and loaded spent resin temperature control.	$10 million cost increase for safety class emergency cooling and temperature monitoring.
Can pressure gradients crush the resin during column operations?	$2.5 million cost increase for 4 additional columns. $2.5 million cost increase for associated jumpers. $2.6 million cost increase for 2 additional personnel during the operational life of the facility.
Difficulty in filtration of sludge and/or MST will produce low filtrate flow rates and require frequent cleaning	$1.5 million cost increase for the larger filters. $5 million cost increase for the larger pumps.
TRU decontamination with MST is not adequate with the design residence time.	$50 million cost increase (based on one half the estimate for cost savings for moving the MST strike to the Tank Farm).

Table 8-1: Quantified Uncertainties (continued)

CST Non-Elutable Ion Exchange	
Uncertainty Statement	**Explanatory Note**
Process chemistry understanding and application are still under development, resulting in 96-1 lessons learned not yet implemented	12 month delay in completing preliminary design.
CST will require "requalification" of glass form.	$10 million cost increase to support glass requalification.
Major sample station modification affecting DWPF operations.	$5 million cost increase for sample cell modifications.
CST resin fines may collect in downstream filters, elbows, imperfect welds, and instrument lines.	$2 million cost increase for related modifications (e.g., shielding).
DOE independent project review and acceptance may impact project milestones.	Schedule impact of 1 month at end of conceptual design, 1 month at the end of preliminary design, 2 months at the end of final design and 1 month prior to radioactive operations.
The requirement for NRC licensing may impact the cost and schedule.	18 month delay to radioactive operations. Additional $1 million cost. SAR may cause 4 month delay in completing preliminary design.
The interfacing facilities operational schedules may impact completion of tie-ins to the new facility.	2 month production delay for DWPF to install new transfer line.
DOE lack of support of required budget and schedule may delay new facility startup.	5 month schedule impact in the first year. 5 month schedule impact in the second year. 4 month schedule impact in the third year.
SRS infrastructure may not support the project needs.	$26.5 million cost increase for overtime resulting from staffing delays.

Table 8-1: Quantified Uncertainties (continued)

CST Non-Elutable Ion Exchange	
Uncertainty Statement	**Explanatory Note**
Pressure on 'old' infrastructure will increase, endangering schedule due to three fold increase in flow requirements from HTF and FTF. This would endanger performance of infrastructure.	9 month delay in completing salt removal from a production schedule delay to reach salt solution feed rate assumption. Basis: 50% material movement in the first year results in 6 months and 75% material movement in the second year results in 3 months.
Improper contract strategy for design work may impact the schedule.	6 month delay in completing conceptual design.
Research and development work performed must be coordinated with the design effort.	6 month delay in completing preliminary design.
Geotechnical problems with siting locations may cause schedule delays.	12 month delay in start of final design. $122 million cost increase (based on 10% of TEC + $34 million for substructure grout + contingency percentage).
A clearly defined safety strategy should be agreed to by the end of conceptual design to preclude schedule impacts.	2 month delay in the start of preliminary design.
Increased foaming in the DWPF Chemical Process Cell.	$5 million cost increase to concentrate the CST slurry.
GT-73 unit operation may not be required.	$27 million cost decrease.
Hydrogen generation in the loaded column.	Tankage for hydrogen gas collection and associated safety equipment. $30 million cost increase.

Table 8-1: Quantified Uncertainties (continued)

Direct Disposal in Grout	
Uncertainty Statement	**Explanatory Note**
Existing vault design may have to be upgraded with liners, ventilation upgrades, temperature monitoring, leachate collection, capping/backfilling, elimination of floor penetrations, HEPA filtration of moist atmosphere and the addition of cell access for failed equipment disposal.	$5 million cost increase for long term hydrogen collection system.
Difficulty in filtration of sludge and/or MST will produce low filtrate flow rates and require frequent cleaning	$1.5 million cost increase for the larger filters. $5 million cost increase for the larger pumps.
TRU decontamination with MST is not adequate with the design residence time.	$50 million cost increase (based on one half the estimate for cost savings for moving the MST strike to the Tank Farm).
Process not acceptable to general public.	24 month delay in start of final design. Can start at end of conceptual design based on NEPA documentation.
Technical regulatory agencies may delay approvals.	5 year delay to complete construction for high level waste in SC. 2 year delay in radioactive operation for redesign and EIS.
Process not technically supportive of future missions (e.g. can-in-can)	$50 million cost increase to support commitment to can-in-can mission.
DOE independent project review and acceptance may impact project milestones.	Schedule impact of 1 month at end of conceptual design, 1 month at the end of preliminary design, 2 months at the end of final design and 12 months prior to radioactive operations.
DOE lack of support of required budget and schedule may delay new facility startup.	3 month schedule impact in the first year. 5 month schedule impact in the second year.
SRS infrastructure may not support the project needs.	$20 million cost increase for overtime resulting from staffing delays.

Table 8-1: Quantified Uncertainties (continued)

Direct Disposal in Grout	
Uncertainty Statement	**Explanatory Note**
Pressure on ‘old’ infrastructure will increase, endangering schedule due to three fold increase in flow requirements from HTF and FTF. This would endanger performance of infrastructure.	9 month delay in completing salt removal from a production schedule delay to reach salt solution feed rate assumption. Basis: 50% material movement in the first year results in 6 months and 75% material movement in the second year results in 3 months.
Improper contract strategy for design work may impact the schedule.	6 month delay in completing conceptual design.
Geotechnical problems with siting locations may cause schedule delays.	12 month delay in start of final design. $105 million cost increase (based on 10% of TEC + $34 million for substructure grout + contingency percentage).
GT-73 unit operations may not be required.	$27 million cost decrease.
DWPF recycle stream does not contain cesium concentration assumed in HLW System Plan.	$65 million cost decrease. Basis is DWPF recycle rerouted to ETF saving evaporator operation.
Suspect product may not be able to be recovered.	$9 million cost increase based on abandoning a vault.
Small Tank TPB Precipitation	
Uncertainty Statement	**Explanatory Note**
Close coupled unit operations adds production complexity. Salt Cell in DWPF has to be operated in this option.	9 month delay in completing salt removal. Basis: 3 months delay to go from 75% to 100% assumed production rate. 6 months to realize assumed efficiencies.
Benzene releases may exceed permit levels due to additional (unknown) catalytic effects or catalyst build-up through plate-out.	Benzene emission reduction system estimated at $5 million to meet permit limits.
Process will not produce the DF required because of slow kinetics of MST and TPB.	$14 million cost increase for additional CSTR.

Table 8-1: Quantified Uncertainties (continued)

Small Tank TPB Precipitation	
Uncertainty Statement	**Explanatory Note**
Geotechnical problems with siting locations may cause schedule delays.	12 month delay in start of Final design. $111 million cost increase (based on 10% of TEC + $34 million for substructure grout + contingency percentage).
DOE independent project review and acceptance may impact project milestones.	Schedule impact of 1 month at end of conceptual design, 1 month at the end of preliminary design, 2 months at the end of final design and 1 month prior to radioactive operations.
The requirement for NRC licensing may impact the cost and schedule.	18 month delay to radioactive operations. Additional $1 million cost. SAR may cause 4 month delay in completing preliminary design.
The interfacing facilities operational schedules may impact completion of tie-ins to the new facility.	6 month production delay for DWPF for SPC modifications.
DOE lack of support of required budget and schedule may delay new facility startup.	5 month schedule impact in the first year. 6 month schedule impact in the second year. 5 month schedule impact in the third year.
SRS infrastructure may not support the project needs.	$22 million cost increase for overtime resulting from staffing delays.
Pressure on 'old' infrastructure will increase, endangering schedule due to three fold increase in flow requirements from HTF and FTF. This would endanger performance of infrastructure.	9 month delay in completing salt removal from a production schedule delay to reach salt solution feed rate assumption. Basis: 50% material movement in the first year results in 6 months and 75% material movement in the second year results in 3 months.
Improper contract strategy for design work may impact the schedule.	6 month delay in completing conceptual design.
Research and development work performed must be coordinated with the design effort.	6 month delay in completing preliminary design.

Table 8-1: Quantified Uncertainties (continued)

Small Tank TPB Precipitation	
Uncertainty Statement	**Explanatory Note**
A clearly defined safety strategy should be agreed to by the end of conceptual design to preclude schedule impacts.	2 month delay in start of preliminary design.

It should be noted that the Team recognized one uncertainty that was not addressed. Recent changes in regulations have raised the possibility that the design of the Saltstone/Grout vaults may have to be upgraded. While this is an uncertainty that could be applied to each alternative, the Team chose not to include it in the selection process. The reasons for this were:

- Since it was equally applicable to each alternative, it would provide no discrimination between them;
- The scope was currently under evaluation and could not be assigned a value with any real confidence;
- The cost of the upgrades was clearly insignificant when compared to Life Cycle Cost.

The Team reviewed the results of the uncertainty analysis and determined the cost uncertainties were small when compared to the assigned contingency values and the range between the upper and lower point estimate limits for the alternatives. The Team decided to eliminate this uncertainty component from further consideration in the selection process because sufficient allowance existed in the contingency and point estimate limits. On the other hand, the monetary value of the schedule uncertainty was significant. This uncertainty was applied as a “whisker” to the Life Cycle Cost Point Estimate for each alternative as depicted in Section 9.0 (Selection).

9.0 Selection

The purpose of this section is to summarize the processes used to establish the Initial List and Short List of alternatives, identify the four Short List alternatives, and describe the process used for selecting the recommended alternatives. Figure 9-1 summarizes the total process.

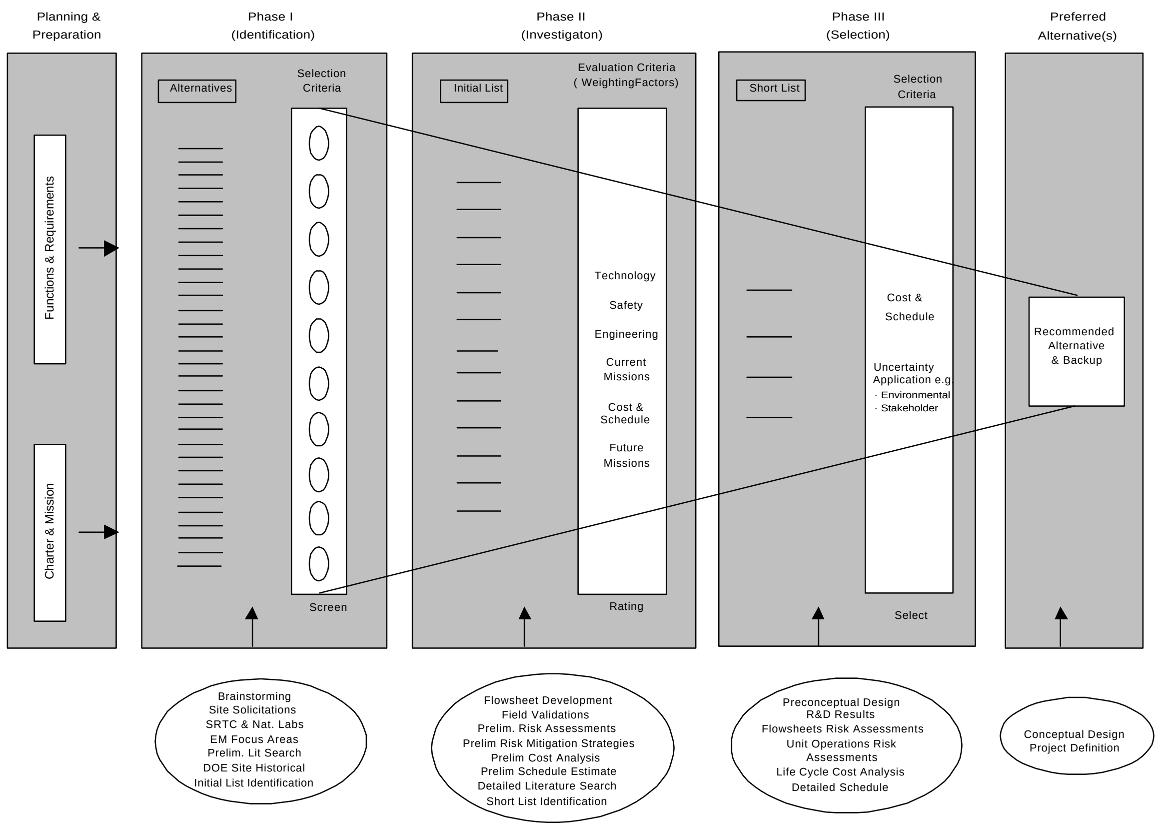

Figure 9-1: Selection Process Summary

9.1 Initial List Selection Process

The purpose of the Identification Phase was to establish a comprehensive list of alternative technologies and to identify a working list of alternative processes that appeared capable of being successfully deployed on the required time scale.

The Team grouped proposed alternatives into categories based upon technology, which were then screened for basic viability (in this case all of the categories passed). The alternatives embodied within the categories were then reviewed individually and screened against criteria from the Initial Design Input. The most favorable alternatives from each category were then carried forward to the Initial List:

- Fractional Crystallization - DWPF Vitrification
- Electrochemical Separation and Destruction – DWPF Vitrification
- Elutable Ion Exchange - DWPF Vitrification
- Potassium Removal followed by TPB Precipitation
- Acid Side Ion Exchange - DWPF Vitrification
- Crystalline Silicotitanate (CST) Ion Exchange – DWPF Vitrification
- Crystalline Silicotitanate (CST) Ion Exchange – New Facility Vitrification
- Zeolite Ion Exchange - DWPF Vitrification
- Crystalline Silicotitanate (CST) Ion Exchange – Ceramic Wasteform
- Reduced Temperature ITP
- Catalyst Removal ITP
- ITP with Enhanced Safety Features
- Small Tank TPB Precipitation
- Caustic Side Solvent Extraction - DWPF Vitrification
- Acid Side Solvent Extraction - DWPF Vitrification
- Direct Vitrification
- Supernate Separation – DWPF Vitrification
- Direct Disposal in Grout

Alternative technologies arising from Team efforts and other sources were screened using the same process until the Team made its recommendation of the preferred alternatives.

9.2 Short List Selection Process

The Team evaluated each of the Initial List alternatives to establish the Short List. This evaluation included facets of a Business Focus, Management Focus, and Technical Focus as shown in Figure 9-2. The Team used a weighted MAUA process and a qualitative assessment, to determine which Initial List alternatives performed well enough, in these focus areas, to be carried to the Short List.

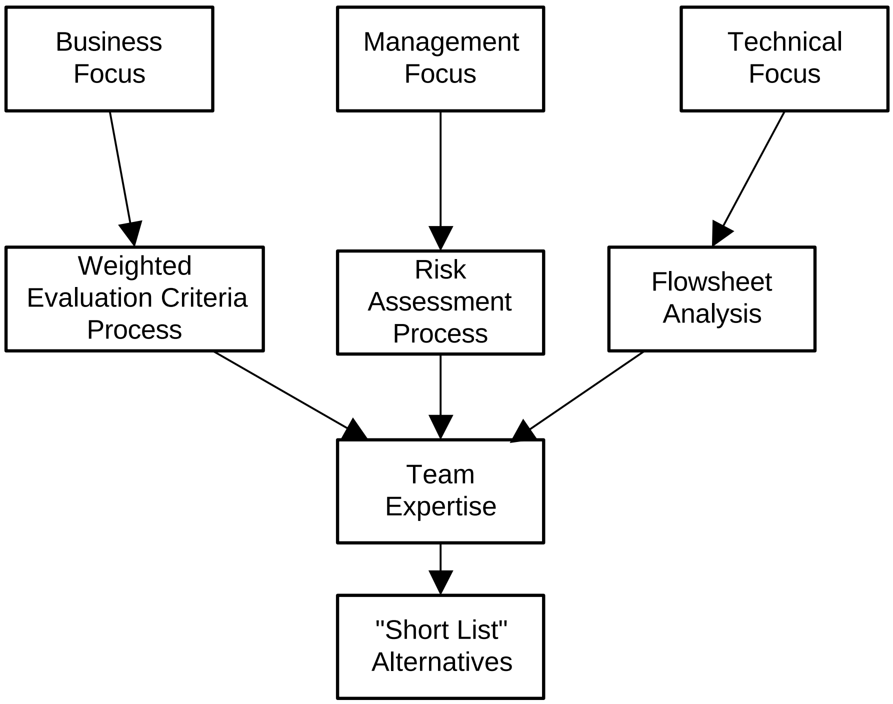

Figure 9-2: Short List Selection Process

The Team performed a preliminary risk assessment to provide the information that supported the Management Focus analysis. The data tables and PFDs developed for each alternative provided the technical information (material balances, process flows, and process system) which was critical to support the Technical Focus analysis.

The MAUA criteria established to support the Business Focus analysis were Technology, Current Mission Interfaces, Future Mission Interfaces, Regulatory/ISMS/Environmental, Engineering (Design), and Cost/Schedule. The highest weights were assigned to Technology, Regulatory/ISMS/Environmental, and Engineering (Design). The Technology and Regulatory criteria were weighted equally while the Engineering category received somewhat lower weighting. The remainder of the criteria divided about one third of the total weighting.

Each of the criteria except Future Mission Interfaces criteria were assigned subcriteria. The Technology criterion was divided into subcriteria of Scientific Maturity (0.4), Engineering Maturity (0.4), and Process Simplicity (0.2). The Current Mission Interfaces criterion was subdivided into DWPF (0.25), Saltstone (0.15), Solid Waste (0.1), Tank Farm (0.2), and Tank Farm Space Management

(0.3) interfaces. The Regulatory/ISMS/Environmental criteria was subdivided into Public /Environmental (0.45), Worker (0.35), and Permitting (0.2). The Engineering (Design) criterion was subdivided into Constructability (0.25), Qualify (Testability) (0.25), Operate (0.25), and RAMI (Reliability, Availability, Maintainability, and Inspectability) (0.25). The final criterion of Cost/Schedule was subdivided into Regulatory Schedule Commitments (0.5), Life Cycle Costs (0.3), and Repository Costs (0.2).

Utility functions were established for each weighted variable. These functions were based on objective descriptions tied to given values. For instance, the function for Scientific Maturity was:

Value	Description
100	Reliable radioactive production scale demonstration and correlation to predicted scientific results.
80	Large-scale radioactive test; “spiked” radiochemistry demonstration
40	Pilot-(small) scale radioactive test, full radiochemistry
10	Lab-scale test; simulant/real waste
0	Theoretical understanding only; no practical demonstration

Values were assigned to each subcriterion (criterion in the case of Future Mission Interface) for each alternative. The assigned value could either be one reflective of a function description (i.e., 100, 80, 40, 10, or 0 for the case above) or an interpolated value reflective of a situation not exactly matching a function description. The assigned values were then compiled for each alternative to provide a MAUA score for each alternative.

The MAUA results for each alternative were then considered along with the Team qualitative assessment. The qualitative assessment considered the strengths and weaknesses of the alternatives and enabled the Team to rank the alternatives. Team decided that there was a clear break point between groups of alternatives. The Short List alternatives chosen were: Direct Disposal in Grout; Non-elutable Ion Exchange (CST-Vitrification was the preferred option within this alternative); Small Tank TPB Precipitation; and Caustic Side Solvent Extraction. These alternatives were carried forward to the final Selection Phase because both the quantitative and qualitative assessments showed significant strengths assuring that they were technically sound and capable of field deployment.

9.2.1 Caustic Side Solvent Extraction

The basic principle of solvent extraction is to use an insoluble diluent material that carries an extractant that will complex with the cesium ions in the caustic solution. The clean aqueous stream (raffinate) is sent to saltstone for disposal. The cesium contained in the organic phase (solvent) can be stripped back into an aqueous phase ready for transfer to DWPF. The solvent is then recycled.

The alkaline salt waste is treated with MST to sorb the actinides followed by filtration to remove the MST and sludge solids. The clarified salt solution flows to the Salt Solution Holding Tank in the Extraction portion of the process (Figure 9-3).

The solvent, consisting of 0.01 M BoBCalixC6 extractant, 0.2 M Cs-3 modifier, and the balance Isopar L® diluent, is contacted with the alkaline waste stream in a series of countercurrent centrifugal contactors (the extraction stages). The resulting clean aqueous raffinate is transferred to Saltstone for disposal. Following cesium extraction, the solvent is scrubbed with dilute nitric acid to remove other soluble salts from the solvent stream (the scrub stages). The solvent is then contacted with a very dilute (0.0005M) nitric acid stream containing a small quantity of cold cesium (0.0001M) to transfer the cesium to the acid stream (the strip stages). The strip effluent is then transferred to the DWPF.

In the extraction stages, cesium and nitrate are extracted into the solvent phase. The cesium is stabilized in the solvent phase by the calixarene molecule while the nitrate ion is stabilized by the modifier molecules. Due to the small size of the opening in the calixarene molecules, cesium is removed in dramatic presence to other cations, in particular sodium and potassium. This selectivity is more than two orders of magnitude versus potassium and more than four order of magnitude versus sodium. This high selectivity is required to achieve the desired separation of the cesium ions from the bulk cations.

In the proposed process, the cesium concentration in the organic phase is 4.3 times that in the aqueous feed solution. For a typical high level waste feed solution containing 0.27 mM cesium, the concentration in the organic stream leaving the extraction stages is approximately 1 mM which is significantly below the 10 mM concentration of calixarene in the solvent. Thus, a large excess of available calixarene sites are available for extraction. However, due to the high concentrations of sodium and potassium in the feed stream, a measurable quantity of both sodium and potassium are extracted, and thus do take up a portion of the sites.

To provide an essentially pure cesium nitrate raffinate stream, the potassium and sodium are scrubbed out of the organic phase using two scrubbing stages between the extraction and strip stages. In addition to removing sodium and potassium from the organic phase, the scrub stages also work to remove aluminum, iron, and mercury from the organic phase. The scrub stages also work to neutralize any caustic carryover into the scrub stages. The neutralization of these species is essential to control precipitation and to allow stable operation of the stripping stages. Since the strip stages employ a weak acidic solution, introduction of caustic into the strip stages would likely result in significant pH shifts and thereby diminish process operability.

In the strip stages, the nitrate ion concentration in the aqueous phase is more than three orders of magnitude lower than in the extraction stages. This decrease in the nitrate ion concentration shifts the equilibrium to favor transport of nitrate into the organic phase. However, due to disassociation of cesium and nitrate in the organic phase, the concentration of extracted cations in the organic phase must be maintained at approximately 10^{-5}M. This objective is achieved by adding cold cesium to the strip feed. Through the use of the cold cesium addition, low distribution coefficients are maintained in the stripping stages. Further information may be obtained from Reference 1.

Over long periods of time, degradation of either the modifier or the calixarene may occur. The most likely degradation is that of the modifier to form a phenolic compound that is highly soluble in the organic phase. Gradual degradation of the solvent will result in some loss of performance. The proposed flowsheet contains two additional unit operations intended to maintain solvent performance.

The two proposed unit operations involve first an acidic wash of the solvent followed by a caustic wash of the solvent. These two wash stages are intended to take out any either acidic or caustic impurities that may acumulate in the solvent system over time. In particular, the caustic wash is known to remove many of the modifier degradation products. In addition, the proposed flowsheet has also assumed that to maintain system performance a percentage of the solvent will be replaced on an annual basis.

After extraction, the aqueous phase will contain either soluble or entrained organics. The proposed process contains two additional contactor stages designed to remove soluble organics and in particular to remove calixarene and modifier from the exiting raffinate stream. A small amount of Iso-par L® is introduced into the stages and used to extract any of the modifier or calixarene from the aqueous phase. The organic phase from these two stages is then mixed with the recycled organic phase and returned to the extraction stages. The aqueous phase from this stage is then sent to a stilling tank where any remaining entrained organics (mostly the Iso-par L®) is allowed to float and is decanted. From the stilling tank, the raffinate is transferred to one of two hold tanks to allow decay of the short half-life beta in the raffinate stream. These two tanks are sized to allow hold time for sufficient beta decay to facilitate determination if the target decontamination has been met to allow transfer of the raffinate material to the saltstone facility. The scrub solutions from the organic clean up process are also transferred to saltstone.

A similar solvent recovery process has been designed for the strip effluent. The proposed process contains two additional contactor stages designed to remove soluble organics from the exiting strip effluent. Again, a small amount of Iso-par L® is introduced into the stages and used to extract any of the modifier or calixarene from the aqeous phase. This organic stream can then be returned to the strip stages. The aqeous phase leaves the clean-up stage and is transferred to a stilling tank where the entrained organics (mostly Iso-par L®) then is allowed to float and is decanted.

Since Iso-par L® was added in the two solvent recovery processes, removal of this additional diluent is required. The proposed process employs a vacuum kerosene still after the caustic wash to boil off the Iso-par L® kerosene at low temperatures. Since the Iso-par L ® was added to the bulk solvent stream, the still must be used to evaporate some of this diluent. The overheads from this still are then condensed and sent to CIF. The cleaned and reconcentrated solvent stream is then sent back to service in the solvent hold tank.

The extraction stage input stream is fed to the process from a 100,000 gallon tank. The use of a relatively large tank provided approximately four days of feed storage and some decoupling of the solvent extraction process from the up stream alpha removal process. Also note that the aqueous strip effluent leaves the stilling tank and is sent to a large storage tank (45 days capacity). The use of a large tank provides for some decoupling of the solvent extraction process and the DWPF. DWPF can operate completely decoupled from the solvent extraction process (i.e., DWPF can run with or without feed from the solvent extraction process). However, the solvent extraction process can only operate as long as DWPF is operating, or storage volume remains in the tanks between the solvent extraction process and DWPF. Cold chemical feed tanks have generally been designed to provide a day’s worth of feed to the process. These feed tanks are fed from larger feed makeup tanks that will provide a buffer in operations to allow for limited (less than a week) outages of process water and other input chemicals.

Strip effluent will be provided at a rate of 1.5 gpm to DWPF. As a result, eliminating the need for an evaporator in the flowsheet. The strip effluent transferred to DWPF is assumed to contain the diluent at the saturation limit (20 mg/L). The strip effluent is evaporated in the DWPF SRAT where the nitric acid content is used to offset the nominal nitric acid requirement. The effluent would contain < 0.01 M Na, < 0.001 M of other metals.

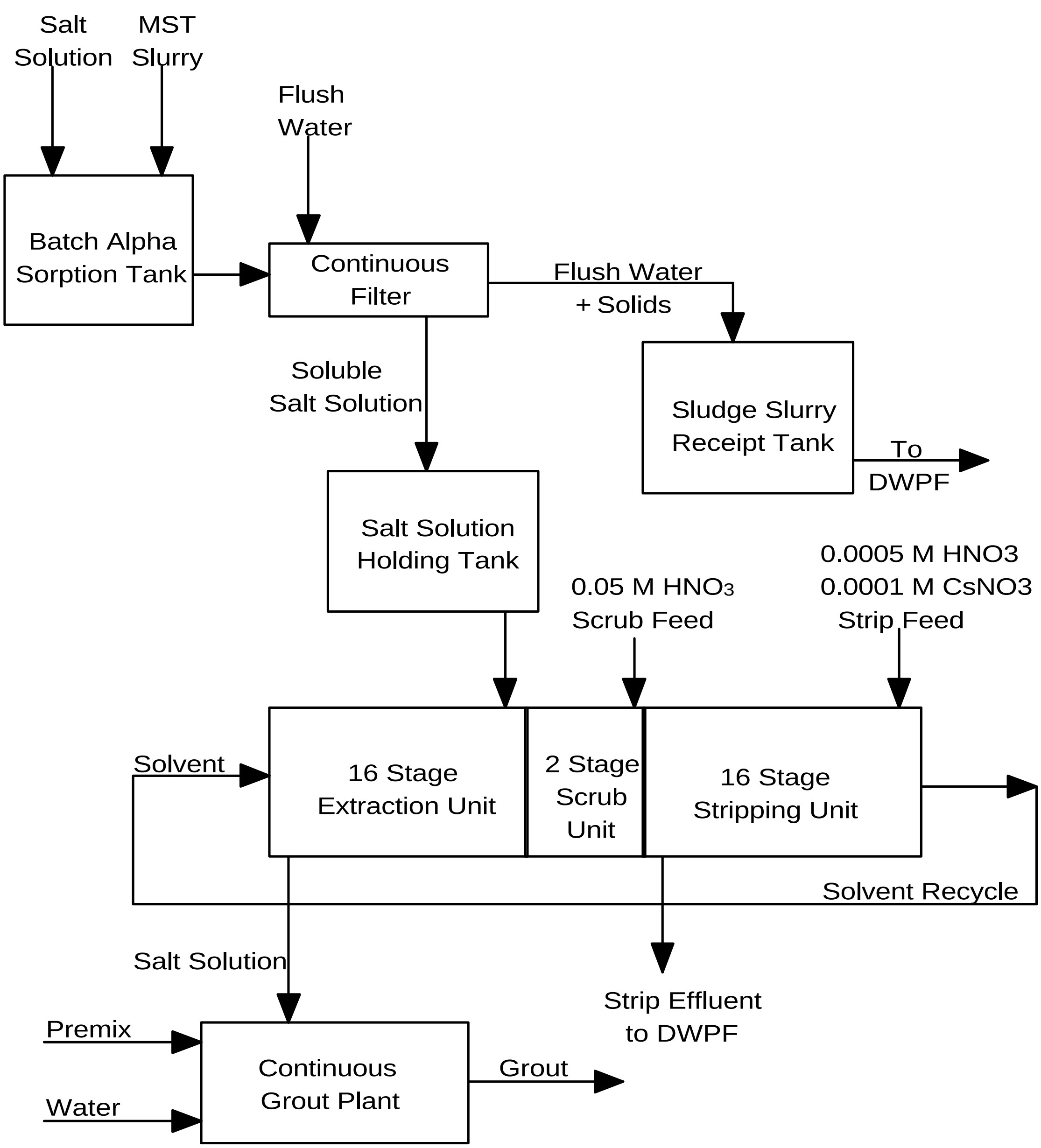

Figure 9-3: Caustic Side Solvent Extraction

9.2.2 CST Non-Elutable Ion Exchange

The proposed process would employ crystalline silicotitanate (CST) resin to remove cesium from the salt solution. Strontium, plutonium, and uranium are removed beforehand by MST addition and sorbtion. The loaded resin is transferred to the DWPF to be combined with sludge and frit to produce borosilicate glass. The decontaminated salt solution would go to the Saltstone Facility to be made into a Class A grout.

The process would include these steps: MST addition to remove strontium, plutonium, and uranium to meet Saltstone TRU limits. Filtration to remove sludge and MST solids from the salt solution to prevent plugging of the ion exchange (IX) columns. After washing to remove soluble salts, the solids would be transferred to the DWPF. The clarified salt solution flows through a series of CST columns to remove the cesium. Cesium-loaded CST is slurried from the bed and transferred to the DWPF. The decontaminated salt solution would be transferred to Saltstone Facility to produce a Class A grout.

The salt solution contains insoluble sludge and soluble species that must be removed to meet Saltstone requirements. In addition, the sludge must be removed to prevent plugging the IX column bed. The first step is to add MST (an insoluble solid) that sorbs the soluble strontium, plutonium, and uranium. Both the MST and sludge are then removed by cross-flow filtration and concentrated to about 5 wt % solids. These solids are transferred to the DWPF for incorporation in the glass but must be washed first to avoid excessive alkali to DWPF.

The clarified salt solution flows to the Recycle Blend Tank in the CST IX portion of the process (Figure 9-4). Here it is combined with the water used to load and unload CST along with the pre- and post-resin treatment NaOH before feeding to the IX train. The train consists of three columns in series where the cesium is exchanged onto the CST. The effluent from the last bed is passed through a fines filter to prevent cesium-loaded fines from contaminating the salt solution. The "clean" salt solution flows to the Decontaminated Salt Solution Tank where the activity is measured to ensure it meets the saltstone limit for cesium 137. It then flows to the Hg removal ion exchange column where Hg is adsorbed onto GT-73 resin and then to Saltstone.

A fourth column is provided to allow continued operation while cesium-loaded CST is being removed and fresh CST is being added to the column. When the first column in the train is close to saturation (expected to be > 90%), that column is taken out of service, the second column becomes the lead column, the third column becomes the middle column, and the fresh, standby column becomes the third, or guard, column. The cesium-loaded CST is then sluiced with water from the column into the Loaded Resin Tank where it is combined with the fines from the fines filter. Excess sluicing water is removed to produce a 10 wt% CST slurry in water and sent to the Loaded Resin Tank. The CST/water slurry is transferred to the DWPF.

Before being loaded into a column, the CST must undergo two treatments. First, the CST is loaded into the Column Preparation Tank, similar in dimensions to an IX column bed. The CST is then backflushed with water to float off the fines. These fines are removed by a filter for disposal as Industrial Waste. The second treatment involves a 24-hour caustic soak. The CST as-received is partially in the hydrogen form and partially in the sodium form. It is converted to the sodium form by circulating a NaOH solution through the bed for 24 hours. The material is then ready to load into the empty standby column by sluicing with water.

Prior to placing the freshly loaded standby column in service, the water must be displaced by a 2 M NaOH solution. If this is not done, aluminum will precipitate from the initial salt solution feed as the pH is reduced by mixing with the residual water. (Water must be maintained in the bed to exclude air which might cause channeling in the bed.) A similar NaOH flush is required after the bed is taken out of service and before the CST is sluiced from the bed with water.

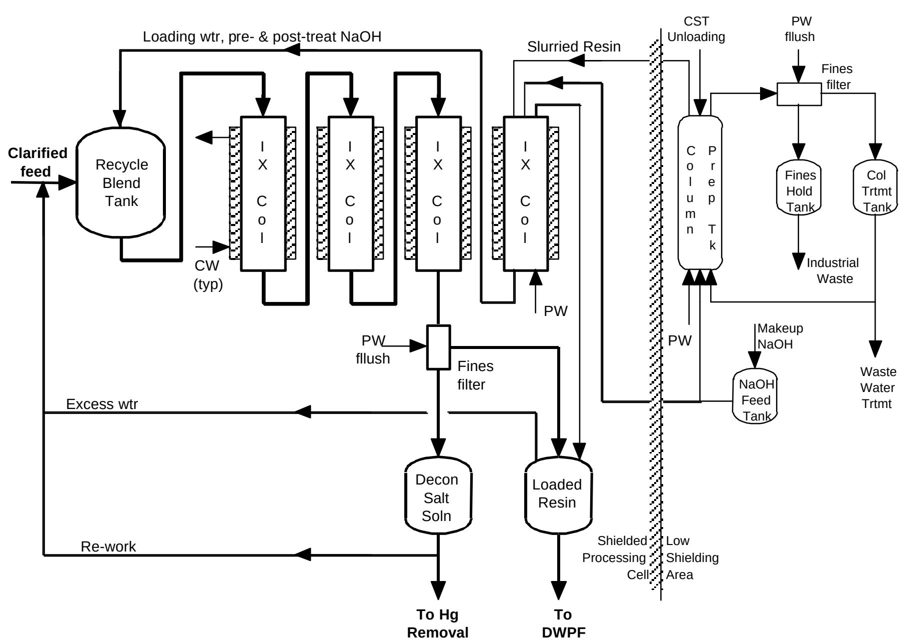

Figure 9-4: CST Non-Elutable Ion Exchange

9.2.3 Direct Disposal in Grout

In this proposed process, cesium 137 is not separated from the salt waste or concentrated supernate. All soluble waste is sent to a new shielded grout facility. The saltstone wasteform generated from dissolved saltcake solution must meet NRC Class C LLW disposal requirements for near-surface disposal. The vaults presently used in the Saltstone Facility meet current regulations for NRC Class C disposal, although the current permit restricts the average curie content in a disposal unit (cell) to be within NRC Class A limits for disposed saltstone. Treatment of salt solution is required to remove entrained sludge so that soluble alpha activity is no greater than 100 nanocurie per gram. If the mercury concentration in the solution is greater than 260 mg/L, it must also be treated to remove mercury before converting the solution to saltstone. At the projected concentration of cesium 137, grout production must be done within a new shielded cell facility, using grout production equipment modified to enable remote operation and maintenance.

In the proposed Direct Disposal in Grout alternative, (Figure 9-5), the concentrated supernate and saltcake solution are combined and transferred to a tank within the new shielded facility. The solution is first treated to remove soluble alpha contaminants by sorbing them on MST. The resulting slurry is then filtered to remove the MST and any entrained sludge solids that accompany the salt solution. The filtrate from the MST treatment would then be processed to produce saltstone grout for disposal.

The grout composition is based on formulations that are the same as the current Saltstone Facility. The clarified salt solution is adjusted to 6.0 M sodium concentration.

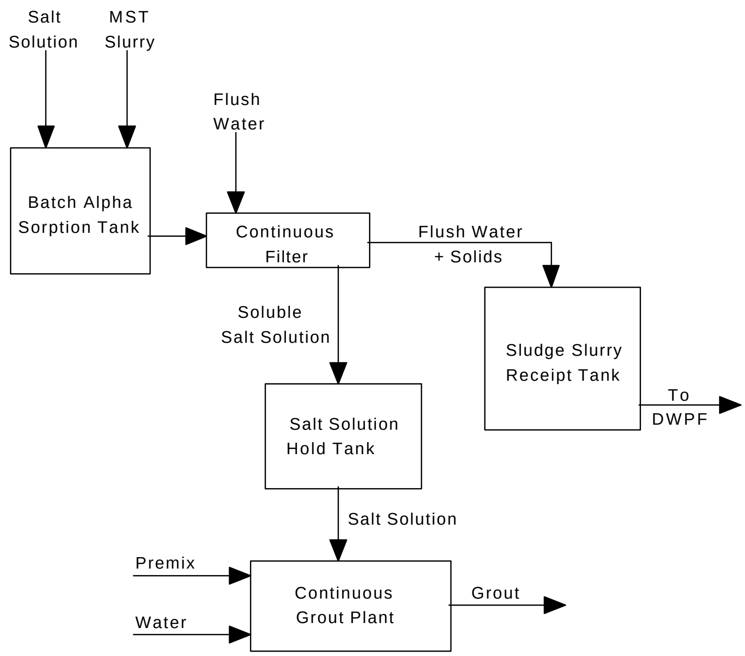

Figure 9-5: Direct Disposal in Grout

9.2.4 Small Tank TPB Precipitation

In the tetraphenylborate (TPB) precipitation process (refer to Figure 9-6), cesium is precipitated with sodium tetraphenylborate and strontium, uranium, and plutonium are sorbed on MST, to form insoluble solids. The resulting precipitate, which contains most of the radionuclides, is filtered to concentrate the solids. The precipitate is sent to the DWPF for vitrification in glass. The decontaminated salt solution, or filtrate, containing primarily sodium salts of hydroxide, nitrate, and nitrite, is transferred to Saltstone for disposal.

Salt solution is pumped from the F/H Tank Farms and is decontaminated in a series of two continuous stirred tank reactions (CSTR). In the first CSTR, salt solution is mixed with process water and recycled wash water, sodium tetraphenylborate (NaTPB or $NaB(C_6H_5)_4$), and MST ($NaTi_2O_5H$). The purpose of the process water or recycled wash water is to adjust the total sodium content to 4.7 molar to optimize the precipitation reaction. The most abundant radionuclide present in salt solution is cesium 137. Sodium tetraphenylborate is added to precipitate the cesium as a tetraphenylborate salt. The non-radioactive potassium, cesium, and ammonium ions are also precipitated in this process. The potassium ion concentration is nominally 100 times that of the total cesium concentration, although this ratio can vary widely. An excess of NaTPB is added to suppress the solubility of cesium and achieve the high decontamination factor.

MST is added to sorb the soluble strontium, plutonium, and uranium ions if these radionuclides are present in quantities exceeding the limit in Saltstone.

The concentration of the slurry, containing the MST and precipitated tetraphenylborate solids, is a nominal 1 wt % insoluble solids after precipitation. The slurry is transferred from the second CSTR to the Concentrate Tank where it is concentrated continuously by cross-flow filtration to a nominal 10 wt % solids. Filtrate is transferred to the Decontaminated Salt Solution Storage Tank prior to being transferred to Saltstone. When 4000 gallons of 10 wt % precipitate is accumulated in the Concentration Tank, it is transferred to the Wash Tank.

The slurry is then washed to remove soluble sodium salts by adding process water and removing spent wash water by filtration. The spent wash water is transferred to either the Recycle Tank for recycling in subsequent batches as dilution water or to the Decontaminated Salt Solution Storage Tank prior to transfer to Saltstone. The washing endpoint is set at 0.01 M NO^{-}_{2}. All of the vessels used in this part of the process are stainless steel to eliminate corrosion concerns.

After precipitation, NaTPB, KTPB, and CsTPB undergo radiolytic and under certain conditions, catalytic degradation. MTPB decomposes to aromatic organics (benzene, biphenyls, and triphenyls) and salts of sodium and boron. The exact mechanism for the catalytic degradation is not completely understood. The catalytic decomposition of TPB results in the formation of triphenylborane, diphenylborinic acid, phenylboric acid, and benzene. The degradation intermediates also decompose catalytically to form benzene. Testing has demonstrated that catalysis with copper ions and sludge solids (Pd has been identified as a primary catalyst in the sludge solids) can significantly increase the rate of decomposition of tetraphenylborate slurries.

The benzene generation will be set at 10 mg/L-hr when excess TPB- is present and 1 mg/L-hr when only solid TPB is present. These have been set at this value to match the current test results by SRTC for decomposition at 25°C.

Controlled benzene removal is required because of flammability concerns. To avoid formation of a free benzene layer (uncontrolled benzene release), accumulation above the saturation limit is avoided by continuous agitation and operating the vessel under nitrogen positive pressure MOC control.

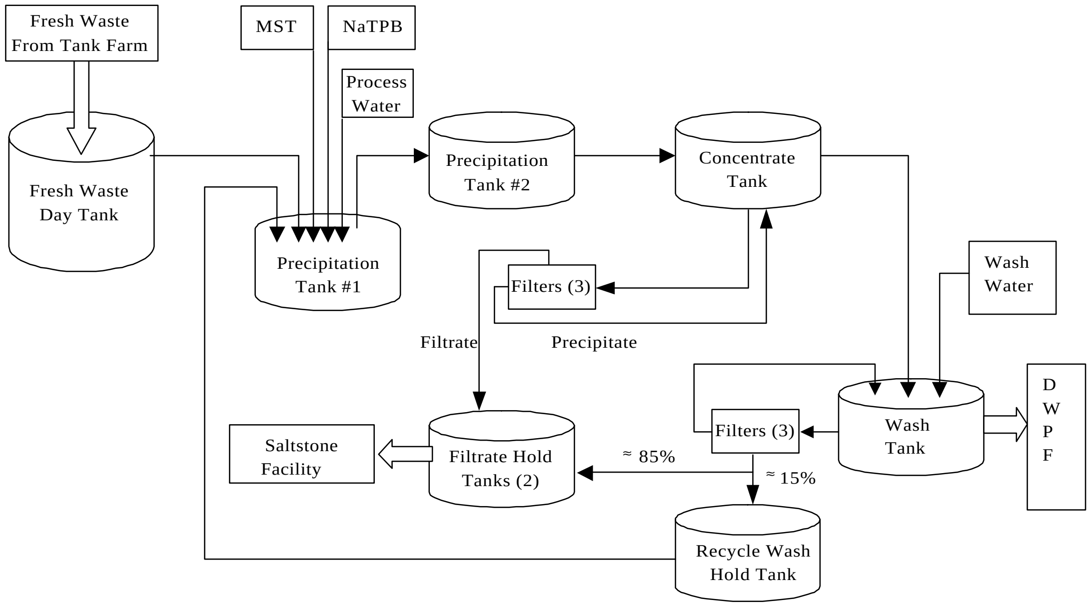

Figure 9-6: Small Tank TPB Precipitation

9.3 Selection of the Preferred Alternatives

The final phase of the Team activities was to recommend a preferred alternative with a backup, if necessary, for implementation. The process used for generating the Short List ensured issues of safety, technical maturity and engineering complexity had been fully considered. Consequently, the Short List alternatives were technically viable for field deployment.

The process for selecting the preferred alternative emphasized the use of cost and schedule as discriminating attributes. These two parameters had been given low weighting in the Investigation Phase because the level of definition of the Initial List alternatives at that stage was insufficient to give a high degree of confidence in the assigned values. Cost and schedule were the focus of attention in the Selection Phase and other attributes which might influence the decision were treated as uncertainties which manifested themselves as a cost and/or schedule impact. However, in order to assure that the preferred alternatives were selected based on a full consideration of their strengths and weaknesses, the Team also performed a qualitative assessment considering the aspects associated with the alternatives.

Therefore, the Team approach to select the preferred alternatives was to base the decision on a combination of quantitative comparisons of cost and qualitative comparisons of other key attributes of the Short List alternatives.

9.3.1 Quantitative

To portray the key information on cost, contingency and uncertainty in a pictorial manner, the Team developed a "Box and Whisker" plot. The "point" represents the LCC Point Estimate derived in Section 7.0. For comparative purposes, the plot also shows the values of TEC and TPC. The "box" represents the upper and lower contingency bounds on the point estimate. The point estimates and "box" are shown in Figure 9-7. The "whiskers" represent the net uncertainties that are considered to be outside the standard contingency definition and have been added in Figure 9-8.

The Team used the results of the contingency analysis to define the bounds of the "box". The upper limit was set at 20% probability of overrun. This was considered to be a reasonably safe upper limit, given the history of typical DOE projects. The lower contingency was set at 60% probability of overrun. This typically is the highest risk which a commercial organization is prepared to manage.

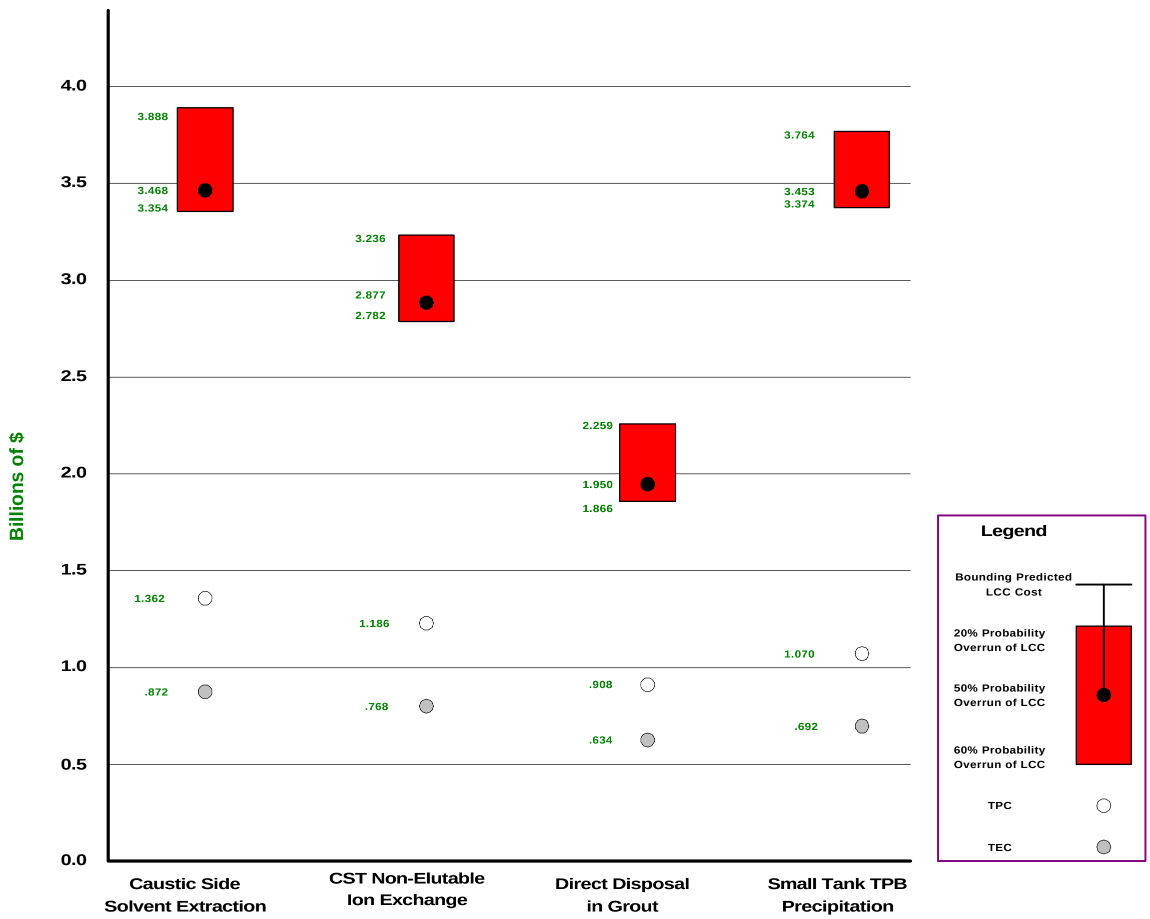

Figure 9-7: Quantitative Comparison of Alternatives

Evaluating the range of contingencies and comparing these with the cost uncertainty values, the Team concluded that the cost uncertainties were within the contingency and the point estimate limits. The schedule uncertainties were an order of magnitude higher than cost uncertainties. Consequently the schedule uncertainties were shown as whiskers in Figure 9-8, representing a pessimistic outcome.

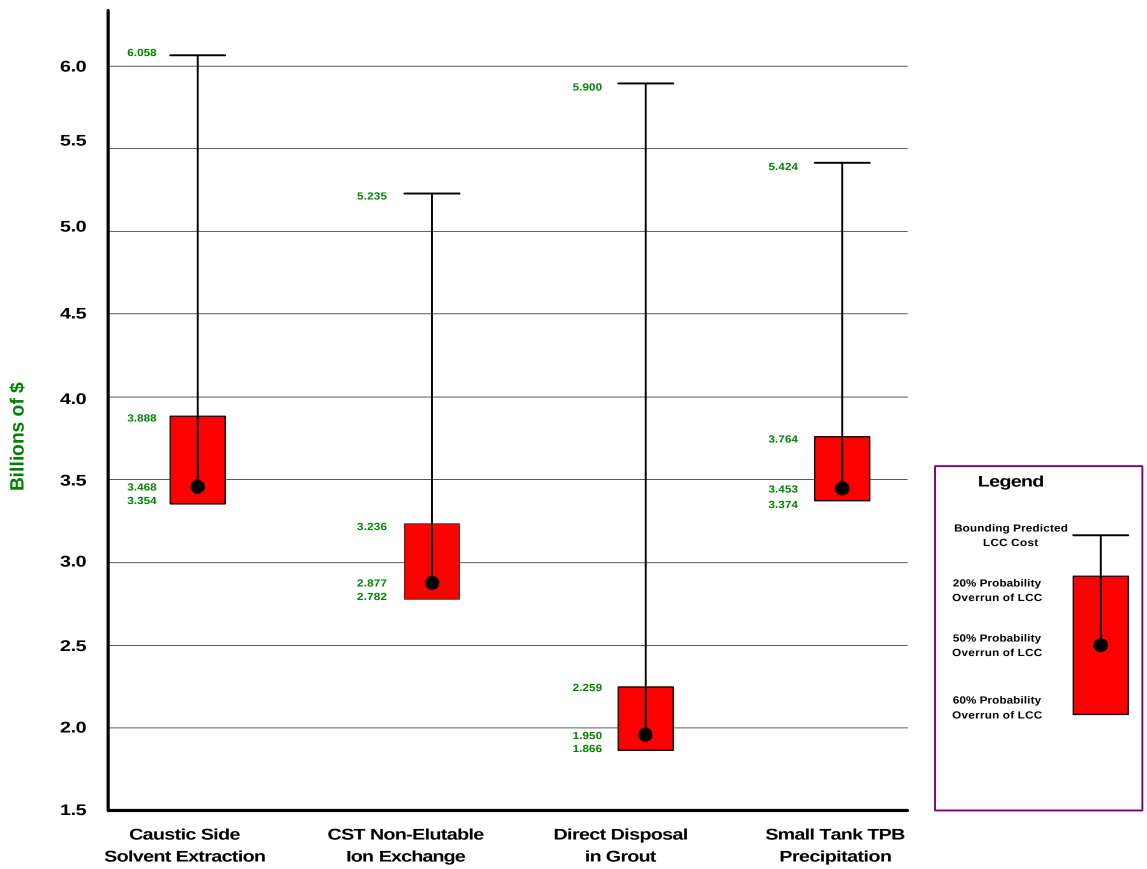

Figure 9-8: Quantitative Comparison of Alternatives With Uncertainties

The quantitative comparison is valuable in comparing the “costs of assured success” for the alternatives. Figure 9-9 shows relationship of the alternatives and the impact of schedule uncertainties on the baseline schedule.

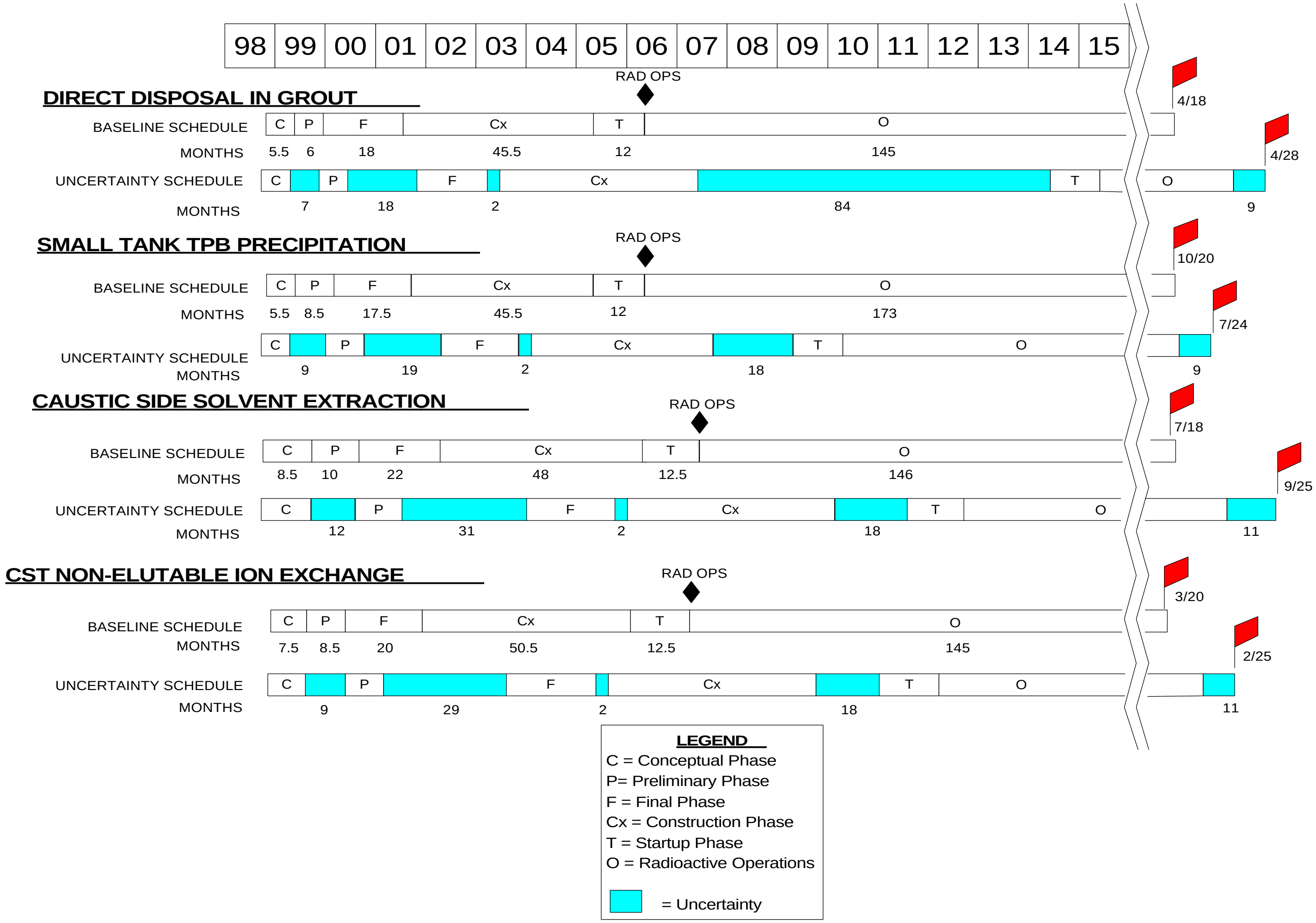

Figure 9-9: Schedule Uncertainty for the Short List Alternatives

Direct Disposal in Grout has the most schedule uncertainty. This raised the issue that delayed radioactive operations would result in waterlogging the Tank Farms. Even with an aggressive management approach to shortening the time for public consultation, regulatory approval and litigation, selection of this alternative would result in exceeding the 2010 Tank Farm space limit. On this basis, there is a high probability that this alternative would not meet the basic requirement. Therefore this alternative was excluded from further consideration. Team evaluation of the other three alternatives resulted in each alternative satisfying the HLW System Plan space management requirement.

The Team reached the following broad conclusions:

- The TPCs for TPB and CST are within the contingency cost of each other.
- TPB and CST are equivalent in representing the "best pessimistic case" on LCC with uncertainty.
- CST represents the "best optimistic case" of the viable alternatives.

In summary, cost differences between the TPC and LCC Point Estimates do not show sufficient discrimination to be the prime driver for making a recommendation.

9.3.2 Qualitative

The format for the qualitative review ensured the Team members would consider the collective attributes of each alternative. Comparisons were performed on two separate bases: first, a comparison relative to each other; second, a comparison relative to the existing ITP flowsheet. This assured that each alternative would have to be considered from more than one perspective.

The attributes chosen for review were: Mission; Technical Maturity; Environmental Protection; Engineering/Design; Operation; Regulatory; Stakeholder Concerns; Safety; and, Radiological Performance. The Mission attribute addressed the flexibility of the alternative to be adapted for possible future applications. Technical Maturity encompassed the maturity of both the underlying science and engineering. Environmental Protection considerations included air and water emissions and waste disposal. Engineering/Design involved the complexity and difficulty of facility implementation. The Operation attribute considered the complexity and intensity of operator activities. The Regulatory category took into account the difficulty of interactions with oversight authorities. Stakeholder Concerns included known preferences with regard to

SRS missions. The vulnerability of the alternatives to accidents involving hazardous material was the focus of the Safety attribute. Finally, Radiological Performance addressed both potential exposures to radiation and potential contamination events.

Five of the six current mission interfaces chosen for review were the normal operating interfaces a salt disposition facility could expect to impact: F and H Canyons; DWPF; F and H Tank Farms; Saltstone; and CIF (Consolidated Incineration Facility). Both chemical composition and volumes of flows to and from these facilities were considered, together with any synergistic effects. The sixth current interface addressed was ITP. This considered the ability of each alternative to deal with the residual material in Tanks 48 and 49. The Future Mission interface was the ability of the alternative to support the operation of missions potentially designated for implementation at SRS.

The results of the review on both bases, i.e., relative comparison and comparison with ITP, are shown in Tables 9-1 and 9-2, respectively. Direct Disposal in Grout was included in the comparison, which was performed before the alternative was eliminated from consideration due to schedule concerns.

Alternative	**Attribute Category**								
	Mission [1]	**Technical Maturity** [2]	**Environment** [3]	**Engineering /Design** [4]	**Operation** [5]	**Regulatory** [6]	**Stakeholder** [7]	**Safety** [8]	**Radiological** [9]
Small Tank TPB	◒	◒	◒	◒	◒	◒	◒	○	◒
Caustic Side Solvent Extraction	○	●	○	◒	○	○	○	○	◒
CST Ion Exchange	○	●	○	●	◒	◒	○	○	◒

●	◒	○
negative attributes	**neutral (indifferent attributes)**	**positive attributes**

Table 9-1: Qualitative Crosscheck Matrix
Comparisons relative to coupled operations

Alternative	Attribute Category								
	Mission [1]	Technical Maturity [2]	Environment [3]	Engineering /Design [4]	Operation [5]	Regulatory [6]	Stakeholder [7]	Safety [8]	Radiological [9]
Direct Disposal As Grout	Negative	Positive	Intermediate	Intermediate	Negative	Negative	Negative	Positive	Intermediate
Small Tank TPB	Intermediate	Intermediate	Negative	Intermediate	Negative	Intermediate	Intermediate	Negative	Intermediate
Caustic Side Solvent Extraction	Positive	Negative	Positive	Intermediate	Intermediate	Positive	Positive	Intermediate	Intermediate
CST Ion Exchange	Positive	Negative	Positive	Negative	Intermediate	Intermediate	Positive	Negative	Negative

Negative **Intermediate** **Positive**

Table 9-1: Qualitative Crosscheck Matrix (continued) - Relative Comparisons

1	TPB:	less flexible facility
	CST:	flexible facility
	Grout:	excludes can-in-can
	SX:	flexible facility
2	TPB:	extensively studied, complex chemistry
	CST:	temperature effect, catalytic decomposition, stability, foaming
	Grout:	mature technology
	SX:	immature solvent system
3	TPB:	benzene emissions *
	Grout:	higher activity leachate *
	*	relative to insult to the environment vice impact of the insult to the environment
4	TPB:	vapor space management, CSTR design
	CST:	H_2 management, carousel design, temperature management complexity
	Grout:	remotable mixer, pig system complexity
	SX:	contactor density, instrumentation
5	TPB:	CSTR operation in series (yield vs throughput), salt process cell coupling, product sampling
	CST:	resin changeout & pretreatment
	Grout:	dry material handling, out-of-spec product, daily startup & shutdown
	SX:	startup balance & crud handling
6	TPB:	benzene permitting
	CST:	waste form qualification
	Grout:	major waste characterization issues
7	TPB:	IX proponents, benzene still present, public credibility – ITP shutdown
	Grout:	cesium remaining in South Carolina
8	TPB:	benzene in multiple locations
	CST:	H_2 from loaded CST in multiple locations (radiolysis & catalytic formic acid decomposition)
	Grout:	inherently safe
	SX:	solvent flammability (low inventory)
9	CST:	highest source term, hot particles

Table 9-1: Qualitative Crosscheck Matrix (continued) - Footnotes

Alternative	F & H[1] Canyons	New[2] Missions	DWPF[3]	Tank Farm[4]	Saltstone[5]	CIF[6]	ITP[7]
Direct Disposal As Grout	◒	●	○	○	○	○	●
Small Tank TPB	◒	◒	◒	◒	◒	◒	◒
Caustic Side Solvent Extraction	◒	◒	○	○	○	○	●
CST Ion Exchange	◒	◒	●	◒	○	○	●

● **negative attributes**
◒ **neutral (indifferent attributes)**
○ **positive attributes**

Table 9-2: Interfaces with Salt Disposition Process Comparisons Relative to coupled operations

Alternative	F & H [1] Canyons	New [2] Missions	DWPF [3]	Tank Farm [4]	Saltstone [5]	CIF [6]	ITP [7]
Direct Disposal As Grout	Intermediate	Negative	Positive	Positive	Positive	Positive	Negative
Small Tank TPB	Intermediate	Intermediate	Negative	Negative	Negative	Negative	Positive
Caustic Side Solvent Extraction	Intermediate	Intermediate	Positive	Intermediate	Intermediate	Intermediate	Negative
CST Ion Exchange	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Positive	Negative

Negative **Intermediate** **Positive**

Table 9-2: Interfaces with Salt Disposition Process (continued) - Relative Comparisons

[1] All alternatives can support F&H Canyon missions as is (baseline schedules), (e.g., at risk fuel & targets, scrap, 94-1).
Variation on TPB and SX to locate in H-Canyon would impact H-Mission

[2] Grout cannot support can-in-can mission (DWPF canister not self protecting – no γ radiation).

[3] TPB: operate salt cell, no late wash, not as closely coupled
CST: waste qualification issue, foaming, sampling, recovery from carryover

Grout: ease of operation (MST only)
SX: ease of operation (MST + Cs aqueous stream)

[4] TPB: organics and Cs in recycle water
CST: Cs (hot particles) and CST in recycle water, less (1/4) recycle water
Grout: no recycle
SX: Cs and very low organics in recycle water

[5] TPB: Baseline
CST: fewer vaults compared to baseline (10% less)
Grout: Saltstone plant replaced by salt Disposition Grout Plant
SX: fewer vaults compared to baseline (30% less)

[6] TPB: Benzene to CIF – baseline
CST; no stream to CIF
Grout: no stream to CIF
SX: small volume (~ 500 gal/yr) of solvent to CIF

[7] TPB: direct feed to precipitators
CST: treatment followed by blending or direct feed
Grout: treatment followed by blending or direct feed
SX: treatment followed by blending or direct feed

Table 9-2: Interfaces with Salt Disposition Process (continued) - Footnotes

Comparing the results in Tables 9-1 and 9-2, the Team drew a number of conclusions which were common to both approaches:

- Solvent Extraction has more positive attributes than either CST or TPB.
- TPB has many neutral attributes; CST has offsetting positive and negative attributes in comparison.
- Technical maturity, specifically the scientific maturity, is higher for TPB than CST or Solvent Extraction.

From the relative comparisons (Table 9.1), the conclusions were:

- CST and Solvent Extraction have many intermediate interface attributes; TPB has more negative attributes in comparison.
- CST has more positive attributes that TPB.

The overall conclusion drawn from the qualitative crosscheck was that, in terms of a range of attributes and interface comparisons, Solvent Extraction was rated higher than either TPB or CST.

9.3.3 Final Selection

At this stage, the Team summarized the conclusions drawn from the combined quantitative cost comparison and qualitative crosscheck of the alternatives:

- CST and TPB are not significantly different from each other, either in the qualitative crosscheck or cost comparisons.
- Solvent Extraction has the most positive attributes, but the highest relative cost (LCC with uncertainty; and TPC).

Recognizing that this conclusion did not provide a clear decision, the Team realized that individual and combined Team expertise would have to be applied to reach a decision. The Team prepared a table of the most important attributes to permit a structured consideration of the merits and weaknesses of the alternative.

The attributes selected for the final Team evaluation were TPC, LCC, Safety, Science & Technology Maturity, and Mission Impact. In addition, the following areas were evaluated based on the Team expertise obtained over the preceding months:

- Likelihood of success – the Team's judgement of successfully deploying the technology and meeting the key schedule requirements.

- Applied engineering – a measure of the difficulty of translating each technology into a functional radioactive facility.
- Management of uncertainty – the characterization of the difficulty in managing the range of uncertainties associated with each technology, with considerable emphasis on the risk of waterlogging the Tank Farm.
- Scope for optimization – the Team view of relative opportunity for throughput improvement or cost reduction, as a result of further R&D or engineering.
- Fallback options – the characterization of the ability of the alternative to recover from a failure of the chosen separation media by use of a fallback chemical in the same equipment.

The Team discussed each area in turn and ranked the three remaining alternatives. Ranking was forced only when the alternatives were very close, to provide discrimination. The results are shown in Table 9-3.

Table 9-3: Alternative Attribute Ranking

Criteria	1	2	3
TPC	TPB	CST	SX
LCC	CST	TPB	SX
Safety	SX	TPB	CST
Science &Technology Maturity	TPB	CST	SX
Mission Impact	SX	CST	TPB
Team Opinion:			
- Likelihood of Success	TPB	CST	SX
- Applied Engineering	SX	TPB	CST
- Management of Uncertainty	TPB	SX	CST
- Scope for Optimization	SX	TPB	CST
- Fallback Options	CST	SX	TPB

Considering the information reviewed during the selection process, the Team reached a consensus that Small Tank TPB Precipitation should be recommended as the preferred alternative, the principal reasons being:

- Best likelihood of success
  - Simple safety strategy
  - R&D scope is small and defined
  - Skill mix of personnel is available
  - Most "discovery" issues likely to be mechanically rather than chemically solved
  - Most schedule margin prior to waterlogging the Tank Farm
  - Even with Team uncertainties fully applied, schedule implementation does not challenge Tank farm waterlogging
- Most manageable risks
  - Safety strategy implementable
  - Cash flow requirements lowest of viable alternatives
  - Risks are operational failures more than technology failures
- Most technically mature
  - Known chemical reaction expression
  - Extensive R&D program experience
  - Large empirical data set
- Best pessimistic life cycle cost (considered equal to CST Non-Elutable Ion Exchange)
- Lowest project cost (marginally)

None of the alternatives were clearly superior to the others and each required further R&D. In order to reduce overall program risk, the Team decided it was prudent to select a backup. The technical maturity and liklihood of success for both Caustic Side Solvent Extraction and CST Ion Exchange could be improved significantly by pursuing an energetic R&D program over the next one to two years. Using the information compiled for the selection process, the Team recommends CST Non-Elutable Ion Exchange as the backup alternative over Caustic Side Solvent Extraction for the following reasons:

The combination of Small Tank TPB Precipitation and CST Non-Elutable Ion Exchange offered the best chance of assured success

- Separation media commercially available
- Once through process
- Reduced rotating equipment

- Risks more manageable
  - More margin than SX for waterlogging the Tank Farm
  - Less technically mature than TPB
  - Applied engineering solutions for known technology issues
- More technically mature
  - Large scale pilot demonstration
  - Multiple National Laboratories research effort
- Better fallback options
  - DWPF campaigning
  - Optional lower performing resin
  - CST only glass formulation (new vitrification facility)

If the criterion for the selection of the backup had been “the alternative offering the best prospects for a return on investment through production schedule improvements”, then Caustic Side Solvent Extraction would have been the choice. Its attributes of best inherent safety and best interface with DWPF made this a very difficult choice for the Team. One member registered a dissenting opinion over the choice of CST Non-Elutable Ion Exchange as the backup.

10.0 Recommendations

The Team concluded that each short list technology can be deployed and operated. In addition, cost differences between the alternatives did not prove to be large enough to be the prime driver for alternative selection.

Critical to the success of implementation of any short list technology is its impact on tank farm space management. The project date when the salt disposition plant is available to begin emptying tanks is key to maintaining viable tank farm operations and site missions. Tank Farm space "waterlogging", as detailed in the approved HLW System Plan, is unavoidable without operation of a salt disposition process. The uncertainties identified with the project schedules for each alternative highlight the need to continue progress on the recommended alternative to mature research & development and conceptual design as rapidly as possible. These uncertainties also indicate the very high risk and unlikely success of implementing Direct Disposal in Grout in the time frame required.

The Team recommends Small Tank TPB Precipitation as the primary technology for deployment and CST Non-Elutable Ion Exchange as the backup technology. Use of available congressional plus-up money should be focused on research & development, as well as development of conceptual design deliverables, to refine technology scope and cost while the project validation process continues.

11.0 Acronyms

AMP-PAN	ammonium molybdophosphate on polyacrylonitrile (resin)
ANL	Argonne National Laboratory
BNFL	British Nuclear Fuels plc
CAB	Citizen's Advisory Board
Ci	Curie
CIF	Consolidated Incineration Facility
CST	Crystalline Silicotitanate
CSTR	Continuous Stirred Tank Reactor
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOE HQ IPE	DOE Headquarters Independent Project Evaluation
DOE-SR	DOE - Savannah River
DWPF	Defense Waste Processing Facility
EPA	Environmental Protection Agency
ESP	Extended Sludge Processing
ETF	Effluent Treatment Facility
FFA	Federal Facilities Agreement
G&A	General and Accounting
HLW	High Level Waste
INEEL	Idaho National Engineering and Environmental Laboratory
ISMS	Integrated Safety Management System
ITP	In Tank Precipitation
IX	Ion Exchange
LCC	Life Cycle Cost
LDR	Land Disposal Restrictions
LLW	Low Level Waste
M	Molar
mM	millimolar
mg/l	Milligrams per liter
MST	Monosodium Titanate
NaTPB	Sodium Tetraphenyl Borate
NRC	Nuclear Regulatory Commission
O&M	Operating and Maintenance
OPC	Other Project Costs
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
PCCS	Product Composition Control System
PCDP	Pre-Conceptual Design Package
PFD	Process Flow Diagram
PNNL	Pacific Northwest National Laboratory

ProdMod	Production Model
R&D	Research and Development
RAMI	Reliability, Availability, Maintainability, and Inspectability
RHLWE	Replacement High Level Waste Evaporator
SCDHEC	South Carolina Department of Health and Environmental Compliance
SEMP	Systems Engineering Management Plan
SPC	Salt Processing Cell
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SX	Solvent Extraction
STP	Site Treatment Plan
TEC	Total Estimated Cost
TPB	Tetraphenyl Borate
TPC	Total Project Costs
TWRS	Tank Waste Remediation System
WCS	Waste Characterization System
WSMS	Westinghouse Safety Management Solutions
WSRC	Westinghouse Savannah River Company

12.0 References

1. HLW Salt Disposition Team, Preconceptual Phase I, Initial Design Input, Dated June 24, 1998
2. HLW-SDT-980122, High Level Waste Salt Processing Alternatives – Life Cycle Analysis Details, Generic Bases, Assumptions Etc.
3. HLW-SDT-980123, High Level Waste Salt Processing Alternatives – Life Cycle Analysis Details, Stabilization in Grout.
4. HLW-SDT-980124, High Level Waste Salt Processing Alternatives – Life Cycle Analysis Details, Caustic Side Solvent Extraction.
5. HLW-SDT-980125, High Level Waste Salt Processing Alternatives – Life Cycle Analysis Details, CST Ion Exchange.
6. HLW-SDT-980126, High Level Waste Salt Processing Alternatives – Life Cycle Analysis Details, Small Tank TPB
7. HLW-SDT-980140, Research and Development Reports
8. HLW-SDT-980141, Desktop Procedures.
9. WSRC-RP-98-00165, HLW Salt Disposition Alternative Identification Preconceptual Phase II Summary Report, Revision 1.
10. WSRC-RP-98-00168, Bases, Assumptions, and Results of the Flowsheet Calculations for the Short List Salt Disposition Alternatives.

Enclosures

1. G-CDP-H-00003, Pre-Conceptual Design Package for the Small Tank TPB Precipitation Facility.

2. G-FDD-H-00014, Facility Design Description for the Small Tank TPB Precipitation Facility.

3. HLW-SDT-980164, Science & Technology Roadmap for Small Tank TPB Precipitation (Primary Selection)

4. G-CDP-H-00004, Pre-Conceptual Design Package for the CST Non-Elutable Ion Exchange Facility.

5. G-FDD-H-00013, Facility Design Description for the CST Non-Elutable Ion Exchange Facility

6. HLW-SDT-980165, Science & Technology Roadmap for CST Non-Elutable Ion Exchange (Backup Selection)

7. HLW-RP-98-00167, LCC, Estimate Bases, Assumptions and Results