Cesium Management and Disposition Alternatives for the Low Activity Waste Pretreatment System

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Summary

The Hanford Advisory Board, following lengthy discussions and reviews conducted by the Board's Tank Waste Committee with the U.S. Department of Energy (DOE) Office of River Protection (ORP), has completed a review of the proposed Direct Feed Low Activity Waste (DFLAW) process and the Low Activity Waste Pretreatment System (LAWPS). Specifically, the Committee's discussions centered on the proposed management and potential disposal paths of the High Level Cesium Waste resulting from the LAWPS process. This review was performed at the request of DOE-ORP Federal Project Director, Low Activity Waste Pretreatment System, as described in the Hanford Advisory Board 2015 and 2016 Work Plans. Specific areas to be discussed in this work plan item included:

- Are there alternate cesium removal, storage, and disposition technologies that should be considered under Direct Feed Low Activity Waste scenarios?

- What would be the implications for long term cleanup planning on the Central Plateau?

The goal of this document is to identify and review alternatives to the current baseline of removing the High Level Cesium Waste and returning it back to the double shell tanks. Specific consideration was adopted to assure that the alternative selected would not generate an additional waste form, that may have to be stored, for the long-term, on the Hanford Site should associated technical or regulatory issues not be resolved. Alternatives that would have grouted the Cesium for long-term disposable, were considered and discussed by the Committee. Grout options were changed to non-grout disposal systems due to long-term destructive radiation effects on grout. Grout will only last 1-10 years when radioactive cesium is incorporated in it at high Class C levels.

Related alternative options are considered and labelled as a subset of each option.

The table below summarizes the options developed during presentations, discussions and on-site tours with DOE, and in-depth dialogue and analysis by members of the Board. A detailed description and discussion of each option is included in the body of this paper.

Cesium Disposition Option	Option Description	Cs Removal Process	DFLAW Cs Deposition	Regulatory Requirements	Comments
1	Return Cesium back to DST	Elutable Resin	DST then PT and HLW	Acceptable	DFLAW Baseline Process Cesium as HLW
1A	Return Cesium to DST under optimized management plan and Expedite Direct Feed HLW Proposal	Elutable Resin	DST then DFHLW	Acceptable	Return Cesium to DST Expedite DFHLW Proposal
2	Dispose of Cesium in deep geologic Bore Holes	Elutable Resin	Bole Hole	Regulatory Pathway Unknown	Feasibility testing not yet started Many years from being viable option
3	Dispose of Cesium as Class C Waste at a Licensed Commercial Disposal Facility	Non-Elutable Resin	WCS	Requires WIR Determination that Cesium can handled as Class C Waste	If waste can meet Regulatory Requirements, send to WCS Disposal Facility
4	Place Cesium in spent fuel type storage containers or in a Cs Tank for Future High Level Waste Disposal	Elutable Resin	On-Site Storage Awaiting Geological Repository	Long term On-site Storage until HLW Operational	Radiation Hazard No Current Path for Permanent Disposal till HLW Operational
5	Store Cesium in Ion Specific Media for Future Federal Disposal	Non-Elutable	On-Site Storage Awaiting Geological Repository	Long term On-site Storage	No Current Path for Permanent Disposal Waste needs re-processing to meet Repository Requirements
5A	Vitrify Cesium in Storage Container for Future Federal Disposal	Non-Elutable	On-Site Storage Awaiting Geological Repository	Long term On-site Storage	Unproven Technology No Current Path for Permanent Disposal Waste form may not meet Repository Requirements

Conclusions

No options were identified that met all of the general criteria that was established at the start of this effort. The key criteria consisted of not returning the Cesium removed during the DFLAW process back to the DSTs, and not to create a waste form that due to regulatory or other factors that could disrupt the disposal path and could result in long-term storage of this waste form on the Hanford Site.

The only viable option that does not return the cesium to the DSTs is Option 3, Dispose of Cesium as Class C Waste in a Licensed Commercial Disposal Facility. The Federal LLRW site located in Texas and operated by Waste Control Specialists (WCS) has a current maximum Curie limit of 5.6 MCi. Of this limit WCS can currently accept ~2.8 MCi of cesium-137. This equates to 608 cubic meters of Class C waste at maximum cesium-137 concentration for LLW Class C. With optimum processing of the lowest supernatant cesium in the DSTs, approximately 5.6 million gallons could be processed before WCS is full in 2-4 years. This is only a fraction of the 10 plus years of DFLAW operations. This option would require a Waste Incidental to Reprocessing (WIR) determination and other regulatory agreements. If these regulatory requirements are not successfully resolved, allowing the waste to be transported to the Commercial Disposal Facility, the cesium waste canisters could end up stored on the Hanford Site. This disposal path also requires an additional cost of $200-340 million to package, ship, and dispose of cesium waste at WCS. This cost estimate can be found in document # RPP-RPT-57115.

The next acceptable Cesium disposal path is Option 1A which initially returns cesium to the DSTs, it uses an optimized management plan to minimize cesium being extracted several times form tank waste, and also expedites the Direct Feed HLW proposal. The cesium management plan would process low cesium waste first to return less total cesium to DSTs and to free up a couple of DSTs for cesium waste which would be sent to HLW without further cesium removal. In the Direct Feed High Level Waste proposal DST solids are not processed by the Pretreatment facility to any significant extent for the vast majority of tank waste. The unwashed solids are sent directly to HLW for vitrification. Once the DFHLW process is operational, the cesium eluent in the DSTs would be added directly into the HLW feed and vitrified into high level glass. DFHLW bypasses many of the Pretreatment unresolved technical issues.

While this approach does not fully satisfy our primary goal of not returning the DFLAW cesium back to the DSTs, it does not create a new waste form and, with the DFHLW approach does have an acceptable regulatory and technical path forward. This option appears to be the most acceptable from an economic, regulatory, and stakeholder perspective. DFHLW is currently only in the proposal stage, and a lacks a detailed feasibility study and economic analysis. Projected potential savings of this option could range between $5-10 billion.

Discussion of Cesium Disposition Alternatives

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Background

Current DFLAW plans call for using an ion exchange process in the LAWPS to strip high level waste constituents, primarily highly radioactive cesium, from a waste stream from the tank farms creating a low activity waste feed for vitrification in the Low Activity Waste (LAW) facility. The cesium or high level waste would be returned to the existing waste tanks in the tank farms for later processing when the capability to process High Level Waste (HLW) in the Waste Treatment and Immobilization Plant (WTP) is available.

On September 24, 2013, the U.S. Department of Energy (DOE) released the Hanford Tank Waste Retrieval, Treatment, and Disposition Framework (Framework) document. This document describes a strategic framework for addressing the risks and challenges to completing the DOE Office of River Protection (ORP) mission by implementing a phased approach that would:

- Begin immobilization of the tank waste as soon as practicable through the Direct Feed Low Activity Waste (DFLAW) process.
- Process transuranic (TRU) tank wastes for disposal at the Waste Isolation Pilot Plant (WIPP).
- Resolve technical issues for the Pretreatment (PT) and High-Level Waste (HLW) Facilities, including determining how to adequately mix and sample the waste prior to processing, to enable design completion, and the safe completion of construction, startup and operations of these facilities.

Immobilization of the approximately 56 million gallons of radioactive and chemical wastes stored in 177 underground tanks located on Hanford's Central Plateau will occur in the Waste Treatment and Immobilization Plant (WTP). The complexity of both the waste itself as well as the WTP facilities has led to difficult, and to date, unresolved technical issues for the portions of the facility (PT Facility and to a much lesser extent the HLW Facility) that will process the solid portions of the waste. Because the current design of WTP anticipates that all waste will be processed through the PT Facility, immobilization of any waste could not occur per the current plan until the many technical issues involving the PT Facility are resolved. Therefore, an alternative approach for immobilizing waste as soon as practicable, while simultaneously resolving the remaining technical challenges, was identified. By adopting a DFLAW option in which the waste bypasses the PT Facility, waste immobilization could begin significantly earlier than if treatment of the waste is delayed until all technical issues are resolved and the PT and HLW Facilities are completed.

The Framework document divided the 56 million gallons of tank waste into three major categories for treatment:

(1) Low-activity waste;
(2) Potential contact-handled transuranic waste (CH-TRU); and
(3) High-level waste, which is further subdivided into waste not requiring special handling (easier to process) and waste requiring special handling (harder to process).

The low-activity waste consists primarily of the supernate (liquid) portion of the tank waste with most of the solids and radioactivity removed before vitrification, low-activity waste will be the largest tank waste stream by volume (approximately 90% of the volume), but the lowest in radioactivity content (approximately 10% of the curies). Since the low-activity waste makes up approximately 90% of the total volume of waste to be treated, and has the greatest influence on the total duration of the Hanford tank waste mission. The liquid form of this waste makes it susceptible to leakage. The low activity waste is also the tank waste most easily processed through the WTP. In particular, at the present time it is felt that there are no significant technical risks associated with vitrifying this waste stream in the LAW Facility.

Beginning LAW Facility operations before the PT Facility is operational would require a capability to remove the cesium and small amounts of transuranic and strontium-90 solids from the liquid supernatant waste stream so that low-activity waste could be directly fed to the LAW Facility for glass immobilization.

ORP's analyses of this approach indicates that a standalone Interim Pretreatment System Facility would best address this need. It would be located between the tank farms and the LAW Facility and would remove the solids and cesium from the liquid waste stream. In addition, some space has been set aside to possibly remove other radioactive elements or test improvements in currently planned separation techniques. This facility would provide the processing capability to support a DFLAW operation prior to the completion of PT. As this option uses mature technologies, DOE felt that the technical risks associated with this alternative were low.

Disadvantages of Returning Radioactive Cesium to the Waste Tanks

The current baseline for the DFLAW process is to return the high level cesium waste that is removed from the waste stream back to the double shell tanks. The focus of this paper is to identify and discuss potential alternate cesium removal, storage, and disposition technologies to this baseline approach.

Cesium is present in HLW mostly in salt cake and supernatant as stable Cs-133 and radioactive Cs-134, Cs-135, and Cs-137. Cs-134 has mostly decayed away, leaving Cs-135 and Cs-137. Cs-137 decays to Ba-137m which decays to Ba-137. This is the principle gamma source in tanks. There is ~3 to 4 times more total cesium verses radioactive Cs-137.

The return of radioactive cesium to the tanks has numerous disadvantages. These include:

- Cesium gamma emissions are the principle radiation hazard to the work force.
- Cesium makes up about 50% of hydrogen generated in tanks/Pretreatment. 7 of 12 tanks scheduled for DFLAW have high hydrogen generation rates.
- Cesium places more radiation/heat stress on tanks; some nearing their design life.

- Cesium return to the DSTs is more expensive and creates more waste. It is cheaper in the short run and costlier in the long run.

- Returning cesium takes up tank space; less free DST space created.

DFLAW impacts on DST Capacity

The actual space taken up by returning neutralized cesium eluded off the LAWPS cesium resin back into the DSTs is ~9% of the supernatant volume removed. This does not include concentration by evaporation which is probably not the choice operation for many reasons. The approximate remaining 24% volume returned to the DSTs (for every 3 parts volume removed from DSTs, ~1 part volume is retuned to DSTs using DFLAW) is from LAWPS resin pretreatment, LAWPS resin post cesium elution reactivation, and from LAW off gas processes, and ETF brine volume from all sources. This 24% of volume returned to the tanks includes significant reduction by evaporation by a factor of ~2.5 or slightly more. The large majority of this is from LAW off gas.

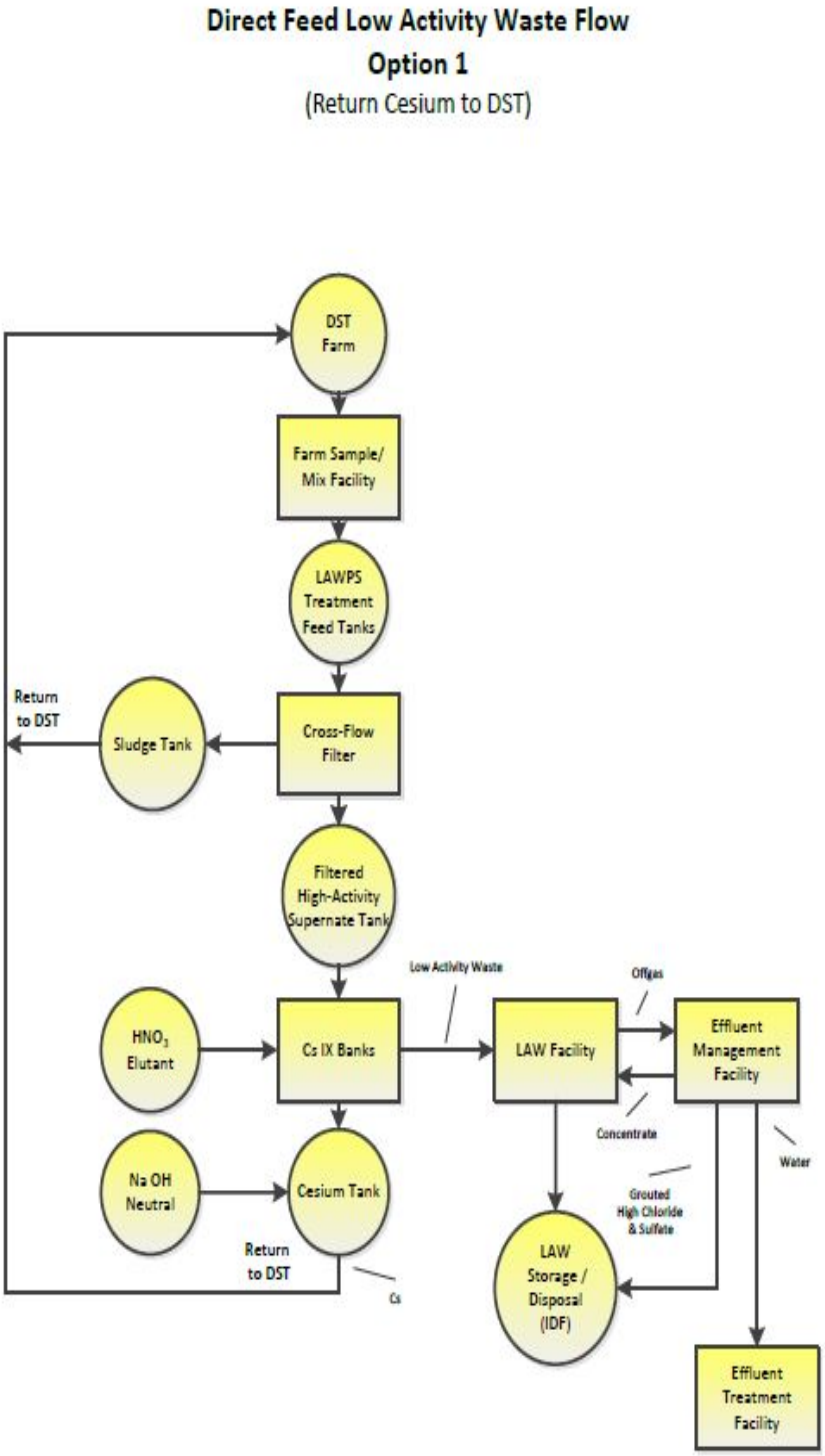
Cesium Disposition Alternatives

As requested by DOE in the Hanford Advisory Board (Board) 2015 and 2016 Work Plan, the Board has conducted an in-depth review of the preliminary design associated with the DFLAW and the possible alternate cesium removal, storage, and disposition technologies that might be considered for use in the DFLAW.

The following alternatives were developed and considered for the disposition of the Cesium removed from the waste steam as part of the DFLAW process.

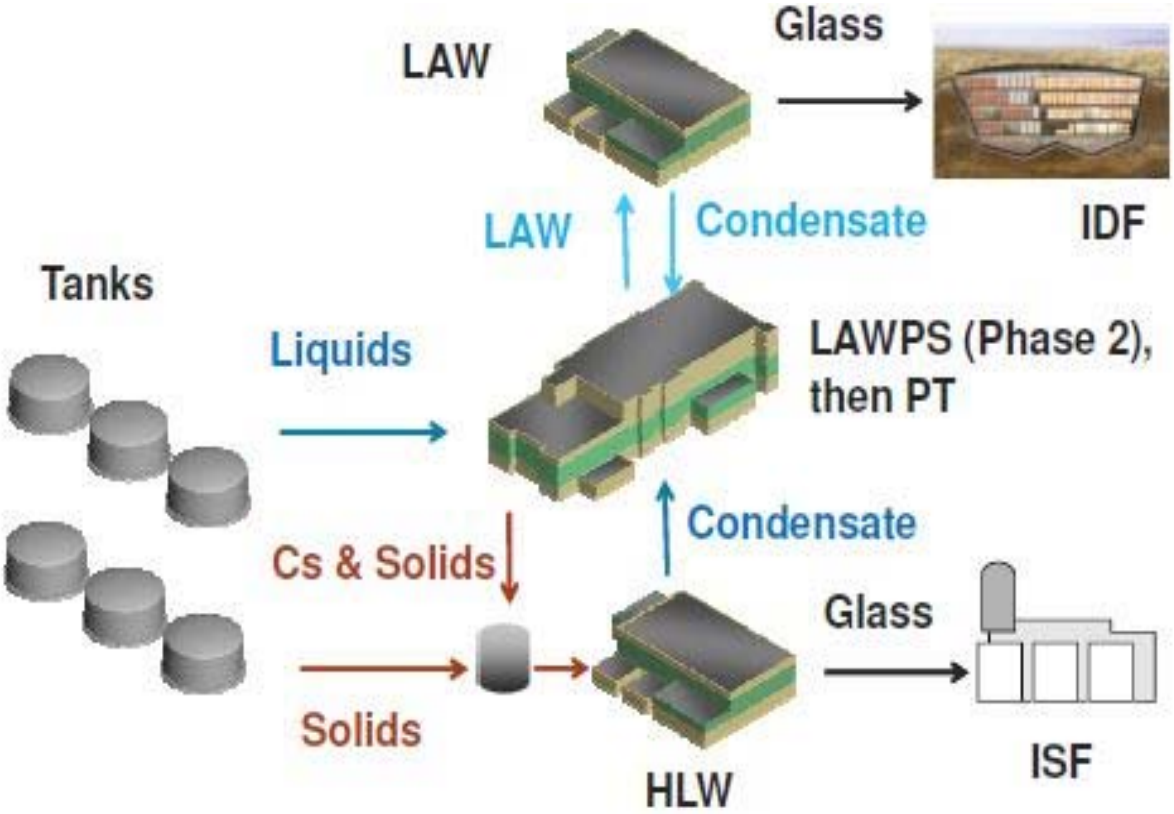
Option 1 - Return Cesium Back to the DSTs (current DOE baseline alternative)

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW Facility. The Cesium is captured using Ion Exchange Resin media, then eluated with nitic acid, neutralized and returned to the DST. Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.



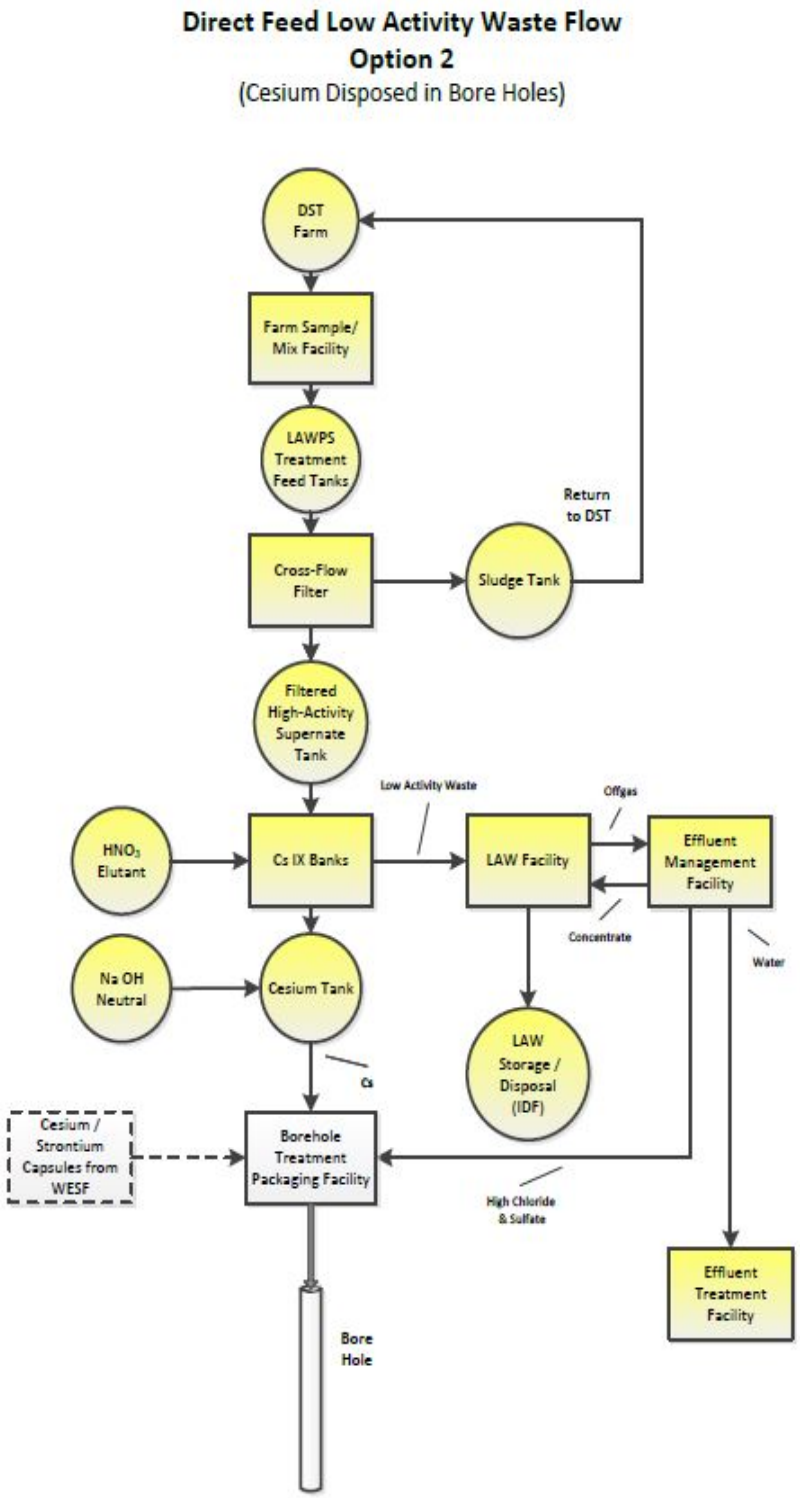
Option 1A – Return Cesium to DSTs with Cesium Management Plan, and Expedite Direct Feed High Level Waste

Process DFLAW baseline with cesium returned back to DSTs using a cesium management to minimize cesium being extracted several times, and expedite Direct Feed HLW. For DFLAW initial runs process low concentration cesium supernatant only (no saltcake in initial runs). Initial process sequence for DFLAW tanks is: 1st tank AP-104, 2nd tank AP-106, 3rd tank AP-103, and 4th tank AP-108, and 5th tank AP-102). Total supernatant processed is 3 million gallons. Designate several DSTs as cesium eluent storage tanks as soon as practical. Expedite Direct Feed HLW process by installing a 100,000 gallon below ground DST tank with some solids/liquid separation capability, large single (replaceable) mixing impeller, hard installed sampling ports, small sampling and ventilation support building, and related underground piping. All tank sludge solids and some related saltcake retain in sludge transfers are to be process by Direct Feed HLW without any pretreatment extraction of any kind for the life of the mission. Once Direct Feed HLW is operational direct all cesium from LAWPS process and cesium eluent previous in DSTs to HLW glass. Once Pretreatment Facility is complete integrate off gas of all glass plants and processes. Expose Pretreatment Facility to minimal entrained solids; only if absolutely necessary for some select HLW glass batches use Pretreatment Facility to process sludge solids.



Option 2 - Dispose of Cesium in Deep Geologic Bore Holes

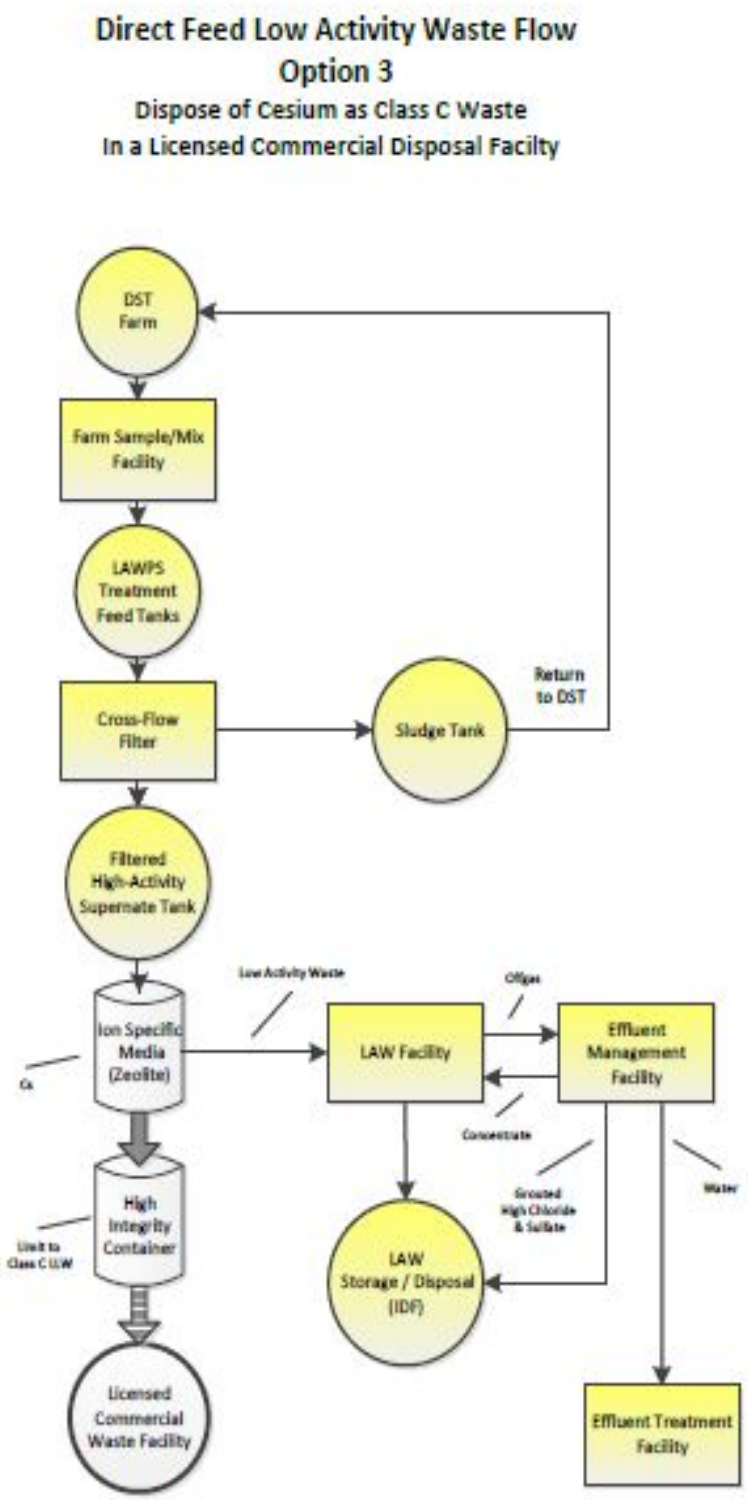
The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW Facility. The Cesium is captured using Ion Exchange Resin media, then eluated with nitic acid, neutralized, and treated and packaged for disposition in a deep geologic Bore Hole. Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.



Option 3 - Dispose of Cesium as Class C Waste in a Licensed Commercial Disposal Facility

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW Facility. The Cesium is captured in LAWPS using zeolite ion specific media and dried and packaged in a High Integrity Container for disposition in a Licensed Commercial Waste Disposal facility. The Zeolite media is low cesium retention to produce Class C LLW. Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through the new Effluent Management Facility and existing Effluent Treatment Facility and 242-A Evaporator in the tank farms.

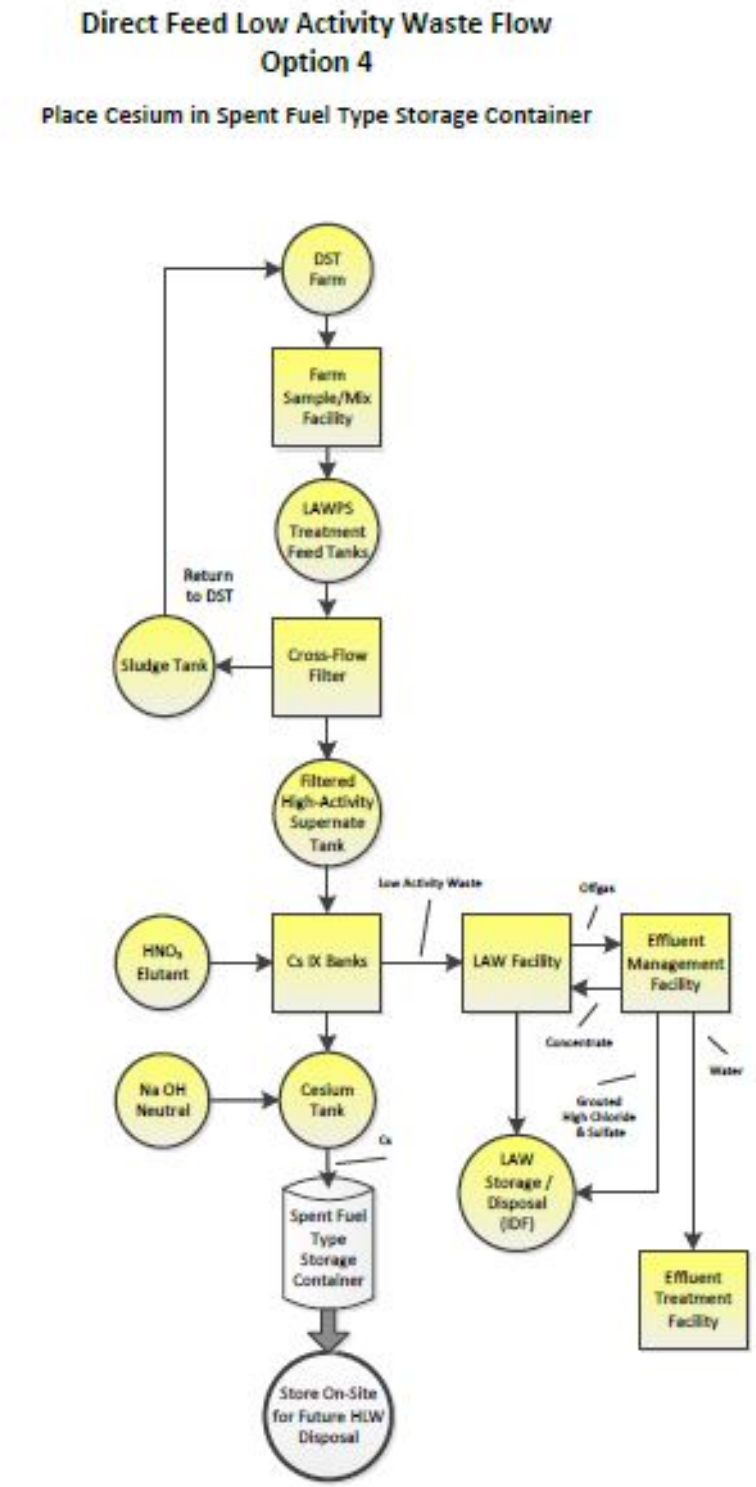
The Federal LLRW site at Texas WCS has a current maximum Curie limit of 5.6 MCi. WCS can currently accept ~2.8 MCi of cesium-137 due to barium-137m progeny. This equates to 608 cubic meters of Class C Waste at maximum cesium-137 concentration LLW Class C.



Option 4– Place Cesium in Spent Fuel Type Storage or a Cs Tank for Future High Level Waste Disposal

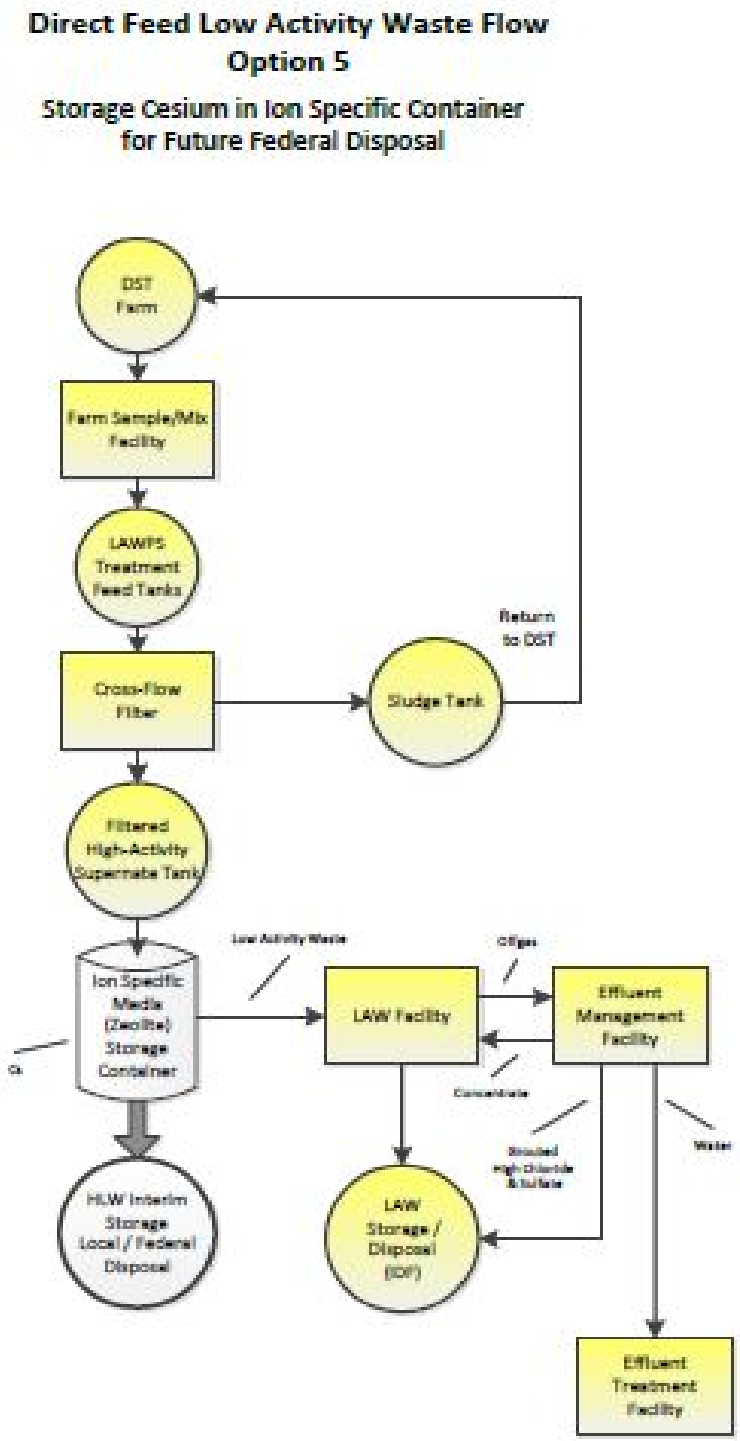
Place cesium eluted from current LAWPS resorcinol formaldehyde baseline resin process with high level off gas waste from LAW in a spent nuclear fuel storage container. Place in a spent fuel type storage container for future high level waste disposal.

An alternative would be to build a purpose built DST to store eluted and neutralized cesium from LAWPS of future disposal in HLW. The cesium tank needed would be about 1.5 million gallons in size and cost approximately $150-200 million.

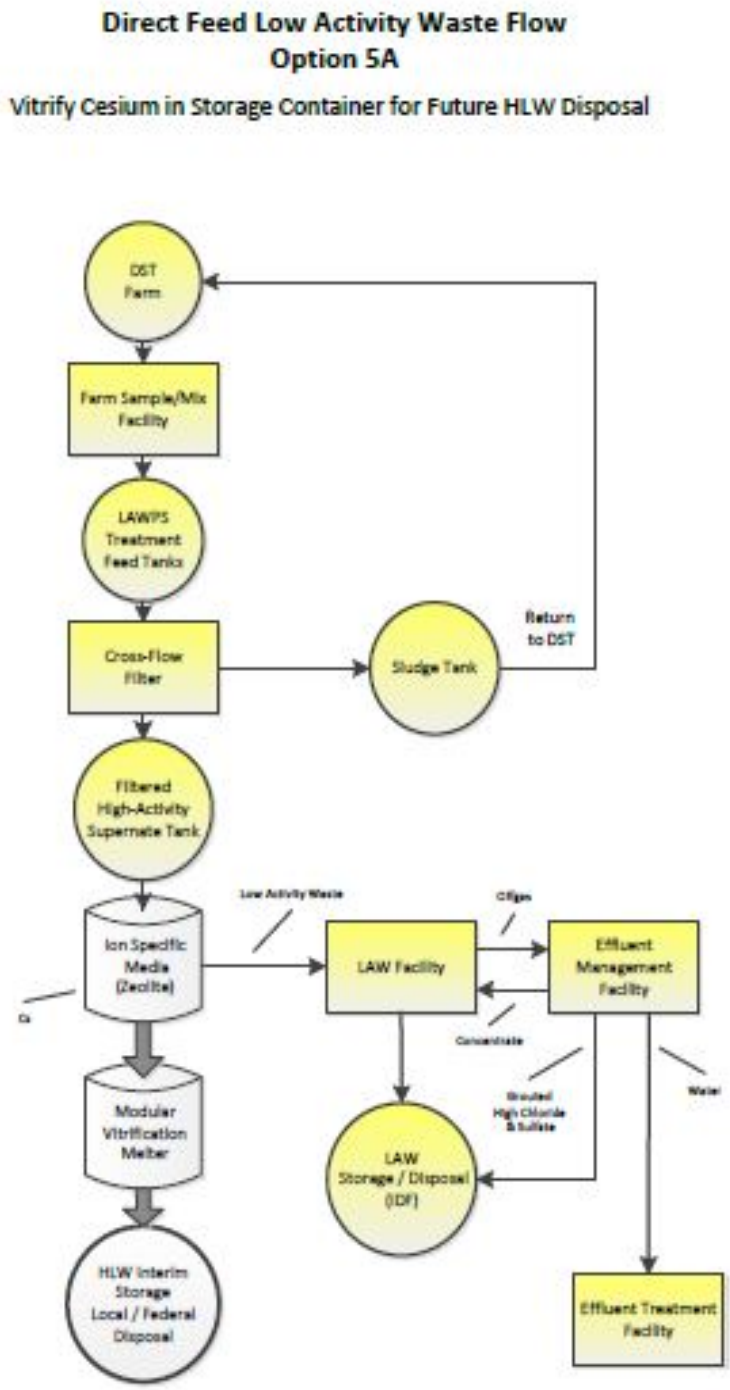


Option 5 - Store Cesium in Ion Specific Media for Future Federal Disposal

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW Facility. The Cesium is captured using a non-elutable Ion Specific media such as crystalline silicotitanate, CST. The cesium could be stored in a high integrity container, HIC. Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.



Option 5A - Vitrify Cesium using non-elutable media, place in spent fuel storage containers for future high level waste disposal

Kurion and SRNL are proposing a modified Kurion system for cesium removal and interim storage in support of DFLAW. Likely a crystalline silicotitanate exchange media that is easily incorporated into glass, Geo Melter.

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW Facility. The Cesium is captured using a non-elutable Ion Specific media, the module containing the Cesium is then vitrified in a modular vitrification melter and stored for future disposal in federal repository. Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.