Waste Treatment and Immobilization Plant U. S. Department of Energy Office of River Protection Submerged Bed Scrubber Condensate Disposition Project – 13460

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ABSTRACT

The Hanford Waste Treatment and Immobilization Plant (WTP) will generate an off-gas treatment system secondary liquid waste stream [submerged bed scrubber (SBS) condensate], which is currently planned for recycle back to the WTP Low Activity Waste (LAW) melter. This SBS condensate waste stream is high in Tc-99, which is not efficiently captured in the vitrified glass matrix [1]. A pre-conceptual engineering study was prepared in fiscal year 2012 to evaluate alternate flow paths for melter off-gas secondary liquid waste generated by the WTP LAW facility [2]. This study evaluated alternatives for direct off-site disposal of this SBS without pre-treatment, which mitigates potential issues associated with recycling.

This study [2] concluded that SBS direct disposal is a viable option to the WTP baseline. The results show:

- Off-site transportation and disposal of the SBS condensate is achievable and cost effective.
- Reduction of approximately 4,325 vitrified WTP Low Activity Waste canisters could be realized.
- Positive WTP operational impacts; minimal WTP construction impacts are realized.
- Reduction of mass flow from the LAW Facility to the Pretreatment Facility by 66%.
- Improved Double Shell Tank (DST) space management is a benefit.

INTRODUCTION

The vitrification of LAW at the WTP generates a substantial amount of secondary liquid waste from the off-gas treatment process. The WTP baseline flowsheet recycles the SBS condensate back to the WTP pretreatment facility (PT) where it is combined with new LAW feed stream. Approximately 140 million liters (37 million gallons) of SBS condensate are estimated to be generated over the WTP 25 year mission [3]. There are three main issues with recycling SBS condensate. These are:

1. Recycling also accumulates halides and sulfates which significantly reduce equipment life and LAW glass waste loading, resulting in increased operating costs and additional LAW packages.

2. In the event of implementing a phased commissioning and operation of the LAW Facility, prior to PT Facility completion, any recycle stream back to PT would have to be returned to tank farms, negatively impacting the continuing depleted storage space.

3. The capture of the radionuclide Tc-99 within the melter glass product may vary from the flowsheet baseline and its overall retention in the glass product is not as good as originally expected. This uncertainty may result in operational issues and increased LAW package production due to low capture of Tc-99 within the glass matrix. This will likely have an adverse effect on overall disposal system performance.

Minimal tank farm space is available to store the SBS condensate if the recycle approach proves to be ineffective. Alternative disposition pathways may be advantageous, providing meaningful life-cycle operational savings, given the low radionuclide levels in the SBS condensate (Class A per 10 CFR 61.55) [4].

Figure 1 indicates that there are two alternatives to the recycle approach for SBS condensate currently available within Hanford Site capabilities. If the baseline recycle approach is ineffective, the only alternative is the return of SBS condensate to the tank farms. However, using the tank farms for disposition of SBS condensate is similar to the baseline, but has a longer recycle path. The Tc-99 in SBS condensate would continue to build to a steady-state concentration, but be distributed throughout a larger volume of waste.

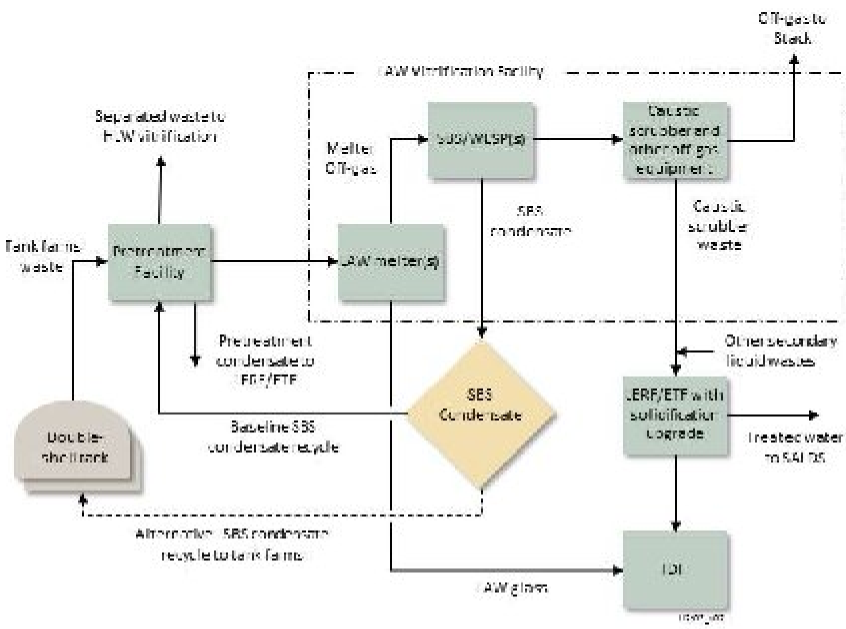

Figure 1. The Currently Available Disposition Paths for Submerged Bed Scrubber Condensate.

A new, second alternative could be to prepare the SBS condensate for off-site disposal. This approach avoids uncertainties associated with recycling by removing SBS condensate, and associated contaminants, from the waste stream to be vitrified, including Tc-99.

The SBS condensate stream as it emerges from the WTP LAW facility condensate tank has been evaluated to be Mixed Low-Level Waste (MLLW), and will be below the Nuclear Regulatory Commission's (NRC) 10 CFR 61.55 Class A waste limits associated with commercial radioactive waste disposal [4]. This enables disposition of the waste to off-site licensed commercial facilities. There are three direct off-site disposal waste form options: liquid, concentrated liquid, solidified concentrated liquid, two commercial waste disposal facilities, and one government low-level radioactive waste disposal facility that could accept the WTP LAW melter SBS condensate. The three waste form options are further described below.

1. **Alternative 1** "Direct Liquid Shipment" – Transfer the SBS condensate from the WTP LAW Vitrification Facility to a waste treatment building (WTB), which would stage the waste for sampling and transport to an off-site disposal facility.

2. **Alternative 2** "Concentrated Liquid Shipment" – Transfer the SBS condensate from the WTP LAW Vitrification Facility to the WTB, which would include an evaporator for liquid waste concentration. Evaporative condensate is disposed on-site. Opportunities associated with employing volume reduction include reduced disposal costs and a reduced number of waste shipments.

3. **Alternative 3** "Solidified Liquid Shipment" – The concentrated SBS generated in Alternative 2 is treated/mixed with a solidification media prior to transport to an off-site disposal facility. Opportunities associated with solidification include reduced transportation costs, as compared to Alternative 1, and potential disposal at the Nevada Nuclear Security Site (NNSS) waste disposal facility. There are no disposal costs currently charged to the U.S. Department of Energy (DOE) waste generator for disposal at the NNSS.

For each alternative, a pre-conceptual design was developed, which includes a material balance, technology selection, equipment sizing, facility hazard categorization determination, and associated process flow diagrams, work flow diagrams, facility layouts, and building layouts. An evaluation of each alternative was performed, which considered regulatory analysis, WTP and tank farms impacts, safety aspects, transportation and disposal, cost and schedule, risks, and opportunities that would result in positive impacts to the project.

The three alternatives are shown in Figure 2. The final design detail of an evaporative unit operation will be made during the project development design phase. For purposes of this study a wiped film evaporator (WFE), representative of thin-film dryer technology, is being used to represent the concentration activity [5].

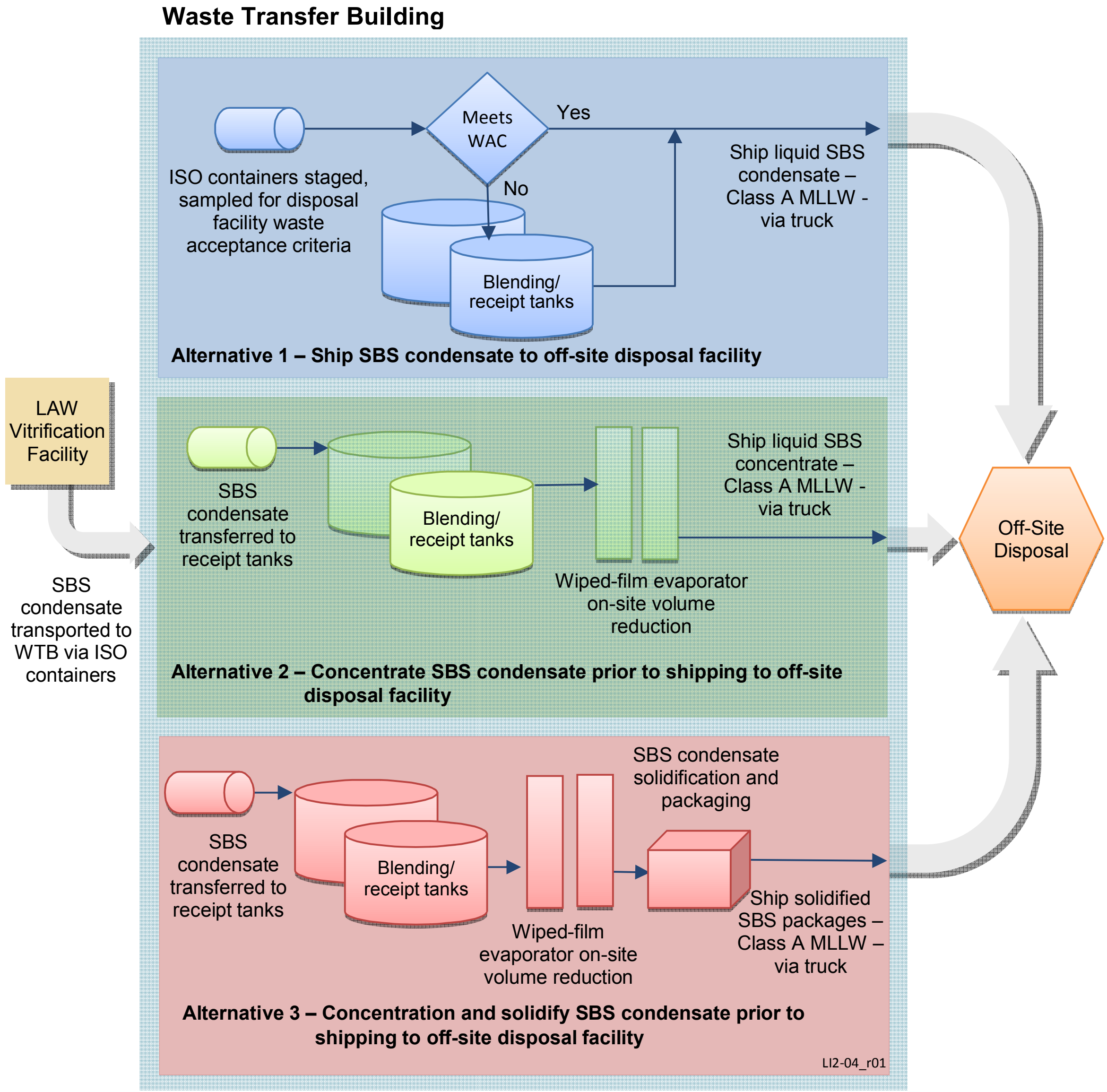

Figure 2. The Submerged Bed Scrubber Condensate Direct Disposal Alternatives.

The WTB will be located near road and rail access for transport from the Hanford Site. Modifications to the WTP LAW Vitrification Facility will be the same for all three alternatives, with sampling and analysis being performed at the WTB.

Transportation and disposal options for each alternative were evaluated for discriminating factors. Transportation options included rail and truck. Trucking the waste to the disposal facility was selected as a basis (versus rail transport) due to the ability to manage the shipments (and reusable containers) to and from the disposal facility. Commercial and government MLLW disposal facilities were identified and evaluated.

Benefits of Off-Site Disposal

The benefits of off-site SBS condensate disposal result in an increase of efficiencies in production and an overall WTP mission life cycle reduction of 0.5 years, realized primarily from increase in processing efficiencies. Savings are also realized from reduction of melter change-outs, reduced WTP operational life, and significant reduction of LAW product canisters. Minimization of environmental risk to the Hanford site would occur by off-site disposal of the long-lived radionuclide Tc-99, and reduced secondary waste handling in Hanford's volume-limited DSTs.

Submerged Bed Scrubber Condensate Direct Disposal Alternatives

Condensate from the WTP LAW Vitrification Facility condensate collection tanks are pumped to a new truck fill load-out station for each alternative, as shown in Figure 3. The liquid will then be transported to a new WTB located outside of the WTP facility boundary, but within the Hanford Site. This facility will be located near road and rail access for transport off the Hanford Site. The modifications to the WTP LAW Vitrification Facility will be the same for all three alternatives.

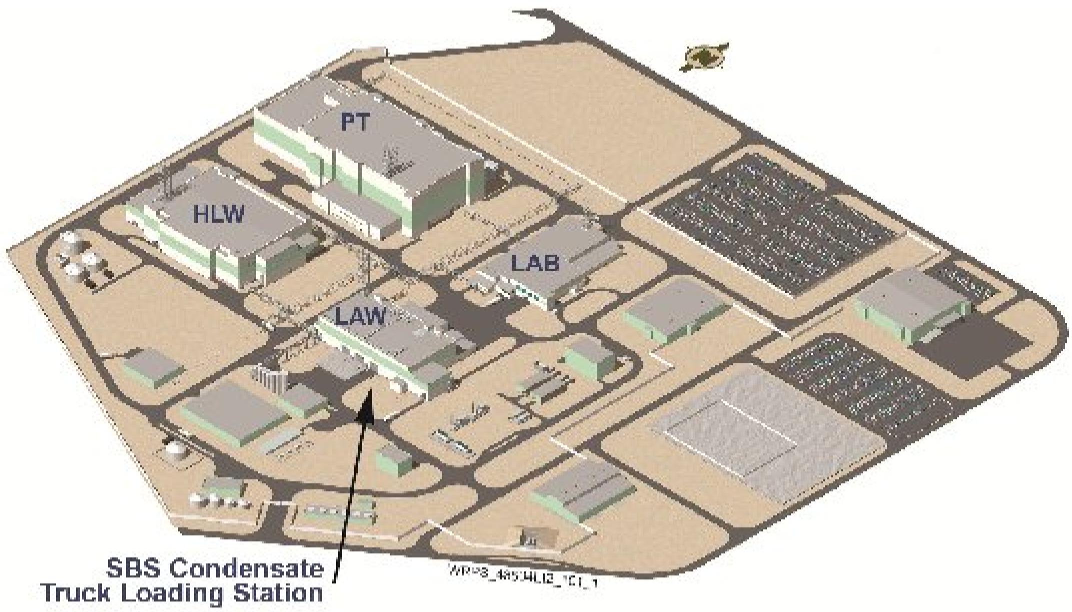

Figure 3. This Figure Shows the WTP Facility Layout SBS Condensate Truck Loading Station Location.

The modifications to the WTP LAW Vitrification Facility (shown in Figure 3) include the following:

- Transfer piping system, including controls and valves, to connect the condensate receipt vessels to the truck loading station.
- Truck loading station, needed to connect the transfer piping to the International Organization of Standardization (ISO) tanks for transfer to the WTB.

- Containment and cover for the truck fill load-out station location, may include collection sump, berm, surveying capability, monitoring capability, and transfer bay.

- Staging area for transfer containers/trucks.

An ISO tank, as shown in Figure 4, is used to transfer the condensate from the LAW Vitrification Facility to the WTB and, for Alternatives 1 and 2, to the disposal facility.

Figure 4. The ISO Tank to be Used for Transport of SBS Condensate.

ALTERNATIVES DESCRIPTION

Alternative 1 – Direct Liquid Shipment

Alternative 1 ships the SBS condensate to an off-site disposal facility with no additional processing. The process control and record samples are collected at the LAW Vitrification Facility prior to transfer to the WTB, as depicted in Figure 5.

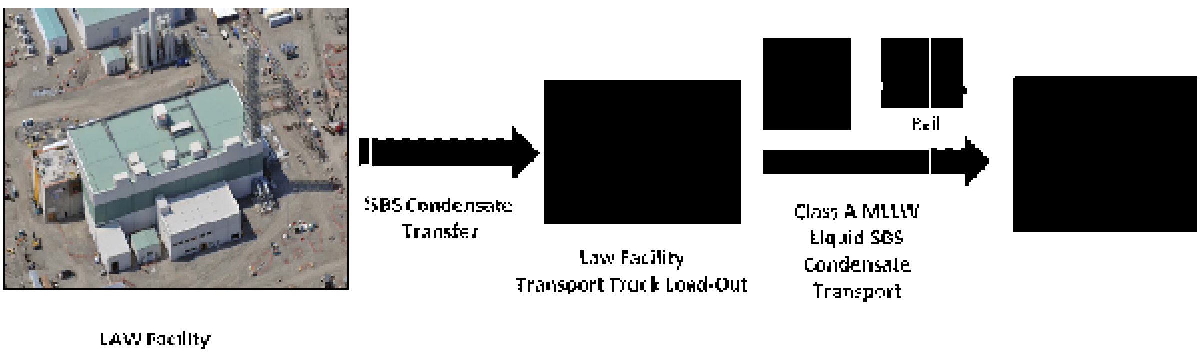

Figure 5. This Figure Shows Alternative 1, Shipping SBS Condensate to Off-Site Disposal.

If the condensate requires blending to meet off-site disposal site waste acceptance criteria (WAC) [6, 7, 8, 9, 10], the containers enter the transfer bay and the SBS condensate is transferred to the receipt/blending tanks. Full ISO tanks are transported to the disposal facility and returned for reuse.

Waste Transfer Building – The Alternative 1 WTB includes a waste transfer station, SBS ventilation system, utilities distribution, and instrumentation and control systems. The WTB contains a large drive-through, over-the-road truck loading bay with rollup doors, and a rail loading bay, which allows ISO tanks to be loaded onto a rail car. The condensate holding tanks are designed as a two-tank system. This allows for one tank to be filled, blended as needed, and sampled, while the second tank is accepting waste.

Alternative 2 – Concentration of SBS Condensate and Liquid Shipment for Disposal

Alternative 2 concentrates the SBS condensate in the WTB using a wiped film evaporator (WFE) [5]. The liquid concentrate is subsequently shipped to an off-site disposal facility. Water evaporated in the WFE is condensed and disposed on-site at the Hanford Effluent Treatment Facility (ETF). A WFE, with 4.65m^2 (50 ft^2) of heat transfer area, is used as the baseline technology for the evaporative process, which will be confirmed in the initial technology development phase of design option analysis. This is depicted in Figure 6.

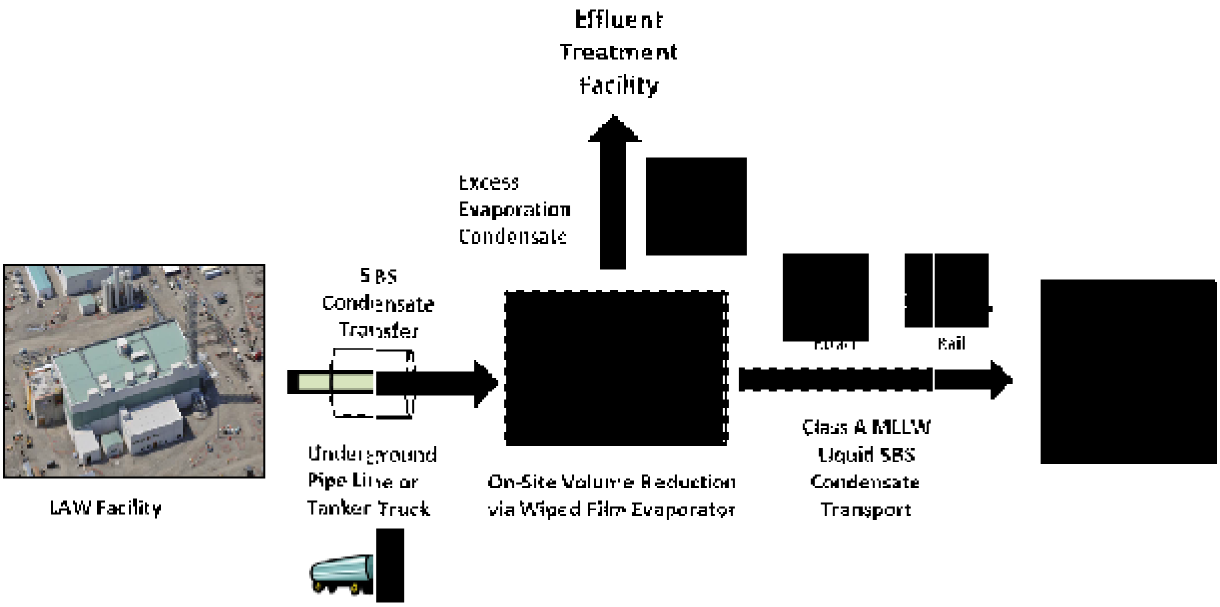

Figure 6. This Figure Shows Alternative 2, Shipping Concentrated SBS to Off-OSite Disposal.

A sample is collected from the receipt tanks and analyzed for process control purposes. The results are used to determine evaporation and processing rates. The WFE concentrate will be below the Department of Transportation Low Specific Activity (LSA-II) requirements for transport on public highways [11]. A sample is collected from the concentration tank to confirm compliance with the off-site disposal WAC prior to shipping offsite. Once confirmed compliant with the disposal site WAC, the full condensate tanks are transported to the off-site disposal facility. Empty ISO tanks are returned to the WTB.

Waste Transfer Building – The WTB is expanded from the Alternative 1 WTB to include WFE units and associated tanks and support equipment.

Alternative 3 – Solidification of Alternative 2 Liquids and Solids Shipment for Disposal

Alternative 3 takes the concentrated SBS condensate, generated in Alternative 2, and solidifies the liquid for transport and disposal in the WTB. Alternative 3 transfers the WFE concentrate from the WFE concentrate tanks to the solidification process. The solidified WFE concentrate is then shipped offsite via over-the-road trucks or rail cars for permanent disposal in a radioactive waste burial ground, as depicted in Figure 7.

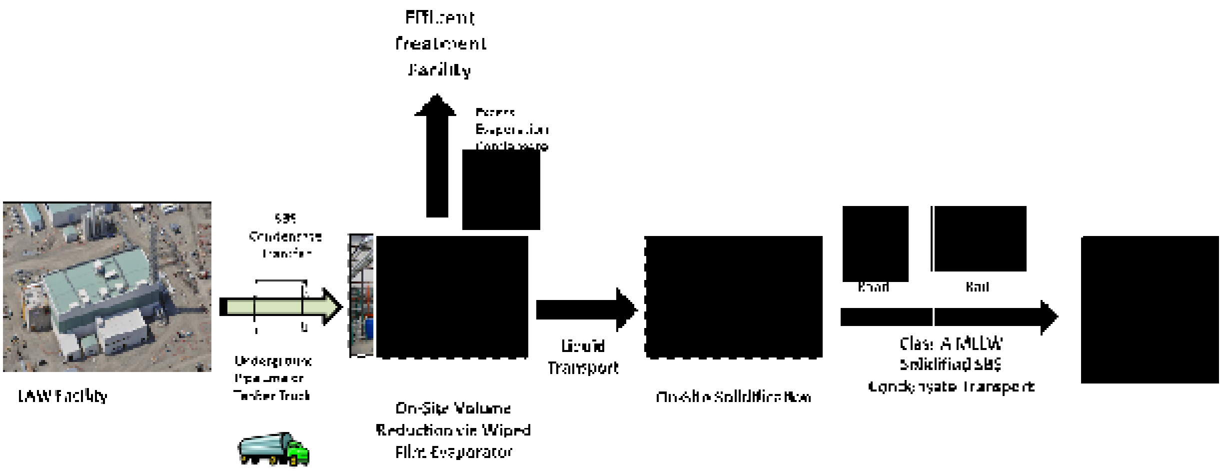

Figure 7. This Figure Shows Alternative 3, Shipping Solidified Concentrated SBS Condensate to Off-Site Disposal.

Waste Transfer Building – The WTB is expanded from the Alternative 2 WTB to include equipment and systems to support the waste solidification system and for the movement, filling, curing, and load-out of soft-sided containers for transport.

The solidification process uses a commercially available solidification agent in a free-flowing powder form that solidifies aqueous liquids. The process requires blending of the concentrated liquid and solidification agent in a mixer, and transfers the mixture by gravity feed into a container for shipment. Soft-sided containers are planned to package the waste for shipment to the disposal facility.

As part of standard processing, a record sample is collected from the WFE concentrate and analyzed prior to mixing with the solidification agent. The system also has the capability to collect a record sample of the solidified mixture for subsequent analysis, as necessary.

TRANSPORTATION & DISPOSAL OPTIONS

Commercial and government low-level mixed waste (LLMW) disposal facilities were identified and evaluated. Three disposal facilities, two commercial and one government owned, were identified that could potentially accept the SBS condensate waste, as depicted in Figure 8:

- Energy*Solutions*, Clive, Utah (Clive) [6, 7]
- Waste Control Specialists (WCS), Andrews, Texas [8, 9]
- DOE Nevada National Security Site (NNSS) near Mercury, Nevada. [10]

The Clive disposal facility was used as the basis for this study for costing purposes; however, each of the disposal facilities listed above will be further evaluated during subsequent phases of the implementation project.

Figure 8. This Figure Shows SBS Condensate Alternative Disposal Locations.

Truck Transportation

Evaluation of truck transport is a function of cost and distance. The primary advantage of truck transport, as opposed to rail, is the level of control of the schedule (transport time, off-loading, and return). Truck transport is available for each of the disposal facilities.

Rail Transportation

Rail transport is only available for shipment to the commercial disposal facilities (Clive and WCS). Because a single railcar can carry roughly four times the freight compared to trucks, rail will be considered.

Although rail costs are approximately 80 percent of the cost of truck transportation, when evaluating rail, the primary issue is the lack of control associated with the schedule. A rail broker could be contracted to assist with keeping freight moving, or a significant amount of support equipment (ISO tanks, rail cars, Intermodal Containers, etc.) would be required.

TECHNOLOGY READINESS

The greatest technical and cost risk in technology development is associated with first-of-a kind application. Although a technology readiness evaluation is planned to occur during the conceptual design phase, technology and associated safety reviews are conducted as part of the SBS project risk evaluation. Project scope definition and schedule were developed taking these risks into account.

Technology elements for SBS condensate direct disposal are summarized in Table I. Critical technology elements (CTE) are identified. Risks and opportunities for technology elements follow the summary table.

Table I. Submerged Bed Scrubber Condensate Direct Disposal Technology Elements

Technology element	New or novel equipment	New or novel application	Critical technology element
Crane to load tanks/boxes	No	No	No
ISO containers to transport waste over roads	No	No	No
ISO containers to transport waste using railroad	No	No	No
Active railroad spur	No	No	No
Sampling capability	No	Yes	Yes
Evaporative capability	No	Yes	Yes
Solidification capability	No	Yes	Yes

Sampling Capability

Sampling capability is a CTE. All waste, liquid or solid, is required to meet the disposal site's WAC. Waste sampling is required to determine waste characteristics whether solid or liquid.

Evaporative Capability

Evaporative capability is a CTE if needed to accomplish off-site disposal volume limitations. Two WFEs ($4.65 m^2$ ($50 ft^2$) heat transfer area), if selected, would be used to concentrate the SBS condensate. This evaporative system technology uses commercial agitated thin-film evaporator technology qualified as a WFE. Testing of the WFE system is needed using SBS condensate simulants. Testing will confirm achievement of concentration levels and constituent parameters. [5]

Solidification Capability

Solidification of SBS condensate waste is a CTE. This solidification technology is needed if the condensate is solidified prior to shipment.

COST AVOIDANCES

Direct disposal of the SBS condensate stream reduces the risks of increasing Tc-99, as well as halides, and sulfate concentration in SBS condensate recycle, and provides opportunities which significantly benefit the WTP project. These benefits include process enhancements, mission risk mitigation, environmental risk mitigation, and cost and schedule savings and avoidances. These benefits result in an increase of efficiencies in production and an overall WTP mission life cycle reduction of 0.5 years. Additionally, savings associated with reductions associated with melter change outs, procurement and use of glass storage canisters, and general facility costs, along with those discussed above bring the total cost savings to over $350 million.

ALTERNATIVE COMPARISONS

Evaluation Results

The evaluation results for each of the areas of consideration are summarized in Table II. The SBS condensate meets the WAC for each of the three disposal facility alternatives. Evaporative condensate meets ETF WAC for Alternatives 2 & 3.

Table II. Hazard Categorization per Alternative

Hazard Category	Alternative 1	Alternative 2	Alternative 3
Transportation	• 5.7 million liters (1.5 million gallons)/year • 300 shipments/year	• 1.26 million liters (333,000 gallons)/year • 67 shipments/year	• 1616 m^3 (57,700 ft^3)/ year solids • 115 shipments/year
Disposal	Liquid SBS condensate to off-site disposal facility	• Liquid concentrated SBS condensate to off-site disposal facility • Evaporative condensate to ETF	• Solidified concentrated SBS condensate to off-site disposal facility • Evaporative condensate to ETF
RCRA permitting [13]	Modification of existing permitting	New or modified permit to treat (concentrate) SBS condensate	New or modified permit to treat (concentrate and solidify) SBS condensate

From a nuclear safety perspective, each Alternative is Hazard Category 3 [12]

ETF = Effluent Treatment Facility
HLW = high-level waste
LAW = low-activity waste
RCRA = Resource Conservation and Recovery Act
SBS = submerged bed scrubber

Risks Evaluation

Risks with potential high severity and/or consequences for implementation of SBS condensate direct disposal, and their potential mitigation measures are provided in

Table III.

Table III. SBS Condensate Direct Disposal Key Risks Summary

Key risks	Potential mitigation measures
The waste characterization of the SBS condensate varies significantly from the current basis of this study.	• As data is available, the design model should be reviewed and adjusted accordingly. • Flexibility of treatment parameters can be designed into the WTB process. • The WTB can be designed to be expandable to accommodate potential facility modifications.
Off-site stakeholder risk, including potential opposition to the public highway transport of high numbers of mixed radioactive/hazardous liquid waste through/to a number of states, as well as the disposal of said waste at a state licensed disposal facility.	• Disposal at a DOE-operated facility, such as the NNSS disposal facility reduces the disposal risk • Conversion of the waste to a solid form would mitigate the potential for leakage of liquids, which would significantly reduce the stakeholder risk.
The off-site waste disposal exemption for disposal of DOE waste at an off-site commercial facility per DOE O 435.1[a] is not obtained [14].	Per DOE O 435.1,[a] the order of preference is (1) disposal at an on-site DOE facility, (2) disposal at an off-site DOE facility, and (3) off-site disposal at a commercial facility. The requirement for an off-site exemption is not required except for disposal at a commercial facility. Disposal at an on-site facility could be viable with further evaluation. Disposal at an off-site DOE facility (NNSS) is a viable solution; however, waste solidification would be required.
The final Tank Closure and Waste Management environmental impact statement does not provide adequate NEPA [b] coverage for the SBS condensate direct disposal activities.	Work with DOE to develop a Supplemental Analysis that will provide necessary NEPA coverage [15].

[a] DOE O 435.1, 2009, *Radioactive Waste Management*, Change 1, U.S. Department of Energy, Washington, D.C. [14]
[b] *National Environmental Policy Act of 1969*, 42 USC 4321, et seq. [15]

DOE	=	U.S. Department of Energy.	SBS	=	submerged bed scrubber.
NEPA	=	National Environmental Policy Act.	WTB	=	Waste Transfer Building.
NNSS	=	Nevada National Security Site.	WTP	=	Waste Treatment and Immobilization Plant.

RECOMMENDATIONS AND FUTURE CONSIDERATIONS

This pre-conceptual study evaluation indicates that direct disposal of the SBS condensate is viable, beneficial to WTP, and warrants further consideration and development. Listed below are recommendations and items for future consideration, which were identified during the initial analysis.

Technology Development

- Consider other solidification media and formulations, provided they are acceptable per the selected disposal facility WAC, from a performance, efficiency, and cost perspective.

Additionally, it is recommended that solidification agents be validated. Bench and small-scale tests should be performed to evaluate the performance of solidification agents and the technology selection.

Programmatic Recommendations and Considerations

- The WTB and WTB technologies could be designed and expanded to accommodate additional waste streams or be co-located to address additional feed streams.
- Consider using area within the WTP LAW Vitrification Facility for the WTB. This could reduce critical path schedule impacts by reducing permitting activities and reduce construction time and cost.
- Other DOE sites have previously obtained an exemption to dispose of their waste at a non-DOE site. Obtaining, reviewing, and applying their exemption documents may result in significant schedule savings, plus the labor costs associated with such an effort.

Design Recommendations and Considerations

- Once the radioactive liquid drain (RLD) waste stream is defined, review the impacts of mixing RLD with the SBS condensate and the effects on WTB technology.
- To help reduce the turnaround times of the laboratory analyses required for process control and record sampling, in-facility laboratory capabilities should be considered.

Waste Transportation and Disposal Recommendations and Considerations

- Further explore rail as a transportation option, which would result in a 20 to 25 percent reduction in cost. Address the issue with the control of ISO containers and rail cars and the timely return from the disposal facility to the WTB.
- The basis of this study is to dispose of the SBS condensate as a 10 CFR 61.55 Class A waste. Consideration should be given to disposing the SBS condensate as a Class C waste, which allows a factor of ten increase in the concentration of long-lived radionuclides and a corresponding reduction in the waste volume to be disposed (by allowing further concentration), from an overall cost effectiveness perspective [4].
- Potential waste treatment options may be available that could immobilize the Tc-99 and open Environmental Restoration Disposal Facility (ERDF) as an option. Since the cost savings associated with transportation and disposal at ERDF would be substantial, it is recommended that discussions occur with ERDF and its regulators to further explore this option [16].
- Additional savings could be realized for Alternative 3 utilizing a WFE system to convert SBS condensate to a solid state without a solidification agent.

CONCLUSIONS

Direct disposal of the SBS condensate stream reduces the risks of increasing halide, sulfate, and Tc-99 concentration. This provides opportunities which significantly benefit the WTP project. These benefits include process enhancements, mission risk mitigation, environmental risk mitigation, and cost and schedule savings and avoidances. These benefits result in an increase of efficiencies in production and an overall WTP mission life cycle reduction of 0.5 years.

If implemented, the potential cost savings realized with enhancements at the WTP offset the costs associated with designing and building the WTB, operating the facility, and transporting and disposing the SBS condensate offsite.

REFERENCES

1. VSL-12R2640-1, 2012, *Final Report, Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet: DM10 Melter Testing*, Rev 0, Washington River Protection Solutions, LLC, Richland, Washington
2. RPP-RPT-52531*, "Submerged Bed Scrubber Condensate Disposal Pre-Conceptual Engineering Study,*" Rev. 0, September 2012, Washington River Protection Solutions, LLC, Richland, Washington
3. SVF-2440, 2012, "*SBS Disposal Pre-Concept Alts.xlsx*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington
4. 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, as amended
5. Artisan, 2010, "Counter-Current Design," http://www.artisanind.com/ps/equipment/rototherm_e.html, queried February 23, Artisan Industries, Inc., Waltham, Massachusetts
6. Energy*Solutions* Clive, Utah "*Bulk Waste Disposal and Treatment Facilities Waste Acceptance Criteria*," Revision 9, Energy*Solutions*, Inc.
7. Energy*Solutions* Clive, Utah "*Containerized Waste Facility Waste Acceptance Criteria*," CL-CW-PR-203, Revision 1, July 2012, Energy*Solutions*, Inc.
8. Waste Control Specialists "*Waste Acceptance Plan for Low-Level Waste Disposal Facilities*," Revision 4, October 2011, Waste Control Specialists LLC
9. Waste Control Specialists "*LLRW & LLMW Processing & Storage Facility Waste Acceptance Criteria*" Revision 3, June 2012, Waste Control Specialists LLC
10. DOE/NV-325, 2012, *Nevada National Security Site Waste Acceptance Criteria*, Rev. 9, Las Vegas, Nevada.
11. 49 CFR 171 through 180, "Hazardous Material Transportation," *Code of Federal Regulations*, as amended
12. DOE O 420.1B, Change 1 (*Facility Safety*), April 2010, U.S. Department of Energy, Washington, D.C.
13. *Resource Conservation and Recovery Act of 1976*, Public Law 94-580, 90 Stat. 2795, 42 USC 6901, et seq.
14. DOE O 435.1, 2009, *Radioactive Waste Management*, Change 1, U.S. Department of Energy, Washington, D.C.
15. *National Environmental Policy Act of 1969*, 42 USC 4321, et seq.
16. WHC-191, 2010, *Environmental Remediation Disposal Facility Waste Acceptance Criteria*, Rev. 2, Washington Closure Hanford, Richland, Washington.