Groundwater Monitoring Optimization of Post Closure Waste Sites at SRS – 13184

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ABSTRACT

Groundwater monitoring at the Savannah River Site (SRS) is required at dozens of waste sites and includes sampling at over 1,000 monitoring wells. The expected longevity of groundwater contamination and associated groundwater monitoring and reporting constitutes a significant long-term cost that represents an increasing proportion of the environmental management budget as surface waste units are closed. Therefore, a comprehensive evaluation of the monitoring program for eighteen regulated waste units was conducted to identify areas where monitoring could be optimized. The units evaluated varied considerably in the scope of monitoring; ranging from two wells to hundreds of wells. In order to systematically evaluate such disparate monitoring networks, SRS developed a decision-logic analysis using flow sheets to address potential areas of optimization. Five areas were identified for evaluation, including: (1) Comparison of current monitoring to regulatory requirements, (2) Spatial distribution, (3) Temporal sampling, (4) Analyte requirements, and (5) Reporting frequency and content.

Optimization recommendations were made for fifteen of the eighteen groundwater units. The spatial evaluation resulted in recommendations to suspend sampling in 79 wells and add sampling at 16 wells. The temporal evaluation resulted in recommendations to reduce the number of well visits per year by 504. Analyte reductions were recommended at three groundwater units, with increases at three other units. Reporting frequency reductions were recommended for five units. Approximately $700,000 (direct dollars) of potential annualized cost savings were identified for these groundwater units, provided all recommendations are approved. The largest area of savings was associated with reducing the reporting frequency. The optimization approach has been presented to the EPA and South Carolina Department of Environmental Control (SCHDEC), with unit-specific recommendations approved for all five units presented. This approach can be expected to be highly successful for sites with rich historical data sets and where the requirements in regulatory monitoring plans can be negotiated.

INTRODUCTION

A comprehensive environmental characterization, remediation, and monitoring program has been implemented at the SRS. Operational facilities have groundwater monitoring conducted to meet various state and federal requirements. Historic waste sites and groundwater plumes are characterized, remediated, and monitored in compliance with the RCRA permit requirements (SCDHEC 2003) and the CERCLA process (FFA 1993). Regulatory monitoring requirements vary for individual groundwater units. For RCRA units, groundwater monitoring is conducted to satisfy the compliance monitoring and corrective action requirements of the South Carolina Hazardous Waste Management Regulations and specific Part B Permit conditions. For

CERCLA units, groundwater monitoring is required early in the CERCLA process as part of contaminant characterization as well as later in the process to assess the effectiveness of the selected groundwater remedies.

Groundwater monitoring at SRS is extensive. Plumes from various waste units and facilities have commingled and formed fourteen areas of groundwater contamination (Figure 1).

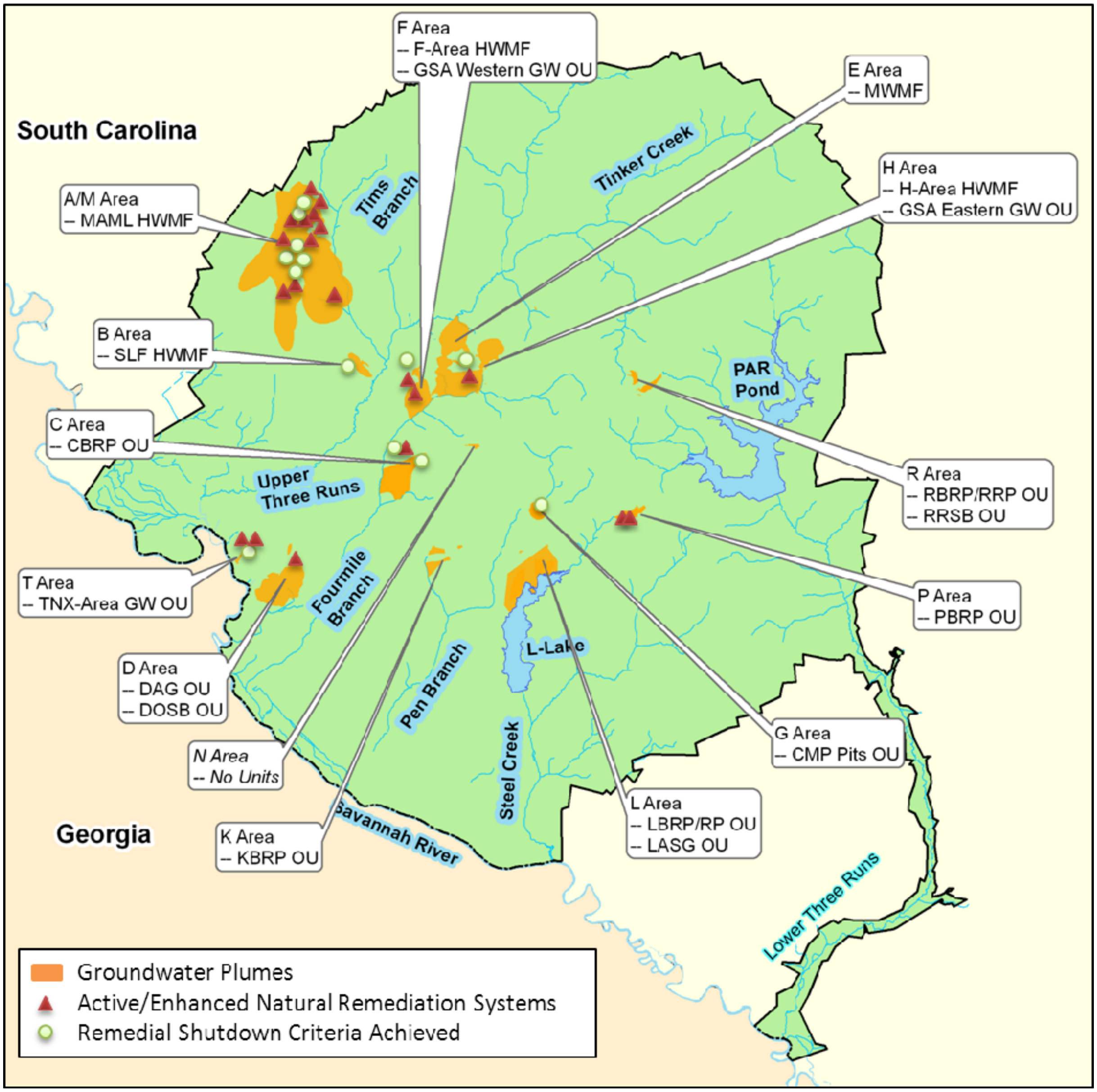


Figure 1. Contaminated Groundwater Areas and Specific Regulated Units

Volatile organic compounds (VOCs) and tritium are the most common contaminants exceeding regulatory standards (maximum contaminant levels [MCLs]) in the groundwater. However depending on the groundwater plume, metals, and other radionuclides are also known to be present. The footprint size of groundwater contamination at SRS is approximately 5,000 acres. Monitoring occurs at more than 3,000 monitoring wells. Multiple aquifer units are monitored with sampling depths ranging from surface samples in wetlands to monitoring wells screened at 105 m (350 ft) below ground surface. Approximately 4,000 groundwater samples are taken each year. Analytical results of those samples comprise about one million data records per year. Data records comprise a wide range of data including field measurements (i.e., water table elevation) and analytical results for over 200 individual constituents. Analytical laboratory costs are approximately $2.5 million per year.

Based on the current size of the monitoring program, and the expected longevity of groundwater contamination, the associated groundwater monitoring and reporting constitutes a significant long-term cost that represents an increasing proportion of the environmental management budget as surface waste units are closed. Therefore, a comprehensive evaluation of the monitoring program was conducted to identify areas where monitoring could be optimized.

DISCUSSION

Methods

Regulatory drivers for SRS groundwater monitoring were assessed to understand the scope of the program. Groundwater monitoring is required by RCRA post-closure care permit conditions at five hazardous waste management facilities, which are regulated by the SCDHEC. Groundwater monitoring is required as part of a Record of Decision (ROD) to satisfy RCRA/CERCLA commitments for thirteen operable units. SRS also has groundwater monitoring for operational facilities, SRS-wide environmental monitoring, and other RCRA/CERCLA groundwater units with future regulatory decisions. The initial optimization evaluation included the eighteen RCRA and RCRA/CERCLA waste units that had specific regulatory requirements (Figure 1).

Groundwater (and surface water) monitoring is based on a set of clearly defined objectives from which monitoring data are collected to specifically fulfill those objectives. Typically, these objectives directly support regulatory decision-making. The design of the monitoring plan (e.g., number of wells, frequency of sampling, laboratory analysis, reporting frequency) is tied to the data quality objectives and uncertainties in order to make project decisions. The regulatory decisions and the project objectives may vary depending on the type or the stage of the project. For a typical waste unit project having a contaminant source and associated groundwater contamination, the following stages can be identified:

- Pre-characterization problem identification;
- Characterization problem identification;
- Remedy selection support;
- Remedy design and implementation support;
- Short-term remedy evaluation;
- Long-term remedy evaluation; and
- Post-closure long-term monitoring.

For each of these stages, the type, the amount, and the sampling frequency of data will vary depending on the nature and the magnitude of the problem being monitored, as well as the specific regulatory decisions needed to remediate the unit. Thus, the groundwater monitoring being conducted is tailored to the objectives to be achieved at each stage of the project.

The seven stages identified above can be divided into two main phases: pre-remedy characterization and post-remedy monitoring. In general, the objectives of these phases are fundamentally very different. Pre-remedy characterization identifies the nature and scope of the problem and selects an appropriate remedy, while the post-remedy monitoring determines the effectiveness of that remedy. Pre-remedy characterization usually consists of groundwater samples collected from a significant number of wells over an extensive area, and analyzed for a broad spectrum of potential contaminants. Post-remedy monitoring includes long-term monitoring of groundwater conditions, typically from a focused area of a few pertinent wells, and a reduced list of contaminant analyses. The key objective of the post-remedy monitoring is to demonstrate whether or not groundwater conditions are corresponding with the expectations of the remedy [1]. It is important to recognize that the groundwater monitoring plan may change significantly for a particular unit as the remedy matures or changes. For example, if an active bioremediation system is shut down and the remedial action continues as monitored natural attenuation (MNA), the various biogeochemical parameters used to monitor the effectiveness of the bioremediation system may no longer be needed.

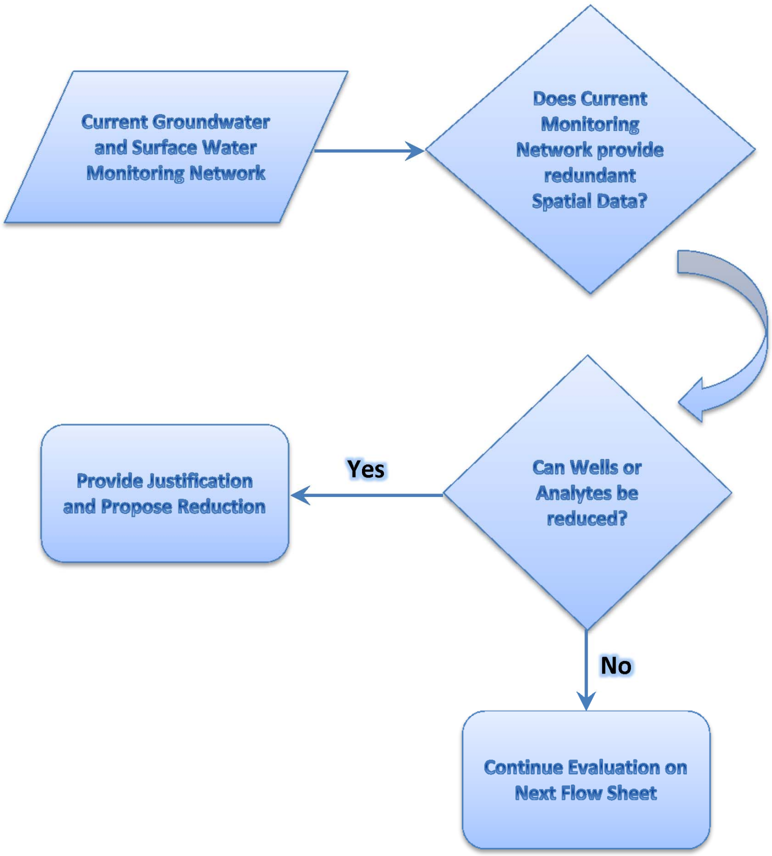
The majority of groundwater monitoring conducted at SRS (and specifically considering the eighteen units identified for evaluation) is post-remedy (closure) monitoring for mature plumes. However, even those units for which the final corrective actions or remedy have not been identified have well characterized and monitored plumes.

In order to optimize (right-size) the groundwater monitoring and reporting, a comprehensive technical approach was applied to each of the groundwater units. Current groundwater sampling, analysis, and reporting practices were evaluated to identify opportunities for optimization and project cost avoidance/reduction.

A decision logic analysis using flow charts was developed to guide an organized systematic evaluation of groundwater monitoring optimization opportunities for the eighteen individual groundwater units. The opportunities for optimization and project cost avoidance are expected to fall into one of these five main categories:

- Comparison of Current Monitoring to Regulatory Requirements;
- Spatial Redundancy Evaluation;
- Temporal Assessment;
- Analyte Assessment; and
- Reporting Assessment.

An example flow chart depicting the decision logic used to identify opportunities in the spatial redundancy evaluation is presented in Figure 2.



Spatial Redundancy Evaluation

For each aquifer unit, consider the following (or other) questions:

- Are source well(s) providing unique data regarding each source monitored; located at historic maximum concentration locations?
- Are plume boundary wells demonstrating that the plume is not expanding, crossing the LUC boundary, or discharging to surface water, and is consistent with model predictions?
- Has flow velocity or direction changed since the monitoring network was established?
- Are intermediate plume wells providing trending information on key contaminants?
- Is plume vertically bounded? Are wells focused on high concentration zones and predicted zones of breakthrough?

Figure 2. Decision Analysis for Comparison of Current Monitoring to Spatial Distribution

The elegance of this decision analysis is that the evaluation is tailored to the specific monitoring program and hydrogeologic conceptual site model at each unit. Therefore, it can be applied to both simple units with monitoring at just a few wells, and complicated regimes with multiple affected aquifer zones and hundreds of wells. Statistical approaches are generally more useful at sites with large monitoring well networks.

In conducting the evaluation of the spatial distribution of the monitoring network, the specific objectives and requirements of the monitoring plan are considered in formulating the questions to be assessed. For example in the figure above, these questions are tailored to an MNA remedy, with predominantly physical attenuation processes, such as for tritium. Thus, some of the key objectives of the remedy (prevent MCL exceedances in surface water, and prevent deeper aquifer contamination) are captured in the questions. If an active groundwater treatment system was being evaluated as part of the monitoring objectives, then an example question might be “Is the predicted capture zone supported by empirical data?”.

Results

The results of the monitoring and reporting optimization evaluation for the eighteen groundwater units were developed. For each groundwater unit where optimization opportunities exist, a proposal was developed that identifies proposed wells and sampling locations to be included in and/or excluded from the monitoring network. The sampling frequency and any modifications to the analyte list were also identified. Additionally, any recommendations to the reporting frequency and content of the monitoring reports were specified. A detailed example of the evaluation for spatial distribution at one unit is provided in the paragraphs below.

The R-Area Reactor Seepage Basins/108-4R Overflow Basin (RRSB) Operable Unit (OU) is located to the north of the R-Reactor Building and includes six unlined seepage basins and associated sewer lines (Figure 3). The basins were excavated in 1957-58 in order to receive low-activity level radioactive purge water from the R-Reactor Building. Due largely to a failed calorimeter experiment in 1957, the basins received large volumes of radioactive wastewater containing primarily cesium-137, strontium-90, and tritium. All basins were deactivated by 1964, and backfilled in 1977.

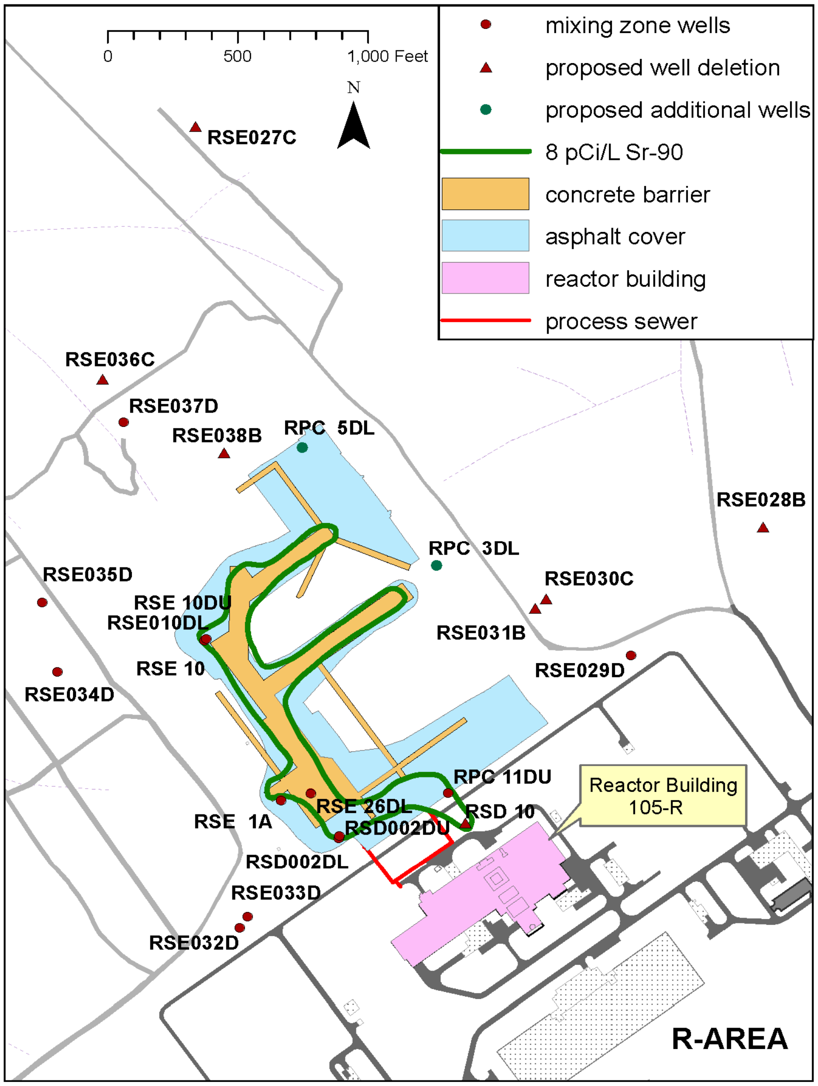


Figure 3. Mixing Zone Monitoring Network at RRSB OU with Proposed Wells

SRS installed new monitoring wells surrounding the RRSBs and sampled existing wells as part of characterization efforts that occurred in the 1990s. To date, over 100 monitoring wells and piezometers have been installed in the vicinity of the RRSB OU. Groundwater in this area was found to be contaminated with strontium-90 above the MCL of 8 pCi/L. A groundwater contaminant transport model was prepared in 2003 [2].

The Record of Decision (ROD) for the RRSB OU was approved in March 2004 [3]. The selected remedy for the surface units (soil, vegetation, sewer lines) included concrete barriers, an expanded asphalt cap, and excavation of select highly contaminated areas. Remediation of surface units was completed in 2007. A Groundwater Mixing Zone with land use controls was the selected remedy for the groundwater.

The water table at RRSB is shallow, about 10 to 30 ft below ground surface in 2011. R Area lies on a watershed divide or "groundwater mound" in the vicinity of the RRSB. Therefore, groundwater beneath the RRSBs flows somewhat radially. The water table is present in the Upper Three Runs Aquifer Unit, which is divided into two aquifer zones and an intervening aquitard. From top to bottom, the zones are upper aquifer zone (UAZ), the informally named "tan clay" (TC), and the lower aquifer zone (LAZ). The LAZ is more conductive than the UAZ. The UAZ, which is about 120 ft thick at RRSB, consists of the A horizon, the AA horizon, and the Transmissive Zone (TZ) from shallow to deep. The water table is located in the A horizon, which has low permeability. As its name indicates, the TZ has higher hydraulic conductivity than the overlying A and AA horizons. Groundwater flow is strongly downward through the UAZ. Within the middle of the TC there is a relatively permeable sand unit, the middle aquifer zone (MAZ), separating the TC confining zone and the TC lower clay. Figure 4 is a schematic cross-section of the area.

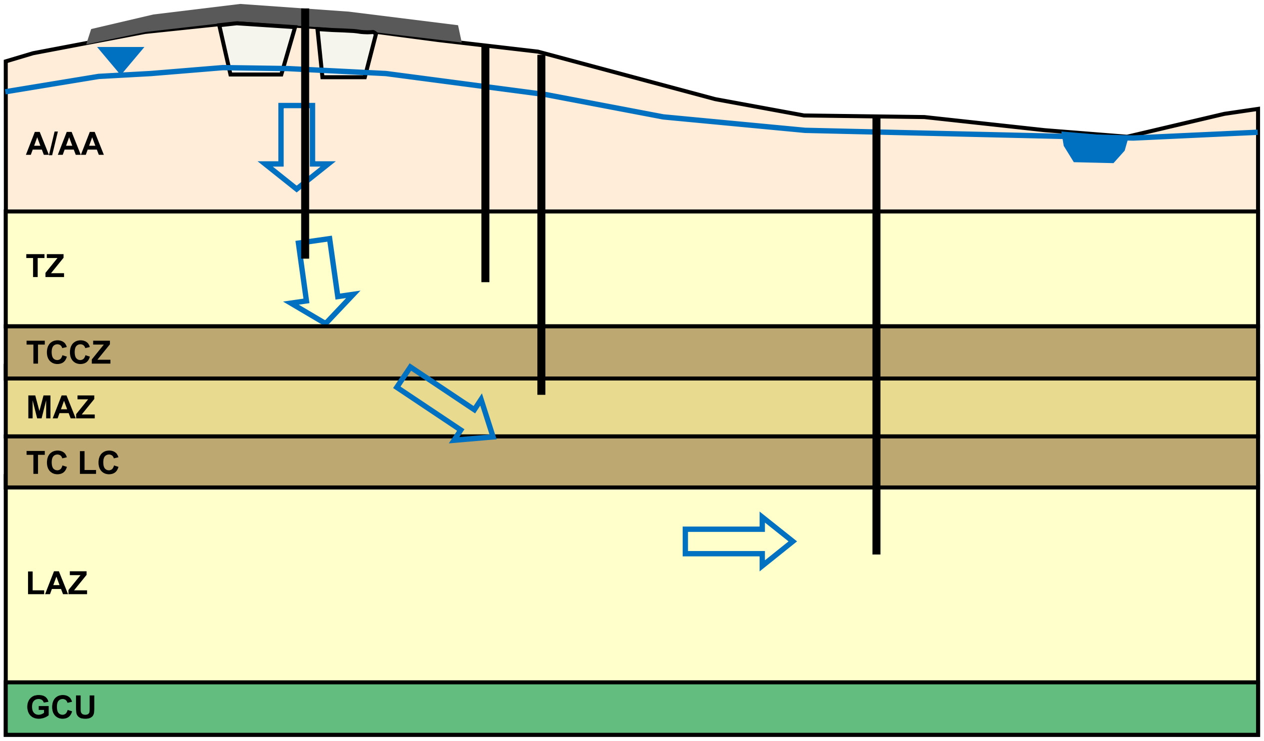


Figure 4. Schematic cross section of RRSB – Upper Three Runs Aquifer

Strontium-90 has been evident in RRSB OU groundwater for many years. Strontium-90 has not migrated far from its source – the seepage basins and sewer lines. Nearly all strontium-90 detections are confined vertically to the A and AA horizons of the UAZ within 40 ft of the ground surface, and laterally no more than 100 ft from basins and sewer lines.

Per the ROD [3], the selected remedy for the RRSB was a Mixing Zone which relies on monitored natural attenuation by radioactive decay of the strontium-90. Objectives of the selected remedy include reducing the strontium-90 concentration in groundwater and preventing the discharge of contaminated groundwater to surface water. It is expected that it will take between 300 and 400 years for natural attenuation to reduce the strontium-90 levels to below MCLs.

The objective of the groundwater monitoring strategy, described in the Mixing Zone Application [4], is to verify the predictions of a groundwater contaminant flow and transport model by determining whether strontium-90 concentrations at selected locations deviate significantly from predicted concentrations. The groundwater flow and transport modeling concluded that the strontium-90 groundwater plume is likely to have very little lateral and/or vertical movement, and is not expected to discharge to surface water at any time in the future [2, 5].

A network of twenty monitoring wells is sampled for strontium-90 and americium-241, including four plume/intermediate compliance wells, twelve boundary MCL compliance wells, and four auxiliary wells. The four plume/intermediate wells were installed as two clusters of two wells each at the locations of the historically highest Sr-90 groundwater concentrations. For each plume/intermediate well, a mixing zone concentration limit (MZCL) has been established based on historic concentrations and transport model predictions. Boundary MCL compliance wells are treated in the same manner as plume/intermediate wells, except that the strontium-90 MCL (8 pCi/L) is used as the benchmark instead of the MZCL. The four auxiliary wells are located in the source area (near seepage basins or sewer lines) and all have a history of strontium-90 contamination.

Auxiliary monitoring wells RPC 11DU and RSD 10 are situated between the seepage basins and the R-Reactor Building (105-R), in the vicinity of contaminated process sewer lines **(**Figure 3**)**. They are 135 ft apart and both screened in the A Horizon. In 2011, groundwater samples from both wells were found to be contaminated with strontium-90 above the MCL. A time-series plot of these wells shows that their strontium-90 concentration trends are similar. RPC 11DU consistently has higher concentrations of strontium-90 than RSD 10, but both wells fluctuate concurrently. Therefore, RSD 10 is providing redundant information and can be eliminated from the monitoring network with no loss of information.

Groundwater sampling from the twelve boundary MCL compliance wells have resulted in non-detects for strontium-90 since they were installed. Additionally, the groundwater model predicts that none of the boundary MCL compliance wells will exceed the strontium-90 MCL (8 pCi/L) due to very slow plume transport and the relatively short strontium-90 half-life (29.1 yrs) [5]. The twelve boundary wells are located along groundwater flow paths at various depths. Therefore, detection of strontium-90 in these locations, which would be contrary to model predictions, would not impact all well locations simultaneously. The shallower wells in the TZ would detect exceedances of strontium-90 before the deeper-screened wells in the MAZ or LAZ. Likewise, the wells in closer proximity to the plume would have detections of strontium-90 before the outlying wells. Therefore, the evaluation concluded that sampling at the six MAZ and

LAZ wells can be discontinued until at least one of the TZ wells shows concentrations of strontium-90 above the MCL. This phased monitoring approach is based on plume migration indicators.

Of the twelve boundary MCL compliance wells, only three (RSE033D, RSE035D, and RSE029D) are screened in the TZ. Potentiometric data indicate that the flow in the TZ is somewhat radial. Groundwater in the TZ flows towards the western, northwestern, northern, northeastern, and eastern directions. RSE033D monitors flow in the western direction; RSE035D covers the northwestern flow; and RSE029D monitors the eastern flow. Although several TZ monitoring wells are present on the northeast side, none of these wells are currently included in the RRSB monitoring program. Thus, the evaluation for RRSB recommended that two existing wells, RPC 3DL and RPC 5DL, be added to the boundary MCL compliance network.

Overall, at RRSB, the spatial analysis recommended removing seven wells from the current monitoring network, but adding two existing wells. A key conclusion was that the fewer wells could be used to still determine whether the plume was expanding, and that the MNA remedy was protective. SRS received regulator concurrence with these recommended changes. This type of analysis was conducted for each of the eighteen units, considering the specifics of the monitoring objectives, hydrogeologic characteristics, and geochemical characteristics.

For each groundwater unit, the following metrics are summarized in Table I below: 1) proposed changes to the number of monitoring wells sampled; 2) reductions/increases in the monitoring frequencies; 3) reductions/increases to the monitored analytes; and 4) changes in reporting frequencies. In addition, an estimated annualized cost savings was also determined.

Optimization recommendations were made for fifteen of the eighteen groundwater units initially evaluated. The spatial evaluation resulted in recommendations to suspend sampling in 79 wells and add sampling at 16 wells. The temporal evaluation resulted in recommendations to reduce the number of well visits per year by 505. Analyte reductions were recommended at three groundwater units, with increases at three other units. Reporting frequency reductions were recommended for five units. The proposed recommendations identified in this evaluation, if all approved by SCDHEC and EPA, are projected to result in an average savings of approximately $700,000 per year continuing through the duration of long term groundwater monitoring. The largest area of savings was associated with reducing the reporting frequency.

Recommendations are being made for each individual unit with the specific project and core team members assigned for that unit in a meeting, and using an appropriate vehicle (such as an annual monitoring report) to document the agreed upon changes.

CONCLUSIONS

The optimization approach has been well received by the EPA and SCHDEC, with unit-specific recommendations approved for all five units presented to date. A strong relationship with EPA and SCDHEC provides a positive working environment for negotiating the recommended changes.

The optimization process used at SRS can be applied broadly to other DOE facilities, federal facilities, and private RCRA or CERCLA regulated sites. This process relies on a clear understanding of monitoring goals and objectives, and is tailored to the specific characteristics of each individual unit evaluated. It can be applied to units with a few wells or hundreds of wells. Statistically based monitoring optimization software was not used as part of this process, as a greater emphasis was placed on the empirical data and depth of technical understanding for each individual unit. The long monitoring history at SRS contributed to a rich dataset, allowing for empirical time trend analysis to help reduce the uncertainty in decision making.

Table I. Optimization Summary for the Evaluated Groundwater Units

Groundwater Unit	Net Wells Reduced	Well Visits Reduced	Net Analytes Reduced	Reporting Frequency Reduced
A/M Area – Central Sector	3	72	0	Y
A/M Area – W. Sector	(1)	0	(4) at 8 wells	Y
A/M Area – S. Sector	(2)	32	0	Y
A/M Area – N. Sector	(6)	6	0	Y
A/M Area – ABRP/MCB	8	0	(1) at 65 wells	Y
H-Area HWMF	6	48	1 at 197 wells	N
F-Area HWMF	3	3	1 at 145 wells	N
MWMF	16	64	0	N
Sanitary Landfill	14	66	0	Y
C-Area BRP	0	0	0	N
CMP Pits	1	13	0	N
D-Area GW	0	9	0	N
D-Area Oil Seepage Basin	0	0	0	N
General Separations Area - E	2	23	0	Y
General Separations Area - W	7	32	(1) at 1 well	Y
KLP BRPs	7	13	0	N
L-Area S. GW	0	22	(2) at 1 well	Y
R-Area BRP	0	2	0	N
R-Reactor Seepage Basin	5	21	1 at 21 wells	Y
TNX Area GW	0	0	0	N
Total	63	505		

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