

ENVIRONMENTAL RESTORATION AT THE SAVANNAH RIVER SITE: STRATEGIC APPROACH PRODUCES SIGNIFICANT PROGRESS WITH INNOVATIVE TECHNOLOGY AND IN-FIELD RESULTS

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ABSTRACT

Remediation progress in closing waste sites and cleaning groundwater at Savannah River Site, a 310-square-mile Department of Energy site presents a full range of cleanup challenges. The basis for originality is the strategic approach used to achieve significant progress. Almost 60 percent of the acreage identified for possible remediation is in field cleanup or finished and over 40 percent of the sites in the program are either remediated or approved for no further action.

The audience should note the Savannah River Site's strategic approach, which has five components: safety, technical capability and performance, cost effectiveness, community and regulatory relations, and corporate perspective. From this framework, environmental technology has evolved to provide better solutions to remediation at lower costs. This remediation-based program thrives on technology and a drive for cost efficiency while operating in an environment of safety and regulatory compliance.

Groundwater technologies discussed in this paper include air recirculation wells, the GeoSiphon, reverse osmosis, and horizontal wells. Surface unit technologies discussed are use of geosynthetics and grout stabilization. The SRS Environmental Restoration Program offers to environmental professionals lessons learned from experience with these remediation approaches.

INTRODUCTION

Savannah River Site began its remediation program in the 1980s. Its Environmental Restoration program has been one of the most results-oriented in the Department of Energy complex. More than half of its 477 waste sites are in the remediation phase, and all regulatory milestones and cleanup goals are being met within budget allocation. The program's success results from following a site and associated program strategy that other sites may study and use. Five focus areas continue to drive the Savannah River Site Environmental Restoration strategy and progress: safety, technical capability and performance, cost effectiveness, community and

regulatory relationships, and corporate perspective. Activities focus on people, missions, and the future.

Safety is clearly the number one priority and Environmental Restoration is using Integrated Safety Management to ensure that all work is planned to identify hazards, develop controls, conduct the work as planned and learn from experience. In 1998, Environmental Restoration workers completed a year of fieldwork without suffering a lost time accident.

Technical Capability and Performance of the Environmental Restoration workforce are at the heart of the program. The program is focused on remediation. By the end of FY 98, more than 300 of the 500 contaminated acres had been remediated. Six major groundwater systems are operating and more than three billion gallons of groundwater have been cleaned to drinking water standards. In the last three years alone, 35 deployments of new and innovative technologies have generated \$36M in cost efficiencies that have been reinvested in the cleanup program.

Cost Effectiveness has ensured that all regulatory milestones and cleanup goals are met within the budget allocation. Since 1995, \$68M in documented cost efficiencies has been reinvested in the program. That means on the average, 20% more regulatory driven work is accomplished each year for the dollars spent, based on approved Life Cycle Cost Estimates.

Community and Regulatory Relationships have been maintained through constant communication and responsive actions. Each year about 100 regulatory enforceable agreement milestones are achieved on time or ahead of schedule. The site's active Community Advisory Board is involved early in strategic planning and decision making. For instance, in 1997 the Citizens' Advisory Board presented a recommendation for SRS-DOE, the U.S. Environmental Protection Agency, and the South Carolina Department of Health and Environmental Control, to work more closely together to expedite actual field cleanup and develop an early action frame work for the high risk waste sites at SRS. This recommendation encouraged the three organizations to participate in workshops that built rapport and drove performance.

SRS's Corporate Perspective has resulted in gathering end users of environmental restoration technology from across the DOE and DOD Complex and Federal Regulatory Agencies for an annual conference focusing on new and innovative technologies to save time and money. In addition, the Director of the SRS Environmental Restoration Program has been chosen to lead the Program Area Integration Team for Environmental Restoration for the DOE Complex.

SITE AND ENVIRONMENTAL RESTORATION PROGRAM BACKGROUND

Adjacent to the Savannah River, SRS covers approximately 310 square miles (198,344 acres) in Aiken, Allendale, and Barnwell counties of South Carolina. The site is approximately 12 miles south of Aiken, South Carolina, and 25 miles southeast of Augusta, Georgia. It is included within the Central Savannah River Area, which is comprised of 18 counties surrounding Augusta. The following sections will highlight field remediation progress, technology deployments, and cost efficiency, as well as the current strategy for completion in each area of the site.

A/M-AREA

Located in the northwest section of the site, the 350-acre A/M Area is one of six project areas that will be discussed in this paper (**See Figure 1**). It is the site of DOE-SRS Operations Office, Westinghouse Savannah River Company management offices, Savannah River Technology Center laboratories and offices, and the former Reactors Materials Production Area. The area is near the site border and the town of Jackson, SC. Now the primary research and development center, the A/M-Area formerly served as the starting point for the manufacture of nuclear defense production reactors. Facilities produced aluminum target assemblies and fuel rods for plutonium production reactors. Discharged degreasing solvents, used in operations and research, have seeped into both the soil and groundwater, which lies some 130 feet below the surface. Groundwater cleanup efforts using above ground air strippers began in 1983. To date, over 3.2 billion gallons of volatile organic compound-contaminated groundwater has been cleaned to drinking water standards at a current rate of one million gallons per day.



Figure 1

New technology is accelerating cleanup in A/M-Area and reducing cost. The team is focused on plume control and optimization of long-term groundwater operations. A star technology promoting progress in A/M-Area has been Soil Vapor Extraction. Installed in the beginning of 1996, six units increased the rate of VOC removal by more than 500%. The soil vapor extraction units are currently extracting volatile organic compounds from 14 vadose zone collection wells. Combined VOC removal rate from air stripping and SVE is currently about 300 pounds per day. Environmental Restoration recently shut down two soil vapor extraction units because cleanup goals had been reached.

While air strippers and SVE units are effectively addressing hot spots in the chlorinated VOC plume, two lines of recirculation wells are being installed to remediate the leading edge of the plume at the southern and western sectors of the area. Attacking the 500 parts per billion-concentration contour of the chlorinated VOC plume, recirculation well technology performs in situ stripping of the contaminant using airlift pumping in a concentric well configuration. Air pumped down the center well then travels upward in the outer well, lifting and stripping the contaminated groundwater. The stripped chlorinated VOC is exhausted to the atmosphere while the cleaned water is returned to the aquifer. The groundwater in the affected zone of the well is cycled through the system several times, adding to the efficiency of this cleanup. This remediation is done at about half the cost of conventional above ground air strippers.

During 1998, a curtain of 12 recirculation wells for the Southern Sector of A/M-Area was completed with the installation of nine new wells. Environmental Restoration took airlift technology a step farther when it enhanced Recirculation Well #12 in the Southern Sector using a multi-stage in-well aerator. Developed by Davis Environmental of California, the aerator adds sparging and extended pathways to the airlift design to increase removal efficiency (**See figure 2**).

Baffles added to the lower and upper well screen areas increase water flow path. Micro air sparging tubes/plates are added in these convoluted pathways to increase single pass VOC removal rate from 50% to over 90%. Cost of equipment inserted in existing recirculation well is under \$5K. Remediation costs using Recirculation Well technology are 50% lower than conventional above ground air stripping (\$2.48 per 1000 gallons versus \$5.05). Further reductions are likely. In light of the overall success of these wells in Southern Sector, Environmental Restoration has begun construction of recirculation wells at the leading edge of the Western Sector plume.

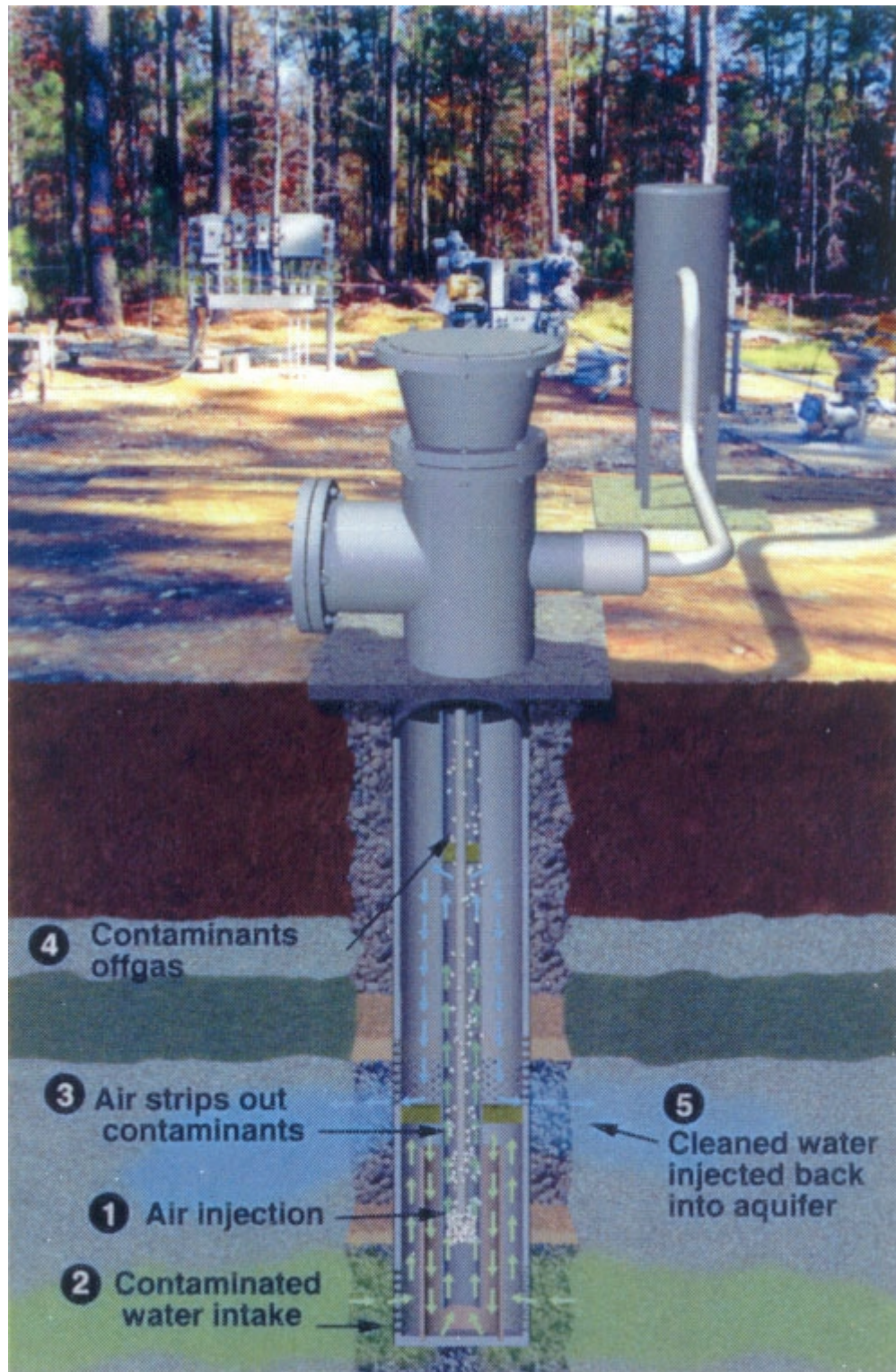


Fig. 2. Recirculation Well

Dense Non-aqueous Phase Liquid (DNAPL) pools are the biggest challenge left to complete remediation of the A/M Plume. Each pound of Dense Non-aqueous Phase Liquid contains enough VOC to contaminate 160,000 gallons of groundwater to 500 PPB. Larger regions of

Dense Non-aqueous Phase Liquid and/or concentrations of volatile organic compounds can be mobilized and collected using underground steam injection and collection. Called Dynamic Underground Stripping, this new technology reduces cleanup schedules by decades over pump and treat methods. The study of recent uses at Lawrence Livermore National Laboratory for a 7,000 gallon gasoline spill and at the Southern California Edison Pole Yard creosote contamination plume indicate Dynamic Underground Stripping is ideal for deployment at an M-Area Solvent Storage Tank Site. Tentatively, four injection wells are planned to encompass the Solvent Storage Tank area with a larger diameter extraction well in the center. Scientists expect steam injection depths at a 180 ft. depth (near confining clay layer) and 80 ft. depth (lower vadose zone limit). Extraction Well suction screens will be placed 20 ft. higher than the steam injection mechanism. Electrical Resistance Tomography (soils electrical resistance measurements) will be used to make a 3-D image of the contamination in order to monitor cleanup progress. In addition, oxygen will be injected with the steam to enhance remediation through breakdown of Dense Non-aqueous Phase Liquids and volatile organic compounds by Hydro Pyrolysis to CO₂ and chloride ion.

The strategy for continued success and completion in A/M-Area is as follows:

- Drive down costs and remediation time using new technologies
- Optimize remediation of A/M Groundwater VOC Contamination Plume
- Install remediation equipment or plan installation during the next two years to approach plume control in A/M Area
- Address major issues impacting final closure schedule for A/M Groundwater
 - 1) Effective technologies needed to locate all Dense Non-aqueous Phase Liquid pools for remediation,
 - 2) Negotiation of alternate MCLs that take credit for natural attenuation
- Aggressively pursue new Dense Non-aqueous Phase Liquid Characterization and remediation technologies that will greatly reduce remediation time and costs
- Use multidisciplinary team formed to research Natural Attenuation basis/benefits/status

THE NONRADIOACTIVE WASTE DISPOSAL FACILITY

Located just south of A/M-Area is the Nonradioactive Waste Disposal Facility. Like A/M-Area, this 55-acre site is volatile organic compound-contaminated. However, in 1997 Environmental Restoration completed surface remedial work at this site in accordance with the Resource Conservation and Recovery Act.

Nonradioactive Waste Disposal Facility was closed using the first geosynthetic cap approved by South Carolina Department of Health and Environmental Control for a hazardous waste site in South Carolina. Geosynthetic caps provide greater protection of groundwater because they are less prone to cracking. Multilayered, lightweight, and impermeable, the caps are a combination of bentonite clay and high-density polyethylene products. This geosynthetic cap saved almost 30,000 truckloads of bulk material (truck=12 cubic yards) when compared to the material used for traditional kaolin capping. Geosynthetics save over 500 truckloads per acre (2 ft of clay, 2 ft of rock). In essence, four feet of rock and clay can be replaced by two inches of geosynthetic material. Additionally, the caps cost \$100K/acre less over the life of the cap.

The marriage of horizontal wells to bioremediation technology is another innovation at Nonradioactive Waste Disposal Facility. Placed at the site last year, the wells are considered to

be the longest horizontal wells in the United States being used for environmental purposes. They were selected over vertical wells due to the project cost advantage and improved treatment coverage the horizontal well technology offers. At first glance, it would seem that vertical wells were the bargain, costing about one-tenth the dollars to install. However, over the life of the system's operation, horizontal wells may save as much as \$1 million. They are more efficient, provide better distribution, and more effective than vertical wells.

Combined with an above ground infrastructure, the horizontal wells are part of an overall in situ bioremediation system. Methane, various microbe-stimulating nutrients, and air will be injected into contaminated groundwater to increase the growth of naturally occurring microorganisms. These microorganisms will then metabolize the chlorinated solvent contamination. After the solvent-contaminated water has been remediated, the nutrient injection is stopped, and the microorganism population reduces to its original size. To date, the aboveground infrastructure has been completed, and the bioremediation system's start-up is projected for April this year. All Nonradioactive Waste Disposal Facility bioremediation work has been brought forward from out-years using dollars made available through cost efficiencies.

The strategy for continued success at Nonradioactive Waste Disposal Facility will include the operation of the bioremediation system with horizontal wells until such time as the contamination has dissipated to acceptable levels. Personnel will also continue to maintain the closure cap at the site in accordance with RCRA requirements.

CENTRAL SAVANNAH WATERSHED AREA

Formerly called the D/TNX-Area, the Central Savannah Watershed Area (CSW-Area) is located right on the Savannah River. Within this area, which is part of the Savannah River Technology Center, applied research and development programs are conducted. In the section formerly referred to as D-Area are central powerhouses and heavy water facilities. Prototypic processes and equipment are developed and demonstrated on bench scale and/or full-scale facilities. The area includes seepage basins, burning rubble pits, a burial ground, an ash basin and contaminated groundwater.

The contamination plume outcrops 660-ft from the river, and the groundwater contaminants include volatile organic compounds, nitrates, and plutonium. Currently, there are no offsite risks from the groundwater contamination. The interim remedial action has included a Low Boy Air Stripper with 4 collection wells that begins remediation at the leading edge of the plume. Since startup in September 96, commitment and team work resulted in reaching the interim milestone to remediate 35 million gallons of groundwater, seven months ahead of schedule, February 8, 1998. In addition to aggressive air stripping technology, an innovative passive technology called GeoSiphon has also been deployed in Central Savannah Watershed-Area (**See Figures 3 and 4.**).

The GeoSiphon cell is a large diameter well containing granular cast iron. Contaminated water is drawn through the cell and through the iron (the remediating medium) by the cell's siphon connection to the Savannah River. The operation began treating water in August 1997. Full-scale deployment at the site will save \$15M in Life Cycle Cost versus conventional Pump and Treat Technology.

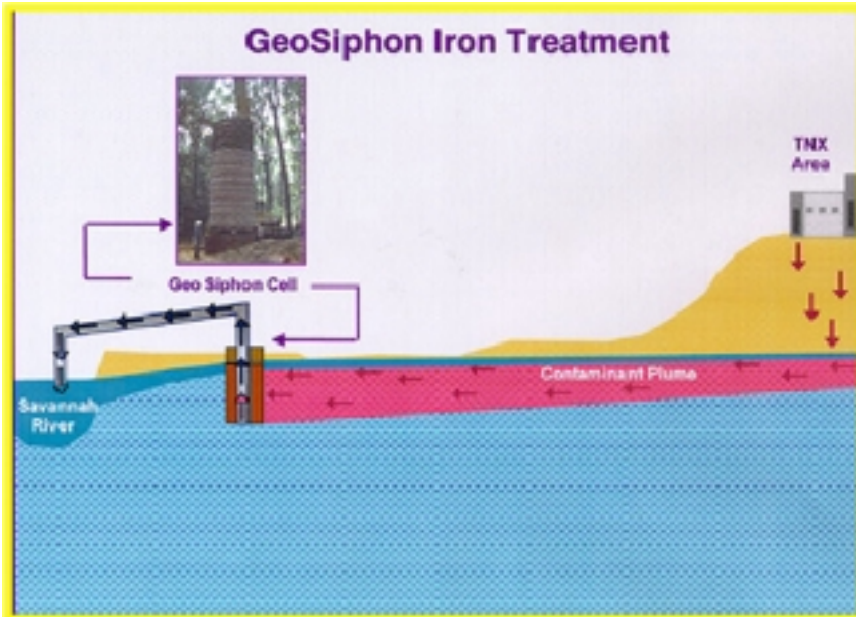


Fig. 3 and 4. The first GeoSiphon well was installed in summer 98.

A key strategy for this area revolves around the GeoSiphon:

- Continue to measure GeoSiphon efficiency. Engineering studies have shown that the new GeoSiphon technology using zero-valence iron is more cost effective than above ground air stripping for volatile organic compounds
- Operate a second GeoSiphon well that was installed in September 98
- Install remaining GeoSiphon Wells, pending final approval by South Carolina Department of Health and Environmental Control

MEETING THE CHALLENGE OF HIGHER RISK SITES

The previously discussed areas are all near the site border and continue to be a priority for the site. The next section of this paper will deal with three project areas that are on the interior of SRS but carry a high-risk priority because of their radioactive content and their impact to groundwater and streams. The areas are the Burial Ground Complex, F- and H-Areas, and Reactors Area.

BURIAL GROUND COMPLEX

The highest risk area of the three to be discussed is the Burial Ground Complex. Located near the center of the reservation, the Burial Ground Complex is divided into a southern area and northern area. The southern area—the Old Radioactive Waste Burial ground—occupies 76 acres. It contains waste trenches covered with four feet or more of soil to reduce surface radiation levels. In addition, 22 tanks once used to store spent radioactive process solvents, are buried in this section. The Old Radioactive Waste Burial Ground was the first part of the Burial Ground Complex to receive waste and was filled to capacity by 1972.

Covered with a low permeability interim cap in December 1997, an engineered native-soil cover prevents water infiltration of the waste site. Studies will determine if this interim action is sufficient. Notwithstanding, the final Record of Decision is scheduled for December 2003.

The northern area of the Burial Ground Complex—the Low-Level Radioactive Waste Disposal Facility—occupies approximately 119 acres and contains solid, low-level radioactive waste. The waste includes contaminated protective clothing, tools, and equipment buried in 20-ft-deep trenches. This area of the complex received waste from 1970 until 1995. Today, low-level waste is disposed of in engineered concrete vaults located here.

Within Low-Level Radioactive Waste Disposal Facility is the 58-acre Mixed Waste Management Facility, comprised of three separate areas that were closed in 1991 in accordance RCRA regulations, i.e., covered with a conventional clay cap. However, the remaining 25 acres of Low-Level Radioactive Waste Disposal Facility have been remediated using geosynthetic-capping materials. As stated earlier, this new alternative to traditional kaolin clay caps is more durable, easier to install, and reduces costs.

F- AND H-AREAS

SRS has two chemical separations operations located in F-Area and H-Area. These areas are also located near the center of the site. The F-Area facilities were used to separate plutonium

from irradiated assemblies for refinement into metal buttons. The facilities in H-Area were used to process tritium and uranium and to produce plutonium-238 for the National Aeronautics and Space Administration missions. This program area includes seepage basins, retention basins, inactive sewer lines, burning rubble pits, burial grounds, tanks, and contaminated groundwater. The seven radioactive seepage basins (three in F-Area and four in H-Area) were remediated and certified closed in 1991.

In 1997, Environmental Restoration deployed new groundwater treatment systems in F- and H-Areas that use reverse osmosis, flocculation, ion exchange, and reinjection wells to remediate groundwater contaminated with volatile organic compounds, tritium, and other radionuclides. During 1998, modifications were made to that system that included the addition of more ion exchange units, which were added for the specific contaminant ions (technetium and iodine). Mixers were also added to assist the flocculation step in the process. Furthermore, a second filter press was added, a filtrate tank after the filter press for increased flexibility and capacity; and a roughing filter was added to protect ion exchange units. A flocculation tank was added, creating a two-stage flocculation-clarifier step.

The strategy for F and H Areas is as follows:

- Establish hydraulic control of the contamination plume at F- and H-Areas to contain tritium until it decays naturally
- Operate both F and H groundwater treatment units to satisfy proposed regulatory requirements, including treatment of metals and radionuclides

The strategy for the Burial Ground Complex is as follows:

- Decide on the most effective and feasible remediation method for Burial Ground Complex groundwater
- Manage the groundwater contaminants of concern at the Burial Ground Complex (similar to those at F and H but the treatment volume required for hydraulic control is significantly less)

REACTORS AREA

The five nuclear reactors at SRS are located in the R-, L-, P-, C-, and K-Areas of the site. Collectively they make up one project area called the Reactors Area. The majority of waste sites remaining to be characterized and remediated in this area are associated with Reactor operations and maintenance activities that occurred in this central area of SRS. Environmental Restoration is finding unique ways to clean up in this area that result in both reuse of resources and cost efficiencies. For instance, in 1997 the program remediated four coal piles and their runoff basins for \$11 million less than had been previously projected. Environmental Restoration personnel proposed streamlining the paperwork on four sites and sending 15,000 tons of coal and residues to a private company for use as road material. Regulators approved the plan, which saved millions over other options such as soil washing or landfill disposal.

Since the beginning of FY98, Environmental Restoration has launched other remediation projects in Reactors Areas.

- Radioactive Seepage Basins vegetation removal
- Lead and mercury battery removal
- L-Area Oil & Chemical Basin Remediation (underway), includes grouting process sewers leading to basin, combining surrounding contaminated soils in basin, solidifying contaminated soils with cement materials

The strategy for continued remediation success in this area includes the following:

- Pursue Plug-In-Record of Decisions for like sites
- Focus on high-risk radioactive seepage basins
- Develop a technology position on tritiated groundwater

CONCLUSION

SRS continues to make the protection of the public and the environment its highest goal. Consequently, its Environmental Restoration program takes a holistic approach, adopting a strategy that considers remediation plans within the context of a waste site's impact on the total environment. Remedial action is designed to stop contamination at its source in the soil before it reaches the groundwater and migrates through watersheds.

With this responsibility to the public and the environment in mind, Environmental Restoration continues to address higher priority nonradioactive contamination near the site border. The program approaches groundwater plume control with new technology deployment and innovative ways of pairing the old with the new. A future focus in these areas will be to address dense solvent zones in A/M-Area and to finish groundwater remediation in lower concentration solvent zones.

The Burial Ground Complex, F- and H-Areas, and Reactors Areas are all near the center of the site, and Environmental Restoration remains committed to controlling and remediating radioactive contamination of these areas. Regarding the Burial Ground Complex, as it nears its Record of Decision in 2000, Environmental Restoration personnel will work to reach a technical decision on the remediation of its groundwater. In addition, both F- and H-Area groundwater treatment units are operating to establish groundwater hydraulic control. Finally, in the Reactors Areas, the program will continue remediation of seepage basins and development of a groundwater strategy.