Waste Retrieval Enhancements to Achieve Preliminary Cease Waste Removal in Savannah River Site Liquid Waste Tanks 9H and 10H – 25348

Jacqueline G. Stetson[1]
[1]Savannah River Mission Completion (SRMC)

ABSTRACT

The Liquid Waste (LW) contractor at the Savannah River Site (SRS) is Savannah River Mission Completion (SRMC). The LW Mission is tasked with processing legacy nuclear waste stored in underground waste tanks for final disposition. The Concentration, Storage, and Transfer Facilities (CSTF) contain 43 active waste tanks and 8 closed waste tanks between the two tank farms, F-Area Tank Farm (FTF) and H-Area Tank Farm (HTF). The first steps in the Waste Retrieval and Tank Closure (WRTC) process are the waste removal campaigns, consisting of either salt dissolution or sludge mobilization. Two tanks that are rapidly approaching the final closure determination and have demonstrated considerable success with salt dissolution are Tanks 9 and 10. The closure of these tanks is a high priority for the LW Mission due to the greater environmental risk they pose since both tanks reside within the water table and contain active leak sites from the primary tank to the annulus space. Tanks 9 and 10 have each recently completed their respective salt dissolution campaigns and achieved the Preliminary Cease Waste Removal (PCWR) milestone.

Both of these waste tanks are built to nearly identical dimensions with a capacity of approximately 3 million liters (791,100 gallons) and are equipped with similar salt dissolution and waste removal equipment. Salt dissolution and waste removal is performed in an iterative campaign process. Each campaign begins with a water addition to the waste tank through their respective downcomers, which falls onto the saltcake surface through wide-angle spray nozzles. The water addition volume for each campaign has varied between approximately 553,000 liters (146,000 gallons) and 1.05 million liters (277,000 gallons) based on the height of the High Liquid Level Conductivity Probe (HLLCP) and the volume of saltcake remaining in the tank. The Commercial Submersible Mixing Pumps (CSMPs) installed in each tank mix the water and waste, which in turn dissolves the soluble saltcake. This Dissolved Salt Solution (DiSS) is then pumped out using the Submersible Transfer Pump (STP) to the hub tank, Tank 11H. The transfer of the dissolved salt solution out of the tank signals the end of that respective campaign. The water addition, mixing, and transfer campaigns are repeated until the bulk saltcake is removed from the tank.

Despite challenges associated with the design of these tanks (cooling coil and support column interference and riser access limitations), Tanks 9 and 10 have exceeded schedule requirements for waste retrieval. There were two key aspects of the operating plan that increased both the efficiency and efficacy of the salt dissolution campaigns: 1) reaching the specific gravity (SpG) of fully saturated solution before transferring the DiSS out, and 2) installing a third CSMP for additional salt dissolution and heel removal. The desired SpG of DiSS is approximately 1.35-1.45 g/mL before a batch is deemed "fully saturated" and ready for transfer to Tank 11H. High saturation is necessary to both make efficient use of limited tank storage space as well as to reduce the number of campaigns performed (and therefore water additions and CSMP run time). Furthermore, the installation of a third CSMP in each waste tank allowed for better mixing pump indexing towards the larger saltcake mounds and an increase in the observed dissolution ratio.

This paper describes how the lessons learned from the waste retrieval efforts in Tanks 9 and 10 have led to efficient retrieval campaigns in waste tanks containing saltcake, and how these lessons may be applied to salt dissolution efforts in other waste tanks during the tank closure process.

INTRODUCTION

The mission of SRMC is to achieve tank closure through the disposition of SRS liquid waste in a safe, timely, and cost-effective manner. SRS Tank Farms receive, store, transfer, and manage radioactive liquid waste generated at SRS. These waste tanks receive radioactive liquid waste, prevent escape of radionuclides and hazardous chemicals to the environment, prevent exposure of facility workers, maintain the waste in a retrievable form, provide evaporator feed, and provide salt solution feed for the Salt Waste Processing Facility (SWPF), where it is processed into a low activity fraction for disposal as grout at the Saltstone Disposal Units and a high activity fraction for immobilization in vitrified glass at the Defense Waste Processing Facility (DWPF).

Since SRS began operations in early 1950, its uranium and plutonium recovery processes have generated liquid radioactive waste. Currently, approximately 126 million liters (33.2 million gallons) of radioactive waste is stored in 43 underground tanks in the F and H areas [1].

Tank 9 and Tank 10 (Figure 1) are both 3 million liters (791,100 gallons) capacity Type I waste tanks located in HTF and were placed into service in 1955 for the storage of aqueous, radioactive wastes produced in the Separations processing of fuel and target material from the nuclear production reactors at SRS. The tank primary shells are 22.9 meters (75 feet) in diameter, and 7.5 meters (24.5 feet) in height constructed from ASTM type A-285B steel with non-stress relieved welds [2]. Tanks 9 and 10 have permanently mounted cooling coils hung from the tank ceiling and supported on the tank floor. The primary shells are set within a full secondary shell that is 27.4 meters (90 feet) in diameter and 10.1 meters (33 feet) in height (Figure 2). Type I waste tanks are considered to be some of the most challenging waste tanks in HTF for removal of solids due to the limited access ports (risers), presence of roof support columns, approximately 6,950 linear meters (22,800 feet) of vertical and horizontal cooling coils throughout each tank, and "field-to-fit" horizontal cooling coil "fences".

A metric for tracking the salt dissolution in waste tanks is the Bulk Saltcake Layer (BSL) height. When supernate coverage is being removed from a waste tank containing saltcake, the BSL is the level within a waste tank where supernate coverage is at its minimum; further liquid removal will uncover sufficient saltcake requiring consideration as Interstitial Liquid Removal (ILR), rather than Free Supernate Removal (FSR).

Prior to salt dissolution with CSMPs in Tank 9, there were 43,500 liters (11,500 gallons) of sludge present with 1.94 million liters (512,000 gallons) of saltcake on top of the sludge layer, with the Bulk Saltcake Layer (BSL) located at 4.83 meters (190 inches).

Prior to salt dissolution with CSMPs in Tank 10, there were 100,000 liters (26,400 gallons) of sludge present with 625,000 liters (165,000 gallons) of saltcake on top of the sludge layer, with the BSL located at 1.60 meters (63 inches).

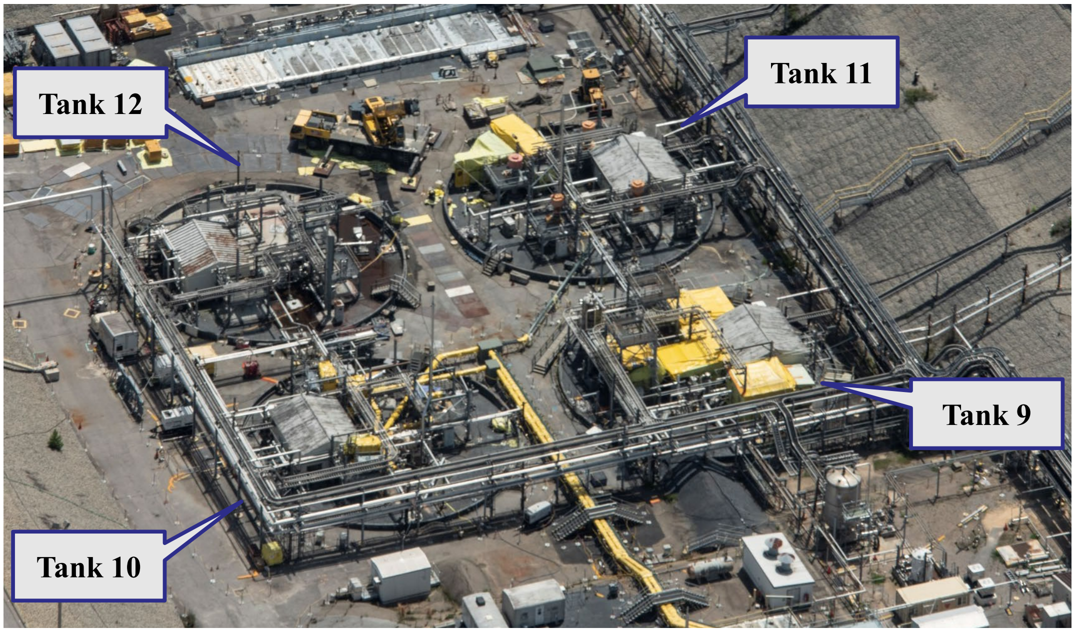

Figure 1. Tanks 9 and 10 Aerial View Within HTF.

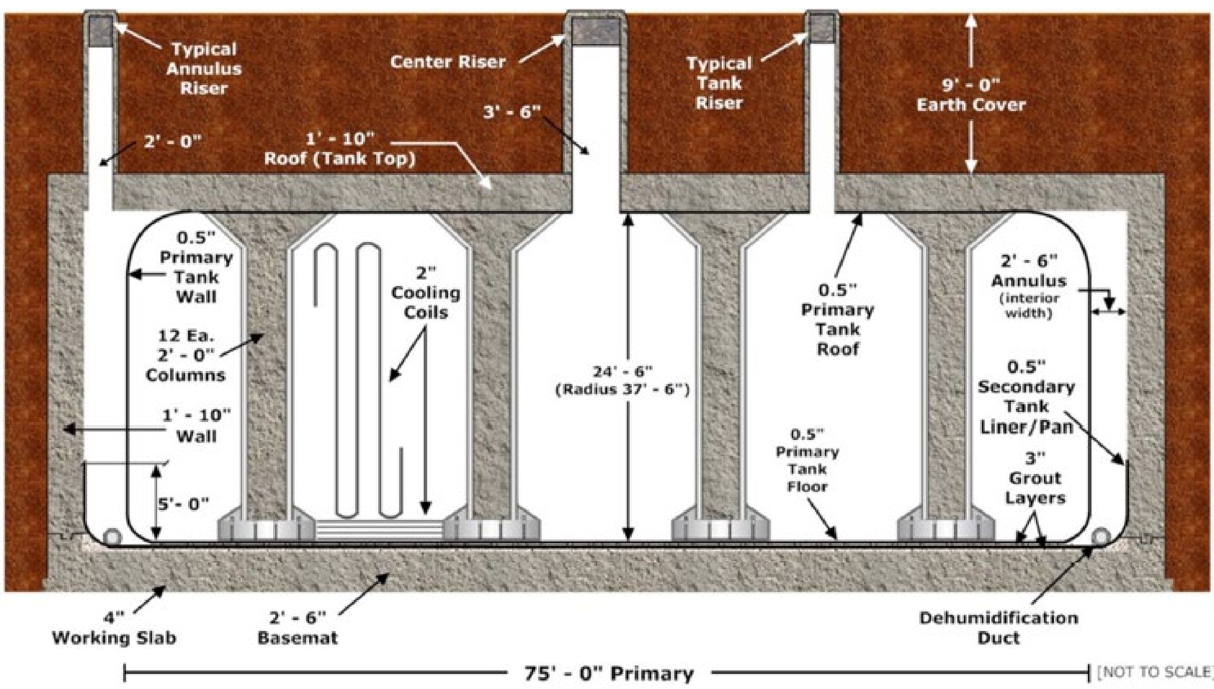

Figure 2. Typical Type I Waste Tank Diagram.

DESCRIPTION OF METHODOLOGY

The primary objective of both waste tank projects was to remove the salt waste remaining in the heel to obtain mutual agreement among the Department of Energy (DOE), the South Carolina Department of Environmental Services (SCDES), and the Environmental Protection Agency (EPA) so that waste removal activities may be suspended and thus enter the Sampling and Analysis phase for final tank closure. This agreement, known as PCWR, is presented to the governing agencies with the entire operational history of the tank and must demonstrate that waste removal occurred to the Maximum Extent Practical (MEP). Operationally, the objective for the salt dissolution campaigns in Tanks 9 and 10 was to transfer the DiSS, insoluble solids, and slurried sludge to Tank 11, the associated receipt tank. From Tank 11, this material would then be sent to SWPF and DWPF to support system planning goals.

The following strategy of salt dissolution was implemented on Tanks 9 and 10: The water source for the tanks was supplied via a hose connection to a downcomer in Tank 9 Riser 8 or Tank 10 Riser 3 for the respective tank. The distribution manifolds contained a flowmeter which allowed for the monitoring of the flowrate and water volume added to each tank. The hose connection points, flowmeters, and independent isolation valves allowed water addition volumes to be monitored, limited, and stopped, thereby preventing continuous makeup to the tanks, which is prohibited per the CSTF Safety Basis (SB).

With the goal of salt dissolution being to dissolve the most salt per campaign so as to ensure the cleaning of the tank in the shortest time frame, it was advantageous to add the largest possible water volume per campaign. The flammability evaluations for each tank assumed that water added is equal to salt dissolved [3, 4]. However, due to the initial BSL height in each tank and the HLLCP height protection limit, initial water additions were limited in volume. The vendor-recommended CSMP submergence is about 2 meters (78 inches). Therefore, during the initial campaigns where coverage was limited to a height less than the minimum submergence due to the limitation from the HLLCP height, the CSMPs would be ran at a lower speed to reduce heating of the waste or overheating of the motor. Once the BSL had been sufficiently lowered, water additions ceased to be limited by the HLLCP protection limit and were then, in the case of Tank 9, limited by the Maximum Salt Dissolution allowed by the respective flammability calculations [3].

Several salt dissolution campaigns were planned for each tank using the CSMPs. Each campaign was expected to be comprised of 48-96 hours of mixing time and up to 24 hours of cooldown time allowance, as well as time allowed for sampling [5, 6]. A density probe would be used to gauge the level of saturation of the DiSS to determine mixing effectiveness. The target density for the DiSS was at least 1.35 g/mL before a batch was deemed fully saturated and ready for transfer to Tank 11. High saturation was necessary to make efficient use of limited tank storage space in Tank 11 and the downstream tanks that would be receiving the DiSS from Tank 11.

For each transfer, DiSS was transferred to Tank 11 until just before the BSL was uncovered, in order to avoid hydrogen generation concerns, marking the end of the respective campaign. The CSMPs would then be lowered to just above the BSL, water would be added, and the next campaign would begin. Iterative campaigns would continue in this manner until salt dissolution utilizing two CSMPs reached the point of diminished effectiveness. A third CSMP would then be installed to remove the remaining salt heel in the tank bottom and to target mounds outside of the Effective Cleaning Radius (ECR) of the original CSMPs.

DISCUSSION OF RESULTS

Tank 9

Approximately 1.94 million liters (512,000 gallons) of salt was removed from Tank 9 using CSMPs during its seven salt dissolution and heel removal campaigns that occurred from November 2023 through PCWR determination in October 2024. The BSL was initially at 483 centimeters (190 inches), but after the final salt dissolution campaign, no saltcake remained. The volume totals and BSL changes in each salt dissolution campaign are shown below in Table 1.

Table 1. Tank 9 Salt Dissolution Results.

Campaign	**CSMPs Operated**	**Water Volume for Dissolution**		**DiSS Transferred Out**		**DiSS Density**	**End of Campaign BSL**	
		kL	***kgal***	***kL***	***kgal***	***g/mL***	***cm***	***in.***
1 (11/23-12/23)	Riser 1 Riser 4	553	146	514	136	1.367	429	169
2 (12/23-1/24)	Riser 1 Riser 4	511	135	617	163	1.369	394	155
3 (1/24-2/24)	Riser 1 Riser 4	579	153	647	171	1.374	363	143
4 (3/24-4/24)	Riser 1 Riser 4	644	170	617	163	1.391	353	139
5 (4/24-5/24)	Riser 1 Riser 4 Riser 6	579	153	1,317	348	1.372	152	60
6 (6/24-7/24)	Riser 1 Riser 4 Riser 6	1,048	277	1,578	417		0	0
Totals	-	**3,914**	**1,034**	**5,290**	**1,398**	-	-	-

At the start of the waste removal campaigns with CSMPs, Tank 9 had a total liquid level of about 564 centimeters (222 inches), a BSL of approximately 483 centimeters (190 inches), and a sludge level of approximately 2.5-5 centimeters (1-2 inches). An additional 223,000 liters (59,000 gallons) of well water was added, making the total liquid available for dissolution approximately 553,000 liters (146,000 gallons). The two CSMPs located in Risers 1 and 4 operated in oscillation mode for ~3.5 days at half speed (900 RPM) since the vendor-provided minimum submergence was not met. Transfer of the 514,000 liters (136,00 gallons) of DiSS from Tank 9 to Tank 11 was then completed in December of 2023. The density of this solution was 1.367 g/mL, indicating very good salt dissolution. The transfer was terminated at a liquid level of 428 centimeters (168.8 inches) as soon as a salt mound was uncovered (Figure 3). The BSL was then estimated to be lowered by 53 centimeters (21 inches), making the post-Campaign 1 BSL 429 centimeters (169 inches).

Figure 3. Camera Inspection Following Tank 9 Campaign 1.

Following Campaign 1, the two CSMPs and the STP were lowered. Campaign 2 was carried out similarly to Campaign 1, again operating the CSMPs at half speed for ~4 days. The DiSS transferred out of Tank 9 post-Campaign 2 indicated very good salt dissolution with a density of 1.369 g/mL. The BSL also experienced a significant decrease, supported by camera inspection, and the CSMPs and STP were again lowered.

At the CSMP heights at the beginning of Campaign 3, the mixing pumps were able to be operated at full speed (1700 RPM) for ~5 days. With the increased speed and mixing duration, the resulting DiSS density from this campaign was slightly higher than the density of the DiSS transferred out of Tank 9 after Campaign 1. During Campaign 3, a mound was noted beneath Riser 8, outside of the ECR of the two operational CSMPs (Figure 4).

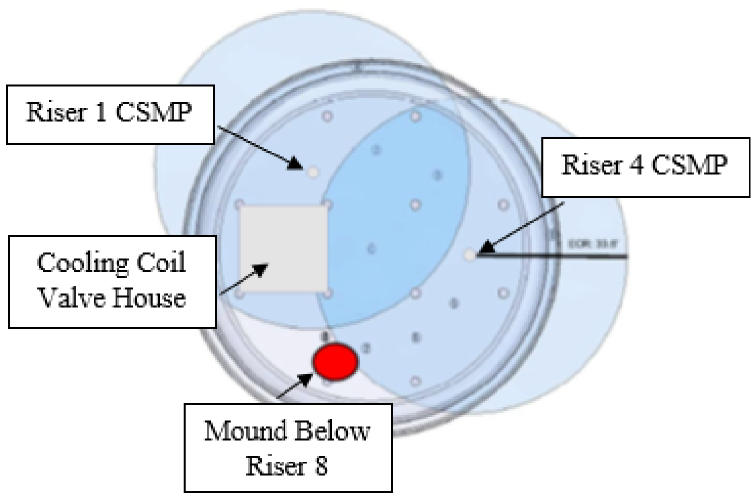

Figure 4. Effective Cleaning Radii of Tank 9 Risers 1 and 4 CSMPs.

For Campaign 4, the two CSMPs were operated at full speed for ~5 days. For the first 72 hours, both CSMPs were indexed towards Riser 8. Then, for the remaining 48 hours, the CSMPs were set to oscillate. The adjusted BSL after this campaign was not significantly reduced from the previous campaign due to salt seen on the tank wall and the relatively unreachable mound below Riser 8.

Before Campaign 5, a new CSMP was installed in Riser 6. The Riser 6 CSMP was indexed towards the previously seen mound under Riser 8 for ~2 days and then oscillated for ~2 days. All three CSMPs in Risers 1, 4, and 6 were then operated for ~4 days. With the addition of this third CSMP, the BSL was estimated to be reduced to a height of 152 centimeters (60 inches). After the transfer to Tank 11 following Campaign 5, no significant mounds were revealed and salt was no longer visible on the tank wall, so the BSL was conservatively set to the liquid level. The resulting density of DiSS transferred out was 1.372 g/mL.

An intermediate mixing campaign (6a) was carried out with all three CSMPs in Riser 1, 4, and 6 operating for ~ 3 days. No DiSS was transferred out follow this pump run. The CSMPs were then all lowered and a full mixing campaign (6b) was run with all three CSMPs in oscillation mode for ~7 days. After the DiSS from Campaign 6 (comprised of 6a and 6b) was transferred out, visual inspection of the primary tank concluded that no saltcake remained in Tank 9.

Tank 10

Approximately 625,000 liters (165,000 gallons) of salt was removed from Tank 10 using CSMPs during its three salt dissolution and heel removal campaigns from August 2023 through PCWR determination in May 2024. The BSL was initially at 160 centimeters (63 inches), but after the final salt dissolution campaign, no saltcake remained. The volume totals and BSL changes in each salt dissolution campaign are shown below in Table 2.

Table 2. Tank 10 Salt Dissolution Results.

Campaign	**CSMP Elevations**	**Water Volume for Dissolution**		**DiSS Transferred Out**		**DiSS Density**	**End of Campaign BSL**	
		kL	***kgal***	***kL***	***kgal***	***g/mL***	***cm***	***in.***
1 (8/23)	Riser 1 Riser 8	863	228	776	205	1.4	46.0	18.12
2 (9/23)	Riser 1 Riser 8	814	215	1,026	271	1.3	11.7	4.62
3 (11/23)	Riser 1 Riser 4 Riser 8	825	218	1,173	310	1.14	0	0
Total	-	**2,502**	**661**	**2,975**	**786**	-	-	-

At the start of the waste removal campaigns with CSMPs, Tank 10 had a total liquid level of about 373 centimeters (147 inches). Since the CSMPs had sufficient submergence, no additional water was added to the tank, making the available liquid volume for dissolution approximately 863,000 liters (228,000 gallons). The two CSMPs located in Risers 1 and 8 operated for ~6 days. Transfer of the 776,000 liters (205,000 gallons) of DiSS from Tank 10 to Tank 11 was then completed. The density of this solution was 1.4 g/mL, indicating very good salt dissolution. The transfer was terminated due to exposure of a salt mound on the West tank wall under Riser 4 at 175 centimeters (69 inches, see Figure 5).

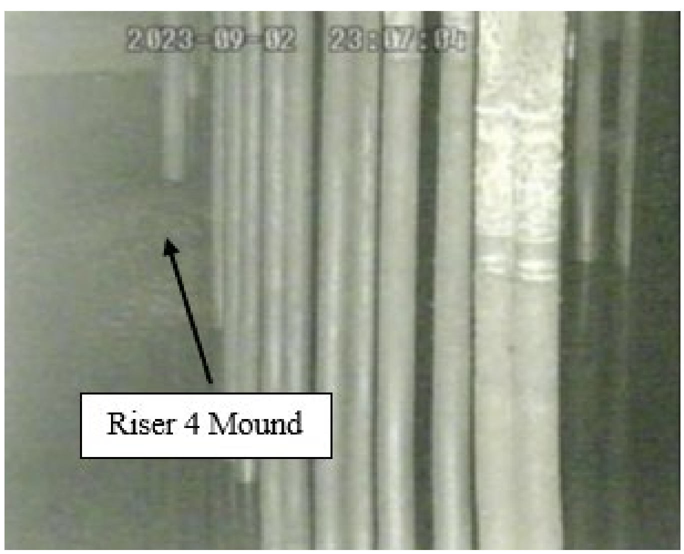

Figure 5. Camera Inspection Following Tank 10 Campaign 1.

For Campaign 2, CSMP suction was lowered and were operated for 4.5 days indexed to the Riser 4 mound. The resulting density of the DiSS was 1.3 g/mL, which was deemed good salt dissolution. The transfer of this material out was again terminated due to exposure of a salt mound on the West tank wall under Riser 4 at the same elevation as discovered after Campaign 1 (175 centimeters, or 69 inches).

Campaign 3 began with Risers 1 and 8 CSMPs ran for a total cumulative time of 6.2 days indexed at the Riser 4 salt mound, interrupted due to software installation and testing of the Riser 4 CSMP. At this time, the DiSS density was 1.13 g/mL, indicating the salt solution was not fully saturated. The Riser 4 CSMP was then started, operated for 4 days, lowered by 76 centimeters (30 inches), and restarted for an additional 4.3 days. The resulting density of the DiSS demonstrated a slight increase to 1.14 g/mL. With diminishing effectiveness, coupled with visual inspection of the primary tank indicating no saltcake remained in Tank 10 (see Figure 6), this was the final salt dissolution campaign in the primary tank before PCWR.

Figure 6. Tank 10 Primary Post-Salt Dissolution Campaigns.

CONCLUSIONS

The Tanks 9 and 10 closure projects have efficiently dissolved and removed enough saltcake and DiSS to achieve the PCWR milestone agreement between the DOE, the SCDES, and the EPA. They are the first two tanks under the SRMC contract to reach PCWR. Due to the success of the nine total salt dissolution campaigns between the two tanks, salt waste was reduced to the maximum extent practical with no saltcake remaining in either tank. Following the favorable results of these campaigns, the methodology described above will continue to be replicated for salt dissolution campaigns in future salt waste tanks undergoing closure projects.

As discussed above and as shown below in Figures 7 and 8, the addition of a third CSMP in both tanks for increased indexing and mixing capabilities resulted in the greatest reduction of the BSL following each. The mounds discovered under Tank 9 Riser 8 and Tank 10 Riser 4, respectively, were both outside of the ECR of the initial two CSMPs installed in each tank. After the final dissolution campaign for both tanks, these previously unreachable mounds had been eliminated. Furthermore, mixing to reach a specific density was proven to be a simple yet effective way to manage tank space and reduce unnecessary water additions.

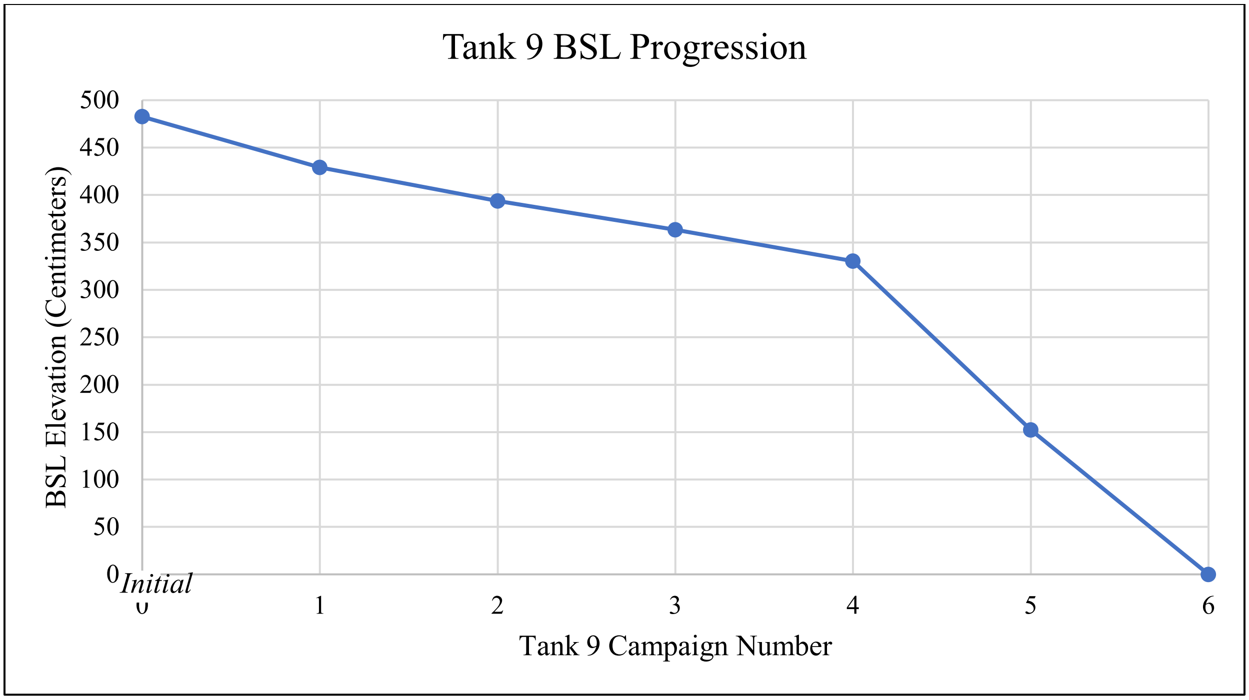

Figure 7. Tank 9 BSL Progression.

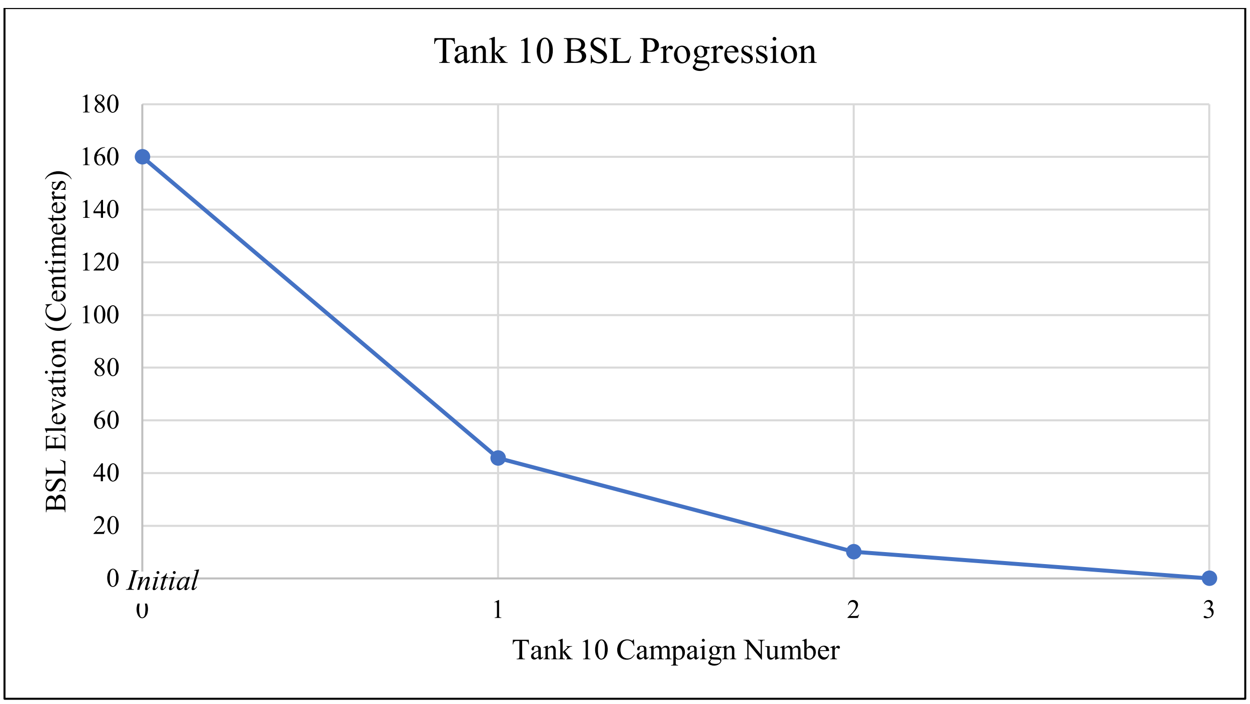

Figure 8. Tank 10 BSL Progression.

The successes in Tanks 9 and 10 have paved a clear path forward for salt dissolution campaigns using CSMPs in waste tanks at SRS and supported the LW Mission goal to accelerate Waste Removal and Tank Closure activities.

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2. M-ESR-H-00613, Revision 0, "Tanks 9 and 10 Accelerated Waste Retrieval Strategy".
3. X-CLC-H-01470, Revision 6, "Tank 9H Gas Release Evaluation for Salt Dissolution Using CSMPs and Interstitial Liquid Removal (ILR)".
4. X-CLC-H-01476, Revision 0, "Tank 10 Gas Release Mode Evaluation".
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