Sludge Solidification Feasibility Study

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Management Summary

1.0 Project Background

The Transuranic (TRU) Waste Processing Center (TWPC) is located adjacent to the Melton Valley Storage Tanks (MVSTs) in the Melton Valley area of the Oak Ridge National Laboratory (ORNL). The TWPC was originally designed to process the following waste stream feeds: 1) tank Supernate (SN) from the Melton Valley Storage Tanks and Capacity Increase Project tanks, 2) tank Sludge (SL) from the Melton Valley Storage Tanks and Capacity Increase Project tanks, 3) Contact Handled (CH) TRU and CH low level and mixed low level solid wastes, and 4) Remote Handled (RH) TRU solid wastes.

The SL aspects of the current TWPC mission are to mobilize and process specific SL wastes currently accumulated at various facilities on the Oak Ridge Reservation (predominantly at the MVST and CIP tanks, but also in the BVST tanks), and to satisfy transportation and disposal criteria for the applicable U.S. Department of Energy (DOE) waste repositories.

The TWPC was originally constructed in the 2001 – 2003 timeframe by Foster Wheeler Environmental Corp. under a privatized contact, based on cost recovery using fixed unit rate pricing per cubic meter of waste processed, shipped, and disposed. Due to delays in approval for WIPP to accept and dispose of RH waste, the TWPC was completed only for the initial Low Level Waste (LLW) campaign (i.e., processing SN) and construction of the RH debris and SL process systems were halted prior to completion. The RH debris areas have been constructed to the initial design. RH debris systems have been completed as of draft date. Numerous reliability, operability, and maintainability improvements were developed and implemented for the RH debris processing systems to support the significant increase in expected RH debris processing operations (i.e., one year base operations has increased to the potential for a 7 year RH processing mission duration). The increase in RH processing mission duration results from the five fold increase in RH debris incoming volume (i.e., the base RH volume of 150 cubic meters has been increased to 600 cubic meters in the latest modification to the prime contract) along with the disallowance of compaction which results in an additional 5 fold increase in final waste volumes. After halting the SL process system construction punch-lists were developed for the remaining activities necessary for build-out of the SL systems required to support the processing of the SL.

2.0 Feasibility Study Background

During 2006, DOE chartered Foster Wheeler Environmental Corporation (FWENC) to conduct an operability study for the RH debris and SL processes. The study was conducted during the fourth quarter of 2006 and the report, “RH Debris and Sludge Operability Review”, RH-R-AD-001, was issued in January, 2007. Near the end of the operability review the SL review team felt that disposal as LLW at NTS should be evaluated if solidification of the SL was without the advantage of volume reduction. This notion was due to the significant escalation in WIPP requirements, limitations in the

number and availability of 72-B RH-TRU shipping casks, and cost/schedule/technical/safety risks for drying or dewatering. This feasibility study report has been prepared to summarize the results of the follow-on study, initiated by FWENC, of this alternate processing option.

An independent external peer review was initiated by DOE. Pro2Serve was selected to perform the independent peer review and this review was conducted between May 7, and June 30, 2007. DOE ORO also requested an independent review by DOE Carlsbad Field Office (CBFO) Subject Matter Experts. Numerous questions were addressed during the face to face meetings between the Pro2Serve team and the TWPC study team on May 21, 2007. A list of the written follow on questions and the TWPC response are provided in Attachment H. Additional detail has been incorporated into this report to address and clarify the aspects related to Pro2Serve's questions.

Selection of the SL Solidification alternative has been endorsed by the Pro2Serve and CBFO review teams as the lowest risk alternative. The SL solidification alternative was the basis of the TWPC's Performance Measurement Baseline.

3.0 Overall Summary of Alternate Sludge Processing Option

From a high level summary, the processing of SL in the solidification option would be accomplished in a manner very similar to the successful 2004 SN processing campaign. Key changes from the base processing approach include: (1) the SL would not be volume reduced following mobilization and transfer from the MVSTs, and (2) additional additives (e.g., dry blend grout, metals stabilization and reducing agents…) would be added to the SL by converting the SN Dryer to a batch SL mixer. A more detailed breakdown of this process option follows:

- Use water, SN or acid solutions (boric or nitric or both) to mobilize and fluidize the SL to produce a transferable SL matrix compliant with the LLLW system administrative requirements (e.g., < 5 wt.% settled solids).
- Transfer mobilized SL to the CIP tank with SL handling capabilities, W-35, for aggregation in a "big batch".
- Blend/homogenize, sample, analyze, and characterize the contents of W-35, and then transfer the mobilized SL to the TWPC SN tanks. If the large composite sample option which uses an SN tank to receive and mix a large, nominal 6,000 gallon composite sample is selected, it will be necessary to transfer the mobilized SL to the TWPC prior to characterization. The TWPC has the capability to return mobilized SL to the CIP tanks, so the composite sample can be returned if required.
- Pump the non-volume reduced mobilized SL to a batch mixer and add metals stabilizing agents, if required, followed by a cement, blast furnace slag, and fly ash based grout dry blend (similar to the SRS Saltstone, Fluor Fernald Silos 1 & 2, and ORNL GAAT Tank blends). Addition of these materials ensure that RCRA metals do not leach out during TCLP testing and that a free-standing monolith is formed with no free liquid. Addition of these materials further prevent stratification or concentration

of fissile isotopes and ensures that the TRU concentration in the final solidified waste form is consistent and remains below 100 nanocuries/g of solidified waste.

- Pre-load the LLW liners with an absorbent material such as Nochar Acid-Bond to absorb any free liquid (e.g., bleed water, chute flush water) that is not absorbed by the monolith during solidification.
- Anhydrous sodium metasilicate may be pre-loaded into the LLW liner or added after filling from the mixer. Sodium metasilicate accelerates solidification of slow setting grout.
- Prepare LLW liner for filling by placing liner into a process shield.
- Discharge a flowable, zero bleed water grout into LLW liners and allow the grout to solidify for 24-48 hours prior to transfer into a shipping cask.
- Stage filled LLW liners, loaded inside process shields, in the 30 Ton Crane Bay to allow for curing and to provide a buffer between transportation and processing.
- Verify, via remote camera, no-free liquids and formation of a solid monolith inside the LLW liner.
- Transfer LLW liners from the process shields into a DOT Type A shipping cask.
- Ship the LLW Liner (i.e., “monolith”), as fissile exempt LLW, to NTS. A total of 1,500-2,500 LLW liners would be shipped to NTS over a 4-7 year period.

A flow diagram of the overall process is shown in Figure 1.

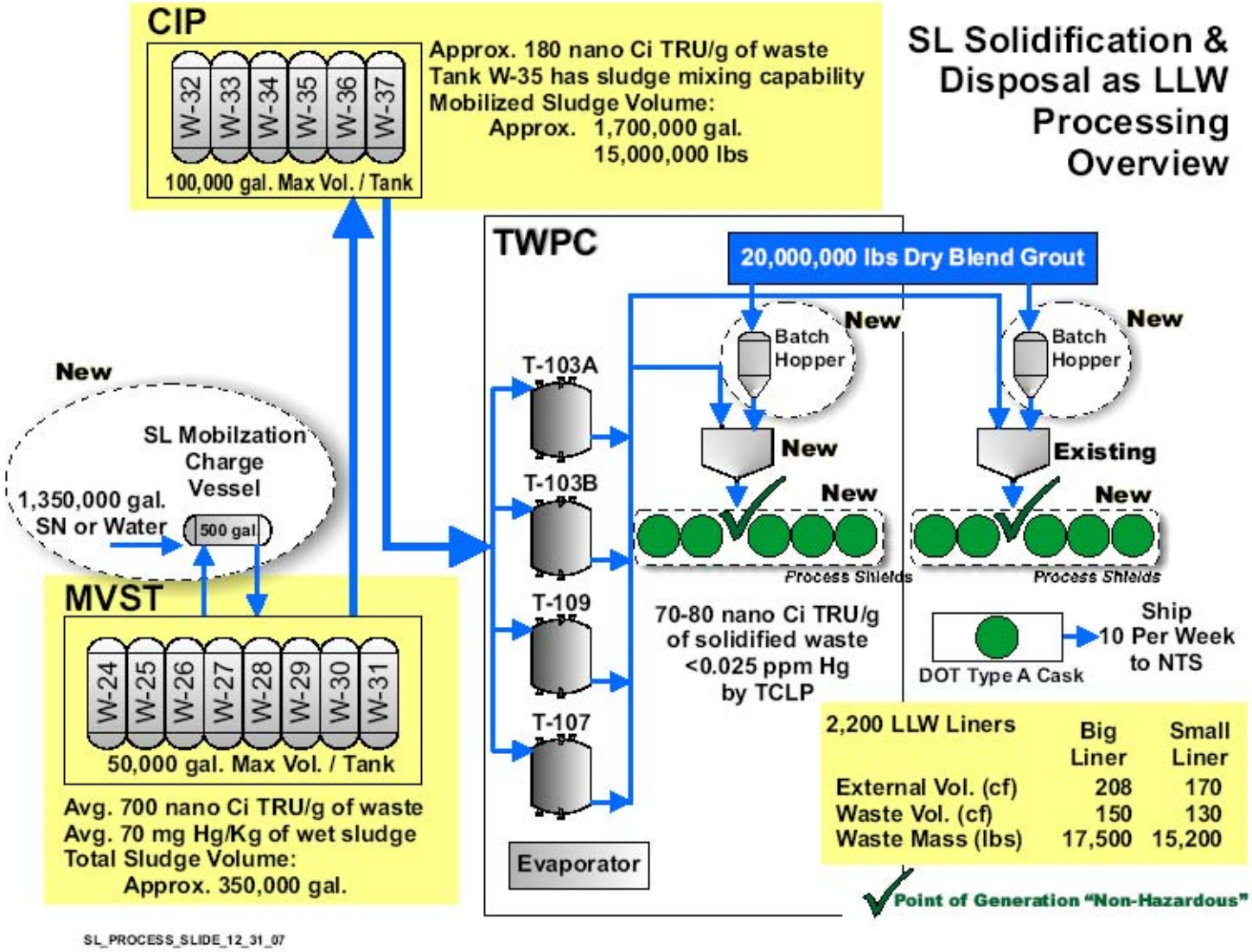


Figure 1: SL Solidification & Disposal as LLW Processing Overview

4.0 Conclusions of the Sludge Solidification Feasibility Study

The SL team members identified the following additional conclusions related to the feasibility of solidification of the mobilized SL and disposal as LLW.

- The latest NNSA paper on the determination of TRU alpha concentration of low-level radioactive waste by NTS (DOE/NV--1121 issued on May 17, 2006) clarified the definition of TRU waste; and, NTS is pursing additional LLW streams which conform to the clarified TRU waste definition and fit within their Waste Acceptance Criteria (WAC) and Performance Assessment (PA).
- A detailed reassessment of the disposition pathway for the MVST SL is recommended in view of WIPP's high life cycle costs for RH waste characterization, shipment, and disposal; and, NTS's ability and desire to take the SL without volume reduction (e.g., after stabilization and solidification of "as mobilized" SL following fluidization and mobilization).
- Solidification and stabilization of "as mobilized" SL can produce LLW (e.g., not TRU waste by the current clarified definition) suitable for shipment to NTS in DOT Type A shipping casks as fissile exempt LLW.
- Mobilization and solidification of the MVST SL should be categorized as permissible dilution by the EPA. EPA acknowledges that dilution that is a necessary part of the treatment process, which otherwise destroys, removes, or immobilizes the hazardous constituents is normally permissible.
- Solidification of the ORNL SL waste is analogous to the example provided in DOE G 435.1-1, Chapter III - Transuranic Waste Requirements, Page III-3 & 4 (see page 37 for the citation).
- Water or acid are being added to facilitate treatment (i.e., fluidization, mobilization, transfer, aggregation, homogenization, sampling, stabilization and solidification) rather than being added to avoid treatment.
- Since the SL is over moderated as it sits in the MVSTs, and the dry blend grout contains neutron absorbers, the addition of water and solidification agents further reduces k_{eff} and ensures that criticality remains incredible. Solidification is compatible with boric acid poisoning should the criticality safety evaluation determine that another administrative control to prevent criticality is necessary.
- Filling of canisters with dewatered SL would be FGE limited (i.e., canisters would be short filled) until and unless the Nuclear Criticality Safety Evaluation is completed and the WIPP WAC definition of FGEs is revised to exclude U-235 at less than 0.96 wt. %. The MVST SL is high in dilute/denatured U-235 content.
- A more likely start date based on realistic funding and support levels is February 1, 2013, as shown in Attachment A.

- Design, fabrication, testing, delivery, installation and start-up of the NuVision Engineering (NUVE) (formerly AEAT) SL mobilization system which is the major system and longest lead item for SL Mobilization and would be on the critical path for SL extraction from the MVSTs if the current proposed schedule were not funding profile constrained.
- The Point of Generation for the SL is at the discharge from the Wastewater Treatment Unit (i.e., the mixer discharge chute) when the grout is discharged into the LLW disposal liner.
- The solidified SL is not anticipated to exhibit any hazardous waste characteristics due to stabilization of the RCRA metals.
- SL solidification bench scale testing is needed to refine the dry grout recipe, verify assumptions in the operating and life cycle cost models, and demonstrate stabilization of the RCRA constituents.
- The use of a high waste loading absorbent such as Nochar Acid-Bond should be considered prior to the addition of grout to provide added assurance against the existence of free liquid in the LLW liner; and,
- Chemical dissolution and mobilization of the SL in the MVSTs should be evaluated during the SL solidification bench scale testing as an alternative to mechanical SL mobilization.

NOTE: Based on chemical dissolution experience with tank wastes at other DOE sites and J.M. Keller's extensive experience dissolving the ORNL SL samples prior to analysis, chemical dissolution is a viable option for removal of ~80% of the SL in the MVST tanks. The acid insoluble fraction (e.g., sand/rust, silica, alumina) is expected to be low in activity and could be left in the MVST tanks since these tanks will be left in service for the foreseeable future and the acid insoluble SL heels will not adversely impact the service life or function of the MVSTs. Chemical dissolution could eliminate the need to design/build/operate and D&D the NUVE Pulse Fluidic SL mobilization system.

5.0 Recommended Near Term Actions

Given the aforementioned issues with RH disposal costs and anticipated RH volumes at WIPP, the feasibility of solidification and stabilization of SL using a flowable cement/grout mixture comparable to Savannah River Site (SRS) Saltstone was evaluated. A conservative waste loading (high dry blend grout to liquid ratio) along with the use of a highly controllable batch mixing process is proposed to provide a high confidence level in achieving an acceptable final monolith. Preliminary operating, dose, and life cycle cost models indicate that SL solidification would further reduce life cycle costs and afford even lower personnel radiation exposures while accelerating the SL processing schedule and significantly reducing RH canister shipments to WIPP.

The following activities need to begin as soon as possible:

1) Conceptual design and project planning.
2) Confirmatory sampling and analysis of W-23 “new generation” SL.
3) Conceptual design for the solidification alternative. Perform risk analysis, management planning, and develop the acquisition strategy.
4) SL solidification surrogate bench scale and pilot scale mixing test program.
5) Finalize the operational cost and life cycle cost estimates, conceptual design, detailed cost estimate, detailed schedule, and SL Project Execution Plan (PEP).
6) Submit the Waste Profile, Sampling Plan, and Process Control Plan to NTS to obtain formal NTS approval of the Waste Profile.
7) Complete a Preliminary Nuclear Criticality Safety Evaluation (NCSE) for SL mobilization and processing.
8) Conduct the SL chemical dissolution bench scale tests.
9) Complete the SL mobilization system design update.
10) Evaluate the conceptual design for an advanced robotic arm from SA Robotics which may be able to accommodate the geometry of the MVSTs.
11) Perform a value engineering assessment based on the pilot scale mixing tests with surrogate wastes to evaluate the cost/benefit of procuring and installing a custom, higher capacity, high-shear mixer as the second mixer rather than converting the SL dryer into a medium shear ribbon mixer.
12) Determine the extent of the DSA/TSR changes required. Then develop and implement an authorization basis revision plan.

Part A: Background

1.0 TRU Waste Processing Center (TWPC) Location, Organization, and Mission

1.1 TWPC Location

The TRU Waste Processing Center (TWPC) is located adjacent to the Melton Valley Storage Tanks (MVSTs) and Capacity Increase Project (CIP) tank farms in the Melton Valley area of the Oak Ridge National Laboratory (ORNL). The TWPC and existing tank farms are situated about 3 miles by road from the center of ORNL. The TWPC was designed and built by Foster Wheeler Environmental Corporation (FWENC) upon unimproved land leased from the U.S. Department of Energy (DOE). The physical boundaries of the facility are defined by a barrier fence surrounding the leased property.

1.2 Facility Organization

FWENC was the prime contractor for the TWPC until January 14, 2008. On January 15, 2008, the prime contract was novated and EnergX TN, LLC was selected by DOE as the primary facility Management & Operations subcontractor responsible for the execution of the mission (e.g., build-out, operations, maintenance, and potentially, ultimate Decontamination & Decommissioning of the TWPC). DOE maintains safety oversight.

1.3 Sludge Mission

The SL aspects of the TWPC mission are to treat specific SL wastes currently stored at various facilities on the Oak Ridge Reservation (predominantly at the MVST and CIP tanks, but also in the BVST tanks), and to satisfy transportation and disposal criteria for the applicable U.S. Department of Energy (DOE) waste repositories. DOE has indicated that a total of 2,000 cubic meters of SL and high activity SN are anticipated to require processing. The principle hazards of the SL are the high alpha and TRU concentrations along with high concentrations of Sr-90 and Cs-137. If the SL were removed from the ORNL Liquid Low Level Wastewater Treatment Unit without completion of treatment, some of it could be classified as hazardous under EPA regulations due to low concentrations of some of the RCRA metals (i.e., Cd, Cr, Pb, and Hg) which would exhibit the characteristic of toxicity. Assignment of waste codes: D006, D007, D008, and D009 would be likely for most of the SL if sampled prior to the point of generation.

However, the SL is expected to be non-hazardous at the Point of Generation. The concentrations of the RCRA metals are relatively low for a metal hydroxide SL (e.g., average values for the total metals are as follows) and do not appreciably increase the risk to workers or environmental hazard of the SL above that due to the radiological content.

- Cd, 27 mg/kg
- Cr, 170 mg/kg
- Hg, 66 mg/kg
- Pb, 552 mg/kg

The mercury concentrations are well below the 260 ppm upper threshold for the low mercury class. The organics content of the SL is quite low with only a few organic compounds present above detection limits. The radiological hazards of these wastes dominate their chemical or physical hazards. A simplistic inhalation dose consequence estimate is shown in Attachment D which compares the relative risk from inhalation of typical dried SN vs. dried SL. In this simplified comparison the relative risk of radiation exposure from inhalation is 110 times higher for SL than for SN and the potential dose consequence to an individual that inhaled a gram of dried SL would be more than twice the fatal dose threshold. Inhalation of as little as 3 mg of dried SL solids could result in a worker exposure greater than the 10 CFR 830 annual limit (5 Rem) These are not intended to be probable scenarios, but only illustrative of the relative magnitude of the radiological risk for workers. In reality, inhalation of a gram of dried SL by an individual is extremely unlikely and medical treatment utilizing prompt chelation therapy would significantly reduce the actual incurred dose. The actual internal worker dose was extremely low during the 2004 SN campaign with only one worker being assigned 3 DAC-hrs.

The initial SN processing campaign was complete in 2004. Approximately 430,000 gallons of lower TRU content SN were concentrated into a molten/super saturated sodium meta-silicate grout in the SN Dryer. A viscous but flowable “metso” grout was discharged into carbon steel liners and solidified into monoliths upon cooling. The liners were shipped to NTS in DOT Type A shipping casks and disposed of as LLW. Following completion of the 2004 SN processing campaign, the SN systems were prepared for interim lay-up. The SN systems have been drained, acid cleaned, flushed, neutralized, dried out and are now under a low pressure inert (i.e., nitrogen) atmosphere to preserve the SN equipment for future reuse.

The TWPC is categorized as a Hazard Category 2 facility when it is treating CH, SL, and RH wastes. The adjacent MVSTs, which currently contain most of the SL awaiting processing, are also Hazard Category 2. The SL tank wastes have been preliminarily characterized by DOE for storage and to support the definition and bounding of the TWPC scope of work. The worker and public safety assessments within this Feasibility Study have been limited to the radiological source term and resultant hazards.

2.0 Feasibility Study Summary

2.1 Charter for Feasibility Study

The RH Debris and Sludge Operability Review, RH-R-AD-001, was conducted during the fourth quarter of 2006 and the report was issued in January, 2007. Near the end of the operability review, the SL review team felt that due to the significant escalation in WIPP requirements, and limitations in 72-B cask shipping capability, that solidification of the SL following mobilization, without volume reduction, and disposal as LLW at NTS should be evaluated. This feasibility study has been prepared by a smaller subset of the SL Operability Review team to summarize the results of this follow-on study of SL solidification and disposal as LLW.

2.2 Approach for Feasibility Study

The approach for this Feasibility Study is comparable to the approach used for The RH Debris and SL Operability Review, along with the following additional approaches:

- Review of DOE and commercial prior art/experience with grout and solidification
- Review of equipment options and budgetary costs for solidification
- Performance of scoping calculations for DOT waste class, criticality coefficient k_{eff}, dose rates, and isotopic concentrations in the final form.

2.3 Feasibility Study Schedule

The SL Solidification Feasibility Study began in December of 2006 and was principally completed in May 2007. A preliminary briefing of this option was presented to DOE-ORO representatives on February 22, 2007. Issuance of the final report was delayed to allow for incorporation of comments from the independent peer review as well as the inclusion of additional findings resulting from the TWPC baseline development and risk analysis for SL. The scope of the Feasibility Study report was also expanded to allow incorporation of much of the technical and pre-conceptual design content into the SL Conceptual Design Report, planned for development and issuance during FY 08.

Part B: Sludge Solidification Process Summary

1.0 Sludge Summary

1.1 SL Background

The TWPC has been designed with engineered safety features to ensure that workers can safely achieve the TWPC mission. The facility employs relatively simple, proven physical treatment processes and equipment. Deploying such equipment tailored to preliminarily characterize waste streams enhances operational reliability during the operating lifecycle. Due to delays in WIPP acceptance of RH waste and other changes in the scope of work (e.g., increased waste volumes, reduction in 72-B cask shipment frequency, change in WIPP certification based on actual waste instead of surrogate waste, and non-concurrent waste processing campaigns), the duration of the operational phase of the mission is now projected to be much longer than the baseline. The longer duration in the operational phase will drive changes to achieve acceptable operational reliability and keep worker doses and operational costs as low as reasonably achievable (ALARA).

1.2 SL Waste Characterization

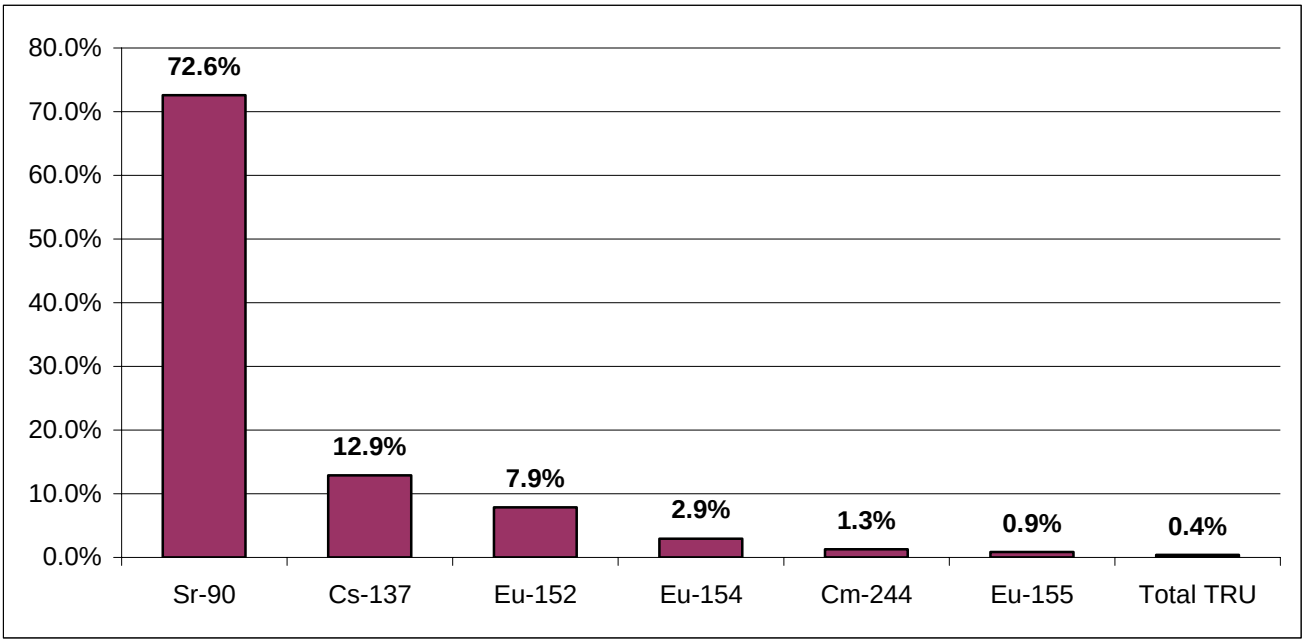
Chemical

The SL in the MVSTs has been accumulated from various tanks throughout ORNL. The SL is a concentrated, alkaline, metal hydroxide SL resulting from caustic precipitation and evaporation of liquid from the ORNL Liquid Low Level Waste system. Small quantities of RCRA metals are present that will require stabilization to ensure meeting the EPA Land Disposal Restrictions (LDR), passing TCLP requirements and production of a non-hazardous waste at the Point of Generation. See Part C, Section 2.17 for details on the RCRA metals. Analysis also indicates that the SL is low in organic content.

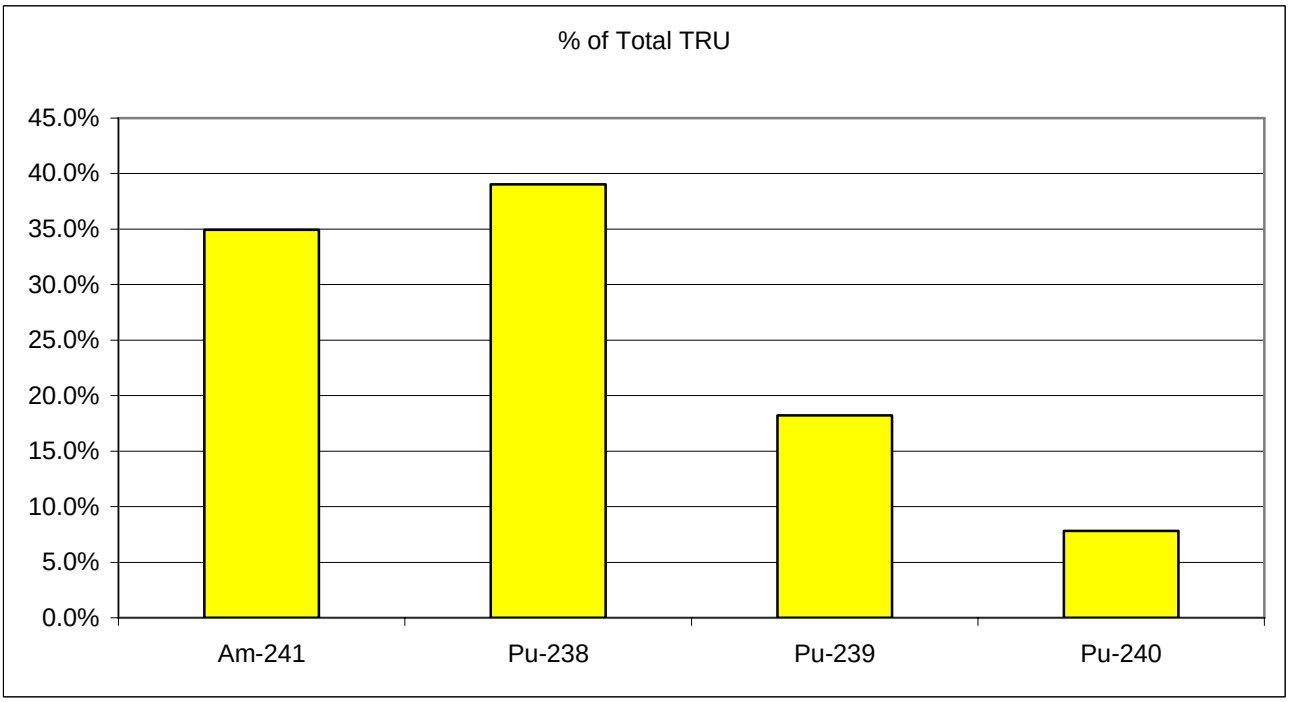
Radiological

The major hazard is related to the radioisotopes present in the SL which generate high levels of alpha, beta, and gamma radiation along with some neutron radiation. Based on preliminary characterization data, the primary isotope is Sr-90 (72.6%) followed by Cs-137 (12.9%). The relative % (versus the total for all isotopes) of the top 6 isotopes plus total TRU is shown in Table 1.2. DOE has indicated that contact beta-gamma dose rate readings in the MVST Pump and Valve Vault (P&VV) have been measured as high as 5 R/hr. The MVST SL has historically been projected as requiring disposal as RH-TRU since most scenarios were based on volume and mass reduction which increases the TRU concentration.

Table 1.2.a Relative % of Top 6 Isotopes and total TRU in MVST SL



The distribution of TRU isotopes is shown in Table 1.2.b



1.3 Process Summary

Mobilize the SL using the NUVE pulse fluidic mobilization system, also referred to as the Tank Waste Retrieval System (TWRS), using the original base approach volume (e.g., 5 volume equivalents) of water, SN, borated water or boric acid. Any of these liquids may be used, singularly or in combination to ensure safe, reliable SL transfer to the TWPC. The use of a sodium tetra-borate or boric acid solution rather than water only, is now proposed if an additional administrative control is deemed necessary for added defense in depth to ensure criticality remains non-credible during the mixing/fluidization of the SL. Boron-10, in the form of borax, is a common, water soluble neutron absorber (e.g., criticality poison) that can be evenly distributed within the SL. The ORNL Liquid Low Level Waste system currently relies on a single administrative control (e.g., isotopic dilution or "denaturing") for criticality control.

Transfer the MVST SL to W-35 at the CIP facility to aggregate and blend a big batch of mobilized SL. After sampling and characterization, transfer the SL to the Process Building at the TWPC. A sampling scenario also exists which would use the SN tanks themselves to receive large (e.g., 6,000 gallon) composite samples. Preload precautionary absorbent like NoChar Acid-Bond and solidification accelerating agents like anhydrous sodium meta-silicate (e.g., metso beads), into a LLW Liner and load the LLW liner into a process shield on a bogie (motorized cart on a track) and move the bogie and liner into the LLW liner fill position in Room 141, under the mixer discharge chute. Stabilize and solidify the SL using stabilization additives as needed to produce a non-hazardous monolith with no free liquid. Borax does retard cement solidification, however, the anticipated concentration of borax is well below the level that inhibits proper solidification. The slower initial set rate due to the borax content is actually beneficial to the proposed processing approach (i.e., converting the SN Dryer to a batch solidification mixer). If the initial set rate is too slow, the SL can be warmed up using the direct steam injection in the SN tanks, by recirculation in the SN Evaporator or direct heating via the SN Dryer/mixer steam jacket. Direct steam injection in the SN Feed tanks is preferred as the chloride content of the SL is high and the risk of chloride stress corrosion cracking of the 304 L stainless steel SN Dryer/mixer is high. Direct heating of the SN Dryer/mixer wall could also lead to rapid scaling of the SN Dryer/mixer wall with increased agitator power draw and abrasion. Another option for set acceleration of an excessively slow setting batch is the addition of metso beads just prior to mixer discharge. The reactivity of the metso beads is slower than liquid sodium metasilicate and will allow for mixing of the metso beads and discharge from the mixer before the grout becomes too thick. Metso beads can also be preloaded to the LLW liner or added as a "cap" after each mixer discharge.

Upon completion of blending the dry grout mix with the SL in the batch mixer, the batch is discharged into the LLW liner. Typically 3 batches from the mixer will load a LLW liner to the weight limit. When the LLW liner weight limit is reached, the LLW liner and process shield are transported on the bogie to the 30 Ton Crane Bay for solidification. After solidification the LLW liner is transferred to a shipping cask for shipment to NTS.

1.4 Process Building Modifications Summary

Some modifications to the Process Building and SN process equipment would be required to implement the SL solidification option. The modifications are described in detail in Part C, Section 7. The primary modifications are the installation of a dry blend grout unloading area, dry blend grout storage silo, batch weight hopper, and enclosure of the 30 Ton Crane Bay.

1.5 Feasibility Study Conclusions

Key conclusions of the SL Feasibility Study are as follows:

1. Mobilization of the MVST sludge followed by solidification, without volume reduction to remove the mobilization water, will yield LLW which is suitable for burial at NTS.
2. NTS's Performance Assessment can accommodate the estimated source term of the SL and they can easily handle the waste shipment schedule and total volume of waste.
3. The Life Cycle costs for SL solidification are lower than the base case of drying or the other alternative, dewatering.
4. Incremental capital costs for solidification are lower than the dewatering option.
5. Additional equipment repair costs have been identified to "rejuvenate" the SN systems after their lengthy (potentially 4 years) and unplanned lay-up (the baseline plan was a single SN campaign followed by D&D with no lay-up and restart).
6. Completion of the NUVE TWRS system for SL mobilization is the critical path activity for the base design SL Mobilization Buildout.
7. "New Generation" SL in W-23 which contains dissolved sources would require blending with a low TRU content MVST tank or low TRU content SN to produce LLW monoliths. If AK determines that the W-23 SL is a separate waste stream, then blending with other MVST SL will not be allowed and the SL from W-23 will have to go to WIPP.
8. The SL solidification process can be adapted to fill smaller RH liners which would fit inside a 72-B canister to allow transport and disposal as RH-TRU waste for high TRU content SL, such as may be obtained from W-23, which may produce RH-TRU following solidification.

Recommended near term actions are as follows:

1) Complete the conceptual and preliminary design for the solidification option. Perform risk analysis, management planning, and develop the acquisition strategy to support development of detailed work packages for incremental capital/conversion costs, schedule and resources.
2) Complete value engineering assessments to evaluate alternatives for reduction of risk, reduction of expected life cycle cost and to accelerate completion of the buildout and processing missions.

3) Conduct the SL solidification surrogate bench scale testing and revise the operational cost and life cycle cost projections. Complete the detailed cost estimate, SL PEP, and baseline change proposals to convert the funding, reserved in planning packages, into work packages.

4) Submit the Waste Profile, Sampling Plan, and Process Control Plan to NTS to obtain formal NTS approval of the Waste Profile.

5) Review the estimates of FGE content, isotopic dilution and intrinsic poisoning (the SL contains high concentrations of a wide variety of neutron poisons/absorbers) in the SL, using a qualified criticality engineer, to confirm the scoping calculations for $K_{eff.}$ Verify that criticality remains non-credible during mobilization, aggregation, and solidification; and demonstrate that additional engineered criticality controls are not needed.

6) Perform SL chemical dissolution tests in conjunction with the SL solidification bench scale testing. Key factors to confirm during testing are: wt. % of dissolved SL, dissolution rates, acid consumption, off-gas and foaming, and temperature rise. These tests need to be done as soon as possible since chemical SL dissolution could eliminate the need to design/build/operate and D&D the NuVision Engineering Pulse Fluidic SL mobilization system.

7) Authorize NuVision Engineering to complete the SL mobilization system design update and firm cost/schedule estimates. The final detailed design, identification and sourcing of long lead items cost and fabrication schedule updates need to be completed in parallel with the other activities to avoid a delay in scheduled SL mechanical mobilization operations should additional DOE early year funding become available.

8) Determine the extent of the DSA/TSR changes required and develop an authorization basis revision plan to ensure that safety basis approval and changes do not become critical path for this change.

Part C: Details of Proposed Change

1.0 Purpose

The purpose of this section is to discuss and compare the advantages and disadvantages of SL solidification in comparison to the base, SL Drying or the alternate SL Dewatering option. Benchmarking and comparisons to SN processing may also be used to enable qualitative comparisons. This section also goes into detail on the physical plant and operational changes required to implement this option.

2.0 Sludge Solidification Advantages/Disadvantages

2.1 Capital Equipment Cost

The estimated ROM capital equipment cost for SL Solidification is $2-5M lower than SL dewatering option since NTS does not require holding a lot/batch until the lot is complete like WIPP, thus the need for the Remote Handling Storage Area or Shielded Interim Storage Area (shielded 72-B canister storage) is eliminated. Initial SL solidification start-up could occur even prior to NUVE completion of the SL Mobilization system since the first batch will come from existing SL already in the CIP tank, W-35. Table 2.1 compares the capital equipment costs (i.e., design and installation, and start-up labor costs are not included) of the two options in three different scenarios (i.e., best case, realistic case, worst case).

Table 2.1

Dewatering Option

	Mobilization	Python Press	Lag Storage RHSA	Lag Storage SISA	Total Capital Cost per Scenario
Cost Elements	$ 3,500,000	$ 3,500,000	$ 2,000,000	$6,250,000	
Best	$ 3,500,000	$ 3,500,000			$ 7,000,000
Realistic	$ 3,500,000	$ 3,500,000	$ 2,000,000		$ 9,000,000
Worst	$ 3,500,000	$ 3,500,000		$6,250,000	$13,250,000

Solidification Option

	Mobilization Mechanical	Mobilization Chemical	SN Process Conversion	Lag Storage	Total Capital Cost per Scenario
Cost Elements	$ 3,500,000	$ 1,600,000	$ 3,500,000	N/A	
Best		$ 1,600,000	$ 3,500,000	N/A	$ 5,100,000
Realistic	$ 3,500,000		$ 4,000,000	N/A	$ 7,500,000
Worst	$ 3,500,000	$ 1,600,000	$ 6,000,000	N/A	$11,100,000

2.2 Life Cycle Cost

SL solidification is projected to be the lowest life cycle cost option. A key cost savings aspect is the shortened duration of the processing and transportation campaign, along with a significantly reduced number of NUVE mobilization and transfer campaigns (only 20 vs. 200 for base case) and elimination of periodic SN campaigns to process accumulated SN. Since transportation is not a bottleneck, 24/7 solidification operations can proceed with maximum efficiency. In the realistic scenarios, life cycle cost savings are estimated as follows:

Solidification vs. Drying (Base Case)	$170,000,000
Solidification vs. Dewatering Option	$106,000,000

Key cost elements and cost estimates for the various scenarios are shown in Table 2.2.

Table 2.2

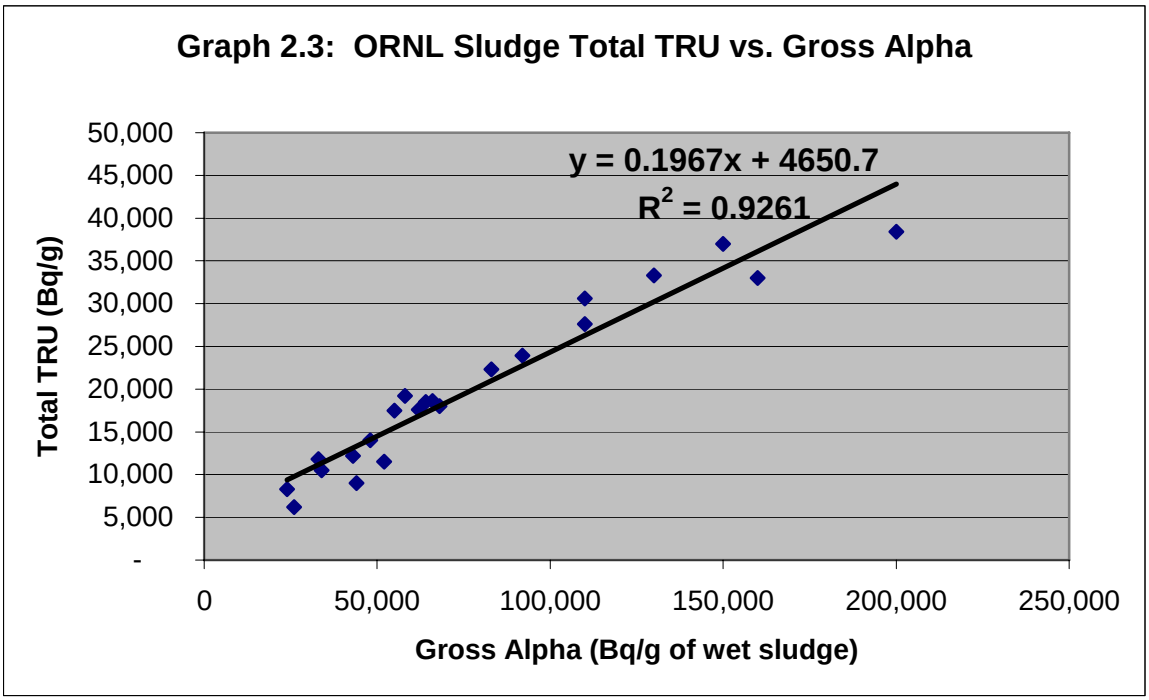
Life Cycle Cost Comparison, TWPC-MVST Sludge Processing Options: Baseline SL Drying vs. Proposed SL Mechanical Dewatering									
	Drying (Base Option)			Dewatering Option			Solidification Option		
Cost Element Scenario	Best	Realistic	Worst	Best	Realistic	Worst	Best	Realistic	Worst
SL Operating Duration (years)	2.4	6.5	19.9	1.3	2.7	8.2	2.6	5.0	9.9
SN Operating Duration (years)	2.4	6.5	19.9	2	2.7	8.2	0.5	0.75	1
Total Operating Duration (years)	2.4	6.5	19.9	3.3	5.4	16.4	3.1	5.7	10.9
72-B Canisters or Liners Produced	583	1011	1153	598	854	1282	1488	1946	2527
Probability of Scenario	20%	40%	40%	20%	60%	20%	30%	40%	30%
Probability wt. mean Duration (years)		**11**			**7**			**7**	
Probability weighted mean # of 72-Bs		**982**			**888**			**1983**	
Operating Crews/Costs									
Mobilization Crews	3	3	3	2	2	2	0.5	0.5	0.5
SL Wet Waste Operating Crews	4	4	4	2	2	2	4	4	4
SN Wet Waste Operating Crews	4	4	4	4	4	4	4	4	4
Support-Ovhd Costs/month	$ 1,700,000	$ 2,000,000	$ 2,200,000	$ 1,700,000	$ 2,000,000	$ 2,200,000	$ 1,500,000	$ 1,800,000	$ 2,000,000
# of concurrent ops to share base	2	2	1.5	2	2	2	2	2	2
Support-Ovhd Costs/month for SL Only	$ 850,000	$ 1,000,000	$ 1,466,667	$ 850,000	$ 1,000,000	$ 1,100,000	$ 750,000	$ 900,000	$ 1,000,000
Mobilziation Crew Size	3	4	5	3	4	5	3	4	5
Crew Size- 4 Crew SL	5	6	7	8	9	10	6	7	8
Crew Size- 2 Crew SL				10	11	12			
Crew Size- 4 Crew SN	5	6	7	7	8	9	6	7	8
Mobilization Labor Costs	$ 4,492,800	$ 16,224,000	$ 62,088,000	$ 1,622,400	$ 4,492,800	$ 17,056,000	$ 824,341	$ 2,078,993	$ 5,143,374
4 Crew SL Labor Costs	$ 7,587,840	$ 24,660,480	$ 88,082,176				$ 10,023,985	$ 22,120,487	$ 50,034,740
2 Crew SL Labor Costs				$ 4,110,080	$ 9,389,952	$ 31,110,144			
4 Crew SN Labor Costs	$ 7,587,840	$ 24,660,480	$ 88,082,176	$ 8,852,480	$ 13,658,112	$ 46,665,216	$ 1,896,960	$ 3,319,680	$ 5,058,560
TWPC Operating Costs	$ 44,148,480	$ 143,544,960	$ 588,492,352	$ 48,244,960	$ 92,340,864	$ 311,311,360	$ 41,024,349	$ 89,593,021	$190,929,915
Dewatering Operating Cost Savings vs. Drying				**$ (4,096,480)**	**$ 51,204,096**	**$ 277,180,992**	**$ 3,124,131**	**$ 53,951,939**	**$397,562,437**
Waste Container/Shipment/Disposal									
Cost for Solidification Agent/Liner							$ 1,740	$ 2,585	$ 3,418
Cost for Neutron Poison (Borax)/Liner							$ 75	$ 163	$ 375
Cost (Canister for WIPP, Liners for NTS)	$ 16,000	$ 18,000	$ 24,000	$ 16,000	$ 18,000	$ 24,000	$ 6,365	$ 7,073	$ 8,487
Characterization Costs	$ 45,000,000	$ 60,000,000	$ 75,000,000	$ 45,000,000	$ 60,000,000	$ 75,000,000	$ 1,800,000	$ 2,400,000	$ 3,000,000
Transportation Costs/shipment	$ 21,831	$ 25,684	$ 29,536	$ 21,831	$ 25,684	$ 29,536	$ 10,000	$ 11,000	$ 12,000
Disposal Costs	$ 36,196	$ 36,196	$ 36,196	$ 36,196	$ 36,196	$ 36,196	$ 4,160	$ 4,160	$ 4,160
Waste Cont./Ship/Disposal Costs	$ 43,157,779	$ 80,758,304	$ 103,461,216	$ 44,268,185	$ 68,217,202	$ 115,036,668	$ 33,240,148	$ 48,604,327	$ 71,873,599
Incremental D&D Costs	$ 30,000,000	$ 37,500,000	$ 45,000,000	$ 25,000,000	$ 30,000,000	$ 35,000,000	$ 2,500,000	$ 5,000,000	$ 7,500,000
Incremental Capital Costs	$ 1,000,000	$ 1,500,000	$ 2,000,000	$ 7,000,000	$ 9,000,000	$ 13,250,000	$ 5,100,000	$ 7,500,000	$ 11,100,000
Life Cycle Costs (excl. cost of capital)	$163,306,259	$ 323,303,264	$ 813,953,568	$169,513,145	$ 259,558,066	$ 549,598,028	$ 83,664,497	$153,097,348	$284,403,514
Cost Savings vs. Base Case (Drying)				**$ (6,206,886)**	**$ 63,745,198**	**$ 264,355,539**	**$ 79,641,762**	**$170,205,916**	**$529,550,054**
Cost Savings vs. Dewatering Option							**$ 85,848,648**	**$106,460,718**	**$265,194,514**
Worst Case Solidification vs. Realistic Case Dewatering									**$ (24,845,448)**

2.3 Sampling Cost

SL solidification provides the lowest sampling cost. NTS has agreed to the "big batch" concept, which reduces the number of batches from ~200 to ~20. Also, NTS will likely be able to accept 4 samples per batch (minimum required per EPA SW-846) vs. the minimum 10 samples per batch required by WIPP (per the RH TRU Characterization Plan) for confirmatory sampling. LLW characterization and analytical costs are projected to be less than ½ the cost of RH-TRU costs even if the same level of rigor and cost per analysis are required.

Preliminary discussions with both CCP/CBFO and NTS characterization personnel regarding the use of modeling to confirm the earlier sampling are encouraging. Given the excellent correlation between Total TRU and Gross Alpha (R^2 = 0.9261), and the relatively consistent distribution of TRU isotopes, modeling of the TRU content could be performed based on the existing sample results with some limited confirmatory sampling/analysis for Gross alpha on a "big batch" basis. Mr. John M. Keller, Radioactive Materials Analytical Laboratory Supervisor, ORNL Chemical & Analytical Sciences Division, has indicated that ORNL can provide same day turnaround on Gross alpha results for less than $1,000 per sample.

Graph 2.3 shows the correlation between Total TRU and Gross Alpha based on the Keller 2001 report.



2.4 Operating Cost

The operating costs for solidification are much lower than drying, and comparable to dewatering. Double handling of waste packages is eliminated since the LLW liner can be loaded from a process shield directly into a shipping cask within 24-48 hours after solidification. DOT Type A cask loading is much easier than 72-B cask loading.

A comparison of the estimated operating crew sizes in the various options and scenarios is shown in Table 2.4.

Table 2.4: Life Cycle Cost Comparison, TWPC-MVST Sludge Processing Options: Baseline SL Drying vs. Proposed SL Mechanical Dewatering

	Drying (Base Option)			Dewatering Option			Solidification Option		
Scenario	Best	Realistic	Worst	Best	Realistic	Worst	Best	Realistic	Worst
Mobilization Crews or Level of Effort	3	3	3	2	2	2	0.5	0.5	0.5
SL Wet Waste Operating Crews	4	4	4	2	2	2	4	4	4
SN Wet Waste Operating Crews	4	4	4	4	4	4	4	4	4
# of concurrent ops to share support/site costs	2	2	1.5	2	2	2	2	2	2
Mobilziation Crew Size	3	4	5	3	4	5	3	4	5
Crew Size- 4 Crew SL	5	6	7	8	9	10	6	7	8
Crew Size- 2 Crew SL				10	11	12			
Crew Size- 4 Crew SN	5	6	7	7	8	9	6	7	8

2.5 Waste Package/Transportation Costs

2.5.1 Waste Package

LLW liners (~$7k each) are about half the cost of 72-B canisters (~$14k each). Total cost for waste packages is less even if twice as many waste packages are required. Special tooling is required to install the RLC lid on the 72-B canisters. The special tooling is expensive to procure and will likely require some maintenance. No special tooling is required for the LLW liner lid installation.

Additionally, given the large number of LLW liners, the LLW Liner supplier, Carolina Fab, indicated that the unit pricing could actually drop below $6,000 in exchange for a commitment for a minimum number of units and an agreement to adjust unit pricing based on an independent third party steel price index (e.g., Ohio DOT, http://www.dot.state.oh.us/construction/OCA/default.htm).

2.5.2 Transportation

Transportation costs to NTS using DOT Type A shipping casks (~$11k/trip) are less than half the cost of 72-B shipping cask (~$26k) cost per trip to WIPP. Additionally, WIPP has a limited number of 72-B casks and the transportation of 72-B Canisters to WIPP can only be performed in a 72-B shipping cask, which can only accommodate a single 72-B Canister. WIPP estimates that the maximum annual 72-B cask shipping capability is 240, and this has to be shared or rationed among all the DOE sites. Even if WIPP were to increase their 72-B cask fleet, WIPP has safety basis limitations that limit the rate at which 72-B canisters can be handled and disposed of at WIPP to about 300 per year.

A simple model has been developed to evaluate three WIPP scenarios (i.e., best, realistic and worst case) from a waste shipment basis and waste generation basis. The best case scenario in the model uses the full WIPP 72-B annual capacity (i.e., 240) from the latest EM Integrated TRU Shipping matrix. In reality, the annual shipments from Oak Ridge will be reduced in some years since other DOE sites also require the 72-B casks (e.g., LANL will require 62 shipments in 2011 and 2012, and ORO RH debris/solid shipments are scheduled which utilize most of the 72-B cask shipping capability out through FY13).

Table 2.5.2 is an oversimplification since during the RH debris only campaign; TWPC RH shipments will be limited by the RH debris output of 6-10 canisters per week until SL is operational and authorized to ship. The realistic case in this model indicates that 7.8 years will be required to ship the Oak Ridge RH Debris and SL to WIPP. A more detailed model derived from the simple model shown below indicates that the shipping campaign can be expected to last from 7-11 years unless additional 72-B shipping cask capabilities are provided. Given the long duration of the transportation campaign, options which streamline the SL processing will need to provide a buffer capacity (e.g., interim 72-B Canister storage) to ensure that 72-B Cask transportation and WIPP cask handling capabilities are maximized. An interim 72-B Canister storage facility was discussed in the RH Debris and SL Operability Review.

Table 2.5.2

	Best	Realistic	Worst
Average ORO Shipments per year	240	168	140
Total # of SL Shipments	598	854	1,282
Total # of RH Shipments	300	450	600
Total # of 72-B Cask Shipments	898	1,304	1,882
Average Shipments/month	20	14	12
Average Shipments/calendar week	4.6	3.2	2.7
Years to Ship	3.7	7.8	13.4

In addition to the higher cost per shipment for 72-B cask shipments to WIPP vs. LLW liners to NTS, the shipping campaign duration and resulting TWPC costs would be greater for the longer duration shipping campaign (i.e., 8 yrs. for WIPP vs. 6 yrs. for NTS in the realistic scenarios).

2.6 D&D Cost

SL solidification is projected to be the lowest incremental D&D Cost option since the existing SN system, which is already contaminated, is modified for SL solidification. The SL systems and areas would not be contaminated. In the drying or dewatering alternatives, there is also a risk of contaminating the Canister Storage Room (CSR or Room 222) during canister filling with dried or dewatered SL. Surface contamination of the CSR would greatly increase the D&D costs for this portion of the Process Building. Since the SL solidification process would not use the Canister Storage Room at all, the risk and potential incremental D&D cost for the CSR are also avoided. There would be a modest increase in D&D costs for the SN systems resulting from the higher alpha and beta surface contamination levels remaining after utilization for SL processing. However, non-destructive decontamination of internal process wetted surfaces, following the SN campaign, was quite successful using the dilute nitric acid decontamination solution. Most of the incremental internal process wetted area contamination from the SL is expected to be removed when using the stronger acid decontamination solution which can be used in the final “destructive” decontamination prior to facility D&D. Most of the incremental D&D costs for the SN systems will likely be due to elevated alpha and beta contamination levels in the general areas of the equipment resulting from process equipment leaks. Steam and dilute acid/foam decontamination solutions can be utilized to reduce general area surface contamination levels and the resulting spent decontamination solutions can be neutralized and solidified as a final campaign prior to decommissioning and dismantling the process equipment.

Historical D&D cost factors and other similar estimates for DOE non-reactor nuclear facilities were reviewed to establish benchmarks for D&D costs. Based on a 1998 Lockheed Martin report, which lists $41.5M for base D&D costs for a MVST SL grouting only building in 1995 dollars. Lockheed also added overhead and contingency on top of the base estimate. The study team assumed that because the DOE and commercial complex has more D&D experience now than 10 years ago and D&D overhead would be “split” between the four waste streams, that the escalation and

overhead costs are offset by more efficient D&D practices and "overhead sharing". However, adding a contingency for changes in safety basis and escalated waste disposal requirements is prudent in the worst case drying scenario. Additionally, given the longer operating mission, increased maintenance and powder handling associated with the dryer scenario, alpha contamination levels will be much higher thus increasing D&D costs for the dryer scenario. Based on the above the following values for incremental D&D (i.e., above the SN D&D cost) were used in the ROM Life Cycle cost estimates for the Drying and Dewatering Scenarios:

	Best	Realistic	Worst
Drying D&D	$30M	$37.5M	$45M
Dewatering D&D	$25M	$30M	$35M

Generating an accurate D&D cost is a project in itself and could easily take several months even using some of the existing programs developed by Rocky Flats. Many assumptions would have to be made about the contamination levels and dose rates of the equipment and general areas at the end of the processing campaign along with detailed work plans to estimate worker stay times. D&D costs for DOE TRU facilities have consistently been underestimated, so a fully integrated bottoms-up cost estimate of the D&D costs is likely to be higher, especially since estimates from 1995 would have been under a less prescriptive/costly safety basis and disposal climate.

2.7 RH Debris Interfaces

SL solidification is the least disruptive to RH Debris operations. SL solidification would not use the CSR, Room 222, for canister filling or canister storage so it could be used exclusively for RH Debris canister handling/storage and the risk of contaminating the Canister Storage Room during SL canister filling is eliminated. The average dose rates in the Canister Storage Room will be much lower by removing the high gamma dose rate SL canisters (typically 25 R/hr), thus allowing easier access should maintenance or entry be required.

By removing the need for SL canister shipments, the 72-B cask shipping fleet would be sufficient to meet DOE complex RH shipping needs during the TWPC RH Debris campaign. Cost savings from RH Debris operations elimination of conflicts (e.g., additional shifts) could be realized since 72-B canister transportation and unloading at WIPP is no longer a limitation. Spreading out the SL operations over 4 shifts, 7 days per week reduces the peak work and overlap with RH Debris operations. The processing and disposal of the SL as LLW eliminates the need to handle and dispose of 1,000-1,500 RH canisters at WIPP. The TWPC would then be better suited to handle additional RH Debris from other DOE sites if DOE elects to centralize RH certification at a regional facility like the TWPC.

The site power supply and Motor Control Center (MCC) are operating near maximum output due to the addition of numerous new electrical loads (e.g., CHSA, CHMB, NDA and NDE trailers, HSGS system, CH support trailer, Macro building, additional support trailers, environmentally controlled parts and consumable storage areas, and additional

PB equipment…). SL solidification does not require the operation of the boiler and associated electrical loads which would free up about 2,000 kW of MCC capacity for other loads and would likely avoid the need to upgrade the main site power supply and MCC.

2.8 Start-up/Operating Schedule

SL solidification provides the shortest duration mission and could reduce overall schedule by 1-2 years. Elimination of WIPP certification requirements reduces risk of schedule delays and initial waste hold-up/storage while awaiting WIPP certification. The NUVE SL mobilization system for the MVSTs is not required for the initial start-up. W-35 already contains SL which could be used for the initial solidification campaign. An opportunity for schedule acceleration exists by installing a high shear, short batch time mixer along with the use of smaller LLW liners. The use of the smaller liners would enable the use of smaller DOT Type A shipping casks which are in less demand and could enable a significant increase in average monthly shipments to NTS. A value engineering study needs to be performed during the conceptual or detailed design phases to evaluate the cost benefit of this schedule acceleration opportunity. This is a complex issue since the ORNL LLLW system will continue to generate SN and the Building 3019/U-233 project, which is now fully funded, is expected to generate SN as well over its 10 year mission. An ongoing need for processing of SN and SL from the LLLW system is likely to exist through FY18.

2.8.1 Build-out/Process Change Schedule

Earlier preliminary schedules for Rad Ops start-date based on SN Conversion to SL Solidification as LLW were constrained by delivery of critical path/long lead items. Preliminary schedules currently indicate that the schedule is funding constrained and funding limitations have pushed the target SL Rad Ops start date out until February 1, 2013.

2.8.2 Start-Up Schedule

The start-up schedule for SL solidification is expected to be the shortest of the three options since the process is quite similar to the SN process and many of the same operators, equipment, and procedures can be utilized for the SL solidification process. Given the reduced radiological and criticality hazards for this option, the DSA implementation verification is also anticipated to be shorter than the other two alternatives.

2.8.3 Operations Schedule

The proposed operations schedule is a 7 day/week, 24 hour per day schedule using 4 wet waste operating crews on the same rotation (similar to the Dupont schedule) used during the SN campaign. By operating 7 days per week, secondary wastes (e.g., mixer cleaning solution, line and tank flushing solutions…) are minimized and total campaign duration is minimized. A steady, methodical pace is preferable for long, repetitive processing campaigns. Most of the LLW liner and DOT cask handling can be performed on back shifts to minimize the overlap with 72-B canister/cask handling on the day shift with RH

Debris operations. Inefficiencies from conflicting competing tasks and competition for 30 Ton Crane usage can be minimized by spreading out the SL processing, and liner/cask handling tasks over the back shifts. Peak crew sizes can also be reduced thus reducing Process Building and parking congestion on the peak day shift. Given the higher total source term at the TWPC during simultaneous processing of multiple RH and CH waste streams, continuous operations presence on site provides added assurances against unusual events that might occur when the TWPC was not manned.

2.9 Process Risk

Solidification is a mature and established technology, which would use the existing reliable/proven SN equipment, with minor modifications, to ensure low equipment risk. The biggest risk is that some of the SL will contain significantly higher TRU levels than indicated by the latest MVST sample analysis results. This higher TRU content SL may require disposal at WIPP as RH-TRU which requires packaging of the waste in 72-B canisters. The SL process could be adapted to fill small liners (i.e., small liners would allow over packing in 72-B canisters to permit disposal at WIPP as RH-TRU) if higher TRU content SL is discovered during MVST mobilization or sampling of the new generation SL. The cost/schedule impacts associated with this risk could be mitigated by performing some concentration of the mobilized SL either via evaporation or settling or a combination of both. The evaporator tubes are made from an alloy that resists chloride stress corrosion cracking and the large diameter tubes are tolerant of suspended solids. The design limit for suspended solids is due to the limitations of the SN pumps and piping to tolerate higher suspended solids levels. It may be necessary to add a separate gravity settling/thickening tank on the third floor or possibly reuse one of the existing SL slurry tanks to allow for gravity transfer of thickened SL into the SL mixer. These are not simple or inexpensive changes, so the clear need for these changes should be confirmed before investing in the design/installation of these risk mitigation concepts.

The secondary process risk is related to the grout mixing discharge step. The discharge chute could plug or the mixer could rock up with solidified product. The mixer is also subject to wear and could fail before completion of the solidification campaign. Concepts to mitigate this risk have been identified and will be discussed in Section 3.2.

The “new generation” SL in W-23 that contains dissolved sources could be classified as another waste stream during the AK process. Classification of W-23 SL as a separate waste stream could preclude blending of the high Pu-241/Am-241 new generation SL with the older MVST SL and the resulting TRU concentration in the final monolith would exceed 100 nanocuries/g of waste and thus require disposal at WIPP. The projected life cycle savings would be reduced if this happens. The details of W-23 are discussed in Section 2.9.1.

2.9.1 New Generation Sludge in W-23

After an initial informal briefing of DOE ORO tank waste SMEs, the estimated radiological content of “new generation” SL in W-23 in the BVST was provided. The isotopic ratios and concentrations in this new generation SL are different than the older MVST SL due to the addition of sources that were dissolved in acid. A preliminary

assessment of the impacts of the high Pu-241 (20X the MVST mean) and high Am-241 (7X the MVST mean) new generation SL in W-23 (upstream of MVST tanks) is as follows:

1. As listed in Table 2.9, the W-23 SL could be accommodated into the solidification scenario if W-23 was blended with 2 of the low TRU content MVST tanks.
2. Accommodation of the new generation SL would consume a significant portion of the contingency in the isotopic loadings. The analysis added two sigma to the average values for each tank based on Keller's 2001 report. Since sigma (variance between average mean values for each tank) is ~25% of the mean for the TRU isotopes, the modeling used 1.5X the mean. These details are provided in the attached spreadsheet in the highlighted fields.
3. The Pu-241 is an issue since its decay daughter is Am-241, a TRU isotope, that will increase the TRU concentration in W-23 during the next several years from in-growth. This will require more indepth analysis to see if the current estimates have been decay corrected. If not, the Am-241 content may be twice as high due to in-growth by the time we process the contents of W-23.

A more sophisticated model of the LLW liners was developed which uses the average TRU concentration per tank and the estimated mass of SL to calculate the total TRU curies per tank. The original analysis was more simplistic since it did not factor in the variation in quantity of SL in each tank. The solidification strategy is more dependent upon the total TRU curies vs. the concentration in a single sample or tank since the SL will be blended in W-35 to produce larger, more consistent batches to simplify characterization as well as processing. The highest reported SL volume per tank was used since there is a discrepancy between Mr. C. B. Scott, Liquid and Gaseous Waste System Operations Supervisor, and Mr. Brian D. Oakley, System Engineer, ORNL Liquid Low Level Waste System, regarding the SL volume and the TWPC has not yet received formal, written confirmation of the SL volumes per tank from DOE. The latest analysis is conservative, but not bounding since high confidence level data on W-23 or the "other" SL beyond the MVSTs are not yet available.

The average TRU curies per tank, along with the standard deviation, were calculated. The variation in total TRU per tank is less (about ½) than the variation in TRU concentration between all the samples from all the tanks. The average TRU content per tank is 105 curies, including W-23. Adding 2 sigma to the total TRU curies would normally provide high confidence (~90% for a normal distribution) that you would not exceed the upper control limit (i.e., 2,540 LLW liners at 100 nanocuries TRU/gram in our model), however, there are several factors that are likely to skew our distribution (e.g., under optimized blending, pockets of higher TRU activity SL in the tanks resulting in a "non-normal" distribution of activy, limited number and randomness of samples from a given tank, uncertainty on W-23 and other new generation SL TRU concentration…).

In summary, the maximum number of LLW liners projected by the model including W-23 (i.e., 2,540) is still comparable to the worst case value used in the Life Cycle cost model (i.e., 2,527).

Table 2.9: Values with New Generation High Acitivity Sludge in W-23 Included

Tanks	Highest TRU (nanoci/g) per Tank	Sludge Vol. Gallons*	% of Total Sludge Vol per Tank	S.G.	kg. of wet sludge	Curies TRU per Tank	Curies TRU + 1 sigma per Tank	Curies TRU + 2 sigma per Tank
W-24	984	29,660	8.5%	1.33	148,826	146	193	240
W-25	827	29,378	8.5%	1.33	147,411	122	161	200
W-26	497	24,265	7.0%	1.33	121,755	61	80	99
W-27	473	32,255	9.3%	1.33	161,847	77	101	126
W-28	532	27,386	7.9%	1.33	137,415	73	97	120
W-29	503	31,653	9.1%	1.33	158,826	80	105	131
W-30	481	27,173	7.8%	1.33	136,347	66	87	108
W-31	632	28,821	8.3%	1.33	144,616	91	121	150
W-23	1,450	16,586	4.8%	1.33	83,224	121	159	198
Other, CIPs	New Generation	100,000	28.8%		502,000	338	447	555
Volume (cubic meters)	1,314	347,177		**Total**	**1,742,267**	**1,174**	**1,551**	**1,928**
Average per MVST/BVST Tank		27,464		**Average**	**92.9**			
				Std Dev	**29.8**	**32%**		
Final Form Net Weight (excl. LLW Liner wt.) lbs.						**17,000**	**17,000**	**17,000**
Total Mass of Final Form/Monoliths (excluding LLW Liner empty wt.) lbs.						**35,076,641**	**46,322,898**	**57,569,156**
Total Number of Final Form Monoliths/LLW Liners @ 75 nanocuries/g						**2,063**	**2,725**	**3,386**
Total Number of Final Form Monoliths/LLW Liners @ 85 nanocuries/g						**1,821**	**2,404**	**2,988**
Total Number of Final Form Monoliths/LLW Liners @ 100 nanocuries/g						**1,547**	**2,044**	**2,540**
Lbs. of Wet Sludge/Lb. of Monolith						**0.11**	**0.08**	**0.07**

Other, CIPs assumed to be equal to the average

A back-up strategy was developed which would keep the W-23 SL as concentrated as practical, potentially even using the evaporator or SN dryer/mixer to thicken the SL, then solidifying and discharging into the small RH liners that could then be over packed into a 72-B canister. The limit for this processing scenario is the fissile content limit of 315 FGE/canister in the WIPP WAC.

2.10 Funding Risk

SL solidification is perceived to be the highest funding risk option. The loss of "premier" RH waste generator status for the TWPC could adversely impact DOE support and funding. It appears that DOE's primary emphasis is on getting RH-TRU waste into WIPP as quickly as possible to maximize utilization of RH transport, handling and disposal capabilities at WIPP. The average life cycle cost per cubic foot of waste disposed at WIPP has been estimated to be between $900-1,000. Assuming that the opportunity cost for unutilized RH transportation and disposal capacity is 1/2 the life cycle cost, each lost opportunity for canister shipment and disposal equates to $16,000 or $6,200,000 if the 400 lost opportunities occur in the next 3 years. If the TWPC does not fill the near term gap in RH shipments to WIPP, the TWPC could now be viewed more as a LLW site rather than a major regional RH-TRU waste processing center.

Additionally, since the SL in the MVSTs is still part of an active Waste Water Treatment Unit (WWTU), it is not defined as waste until it is discharged from an active WWTU.

DOE has a good position to request removal of the MVST SL from the Site Treatment Plan (STP) and thus eliminate the state milestones for SL processing from the STP. Removal of the SL milestones from the STP would give DOE the flexibility to defer SL buildout and processing. Without the political and financial pressure to maximize early year shipments of RH, and in view of current DOE budget limitations, this alternative has already resulted in a deferral of SL rad ops until February 1, 2013.

2.11 Certification Risk

SL solidification provides the lowest risk due to the TWPC's strong SN track record with NTS and minimizes the impact on CCP/WIPP after initial agreement that solidified SL is not TRU. The TWPC successfully characterized the SN waste and NTS successfully handled the 97 SN LLW liner shipments in DOT Type A shipping casks during the 2004 campaign.

Since CBFO has indicated that W-23 should be processed and disposed of as RH-TRU, a second (i.e., after the initial RH/CH certification audit) certification audit would be required for the SL. CBFO's second constraint, to process and dispose of the W-23 first before the baseline MVST SL, effectively eliminates any reduction in certification risk in relation to dewatering. The certification risk is now a neutral aspect between SL solidification and dewatering.

2.12 Transportation Risk

Potentially twice the number of LLW cask shipments would be required; however, DOT Type A shipping casks are available from two different commercial companies. The larger number of available DOT Type A shipping casks eliminates the 72-B Cask bottleneck, however, a risk exists that the commercial cask availability could be insufficient to meet the SL shipping needs and could result in delays to production. A value engineering assessment is recommended to evaluate the cost benefit of the long term lease or purchase of a fleet of dedicated shipping casks to ensure that LLW liner transportation will always keep up with production. Initial transportation analysis indicates that the solidified SL meets the standard fissile exemption criteria and no special permit is needed.

2.13 Safety Basis (SS SSCs) Implications

The PE Ci content per drum equivalent volume of the SL is bounded by the CH and RH debris. Additionally, the SL is a non-combustible, non-reactive, inorganic aqueous SL which would result in far less worker and off-site dose consequences in bounding release scenarios like the CH fire events. While the total volume of SL and SN, approximately 2,000 cubic meters is rather large, the maximum quantity of SL which can be stored in the Process Building is limited by the size of the SN processing tanks and the anticipated dilution with water or SN during SL mobilization. SL accident event dose consequences are not expected to exceed the CH accident consequences, and thus are not expected to require additional safety basis controls.

While the potential SL source term is slightly elevated (~100 PE Ci) in the SN Tank Vault when all 4 tanks are full, the potential dose consequences for off-site/public

receptors and co-located workers is expected to be low since the SL is an inorganic, non-combustible material. Review of Criticality Safety is beyond the scope of the current review. Since the SL has been denatured/poisoned and is currently being stored in aqueous form in much larger (e.g., 50,000 gallon) tanks, and the SL is already over-moderated, (i.e., additional water does not increase criticality concerns), criticality concerns are not anticipated for the SL processing. However, a qualified criticality engineer is needed to review the denaturing/poisoning of the SL, the SL process inventory, concentration and geometry; and to confirm that criticality remains non-credible since the process adds water, mixes/mobilizes the SL, adds other solidification agents to the SL, and since current administrative requirements for criticality controls are more conservative than past practices when the bulk of the SL was generated. The Criticality Safety Evaluation will require DOE review and approval under an approved Criticality Safety Program.

2.14 OSHA/ALARA Worker Safety Implications

2.14.1 OSHA/Industrial Safety

No significant increase in OSHA/industrial safety hazards is anticipated for the SL vs. SN. Once again, the key issue here is how to safely keep a process operating for well beyond the original design life. The simplicity of the additional SL solidification equipment in combination with the use of the former SN equipment, procedures, and personnel maintains a low risk industrial safety working environment. The elimination of the use of steam also eliminates minor industrial safety hazards related to the high amperage electrical supply for the boiler and elevated temperature of pressurized steam.

Solidification of the SL is a proven and mature technology. The planned process would use the existing proven SN equipment along with many of the same personnel and procedures that successfully completed the SN processing campaign in 2004. Overall, the relative OSHA/Industrial safety risk is comparable to or lower than the risk during the 2004 SN processing campaign.

2.14.2 ALARA

The specific activity in the mobilized SL, containing a nominal 5 wt. % suspended solids is a factor of 5-10 lower than the activity in the volume reduced press cake or dryer product from the other two options.. The lower specific activity and lower dose rates for the mobilized SL reduce the maximum potential worker and off site dose consequences for off normal and routine events. While the alpha and beta radiation levels from the mobilized SL would be higher than SN, the gamma radiation levels would actually be lower, with anticipated monolith/final form dose rates of 3 R/hr on contact vs. 20 R/hr on contact for SN LLW liners. Overall, only a modest increase in worker radiation exposure risk is anticipated for SL solidification vs. SN processing. This modest increase in worker radiation exposure risk is well within the capabilities the TWPC safety management and radiological protection programs. The simple, low risk process based on proven SN systems combined with lowest dose rates on waste and waste final form are expected to maintain collective worker exposures ALARA. Since the mobilization water is not removed, the alpha/TRU concentration of the mobilized SL is only about 4 times higher

than the alpha/TRU concentration in the concentrated SN.

Scoping calculations were performed using the recently acquired Monte Carlo N-Particle transport code MCNP® dose rate modeling software. The scoping calculations indicate that the neutron dose from the SL is negligible, thus there is no significant increase in worker safety hazard related to neutron dose. More detail is provided in the section on Criticality.

2.14.3 Criticality

While the SL has been isotopically diluted (denatured) by adding additional non-fissile isotopes, to dilute the fissile isotopes, the total fissile gram equivalents in the SL can be high (e.g., 215 U-235 FGEs in a single monolith).

Preliminary scoping calculations indicate that criticality remains incredible and that criticality risk can be further reduced (even lower K_{eff}) by the addition of boron and solidification additives. Monte Carlo N-Particle transport code (MCNP®) dose rate modeling software has been used to perform additional dose rate modeling to assess the impact of the neutron dose from the SL as well as criticality scoping. The preliminary scoping calculations indicate that the neutron dose rate on a solidified SL LLW liner is negligible (e.g., 1E-08R/hr).

NOTE: Based on preliminary scoping calculations, the SL would remain sub-critical even if no U-238 and Th-232 were present. The SL contains sufficient quantities of other neutron absorbers to prevent criticality. The scoping calculations were not performed by a criticality engineer, however, the scoping calculations provide high confidence that additional engineering or administrative criticality controls for the SL are not necessary, and the Criticality Safety Evaluation to support this conclusion and obtain DOE concurrence should be straightforward.

2.15 Training/Procedure Impacts

The simple nature of the solidification process along with use of existing SN equipment greatly reduces the procedure and training effort. Several TWPC personnel have extensive experience with solidification. For example, Quincy Carter ran the ORNL SN solidification campaign in 1995 and Mike McCauley supervised wet waste operations using solidification at numerous commercial nuclear sites. Additionally, given the similarity between SL solidification and the concentration and solidification of SN into a monolith, and the fact that most of the original SN Wet Waste operations personnel still work at the TWPC, the training and procedure impacts for SL solidification is the lowest of the three options.

2.16 Final Waste Form Attributes

Confirmatory test solidification is performed on a sample from each “big batch” (i.e., CIP tank) to ensure that an acceptable final form will be a robust, solid monolith that is no longer mixed waste (i.e., characteristic of toxicity eliminated by stabilizing the RCRA metals). Conservative waste loading (i.e., high solidification agent to SL ratio) provides high confidence level that there will be no free liquid in the final waste form. Verification of solid waste form can be accomplished with the temperature profile of exothermic

cementation reaction, visual via in-liner camera, or penetrometer. While not required by the NTS WAC, the monolith also provides added stabilization and leach resistance to minimize leaching of mobile isotopes such as Cs-137 and Sr-90. The compressive strength of the monolith also provides improved mitigation against subsidence in the burial trench. The reducing and alkaline chemistry of the grout also minimizes corrosion rates on the interior surfaces of the carbon steel liner and maximizes the service life of the LLW liner.

2.17 Processing vs. Dilution Implications

2.17.1 DOE O 435.1 Perspective: Processing vs. Dilution

Processing of the SL is not anticipated to be classified as impermissible dilution based on the guidance in DOE G 435.1-1 for compliance with DOE O 435.1, Change 1. The following is an excerpt from DOE G 435.1-1, Chapter III - Transuranic Waste Requirements, Page III-3:

> "Dilution of a transuranic waste stream to reclassify the waste as low-level waste (i.e., reducing the concentration to less than or equal to 100 nanoCi (3700 Bq) per gram) is not permitted by the Department. While it is recognized that in the course of stabilizing a waste stream some changes in waste concentration may occur, actions to dilute a waste stream below the concentration limits for transuranic waste are prohibited. It is also recognized that actions taken to process a waste stream for safety or technological reasons that are justified, may result in the waste being reclassified after processing as low-level waste.
>
> > *Example: Due to the moisture content of a transuranic waste sludge, the waste does not meet the WIPP WAC. The site evaluates several treatment options taking into consideration factors such as worker exposure, waste minimization, cost and complexity of the treatment process and disposal facility waste acceptance requirements. The treatment process selected involves adding grout to the transuranic waste sludge to eliminate free liquids resulting in a solidified waste form that contains transuranic radionuclides in concentrations less than 100 nanoCi (3700 Bq) per gram and meets the waste acceptance criteria for a low-level waste disposal facility*."

At the concept level, the proposed ORNL SL solidification conforms to the DOE G 435.5-1 example cited above. Mobilization and transfer of the SL to W-23 for homogenization, aggregation, and sampling; followed by transfer to the TWPC SN process enables the use of the existing contaminated facility to produce a stable, robust final waste form that is well suited for disposal at NTS. This processing approach minimizes life cycle costs and avoids the cost, worker exposure, and waste disposal volume for D&D of the SL systems/areas which are not currently contaminated. This approach also minimizes or eliminates the SL waste volume destined for WIPP as RH-TRU. A more detailed description of the proposed processing, with regard to concerns pertaining to dilution, is as follows:

Water, acid, or SN is added to facilitate mobilization and transfer as well as prepare a slurry within the design limits of the SN equipment. The proposed processing concept utilizes NuVision Engineering (formerly AEA Technology) fluidic pulse jet mixing technology to mobilize the SL and produce a consistent SL which can be pumped to the TWPC for treatment. The AEAT system was used in 1997 to mobilize ORNL SL and enable transfer of the SL from the BVEST tanks to the MVST tanks. The typical settled solids content of the transferred SL ranged from 0.24 to 4.6 wt. %. For example, 64,000 gallons of liquid were required to fluidize, mix and transfer 7,100 gallons of SL from W-21 to the MVSTs. The proposed liquid addition for SL solidification is comparable to the liquid addition ratio utilized successfully during 1997 for mobilization and transfer.

SL Consistency for Processing via the SN Process Equipment

The proposed processing concept utilizes the existing SN processing equipment with some modifications and expanded solidification agent addition capability. The SN Process Tanks and SN process pumps were designed for thin slurry service (<5 wt. % settled solids). The compact design of the Process Building required the use of extensive tees and elbows in the small diameter piping systems which are at risk from plugging when handling higher settled solids slurry or SL. Given the equipment design, piping design, and consequences of a line plug while handling the highly radioactive SL, The 5 wt. % settled solids design limit for the SN tanks and pumps should not be exceeded, and additional reduction in risk related to line plugging can be obtained by operating below the 5 wt. % design limit.

The SL transfer and processing target has been set at less than or equal to 4 wt. % settled solids. It will be necessary to perform some blending at the CIP tanks to ensure that every batch stays within the physical and radiological profile for the waste.

Confirmatory Sampling of W-35

Confirmatory sampling is required in W-35 to ensure that the waste can be processed safely and that the final solidified waste form will be packaged correctly (i.e., LLW liner for NTS, 72-B canister for WIPP). Waste in W-35 (the “big batch” feed tank) that was found to be greater than the upper LLW processing limit, (e.g., 200 nanocuries TRU/g assuming a 1.2:1 dry blend grout: SL mass ratio with a final TRU content in the monolith of 90 nanocuries/g) would not be diluted by adding water solely for the purpose of reducing the TRU concentration if all other process parameters were in specification. There are two options at this point.

Blending with SN

Blend the contents of W-35 with other low TRU activity SN contained in another CIP tank. The SN typically has less than 8 nanoCi TRU/g and would bring down the average TRU content of the big batch. Blending of SN in the CIP tanks to produce a final form acceptable for disposal as LLW at NTS was allowed during the 2004 SN campaign.

Return to the MVST for processing with other SL

- Blending of the various ORNL tank liquids/SLs has been routinely done for many years. The SL and SN are in an active WWTU and as such are not defined as waste until they are discharged from the WWTU.
- While the isotopic ratios for W-23 are different from the other MVST SL samples, the SL overall is quite homogeneous in comparison to the RH or CH debris. The isotopic ratio variation among the SL, even including W-23, is well within the variation for a typical debris waste stream.
- Isotopic concentrations will be developed on a "big batch" and the ratio of the TRU isotopes will be kept relatively consistent for the big batch, so blending of W-23 in with the other SL will not adversely impact waste characterization and assignment of activity.

If W-23 co-processing with other SL is not allowable due to an AK determination that the SL in W-23 is a separate waste stream and must be kept isolated from the other MVST SL, then blending with SN would be required.

If a batch of SL can not meet the upper LLW processing limit even after blending with other liquid low level waste, then processing and packaging of the waste as RH-TRU waste in 72-B canisters would be required.

2.17.2 RCRA Perspectives

2.17.2.1 Treatment vs. Impermissible Dilution

Concerns have been raised that this concept, which adds water in order to mobilize the SL and facilitate centralized aggregation and sampling of the waste in the CIP tanks, may be considered impermissible dilution.

1. We are not diluting the waste to avoid treatment.
2. We are adding water to facilitate treatment (i.e., transfer, aggregation, homogenization, sampling, stabilization and solidification)
3. For highly radioactive SLs like these, the added self shielding of the water reduces radiation levels and personnel exposure.
4. For over moderated fissile SLs, which the MVST SLs are, the addition of more water and the solidification agents reduces k_{eff} even more and provides greater assurance that criticality remains incredible now and in the future.
5. The SL is in a closed loop waste water treatment system. The SL is not a "waste" until it is discharged from the system. Addition of the water to mobilize the SL and facilitate processing should be within the operating envelope of the ORNL LLLW system.
6. Hanford has been in this same situation with their tank waste and determined that adding water to facilitate mobilization and treatment was not impermissible dilution.

Some RCRA excerpts which support the above statements are as follows:

http://www.epa.gov/fedrgstr/EPA-WASTE/2002/August/Day-13/f20352.htm

RCRA regulations do not prohibit dilution during reclamation. While dilution is impermissible in the LDR program to avoid a treatment standard (see 40 CFR 268.3 generally), dilution is permissible when done to facilitate treatment (i.e., adding cement to stabilize waste).

http://www.epa.gov/epaoswer/hazwaste/ldr/memorcra.txt

Consistent with these authorities, the Agency has stated that the dilution prohibition serves one chief purpose -- "to ensure that prohibited wastes** are treated by methods that are appropriate for that type of waste." 55 FR at 22532 (June 1, 1990).

http://www.hanford.gov/chgcp/SafetyExternalWeb/v18s02p05.pdf

“Dilution of waste to facilitate centralized aggregation of wastes is not considered impermissible dilution”

http://www.hanford.gov/hanford/files/TPA_Treatment-Disposal-Plan-300FF-1.pdf

Page A.3

“The LDR treatment standards do not specifically prohibit the use of stabilization to treat hazardous wastes containing organic constituents, but meeting the standards through dilution alone is not allowed. However, EPA acknowledges that dilution that is a necessary part of the treatment process, which otherwise destroys, removes, or immobilizes the hazardous constituents, is normally permissible.”

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=2b06b6faf35eab4d4deb1f4b8f652150&rgn=div8&view=text&node=40:26.0.1.1.3.1.27.3&idno=40

§ 268.3 Dilution prohibited as a substitute for treatment.

(a) Except as provided in paragraph (b) of this section, no generator, transporter, handler, or owner or operator of a treatment, storage, or disposal facility shall in any way dilute a restricted waste or the residual from treatment of a restricted waste as a substitute for adequate treatment to achieve compliance with subpart D of this part, to circumvent the effective date of a prohibition in subpart C of this part, to otherwise avoid a prohibition in subpart C of this part, or to circumvent a land disposal prohibition imposed by RCRA section 3004.

(b) Dilution of wastes that are hazardous only because they exhibit a characteristic in treatment systems which include land- based units which treat wastes subsequently discharged to a water of the United States pursuant to a permit issued under section 402 of the Clean Water Act (CWA), or which treat wastes in a CWA-equivalent treatment system, or which treat wastes for the purposes of pretreatment requirements under section 307 of the CWA is not impermissible dilution for purposes of this section unless a method other than DEACT has been specified in §268.40 as the treatment standard, or unless the waste is a D003 reactive cyanide wastewater or nonwastewater.

2.17.2.2 Permit-by-Rule Exemption

The SL storage tanks and the treatment process at the TWPC will be included under the WWTU exemption. Correspondence between DOE and TDEC which supports this is included as Attachment I. The TWPC process tanks are hard piped to the MVST and CIP portions of the ORNL Liquid Low Level Waste system and are an integral part of the LLLW System. The TWPC is also included in the ORNL LLLW NPDES permit application.

2.17.2.3 Point of Generation

The waste at the point of generation for RCRA is not anticipated to be hazardous and is therefore not subject to RCRA regulations including the LDR standards. EPA has provided written guidance on the point of generation for SLs generated from the WWTUs which states that the point of generation is when the waste is removed from the WWTU. EPA guidance includes an example where SLs from a WWTU are treated using a filter press and clearly states that the point of generation is when the treated SL is loaded into a roll off box. The SL storage tanks and the treatment process at the TWPC will be included under the WWTU exemption and for RCRA purposes the point of generation will be when the treated SL is discharged into a disposal canister or liner. Based on review of the data and the solidification process the waste will not be hazardous after solidification/treatment to remove all free liquids to meet the NTS WAC.

The point of generation under RCRA for this waste is the point where it is released into the waste canister or liner (i.e., discharge chute from the batch mixer).

2.17.3 Chemical Characteristics

Since the chemical characterization is not as impactive of an issue for WIPP, due to their ability to accept a wide range of RCRA waste codes based on the robust nature of the WIPP disposal cells, the RH operability report did not focus much effort on this aspect. Since the LLW option relies upon stabilization of the RCRA metals, the SL Solidification Feasibility Study report goes into detail on this aspect.

Other than small quantities of three RCRA metals (lead, mercury, chromium) which are present at or above the RCRA total metals level (TCLPs were not done by Keller) in the SL, the SL has no assigned RCRA waste codes. The basic strategy for SL has been stabilization of the heavy metals, if required, to eliminate the characteristic of toxicity. The SL is highly buffered at a mean pH of 10, which is near the solubility minimum of most of the metals. Mercury can exist in multiple forms and is typically difficult to stabilize using alkaline solidification only. Mercury typically requires the use of sulfide or polythiocarbonate precipitation in conjunction with alkaline solidification and sometimes even requires coagulation prior to solidification to ensure a passing TCLP.

The original pilot testing with surrogate SL demonstrated successful mercury stabilization using a proprietary polythiocarbonate (Thio Red). The proposed LLW solidification agent includes 46 wt. % blast furnace slag which contains sulfides and has been shown to stabilize mercury. The concentration of mercury in the SL places the SL in the “low mercury subcategory” and the total quantity of mercury (~300 lbs) present in the

SL is trivial (0.3%) in comparison to the annual EPA emissions limit for mercury from power plants. Bench scale testing along with our Process Control Program would be utilized to minimize or eliminate additional confirmatory TCLP testing on the final waste form.

A significant body of knowledge exists within DOE pertaining to the stabilization of mercury bearing tank SLs in cement/grout based formulas. Reports from testing done at ORNL (GAAT SL), SRS (Saltstone), Fernald (Silos 1 & 2), and Hanford have been reviewed along with a general literature review of cement/flyash/blast furnace slag solidification. The performance of the original FWENC stabilization process was spotty at best and was one of the drivers to motivate the TWPC team to evaluate a more robust mercury stabilization alternative. The data from the ORNL independent evaluation of the FWENC process does not allow for a firm conclusion, but it would appear that the original FWENC process was using excess ThioRed, which may have formed soluble mercury poly sulfides. The best performance of the FWENC process was achieved on the dilute samples (before evaporation), this would correlate with a lower Thio-Red concentration in the dilute samples.

The proposed flyash, blast furnace slag (BFS), cement, and fumed silica mixture is the same basic mixture used by SRS for Saltstone, by SEG during the 1995 ORNL LLW solidification campaign, and for the GAAT SL (excerpts below show mercury levels in the TCLP extract 2-3 orders of magnitude below the UTS limit). For untreated, dried MVST SL, only 1-10% of the mercury leached during the TCLP test, indicating that 90+% of the mercury is already in an insoluble form. Even if the solidified monolith performed no better than the worst, untreated, dried MVST SL sample, the average estimated TCLP value for mercury would be only 0.031 mg/kg (see Attachment H). Realistically, the TCLP values should be closer to those achieved on the ORNL GAAT Tank stimulants. Some limited sensitive analysis testing would be performed during the bench scale testing to determine the benefit of small additions of fumed silica (e.g., 0-3 wt. % of the final monolith) and Thio-Red (e.g., 0-10% of the concentration used in the original FWENC process). Previous sensitivity testing with the GAAT simulants showed little impact from variations in the major components (i.e., BFS, flyash, cement).

The proposed solidification agents are also finely ground grades to ensure a low viscosity, free-flowable grout with minimal abrasive properties. The resulting solidified monolith will have a fine grain structure and low permeability to minimize the leaching of soluble mercury compounds or the release of colloidal forms of mercury which are agglomerated or encapsulated within the grout matrix. The proposed dry blend grout is highly alkaline and at the proposed conservative waste loadings, the TCLP extraction fluid will be quickly overwhelmed by the alkalinity of the ground monolith, and the TCLP test will become a buffered alkaline leaching test rather than an acid leaching test.

NOTE: TCLP extraction fluid #1 contains only 5.7 ml of glacial acetic acid along with 64.3 ml of 1 N NaOH in 1 liter of solution. The standard TCLP protocol uses 2000 ml of extraction fluid for a 100 gram sample. The excess, free alkalinity in a 100 gram sample of solidified SL will quickly overwhelm the weakly buffered acetic acid in the extraction fluid. Rapid buffering of the extraction fluid pH up to ~10 was observed in the GAAT SL testing.

Some of the variability in TCLP testing has been traced to the absence of a lower size limit in the TCLP (the TCLP only specifies a maximum particle size of 9.5 mm). Scientific Ecology Group, Inc. (SEG) performed sensitivity testing during the early 1990's on the TCLP sample preparation and found that for lead bearing wastes (e.g., lead forms a low solubility hydroxide) in an alkaline matrix, a finer ground sample (< 1 mm) would provide the lowest TCLP results since the TCLP extraction fluid pH was quickly raised to 10 and lead dissolution into the extraction fluid stopped. For metals that do not form a low solubility hydroxide (e.g., arsenic, mercury), a coarser grind/sieve cut (e.g., 2-9 mm particle size) would give lower TCLP results since the soluble metals were encapsulated inside the particles. A coarser particle size was also beneficial for microencapsulation process such as bituminization and sulfur polymer cement. The best results for microencapsulation processes were obtained by pouring the mix into 9X9 mm molds/forms and then sectioning the cured samples into 9 mm long pieces. This provided the lowest surface area and lowest permeability surface texture on the sample "cubes". Variation in sample preparation techniques, within the allowable limits of EPA Method 1311, could vary the TCLP results by orders of magnitude. Sensitivity testing will also be done during the TCLP testing to see if the sample preparation (e.g., TCLP sample particle size) is influencing the TCLP results. The next proposed step, following endorsement of the feasibility study, is the development of the treatability study and sampling plan.

Another element of the treatability study is to identify near real time process control parameters. Real time confirmatory analysis would be needed if NTS/RWAP requires confirmatory testing on every "big batch". Waiting on conventional TCLP results will be very time consuming/expensive since the typical cement solidification TCLP protocol requires 35 days to get results (e.g., 1 day sample solidification, 28 day cure, 1 day solidified sample prep, 1 day extraction, 4 days metals analysis/results). If performance comparable to the GAAT tank simulants is achieved after a standard 28 day cure, it is likely that the solidified SL would pass the TCLP (0.2 ppm) after only a single day cure and potentially after no cure time at all.

Summary

By using a robust, proven solidification recipe, along with a well designed treatability testing plan and process control plan to ensure that the final monolith properties are maintained, a high confidence level in compliance with the NTS WAC and RWAP requirements is achieved.

A key next step for the SL solidification option is obtaining new samples from the MVST tanks and performing bench scale testing which will include TCLP testing on the solidified final form test samples.

2.18 SL Mobilization

In-tank dissolution of the SL in the MVSTs in passivated nitric acid may be possible and would eliminate the need to design, build, and operate the NUVE Sludge Mobilization system (potential $5M savings). The solution would be neutralized prior to solidification with little or no increase in disposal volume vs. solidification of the dilute, mobilized SL.

2.18.1 Chemical Mobilization

DOE has performed an extensive amount of lab and full scale work on the chemical dissolution method for SL mobilization/transfer. It has primarily been used for removal of the residual SL heels in large tanks after mechanical mobilization. However, it can also be used as the primary SL mobilization technique in our situation. The key to chemical mobilization is slow, controlled metering of the acid into the SL while monitoring SL temperature (the reaction between the alkaline SL and a strong acid is quite exothermic), and the offgas from the tanks to ensure that the dewpoint of the offgas does not get too high and thus damage the HEPA filters. The SLs are high in carbonates (like Alka Seltzer) and will offgas when acid is added. Also trace unreacted acid fumes could be release and these need to be kept dilute so that corrosion of the offgas system is minimized. The MVST tanks are made of 304 L SS which is highly resistant to nitric acid and would allow use of concentrated technical grade nitric acid for the chemical dissolution/mobilization.

The chemical mobilization concept is straightforward:

1) Remove as much of the SN liquid above the SL layer as possible in the MVST tanks to make room for acid addition.
2) Slowly (~0.5 gpm) inject acid into an MVST tank near the pump suction to dissolve the SL in this area of the tank.
3) For tanks that are quite full, it will be necessary to remove some of the dissolved SL from the tank prior to adding all the required acid to make room for the remainder of the acid. Acid usage is estimated at ~50% of the SL volume if using 67 wt. % nitric acid (tech grade).
4) After the required acid (~20,000 gallons/MVST) has been added, the tank is allowed to soak for a couple weeks to maximize dissolution of the SL.
5) The MVST tank is then pumped to a CIP tank which has already been pre-charged with water or SN to facilitate sampling and neutralization, using the existing MVST transfer pumps.
6) CIP tanks are blended to average out the TRU concentration between MVST tanks.
7) After the CIP tank has been sampled, caustic and a corrosion inhibitor are added to raise the pH back near neutral to minimize corrosion on the carbon steel process piping in the TWPC PB.

Advantages

1) Eliminates the cost to design, fabricate, test, start-up, operate, decommission and dispose of the AEAT Pulse Fluidic mixing system (~$5M).
2) Eliminates the worker radiation exposure to install the AEAT system hoses. This is a significant dose avoidance since this task is expected to incur 5,000-10,000 mRem in collective dose over the campaign. Acid can be added to the MVSTs using the existing chemical addition system.
3) Accelerates the earliest possible start date for SL by eliminating the AEAT critical path.
4) Produces a low dissolved solids solution, like SN, which can be homogenized in the CIPs and thus making it easier and less expensive to sample and characterize the contents of a CIP tank.
5) A MVST tank can be mobilized and transferred to the CIP tanks within 6 weeks.
6) Nitric acid addition is easy to start/stop; with only line flushing required to lay-up the system between mobilization campaigns.
7) WWO personnel already have experience using nitric acid to Decon the SN systems prior to lay-up. Existing WWO personnel could be used to perform the MVST chemical mobilization.
8) The contents of the CIP tanks can be blended to minimize the volume of solidified SL sent to NTS.
9) Compatible with boric acid if boron addition is needed for an additional administrative criticality control.

Disadvantages

1) Additional chemical costs (~$600k) for nitric acid and caustic
2) Will require the design, installation, and operation of a nitric acid storage tank and injection/metering system (~$500k)
3) Will require addition of relative humidity monitoring in the MVST offgas
4) Additional worker hazards introduced related to handling of a strong acid
5) May reduce the service life of the MVST pump stators depending upon the stators resistance to low pH conditions
6) Only about 90% of the SL will be removed. The insoluble solids (e.g., sand, dirt, clay, rust…) will not dissolve in nitric acid alone. Some low activity inert SL heels will be left in the MVSTs.

2.18.2 Mechanical Mobilization

The base design for mechanical mobilization is currently fluidic pulse jet mixing.

3.0 SL Solidification

3.1 Summary

The SL Feasibility Study team has determined that the drying of SL is a high risk factor for the project based on the lessons learned from the SN surrogate and actual SN campaigns, as well as a review of the radiological and chemical data for the SL based on the latest data in ORNL/TM-2001/151 (Keller et al. 2001). The potential processing difficulties are discussed below and the potential worst case scenario is described in the Operating model section.

3.2 Conversion of SN Dryer to a Batch Mixer

The following list summarizes the new or changed design features and administrative controls to enable conversion of the SN Dryer to a Batch Mixer:

- Increase the maximum speed of the agitator shaft from 10 RPM to 50 RPM via a gearbox change.
- Install an acid injection system on the third floor than can be used to add acid into the Batch Mixer, even if power is lost, to partially dissolve and mobilize the grout and prevent inadvertent solidification of a batch from occurring in the Batch Mixer.
- Convert the manual agitator shaft injectable packing addition system to a continuous, automated, injectable packing system to keep this area flushed with injectable packing and minimize shaft wear from the grout.
- Process smaller batches in the Batch Mixer so that the grout level is below the agitator shaft.
- Qualify the grout recipe with additional water absorbing ability (i.e., excess dry blend grout) so that two discharge chute flushes per mixer batch can be performed if required.
- Utilize process shields during the filling of LLW liners to minimize dead time for the Batch Mixer.
- Operate 24 hours per day, 7 days per week to minimize the number of process shutdowns and idle time which contribute to grout build-up on the mixer, agitator and discharge chute. Generation of secondary wastes, associated with equipment flushing, are also minimized by round the clock operations.
- Develop a grout recipe with using fine additives and no abrasive fill (e.g., sand) so the grout is thin, free flowing and minimally abrasive to rotating components.
- Install a grout dry blend addition line to the mixer.
- Convert the demister to a reverse pulse jet baghouse or dust filter to prevent carryover of grout dry blend into the offgas and building ventilation systems.
- Modify the SN Dryer room and piping to facilitate replacement of the Batch Mixer.

- Disconnect B-202 and H-202 (only needed for SN evaporation) from the back-up diesel generator and power the Batch Mixer system from the diesel generator to allow completion of mixing and discharge of a grout batch should primary power fail during these critical steps in the solidification process.

Also, the existing SL Dryer has already been removed to allow installation of the bulk dry blend grout storage silo and a potential modular wet chemistry lab. The SL Dryer would be converted to a Batch Mixer and stored as a critical spare for the SL solidification process. The cost benefit of proactive removal of other large SL equipment (e.g., SL pumps, tank mixers…) to stage as SN spares should be evaluated.

3.3 Solidification Operating Models

Operating models were developed to assess the impact of process and operating variables on the process throughput and resulting processing duration and volume of LLW liners sent to NTS for disposal. Three scenarios were developed on the basis that the SN Dryer can be converted to a grout batch mixer and grout can be discharged from the batch mixer through the existing SN discharge chute into a LLW Liner located in Room 141. The detailed operating models are included in Attachment D.

4.0 SL LLW Liner Filling/Handling

4.1 Summary

The SL LLW liner filling will mimic the SN LLW liner filling which successfully filled 97 liners with high contact dose rate (e.g., 15-30 R/hour) thermally grouted SN during 2004. A flowable grout will be gravity discharged from the SL Batch Mixer through a double transfer sleeve into a SL LLW liner contained in a process shield on a bogie (i.e., motorized shield cart with load cells for weight indication) in Room 141. Typically 3 mixer batches will fill a SL LLW liner to the maximum allowable weight limit, which is about 75% of the internal volume. It may be necessary to use smaller liners (e.g., 170 cubic feet filled to ~90% of the internal volume) for SL solidification since the number of larger 215 casks which can accommodate the larger LLW Liners (e.g., 210 cubic feet) could become the limiting factor in throughput for sustained LLW shipment rates exceeding 7 per week.

4.2 SL LLW Liner Filling

Potential issues, associated with the SL LLW liner filling, are as follows:

- SL batch mixer discharge port bridging and discharge valve plugging
- SL batch mixer discharge chute plugging
- Overfilling a liner and exceeding the allowable cask payload limit
- Excessive discharge chute flush water added to monolith

In order to mitigate these potential issues, several strategies have been developed. The first is by using stringent process control to ensure accurate mass balance control of the feed streams into the batch mixer combined with confirmatory load cell readings of the LLW liner during filling. The grout will be formulated to achieve a low viscosity and slow set time to facilitate mixing and discharge into the liner and minimize issues related to plugging and build-up. Regular cleaning of the batch mixer and discharge chute will be performed using process water or dilute acid, as was done successfully during the SN campaign. A high dry blend grout to waste ratio (i.e., low waste loading) is proposed to provide a high confidence level of achieving an acceptable monolith. Additionally, the use of a high efficiency absorbent such as Nochar Acid-Bond is proposed to provide even greater assurances against the presence of free liquid in the LLW Liner. The absorbent would be pre-loaded into the LLW liner prior to filling with grout. Two or three different types of absorbent would be utilized;

- a dense, granular product which would tend to stay on the bottom (e.g., metso beads which have a true density of ~2.6 g/cc and will not float in the grout) and
- one or two much finer and lighter grades [e.g., Nochar Acid-Bond Standard Grind (0.2-0.4 mm) or Acid-Bond Granular (2-4 mm)] which would tend to commingle and become trapped within the more viscous grout, with some of the lighter absorbent actually floating on top of the grout.

This is very similar to the use of anhydrous sodium metasilicate (metso) beads as a pre-load in the SN LLW liners and occasionally, additional metso beads were added as a cap on top of the final SN LLW liner if multiple discharge chute flushes were performed following the final SN grout discharge to the liner. The use of a camera inside the LLW liner is also proposed to provide real time visual feedback on the filling of the LLW liner and provide final visual confirmation of the absence of free liquid inside the LLW liner prior to shipment to NTS.

4.3 SL LLW Liner Process Shields

The proposed concept for the process shields is a simple, reusable shield that resembles a DOT Type A shipping cask, but is thinner walled, lighter, and much less expensive since it is merely an on-site process shield. The process shields would need to have lifting lugs that allow movement of the process shield plus the weight of a filled LLW liner (e.g., 20,000 lbs payload). The shielding objective would be to reduce the LLW liner contact dose rate (nominal 3 R/hr) to less than 100 mRem/hr (contact dose rate with the process shield). The shielding is estimated to require approximately 3 ½” of steel thickness equivalent for Cs-137. The initial driver for the use of the process shields was to avoid the risk of contaminating a shipping cask during the LLW liner filling, as well as maximizing the utilization of the shipping casks for actual shipping vs. the role of a process shield. However, the process shields also provide additional benefits (e.g., transportation buffer, easier to load/unload the liners, ability to continue usage with higher levels of fixed contamination) that could reduce the average cycle time per liner, reduce transportation delays, and shorten the operating duration in turn.

During the SN campaign, it was necessary to survey and decontaminate, if required, the shipping cask and then transfer the cask outside to the 30 Ton Crane Bay for loading onto a flatbed. Then another empty cask was loaded onto the bogie, wrapped with anti-contamination materials and then moved back into Room 141. Early in the SN campaign, it could take several hours for the liner filling sleeve remnant to deflate and allow lid installation on the liner. Near the end of the SN campaign, a vacuum system was developed and successfully utilized to reduce the liner sleeve remnant deflation time from hours to minutes, effectively eliminated the dead time from the liner sleeve remnant deflation. The cask/liner change out process used to take from 6-24 hours per liner during the SN campaign with an average of 12 hours. The use of multiple process shields and the liner sleeve remnant vacuum deflation system could reduce the "dead time" between solidification operations (i.e., shield/liner change out) to an average of a couple hours. Additional time/motion studies of this process step would likely provide justification for reducing the current cycle times in the operating models for cask/liner change out by 50%.

5.0 SL LLW Liner Transfer from Process Shield to Shipping Cask

The process shield and LLW liner will be surveyed and decontaminated much like the SN LLW casks were and transferred from the Process Building to the 30 Ton Crane Bay. Enclosure of the 30 Ton Crane Bay along with the addition of filtered ventilation for the 30 Ton Crane Bay would allow LLW liner transfer to occur prior to LLW liner lid installation and prior to a final release survey, which would further minimize LLW liner cycle time. The LLW liner would remain in the process shield for 24-48 hours following the last grout fill to allow time for grout solidification and absorption of any surface water back into the monolith. Upon verification of a solid monolith with no free liquid, the LLW liner would be rigged up out of the process shield and into a DOT Type A shipping cask using the 30 Ton Crane. Upon cask lid installation/torque and an acceptable final DOT shipment survey, the cask would be removed from the 30 Ton Crane Bay using a conventional power unit and then transported, typically on the same shift, to NTS for disposal.

6.0 SL Solidification Conversion Completion Schedule

Review of the existing punch lists along with extensive system walk downs were performed by various team members to prepare a detailed estimate of remaining activities required to complete the SL buildout.

A detailed build out schedule was not prepared, but the critical path appears to be the design and completion of the SL mobilization system for the original base design (drying), while the design and completion of the tube press is critical path for the mechanical dewatering option.

7.0 SL Solidification Proposed Changes

7.1 Summary

After review of the base design, characterization/certification requirements for NTS, throughput and shipping expectations, and lessons learned from SN & CH operations, the following modification concepts have been identified as follows:

1) Convert SN Dryer to a Batch Mixer
2) SL Solidification Bench Scale Testing Program
3) Install Powdered Grout Addition System
4) LLW Liner Filling/Curing Process Shields
5) Enclose and ventilate (filtered) the 30 Ton Crane Bay
6) Provisions for Decontamination and Lay-up for SL/SN campaigns
7) SN Rejuvenation
8) Upgrade or replace Isolok® samplers with an improved design to prevent sampler leak-by
9) SL Batch Mixer Shaft Seals Continuous Injectable Packing Injection
10) Provisions for Replacing the SL Batch Mixer
11) Back-Up Power for the SL Batch Mixer

Each change is discussed in more detail in the following individual sections.

7.2 Convert SN Drying Process to SL Solidification Process

7.2.1 Summary

Since the solidification process is not constrained by cask/transportation limitations, 7 day per week solidification operations are possible. This also spreads out the operating personnel and logistics over four shifts and minimizes the peak overlap on day shift with other day shift waste processing operations (e.g., CH, LLW, MLLW, RH debris). The use of the large CIP tanks as a big batch/feed tank also reduces the number of SL mobilization and transfer campaigns. Instead of virtually continuous SL mobilization/transfer operations by NUVE, 20 mobilization/transfer campaigns are performed over the course of the SL solidification campaign. The proposed operating mode would allow NUVE to begin mobilization when the CIP feed tank is nearly empty and thus be ready to transfer from the MVST tanks to the CIP tank as soon as it is empty. The TWPC can process from the inventory of the four SN tanks, which would be filled with the final transfer from the CIP tank, while the CIP tank is filled, homogenized, sampled and characterized.

SL contained in the SN tanks is transferred to the batch mixer where the dry blend gout is added and mixed to form a flowable grout. The grout is discharged into a LLW Liner. After typically three discharges from the batch mixer, the LLW liner has reached the allowable weight limit and is transferred to the 30 Ton Crane Bay for curing and then loading into a DOT Type A shipping cask. The LLW liners are shipped to NTS as soon as the grout sets (48-72 hours after filling).

7.3 SL Solidification Bench Scale Testing Program

In order to confirm the performance of the solidification on the MVST SLs and produce some specific data for scale-up (dry blend grout recipe, mixing times, grout viscosity and set times, ability to accommodate excess water from chute flushing, cure times, grout density, TCLP results for RCRA metals …), a bench scale testing program is recommended. Testing on surrogates is of limited value since modeling of the SL solidification behavior is a complex function of the wide range of chemicals and chemical forms present in the SL. To be meaningful, the bench scale testing needs to be performed on actual MVST SL samples. Full core samples (one from the upper layer of SL and one from the lower layer) taken from at least four SL tanks is proposed since this is the minimum number of samples required by EPA SW846 and this will provide a reasonable range of SL properties given the limitation of only one sample port per MVST tank. The upper layer of SL should contain more of the finer/colloidal solids which typically do not settle or filter as well. In addition to evaluating the range of solidification characteristics of the SL, different grades and loadings of dry blend grout and mercury stabilization additives will also be evaluated.

7.4 Install Dry Blend Grout/Powder Unloading and Storage System

A bulk powder tanker unloading area would be added north of the 30 Ton Crane Bay and west of the Maintenance Shop. A concrete pad along with an overhead roof would be installed along with the tanker unloading/transfer connections. A bulk powder transfer system would be installed to provide the additional vertical lift to transfer the powder up to the top of the bulk storage silo on top of the third floor since the vertical lift exceeds the standard pneumatic unloading capability of the commercial bulk powder tankers. The tanker would be unloaded in approximately 2 hours.

One of the existing SL tanks, T-101A or T-101BA, and the corresponding roof shield panels would be removed and a storage silo would be installed instead. The bulk storage silo would be sized to accommodate 1 ½ bulk powder tankers (a typical bulk powder tanker can hold 52,000 lbs of material) to prevent disruptions in solidification operations. The top of the bulk storage silo would extend above the existing roof on the third level, so a weather enclosure (e.g., penthouse) would be added above the bulk storage silo.

7.5 Install Dry Blend Grout/Powder Transfer and Weigh Hopper Charging System

A dry blend grout/power transfer system would be installed to convey the powder from the bulk storage silo to a batch weigh hopper charging system located in the Hot Cell maintenance area, which is the third floor elevation directly above the batch mixer on the second floor. The weigh hopper charging system would utilize load cells to ensure accurate mass tracking of the dry blend grout or other additives. The weigh hopper charging system would normally be filled from the bulk storage silo, however, the ability to manually add bags of powdered additives would also be provided. The weigh hopper would be sized to hold up to 5,000 lbs which is adequate to hold the entire dry blend grout for a single solidification in the batch mixer.

The weigh hopper would have a variable speed rotary airlock/feeder, like the Polimak rotary valve seen via the hyperlink below, to control addition of the dry blend grout.

http://www.polimak.com/PolEnAirlock.htm

During the SN campaign, 500 lbs. of Metso were added to the SN Dryer via the Metso addition system in less than 5 minutes. Addition of up to 5,000 lbs. of dry blend grout to the batch mixer should be accomplished in less than one hour with the 5X increase in batch mixer speed. Variable speed operation of both the batch mixer and the rotary airlock/feeder ensures that the dry blend grout addition rate can be matched with the mixing performance of the batch mixer, thus avoiding the production of lumps which require high shear or lengthy mixing times to disperse. Dry blend grout is basically added at the maximum rate without forming large lumps to minimize batch mixing times.

7.6 Build LLW Liner Process Shields

During the SN campaign, the LLW liners were pre-loaded into the shipping casks and the shipping cask was used as the process shield. While this was effective, it did tie-up the shipping casks and precluded their use for shipment, and also put the shipping cask at risk of becoming contaminated during LLW liner filling or fill sleeve heat sealing. A couple of casks were contaminated during the SN campaign. Based on lessons learned during SN and the need to maximize the shipping utilization of the shipping casks, the use of process shields is proposed. The process shields would look similar to a shipping cask, but would only need to provide shielding adequate for the 3 R/hour contact dose rate from the monoliths. Simple, carbon steel/cement composite process shields could be fabricated. A minimum of 5 process shields are required to provide cure time and hold-up of the filled LLW liners while awaiting loading into a shipping cask (i.e., transportation buffer).

7.7 Enclose and Ventilate (via MBV HEPA system) the 30 Ton Crane Bay

The 30 Ton Crane Bay Area is located west of the Process Building and is covered by a roof and is partially enclosed by a retaining wall and partial wall on the south side. Enclosure of the west and north sides would be required to enclose this area and allow use of filtered ventilation from the MBV HEPA system. Enclosure and ventilation of the 30 Ton Crane Bay would provide another layer of confinement against the release of contamination and would facilitate movement of LLW liners from Room 141 into the

30 Ton Crane bay, thus allowing another LLW liner to be filled in Room 141. Final lid installation, verification of monolith properties, and the DOT shipment survey could be performed in the 30 Ton Crane bay.

A camera system would also be installed in the 30 Ton Crane Bay to allow remote operation of the crane so that open air transfers of the LLW liners could be made from the process shields to the shipping cask. While a detailed ALARA study is needed to confirm the acceptability, open air transfers of 3 R/hour, and much higher, containers is routinely done at commercial facilities. The cost to design and use a transfer shield bell is not in the current ROM cost estimate, thus the basis of the current concept relies upon the ability to make open air transfers of the LLW liners.

7.8 Provisions for Decontamination and Lay-up

Based on the extended duration of the SL transportation campaign, it is likely that the SN/SL systems will have to undergo non-destructive decontamination and lay-up like the SN systems, to preserve the functionality of the equipment between processing campaigns. Additionally, it would be beneficial to have the ability to inject an acid solution into the pump suctions in the event of pump suction line plugging from SL solids or to perform more effective system decontamination prior to unplanned, corrective maintenance. Acid decontamination would also assist in keeping worker radiation exposures ALARA during maintenance. This concept is to add an acid mix tank, acid injection pump and acid transfer tubing that would allow acid decontamination solution injection in the SN pump suction lines just below the tank bottom valves. The risk of SN feed tank pump suction line plugging is reduced by keeping the SL solids low as is proposed for solidification. The increased provisions for acid injection may only be necessary at the SL batch mixer.

7.9 SL Batch Mixer Shaft Seals Continuous Injectable Packing Injection

The SN Dryer shaft has packing glands located on opposite ends of the dryer. Prior to the SN campaign, three major upgrades were made to the shaft packing glands:

- A split packing gland which would allow packing replacement in the dryer shield vault,
- Live loading of the packing gland to increase packing performance and service life, and
- Remote, manual injection of a viscous injectable packing material

While these upgrades were adequate for SN processing, the proposed SL solidification grout will be much more abrasive than the SN thermal grout, the shaft speed will be five times higher, and significantly more batches (~6,000 SL solidification batches vs. 500 SN solidification batches) will be required. In order to maximize the packing gland and shaft life under the more demanding SL solidification conditions, an automated, continuous injectable packing injection system is required. This will ensure that injectable packing is always present in the packing gland area and will keep the more abrasive grout material from entering the packing gland area.

7.10 Provisions for Acid Cleaning the SL Batch Mixer

During the SN campaign, the Metso addition system was used along with the SN Dryer vacuum system, to enable the vacuum transfer of dilute acid solutions from the Metso hopper into the SN Dryer. While this achieved satisfactory performance during the thermal grouting of the SN, a more efficient and versatile acid injection system is needed for SL solidification to mitigate the increased sticking, build-up and accumulation aspects of the SL grout. A dedicated acid injection system would be installed to allow injection of acid cleaning solution into the spray nozzles above the demister pad. Dry blend grout will tend to build-up in the demister pads. Regular acid flushing of the demister pads will ensure their continued operability. The acid will flow from the demister pad into the batch mixer where it can be used to clean the lower section of the batch mixer and the discharge valve area. Dilute acid solutions, which are compatible with the elastomer of the discharge chute pinch valve (i.e., Red Valve) could be gravity drained into the chute area by opening the batch mixer discharge valve while acid cleaning solution is present in the batch mixer.

7.11 Provisions for Replacing the SL Batch Mixer

The original design for the SN Dryer did not envision the need to replace the SN Dryer during the life of the campaign, given the short estimated duration of the SN campaign, the low abrasive nature of the SN material, and the robust nature of the SN Dryer. These base assumptions were demonstrated by the successful operation of the SN Dryer during the 2004 SN campaign. The only known deterioration of the SN Dryer is some wear of the tip of the agitator blades, as evidenced by wire cutting of the edge as seen via the camera, resulting from wear between the agitator blades and calcium deposits on the dryer wall.

The design requirements for the SN Dryer, which include operation at full vacuum with up to 50 psig steam on the jacket, required a robust shell design, far more robust than a typical mixer design alone would require. The nominal 1” shell wall thickness of the SN Dryer is far thicker than the shell wall thickness of a typical mixer of comparable size which would use only 6 or 7 gauge steel (i.e., < 0.25” wall thickness). The SN Dryer agitator shaft is also a robust design due to the formation of a viscous, fouling phase (like wood putty) during the transition to a dry, granular powder. The design of this agitator shaft is also far more robust than a standard helical coil ribbon mixer. While the robust design of the SN Dryer lends itself to conversion to a batch mixer for solidification of the SL, it is possible that failure of the batch mixer could occur during the long solidification campaign, thus incorporation of design changes to facilitate batch mixer replacement should be developed and implemented. The details of this concept are beyond the scope of this study, and will likely required a good bit of effort by operations, maintenance, radiation protection and engineering personnel.

Some simple concepts such as removal of unnecessary piping and re-routing of any lines/conduits that preclude pulling of the batch mixer out the west wall should be considered. More elaborate concepts might entail provisions to remove the Process Building west wall shield plugs and a monorail to allow rigging of the batch mixer out of

the SN Dryer Room. The existing SL Dryer should be removed from the SL Room while the roof panels are off and the 200 Ton portable crane is on-site for the activities. Once the SL Dryer has been removed, it should be retrofitted with the same upgrades used for the SN Dryer conversion to a batch mixer.

7.12 Back-Up Power for the SL Batch Mixer

One of the worst operational upsets for the SL solidification process would be the extended loss of primary power with a solidification batch underway in the batch mixer. In a worst case scenario, the grout would solidify prior to the reinstatement of primary power and the SL batch mixer would potentially have to be abandoned in place. While extended loss of primary power is not anticipated, it is possible, and the SL Batch Mixer should be connected to the back-up power supply. Since the back-up power supply is fully utilized, it would be necessary to disconnect B-202 and H-202 (only needed for SN evaporation) from the back-up diesel generator and to power the Batch Mixer system from the diesel generator and allow completion of mixing and discharge of a grout batch should primary power fail during these critical steps in the solidification process.

Part D: Sludge Mobilization Options

1.0 Purpose

The SL Feasibility Study has been performed to evaluate the operability of the SL processing systems and equipment, and to determine the scope of the remaining SL buildout activities.

2.0 SL Mobilization/Transfer from MVSTs to CIPs to TWPC

2.1 Summary

NUVE still appears to have the expertise to design, construct and operate the SL mobilization equipment. A key issue is related to the technology used by NUVE to mobilize the SL which limits their ability to control the fluidization of the SL (i.e., the wt. % settled solids content). During the initial mobilization of a MVST tank, the wt. % settled solids can be closer to 10-15 wt. %. While near the end of a MVST tank retrieval campaign, when trying to remove the coarse solids and "heels", the wt.% settled solids can drop below 1 wt.%. Since the MVSTs will remain operational when the SL campaign has been completed, a concept to leave the tank heels until the tanks are taken out of service has been proposed. This would avoid the technical and cost issues of sending large quantities of dilute slurry to the TWPC for processing. Also, the heels are believed to be comprised of larger, more abrasive particles like sand which are detrimental to the valves and rotating process wetted components of the SL system. The heels are also believed to be lower in specific activity since the composition is mainly inert solids like sand. Even if the heels must be removed from the MVSTs, it is recommended that this be done in a campaign manner after most of the SL has been removed from all the MVST tanks. If the heels are indeed lower in activity and fall within low level waste criteria, then conventional dead end filtration (e.g., dewatering in a LLW liner) could be considered for handling the large volumes of dilute tank "cleaning" water with coarse, rapidly settling abrasive solids.

SN recycle can be used by NUVE to minimize the usage of flush water, however, NUVE has indicated that water is preferred during the initial mobilization of a tank to help dissolve the larger solids/crystals, while SN is preferred when nearing the end of a tank and trying to mobilize the coarse/dense heels. If WIPP or NTS requirements dictate "tank by tank" characterization rather than grouping the MVST system as a single lot, then addition of SN to a MVST tank may not be possible since this could alter the isotopic ratios in the SL from a particular MVST tank.

Final design and construction of the NUVE SL mobilization equipment has not been completed. NUVE needs ~12 months of time prior to the SL CORR to complete these tasks.

2.2 Issues and Discussions

The following is a list of issues and discussion related to SL mobilization:

2.2.1 Off-Gas System Interfaces

The Main Building Ventilation system at TWPC Process Building will provide ventilation and off-gas removal for the AEAT Charge Vessel Skid. The MVST Off-Gas system will provide off-gas to all 8 MVST tanks. The boiler system Pressure Safety Valve discharge piping and condensate receiver tank vent were routed into the Main Building Ventilation system header east of the Process Building after the TWPC boiler system became contaminated. The tie-in point is the same location intended for the connection of the NUVE Charge Vessel Skid ventilation line. An engineering and USQ review of this change needs to be conducted to ensure that potential impacts to the future operation of the charge vessel skid have been adequately considered in this change to the base design.

2.2.2 MVST Tank Sampling

The recent sampling data was obtained from the same 3 inch port in all the MVST Tanks. It is still not known just how representative these samples are in relation to the actual SL in the tanks. These samples may have been a collection of top layer materials that flowed into the core void after the last core sample of material was removed. The high variation in sample dose rates (i.e., 0.25-30 Rem/hr beta/gamma) suggests that different layers were being captured in the core sampler. It may be necessary to pull samples of the contents of the charge vessel. The G-3 tank port on the MVST tanks will be used to conduct tank sampling and possible SN removal. No other ports are available to support sampling. The charge vessel is the next logical place to draw samples, so the Feasibility Study team recommends that NUVE's system include the capability to extract a sample from the charge vessel/line.

2.2.3 Sludge Delivery and Fluidization Rates

The transfer of SL from the MVSTs to the Process Building is different than the typical mission for NUVE to transfer SL from one relatively large storage tank to another relatively large storage tank. Delivery of SL = 800 gallons per day.

Original fluidization rates = (5:1) 5 parts water to 1 part SL.

The TWPC Sludge Feasibility Study Team is proposing a "big batch" and solidification alternative to drying which is more tolerant of wide variation in wt. % solids of incoming fluidized SL and also has higher throughput capabilities.

2.3 Site Operations Scenarios

The base SL drying process would require approximately 8,000 gallons (i.e., filling 2 – 4,000 gallon working volume holding tanks) of diluted/mobilized SL 3 times a week. Possible scenarios with current SL drying approach will require 5 days a week mixing Sunday – Thursday. Transfers would have to occur on a Mon, Wed, and Friday interval to support a Monday – Sunday (i.e., 7 day/week) SL processing schedule. This operations approach could change if the TWPC converts to SL solidification technology. The

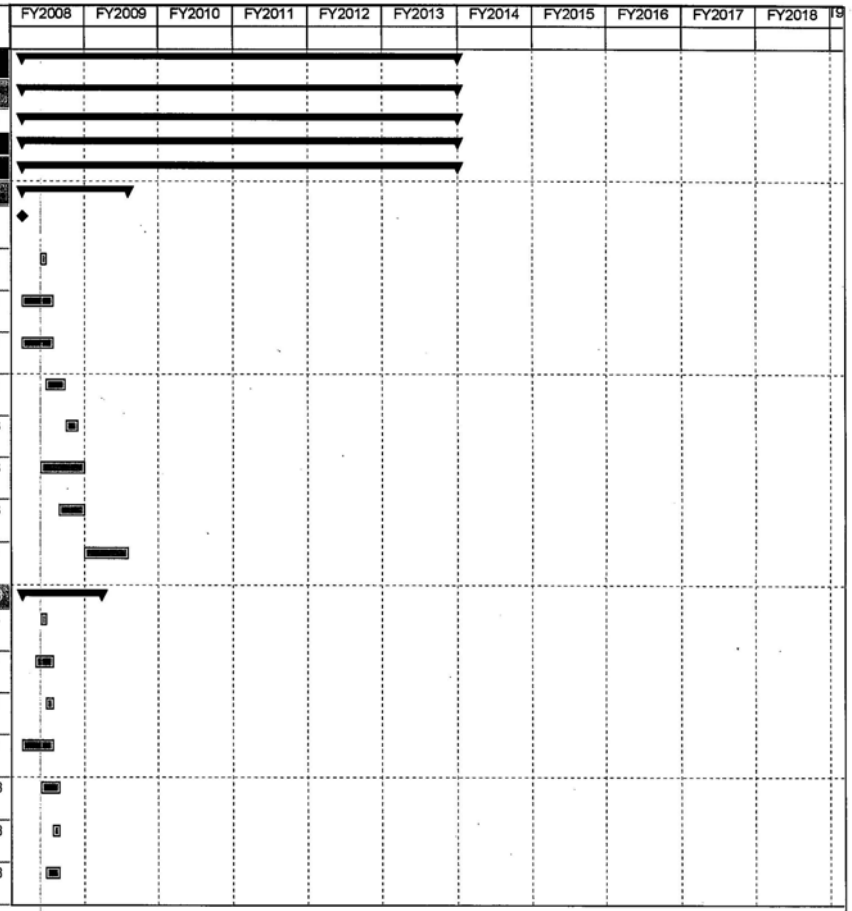
proposed tube press option would likely operate Tue-Thu, 2 shifts, due to the higher SL solids processing capacity thus allowing NUVE to operate on a more conventional Monday-Thursday, schedule. Current projected dried SL/SL cake volumes (800-1,000 cubic meters) would generate ~1,000 72-B Canisters. 72-B cask availability/shipments may be the limit as only three 72-B shipments per week were planned by DOE/CBFO during the SL processing campaign (this assumes that 1 of the 4 available shipments for ORO is utilized for RH debris shipments). ORO has no current storage or interim staging capability for 72-B Canisters. At a shipping rate of three 72-B Canisters per week, it could take in excess of 300 weeks to complete the SL processing and transportation campaigns. Life cycle cost comparisons between the increased cost for extended duration SL mobilization/processing operations and the cost of more 72-B casks or interim storage capabilities must be performed. An extended duration SL processing campaign is not desirable for the TWPC due to higher operating costs and higher maintenance costs/dose resulting from exceeding the design life/total integrated dose of many components.

Water requirements of 200-300 gallons of flush water will be needed to flush the SL transfer line to the TWPC Process system based on the operational and ALARA experience with SN transfers to the TWPC. SL transfer line flush water requirements were higher for SN that contained some SL solids. SL transfer line flush requirements for “thick” or “sticky” SL will likely be higher. SL transfer line flushing is performance based (e.g., until transfer line contact dose rate is no longer decreasing).

Water balance for mixing and transfer operations could be as low at a 2:1, and as high as 5:1 water to SL mix.

Attachment A: Sludge Solidification Conversion Gantt Chart, July 2010 Rad Ops

Activity ID	Activity Name	Start	Finish
	TWPC Baseline - 1-8-08 - CA...	03.Dec.07	01.Oct.13
	TRU Waste Processing Center	03.Dec.07	01.Oct.13
	TWPC Foster-Wheeler/EnergX TN...	03.Dec.07	01.Oct.13
	Capability Development Projects	03.Dec.07	01.Oct.13
	Sludge Processing Facility Buil...	03.Dec.07	01.Oct.13
	Project Management, Prelimi...	03.Dec.07	30.Apr.09
SP0015	Start of Sludge Processing Facility Buildout	03.Dec.07*	
SP1080	Obtain HQ Authorization for SL Solidify Alt	03.Mar.08*	31.Mar.08
SP0200	Complete Feasibility Studies & Preliminary Conceptual Design	03.Dec.07*	30.Apr.08
SP0210	FY08 Work Package Development/Planning	03.Dec.07*	30.Apr.08
SP1260	Grading of Design Activities	01.Apr.08	30.Jun.08
SP1265	Develop FY 09 Phase 2 Work Packages	01.Jul.08*	28.Aug.08
SP1250	Conceptual Design	03.Mar.08*	30.Sep.08
SP1270	Preliminary Criticality Safety Eval.	02.Jun.08	30.Sep.08
SP1280	Pre. Design/Equp. Layout/Long Lead ID	01.Oct.08	30.Apr.09
	Testing	03.Dec.07	24.Dec.08
SP1150	USQ for Treatability Study/Testing	03.Mar.08	31.Mar.08
SP1140	Develop Test Instruction/Test Equip. Specs	04.Feb.08*	30.Apr.08
SP1160	Tech. Review/Selection of Additives	01.Apr.08	30.Apr.08
SP0220	Surrogate Testing	03.Dec.07*	30.Apr.08
SP1120	EPA/TDEC Review/Approval of Treat. Study	03.Mar.08*	30.May.08
SP1130	Sample Sludge, W-35, One MVST, W-23	01.May.08	30.May.08
SP1170	Procure Test Equip.	01.Apr.08	30.May.08



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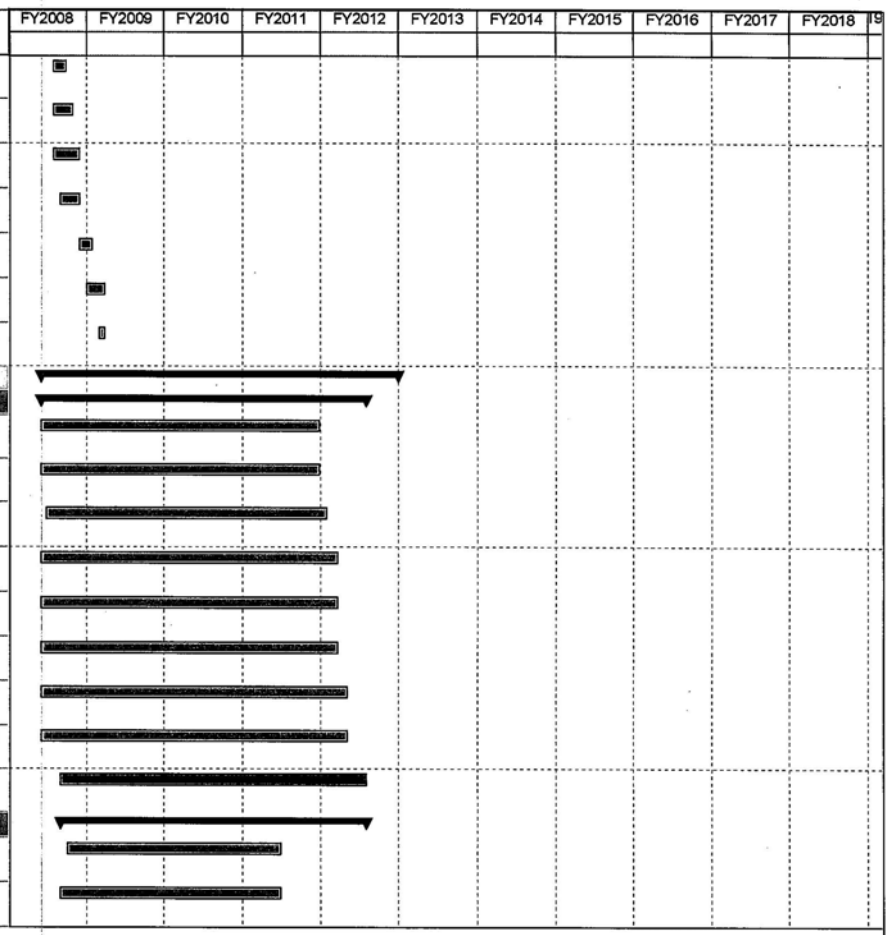
Activity ID	Activity Name	Start	Finish
SP1180	Set-up Bench Scale Testing Area/Equip	01.May.08	30.Jun.08
SP1240	Mixing System Pilot Scale Testing	01.May.08	31.Jul.08
SP1190	Conduct Treatability Study/Bench Tests	01.May.08	28.Aug.08
SP1200	Preliminary Sample Analysis	02.Jun.08	28.Aug.08
SP1210	Detailed/Final Sample Analysis	03.Sep.08	30.Oct.08
SP1220	Prepare Test Report/Revise NTS Profile	01.Oct.08*	24.Dec.08
SP1230	Update Operating/Life Cycle Models	01.Dec.08	24.Dec.08
	Plant Modifications/Improve...	03.Mar.08	27.Sep.12
	Solidification Agent (SA) S...	03.Mar.08	30.Apr.12
SP3740	SA Batch Weight Hopper Feeder Silo 1	03.Mar.08*	29.Sep.11
SP3745	SA Batch Weight Hopper Feeder Silo 2	03.Mar.08*	29.Sep.11
SP3530	Bulk Transfer Unloading Pad/Roof	01.Apr.08*	31.Oct.11
SP3560	Bulk Unloading/Transfer System to Silo	03.Mar.08*	21.Dec.11
SP3710	SA Storage Silo 1	03.Mar.08*	21.Dec.11
SP3715	SA Storage Silo 2	03.Mar.08*	21.Dec.11
SP3730	SA Transfer to Batch Wt. Hopper/Feeder Silo 1	03.Mar.08*	31.Jan.12
SP3735	SA Transfer to Batch Wt. Hopper/Feeder Silo 2	03.Mar.08*	31.Jan.12
SP3720	SA Silo 1 & 2 Penthouse (Environ. Enclosure)	02.Jun.08*	30.Apr.12
	Facility Mods	02.Jun.08	30.Apr.12
SP3750	30 Ton Crane Bay Area Enclosure	01.Jul.08*	31.Mar.11
SP3760	Ventilation Mods Silo 1	02.Jun.08*	31.Mar.11



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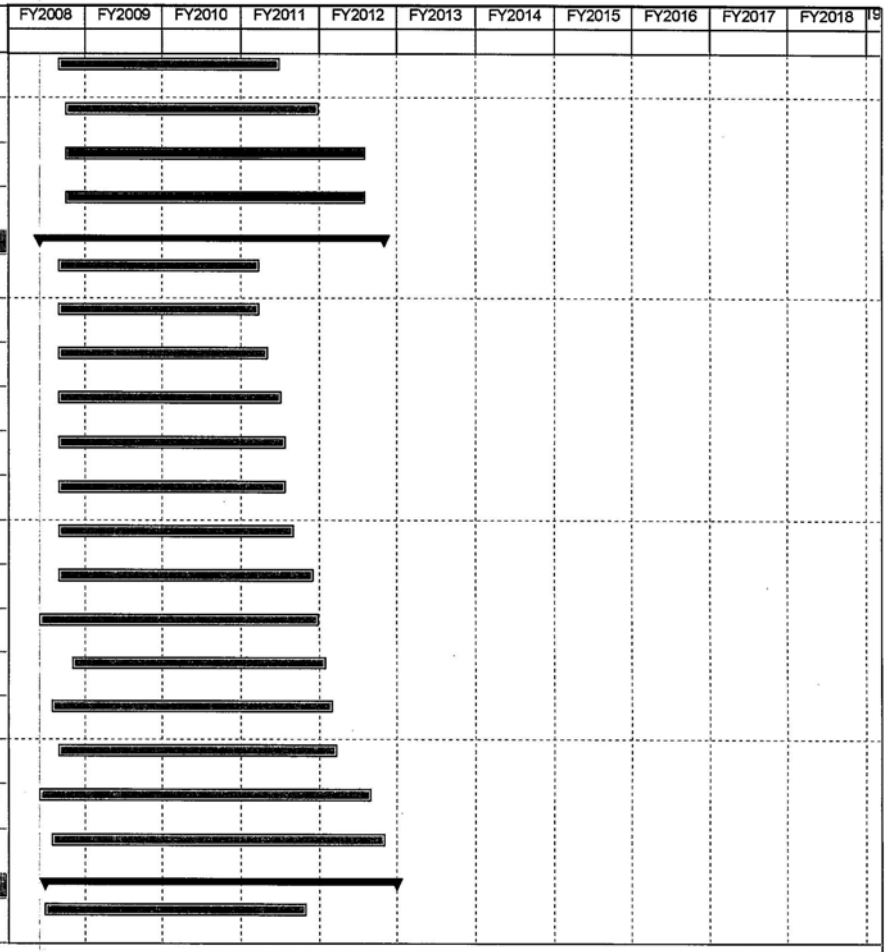
Activity ID	Activity Name	Start	Finish
SP3765	Ventilation Mods Silo 2	02.Jun.08*	31.Mar.11
SP3770	Back-Up Power to SN Dryer System	01.Jul.08*	29.Sep.11
SP3780	Interconnecting Electrical	01.Jul.08*	30.Apr.12
SP3790	PLC/HMI Interface Programming	01.Jul.08*	30.Apr.12
	SN Process Mods	03.Mar.08	31.Jul.12
SP3850	LLW Cask Bogies (10)	02.Jun.08*	22.Dec.10
SP3880	Process Shields	02.Jun.08*	22.Dec.10
SP3830	Cont. Press. Injectable Packing/Seal Flush	02.Jun.08*	31.Jan.11
SP3870	Acid Decon/Injection System	02.Jun.08*	07.Apr.11
SP3840	Dryer 1 Room Mods (Facilitate Replacement)	02.Jun.08*	28.Apr.11
SP3890	LLW Liner Transfer Shield Bell	02.Jun.08*	28.Apr.11
SP3900	Mini Glovebox Refurb/Replacement	02.Jun.08*	31.May.11
SP3810	New LLW Liner Fill Sleeve Heat Sealer	02.Jun.08*	31.Aug.11
SP3820	SA Charging Mods to SN Dryer/Mixer 1	03.Mar.08*	29.Sep.11
SP3860	Port. Temp. Loggers for Monoliths	04.Aug.08*	31.Oct.11
SP3800	Modify SN Dryer or Purchase New Mixer 1	01.May.08*	30.Nov.11
SP3845	Dryer 2 Room Mods (Facilitate Replacement)	02.Jun.08*	21.Dec.11
SP3825	SA Charging Mods to SN Dryer/Mixer 2	03.Mar.08*	31.May.12
SP3805	Modify SN Dryer or Purchase New Mixer 2	01.May.08*	31.Jul.12
	SL System Mods	01.Apr.08	27.Sep.12
SP3920	Remove SL Roof Panels and 1 SL Tank	01.Apr.08*	28.Jul.11



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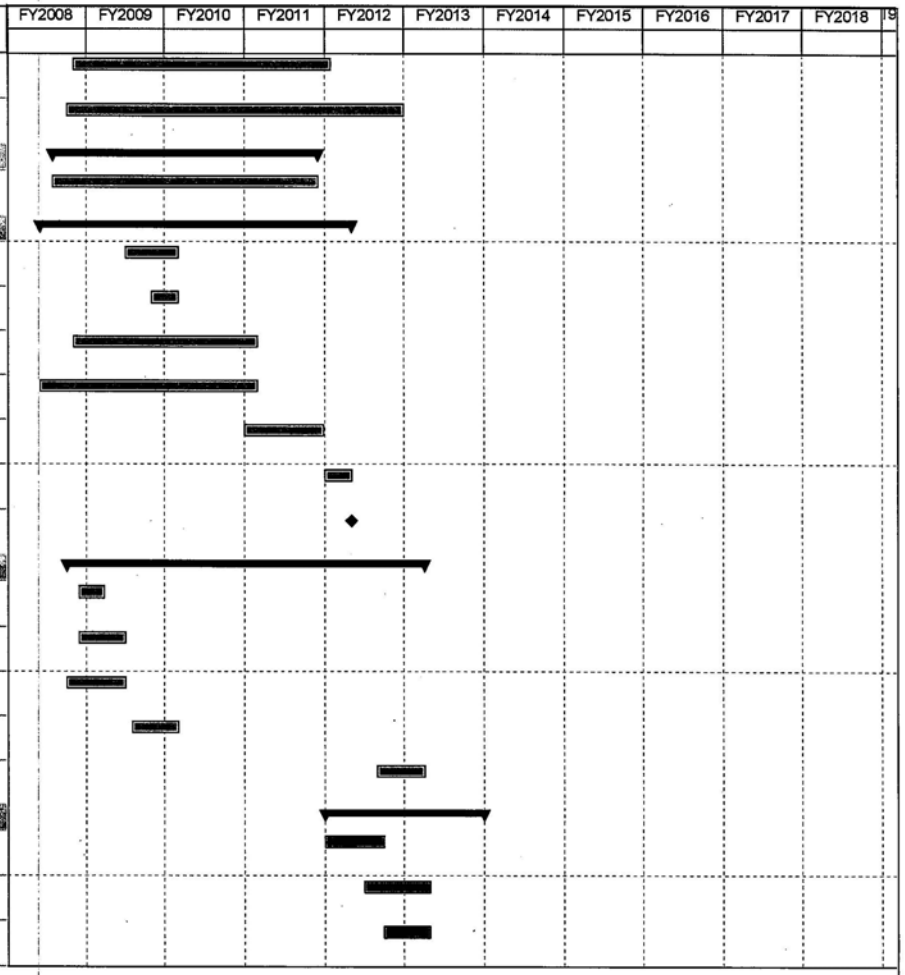
Activity ID	Activity Name	Start	Finish
SP3910	SL to SN Jumper & Remote Valves	04.Aug.08*	31.Oct.11
SP3930	SL Dryer Refurb as Spare for SL Dryer	01.Jul.08*	27.Sep.12
	SN Rejuvination	01.May.08	31.Aug.11
SP1880	SN Rejuvination	01.May.08*	31.Aug.11
	Regulatory Compliance	03.Mar.08	31.Jan.12
SP1580	Nuclear Criticality Safety Evaluations	01.Apr.09*	30.Nov.09
SP1590	Fire Hazard	03.Aug.09*	30.Nov.09
SP1560	Permits (NPDES, WWTU POG)	04.Aug.08*	30.Nov.10
SP1570	EIS Supplemental Analysis	03.Mar.08*	30.Nov.10
SP1530	Safety Basis Preparation	04.Oct.10*	29.Sep.11
SP1540	DOE Review of Safety Basis	03.Oct.11	31.Jan.12
SP1550	DOE Approval of SB/Issue SER		31.Jan.12
	Waste Characterization/Disp	01.Jul.08	31.Dec.12
SP1595	Prepare Test Report/Prelim NTS Profile	03.Sep.08*	24.Dec.08
SP1600	Process Knowledge (PK)	03.Sep.08*	31.Mar.09
SP1610	LLW Ship Prelim. Sub-Contracts	01.Jul.08*	31.Mar.09
SP1620	Waste Profile	04.May.09*	30.Nov.09
SP1615	LLW Ship Final Sub-Contracts	01.Jun.12*	31.Dec.12
	Startup Preparation	03.Oct.11	30.Sep.13
SP1630	Operational Documents	03.Oct.11*	28.Jun.12
SP1640	Training	02.Apr.12*	31.Jan.13
SP1650	Plant Preparation	02.Jul.12*	31.Jan.13



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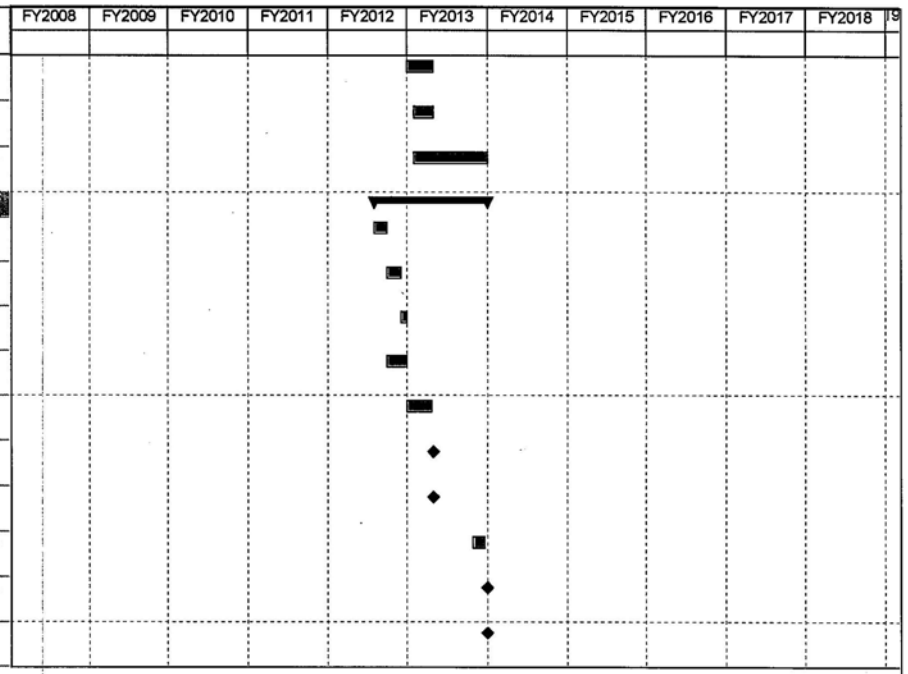
Activity ID	Activity Name	Start	Finish
SP1660	Materials/Supplies	01.Oct.12*	31.Jan.13
SP1670	Operational Equipment Mixer 1	01.Nov.12*	31.Jan.13
SP1675	Operational Equipment Mixer 2	01.Nov.12*	30.Sep.13
	System Testing/Assessment	01.May.12	01.Oct.13
SP1680	Functional Testing	01.May.12*	30.Jun.12
SP1690	Surrogate Testing	01.Jul.12	31.Aug.12
SP1700	Finalize Procs, ORR Prep, MSA	01.Sep.12	30.Sep.12
SP1710	Design & Configuration Changes	01.Jul.12	30.Sep.12
SP1720	CORR/LMA/DORR Mixer 1	01.Oct.12	24.Jan.13
SP1725	DOE Approval for Rad Ops Mixer 1		31.Jan.13
SP1730	SL Rad Ops Start-Up Mixer 1	01.Feb.13*	
SP1740	MSA/RA Mixer 2	01.Aug.13*	19.Sep.13
SP1745	DOE Approval for Rad Ops Mixer 2		30.Sep.13
SP1750	Rad Ops Mixer 2	01.Oct.13*	



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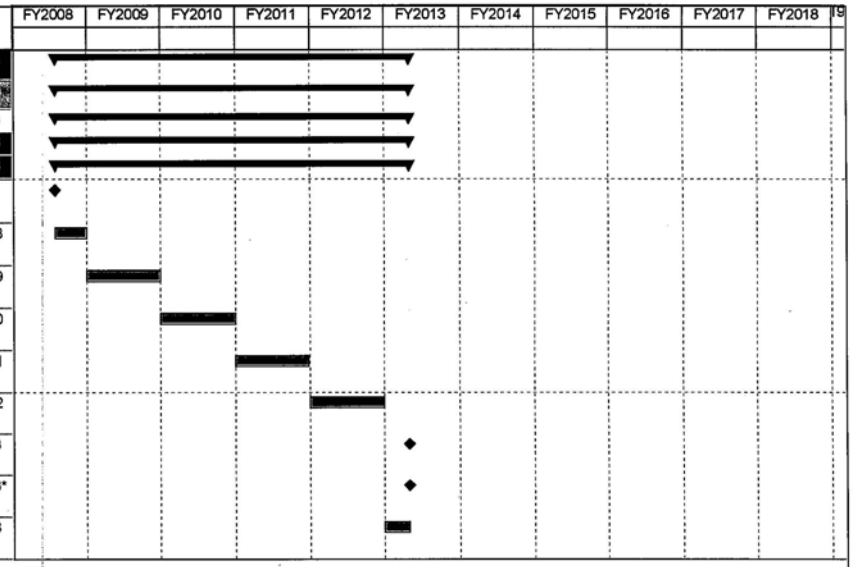
Attachment B: Sludge Mechanical Mobilization, Gantt Chart, July 2010 Rad Ops

Activity ID	Activity Name	Start	Finish
TWPC Baseline - 1-8-08 - CA...		01.May.08	31.Jan.13
TRU Waste Processing Center		01.May.08	31.Jan.13
TWPC Foster-Wheeler/EnergX TN...		01.May.08	31.Jan.13
Capability Development Projects		01.May.08	31.Jan.13
Sludge Mobilization		01.May.08	31.Jan.13
SM0005	Start of Sludge Mobilization Buildout	01.May.08*	
SM1000	Sludge Mobilization FY08	01.May.08	30.Sep.08
SM1010	Sludge Mobilization FY09	01.Oct.08	30.Sep.09
SM1020	Sludge Mobilization FY10	01.Oct.09	30.Sep.10
SM1030	Sludge Mobilization FY11	04.Oct.10	29.Sep.11
SM1040	Sludge Mobilization FY12	03.Oct.11	27.Sep.12
SM9010	Sludge Mobilization Mods Complete		31.Jan.13
SM9900	Sludge Mobilization Ready for Hot Ops		31.Jan.13*
SM1050	Sludge Mobilization FY13	01.Oct.12	31.Jan.13



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Attachment C: Bounding Sludge Source Term in Handling Areas

Vessel	Volume (gal)	Sludge Mass (lbs)	PE Ci	WIPP FGE	Ratio of FGE to PECi
LLW Liners	5625	87,500	13.24	1,385	104.6
Dryer	660	1,643	1.19	125	
Tank T-103A	7800	19,422	14.10	1,476	
Tank T-103B	7800	19,422	14.10	1,476	
Tank T-109	7800	19,422	14.10	1,476	
Tank T-107	7800	19,422	14.10	1,476	
		Supernate-Sludge Tank Vault Total	**58**	6,028	

Activity derived from Keller 2001 report, W-24 to W-31, mean plus 2 sigma

Wt. % Total Solids in Sludge in MVST	50%
Wt. % Sludge Solids in Monolith in LLW Liner	4.2%

Assumes that Tanks are filled with sludge at 10 wt. % total solids, nominal 5 wt.% suspended solids

Lung clearance classes are assumed to be those associated with oxides

Samples less with less than the minimum detectable concentration are assumed equal to the MDC if the isotope was detected in other samples

If no samples of an isotope were found above the minimum detectable concentration, the isotope was assumed not to be present

Supernate Tank T-103A, T-103B, T-109, T-107 Tank Vault

Vessel	PE Ci	WIPP FGE
Tank T-103A	14.10	1,476
Tank T-103B	14.10	1,476
Tank T-109	14.10	1,476
Tank T-107	14.10	1,476
Total	**28.21**	2,952

LLW Liner Staging on First Floor of PB and 30 Ton Crane Bay

Vessel	PE Ci	WIPP FGE
5 LLW Liners	13.24	1,385

NuVision Engineering (AEAT) Charge Vessel

Assumes that undiluted sludge is sucked into the charge vessel

Vol. (gal)	500	Wt.% Total Solids	50%
Sludge Density (g/ml)	1.35		

	PE Ci	WIPP FGE
Charge Vessel	20	2,129

Attachment D: Comparison of Key Isotopes & Rel. Inhalation Risk, SL vs. SN

Comparison of Key Constituents in SN and SL

BAFO SN vs. Actual SN

Estimate, awaiting data in SN Travellers

	BAFO	Actual	Increase Factor
Cs-137 ci	5,127	22,698	4.4
TRU Ci	0.6	2	3.3
Calcium,kg	818		-
Solids, kg	184,791	440,909	2.4
Contact Dose Rate R/hr	5	18	3.6

Estimated SN vs. Estimated SL based on Keller 2001 Data

Average value used for TRU isotopes

	SN	SL	Increase Factor	DCF mRem/micro Ci	Total Possible Inhalation Dose (mRem) SN	SL
Cs-137 ci	22,698	40,000	1.8	32	7.26E+11	1.28E+12
Co-60 Ci	16	1,000	63.7	219	3.43E+09	2.19E+11
TRU Ci	0.6	1,200	2,000	350,000	2.10E+11	4.20E+14
Solids, kg	440,909	800,000	1.8	N/A	-	-
Eu-152 Ci	74	15,000	202.7	221	1.64E+10	3.32E+12
Eu-154 Ci	31	6,000	194.2	286	8.84E+09	1.72E+12
Eu-155 Ci	20	2,200	112.8	42	8.09E+08	9.13E+10
Sr-90 ci	1,000	140,000	140	1,299	1.30E+12	1.82E+14
U-233 Ci	3	200	74	135,420	3.66E+11	2.71E+13
U-238 Ci	0.1	30	300	118,400	1.18E+10	3.55E+12
Cm-244 ci	17	3,000	182	247,900	4.09E+12	7.44E+14
Pu-239 Ci	2	280	140	307,000	6.14E+11	8.60E+13
					7.35E+12	1.47E+15
Relative Inhalation Risk Ratio of SL to SN						110
Rem/gram					17	1,836
100% Mortality with best available treatment (Rem)					800	800
Ratio of Rem/gram inhaled vs. 100% Mortality dose					0.02	2.29
10CFR 830 Annual Limit (Rem)					5	5
Minimum quantity inhaled to exceed 10 CFR 830 limit (mg)					300	3

Attachment E: Sludge Solidification Operating Models

Summary of Key Input Variables	Best	Realistic	Worst
Solidified Monolith Density	2.1	1.9	1.8
Gallons of Dilute Sludge in W-35 (feed batch)	90,000	85,000	80,000
% Fill Solidification Liner	90%	85%	80%
Max. Inner Volume of LLW Liner (cubic feet)	208	208	208
Max. SL Loading (gal. of SL/gal. of LLW vol.)	60%	55%	50%
Gallons/Liner Batch	936	858	780
wt.% TDS in feed to solidification	10%	9%	8%
Solidification Cycle Time (hours)	8	10	12
Ratio of Solidification agent to SL weight	1	1.1	1.2
Delivered Cost of Solidification agent/lb	$ 0.20	$ 0.30	$ 0.40
Mobilization Water Vol. (gal. water/gal. sludge)	4	4.5	5
Avg loading of Borax (neutron poison) lbs/liner	150	250	500
Delivered Cost of Borax per lb.	$ 0.50	$ 0.65	$ 0.75
Liner/Cask Change-out time (hours)	6	8	12
Operating Days/year	365	365	365
Operating Hours/day	24	24	24
Overall Annual Availability	90%	80%	70%

Benchmark Comparison to SN Dryer overall availability:

Actual SN Processed in Campaign	430,000
Average Vol. Reduction in Evaporator	2.3
Estimated Feed to SN Dryer	186,957
Dryer "Theoretical" Capacity (GPH)	60
Campaign Duration (months)	9
Total Campaign Hours	6480
Average Cycle Time/SN Liner Changeout	12
# of SN Liners	97
Available Hours for SN Dryer Ops	5316
Annual "Availability" of SN Dryer	59%

Dryer Feed Cross Check
(5 batches/liner*375 gal/batch*97 liners)
181,875

NOTE: Actual availability of SN Dryer was better than calculated since the high calcium SN affected the process and reduced the theoretical capacity.

Best Case SL Solidification Operating Model: TWPC MVST Sludge

Monolith Specific Gravity	2.1
Solidified SL bulk density (lbs/cubic foot)	*131*
Percentage Fill of LLW Liner	*90%*
Burial volume of Liner canister (cubic meters)	5.89
Liner Batch (gallons)	936
Specific Gravity of SL feed (gm/cm^3)	1.12
Weight of SL per liner	8,701
Ratio of Solidification agent to SL weight	1.00
Sluice/Mobilization Water Volume Increase	500%
Mass of Neutron poison (borax) per Liner (lbs)	150
Mass of Solidification Agent per Liner (lbs)	8,701

Tank	Gallons	S.G.	lbs. of wet sludge
W-24	*27,600*	*1.33*	*304,676*
W-25	*29,380*	*1.33*	*324,326*
W-26	*24,265*	*1.33*	*267,861*
W-27	32,255	*1.33*	*356,063*
W-28	27,386	*1.33*	*302,314*
W-29	31,653	*1.33*	*349,417*
W-30	27,173	*1.33*	*299,963*
W-31	28,821	*1.33*	*318,155*
CIPs, other	50,000	*1.33*	*551,950*
Totals-	278,533		3,074,726

Final Sludge Volume after Mobilization/Transfer (gal)	1,392,665
Gallons of Dilute Sludge in W-35 (feed batch)	90,000
Number of feed batches (e.g. for confirmatory samples)	15
# Solidification Batches	1,488
Total burial volume of Liners (cubic meters)	8,767
Net weight of Final Solidified Monolith (lbs)	17,552
Net weight of Final Solidified Monolith (kg)	7,978
# Solidification Batches/Liner	1.0
# of LLW Liners	1,488
Avg. Batch Cycle Time (hours)	8
Avg. Changeout Time per Canister (hours)	6
Avg. Solidification Availability	90%
Total Time to process SL (Years)	**2.6**
Avg. Shipments per week	**10.8**

Realistic Case SL Solidification Operating Model: TWPC MVST Sludge

Monolith Specific Gravity	1.9
Solidified SL bulk density (lbs/cubic foot)	*119*
Percentage Fill of LLW Liner	*85%*
Burial volume of Liner canister (cubic meters)	5.89
Liner Batch (gallons)	858
Specific Gravity of SL feed (gm/cm^3)	1.10
Weight of SL per liner	7,834
Ratio of Solidification agent to SL weight	1.10
Sluice/Mobilization Water Volume Increase	550%
Mass of Neutron poison (borax) per Liner (lbs)	250
Mass of Solidification Agent per Liner (lbs)	8,617

Tank	Gallons	S.G.	lbs. of wet sludge
W-24	*27,600*	*1.33*	*304,676*
W-25	*29,380*	*1.33*	*324,326*
W-26	*24,265*	*1.33*	*267,861*
W-27	32,255	*1.33*	*356,063*
W-28	27,386	*1.33*	*302,314*
W-29	31,653	*1.33*	*349,417*
W-30	27,173	*1.33*	*299,963*
W-31	28,821	*1.33*	*318,155*
CIPs, other	75,000	*1.33*	*827,925*
Totals-	303,533		3,350,701

Final Sludge Volume after Mobilization/Transfer (gal)	1,669,432
Gallons of Dilute Sludge in W-35 (feed batch)	85,000
Number of feed batches (e.g. for confirmatory samples)	20
# Solidification Batches	1,946
Total burial volume of Liners (cubic meters)	11,465
Waste Volume (cubic meters)	5.0
Liner Void Volume (cubic meters)	0.9
Net weight of Final Solidified Monolith (lbs)	16,700
Net weight of Final Solidified Monolith (kg)	7,591
# Solidification Batches/Liner	1.0
# of LLW Liners	1,946
Avg. Batch Cycle Time (hours)	10
Avg. Changeout Time per Canister (hours)	8
Avg. Solidification Availability	80%
Total Time to process SL (Years)	**5.0**
Avg. Shipments per week	**7.5**

Worst Case SL Solidification Operating Model: TWPC MVST Sludge

Monolith Specific Gravity	1.8
Solidified SL bulk density (lbs/cubic foot)	*112*
Percentage Fill of LLW Liner	*80%*
Burial volume of Liner canister (cubic meters)	5.89
Liner Batch (gallons)	780
Specific Gravity of SL feed (gm/cm^3)	1.10
Weight of SL per liner	7,121
Ratio of Solidification agent to SL weight	1.20
Sluice/Mobilization Water Volume Increase	600%
Mass of Neutron poison (borax) per Liner (lbs)	500
Mass of Solidification Agent per Liner (lbs)	8,546

Tank	Gallons	S.G.	lbs. of wet sludge
W-24	*27,600*	*1.33*	*304,676*
W-25	*29,380*	*1.33*	*324,326*
W-26	*24,265*	*1.33*	*267,861*
W-27	32,255	*1.33*	*356,063*
W-28	27,386	*1.33*	*302,314*
W-29	31,653	*1.33*	*349,417*
W-30	27,173	*1.33*	*299,963*
W-31	28,821	*1.33*	*318,155*
CIPs, other	100,000	*1.33*	*1,103,900*
Totals-	328,533		3,626,676

Final Sludge Volume after Mobilization/Transfer (gal)	1,971,198
Gallons of Dilute Sludge in W-35 (feed batch)	80,000
Number of feed batches (e.g. for confirmatory samples)	25
# Solidification Batches	2,527
Total burial volume of Liners (cubic meters)	14,891
Net weight of Final Solidified Monolith (lbs)	16,167
# Solidification Batches/Liner	1.0
# of LLW Liners	2,527
Avg. Batch Cycle Time (hours)	12
Avg. Changeout Time per Canister (hours)	12
Avg. Solidification Availability	70%
Total Time to process SL (Years)	**9.9**
Avg. Shipments per week	**4.9**

Attachment F: Abbreviations and Acronyms

°C	Degree Celsius
AB	Authorization Basis
AEAT	AEA Technologies
AK	Acceptable Knowledge
ALARA	as low as reasonably achievable
ASTM	American Society for Testing and Materials
BAFO	Best and Final Offer
Bq BVST	Becquerel Bethel Valley Storage Tanks
CAM	Continuous Air Monitor
CBFO	Carlsbad Field Office
CCP	Central Characterization Project
CCTV	Closed Circuit Television
CH	Contact Handled
CHGB	CH Glovebox and Box Breakdown Area
CHSA	Contact Handled Staging Area
Ci	Curie
CIP	Capacity Increase Project
CMB	Completely Mixed Batch
CORR	Contractor Operational Readiness Review
CSA	Canister Storage Area
D&D	Decontamination and Decommissioning
DAC	Drum Aging Criteria
DID	Defense in depth
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
d/p	Differential Pressure
DRS	Dispersibles Removal System
DSA	Documented Safety Analysis
DTC	Dose-to-Curie
ES&H	Environmental Safety and Health
ENS	Employee Notification System
EPA	U.S. Environmental Protection Agency
EPDM	Ethylene Propylene Diene Monomer
FGE	Fissile Gram Equivalent
FMEA	Failure Modes and Effects Analysis
FSAR	Final Safety Analysis Report
ft	foot or feet
FWENC	Foster Wheeler Environmental Corporation
g/cc	grams per cubic centimeter
gal	gallon(s)
GB	glovebox
HEPA	High Efficiency Particulate Air
HSGS	Head Space Gas Sampling
ICRP	International Commission of Radiation Protection

ID	Inner Diameter
in.	inch(es)
INEL	Idaho National Engineering Laboratory
IV	Inner Vessel
Keff	K-Effective, criticality coefficient
kg	Kilogram
lb	Pounds
LET	Lid Extraction Tool
LLLW	Liquid Low-Level Waste
LLW	Low-Level Waste
m	meter(s)
m^3	cubic meters
MBV	Main Building Ventilation
MCNP	Monte Carlo N-Particle
MLLW	mixed low level waste
MSM	Master-Slave Manipulator
mRem	Millirem
mRem/hr	millirem per hour
MSRE	Molten Salt Reactor Experiment
MVSTs	Melton Valley Storage Tanks
nanoCi/g	nanocuries per gram
NCR	Non-Conformance Report
NDA	Non-Destructive Assay
NDE	non-destructive examination
NTS	Nevada Test Site
NUVE	NuVision Engineering
OC	Outer Cask
OD	Outer Diameter
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
PAC	Powdered Activated Carbon
P&VV	Pump and Valve Vault
PB	Process Building
PE Ci	Plutonium (239) equivalent curies
RCRA	Resource Conservation and Recovery Act
RCT	Radiological Controls Technician
REDC	Radiological Engineering Development Center
RH	Remote Handled
RLC	Removable Lid Canister
rem/hr	rem per hour
rpm	revolutions per minute
ROM	Rough Order of Magnitude
SL	Sludge
SME	Subject Matter Expert
SN	Supernate

SS	Safety Significant
SS SSCs	Safety-significant structures, systems, and components
SSCs	Structures, systems, and components
ST	Source Term
TRU	Transuranic
TSR	Technical Safety Requirements
TWBIR	Transuranic Waste Baseline Inventory Report
TWPC	TRU Waste Processing Center
TWR	Tank Waste Retrieval
TWRS	Tank Waste Retrieval System
UF	Ultra-Filtration
UPS	Un-interruptible Power Supply
USQ	Unresolved Safety Question
VE	Visual Examination
VOG	Vessel Offgas
VR	Volume Reduction
WAC	Waste Acceptance Criteria
w.c.	water column
WIPP	Waste Isolation Pilot Plant
Yr(s)	Year

Attachment G: References

Riner, Gary, (DOE-OR), 1996, Letter to Don Watkins, Manager, National TRU Program, Carlsbad Area Office, Attachment 1, Oak Ridge Data Package for Rev. 3 of the TWBIR, June 1996

Department of Energy (DOE), 1996. Transuranic Waste Baseline Inventory Report, Revision 3, DOE/CAO-95-1121, June 1996

J.M. Keller and J.M. Giaquinto, 2001, Characterization of the Radioactive Sludge from the ORNL MVST Waste Tanks, ORNL/TM-2001/151, September 2001

D. Gagel and J. Lamendola, TRU Waste Processing Center, RH Debris and Sludge Operability Review, RH-R-AD-001, Revision 1, February, 2007

T.E. Kent, J.J. Ferrada, L.R. Dole, I.D. Lee, and J.W. Nehls, Cost Comparison for Treatment of ORNL Remote-Handled Transuranic Sludge by Grout and Vitrification Processes, Prepared by ORNL for the U.S. Department of Energy (DOE), under contract DE-AC05-96OR22464, September, 1998

Evaluation of FWENC Process for Treatment of MVST Sludge, Supernates, and Surrogates, ORNL/TM-2003/30, John W. Barton, February 2003

Solidification/Stabilization of Organic and Inorganic Contaminants using Portland Cement: A Literature Review, Santanu Paria and Pak K. Yuet, 2006

Stabilization/Solidification Processes for Mixed Waste, EPA 402-R-96-014, June 1996

Guide for Curing of Portland Cement, FHWA-RD-02-099, January 2005

Waste Form Development for the Solidification of PDCF/MOX Liquid Waste Streams, WSRC-MS-2004-00178, A.D. Cozzi and C.A. Langton, 2004

Stabilization of High Salt Waste Using a Cementitious Process, DOE/EM-0500, Roger D. Spence, September, 1999

Oak Ridge National Laboratory Old Hydrofracture Facility Tank Closure Plan and Grout Development Status Report for FY 1999, B.E. Lewis, R.D. Spence, J.V. Draper, R.E. Norman, April 2000

Cost Comparison for Treatment of ORNL Remote-Handled Transuranic Sludge by Grout and Vitrification Processes, T.E. Kent, J.J. Ferrada, L.F. Dole, I.D. Lee and J.W. Nehls, September 1998

State of the Art Report on High-Level Waste Tank Closure, WSRC-TR-2001-00359, Christine A. Langton, Roger D. Spence, John Barton, July 2001

Grout and Glass Performance Maximizing the Loading of ORNL Tank Sludges, ORNL/TM-13712, R.D. Spence, M.W. Burgess, A.J. Mattus, J.F. Travis, March 1996

Grout Performance in Support of In-Situ Stabilization/Solidification of the GAAT Tank Sludges, ORNL/TM-13389, R.D. Spence, J.L. Kauschinger, March 1996

Evaluation of Organic Vapor Release from Cement-Based Waste Forms, A.D. Cozzi, R.E. Eibling, A.R. Marinik, J.R. Zamecnik, 2006

Controlled Low-Strength Materials, ACI 229R-99, 2005

CIP 17 Flowable Fill Materials, NRMCA, 2000

Laboratory Evaluatio of Underwater Grouting of CPP-603 Basins, V.J. Johnson, J.H. Pao, R.L Demmer, J.L. Tripp, February 2002

Idaho Nuclear Technology and Engineering Center Low-Activity Waste Process Technology Program FY-99 Status Report, INEEL/EXT-99-00973, A.K. Herbst, J.A. McCroy, R.J. Kirkham, J. Pao, S.H. Hinckley, September 1999

SRS Draft EIS, Appendix A, Technology Descriptions, Draft/EIS-0082-S2D, March 2001

Flyash Facts for Highway Engineers, FHWA-IF-030-019, American Coal Ash Association, June 2003

EPA SW-846 Method 1311, Toxicity Characteristic Leaching Procedure, July 1992

Development and Selection of Technologies for Mercury Management on US Department of Energy Sites: The MER01-MER04 and Mercury Speciation Demonstrations, Michael I. Morris, Greg A. Hulet, February 2003

Treatment Standard for Mercury-Containing Debris, Robert Springer, October 2003

Demonstration of GTS Duratek Process for Stabilizing Mercury Contaminated (<260 ppm) Mixed Wastes, DOE/EM-0487, Mercury Working Group and Prairie View A&M University, September 1999

Preliminary Criticality Safety Evaluation for In-Situ Grouting in the Sub-surface Disposal Area, INEEL/EXT-2000-00794, L.J. Slate, August 2000

Characterization of the Old Hydrofracture Facility (OHF) Waste Tanks Located at ORNL, ORNL/TM-13394, J.M. Keller, J.M. Giaquinto, A.M. Weeks

NCRP Report No. 98 "Guidance on Radiation Received in Space Activities, NCRP, Bethesda, MD (1989)

Attachment H: SN Processing ALARA Dose Report, S. Byers, 2004 Pro2Serve (External Independent Peer Review) Written Questions and TWPC Response

TRU Sludge Waste Processing Questions

5/29/07

1. Does Energ-X have any examples/ reports where they have used Chemical Mobilization on this type of sludge and on this scale?

Chemical dissolution of tank heels has been performed at SRS on a scale (gallons of sludge basis) comparable to the MVST sludge. Two DOE reports are attached for reference. Hanford has also performed some full scale sludge dissolution (e.g., Tank C-106).

2. Is adding grout to the canister instead of the mixer a viable option?

Mechanical/powered mixing is necessary to ensure even mixing and thorough treatment to meet the NTS WAC. Yes, this is possible, and in-container solidification has been performed for many decades in the larger LLW Liners and High Integrity Containers (HICs). A back-up concept using a hydraulic, batch liner solidification system was evaluated using commercially available equipment from Nukem. The in-container option could be implemented if there was an unrecoverable failure of the SN Dryer/mixer.

3. Does the proposed 24 hour/day operating schedule include scheduled maintenance time?

Yes, the operating models have factored in downtime on an annual basis for planned and unplanned maintenance which prevents solidification (e.g., 80% annual availability in the realistic case). The TWPC utilizes both time based and condition based maintenance initiators, along with preventive and predictive techniques to minimize unplanned corrective maintenance.

The following questions are a result of the following statement in this report. The bold italics have been added. "The use of the Thio Red precipitating agent is still proposed even if the sludge passes the TCLP with solidification only since the incremental cost is quite low and the use of Thio Red would provide even greater assurance that the final waste form would not fail the TCLP and may even meet the more stringent Universal treatment Standard (0.025 mg/l in TCLP) extract) ***which is not required***, but would be desirable."

4. Why does Energ-X TN LLC believe that the sludge solidification waste will meet the NTS WAC including Land Disposal Restrictions (i.e., mercury stabilization)?

The waste at the point of generation for RCRA is not anticipated to be hazardous and is therefore not subject to RCRA regulations including the LDR standards. EPA has provided written guidance on the point of generation for sludges generated from the WWTUs which states that the point of generation is when the waste is removed from the WWTU. EPA guidance

includes an example where sludges from a WWTU are treated using a filter press and clearly states that the point of generation is when the treated sludge is loaded into a roll off box. The sludge storage tanks and the treatment process at the TWPC will be included under the WWTU exemption and for RCRA purposes the point of generation will be when the treated sludge is discharged into a canister or liner. The TWPC is beginning the process of adding our treatment system into the ORNL NPDES permit which currently covers the MVSTs where these sludges are currently located.

5. Why will the solidified waste stream not be considered a MLLW? Have NTS and/or the Nevada regulators concurred with this assessment?

Based on review of the data and the solidification process the waste will not be hazardous after solidification/treatment to remove all free liquids to meet the NTS WAC. We are providing NTS our justification for this determination and obtaining their concurrence.

6. What is the point of generation of the waste? Have NTS and/or the regulators concurred with this interpretation?

The point of generation under RCRA for this waste is the point where it is released into the canister or liner. See question 4 above for more detail.

7. Why does Energ-X TN LLC believe that the solidified monoliths are not required to meet the UTS standards? 40 CFR 261.3(d)(1) seems to imply that they must meet them, even if they no longer exhibit the toxicity characteristic at the point of land disposal. Have NTS and/or the Nevada regulators concurred with Energ-X's interpretations?

Since the waste at the point of generation will not be hazardous based on current characterization and assumptions regarding the solidification process it will not be subject to regulation under RCRA including the LDR and associated UTS treatment standards. As stated above we are providing NTS our justification for this determination and obtaining their concurrence.

Attachment 1: Technical Basis for Question 4: Why does Energ-X TN LLC believe that the sludge solidification waste will meet the NTS WAC including Land Disposal Restrictions (i.e., mercury stabilization)?

A significant body of knowledge exists within DOE pertaining to the stabilization of mercury bearing tank sludges in cement/grout based formulas. Reports from testing done at ORNL (GAAT sludge), SRS (Saltstone), and Hanford have been reviewed along with a general literature review of cement/flyash/blast furnace slag solidification. The performance of the original FWENC stabilization process was spotty at best and was one of the drivers to motivate the TWPC team to evaluate a more robust mercury stabilization alternative. The data from the ORNL independent evaluation of the FWENC process does not allow for a firm conclusion, but it would appear that the original FWENC process was using excess ThioRed, which may have

formed soluble mercury poly sulfides. The best performance of the FWENC process was achieved on the dilute samples (before evaporation), this would correlate with a lower Thio-Red concentration in the dilute samples.

The proposed flyash, blast furnace slag (BFS), cement, and fumed silica mixture is the same basic mixture used by SRS for Saltstone, by SEG during the 1995 ORNL LLW solidification campaign, and for the GAAT sludge (excerpts below show mercury levels in the TCLP extract 2-3 orders of magnitude below the UTS limit). For untreated, dried MVST sludge, only 1-10% of the mercury leached during the TCLP test, indicating that 90+% of the mercury is already in an insoluble form. Even if the solidified monolith performed no better than the worst, untreated, dried MVST sludge sample, the average estimated TCLP value for mercury would be only 0.031 mg/kg (see attached Excel file). Realistically, the TCLP values should be closer to those achieved on the ORNL GAAT Tank stimulants. Some limited sensitive analysis testing would be performed during the bench scale testing to determine the benefit of small additions of fumed silica (e.g., 0-3 wt. % of the final monolith) and Thio-Red (e.g., 0-10% of the concentration used in the original FWENC process). Previous sensitivity testing with the GAAT simulants showed little impact from variations in the major components (i.e., BFS, flyash, cement).

The proposed solidification agents are also finely ground grades to ensure a low viscosity, free-flowable grout with minimal abrasive properties. The resulting solidified monolith will have a fine grain structure and low permeability to minimize the leaching of soluble mercury compounds or the release of colloidal forms of mercury which are agglomerated or encapsulated within the grout matrix. The proposed dry blend grout is highly alkaline and at the proposed conservative waste loadings, the TCLP extraction fluid will be quickly overwhelmed by the alkalinity of the ground monolith, and the TCLP test will become a buffered alkaline leaching test rather than an acid leaching test.

NOTE: TCLP extraction fluid #1 contains only 5.7 ml of glacial acetic acid along with 64.3 ml of 1 N NaOH in 1 liter of solution. The standard TCLP protocol uses 2000 ml of extraction fluid for a 100 gram sample. The excess, free alkalinity in a 100 gram sample of solidified sludge will quickly overwhelm the weakly buffered acetic acid in the extraction fluid and drive the pH up to ~10 as was observed in the GAAT sludge testing.

Some of the variability in TCLP testing has been traced to the absence of a lower size limit in the TCLP (the TCLP only specifies a maximum particle size of 9.5 mm). At SEG we did sensitivity testing on the TCLP sample preparation and found that for lead bearing wastes (e.g., lead forms a low solubility hydroxide) in an alkaline matrix, a finer ground sample (< 1 mm) would provide the lowest TCLP results since the TCLP extraction fluid pH was quickly raised to 10 and lead dissolution into the extraction fluid stopped. For metals that do not form a low solubility hydroxide (e.g., arsenic, mercury), a coarser grind/sieve cut (e.g., 2-9 mm particle size) would give lower TCLP results since the soluble metals were encapsulated inside the particles. A coarser particle size was also beneficial for microencapsulation process such as bituminization and sulfur polymer cement. The best results for microencapsulation processes were obtained by pouring the mix into 9X9 mm molds/forms and then sectioning the cured samples into 9 mm

long pieces. This provided the lowest surface area and lowest permeability surface texture on the sample “cubes”. Variation in sample preparation techniques, within the allowable limits of EPA Method 1311, could vary the TCLP results by orders of magnitude. Sensitivity testing will also be done during the TCLP testing to see if the sample preparation (e.g., TCLP sample particle size) is influencing the TCLP results. The next proposed step, following endorsement of the feasibility study, is the development of the treatability study and sampling plan.

Another element of the treatability study is to identify near real time process control parameters. Real time confirmatory analysis would be needed if NTS/RWAP requires confirmatory testing on every “big batch”. Waiting on conventional TCLP results will be very time consuming/expensive since the typical cement solidification TCLP protocol requires 35 days to get results (e.g., 1 day sample solidification, 28 day cure, 1 day solidified sample prep, 1 day extraction, 4 days metals analysis/results). If performance comparable to the GAAT tank simulants is achieved after a standard 28 day cure, it is likely that the solidified sludge would pass the TCLP (0.2 ppm) after only a single day cure and potentially after no cure time at all.

Summary

By using a robust, proven solidification recipe, along with a well designed treatability testing plan and process control plan to ensure that the final monolith properties are maintained, a high confidence level in compliance with the NTS WAC and RWAP requirements is achieved.

Table 2. Average composition of the GAAT sludges

	Tank									Weighted average	20 × TCLP UTS (mg/kg)
	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	TH-4		
	Concentrations of metals in the wet sludge (mg/kg)										
Ag	24	25		9	4			5		4	6
As			1	1					4	1	100
Ba	6	9	65	176	81	41	101	156	11	90	152
Cd	1	4	4	7		5	3	4	2	3	4
Cr	336	228	1,273	1,363	198	259	120	169	281	452	17
Hg	15	24	104	78	151	184	67	225	7	130	1
Ni	6	11	104	151	33	120	73	130	43	92	100

Table 14. Results of leach testing of sensitivity of in situ GAAT grouts

Surrogate	Grout	TCLP extract concentration (mg/L)[a]				Leachability index	
		Hg	Pb	Cr	U	^{85}Sr[b]	^{137}Cs[c]
Standard	1	0.00007	<0.009	0.023	<0.089	10.4	11.1
	2	0.00005	<0.009	0.07	<0.089	10.3	11.1
	3	<0.00001	<0.009	0.13	<0.089	10.6	11.6
	4	0.00004	<0.009	0.108	<0.089	10.7	11.3
	5	0.00006	<0.009	0.092	<0.089	10.5	11.4
Maximum water	1	0.00012	<0.009	0.079	<0.089	10.4	10.9
Minimum water	1	<0.00001	<0.009	0.39	<0.089	10.3	11.2
Wet surrogate sludge		8.38	0.275	46.4	4,198		
TCLP characteristic limit		0.2	5	5	NA[d]		
TCLP LDR limit		0.2	5	5	NA		
TCLP UTS limit		0.025	0.37	0.86	NA		

[a]All of the grout samples were extracted with TCLP extraction fluid number 1, and the final extract pH was about 10; the wet surrogate sludge was extracted with TCLP fluid number 2, and the final extract pH was about 6.

[b]This index was measured to be 9.5 and 11.9 for the standard MVST grout and MVST grout with crystalline silicotitanate (CST) replacing IRPC, respectively.

[c]This index was measured to be 9.9 and 11.4 for the standard MVST grout and MVST grout with CST replacing IRPC, respectively.

[d]Not applicable.

7. SUMMARY AND CONCLUSIONS

Based on the work with the surrogate sludges, in situ grouting of the GAAT sludges by MPJ™ can produce grouts with little or no free water that are resistant to solids segregation, that stabilize the RCRA metals within TCLP limits, and that provide excellent leach resistance for the radionuclides. These results must be confirmed with actual hot sludge before final acceptance of this approach. The tank sludges can be stabilized at a wet sludge loading of 37 wt %, or less, resulting in a volume increase of 150%, or more, with little or no secondary waste generation. The grout strength is relatively low at 100 to 500 psi but is more than strong enough to support anticipated overburdens. A strong monolithic solid is not usually a waste acceptance criterion, although a monolith does decrease the surface area available for leaching and consequently improves leach resistance. Grouts can stabilize the RCRA metals, including mercury, a potential problem species for the tank sludges, and pass the TCLP test. The grout selected for sensitivity testing decreased the concentrations of Hg, Pb, and Cr in the TCLP extract by orders of magnitude. Despite the high water content, the selected grouts exhibited excellent leach resistance, with ^{85}Sr and ^{137}Cs leachability indexes in excess of 10.

None of the properties of this grout proved sensitive to the variations in grout and surrogate sludge compositions tested except for the pumpability of the jetting slurry. Designing the grout to resist settling of solids made it borderline in the objective test of pumpability. Further refinement or testing may be

Attachment I: Correspondence between DOE and TDEC

11/19/2002 10:23 615-532-0686 WATER POLLUTION PAGE 02
NOV-19-2002 10:39 P.02/03

Department of Energy

Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, Tennessee 37831—

November 18, 2002

Mr. Larry Bunting
TDEC Division of Water Pollution Control
6th Floor, L&C Annex
401 Church Street
Nashville, Tennessee 37243-1534

Dear Mr. Bunting:

FOSTER WHEELER TRANSURANIC WASTE REMEDIATIONFACILITY CONNECTED TO THE MILTON VALLEY STORAGE TANKS

To confirm our conversation of November 15, 2002, we agreed that the Foster Wheeler Transuranic Waste Remediation Facility (TWRF), which is connected to the Process Waste Water Treatment Facility (Outfall X12) via the Melton Valley Storage Tanks, is subject to Permit-By-Rule regulation under the Clean Water Act Section 401. There will be no direct discharges of liquid effluents to the environment from the TWRF when it becomes operational but there will be pumped exchanges of wastewater and wastewater sludges between the Melton Valley Storage Tanks and the TWRF treatment units. The TWRF will be a terminal process for the low-temperature thermal evaporation, stabilization and packaging of sludges to facilitate eventual shipment to an out-of-state repository. This was noted in the supplemental information for Outfall X-12 in the Oak Ridge National Laboratory (ORNL) National Pollutant Discharge Elimination System (NPDES) Permit Application submitted in June of 2001.

A letter from David C. Graham with the Tennessee Department of Environment and Conservation Division of Solid Waste Management to Mr. Robert C. Sleeman further states the Transuranic Waste Remediation Facility should be regulated under the provisions of the ORNL NPDES Permit.

According to our discussion, no further notification or documentation is necessary for the facility to be covered by either the Waste Water Treatment Units Exemption or Permit-by-Rule.

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11/19/2002 10:23 615-532-0686 WATER POLLUTION PAGE 03
NOV-19-2002 10:39 P.03/03

Mr. Larry Bunting -2- November 18, 2002

If you are in agreement with this, please sign and fax confirmation to me at (865) 574-9275.

Sincerely,

David L. Buhaly
Laboratory Support Team
ORNL Site Office

Enclosures

Larry Bunting

Larry Bunting

19 November 2002

Date

TOTAL P.03

ORNL NPDES-Related Facilities with Resource Conservation and Recovery Act (RCRA) Permit-by-Rule Wastewater Treatment Unit Exclusion

Certain ORNL wastewater treatment facilities treat some wastewaters that are subject to both RCRA and the Clean Water Act (CWA) regulations. These facilities include:

1. The Process Waste Treatment Complex (PWTC), Building 3544 (formerly known as the Process Waste Treatment Plant), for treatment of process wastewaters;
2. The PWTC, Building 3608 (formerly known as the Nonradiological Wastewater Treatment Plant) for treatment of process wastewaters; and
3. The Liquid Low Level (Radioactive) Waste Evaporator System in Building 2531 and LLW Tanks for volume reduction of liquid low level waste.

These facilities are interconnected, step-wise, by permanent piping (except for some generator accumulation tanks) and ultimately both discharge treated effluent through NPDES Outfall X12, and concentrate radioactive waste from the evaporator system in the Melton Valley Storage Tanks. Both federal and state RCRA regulators have recognized the potential conflicts of dual regulations and have recognized the importance of allowing wastewaters to be treated and discharged by facilities that operate under CWA standards. RCRA regulations provide a special form of a permit called permit-by-rule (PBR) which offers some exclusions to some RCRA requirements for facilities operating under CWA standards.

Prior to 1992, DOE submitted PBR notifications for changes or additions to the wastewater treatment facilities discussed above. In 1992, a PBR change caused the ORNL wastewater treatment units (WWTUs) to be classified as *exempt wastewater treatment units* for receipt of on-site wastewaters. This means that DOE was exempt from RCRA permitting and no longer had to submit PBR notifications for changes or additions to the systems. The WWTU exemption applies since the ORNL systems (1) receive only on-site RCRA wastewaters or off-site wastewaters from the same corporation, (2) are part of a wastewater treatment facility that is subject to regulation under the CWA, (3) receive and treat or store an influent wastewater that is a hazardous waste or wastewater treatment sludge, and (4) meet the definition of a tank or tank system.

A facility is to be constructed at ORNL called the Transuranic Waste Remediation Facility (TWRF). The TWRF will be directly connected (hard piped) to ORNL's Melton Valley Storage Tanks (MVSTs). The MVSTs are a group of doubly contained, stainless steel underground tanks, located at the Melton Valley 7830 Area for storage of liquid LLW. The wastes in the MVSTs, which typically consist of liquid under lain by a sludge layer, are the residual LLWs that have been treated by evaporation at the ORNL LLLW Evaporator in Building 2531. Prior to 1992, the MVSTs and ancillary wastewater treatment/storage tanks were compliant with RCRA via the Tennessee requirements for PBR. Based on the 1992

revisions to the Tennessee RCRA regulations, the MVSTs are exempted from RCRA permitting under the on-site WWTU exclusion.

Beginning in approximately 2002, the TWRF will treat and package the concentrated radioactive liquids and sludges contained in the MVSTs that have resulted from the treatment and evaporation of ORNL's LLW waste waters. While there will be no direct discharges of liquid effluents to the environment from the TWRF when it becomes operational, there will be pumped exchanges of wastewater and wastewater sludges between the MVSTs themselves and the TWRF's treatment units. The TRWF will provide low-temperature thermal evaporation, stabilization, and packaging of LLW to facilitate eventual shipment to an out-of-state repository.

Foster Wheeler Corporation is under contract to DOE to construct and operate the TWRF. As indicated in the March 22, 2001 letter from D. C. Graham of TDEC to R. C. Sleeman of DOE (see following page), it has been determined that the TWRF, as currently planned, will meet the requirements for exclusion from RCRA permitting. Therefore, the TWRF wastewater treatment units are referenced in this ORNL NPDES permit application since those units would then become subject to CWA regulation under CWA Section 402. An actual effluent discharge is not required under RCRA; however, regulatory oversight or permitting under the CWA is required for the WWTU to be covered by either the WWTU exemption or PBR.

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