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Estimating Residual Solids Volumes in Underground Storage Tanks – 14198

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ABSTRACT

The Savannah River Site liquid waste system consists of multiple facilities to safely receive and store legacy radioactive waste, treat, and permanently dispose waste. The large underground storage tanks and associated equipment, known as the 'tank farms', include a complex interconnected transfer system which includes underground transfer pipelines and ancillary equipment to direct the flow of waste. The waste in the tanks is present in three forms: supernatant, sludge, and salt. The supernatant is a multi-component aqueous mixture, while sludge is a gel-like substance which consists of insoluble solids and entrapped supernatant. The waste from these tanks is retrieved and treated as sludge or salt. The high level (radioactive) fraction of the waste is vitrified into a glass waste form, while the low-level waste is immobilized in a cementitious grout waste form called saltstone. Once the waste is retrieved and processed, the tanks are closed via removing the bulk of the waste, chemical cleaning, heel removal, stabilizing remaining residuals with tailored grout formulations and severing/sealing external penetrations. The comprehensive liquid waste disposition system, currently managed by Savannah River Remediation, consists of 1) safe storage and retrieval of the waste as it is prepared for permanent disposition; (2) definition of the waste processing techniques utilized to separate the high-level waste fraction/low-level waste fraction; (3) disposition of LLW in saltstone; (4) disposition of the HLW in glass; and (5) closure state of the facilities, including tanks. This paper focuses on determining the effectiveness of waste removal campaigns through monitoring the volume of residual solids in the waste tanks. Volume estimates of the residual solids are performed by creating a map of the residual solids on the waste tank bottom using video and still digital images. The map is then used to calculate the volume of solids remaining in the waste tank. The ability to accurately determine a volume is a function of the quantity and quality of the waste tank images. Currently, mapping is performed remotely with closed circuit video cameras and still photograph cameras due to the hazardous environment. There are two methods that can be used to create a solids volume map. These methods are: liquid transfer mapping / post transfer mapping and final residual solids mapping. The task is performed during a transfer because the liquid level (which is a known value determined by a level measurement device) is used as a landmark to indicate solids accumulation heights. The post transfer method is primarily utilized after the majority of waste has been removed. This method relies on video and still digital images of the waste tank after the liquid transfer is complete to obtain the relative height of solids across a waste tank in relation to known and usable landmarks within the waste tank (cooling coils, column base plates, etc.). In order to accurately monitor solids over time across various cleaning campaigns, and provide a technical basis to support final waste tank closure, a consistent methodology for volume determination has been developed and implemented at SRS.

INTRODUCTION

Alkaline radioactive wastes resulting from the chemical separation of fission products from plutonium and uranium at the SRS are stored underground in carbon steel waste tanks having capacities that range from 2.8 to 4.9 million liters (0.75 to 1.3 million gallons). There are five “types” of waste tanks: Type I, II, III, IIIA, and IV. Each has unique attributes but all are intended to safely contain radioactive waste.

Waste removal activities are currently underway in multiple waste tanks. Strategic planning for each waste removal campaign is dependent on the current waste tank conditions – including the volume and locations of solids accumulations. For chemical cleaning activities, the solids volume is an input to the chemical cleaning calculation.

The ability to accurately determine a volume is impacted by the limited ability to take direct measurements of the solids. Direct measurement is not feasible due to the hazardous environment; therefore, volume determination is performed remotely with closed circuit television cameras. The images are used to create a map of the solids on the waste tank bottom, which is then used to calculate the residual solids volume. Because this process is dependent on the technique and experience of the personnel involved, consistency across waste tanks and among individuals is paramount. Conducting a solids volume estimate of a waste tank is referred to as “mapping” and the individuals that conduct the estimate are known as “mappers”.

DISCUSSION

Training

Individuals qualified to estimate solids volume in a waste tank have completed a classroom training program and demonstrated competence in the field. The training program was implemented to ensure consistency across waste tanks and among individual mapping personnel for the life of the project.

Classroom training consists of students reviewing many different images from the interiors of waste tanks and annuli. Students are shown examples of solids accumulations. The methodology for determining the accumulation relative size and position is discussed. The classroom session also discusses the importance of the residual solids mapping and volume data and how it is used to support the waste removal and waste tank closure processes. [1]

The second element of training involves each student developing a volume estimate using the different methods available. The estimates come from field data gathered by the students or from simulated data provided by Subject Matter Experts (SMEs). SMEs or trained mappers review and critique the work of the students.

Preparation

Available blue prints and drawings of the waste tanks at SRS have been gathered and are available to individuals conducting a waste tank volume estimate. Plan view drawings allow mappers to visually locate accumulations in the waste tank interior using landmarks such as structural columns and vertical cooling coils (see Figure 1). Section view drawings and section details give landmarks that allow for reasonably precise determination of solids height.

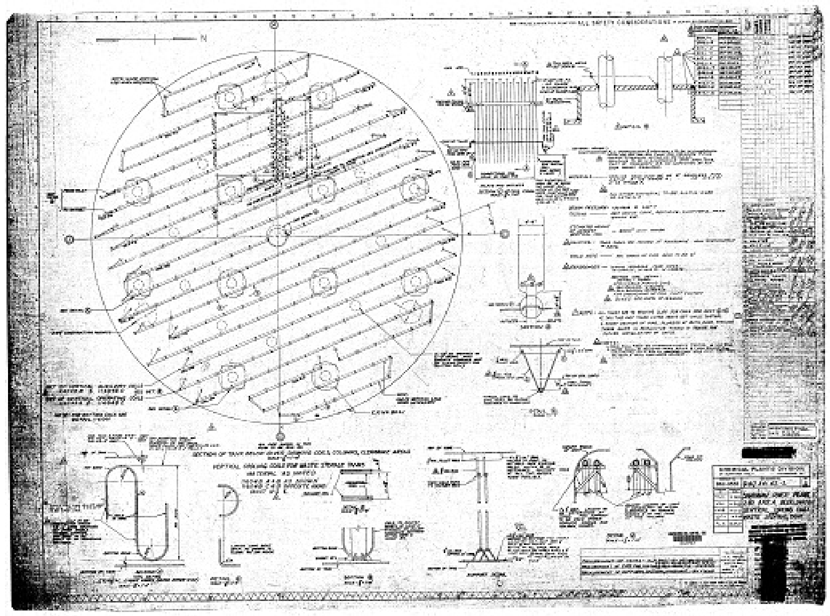

Fig. 1: Blue Prints / Drawings

Liquid Level Mapping

The liquid level mapping method is one way to determine the residual sludge volume remaining on the bottom of the waste tank. This method is normally performed during bulk waste and heel removal activities. The method is performed using pan/tilt/zoom video cameras during the transfer of waste from the waste tank. The mapping process begins with selecting a team of engineers and camera crew to perform the mapping activity. Prior to mapping, the team will put together a waste tank inspection plan to determine if accessible risers are sufficient for cameras and lights to adequately support mapping. If necessary, additional access points must be provided.

Following a satisfactory waste tank entry assessment, video cameras and lights are installed in the accessible risers. The cameras are lowered to an optimum elevation based on the location of the solids. As the liquid transfer begins, the mapping team will monitor a live camera feed of the inside of the waste tank. Mapping begins at a level just above the expected height of solids. As solids begin to appear a hand sketched contour map is created using either a blue print drawing of the waste tank or engineering calculation paper with a scaled grid across the waste tank area (see Figure 2). General practice is to take a new reading in each area for every 76 to 101 mm (3 to 4 inches) of waste tank exposed, although this may vary depending on the stage of waste removal or situation. Cooling coils, tank columns and support bases, Submersible Mixer Pumps (SMP), Submersible Transfer Pumps (STP) and the transfer pump caissons are used as reference points and landmarks to estimate exposed solid accumulation areas as accurately as possible.

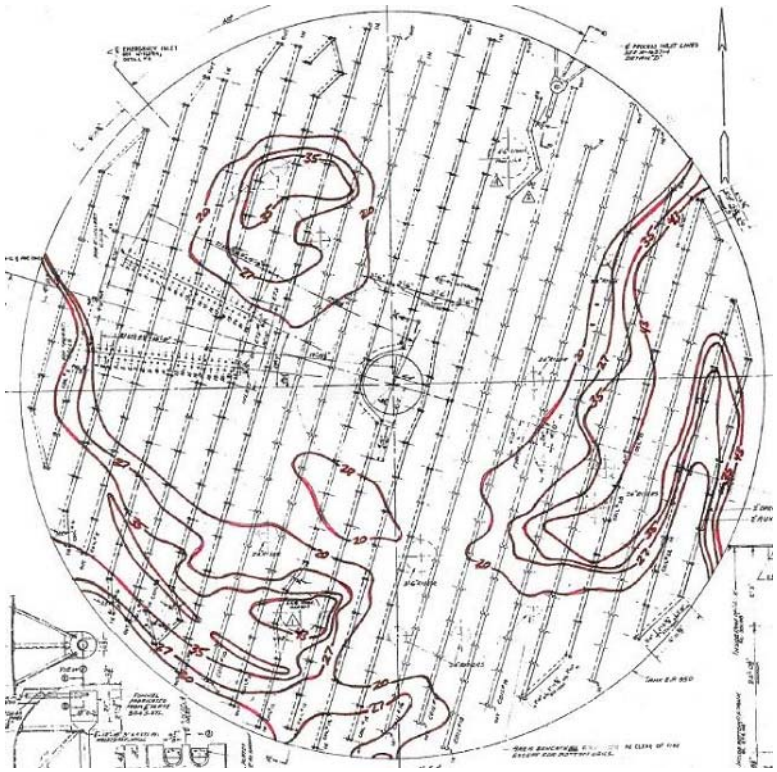

Fig. 2: Hand Sketched Contour Map

The heights of the solids are assessed by obtaining liquid levels using radar level transmitters, reel tape, and tank landmarks. At lower liquid levels the radar and reel tape are typically known to give erroneous readings due to the waste tank obstructions and equipment limitations. Therefore, at lower levels, landmarks are more reliable when obtaining liquid levels and height of the solids at lower liquid levels. If necessary, videos are reviewed and areas of the waste tank are re-evaluated. Mapping at low levels can also be instrumental in the investigation of material balance differences.

A post review is typically done about 24 hours after the transfer when visibility improves as a result of allowing time for the suspended solids to settle, exposed solids to dry, and vapor to clear (see Post Transfer Mapping Method section). The team will go back and take another series of videos to confirm the areas and heights of the solid accumulations and to modify the map accordingly.

Once the areas and heights of the solids are collected and confirmed they are entered into a computer spreadsheet. The computer spreadsheet is utilized to calculate a total waste tank volume estimate. It is essential that the team review and agree with the spreadsheet data entry. The team will then generate a waste tank volume estimate report. [2]

Post Transfer Mapping Method

This mapping method is primarily utilized after heel removal activities are complete. This method relies on video and still digital images of the waste tank after the waste transfer is complete to obtain the relative height of solids across a waste tank in relation to known and usable landmarks. Due to the uncertainty associated in determining the solids heights under the liquid surface, minimal liquid conditions are best when performing this mapping method. Lower liquid levels mean that a majority of any residual solids accumulations are exposed for viewing. Also lower liquid levels increase visibility toward the waste tank bottom. This method has been used numerous times to observe solids spread across the waste tank floor beneath several centimeters of liquid. [3]

Once the liquid level has been reduced as much as possible and the solids have fallen out of solution, the team can begin installing lights and cameras in the waste tanks. Video and photographs are taken inside the waste tank area at designated elevations, typically high, med, and low-level. Usually, photographs are taken to capture 360 degree views of the waste tank floor from the riser. This process is repeated multiple times at different heights and in other accessible risers.

A catalog of photographs is created by risers accessible during the mapping campaign. Once the photographs are taken, the team will evaluate them using widescreen high definition monitors and picture enhancement software to adjust color, contrast, and brightness to provide the best views possible. Known landmarks are identified inside the waste tanks depending on the tank type. As an example, the floor of a Type IV waste tank has 69 lifting plates that measure 305 mm by 305 mm by 13 mm (1 foot by 1 foot by ½ inch) arrayed in a grid pattern across the floor. Figure 3 provides an illustration of the lifting plates found in Type IV waste tanks.

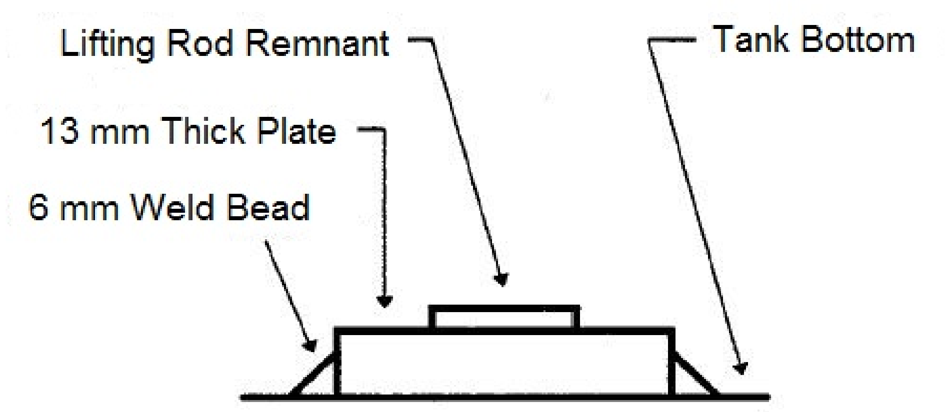

Fig. 3: Lifting Plate Elevation View (Not To Scale)

Using the known landmarks, a criteria table is created to assign height values in mm to the residual solids. Table 1 is an example of a criteria table used in Type IV waste tanks.

TABLE I: Solids height criteria

Material height (millimeters)	Criteria
3	Dusting of Solids evident with some clean steel floor visible.
6	Sides of lifting plate visible. Solids are mostly well below the top of lifting plate.
13	The shape of the lifting plate is clearly visible but the material appears to be the same height as the top of the lifting plate.
19	Shape of lifting plate can be discerned through solids.

In the case that landmarks are not available or usable in the waste tank, other landmarks with known dimensions can be inserted to collect additional height measurements. Landmarks may be as simple as a pole with marked height dimensions or as complex as a remotely controlled robotic crawler device (see Figure 4).

Fig. 4: Reference Heights On Tank Crawler

Lights and cameras are installed by the team and the landmark is placed in the waste tank to survey designated portions of the tank. It is important to ensure the landmark is placed on the waste tank floor. For example, a crawler should dig its wheels or claw down to bare tank floor to ensure the accuracy of the measurement. Height measurements are logged with their corresponding location and video time stamp. This information is recorded on a hand sketched map using either a blue print drawing of the waste tank or engineering calculation paper with a scaled grid across the tank area with the best area and height estimates. Any area in question will be re-evaluated and compared against specific video and photographs if necessary.

Once the areas and heights of the solids are collected, they are entered into an Excel spread sheet. The Excel spread sheet is utilized to calculate a total waste tank volume estimate. It is essential that the team review and agree with the Excel data entry. The team will then generate a waste tank volume estimate report.

Final Residual Solids Mapping Method

Final Mapping is conducted as a part of final waste tank closure efforts. At the point of Final Mapping, all liquid has been evaporated from the waste tank. High resolution photographs are taken from the accessible risers to give the clearest views available of the waste tank. Final sampling efforts in the waste tank involve deploying one or more robotic crawlers to collect small amounts of residual solids. Cameras on the crawlers allow for up close observations of the solids. [4] Camera footage obtained by the crawlers during sampling is data used to generate the final volume estimate. Final Mapping is also performed by a team of qualified individuals. The team reviews various sources of data including the high resolution photographs and crawler video.

The high resolution photographs used in Final Mapping are collected by suspending a camera at three elevations in the waste tank and taking pictures every approximately 20 degrees while the camera is rotated. This results in a full 360 degree view of the waste tank from floor to ceiling (see Figure 5). The pictures are of such high resolution that individual areas can be enlarged and clearly displayed on a large monitor.

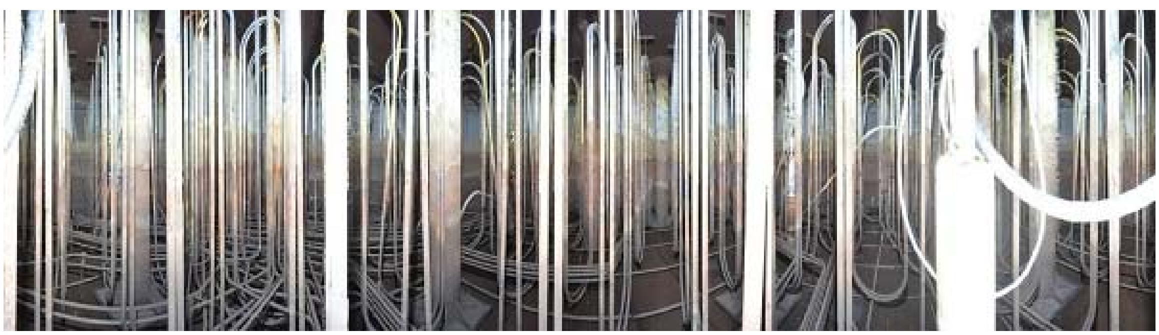

Fig. 5: High Resolution Photographs of Tank Interior

Data Processing

A hand sketched map of the remaining solids is generated by the mapping team in a collaborative effort. The map data is then transposed to a computer spreadsheet. The spreadsheet is verified and checked by an independent source per SRS site procedure.

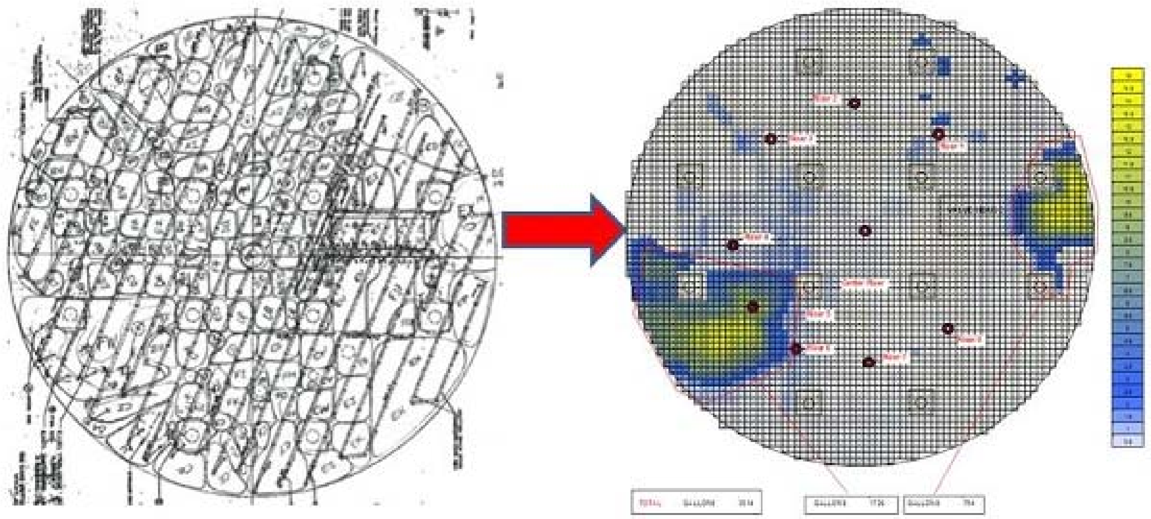

Fig. 6: Hand Sketch Transposed To Spreadsheet

The team will then assess the uncertainty in the volume calculation. The mapping team will assign a low end volume estimate, a high end volume estimate, and a “best” estimate for each area. If landmarks are not visible, then there will typically be a larger range between the low end estimate and high end estimate because of greater uncertainty in the solids heights. These values are then compared to the original volume estimate and a percent difference is found. This percent difference is utilized as a measure of the uncertainty and variability in the mapping process. The team will then generate a final waste tank volume determination and uncertainty report. The final volume report contains such information as the waste tank final volume estimate, tank mapping methodology, images of the waste tank interior, mapper’s tank sketch, computer spreadsheet model, and volume uncertainty discussion. [1]

Future Technology

Advancements in laser mapping technology show the potential to partially automate solids volume determinations as well as decrease the uncertainty of results. A laser mapping system has been researched by Engineering at SRS. Additional testing of the laser scanner is required to determine if the scanner could be used in the volume estimation applications at SRS.

CONCLUSIONS

Mapping and volume determination results provide important information that is used throughout the waste removal and waste tank closure processes. During waste removal, the residual solids configurations following each campaign are key inputs to the successive campaign mixing strategies. Mixer discharge jets are typically aimed at residual solids mounds to erode and suspend solids into a slurry for transfer out of the waste tanks. If chemical cleaning is selected, the residual solids volume and configuration are inputs to the chemical cleaning flowsheet and strategy. The residual solids volume remaining after each waste removal and cleaning campaign is one metric that is typically portrayed graphically to demonstrate overall waste removal efficiency in a waste tank as shown in Figure 7.

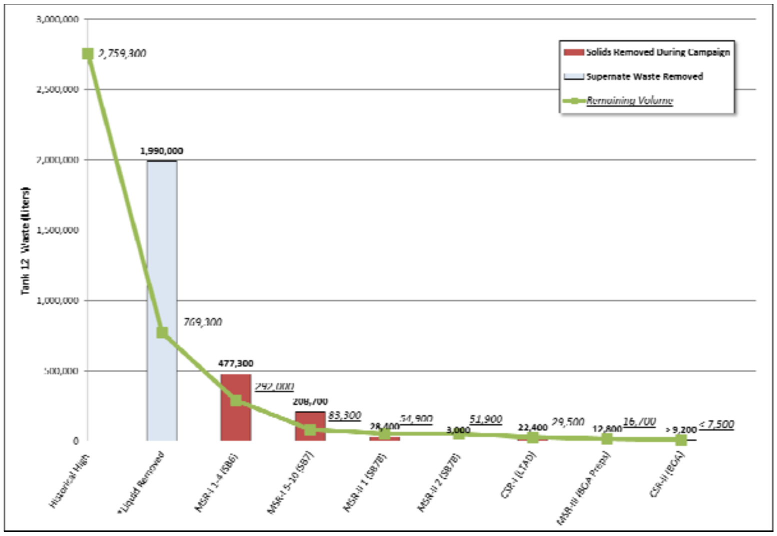

Fig. 7: Residual Solids Volume Graph – Example

Following waste tank cleaning efforts, the residual solids configuration and volume are inputs to sampling and analysis plans. In order to represent and characterize the residual solids in the waste tank, a stratified random sampling with volume proportional compositing approach is used. [5] In essence, the residual solids configuration and volume determines the sample locations and required sample volume from each location. Figure 8 is an example of a residual solids map depicting sample locations (shown in red).

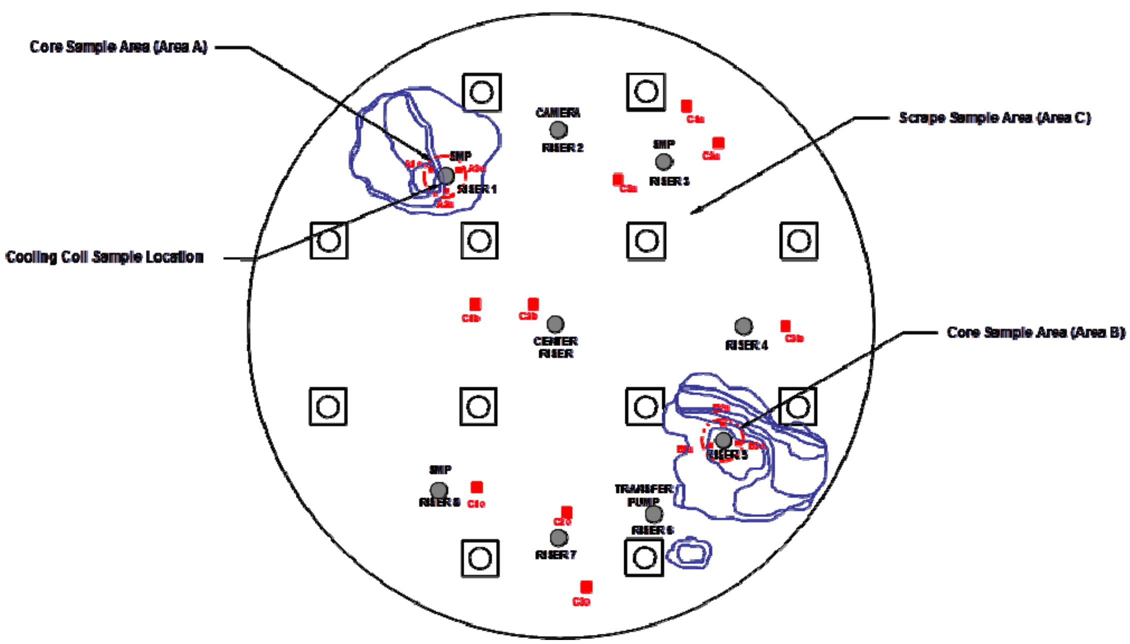

Fig. 8: Sample Locations Shown On Residual Solids Map – Example

Residual solids volume and sample analysis results are used to calculate the final inventory of radioactive and chemical contaminants in the waste tank at closure. This final inventory is an input to the special analysis to demonstrate regulatory compliance with waste tank closure performance objectives. In summary, mapping and volume determination results provide essential data that is integrated into each key step in the waste removal and closure processes.

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