G-ADS-H-00007
Revision 0

CLOSURE BUSINESS UNIT

LIQUID WASTE DISPOSITION PROJECTS

SALT PROCESSING PROJECTS

Tank 48 Disposition Project

WSRC In-House Treatment Option Evaluation (U)

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

DISCLAIMER

APPROVAL PAGE

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Table of Contents

Summary of Revision

Revision Number	Date	Description of Change
0	2/4/04	Initial Issue

EXECUTIVE SUMMARY

Tank 48 return to service is critical to the processing of high level waste (HLW) at SRS. Tank 48 currently holds legacy material containing organic tetraphenylborate (TPB) compounds from the operation of the In-Tank Precipitation (ITP) process. This material is not compatible with the waste treatment facilities at SRS and must be removed or undergo treatment to destroy the organic compounds before the tank can be returned to Tank Farm service. The scope of Tank 48 Disposition Project is to initiate and complete a project that will include any required design, modifications, testing, material processing, heel removal and return to service procedures.

The Tank 48 Disposition Project strategy is to develop WSRC in-house options and, in a parallel effort, to solicit and evaluate vendor bids on the design and installation of a waste treatment unit (WTU) for Tank 48.

This report documents the results of the WSRC in-house option evaluation performed by the Tank 48 Disposition Project Team.

The Tank 48 Disposition Project Evaluation Team built upon the previous work performed on Tank 48 disposition and documented in the HLW Tank 48 Disposition Alternatives Identification Phase I and II Summary Report (Reference 5.1), and research data developed by Savannah River Technology Center (SRTC) (References 5.2 through 5.7). The options were developed to sufficient maturity to allow major risks to be identified; rough order of magnitude (ROM) cost estimates to be developed and preliminary schedule durations to be estimated.

The Team developed weighted evaluation criteria including: Cost, Schedule, Safety Basis, Research and Development, Operations, Regulatory, and Downstream Process impacts. The Team scored the options for each of the criteria. The results from this evaluation showed that in order of preference the WSRC in-house options ranked as follows:

1. Blending
2. In-Tank Thermal Hydrolysis
3. In-Tank Catalytic Hydrolysis
4. In-Tank Fenton's Hydrolysis
5. DWPF Salt Cell Fenton's Hydrolysis

Blending was ranked as the most favorable WSRC in-house option followed closely by the second-placed option of In-Tank Thermal Hydrolysis. A summary of the two options are listed below.

Blending - This option consists of blending material from the DWPF recycle tanks with the material in Tank 48. The blending will occur in Tank 48 and Tank 50 (initially Tank 50 then Tank 48). The blended material will be transferred to the Saltstone Processing Facility (SPF). The cost of this option is estimated at $15 million with 23 months schedule duration. The major risks associated with this option are:

- Saltstone (SPF) Class C Permit not received from the state of South Carolina in the timeframe assumed in this evaluation.
- Insoluble TPB concentration not acceptable in SPF for grout formulation.
- Benzene generation rates require equipment modifications to Tank 50, SPF and interconnecting transfer systems (including Low Point Drain Tank, LPDT).

In-Tank Thermal Hydrolysis - Thermal Hydrolysis in Tank 48 decomposes TPB through a hydrolysis reaction to produce benzene. Reaction conditions for this tank treatment option are a pH of 11 and a temperature of 45°C. The cost of this option is estimated at $11 million with 27 months schedule duration. The major risks associated with this option are:

- Organic destruction efficiency (based on extrapolation of data from a limited 2 week test) does not meet end state acceptance criteria (<5% of lower flammability limit [LFL]) within the treatment time assumed in this evaluation.

As noted above, the selected strategies are not without risk, and will require additional evaluations and testing before a completely defined disposition plan can be finalized. Additionally, to bound this study, the estimate of final disposal costs (Saltstone, Canisters, etc.) was considered outside the scope of this evaluation. In addition to the schedule durations noted, the Team also estimated that after achieving the desired end state approximately 3 months should be allowed to enable Tank 48's return to service into the Tank Farm System. This would be applicable to all the options being evaluated; therefore, it was not included in the schedule comparison data for any of the options.

In conclusion, the Team is confident that the Blending option can successfully be completed. As a risk handling strategy to the permitting requirement associated with Blending, the Team also recommends that the In-Tank Thermal Hydrolysis be developed as a backup option.

1.0 Background

The Tank 48 Disposition Project was initiated with the mission of returning Tank 48 to Tank Farm service. Tank 48 return to service is critical to the processing of HLW at SRS as it will provide approximately one million gallons of Type IIIA tank storage space. Tank 48 currently holds legacy material containing organic TPB compounds from the ITP process. This material is not compatible with the waste treatment facilities at SRS and must be removed or undergo treatment to destroy the organic compounds before the tank can be returned to Tank Farm service.

The Tank 48 Disposition Project strategy is to develop WSRC in-house options and, in a parallel effort, to solicit and evaluate vendor bids on the design and installation of a WTU for Tank 48. This strategy is identified in the Tank 48 Disposition Project Risk Analysis Report (Reference 5.8).

This option analysis documents the investigation, evaluation and ranking of the Tank 48 WSRC in-house options.

2.0 Investigation

The Tank 48 Disposition Project Team built upon the previous work performed on Tank 48 disposition and documented in the HLW Tank 48 Disposition Alternatives Identification Phase I and II Summary Report (Reference 5.1). The study selection process concluded the first and second choice were the original Salt Cell Process and Steam Reforming. The Phase II study also concluded that the amount of research needed to complete development of the technical bases for the in-tank process options appears relatively modest versus the costs required to pursue the two leading candidates and the most promising options should be pursued.

From the Phase I & II assessment, potential treatment options for destroying/removing the TPB salts in Tank 48 were downselected for further study as determined in the Technical Program Plan for Tank 48H Processing (Reference 5.9). Some of the downselected option processes could potentially be performed in Tank 48 itself while others would require dedicated facilities. The processes selected are those with the highest potential to successfully disposition Tank 48 contents, either based on process knowledge or limited experimentation. The research effort to recover Tank 48 can be categorized by the process used and by where the process takes place: in-tank and out–of-tank. The processes selected in the Technology Plan were:

- Accelerated Degradation Using Elevated Temperature and Decreased pH
- Catalytic Hydrolysis Using Metals and Decreased pH
- Catalytic Oxidation Using Fenton's Reagent
- Thermal Degradation Using Steam Reforming

The out-of-tank options are considered to be enveloped by the Scope of Work (SOW) (Reference 5.10) used to solicit vendor proposal for the Tank 48 WTU. The SOW allowed the vendors to specify the process and "Best Value" criteria was developed for the selection of the contractor.

The WSRC (i.e., "in-house") options developed in parallel with the vendor solicitation include:

- In-Tank Thermal Hydrolysis
- In-Tank Catalytic Hydrolysis
- In-Tank Fenton's Hydrolysis
- DWPF Salt Cell Fenton's Hydrolysis
- Blending

The combination of the vendor proposed processes and the in-house processes represents the conclusion of the Phase I & II evaluation and the Technical Program Plan (Reference 5.9). In that report, the Low Curie Salt cesium limit of 0.05 Ci/gal was used to feed Saltstone. A project has been initiated to install modifications that would allow an increase in this limit pending approval by the South Carolina regulatory authority. Given this change, the blending option is now included as an option. The preferred option from the Phase I & II report, using the original DWPF Salt Cell Process, was considered to have a cost and schedule that was excessive for a one time process. A substitution was identified (Fenton's) that could possibly present an improved cost and schedule and have potential for other HLW programs, therefore was included in this evaluation.

Investigations focused on In-Tank options, DWPF Salt Processing Cell (SPC) and Blending, as other out-of-tank options were assumed to be enveloped by the solicited scope of work.

Initial conditions for the contents of Tank 48 are defined in Appendix 6.1. (Extracted from Reference 5.10, "Statement of Work, SRS Tank 48H Material Treatment"). The critical initial condition to the investigation was the quantity of TPB, estimated at 23,000 kg in Tank 48.

The final end state of Tank 48 is based on reducing the amount of TPB in Tank 48 to meet the 5% waste tank organic flammability contribution limit (reference 5.11). A conservative calculation (Reference 5.12) was developed that shows that 0.3 kg of TPB meets this requirement. The Team concluded that after achieving the desired end point, additional time (approximately three months) would be required to enable Tank 48's return to service into the Tank Farm System. This additional time primarily accounts for sample analysis, validation of end state achievement by all interested stakeholders (WSRC, DOE, DNFSB, etc.), and equipment and procedure implementation for return to service conditions. This would be applicable to all the options being considered; therefore, it was not included in the schedule comparison data for any of the options.

2.1 Tank 48 WSRC In-House Processing Options

Technical reports, preliminary flow sheets and risk assessments were utilized during the investigation for use by the Team during the evaluation process (References 5.2 through 5.7, and 5.13 through 5.19). To summarize critical information, a data sheet was developed for each option. The salient technical data, schedule, cost and major risks associated with each option was included in the data sheets. These data sheets are contained in Appendix 6.2. The following sections provide a general description of each in-house option as well as a summary of the major risks associated with each option.

2.1.1 In-Tank Thermal Hydrolysis

2.1.1.1 Description

In this option the TPB in Tank 48 is decomposed using elevated temperature and reduced pH. To accomplish thermal decomposition, the alkalinity will be lowered to a pH of 11. The temperature of the tank will be increased to 45ºC primarily by using heat generated by slurry pump operation and controlling cooling water flow as required. Initial studies have shown that with a pH of 11 and elevated temperature, there is sufficient decomposition reaction while still maintaining corrosion protection for the tank internal components. The primary products of the reaction are benzene, phenol and borate salts. The benzene is released to the tank vapor space and removed from the tank by the existing Tank 48 nitrogen purge ventilation system. The phenol and borate salts remain with the tank liquid along with the monosodium titanate (MST) solids left over from ITP operations and pose no significant flammability hazard. Once the analysis shows the material is below the established organic limit the resulting liquid can be sent to any tank farm waste tank or concentrated in the HLW evaporator system.

2.1.1.2 Risks

As decomposition efficiency has been extrapolated from limited duration test results (Reference 5.5), this process carries the risk that the decomposition efficiency is not adequate to meet the end state requirement within the 12 month treatment time assumed in this evaluation. A more detail discussion of the risks associated with this option is provided in reference 5.13.

2.1.2 In-Tank Catalytic Hydrolysis

2.1.2.1 Description

In this option the TPB in Tank 48 is decomposed by a hydrolysis reaction using elevated temperature, reduced pH and an added catalyst. To accomplish catalytic decomposition, the alkalinity will be lowered to a pH of 11. The temperature of the tank will be increased to 45ºC (primarily by slurry pump operation as discussed in Section 2.1.1.1) and a catalyst (copper nitrate or palladium nitrate) added to promote the decomposition reaction. Initial studies have shown that with a pH of 11, elevated temperature, and a catalyst addition, there is sufficient decomposition reaction while still maintaining corrosion protection for the tank internal components. The primary products of the reaction are benzene, phenol and borate salts. The benzene is released to the tank vapor space and removed from the tank by the existing Tank 48 nitrogen purge ventilation system. The phenol and borate salts remain within the tank liquid along with the MST solids left over from ITP operations and pose no significant flammability hazard. This resulting liquid can be sent to any tank farm waste tank or concentrated in the HLW evaporator system once the analysis shows the material is below the established organic limit.

2.1.2.2 Risks

As decomposition efficiency has been extrapolated from limited duration test results (Reference 5.5), this process carries the risk that the decomposition efficiency is not adequate to meet the end state requirement within the 12 month treatment time assumed in this evaluation. A more detail discussion of the risks associated with this option is provided in reference 5.14.

2.1.3 In-Tank Fenton's Hydrolysis

2.1.3.1 Description

This option utilizes a catalyst (usually iron [ferric nitrate], copper [cupric nitrate] or a combination of both) in conjunction with hydrogen peroxide (H_2O_2) to destroy organic materials through oxidation. This combination of hydrogen peroxide and catalyst is known as Fenton's Reagent. To accomplish Fenton's decomposition, the alkalinity will be lowered to pH of 11. The temperature of the tank will be increased to 45ºC (primarily by slurry pump operation as discussed in Section 2.1.1.1). Catalyst will be added to the tank and hydrogen peroxide will be introduced to the tank sub-surface at a controlled rate. Initial studies have shown that with a pH of 11, elevated temperature, and the presence of Fenton's Reagent there is sufficient decomposition reaction. The primary products of the reaction are carbon dioxide, water and borate salts. The carbon dioxide is released to the tank vapor space and removed from the tank by the existing Tank 48 air-based ventilation system. In addition to carbon dioxide gas, other minor decomposition products are oxygen and benzene due to reaction inefficiencies. The water and borate salts remain within the tank liquid along with the MST solids left over from ITP operations and pose no flammability hazard. Once the analysis shows the material is below the established organic limits the resulting liquid can be sent to any tank farm waste tank or concentrated in the HLW evaporator system.

2.1.3.2 Risks

The presence of peroxide, milder pH conditions, and elevated temperature could result in an increased risk to the tanks internal components due to corrosion unless corrosion chemistry is maintained. This could reduce the service life of the tank based on corrosion study results that identified potential pitting concerns (Reference 5.7). Second, as decomposition efficiency has been extrapolated from limited duration test results (Reference 5.5), this process carries the risk that the decomposition rate is not adequate to meet the end state requirement within the 12 month treatment time assumed in this evaluation. A more detail discussion of the risks associated with this option is provided in reference 5.15.

2.1.4 Salt Cell Fenton's Hydrolysis

2.1.4.1 Description

This option utilizes the same Fenton's reagent (catalyst and peroxide) as does the in-tank Fenton's option, but performs the reaction in the DWPF Salt Cell. The reaction tanks and piping in the Salt Cell are constructed of corrosion resistant alloys and can withstand higher temperatures and a highly acidic environment. The Salt Cell Fenton's option would operate at boiling (around 100ºC) and a pH range of 3-5. These conditions are considered the most efficient for destroying organic compounds using a Fenton's Reagent process.

The primary products of the reaction are carbon dioxide, water and borate salts. The carbon dioxide is released through the salt cell tank ventilation system. In addition to carbon dioxide gas, other minor decomposition products are oxygen and benzene due to reaction inefficiencies. The water and borate salts remain within the tank liquid along with the MST solids left over from ITP operations and pose no flammability hazard. This resulting liquid would be processed through the DWPF system and vitrified with the existing waste stream from the Tank Farm.

2.1.4.2 Risks

The primary risk of this option is that it could negatively impact glass production in DWPF. Coupling this process with DWPF, a series of batch processes, means that any outage of the Fenton Processing Equipment has the potential to shut down DWPF processing. The sharing of process equipment, including condensate collection storage space also has the potential for impacting DWPF production. The Salt Cell would require significant modification in order to process the Tank 48 material. The time to modify the equipment and process the contents may not meet the needed Tank 48 return to service date. No detailed risk analysis was developed and issued for this option. A preliminary risk analysis performed for a small tank precipitation process in the DWPF Salt Cell was reviewed by the Team for guidance in identifying potential risks for the use of Fenton's Hydrolysis in the Salt Cell.

2.1.5 Blending

2.1.5.1 Description

This option consists of blending material from Tank 48 with DWPF recycle. Initially DWPF recycle will be transferred to Tank 50 and then an appropriate quantity of Tank 48 material will be transferred into Tank 50. The solution will be mixed, sampled and compared to SPF waste acceptance criteria (WAC) limits. The blended material will be transferred to SPF for final disposition as grout. The next phase of the blending occurs in Tank 48. DWPF recycle will be sent to Tank 48 in small batches (approximately 55,000 gallons), mixed and the blended solution transferred to Tank 50. This operation will be repeated until the quantity of residual TPB in Tank 48 can meet the end state requirement of less than 5% organic contribution to the LFL. The primary product from this option is grout containing the TPB and MST solids. The blending in Tank 48 will result in two batches of material being sent from Tank 50 and then to SPF. This will result in a total of three batches being used to send material from Tank 48 to final disposition in SPF. Emissions resulting from benzene generation are assumed to be below the permit limit.

2.1.5.2 Risks

The largest risk to this option is a regulatory one. The current radiological permit limits for Saltstone are very low and would require significant amounts of grout to completely disposition Tank 48 material through SPF. SRS is currently pursuing a modification to the permit with South Carolina authorities. Failure to receive relief from current radiological limits is the primary risk for this option. Additionally, the timeliness of permit approval could jeopardize the schedule estimate assumed in this evaluation. Next, at the normal Tank 48 conditions of low temperature (<35ºC) and high alkalinity (pH ≥ 14) the TPB is very stable and minimal degradation of the TPB is expected. If DWPF recycle contains active catalysts, then mixing this material with DWPF recycle could produce undesirable benzene generation rates in Tank 48 and Tank 50. This could require modifications to Tank 50. The risk of undesirable benzene generation rates also applies to SPF and the interconnecting transfer system (including the LPDT). Another risk for this option is the ability to form acceptable grout with the blended material at SPF. The blended material will contain both TPB and MST solids left over from ITP operations. There is a risk that the concentrations of these solids, particularly the actinides or organic, may not produce an acceptable grout form and in the case of TPB may additionally create problems in leaching organic materials. No testing has been completed with grout containing actinides adsorbed on MST or insoluble TPB at the concentrations planned for Tank 48 processing. Further testing is required to minimize this risk. A detailed discussion of the risk associated with this option is provided in Reference 5.16.

3.0 Evaluation

3.1 Evaluation Team

Team members were selected for their specific expertise, SRS experience and knowledge, research and development knowledge, and familiarity with planning, design and operation of facilities at SRS. In addition to the resources of the Team, subject matter experts were consulted on an as-needed basis. This ensured that the necessary expertise was available for a knowledgeable decision.

The Team was comprised of the following members:

Team Member	**Organization**
Jim Barber	Salt Engineering
Christopher Cope	WSMS
Gerald Eide	HDP Facility Engineering
Rick Fowler	HLW Program Development and Integration
Anthony Giordano	Tank 48 Project Manager
Dan Lambert	SRTC
Bernice Rogers	Tank 48 Project Owner
Steve Strohmeier	Salt Engineering
Gavin Winship	Salt Engineering
Ben Dean	Salt Engineering

3.2 Evaluation Process

The process used by the Team followed the guidance within the System's Engineering Methodology Guidance Manual (Reference 5.20) and employed a simplified scoring methodology. The major steps of the process were:

- Development of evaluation criteria
- Weighting of evaluation criteria
- Evaluation of options versus criteria
- Performance of sensitivity analysis

These steps are discussed in detail below.

3.2.1 Development of Evaluation Criteria

The Team began the development of evaluation criteria by identifying those criteria that are independent and discriminating between the options. Many criteria were considered for use in evaluating the options. A criterion may be important, but it may not necessarily be useful if it does not discriminate between the options. The criteria below were developed by the Team and agreed to by consensus. Additional details for each option are found in Appendix 6.2.

Cost

The Team, drawing from past experience, issued project estimates and other cost information to develop a Rough Order of Magnitude (ROM) Total Project Cost (TPC) estimate for each of the options. The variation in the estimates are based on the perceived complexity of the modifications, estimated consumables required by the treatment, level of research and development, level of Safety Basis (SB) development and required controls. These estimates are intended for comparison only and may be off by as much as 50%. However, the Team believed that the quality of the estimates and the consistency between the estimates make them acceptable for this evaluation.

Schedule

Again, the Team drew from past experience, existing project schedules and other information to develop critical path logic for each of the options. However, the Team believed that the quality of the schedule and the consistency between the logics make them acceptable for this evaluation.

The base schedule estimates were developed for the options by identifying the critical path (not total time) elements. These elements are:

- Research & Development
- Program Implementation (Stakeholder buy-in for DSA, Modifications, Testing, Procedures)
- SB Development
- Operations

Again, as with the cost data, these schedules are intended for comparison only.

Safety Basis (SB)

The evaluation criterion for the SB focuses on the difficulty in developing an acceptable control strategy for each of the options. Although the development for qualified inputs for the SB is captured as part of the Research and Development Evaluation Criteria, the evaluation applied to the SB criterion must also consider this aspect. Four of the options introduce "new" processes as it relates to control strategies defined within the current DSA (i.e., potential introduction of unanalyzed risk). Another major factor in the evaluation is the ability to satisfactorily address (control) the potential flammability risk associated with each of the options. The ability to produce an acceptable control strategy as it relates to organic production has been very challenging in the past.

Research and Development (R&D)

The evaluation criterion for R&D measures technical maturity between the different processing options. This criterion evaluates whether the process has been used elsewhere, particularly in radioactive service, whether any testing has been completed with simulant or actual waste, whether the chemistry of the resulting product is well enough understood to estimate its downstream processing impacts, and whether any safety concerns were identified during testing. This criterion also evaluates the availability or R&D needed to obtain qualified data for input to DSA development.

Operations

The evaluation criterion for Operations focuses on the required operations difficulty for each of the options. The level of difficulty was determined based on the level of previous operational experience with the proposed option; the level of complexity of the activity; and the handling and management of new and or hazardous materials.

Regulatory

The evaluation criterion for Regulatory focuses on assessing environmental impacts from secondary waste streams, airborne emissions and liquid effluents. This criterion also assesses the relative difficulty in resolving potential issues with interested stakeholders, including the DOE, Defense Nuclear Facilities Safety Board (DNFSB), and South Carolina Department of Health and Environmental Control (SCDHEC).

Downstream Process Impacts

Chemistry and physical differences in the waste streams produced by each process require that they be handled by downstream facilities in different manners. The final waste form is different between the options. This criterion also assesses the relative difficulty in resolving potential impacts on downstream processes.

3.2.2 Weighting of Evaluation Criteria

After defining the evaluation criteria, the Team determined the weight or importance of each criterion in selecting the option. This was derived through Team consensus with the weights being assigned to represent the relative importance of each criterion. The following weights were assigned by the Team:

Evaluation Criteria Weights

Criteria	Weight
Schedule	25
Cost	20
Safety Basis	10
R&D	15
Operations	5
Regulatory	15
Downstream Process Impacts	10

3.2.3 Evaluation of Options Versus Criteria

To assist in scoring each option against the criteria, a scale of 1 through 5 was developed with appropriate guide words or values to allow a consistent scoring. The higher score represented a less desirable evaluation result while the lower score represented a more desirable evaluation result. The following summarizes the scale established for each criterion.

Cost Scoring Scale:

- 1 - $0-5.9 Million
- 2 - $6-11.9 Million
- 3* - $12-17.9 Million Based on the current budget forecast for Tank 48
- 4 - $18-23.9 Million
- 5 - Above $24 Million

Schedule Scoring Scale:

- 1 - 0-8.9 months
- 2 - 9-17.9 months
- 3* - 18-26.9 months Based on the current milestone for Tank 48
- 4 - 27-35.9 months
- 5 - Greater than 36 months

Safety Basis Scoring Scale:

- 1 - Potential for minimal impacts to existing control strategy
- 3 - Potential for moderate impacts to existing control strategy
- 5 - Potential for significant impacts to existing control strategy

Research and Development Scoring Scale:

- 1 - Proven technology - little or no R&D required
- 3 - Limited application of technology – moderate amount of R&D required
- 5 - Technology application unproven - extensive R&D required

Operations Scoring Scale:

- 1 - Simple and easy to operate and coordinate
- 3 - Moderately difficult to operate and coordinate
- 5 - Complex and difficult to operate and coordinate

Regulatory Scoring Scale:

- 1 - Minimum permitting changes required/Minor stakeholder concerns
- 3 - Some permitting changes required/Moderate stakeholder concerns
- 5 - Major permitting changes or new permits required/Major stakeholder concerns

To allow the score of the evaluated option to represent the aggregate of permitting and stakeholder concerns, both permitting and stakeholder concerns were scored separately, averaged and rounded to give a single score for regulatory.

Downstream Process Scoring Scale:

1 - Minimal impact on downstream facilities
3 - Some impact on downstream facilities
5 - Major impact on downstream facilities

3.2.4 Results

The evaluation of the options against the criteria was performed using a simplified scoring process as described above and outlined in Reference 5.20 (Systems Engineering Methodology Guidance Manual). Each option was evaluated against each of the evaluation criteria using the guide words and values to arrive at a score (between 1 and 5) for a given criterion. The scores were then multiplied by the weighting criteria and a total score for each option obtained. The data and total scores are shown in Appendix 6.3. The scoring technique was applied such that a higher score was indicative of an adverse evaluation result and the lower score indicative of a favorable evaluation result. Thus the lowest scoring option is the preferred option in this evaluation.

After all evaluation criteria were used, the total scores were obtained. The ranking results were as follows:

Ranking Results

Ranking	Option	Score
1	Blending In-tank	280
2	In-tank Thermal Hydrolysis	290
3	In-tank Catalytic Hydrolysis	310
4	In-tank Fenton's Hydrolysis	385
5	Salt Cell Fenton's Hydrolysis	460

3.2.5 Sensitivity Analysis

A sensitivity analysis was performed on the selected options to determine if changes in the weighting of evaluation criteria could alter the final ranking (prioritization).

This was performed by adjusting the weight of a selected criterion upwards and downwards by 50%, proportionally reducing the weights of the other criteria accordingly and calculating the final score for all the options. Adjustments of 20% are normally done but as the cost and schedule estimates have an accuracy of 50%, an adjustment of 50% was used. This was done for all criteria. Of the fourteen cases, ten maintained the same ranking (Blending followed by In-Tank Thermal Hydrolysis). In four cases, In-Tank Thermal Hydrolysis was the top ranked option. The cases were: Cost +50%, Regulatory +50%, Schedule -50%, Down Stream Impacts -50%

Blending was the top ranked option in most of the sensitivity analyses. In half the analyses, the relative score of Blending improved over the other options. As the importance of Schedule, SB, R&D, and Down Stream Impacts was increased, Blending separated from the other options. Decreasing the importance of Cost, Operation, and Regulatory had the same result.

Sensitivity analysis results are shown in Appendix 6.4.

4.0 Conclusions

In conclusion, Blending was ranked as the most favorable WSRC in-house option. In-Tank Thermal Hydrolysis followed closely as a second option.

The Team discussed the results of the evaluation and satisfactorily reached consensus with the process used and the results obtained. Blending was the highest ranked option for the analysis and most of the sensitivity analysis. As shown in the sensitivity analysis, adjusting some criterion, In-Tank Thermal becomes more attractive. With respect to the major risk, should an item not be realized, an adjustment could be shown in the ranking. For example, should the permit risk for Blending not be realized, the Regulatory criterion relative importance would decrease, thus causing Blending to separate from the others as a clearer option.

The Team concluded that In-Tank Thermal Hydrolysis should be pursued as a second option, due to the relative ranking, based on variations in the sensitivity analysis, the accuracy of the inputs, and as a mitigation strategy to the risks associated with Blending.

In-Tank Catalytic Hydrolysis is a viable backup should unforeseen problems be encountered in implementing the preferred options.

Several items of note were discussed by the Team during the final closing session:

1. Although a ranking was performed and a preferred option apparent, each of these options have risks associated with them. The Team attempted to address these risks by including them in the evaluation process to achieve a meaningful ranking of options.

   The major risks associated with the top-ranked option (Blending) are as follows:

   - SPF Class C Permit not received from the state of South Carolina in the timeframe assume in this evaluation.
   - Insoluble TPB concentration not acceptable in SPF for grout formulation.
   - Benzene generation rates require equipment modifications to Tank 50, SPF and interconnecting transfer systems (including Low Point Drain Tank (LPDT).

   The major risk associated with the second-ranked option, In-Tank Thermal Hydrolysis, is as follows:

   - Organic decomposition efficiencies are lower than predicted resulting in a longer processing rate.

2. During the closing discussions, the Team recognized the requirement for removal of the residual TPB film deposited on the tank wall and in-tank equipment (cooling coils, pump columns, thermowells, etc.) from the maximum working inventory

levels in 1995. The maximum inventory level was approximately 526,000 gallons or 150 inches. This requirement will be incorporated into the strategy. Residual TPB build up and film removal from Tank 49 was accomplished with filling the tank and normal tank agitation. The Tank 48 flow sheet will incorporate these activities to effectively manage the removal of this film as part of the Tank 48 Return to Service Strategy. The removal of this film is common to all options and therefore, was not considered in this evaluation.

3. The ability to reach a theoretical residual TPB level of 0.3 kg in Tank 48 may be shown as achievable by calculation and extrapolation of data, but for all the options considered, a method of validating the end point will have to be developed. Currently the 0.3 kg of TPB is at or below detection limits depending on the assumed residual heel volume after the end of processing.

4. When Tank 50 is used for the blending option, it is assumed that it will perform future feed missions to the SPF as the residual organics are removed by being blended to decreasing concentrations with future Saltstone feed.

5.0 References

5.1 WSRC-RP-2002-00154, "HLW Tank 48 Disposition Alternatives Identification Phase I and II Summary Report," Revision 1, 7/15/02.

5.2 WSRC-RP-2003-00588, "Downstream Impacts of Tank 48H In-tank and Out-of tank Processing Alternatives," October 22, 2003.

5.3 WMTD (03) P143, "Chemical Oxidation of Tank 48 Simulant," September 2003.

5.4 WSRC-TR-2003-00445, "Electrochemical Tests of Carbon Steel in Simulated Waste Containing Fenton's Reagent," October 2003.

5.5 WSRC-RP-2003-00560, "Tank 48 In-tank Flowsheets," September 11, 2003.

5.6 WSRC-TR-2003-00365, "Process Development for Destruction of Tetraphenylborate in SRS Tank 48H," Revision 0, 10/15/03.

5.7 SRT-LWP-2003-00050, "Tank 48 Corrosion Analysis Sample (THE-03-069, THE-03-070 and HTF-E-03-73)," Revision 1, 9/8/03.

5.8 Y-RAR-H-00042, "Closure Business Unit, Liquid Waste Disposition Projects, Salt Processing Projects, Tank 48 Project, Risk Analysis Report," Revision 0, 9/8/03.

5.9 CBU-PED-2003-00014, "Technical Program Plan for Tank 48 Processing," Revision 0, September 2003.

5.10 G-SOW-H-00032, "Statement of Work, SRS Tank 48H Material Treatment," Revision 1, 9/29/03.

5.11 WSRC-SA-2002-00007, "CSTF Documented Safety Analysis", Revision 2, December 2003.

5.12 X-CLC-H-00445, Maximum Quantity of Residual KTPB Solids Allowed, Revision 0, 7/30/03.

5.13 Y-RAR-H-00045, "CBU, LWDP, Salt Processing Projects, Tank 48 Project, Thermal Decomposition In-Tank Process, Risk Analysis Report," Revision 0, 9/8/03.

5.14 Y-RAR-H-00044, "CBU, LWDP, Salt Processing Projects, Tank 48 Project, Catalytic Decomposition In-Tank Process, Risk Analysis Report," Revision 0, 9/8/03.

5.15 Y-RAR-H-00043, "CBU, LWDP, Salt Processing Projects, Tank 48 Project, Fenton's In-Tank Process, Risk Analysis Report," Revision 0, 9/8/03.

5.16 Y-RAR-H-00049, CBU, LWDP, Salt Processing Projects, Tank 48 Project, Blending, Risk Analysis Report," Revision 0, January 2004.

5.17 CBU-SPT-2003-00139, "Salt Program Flowsheet Development for Treatment of Cs, Sr and Actinides Utilizing Existing Facilities," Revision 0, 8/19/03.

5.18 CBU-SPT-2003-00132, "SRS Closure Business Unit, Salt Decontamination Project Development Team, Small Tank Precipitation Engineering Scope Document," Revision 0, 8/12/03.

5.19 CBU-SPT-2003-00011, Tank 48 TPB Disposition / Return to High Level Waste Service, Engineering Scope Document, Blending Option, January 2004.

5.20 WSRC-IM-98-000033, "Systems Engineering Methodology Guidance Manual, Appendix-A, Alternative Study," Revision 7, September 28, 2001.

6.0 Appendices

6.1 Tank 48 Initial Conditions

The following data for the Tank 48 initial condition was extracted from Appendix 6.3 of Reference 5.10, "Statement of Work, and SRS Tank 48H Material Treatment."

Tank 48H contains approximately 250,000 gal of a radioactive alkaline slurry (pH 14) with roughly 2.3 wt % solids (<10 µm). The solids consist of a mixture of MST, TPB salts, and entrained metal hydroxide sludge. The potassium and cesium tetraphenylborate (KTPB and CsTPB) salts resulted from precipitation after addition of sodium tetraphenylborate (NaTPB).

Non-Radioactive Components

Tables 1 and 2 provide the concentration of non-radioactive components in Tank 48.
Table 3 provides the concentration of major isotopes in Tank 48.

Table 1 -- Tank 48H Major Components

Component	M
KTPB	0.0728
NaOH	1.8425
$NaNO_2$	0.4709
$NaNO_3$	0.3481
Na_2CO_3	0.1295
$NaAlO_2$	0.1118
Na_2SO_4	0.0071
Na_3PO_4	0.0077
NaCl	0.0088
NaF	0.0059
KNO_3	0.0051

Table 2 – Metals and Trace Organics

Component	Compound	Concentration in Slurry (mg/L)
Pd	$Pd(NO_3)_2$	13.0
Cu	$Cu(SO_4) \bullet 5H_2O$	3.7
Hg[b]	$Hg(NO_3)_2 \bullet H_2O$	2.2
diphenylmercury[b,c]	$(C_6H_5)_2Hg$	150
Mo/Cr/Si/Se/As	$Na_2MoO_4 \bullet 2H_2O$ Na_2CrO_4 $Na_2SiO_3 \bullet 9H_2O$ Na_2SeO_4 As_2O_3	12 60 16 1 0.04
Zn/Pb/Fe	$Zn(NO_3)_2 \bullet 4H_2O$ $Pb(NO_3)_2$ $Fe(NO_3)_3 \bullet 9H_2O$	8.8 1.2 2.6
Sn	$SnCl_2$	2.1
Ca/La/Co	$Ca(NO_3)_2 \bullet 4H_2O$ $La(NO_3)_3 \bullet 6H_2O$ $Co(NO_3)_2 \bullet 6H_2O$	12.2 0.05 0.04
Cd/Ce	$Cd(NO_3)_2 \bullet 4H_2O$ $Ce(NO_3)_3 \bullet 6H_2O$	0.4 0.3
Rh	$Rh(NO_3)_3$	1.4
Ag	$AgNO_3$	6.8
Ru	$RuCl_3 \bullet xH_2O$	5.4
sludge	Sludge	500
MST	MST	500

Table 3 - Radionuclide Data from Tank 48H

	Supernate (liquid only)			Slurry (liquid and solids)			Total Mass
Isotope	Conc. (mg/L)	Mass (mg)	Mass (g)	Conc. mg/L	Mass (mg)	Mass (g)	(g)
Sr-90	4.78E-06	4.20E+00	4.20E-03	ND	-	-	4.20E-03
Cs-137	1.72E-01	1.51E+05	1.51E+02	1.15E+01	1.09E+07	1.09E+04	1.16E+04
U-233	5.06E-02	4.44E+04	4.44E+01	3.63E-06	4.05E+04	4.05E+01	8.49E+01
U-234	3.67E-01	3.22E+05	3.22E+02	1.14E-05	1.27E+05	1.27E+02	4.49E+02
U-235	5.88E-01	5.16E+05	5.16E+02	3.20E-05	3.57E+05	3.57E+02	8.73E+02
U-236	1.44E+00	1.26E+06	1.26E+03	6.06E-06	6.76E+04	6.76E+01	1.33E+03
U-238	3.71E+00	3.25E+06	3.25E+03	2.05E-04	2.29E+06	2.29E+03	5.54E+03
total U	6.15E+00	5.40E+06	5.40E+03	2.58E-04	2.88E+06	2.88E+03	8.28E+03
Np-237	5.52E-02	4.85E+04	4.85E+01	1.85E-05	2.06E+05	2.06E+02	2.55E+02
Pu-238	1.81E-02	1.59E+04	1.59E+01	5.70E-06	6.36E+04	6.36E+01	7.94E+01
Pu-239	2.87E-03	2.51E+03	2.51E+00	3.76E-06	4.19E+04	4.19E+01	4.44E+01
Pu-240	ND	-	-	4.58E-07	5.11E+03	5.11E+00	5.11E+00
Pu-241	ND	-	-	7.65E-08	8.53E+02	8.53E-01	8.53E-01

ND=Not Detected

6.2 Option Information

OPTION - In-Tank Thermal Hydrolysis

Description: Thermal Hydrolysis decomposes TPB through a hydrolysis reaction to produce benzene. Reaction conditions for this tank treatment option are a pH of 11 and a temperature of 45 ^{o} C.

Evaluation Comments	Schedule & Experience	Rough Order of Magnitude ROM Cost ($)

Safety Basis
• Moderately difficult to control benzene generation rate with respect to flammability.
• New process (not currently analyzed in the DSA) requiring a Consolidated Hazard Analysis Process (CHAP) evaluation for organic destruction (quantification of degradation products). Past experience with Tank 49 did not show any significant SB concerns although it used a pre-830 SB platform and Justification for Continued Operations (JCO).
Research and Development
• Thermal hydrolysis process has been used in Tank 49H and Tank 50H.
• Testing with simulants has demonstrated TPB decomposition at a pH of 11 and an elevated temperature.
• Corrosion testing with simulants demonstrated minor corrosion concern.
• Gaseous decomposition products have not been quantified.
• Need to confirm complete degradation of TPB
Operations
• Involves routine tank farm operations with increased oversight
• Requires handling and use of 50 wt% Nitric Acid
Regulatory
• Minimum permit modification necessary
• Stakeholder interest expected (familiar with option based on past Tank 49 and 50 experiences)
Downstream Process Impacts
• Product is acceptable for Tank Farm storage
• Product is compatible with DWPF processing
• Biphenyl, terphenyl, or tarry compounds, if produced as by-products, may require an intermediate treatment step
• No solids addition
	Schedule
	Total duration to return tank to service is estimated to be 27 months
	• Estimated time to treat tank contents is 12 months. (Based on extrapolation of a limited duration test)
	• Time to prepare tank– 15 months
	    • This includes R&D, SB, Engineering, Modifications, Testing and Procedures.
	
	Experience
	• Thermal hydrolysis was part of the process used in Tank 49H to treat TPB (along with catalysts).
	• Thermal hydrolysis was used to treat TPB in Tank 50H. Although the pH was not lower as part of this treatment.
		Cost for the In-Tank Thermal Hydrolysis is estimated to be approximately $ 11 Million.
		
		The TPC estimate is based on the following:
		• Operating cost excluding tank returned to service
		• Addition of Nitric Acid Unloading Area
		• Other Equipment needed:
		    • Piping/hose
		    • Process Controls
		    • Separate VFDs for Tank 48 slurry pumps
		
		Major Risks
		• Organic destruction efficiencies are slower than predicted resulting in a longer processing time

<table>
<tr><td colspan="3">OPTION – In-Tank Catalytic Hydrolysis</td></tr>
<tr><td colspan="3">Description: Catalysis decomposes TPB through an accelerated hydrolysis reaction to produce benzene. Reaction conditions for this tank treatment option are a pH of 11, a temperature of 45 ^{o} C, and addition of a catalyst (copper or palladium).</td></tr>
<tr><th>Evaluation Comments</th><th>Schedule & Experience</th><th>Rough Order of Magnitude
ROM Cost ($)</th></tr>
<tr><td rowspan="3">Safety Basis
• Moderately difficult to control benzene generation rate with respect to flammability.
• New process (not currently analyzed in the DSA) requiring a CHAP evaluation for organic destruction (quantification of degradation products). Past experience with Tank 49 did not show any significant SB concerns although it used a pre-830 SB platform and JCO.
Research and Development
• Catalyzed thermal hydrolysis process has been used successfully in Tank 49H.
• Testing with simulants has demonstrated TPB decomposition at a pH of 11 and an elevated temperature and in the presence of a catalyst.
• Corrosion testing with simulants demonstrated minor corrosion concern.
• Gaseous decomposition products have not been quantified
• Need to confirm complete degradation of TPB
Operations
• Involves routine tank farm operations with increased oversight
• Requires handling and use of 50 wt% Nitric Acid and catalyst
Regulatory
• Minimum permit modification necessary
• Stakeholder interest expected (familiar with option based on past Tank 49 and 50 experiences)
Downstream Process Impacts
• Product is acceptable for Tank Farm storage
• Product is compatible with DWPF processing
• Biphenyl, terphenyl, or tarry compounds, if produced as by-products, may require an intermediate treatment step
• Minor solids addition</td><td rowspan="3">Schedule
Total duration to return tank to service is estimated to be 27 months
• Estimated time to treat tank contents is 12 months. (Based on extrapolation of a limited duration test)
• Time to prepare tank– 15 months
  • This includes R&D, SB, Engineering, Modifications, Testing and Procedures.

Experience
• Catalyst (cupric nitrate) and heat utilized to treat Tank 49H.</td><td>Cost for the In-Tank Catalytic option is estimated to be approximately $ 12 Million.

The TPC estimate is based on the following:
• Operating cost excluding tank returned to service
• Addition of Nitric Acid Unloading Area
• Other Equipment needed:
  • Catalyst Feed tank
  • Agitator
  • Piping
  • Process Controls
  • Separate VFDs for Tank 48 slurry pumps</td></tr>
<tr><th>Major Risks</th></tr>
<tr><td>• Organic destruction efficiencies are slower than predicted resulting in a longer processing time.</td></tr>
</table>

<table>
<tr><td colspan="3">OPTION – In-Tank Fenton's Hydrolysis</td></tr>
<tr><td colspan="3">Description: Fenton's Hydrolysis utilizes catalysts (iron, copper or both) in conjunction with peroxide to destroy organic materials through oxidation. Reaction conditions for this tank treatment option are a pH of 11 and a temperature of 45 ^{o}C. The use of this oxidant minimizes the production of benzene, and produces carbon dioxide and water as the major byproducts.</td></tr>
<tr><th>Evaluation Comments</th><th>Schedule & Experience</th><th>Rough Order Magnitude (ROM) Cost ($)</th></tr>
<tr>
<td rowspan="3">Safety Basis
• Difficulty in controlling flammable vapor generation rate (large-scale in-tank reaction) due to oxygen.
• Difficulty in controlling tank pressure due to large-scale in-tank reaction.
• New process (not currently analyzed in the DSA) requiring a CHAP evaluation for organic destruction (quantification of degradation products).
Research and Development
• In-Tank Fenton processing has only been demonstrated in the laboratory with simulants.
• Testing with simulants has demonstrated TPB decomposition at a pH of 11, an elevated temperature, and in the presence of a catalyst.
• Corrosion testing with simulants identified significant pitting potential.
• Gaseous decomposition products have not been quantified.
• Determination of oxygen generation rate
• Need to confirm complete degradation of TPB
Operations
• Involves non-routine (handling of peroxide) tank farm operations with increased oversight
• Requires handling and use of 50 wt% Nitric Acid and catalyst
• Requires closer control of chemical addition rates due to peroxide reactivity
Regulatory
• Minimum permit modification necessary
• Potential for significant Stakeholder concerns (no HLW In-Tank experience)
• New process for HLW
Downstream Process Impacts
• Product is acceptable for Tank Farm storage
• Product is compatible with DWPF processing
• Creates twice the volume of waste than other In-Tank options
• Minor solids addition</td>
<td rowspan="3">Schedule
Total duration to return tank to service is estimated to be 30 months
• Estimated time to treat tank contents is 12 months. (Based on extrapolation of a limited duration test)
• Time to prepare tank– 18 months
  • This includes R&D, SB, Engineering, Modifications, Testing and Procedures.

Experience
• No HLW experience at these conditions</td>
<td>Cost for the In-Tank Fenton's Reagent is estimated to be approximately $ 17 Million.

The TPC estimate is based on the following:
• Operating cost excluding tank returned to service
• Addition of Unloading Areas:
• Peroxide, Nitric Acid, and Catalyst.
• Other Equipment needed:
  • 2 - 1000 gal mixing tanks
  • Agitators
  • Piping
  • Process Controls
  • Separate VFDs for Tank 48 slurry pumps</td>
</tr>
<tr><th>Major Risks</th></tr>
<tr><td>• Organic destruction efficiencies are slower than predicted resulting in a longer processing time.
• Tank service life and operational capacity reduced due to corrosion (defined as performing operations outside of the allowable limits of the corrosion control program).</td></tr>
</table>

<table>
<tr><td colspan="3">OPTION - Salt Cell Fenton's Hydrolysis</td></tr>
<tr><td colspan="3">Description: Proposal utilizes Fenton's Chemistry at ideal conditions (pH of 3-5) at boiling (100°C) to maximize the effectiveness of organic destruction. The use of this oxidant minimizes the production of benzene, and produces carbon dioxide and water as the major byproducts. This occurs in the DWPF Salt Cell.</td></tr>
<tr><th>Evaluation Comments</th><th>Schedule & Experience</th><th>Rough Order of Magnitude
ROM Cost ($)</th></tr>
<tr><td rowspan="3">Safety Basis
• Moderately difficult in controlling flammable vapor generation rate
• Difficulty in addressing interface issues between DSAs (CST and DWPF).
• New process (not currently analyzed in the SB) requiring a CHAP evaluation for organic destruction (quantification of degradation products).
• A potential benefit is a smaller scale reaction vessel. Additionally, the salt cell is located within a robust enclosure (built to SC criteria).
Research and Development
• Fenton processing has been proven at a smaller scale by destroying organics in radioactive ion exchange resins for over a decade.
• A process has been developed and tested at two laboratory scales and has demonstrated that complete destruction of TPB.
• Gaseous decomposition products have not been quantified.
• Determination of oxygen generation rate
• Required glass testing for DWPF
Operations
• Easier to control reaction in smaller batches
• Equipment is designed to accommodate this similar process
• Requires use of Salt Cell which has never operated in radioactive service.
• No experience with this process
• Addition coordination of transfers
• Requires multiple batches to process material
• DCS control for process
Regulatory
• Requires moderate permit modification
• Potential for significant Stakeholder concerns (no HLW experience)
Downstream Process Impacts
• Product should be acceptable in DWPF process
• Negative impact to DWPF canister production due to coupling of this process with DWPF. Any outage could effect production.
• Minor increase in DWPF recycle</td><td rowspan="3">Schedule
Total duration to return tank to service is estimated to be 42 months
• Estimated time to treat tank contents is 12 months.
• Time to prepare tank– 30 months
  • This includes R&D, SB, Engineering, Modifications, Testing and Procedures.

Experience
• Similar process is used in nuclear industry. No experience at SRS.
• DWPF Salt Cell never used.</td><td>Cost for the Fenton's Salt Cell is estimated to be approximately $50 Million.

The TPC estimate is based on the following:
• Operating cost excluding tank returned to service
• Major Equipment Impacts:
  • DWPF
  • Fenton's Reactor
  • Cold Feed Tanks
  • Evaporator
  • Overheads Collection Tank</td></tr>
<tr><th>Major Risks</th></tr>
<tr><td>• Impact canister throughput and waste loading.
• Salt Cell modification and operation does not meet Tank 48H Return To Service Milestone Date</td></tr>
</table>

OPTION - Blending

Description: This option consists of blending material from the DWPF recycle tanks with the material in Tank 48. The blending will occur in Tank 48 and Tank 50. The blended material will be transferred from Tank 50 to SPF.

Evaluation Comments	Schedule & Experience	Rough Order of Magnitude ROM Cost ($)

Safety Basis
• Based on known technology/process therefore no CHAP required
• Moderate difficulty in controlling benzene generation rate (flammability control) due to addition of tank farm waste with Tank 48 material in Tank 50 (potential benzene generation due to the addition of active catalysts from DWPF recycle)
• SPF SB will need to be reviewed for impacts due to an increase in insoluble TPB concentration
Research and Development
• SRS's SPF has been making grout since the early 1990's although grout formulation has not been demonstrated at levels that are being considered that will pass TCLP testing (~4000 ppm TPB and 3.5E+4 d/m/mL Gross Alpha) with KTPB and loaded MST present.
• Tanks 49 and 50, both tanks containing TPB, have been successfully processed through the SPF at reduced levels.
• Determination of benzene generation rate due to catalytic elements
• Blending may not be practical if high concentrations of TPB and actinides can not be stabilized in the grout matrix.
Operations
• Involves routine tank farm operations although with increased oversight (mass balance, route coordination, etc.)
• Multiple transfer requires coordination with other activities
Regulatory
• Saltstone permit modification required to proceed
• Potential for moderate Stakeholder concerns
Downstream Process Impacts
• Blended product may not form acceptable grout
• Process will consume significant Saltstone vault space
	Schedule
	Total duration to return tank to service is estimated to be 23 months
	• 9 months to blend and meet end state TPB requirements in Tank 48.
	• Time to prepare tank – 14 months
	    • This includes R&D, Engineering, Modifications, Testing, Procedures and regulatory (permit) activities.
	    • This assumes SFP permit is approved in 14 months.
	
	Experience
	• Extensive experience blending different solutions to meet both regulatory and safety basis issues.
		Cost for Blending is estimated to be approximately $15 Million
		
		The TPC estimate is based on the following:
		• Operating cost excluding tank returned to service
		• Major Equipment Impacts:
		    • Transfer Path Tank 48 to 50
		    • Transfer path Tank 21/24 to 50
		    • Transfer Path Tank 21/24 to 48
		    • New Transfer pump(Pump on a Stick) in Tank 48
		    • Separate VFDs for Tank 48 slurry pumps
		
		Major Risks
		• SPF Class C Permit not received from state within the timeframe assumed herein
		• Benzene generation rates require equipment modifications to Tank 50, SPF and interconnecting transfer system (including LPDT)
		• TPB form (insoluble versus soluble) or concentration not acceptable in Saltstone

6.3 Results

	Schedule (25)	Cost (20)	SB (10)	R&D (15)	Operations (5)	Regulatory (15)	Downstream (10)	Total Score
Blending	3	3	3	2	3	4	1	280
Thermal	4	2	4	3	1	2	3	290
Catalytic	4	3	4	3	1	2	3	310
Fenton's	4	3	5	5	3	3	4	385
Salt Cell	5	5	4	5	5	3	5	460

6.4 Sensitivity Analysis Results

Criteria Number	1	2	3	4	5	6	7
Criteria Name	Schedule	Cost	Safety Basis	R&D	Operation	Regulatory	Down Stream Impacts
Criteria Weight	25	20	10	15	5	15	10
Option							
Blending	3	3	3	2	3	4	1
Thermal	4	2	4	3	1	2	3
Catalytic	4	3	4	3	1	2	3
Fenton's	4	3	5	5	3	3	4
Salt Cell	5	5	4	5	5	3	5

Criteria Weights (Sensitivity Analysis)	50%	50%	50%	50%	50%	50%	50%
1+50%	37.50	16.67	8.33	12.50	4.17	12.50	8.33
2+50%	21.88	30.00	8.75	13.13	4.38	13.13	8.75
3+50%	23.61	18.89	15.00	14.17	4.72	14.17	9.44
4+50%	22.79	18.24	9.12	22.50	4.56	13.68	9.12
5+50%	24.34	19.47	9.74	14.61	7.50	14.61	9.74
6+50%	22.79	18.24	9.12	13.68	4.56	22.50	9.12
7+50%	23.61	18.89	9.44	14.17	4.72	14.17	15.00
1-50%	12.50	23.33	11.67	17.50	5.83	17.50	11.67
2-50%	28.13	10.00	11.25	16.88	5.63	16.88	11.25
3-50%	26.39	21.11	5.00	15.83	5.28	15.83	10.56
4-50%	27.21	21.76	10.88	7.50	5.44	16.32	10.88
5-50%	25.66	20.53	10.26	15.39	2.50	15.39	10.26
6-50%	27.21	21.76	10.88	16.32	5.44	7.50	10.88
7-50%	26.39	21.11	10.56	15.83	5.28	15.83	5.00

	Weighted Scores							
Option	Normal	1+50%	2+50%	3+50%	4+50%	5+50%	6+50%	7+50%
Blending	280	283	283	281	273	281	291	270
Thermal	290	308	279	296	291	285	282	291
Catalytic	310	325	309	315	309	304	300	309
Fenton's	385	388	374	391	395	383	378	386
Salt Cell	460	467	465	457	464	461	446	462
Option	Normal	1-50%	2-50%	3-50%	4-50%	5-50%	6-50%	7-50%
Blending	280	277	278	279	287	279	269	290
Thermal	290	272	301	284	289	295	298	289
Catalytic	310	295	311	305	311	316	320	311
Fenton's	385	383	396	379	375	387	393	384
Salt Cell	460	453	455	463	456	459	474	458