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Tank 241-Z-361 Sludge Retrieval and Treatment Alternatives

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200
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Contents

Tables

Figures

Acronyms

Acronym	Definition
ARARS	Applicable or Relevant and Appropriate Requirements
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWC	Central Waste Complex
ECN	Engineering Change Notice
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency
FHI	Fluor Hanford Incorporated
FFS	Focused Feasibility Study
ISV	In Situ Vitrification
JCO	Justification for Continued Operation
O&M	Operations and Maintenance
PFP	Plutonium Finishing Plant
RCRA	Resource Conservation and Recovery Act
RL	Richland Laboratories
ROD	Record of Decision
TI/FS	Remedial Investigation/Feasibility Study
TPA	Tri-Party Agreement
TRU/TRUM	Transuranic/Transuranic-Mixed
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION

1.1 Background

The Plutonium Finishing Plant (PFP) Tank 241-Z-361 (Z-361) contains legacy sludge resulting from waste discharges from past missions at PFP. A sketch of the tank is shown in Figure 1. In this view various risers and penetrations are shown along with the sludge level depicted by the horizontal line halfway up the tank, and the ground level depicted by the horizontal line above the tank. The HEPA filter installed for breathing is also shown on one of the risers.

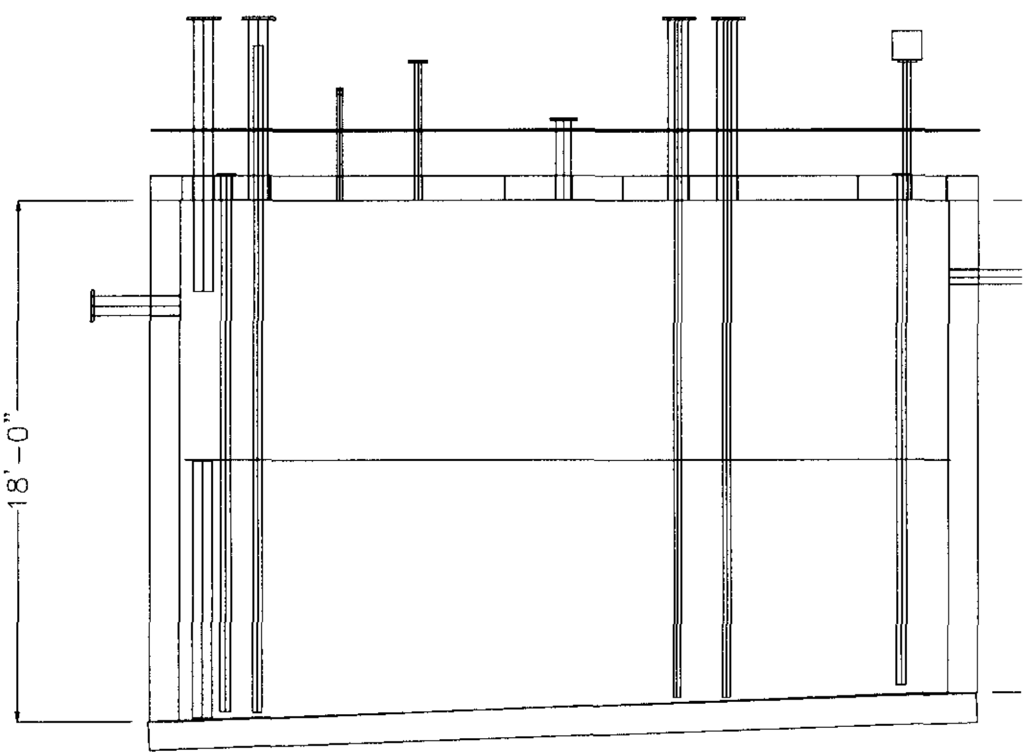

Figure 1 – Elevation View of Tank Z-361

Details of the history of operation and evaluations of the contents of the tank are presented in Reference 1and 2. This report has been written with the assumption that readers are familiar with the subject matter of Z-361 and have a general knowledge of processes discussed and waste issues. Therefore, background is minimal and historical details are not addressed. The references provide detail for those who so require.

Videotaping, surveying, and sampling have been completed during 1999 and 2000. Radionuclide and chemical analyses of the caked sludge are in the process of being formalized and will be available in the near future. These results are essential for technical planning decisions and recommendations to the customer, regulators, and stakeholders for retrieving, conditioning, packaging, and disposing of the sludge.

1.2 Purpose

The remediation of the sludge in Z-361 is via the CERCLA process. In that regard TPA Milestone M-15-37B (Reference 3) is for RL to recommend a path forward to the EPA. The work reported here is for input to timing recommendations and decisions by RL and EPA as part of that process and the milestone. Development of those recommendations and decisions necessarily requires an understanding at a conceptual level of the alternatives for retrieving and treating the sludge. However, meeting the milestone does not require selection of an alternative at this time.

This report describes concepts and a comparative assessment. Sludge remediation alternatives are developed and ranked. This report presents:

- Four concepts of systems and operations for sludge remediation.
- The method for ranking the alternatives.
- Results of applying the method to arrive at a ranking.

Note is taken of TPA Milestone M-91-03 to submit a TRU/TRUM Waste Project Management Plan. Depending on EPA decisions and ultimate timing of Z-361 sludge remediation, the results of the evaluation addressed here may be useful for that plan. However, it is not the purpose for this work.

1.3 Scope and Assumptions

This study has been conducted at a conceptual level. The following scope and assumptions apply:

1. The scope is limited to the caked sludge in Z-361. Remediation of the tank itself is beyond the scope of this report except where an alternative does not allow separation.
2. The alternatives serve to bound a reasonable set of technical concepts. However, the level of detail is not intended to be sufficient as a preliminary design.
3. It is assumed that human entry into Z-361 is prohibited.
4. Feasibility for retrieval equipment at the level addressed here does not require final results of the physical and chemical properties of the material. (Eventually it will.)
5. Assessment of alternatives has not considered institutional factors; that is, influences other than design, installation, and operation.

The four alternatives presented here address a wide range of options for the purpose stated above. They have not been developed to a level of detail that would permit launching a detailed design project. Any future design effort will necessarily require a more detailed development of alternatives before selecting one. Several tradeoff studies and investigations will be required before settling on the ultimate remediation method. Such a decision will depend as much on non-technical factors (for example, possible motivation to demonstrate in situ vitrification) as it will optimization of sludge handling and treatment.

Each of the alternatives addressed here have endpoints varying in time and destination. As such, life cycle costs have not been addressed. Eventual selection of an alternative should consider life cycle costs.

1.4 Approach

Assessing the alternatives has been conducted with criteria related to:

1. Environmental and Safety Criteria
2. Technical Criteria
3. Schedule Duration
4. Cost Magnitude

Specific criteria for the first two above are presented in Section 4. They use a weighted grading procedure described below, whereas the project schedule and project cost results are used directly. Schedule and cost have been separately assessed. The results are presented for each area in Sections 4 through 7 respectively.

The overall approach for assessing alternatives was to develop concepts in sufficient detail that were used for assessment by an expert group. The steps are delineated in Table 1.

Table 1 – Activities to Assess Alternatives

	Planning Activity	Result
1.	Define Alternatives	A planning study was conducted to define retrieval and treatment concepts. This was done by experienced engineers, discussion with and information from vendors and suppliers of equipment and services, and discussion with others involved in sludge processes at Hanford. Four alternatives evolved that provided a basis for evaluation by an expert group. Sufficient detail was provided to define and evaluate the issues, factors, and attributes of each alternative. The results of physical properties resulting from the sampling are used for equipment selection. The planning study also served to define the criteria to be used for technical, environmental, and safety assessment.
2.	In Situ Vitrification Concept Development	One alternative used ISV. Since this method is somewhat unique and there is limited general experience, a supplier of ISV, Geosafe Corporation, was contracted to provide details of how this concept would be applied to Z-361.
3.	Expert group assigned	Individuals with expertise in remotely operated equipment, cementation, waste packaging, waste disposal, and environmental requirements were assigned to participate in the evaluation.
4.	Evaluation Conducted: • Environmental and Safety Risks • Technical Evaluation	The expert group in working sessions conducted the evaluation as described in Section 3. Using the concepts and alternatives, the technical factors, environmental and safety risks were identified and graded according to the criteria. If any present unusual challenges, the details were elaborated.
5.	Schedule Development	A schedule was developed for each alternative based on major activities.
6.	Cost Development	An order-of-magnitude cost estimate was developed for each alternative. Life cycle costs that include waste disposal were not addressed.
7.	Evaluating options, Develop preliminary Recommendations	Using the results of the above tasks, each alternative was assessed relative to the others. Perceived technical difficulties were elaborated.
8.	Customer Workshop	A workshop with DOE representatives and EPA observers was used to validate the assessments. Comments were incorporated for later presentation to the DOE for its milestone recommendation.

2. Summary

Over the course of this study, several alternatives were considered. Four alternatives, further elaborated in Section 3, have been identified and assessed. They are as follows:

I. Sludge retrieval, cementation, transport to TSD onsite (eventual disposal at WIPP)

II. Sludge retrieval to containers, transport to T-Plant storage (eventual conditioning and disposal at WIPP)

III. Sludge retrieval, transport to tank farms for storage (eventual vitrification)

IV. In situ vitrification

Since the Z-361 sludge is contact handled, storage at CWC is an option for Alternative II.

2.1 Comparative Ranking in the Four Evaluation Areas

The results of the four areas of evaluation scored by the expert group, by schedule derivation, and cost estimate are in Table 2 and used to rank the alternatives. (The scoring for the first two columns is from 1 to 10 with 10 being most favorable.) An elaboration of the basis for scoring is in Section 4.

Table 2 – Evaluation Summary Tabulation

(Notes following the table must be read in concert with these results.)

Alternative	Environmental and Safety Criteria Grade		Technical Criteria Grade		Project Schedule Duration		Estimated Cost (Thousands)	
	Score	Rank	Score	Rank	Months	Rank	$1,000	Rank
I. Sludge retrieval, cementation, transport to TSD onsite (eventual disposal at WIPP)	7.1	4	7.0	3	10	4	$7,970	4
II. Sludge retrieval to containers, transport to T-Plant storage (eventual conditioning and disposal at WIPP)	7.6	2	8.1	1	6.5	2	$5,840	2
III. Sludge retrieval, transport to tank farms for storage (eventual vitrification)	7.4	3	7.8	2	5.5	1	$3,560	1
IV. In situ vitrification	8.1	1	5.9	4	7	3	$6,800	3

Notes:

Two key pieces of information were obtained subsequent to the results above that have the following effects:

- The sample results indicate concentrations of PCBs that are currently not acceptable at WIPP nor at the tank farms. This would serve to further reinforce the ranking of Alternatives II and IV relative to the others.
- Alternative III is ranked too favorably in Table 2 for technical, schedule, and cost (last 3 column groups) because of the potential need for pretreatment to meet tank farm particle size acceptance criteria, as well as resolving PCB issues.

Environmental and Safety Summary

The relative scores for Environmental and Safety assessment are close among all four alternatives. This is to be expected as all technologies have past experience and any special environmental safety considerations will be accommodated as a result of safety assessments and job hazards analyses. In situ vitrification ranked first because, for the most part, the most hazardous conditions are underground.

Technical Summary

The technical ranking illustrates the relative simplicity/complexity of each alternative in terms of equipment, operations, and sophistication. The intermediate score for cementation is a primarily a result of the additional equipment scope relative to Alternatives I, II, and III. However, it is important to note that at the time of the evaluation, the tank farm alternative did not consider the need for pretreatment to meet particle size criteria that would be required for the tank farm vitrification system. A pretreatment system will result in this option being third or fourth in technical grade because the ability to assure a maximum particle size is not a normal type of process for sludge. In addition, pretreatment would result in "left-over" large size debris that would be a nuisance to deal with.

Thus, storage at T-Plant is ranked highest from a technical standpoint.

The ISV is ranked low technically because of the complex electrical supply system and off-gas treatment equipment and operations.

Schedule Summary

The schedule durations reflect the overall project schedule and not just the processing part. For example, ISV actual melt process is about 3 weeks.

The cementation schedule is longest because of the large number of 55-gallon drums required for disposal at WIPP.

Because of the need for pretreatment, which was determined after the evaluation, the schedule for the tank farm alternative would probably rank third instead of first, which originally considered only the need to sluice the sludge into tanker trucks.

Thus, storage at T-Plant and ISV are the most favorable from a schedule duration standpoint.

Cost Summary

Cost estimates are for the near-term only. This is not life cycle cost. That is, ultimate waste disposal cost was not included because of uncertainties in costs several years from now, whether or not ISV glass mass would have to be removed, etc. Also, possible credit for Alternative IV for tank remediation is not included.

Because of the need for pretreatment, which was determined after the evaluation, the cost for the tank farm alternative would probably rank third instead of first.

Thus, storage at T-Plant and ISV are the most favorable from a schedule duration standpoint.

In all cases the cost is considerably less than the current PFP project baseline cost for Z-361, of the order of one-half to one-third, or less. This is a result of the sampling and analyses that indicate criticality control is not a severe constraint for bulk handling of the material; baseline cost estimate conservatively assumed the contrary based on information available at the time.

2.2 Overall Conclusions

Four concepts have been defined and assessed for remdiation of the sludge in Tank Z-361. All four are feasible. While an ultimate design will vary, they are sufficiently representative of what will finally be used to provide an understanding of a project approach and magnitude. Regardless of alternative, it is concluded that processing can be conducted in less than a year, once a budget is authorized. The estimated near-term cost is in the range of $5 to $10 million, considerably less than the current baseline.

Two of the four alternatives, storage at T-Plant and in situ vitrification, appear more favorable than the other two. At this point, these two should be considered equivalent until further study is conducted and decision factors other than techncal feasibility, cost, and schedule are defined.

<u>**Key Questions for Proceeding**</u>

To proceed, a more detailed conceptual development of the alternatives must be conducted, and evaluation conducted for selection of a preferred path forward. Selection of an alternative must address several key considerations/decisions. A few are:

- If sludge is to be retrieved, should it be done with mechanical removal as a semisolid or by sluicing?
- If sludge is to be retrieved by sluicing, should it be done as a thick or thin slurry?
- What is the stabilization method to be used (for example, containerizing, cementing, vitrifying) and is it *permanent or interim?*
- What type of in-process characterization is needed?
- Where is the stabilized material to be stored until ultimate disposal?
- Where is the ultimate disposal location and what disposal site acceptance criteria must be satisfied?
- How will tank farm vitrification particle size criteria affect the cost and schedule for this alternative? Further, given the recent doubling of tank farm vitrification cost estimate, will some other system be used?

3. Retrieval And Treatment Concepts

Four alternatives have been identified and assessed. They are summarized in Table 3 and described in following sections. The four are:

I. Sludge retrieval, cementation, transport to TSD onsite (eventual disposal at WIPP)

II. Sludge retrieval to containers, transport to T-Plant storage (eventual conditioning and disposal at WIPP)

III. Sludge retrieval, transport to tank farms for storage (eventual vitrification)

IV. In situ vitrification (although the scope of the milestone is for the sludge only, the ISV alternatives also remediates the tank.)

Table 3 – Conceptual Alternatives for Remediation of the Sludge in Z-361

Alternative	*Description*
I. Sludge retrieval, cementation, transport to storage onsite.	Sludge is retrieved by pumping as a thick slurry to approximately fifteen hundred (1,500) 55-gallon drums containing mixers for cement/sludge homogenization. The sludge is assayed in-process before solidification. Cement, plus other additives as determined by the process control program, are added to the sludge which is allowed to harden. The drums are transported to on-site storage and eventual disposal will be to the Waste Isolation Pilot Plant (WIPP). The possibility for larger containers to meet WIPP Waste Acceptance Criteria needs to be investigated.
II. Sludge retrieval to containers, transport to T-Plant storage.	Sludge is retrieved by pumping as a thick slurry, or mechanically removed as a semisolid, and placed in approximately 50 large containers. The material is assayed during removal while being placed in containers. The containers are transported to storage in the T-Plant canyon along with the K-Basin sludge (or optionally at the CWC). At some later time, solidification will be conducted with a system to be provided for treating the K-Basin sludge. Eventual disposal will be to WIPP.
III. Sludge retrieval, transport to tank farms for storage.	Sludge is retrieved by pumping as a thin slurry to a processing system designed to reduce particle size to meet acceptance criteria for compatiblility with the tank farm vitrification equipment. The processed sludge is then assayed and conveyed via approximately 16 tanker truck loads to a double walled storage tank. Ultimately, the sludge will be vitrified as glass logs with other tank farm waste.
IV. In situ vitrification (ISV)	The ISV process converts the sludge, the tank, and a limited amount of surrounding soil to a vitrified, monolithic mass. The sludge remains in the tank. The tank is filled with soil and the top is fractured. Large electrodes are placed alongside tank and an offgas hood and treatment system is placed atop the tanks. An electrical supply of approximately 4 megawatts is converted to proper time-programmed voltage and current with special equipment trailers. The tank and contents are converted to glass over a two week period. The glass becomes cool enough for access in approximately one year after which a verification characterization of the solidified mass is anticipated to be conducted. Eventual disposal needs to be determined; that is, whether the vitrified mass can remain in situ at Hanford, or must be removed for disposal to WIPP.

The original approach was to consider a variety of retrieval methods for Alternatives I through III. However, it was decided that any of several methods is feasible and that evaluating them requires a detailed level of information and effort greater than was being considered for the balance of the process. Therefore, one retrieval method was assigned for these three alternatives (the fourth does not require retrieval). Section 3.5 discusses several retrieval methods for future consideration.

In Alternatives I, II, and III, the concepts evaluated included a 10,000-psi dislodger mounted on the TracPump™ vehicle. This dislodger has been tested on both soft sludge and hard pan simulants. Retrieval with this device requires the addition of water, which increases the total waste inventory. Based on testing on simulated soft sludge waste, it is estimated that about 23,000 gallons of water would be required to dislodge the waste during the retrieval operation. This will bring the total retrieved volume to about 46,246 gallons, and result in waste slurry that contains approximately 85% moisture. Assuming a 100% efficient nonstop operation to a properly sized receiver tank, total retrieval of the Z-361 sludge would take about 50 hours. This indicates that the total operating time for alternatives I, II and III are not constrained by the retrieval operation, and that the process (cementation) or container loading times will dictate the overall time required for each alternative.

3.1 Alternative I - Sludge Retrieval, Cementation, Transport To TSD Onsite

Alternative I incorporates an in-tank vehicle that acts as a platform for a high-pressure-water-dislodging device and a waste transfer pump. Waste will be dislodged by the high-pressure-device and the resulting slurry retrieved by the on-board transfer pump. A closed-circuit television camera in the tank will be used to direct the vehicle's operating location within the tank. The vehicle's on-board pump will scavenge the waste and pump it to the surface where it will feed into a cementation process. The cementation process will produce containers filled with grouted sludge that will meet the waste acceptance criteria of the WIPP.

Figure 2 shows the concept for Alternative I equipment arrangement installed on tank Z-361.

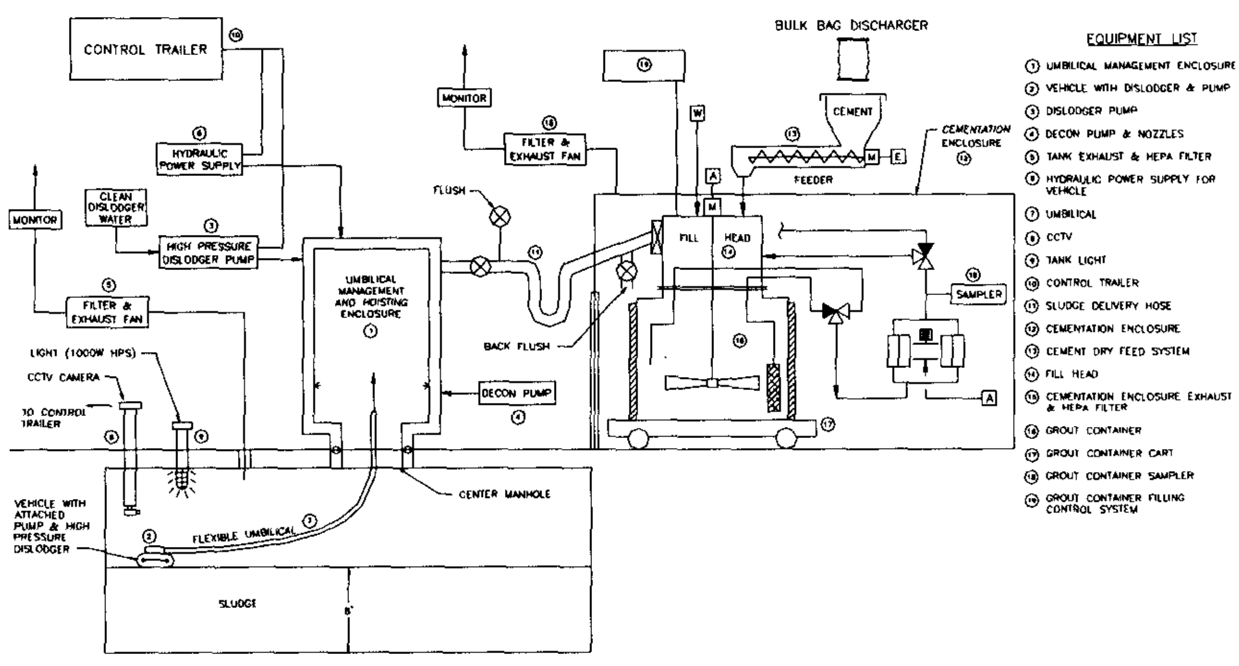

Figure 2 – Alternative I

Cementation Process

For this process, it is assumed that waste slurry with a solids content of 15% is grouted with cement in a volume ratio of 1 to 1. The components are mixed in a 55-gallon drum filled to 85% capacity. Under these assumptions, 1484 drums are required to contain all of the sludge in Z-361. Because of the plutonium content of the sludge, it is assumed that the operation is performed remotely within an alpha-tight enclosure. Drum interface to the enclosure is assumed to occur through an alpha-free double-door transfer device in order to keep the outside of the drums clean.

If we assume that two cementation lines are employed, and that 6 drums are loaded in a single 12-hour shift, then 247 shifts would be required to complete the work.

Issues Requiring Further Resolution

- Allowable size of the grout container. Using containers larger than 55-gallon drums will decrease the grouting operation schedule and make for more efficient processing. This is primarily a consideration for acceptance at WIPP.
- Should a turnkey outside contractor be considered for the retrieval and/or cementation operations? Does security at PFP pose a major problem for this?
- Amount of waste to remain in the tank (1%, 0.1%)?
- NDA requirements for the drums.

3.2 Alternative II - Sludge Retrieval To Containers, Transport To T-Plant Storage

Since the Z-361 sludge is contact handled, storage at CWC is an option for Alternative II.

Alternative II can use the same tank waste retrieval system that appears in Alternative I. In this alternative, the vehicle's on-board pump will scavenge the waste and pump it to the surface where it will be loaded into high integrity containers (HIC). These HICs will then be transported to T-Plant or CWC for interim storage, prior to further conditioning for acceptance at WIPP.

Figure 2 shows the concept for Alternative II equipment arrangement installed on tank Z-361.

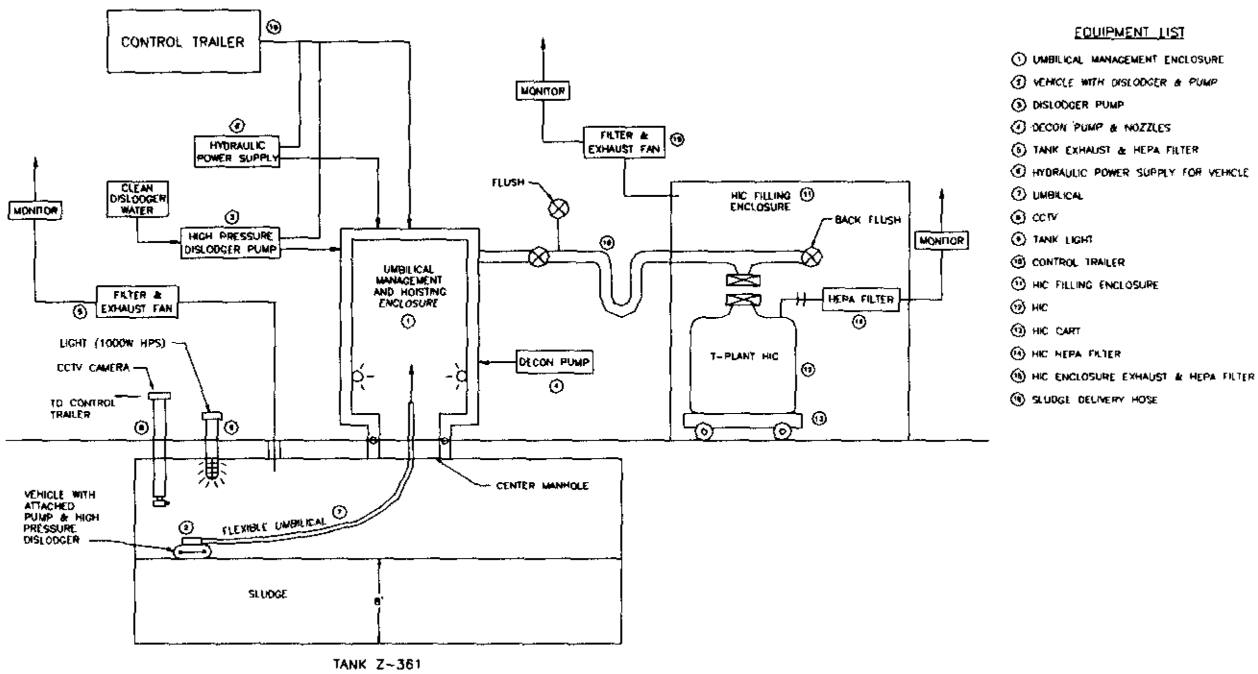

Figure 3 – Alternative II

High Integrity Container Loading

The HICs will be loaded in an enclosure located adjacent to the Z-361 tank. The enclosure will provide for weather protection and act as a barrier for any unanticipated releases that might occur during the loading process. During loading, the air expelled from within the HIC will be passed through a HEPA filter prior to being released to the atmosphere. The HIC will have a waste capacity of 125 cubic feet and will weigh about 8,500 pounds fully loaded. It is anticipated that a cart will be provided for transfer of the HIC into and out of the enclosure. Once loaded, the HIC will be transferred to T-Plant on a flatbed truck. It is estimated that 52 HICs will be required to store the entire content of the tank. If it is determined that dewatering of the waste slurry is required, a HIC design incorporating internal dewatering features will be considered.

The HIC loading operation will involve positioning the empty HIC at the slurry loading station, filling the HIC, sealing the HIC, removal from the loading station, and loading and securing the HIC on the truck transporter. It is estimated that one (1) HIC will be loaded per day of operation.

Issues Requiring Further Resolution

- Configuration of the slurry container. Is it necessary to use the same container that will be used for K-Basin sludge?
- Is dewatering of the slurry required?
- Is individual container characterization required?
- Amount of waste to remain in the tank (1%, 0.1%)?

3.3 Alternative III - Sludge Retrieval, Transport To Tank Farms For Storage

Alternative III necessarily requires a pumping system since the sludge will have to be sluiced to tanker trucks. Conceptually, it incorporates the same tank waste retrieval system that appears in Alternative I. In this alternative, the vehicle's on-board pump will scavenge the waste and pump it to the surface where it will be loaded into a tank truck. The tank truck will transport the waste to an appropriate double-shell tank for interim storage, prior to eventual vitrification at the Hanford vitrification plant.

Figure 4 shows the concept for Alternative III equipment arrangement installed on tank Z-361.

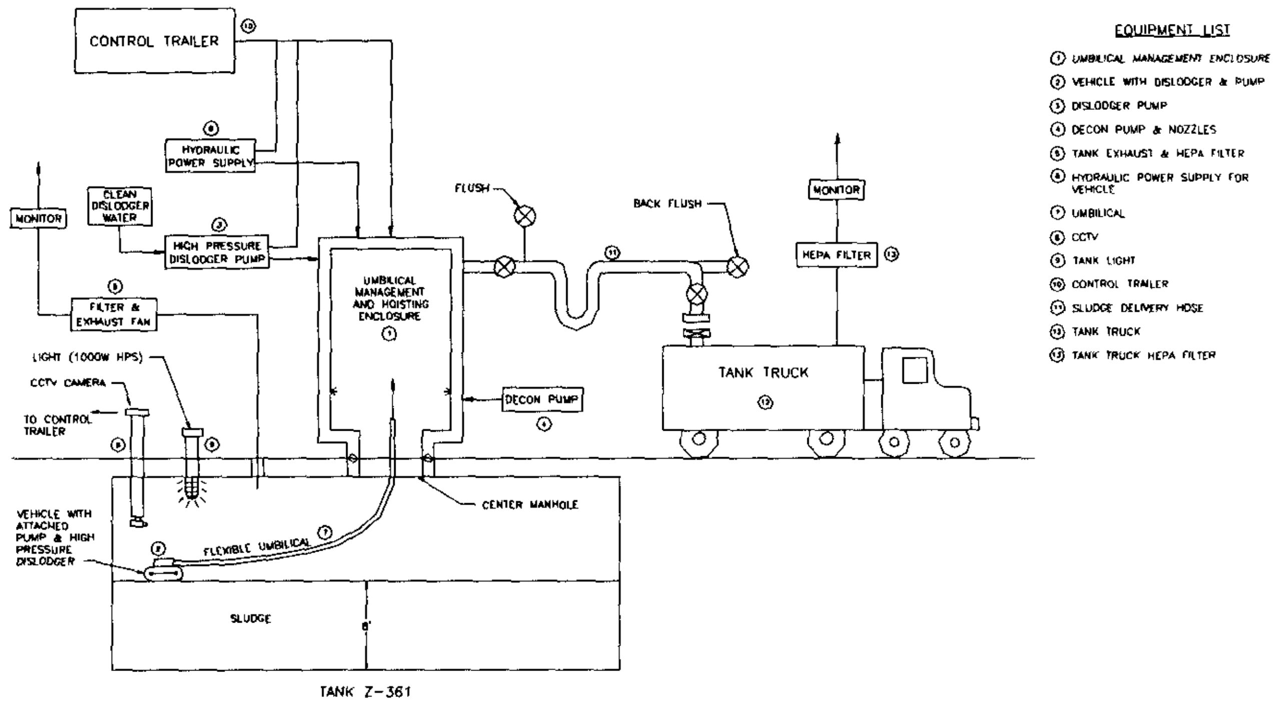

Figure 4 – Alternative III

Tank Truck Loading

The tank truck will be loaded adjacent to the Z-361 tank. The tank truck will be provided with a filtration system to handle the air released from the tank during the loading process. Assuming a tank truck with a capacity of 3000 gallons, it is estimated that 16 trips to the desired double-shell receiver tank will be required to transfer all of the Z-361 contents. A one-day turnaround of the tank truck is estimated.

Issues Requiring Further Resolution

- Compatibility of the Z-361 waste slurry with the contents of the double-shell receiver tank.
- Characterization requirements of the Z-361 tank truck waste batches.
- Design and requirements for pretreatment to meet particle size criteria?
- Amount of waste to remain in the tank (1%, 0.1%)?

3.4 Alternative IV - In Situ Vitrification

The basic in-situ vitrification processing and equipment system is illustrated in Figure 5[1]. The process works by melting soil in place using electricity applied between pairs of graphite electrodes. A highly conductive starter path is placed between the electrodes to allow initiation of melting. As electricity flows through the starter path, the path heats up and causes the surrounding media to melt. Once the media is molten, it too becomes electrically conductive. Continued application of electricity results in joule heating within the molten media between the electrodes. The process typically operates in the range of 1,600 to 2,000 °C for most earthen materials. After the melt is fully established, the melt zone grows steadily downward and outward through the contaminated volume. Since the processing is performed within the earthen media being treated, no melter vessel is required.

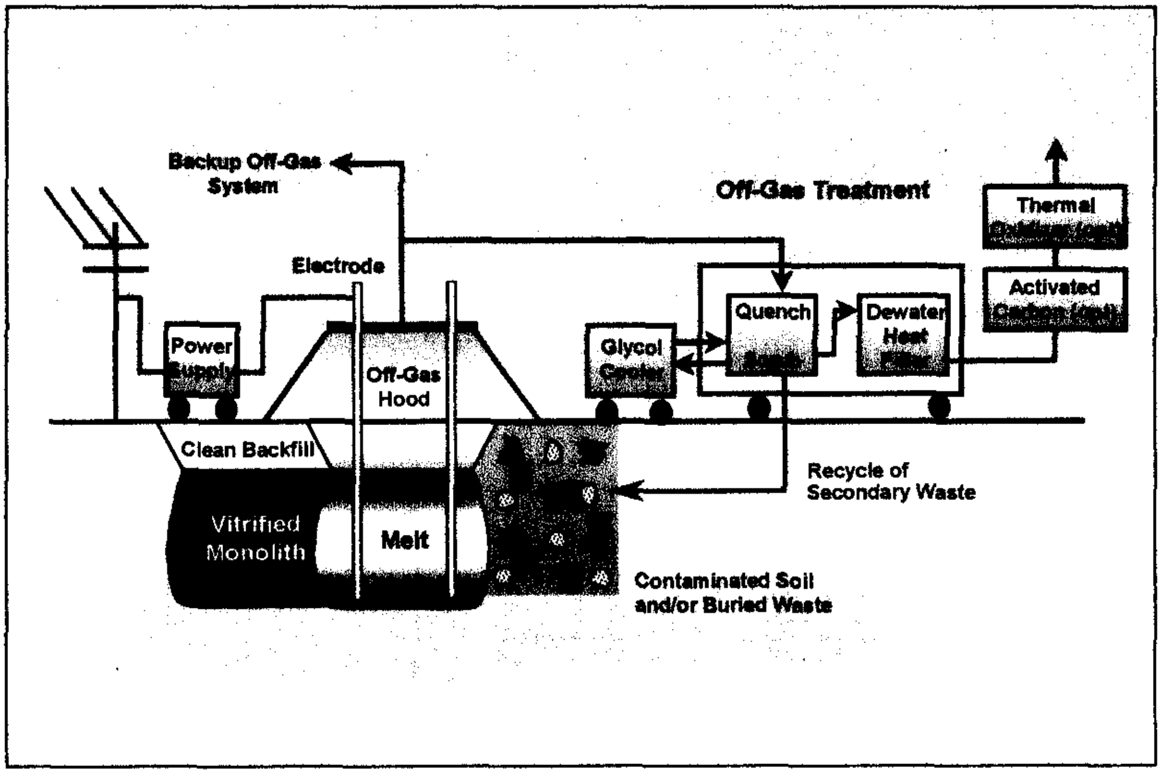

Figure 5 – In Situ Vitrification Concept

Geosafe® recommends application of subsurface planar ISV as the preferred method, illustrated in Figure 6. This recommendation is based primarily on the facts that the sludge has a high liquid content, and the tank walls may serve as a barrier to gas flow for top down melting. These factors are important in that during processing, liquids are vaporized within the thermal gradient that moves in advance of the melt body itself. The vapors then move toward the surface through the porous dry zone that exists immediately adjacent to the melt.

In the planar-ISV process, vertically oriented planes of starter material are used. The planes can be positioned at the desired depth and separation. The separation of the starter planes allows two independent melts to form during the initial stages of the process. This allows control of the initiation of the melting process so that it can be focused for optimal treatment of the waste zone. Moreover, because the melts are separated laterally during their initial stages of development, a tank or other treatment zone can be processed in a predominantly sideways-in fashion. This configuration maintains a permeable pathway in the region between the melts for gases and vapors to move to

[1] Material in this section describing in situ vitrification has been edited from Reference 4., provided by Geosafe® Corporation under contract to Fluor Hanford Incorporated.

the surface without passing through either of the melts themselves. While the melts will grow toward each other, they will not merge and coalesce until such time as there is no further movement of vapors between them (i.e., until the central zone has been dried out). In this way, treatment zones containing large amounts of liquids can be safely treated without the movement of vapors causing difficulties for the process.

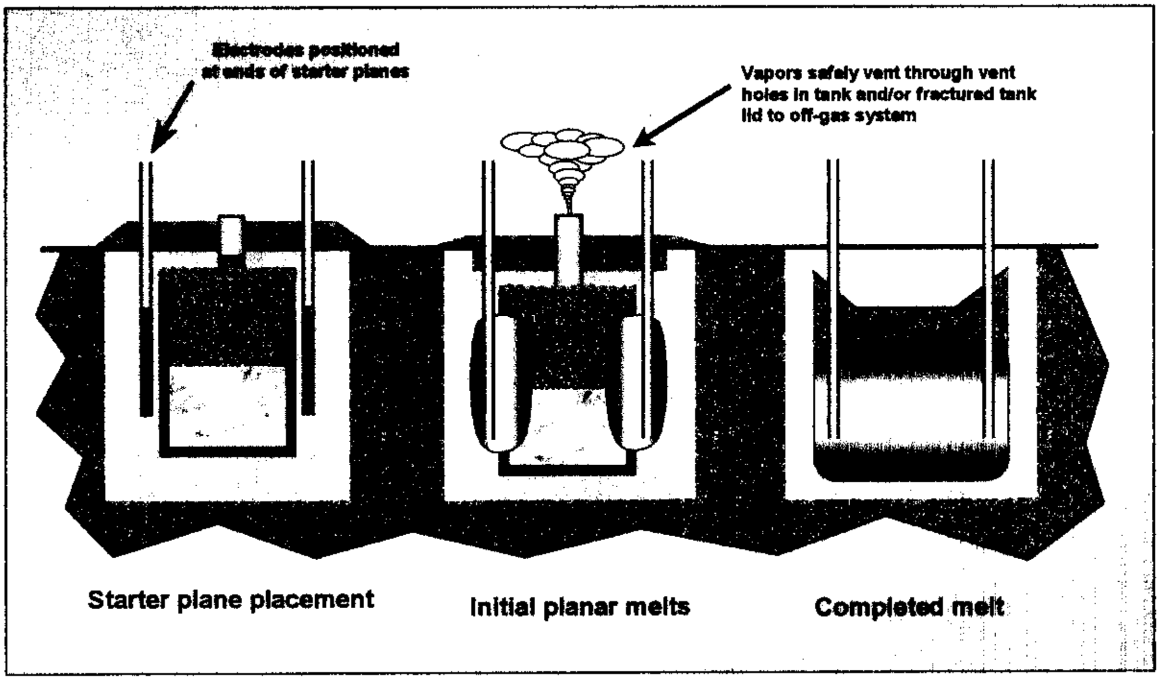

Figure 6 – In Situ Vitrification Operation

Remediation of Tank Z-361 with the planar ISV technology would involve the following basic steps:

1. Filling the void space in the tank over the contained sludge with earthen material to eliminate the void space.
2. Placement of about 4 feet of overburden over the tank.
3. Performance of dynamic disruption through the overburden to fracture and collapse the tank roof upon the fill material within the tank.
4. Formation of two vertically planar melts immediately outside the long sides of the tank.
5. Completion of melts during which all the sludge and tank materials are incorporated into the melts.
6. Covering the subsidence volume produced over the melts with clean backfill soil.
7. Cooling of the melt over approximately a one-year period.

<u>Issues Requiring Further Resolution</u>

- Will the solidified mass have to be removed for WIPP disposal?
- What is the nature of the post-solidification characterization required?
- How difficult will it be to deal with the proximity of the security fence and intruder detection system?

3.5 Sludge Retrieval

Various methods of retrieval can be applied to the sludge in Z-361. A few of the methods are described here.

Retrieval Vehicle

The retrieval vehicle (TracPump™) used as the basis for this study is similar to that demonstrated in a recent Hanford demonstration test program. The vehicle would be a hydraulic motorized, track-driven device that acts as the platform for a high-pressure-water-dislodging device and a hydraulic scavenging pump. The vehicle would be tethered by an umbilical that consists of the pump's discharge line, the high-pressure water line and various hydraulic lines. The vehicle would be sized to pass through the tank's 48-inch center manhole. An umbilical management and hoisting system would be located on the surface. An operator viewing the vehicle through a closed circuit television camera located in one of the tank's smaller risers would remotely control the vehicle.

A similar retrieval vehicle with on-board pump and dislodger has been demonstrated in radioactive tanks. ORNL has successfully deployed a similar vehicle in a 50-foot diameter radioactive waste tank. The ORNL vehicle uses a confined sluicer and a jet pump to remove waste from the tank. Our alternative is modeled after commercially available hardware used routinely in private industry to clean out large hydrocarbon tanks. One vendor (ESG) has 600 units on the market with over 30,000 hours of operating time in total.

Several other tethered vehicles have been proposed and/or used for retrieval of tank waste. The Houdini™ (by RedZone Robotics) is a tethered hydraulically operated vehicle that is planned for use at Fernald and Oak Ridge. Although this device can be fitted with tools such as grippers, a plow blade and a local sluicing nozzle, it does not incorporate a transfer pump. The ARD (ARD Environmental) vehicle, which was tested as part of a demonstration program, incorporated a low-pressure sluicer, a small pump, and a larger externally located pump to transfer the slurry to the surface. Both of these vehicles may be capable of incorporating a transfer pump and dislodging device and they would most likely be considered as potential candidates in subsequent phases of this project.

Power Fluidics[2]

Power Fluidics is the technology of moving and controlling large-scale fluid flows of process fluids, including sludge, using devices with no mechanical moving parts that operate on fluid phenomena such as the Bernoulli effect, entrainment, vortex, and surface tension. Such devices have been used with good reliability in the United Kingdom for the past 20 years in 400 systems of pumps, mixers, and samplers. They are particularly well suited to sludge pumping because of the absence of moving parts as the primary pumping equipment. Reference 5 reports successful application of a pulse jet system at the Bethel Valley Evaporator Service Tanks at Oak Ridge in which approximately 20,000 gallons of sludge were removed.

Sluicing to an Interim Receiver Tank

This concept would include a sluicing with suitable nozzle mounted from the top of Z-361, a submersible pump capable of being lowered to the bottom of Z-361 through one of the existing manholes and an interim storage tank on the surface that would act as a sluicing source tank. This tank would have to incorporate a sluicing pump and an agitator to mix the slurry feed to the cementation process.

This concept requires quite a bit of waste slurry handling on the surface, including the pumping of contaminated supernatant back into Z-361 and decanting the slurry on the surface. The amount of new water introduced to the waste slurry would be equal to or greater than that for the TracPump™ method.

Direct pumping, for example, with a pneumatic diaphragm pump, or a septic-tank type suction pump adapted for radiological service are also a method of sluicing.

[2] Material for this discussion provided by AEA Technology.

Mechanical Retrieval

This concept included a robotic tracked vehicle equipped with a plow blade (Houdini™ type) that would dislodge the waste sludge and introduce it to a mechanical conveyor that would then transfer the waste to the surface. The potential advantage of this option is that little additional water would be added to the sludge. A significant amount of water would have to be used to decontaminate the conveyor upon completion of the retrieval process, and additional water would have to be added to accomplish the cementation process.

This concept will require a relatively complex mechanical conveyor to move the sludge on the surface. This conveyor will become highly contaminated and may prove difficult to decontaminate.

4. Ranking Method and Criteria

4.1 Weighted Grading Evaluation Procedure

To apply the criteria to the Environmental and Safety evaluation, and to the Technical evaluation, the following steps were used.

Desirable attributes were identified independent of alternatives.

1. Assigned a weighting factor (1 to 5) to each attribute.
2. Identified factors pertinent to each alternative.
3. Assigned a grade (1 to 10) to each alternative based on its meeting the particular attribute.
4. Calculated a score for the particular attribute for the particular alternative (= grade x weighting factor).
5. Added up the scores for each alternative. Highest sum = highest ranking.

4.2 Evaluation Criteria For Ranking

Development of recommendations used the results of concept development to assess the four alternatives with criteria related to:

1. Environmental and Safety Evaluation
2. Technical Evaluation
3. Schedule Evaluation
4. Cost Evaluation

The first two use a weighted grading procedure applying criteria that follow, whereas the project schedule and project cost results are used directly.

The criteria used for the Environmental and Safety Ranking are in the first column of Table 4. The examples in the second column of provide guidance for application of the criteria during the evaluation.

The criteria used for the Technical Ranking are in the first column of Table 5. The examples in the second column of provide guidance for application of the criteria during the evaluation.

Table 4 – Environmental and Safety Evaluation Criteria Description

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable
1. Radiation safety	Reasonable amount of shielding is needed for protection of operating personnel. System equipment and piping has a low probability of leakage. System does not create airborne activity by promoting splashing or agitation. Design of equipment and piping avoids crud traps.
2. Industrial safety	Equipment is provided with OSHA machinery guarding, ladders, and platforms. Personnel not likely to be exposed to sources of high voltage. Systems operated at low pressure (< 150 psig) and temperature (< 200 °F). Personnel not exposed to swinging crane booms or whips. Personnel entry not required for normal operation or emergencies. Personnel are not required to work over open manways.
3. Environmental safety	Minimal danger of unmonitored, accidental chemical or radiological discharges. Minimal risk of contamination of adjacent soil.

Table 4 – Environmental and Safety Evaluation Criteria Description

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable
4. Regulatory acceptability	This is a CERCLA process. NEPA values will be incorporated in the CERCLA documentation. Process has been accepted for use at other DOE sites or at commercial facilities. Subjective perceptions by regulators or the public is likely to be that effluents are not significant. Effluent discharge permits have been issued for the process in similar applications. Permitting is not required for this CERCLA process. However, substantive environmental requirements of permits are taken into account through the ARARs analysis and incorporated in the results.
5. Reduced volume for disposal	Processes that reduce the volume of waste to be disposed below that existing in the tank are given a higher grade.
6. Minimal site preparation	No or little additional land use. Building heavy haul roads not required. Minimal number of equipment pads to be poured. Overhead and underground utilities and piping need not be relocated or provided with special protection. Additional reinforcement of the tank top not required.
7. Minimal contaminated equipment disposal and/or generation of secondary waste	Equipment is easily decontaminated and salvaged for re-use, or is provided by a service company. Number of items of equipment that cannot be easily decontaminated, or their economic value, is relatively small. Minimal secondary waste (contaminated) is created.
8. Simple and reliable effluent monitoring	Effluents are readily maintained below applicable radiological and non-radiological limits/standards.
9. Simple and reliable effluent treatment processes	Standard and proven effluent treatment processes and monitoring are employed.
10. Achievement of final cleaning criterion	Process inherently obviates this step or it is inherently a part of the process. Can be achieved and verified by remotely operated equipment; personnel entry is not required.
11. Insensitive to limits of accuracy of characterization	The effectiveness of cementation or vitrification and the acceptability of product for disposal at WIPP would not be threatened by chemical properties of any given batch that were different than those determined by characterization because of the limits of accuracy of the characterization.
12. Insensitive to waste variability	The effectiveness of the cementation or vitrification and the acceptability of product for disposal at WIPP would not be threatened by chemical properties of any given batch that were outside the expected range of properties as determined by characterization because of non-homogeneity of the waste sludge.

Table 5 – Technical Evaluation Criteria Description

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable
1. Proven technology	Technology is in common use. Technology has been used for similar projects. No first-of-a-kind applications or basic R&D required.
2. Mechanical simplicity	Minimal number of mechanical components (valves, pumps, treatment units, and conveyors). Reliance on passive (e.g., gravity) rather than active effects. Low pressures and temperatures.
3. Operational simplicity	Minimal automatic controls. Specialized training of operators not required. Number of control steps, manual and automatic, is minimal. Once placed in steady-state operation, the process is stable and not easily upset by slight variations in physical or chemical parameters.
4. Ease of electric power supply	Local power is adequate for the process. No need to bring in diesel generators, large capacity transformers, or new high voltage feeds.
5. Ease of product testing	Meeting waste acceptance criteria requires minimal testing of the product (inherently assured by the type of process). Chemical process control not required. Direct handling of product for sampling and analysis is not required. Destructive analysis not required.
6. Low susceptibility to underground interferences	On-grade equipment and vehicles not so heavy as to endanger underground piping or cable ducts. Relocation or isolation of undergrounds not required.
7. Low susceptibility to above ground interferences	To bring in and set up equipment will not require relocation or removal of overhead utilities such as power lines and steam pipes. Similarly, cranes can be used in the process without danger of contacting overhead power lines.
8. Ease of equipment set-up	Heavy rigging and hauling not required. Specialized craft (e.g., high alloy welders) not required. Minimal number of different craft types (pipe fitters, ironworkers, carpenters, electricians, boilermakers, millwrights, etc.) required. Site haul roads adequate for the axle loads and turning radii of equipment delivery vehicles.
9. Independent of off-site logistics	Regular, frequent, and large quantities of commodities delivered from off site, such as fuel or concrete, are not required. Process could not be threatened by interruption of offsite supply because of weather or labor disputes.
10. Unaffected by inclement weather	Process would not have to be shut down or equipment would not be damaged by high winds, lightning, or prolonged freezing temperatures. Protection measures, if required, would be straightforward and not overly complex or costly.
11. Minimal O&M requirements	Equipment is rugged and has history of high reliability. Equipment is designed for quick disassembly and re-assembly if maintenance is required. Special tools and supplier-trained personnel are not required to perform maintenance. Piping is designed for non-plugging performance.
12. Insensitive to electrical power interruption	Process can be re-started without loss of product, recycling of product, system tear down and maintenance, or abnormal radiation exposure of personnel in the event of a power interruption.

5. Evaluation Results

The results of the Environmental and Safety Evaluation are shown in Table 6, which compares the alternatives for the stated criteria and Table 7, which contains the numerical scoring.

The results of the Technical Evaluation are shown in Table 8, which compares the alternatives for the stated criteria and Table 9, which contains the numerical scoring.

In both these evaluations, the expert group first decided the weight assigned to each criterion. Then, the individual scores were assigned to arrive at overall scores.

Table 6 – Environmental and Safety Comparison

Evaluation Criteria (EE/CA Criteria)	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
1. Radiation safety	Reasonable amount of shielding is needed for protection of operating personnel. System equipment and piping has a low probability of leakage. Systems do not create airborne activity by promoting splashing or agitation. Design of equipment and piping avoids crud traps.	Alternative I involves a greater amount of waste handling above the tank than does alternatives II and III. In alternative IV, processing is performed in-place and underground, providing maximum radiation safety to operating personnel.
2. Industrial safety	Equipment is provided with OSHA machinery guarding, ladders, and platforms. Personnel not likely to be exposed to sources of high voltage. Systems operated at low pressure (< 150 psig) and temperature (< 200 °F). Personnel not exposed to swinging crane booms or whips. Personnel entry not required for normal operation or emergencies. Personnel are not required to work over open manways.	Alternatives I, II and III are equal in this area. In all cases, the equipment will be specified to OSHA standards. Alternative IV requires a high temperature underground process involving large quantities of molten radioactive material. This process must be evaluated from the standpoint of containment and explosive potential.
3. Environmental safety	Minimal danger of unmonitored, accidental chemical or radiological discharges. Minimal risk of contamination of adjacent soil.	Risks from Alternatives I and II are equal in this area since they both involve sluicing out of the tank. Alternative III, in addition to risk from sluicing, also has somewhat higher risks due to truck transport of loose sludge. Alternative IV is better than the others because all material except offgas remains underground.
4. Regulatory acceptability (this is a CERCLA process).	Permitting is not required for this CERCLA process. However, substantive environmental requirements of permits are taken into account through the ARARs analysis and incorporated in the results. Residual effects are minimal or non-existent with respect to conflicting with the aims of the CLUP (Comprehensive Land Use Plan). Conflicts with goals of the operable unit remediation are minimal or non-existent.	Alternatives I, II, and III are equal and represent methods for which there is much precedent. Alternative IV ranks somewhat lower because of the significant offgas system that would otherwise be permitted and undergo substantial review.

Table 6 – Environmental and Safety Comparison

Evaluation Criteria (EE/CA Criteria)	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
5. Reduced volume for disposal	Processes that reduce the volume of waste to be disposed below that existing in the tank are given a higher grade.	Alternative I increases the volume of waste to be disposed of by a factor of 1.5 to 2 because of addition of sluice water and cement. Alternatives II and III add water to the existing sludge so as to double the total volume of waste slurry to be handled. Alternative IV increases the total waste quantity by a factor of 4.4, but this volume includes waste associated with the remediation of the tank as well, not included in I, II, and III, and some of the surrounding soil.
6. Minimal site preparation	No or little additional land use. Building heavy haul roads not required. Minimal number of equipment pads to be poured. Overhead and underground utilities and piping need not be relocated or provided with special protection. Additional reinforcement of the tank top not required.	Site preparation for Alternatives I, II, and III is minimum and about equal for the three alternatives. For alternative IV, site preparation will as a minimum include a thorough survey of the underground utilities, piping and ducts within about 40 feet of each side of the tank. Any items found will need to be rerouted to clear the area potentially affected by the ISV process. The ISV process will also require soil drilling in close proximity to the tank for installation of the electrodes. Temporary relocation of the intrusion fence will be required to make room for the offgas hood.
7. Minimal contaminated equipment disposal and/or generation of secondary waste	Equipment is easily decontaminated and salvaged for re-use, or is provided by a service company. Number of items of equipment that cannot be easily decontaminated, or their economic value, is relatively small. Minimal secondary waste (contaminated) is created.	Alternatives I, II, and III generate about the same amount of contaminated equipment waste and secondary waste for disposal. Cementation will generate slightly more in the near term. Alternative IV appears to produce a smaller amount of equipment and secondary waste than the other alternatives because the waste remains underground, and the only potential for waste generation is with the off-gas system. Alternative IV is also believed to produce a high retention of the radionuclides, resulting in minimum off-gas activity.

Table 6 – Environmental and Safety Comparison

Evaluation Criteria (EE/CA Criteria)	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
8. Simple and reliable effluent monitoring and treatment	Effluents are readily maintained below applicable radiological and non-radiological limits/standards. Standard and proven effluent treatment processes and monitoring are employed.	Alternatives I, II, and III do not involve high temperature processing and will employ standard effluent monitoring equipment. The potential for more complex radionuclide releases that could occur in a high temperature vitrification process must be addressed in alternative IV.
9. Minimal transportation of waste required	Off-PFP transportation.	Alternatives I, II, and III are equal even though the form for transport is different. From a transport risk perspective, the greater number of containers in Alternative I is compensated by the fact that the waste is solidified. Alternative IV does not require transport of waste under the high likelihood that the glass mass will remain in-situ indefinitely.
10. EE/CA Criteria not addressed elsewhere	Ability to achieve removal objectives (level of treatment/containment and maintain control until long-term solution is implemented). Off-site treatment and/or disposal is available, Post Removal Site Controls are available, Administrative Feasibility of imposing institutional controls.	Alternative IV ranks higher than the other three in this area because in addition to the sludge, the tank itself will be remediated and it is effectively a final solution. The others will require some degree of control and monitoring until ultimate disposal of the sludge.
11. Insensitive to limits of accuracy of characterization	The effectiveness of cementation or vitrification and the acceptability of product for disposal at WIPP would not be threatened by chemical properties of any given batch that were different than those determined by characterization because of the limits of accuracy of the characterization.	Alternative I is lowest in this area because of the large number of containers and the difficulty of re-characterizing material once it is hardened. Further, characterization for WIPP disposal necessarily will have to be done as a just-in-time process during cementation. Alternatives II and III are much larger batches than I. Alternative IV has no sludge characterization requirements during processing. In addition, there may be no post-processing characterization since it is highly likely that the glass will remain in-situ indefinitely. (A few confirming samples may be required.)

Table 6 – Environmental and Safety Comparison

Evaluation Criteria (EE/CA Criteria)	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
12. Insensitive to waste variability	The effectiveness of the cementation or vitrification and the acceptability of product for disposal at WIPP would not be threatened by chemical properties of any given batch that were outside the expected range of properties as determined by characterization because of non-homogeneity of the waste sludge.	Alternative I is most sensitive to waste variability because there is no overall mixing of the tank contents before cementation, resulting in a need for more frequent sampling and analysis. Alternatives II and III result in substantial homogenization once the material is removed and this will be much more the case during final processing when this sludge is mixed with other materials for final stabilization. The ISV process adapts to highly variable waste conditions without difficulty. The vitrified product will be uniform and should easily meet the WIPP waste acceptance criteria.

Table 7 – Environmental and Safety Ranking Results

Assign Weight of 1 to 5, Grade 1 to 10

Environmental and Safety Ranking Evaluation Criteria	Weight		Alternative							
			I		II		III		IV	
	1 to 5	%	Grade	Score	Grade	Score	Grade	Score	Grade	Score
1. Radiation safety	5	12.2%	6	0.73	8	0.98	7	0.85	9	1.10
2. Industrial safety	5	12.2%	8	0.98	8	0.98	8	0.98	6	0.73
3. Environmental safety	5	12.2%	8	0.98	8	0.98	7	0.85	9	1.10
4. Regulatory acceptability (this is a CERCLA process*).	5	12.2%	8	0.98	8	0.98	8	0.98	7	0.85
5. Reduced volume for disposal	2	4.9%	4	0.20	5	0.24	5	0.24	10	0.49
6. Minimal site preparation	3	7.3%	7	0.51	7	0.51	7	0.51	5	0.37
7. Minimal contaminated equipment disposal and/or generation of secondary waste	3	7.3%	6	0.44	8	0.59	8	0.59	9	0.66
8. Simple and reliable effluent monitoring and treatment	3	7.3%	8	0.59	8	0.59	8	0.59	7	0.51
9. Minimal transportation of waste required	2	4.9%	8	0.39	8	0.39	8	0.39	10	0.49
10. EE/CA Criteria not addressed elsewhere	5	12.2%	7	0.85	7	0.85	7	0.85	9	1.10
11. Insensitive to limits of accuracy of characterization	2	4.9%	6	0.29	7	0.34	7	0.34	9	0.44
12. Insensitive to waste variability	1	2.4%	7	0.17	9	0.22	9	0.22	10	0.24
		100%		7.1		7.6		7.4		8.1

Table 8 – Technical Comparison

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
1. Proven technology	Technology is in common use. Technology has been used for similar projects. No first-of-a-kind applications or basic R&D required.	All alternatives use proven technology. The retrieval technology used in Alternatives I, II and III has been used on radioactive waste at ORNL and INEEL and has over 30,000 hrs of operating time in commercial applications. The ISV process used in alternative IV has been used at Hanford and other Government sites for vitrification of plutonium contaminated waste. The ISV process has been employed on 54 large0scale melts. For this project the "new planar sideways melting" method is recommended. This method has less operating history.
2. Mech., Elec., I&C Simplicity	Minimal number of mechanical components (valves, pumps, treatment units, and conveyors). Reliance on passive (e.g., gravity) rather than active effects. Low pressures and temperatures.	Alternatives I, II, and III incorporate the same retrieval components. However II and III are simpler than I since no waste processing is required. Alternative IV does not utilize mechanical components other than those required for the HVAC systems. The offgas handling is extremely important and must be reliable. Alternative IV also uses a substantial number of large electrical components.
3. Operational simplicity	Minimal automatic controls. Specialized training of operators not required. Number of control steps, manual and automatic, is minimal. Once placed in steady-state operation, the process is stable and not easily upset by slight variations in physical or chemical parameters. Final cleanout is readily achieved and verified without personnel entry.	Alternatives I, II, and III are equal from a retrieval standpoint. However I is more complex than II and III because it include the cementation process. Alternative III is simpler then II because it does not involve loading of individual containers. Alternative IV does not require a retrieval operation and thus is very simple from an operational standpoint.
4. Ease of electric power supply	Local power is adequate for the process. No need to bring in diesel generators, large capacity transformers, or new high voltage feeds.	Alternatives I, II, and III are equal and require power that is readily available on-site. Alternative IV requires large capacity transformers and potentially a diesel generator. However, this equipment would be available as part of the ISV contractor's scope, and would not have to be purchased expressly for this project.

Table 8 – Technical Comparison

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
5. Ease of product testing	Meeting waste acceptance criteria requires minimal testing of the product (inherently assured by the type of process). Chemical process control not required. Direct handling of product for sampling and analysis is not required. Destructive analysis not required.	Alternative I requires remote product testing to assure compliance to the WIPP WAC. Alternative II does not require product testing since no processing is defined at this time. Alternative III requires product testing to meet the criteria of future Hanford vitrification, including particle size criteria, which will require a pretreatment system. Alternative IV will require product testing to characterize the product. This will most likely be preformed by core drilling after the glass has cooled down in about 1 year. The product most likely can be directly handled in alternative IV.
6. Low susceptibility to underground interferences	On-grade equipment and vehicles not so heavy as to endanger underground piping or cable ducts. Relocation or isolation of undergrounds not required.	Alternatives I, II, and III are equal in their low susceptibility to underground interferences. For these alternatives, it is not expected that any relocation or isolation of underground piping or cable ducts will be required. Alternative IV will require a thorough review of all underground piping and cable ducts or other structures within a TBD distance of the tank. These items will then have to be removed or rerouted so as not to remain within the melt zone of the ISV process. As a minimum, the inlet piping to the tank, which has been isolated and plugged some 2 feet from the outer wall of the tank, will have to be moved a greater distance from the tank.
7. Low susceptibility to above ground interferences	To bring in and set up equipment will not require relocation or removal of overhead utilities such as power lines and steam pipes. Similarly, cranes can be used in the process without danger of contacting overhead power lines.	Alternatives I, II, and III are equal in their low susceptibility to aboveground interferences. Alternative IV will require relocation of the fence that is adjacent to Z-361, in order to make room for the hood structure that must be erected above the tank and to remove it from the melt zone.

Table 8 – Technical Comparison

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
8. Ease of equipment set-up	Heavy rigging and hauling not required. Specialized craft (e.g., high alloy welders) not required. Minimal number of different craft types (pipe fitters, ironworkers, carpenters, electricians, boilermakers, millwrights, etc.) required. Site haul roads adequate for the axle loads and turning radii of equipment delivery vehicles.	Alternatives I, II, and III will require the construction of concrete support pads on each side of the tank in the narrow direction in order to support the Umbilical Management and Hoisting Enclosure. In addition, Alternative I will require a concrete pad for the cementation equipment. Alternative II might require a support pad for the HIC loading area. Alternative IV will require the installation of 4 one-foot diameter electrodes adjacent to the tank walls. This will require the operation of an earth drilling machine in close proximity to the tank.
9. Independent of off-site logistics	Regular, frequent, and large quantities of commodities delivered from off site, such as fuel or concrete, are not required. Process could not be threatened by interruption of offsite supply because of weather or labor disputes.	Alternative I will require the largest number of off-site shipments of commodities. These will include concrete and containers for the grouting operations. Alternative I will also require a storage area somewhere on site for the grout-filled containers, which could number in the hundreds, depending on the size of the container selected. Alternative II will require the delivery about 52 HICs to the work area and subsequent transfer of the filled HICs to T-Plant or CWC. Alternative III will require the loading and transfer of about 16 tanker truck loads from the work area to some yet to be determined double-shell tank receiving area. For Alternative IV, the vitrified waste product will stay in the ground unless it is determined that the glass needs to be unearthed and sent to WIPP. Should this be required, some 600 tons of glass will have to be unearthed, broken into pieces and loaded into shipping or storage containers.
10. Unaffected by inclement weather	Process would not have to be shut down or equipment would not be damaged by high winds, lightning, or prolonged freezing temperatures. Protection measures, if required, would be straightforward and not overly complex or costly.	Alternatives I, II, and III are about equal with regard to the effect of inclement weather. All will rely on trucks to transport the waste out of the area. Truck transport might be adversely affected in heavy rain or snow conditions. Alternative IV requires a large hood over the tank. High wind or heavy snow conditions may affect operations.

Table 8 – Technical Comparison

Evaluation Criteria	Examples of Attributes for Grading Toward Favorable	Comparison of Alternatives
11. Minimal O&M requirements	Equipment is rugged and has history of high reliability. Equipment is designed for quick disassembly and re-assembly if maintenance is required. Special tools and supplier-trained personnel are not required to perform maintenance. Piping is designed for non-plugging performance.	Alternatives II and III will require about the same O&M. Most of the equipment will be commercially available subsystems with a history of high reliability. However, any equipment that has been in contact with the waste will most likely be highly contaminated and will require suit-up and special precautions during maintenance. Alternative I requires a greater amount of equipment that might be subject to decontamination and maintenance. Alternative IV should not require much maintenance because of the small amount of mechanical equipment. Power supplies and other electrical equipment required for this alternative should be highly reliable.
12. Insensitive to upsets and inadvertent interruption	Process can be re-started without loss of product, recycling of product, system tear down and maintenance, or abnormal radiation exposure of personnel in the event of an interruption (for example, electric power).	Alternative I appears to be most sensitive to upsets and inadvertent power interruptions. A power interruption during the grout loading operation could result in the solidification of a partially filled or mixed drum of grout. Alternatives II and III are about equal, and are most insensitive to upsets or power outages. Alternative IV is indicated to be insensitive to a power outage, unless the outage lasted for more then 3 or 4 days. In this case, the melt would have to be restarted with a new set of electrodes.

Table 9 – Technical Ranking Results

Assign Weight of 1 to 5, Grade 1 to 10

Technical Ranking Evaluation Criteria	Weight		Alternative							
			I		II		III		IV	
	1 to 5	%	Grade	Score	Grade	Score	Grade	Score	Grade	Score
1. Proven technology	5	12.5%	10	1.25	10	1.25	10	1.25	7	0.88
2. Mech., Elec., I&C Simplicity	4	10.0%	6	0.60	8	0.80	8	0.80	5	0.50
3. Operational simplicity	4	10.0%	4	0.40	6	0.60	5	0.50	7	0.70
4. Ease of electric power supply	2	5.0%	8	0.40	9	0.45	9	0.45	3	0.15
5. Ease of product testing	3	7.5%	6	0.45	9	0.68	7	0.53	5	0.38
6. Low susceptibility to underground interferences	3	7.5%	10	0.75	10	0.75	10	0.75	3	0.23
7. Low susceptibility to above ground interferences	3	7.5%	8	0.60	8	0.60	8	0.60	6	0.45
8. Ease of *equipment* set-up	4	10.0%	7	0.70	7	0.70	7	0.70	5	0.50
9. Independent of off-site logistics	1	2.5%	3	0.08	7	0.18	7	0.18	3	0.08
10. Unaffected by inclement weather	3	7.5%	9	0.68	9	0.68	8	0.60	8	0.60
11. Minimal O&M requirements	4	10.0%	5	0.50	7	0.70	7	0.70	8	0.80
12. Insensitive to upsets and inadvertent interruption	4	10.0%	6	0.60	7	0.70	7	0.70	6	0.60
		100%		7.0		8.1		7.8		5.9

6. Conceptual Schedule

An overall project schedule is shown in Figure 7 that considers a possible budget cycle. A comparison of individual alternatives processing schedules is shown in Figure 8. Those individual schedules are indicated as starting in 10/1/2002 and requiring 5 to 10 months, depending on the alternative. The individual schedules are pessimistic.

Preceding actual operations, a 12 to 18 month period is judged for project activities once budget has been authorized. Again, a pessimistic uncertainty of 6 months is shown for project activities prior to tank operations.

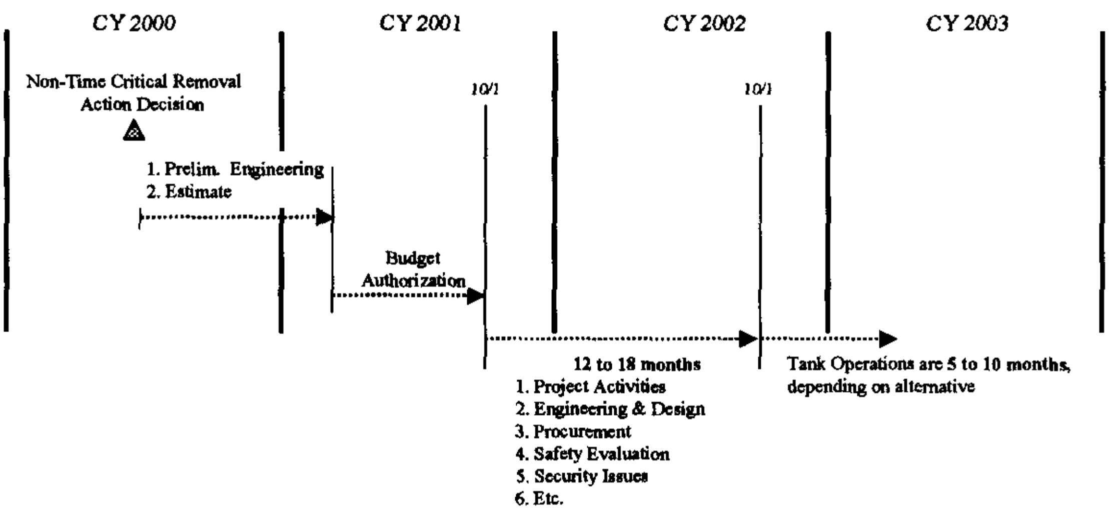

Figure 7 – Overall Project Conceptual Schedule

The schedule for the various alternatives in Figure 8 is based on processing time discussed with the description of alternatives. Alternative I requires the longest schedule because of the cementation process into 55-gallon drums.

For Alternative II, pumping sludge into larger high integrity containers for the T-Plant option, with no cementation, requires much less time. Similarly, a short time is required in Alternative III for pumping to tanker trucks for transfer to a double-shell tank. However, pretreatment for particle size acceptance criteria will require additional time.

In situ vitrification is estimated to take approximately 3 weeks of actual melt processing time. The glass solidification and cooling to a low temperature takes approximately one year.

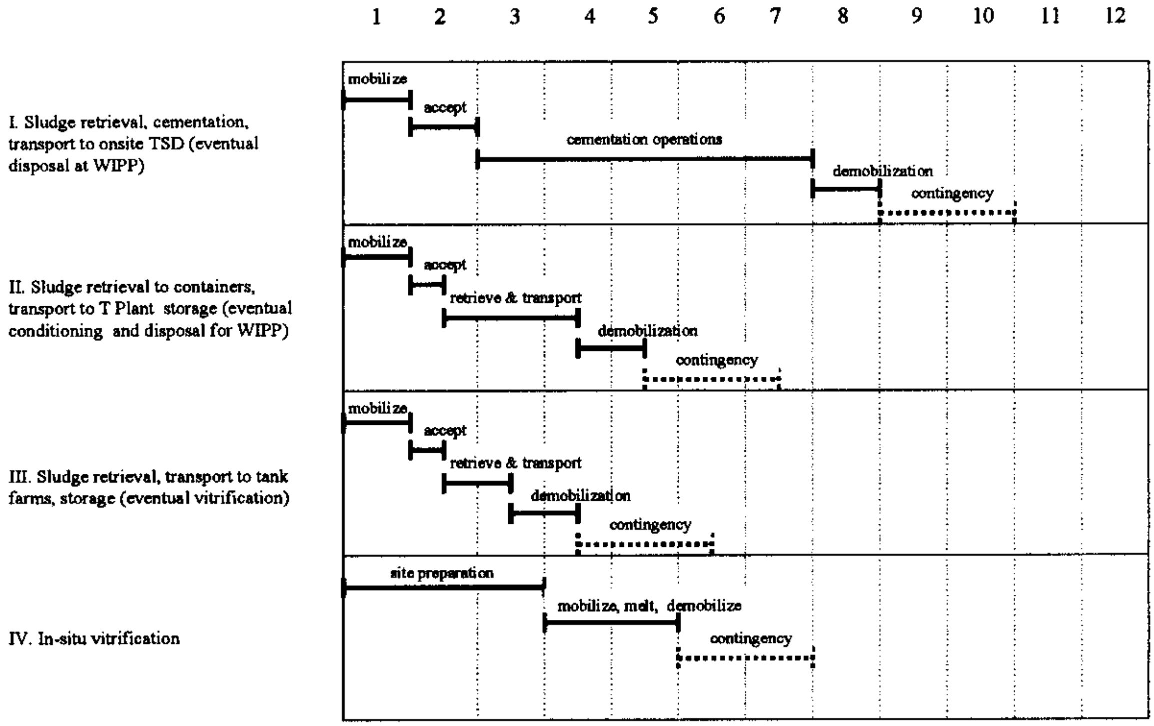

Figure 8 – Processing Campaign Conceptual Schedules

7. Conceptual Cost Estimate

The conceptual cost estimate results are presented in Table 10. The cost elements were selected to facilitate comparison alternatives, in contrast with an accurate total estimate. A 30% contingency and several cost factors were added to the base estimates to account for the lack of detail appropriate to this study.

Cost factors include:

- 35% engineering and design not directly in the scope of a service provider. This would include site interfaces, relocation of the security fence, preparation of a bid specification and evaluation of suppliers, selection of the alternative of choice, and others.
- 25% project management. In addition to management effort, this would include site operations interface, readiness reviews, production of ARARS, and others.
- 35% for site overheads.

The level of estimate is considered as Order-of-Magnitude and individual elements have been rounded to the nearest $10,000.

Table 10 – Conceptual Cost Estimate

Values in $1,000, Rounded up to next $10,000

Cost Element	Alternative I		Alternative II		Alternative III		Alternative IV	
	Labor	Capital or Contract	Labor	Capital or Contract	Labor	Capital or Contract	Labor	Capital or Contract
1. Evaluations and Demonstrations Required for Technical Feasibility							250	
2. Conduct ARARs Analysis and Report	150		150		150		150	
3. Procurement or Lease and Support Equipment		50		50		50		50
4. Procurement of Retrieval Equipment and Retrieval Services		340		340		340		
5. Procurement of Treatment Equipment and Treatment Services		900		500		170		1,400
6. Site Preparation and Non-Vendor Mobilization	150	10	150	10	150	10	170	
7. Radcon and Oversight of Operations	620		280		200		250	
8. Utility costs (electricity)							20	
9. Analyses during Processing	150		50		20		30	
10. Consumables		10		10				10
11. Primary Waste Containers and Packaging	180	210	70	330				
12. Contaminated Equipment and Secondary Waste Disposition		140		130		110		
13. On-Site Waste Transport to storage for future WIPP disposal	80							
14. Transfer to T-Plant storage for future WIPP disposal			80					
15. Transfer to Tank Farms					50			
16. Future Characterization of Vitrified Mass							200	
Subtotal	1,330	1,660	780	1,370	570	680	1,070	1,460
Combined Subtotal	2,990		2,150		1,250		2,530	
17. Engineering and Design for Scope not by a Service Contract; Cost Factor = 35%	1,047		753		438		886	
18. Project Management; Cost Factor = 25%	748		538		313		633	
19. Site Overheads; Cost Factor = 35%	1,047		753		438		886	
Subtotal	5,831		4,193		2,438		4,934	
20. FY 2000, 2001 Pre-Project Activities (2.5 FTE)	300		300		300		300	
Subtotal	6,131		4,493		2,738		5,234	
30% Contingency	1,839		1,348		821		1,570	
Total	7,970		5,840		3,559		6,804	
Rounded Total	7,970		5,840		3,560		6,800	

8. References

1. Mulkey, C.H., M. S. Miller, and L. P. Jackson, 1999, *Data Quality Objectives for Tank Farms Waste Compatibility Program*, HNF-SD-WM-DQO-001, Rev. 3, Lockheed Martin Hanford Corporation and Environmental Quality Management, Richland, Washington.
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3. Ecology, EPA, and DOE, 1996, *Hanford Federal Facility Agreement and Consent Order*, (Tri-Party Agreement), 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington..
4. Geosafe Corporation, *Conceptual Study of In Situ Vitrification Treatment for PFP Tank 241-Z-36*, Study conducted under FHI Contract 6748, March 31, 2000.
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