

**TECHNOLOGY DEPLOYMENT AT THE SAVANNAH RIVER SITE: DRIVING
REMEDICATION & COST EFFICIENCIES IN ENVIRONMENTAL RESTORATION**

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ABSTRACT

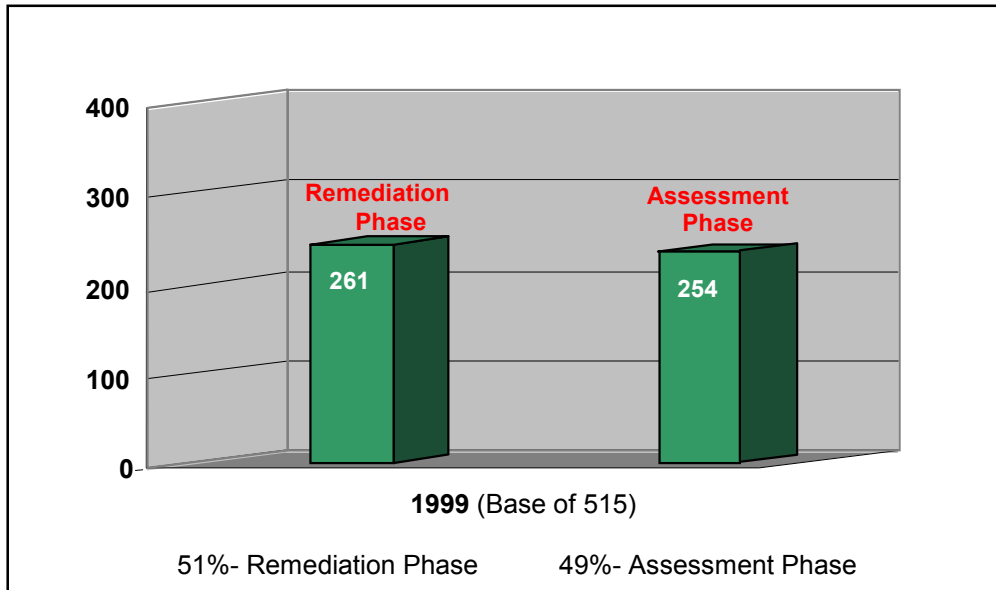
Cleanup of 515 Savannah River Site operable units with diminishing federal budgets presents a significant challenge for DOE. Initially, conventional technologies like kaolin clay cover systems for soil, and pump-and-treat systems for groundwater contamination were deployed with only marginal efficiency. In recent years plans have been established to accelerate remediation at decreased costs and more streamlined schedules. These plans have been facilitated with the deployment of new, innovative technologies that promise to bring results in the field. Each new technology introduced at the site builds upon the effectiveness of previous technology used, which serves as a major driver in the success of the site's environmental restoration program. The experience with ten such technologies is shared in this paper

INTRODUCTION

In an effort to facilitate environmental remediation efforts, the DOE, EPA, and the state of South Carolina (tri-parties) made a collaborative technology agreement to seek and evaluate new and innovative technologies that would improve the effectiveness and efficiency of environmental waste site remediation at reduced cost and schedule. This tri-party agreement resulted in several actions taking place, all aimed at positioning the site for a successful environmental restoration program. The deployment of 49 new/innovative technologies between 1996 and 1999, with an average cost saving of \$11 million a year and a lifecycle cost saving in excess of \$180 million, is a clear indicator of the site's aggressive stance toward cleanup efforts. More than half of the site's waste units (261 of 515 sites) are in the remediation phase, as shown in Table 1. Well over half of the estimated acreage earmarked for cleanup is complete (340 of 500 acres).

Because of the three parties' increased commitment and discipline to remediation efforts, a cost-effective culture that values technology has emerged, producing impressive results in the field. Each year the cumulative effect of current and past deployments provides overwhelming justification for the incremental investment in resources expended on technology initiatives. Examples of significant successes in technological innovation and cost-effectiveness will follow.

Table I - Site Inventory



BACKGROUND

The DOE-operated Savannah River Site is located in the coastal plains of South Carolina. To date, 515 operable units have been identified with a total cleanup bill estimated at \$3 billion for the site. The cleanup effort is being conducted under both CERCLA and RCRA through a Federal Facilities Agreement approved by the DOE, EPA and the state of South Carolina. The most significant challenges the site faces include remediation of buried radioactive contaminated solvent tanks, radionuclide-contaminated soils and groundwater, and solvents both dense and dissolved in soil and groundwater. Rainfall in excess of 50 inches per year and relatively shallow groundwater provides a formidable challenge in protecting the public and ecology in the region.

The initial approach to tackling remediation challenges involved deployment of conventional technologies to accomplish the cleanup. Early estimates utilizing these conventional approaches ranged from \$3.5 - \$5 billion at a time when approximately 420 waste units were identified.

As the scope increased and budgets tightened, the three parties increased focus on more cost effective approaches and technologies to accomplish the necessary cleanup.

TECHNOLOGY AGREEMENT

DOE, EPA, and the state of South Carolina developed a technology agreement in 1996 with a commitment to assess innovative technologies with the objective of achieving more effective remediation at reduced cost and schedules. Elements of the agreement include:

- Involvement of regulators and public early in the technology selection process

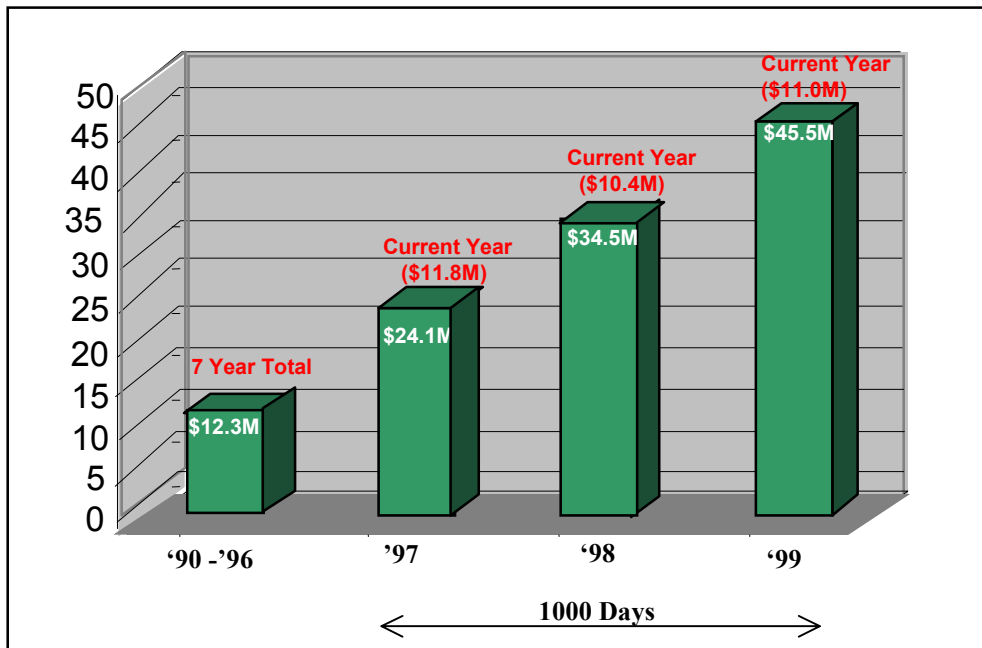
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- Development of technology needs for the program annually
- Redesign of the technology selection process by the participants in the program
- Establishment of a technology panel integrating end users with developers
- Establishment of technology baselines
- Development of a disciplined cost savings management plan to evaluate benefits
- Implementation of a variety of technical exchange forums

These initiatives were complemented with a strong and consistent message from the management team of the DOE, WSRC, EPA and SCDHEC, that innovation and the pursuit of more effective streamlined approaches to remediation were valued. The management team created a philosophy that embraced the pursuit of insitu, passive, real -time technologies for characterizing and remediating sites.

Since 1996, the ER program has deployed 49 new/innovative technologies with estimated life cycle cost savings in excess of \$200M dollars. Table 2 depicts the cumulative effect of cost-effective solutions over the past decade. Each year the cumulative effect of current and past deployments provides overwhelming justification for the incremental investment in resources expended on technology initiatives. Examples of significant successes in innovation and cost effectiveness follow.

Table II- Cumulative Technology Savings



REMEDIATION OF SOILS

Kaolin Clay Cap

Initially, conventional approaches to remediation technologies were applied to accomplish cleanup goals where surface contamination was evident. Among those technologies applied were RCRA-type kaolin clay cover systems. These systems were used on basins early in the program to prevent leaching of contamination to groundwater streams.

The caps provide good protection at a reasonable cost; however, they do require more extensive long-term maintenance because they are prone to cracking and water infiltration. This approach was replaced with geosynthetic cover systems.

Geosynthetic Caps

The first geosynthetic cap used at the Savannah River Site was installed at the Nonradioactive Disposal Facility. Geosynthetic material was used instead of traditional kaolin clay. The South Carolina Department of Health and Environmental Control approved the closure plan in 1995. The flexibility and ease of installation with geosynthetic capping shortens installation and construction time. The key to the cap's effectiveness is the thin bentonite clay mat that seals when wet and is reinforced with other geosynthetics. This makes the cap much more durable and less likely to crack or allow rainwater to seep through. Millions of dollars are saved compared to the conventional kaolin cap clay closure. Savings are calculated on an average of \$100,000 per acre over the life of the cap. The geosynthetic cap also provides greater protection of groundwater than conventional caps. (See Figure 1)

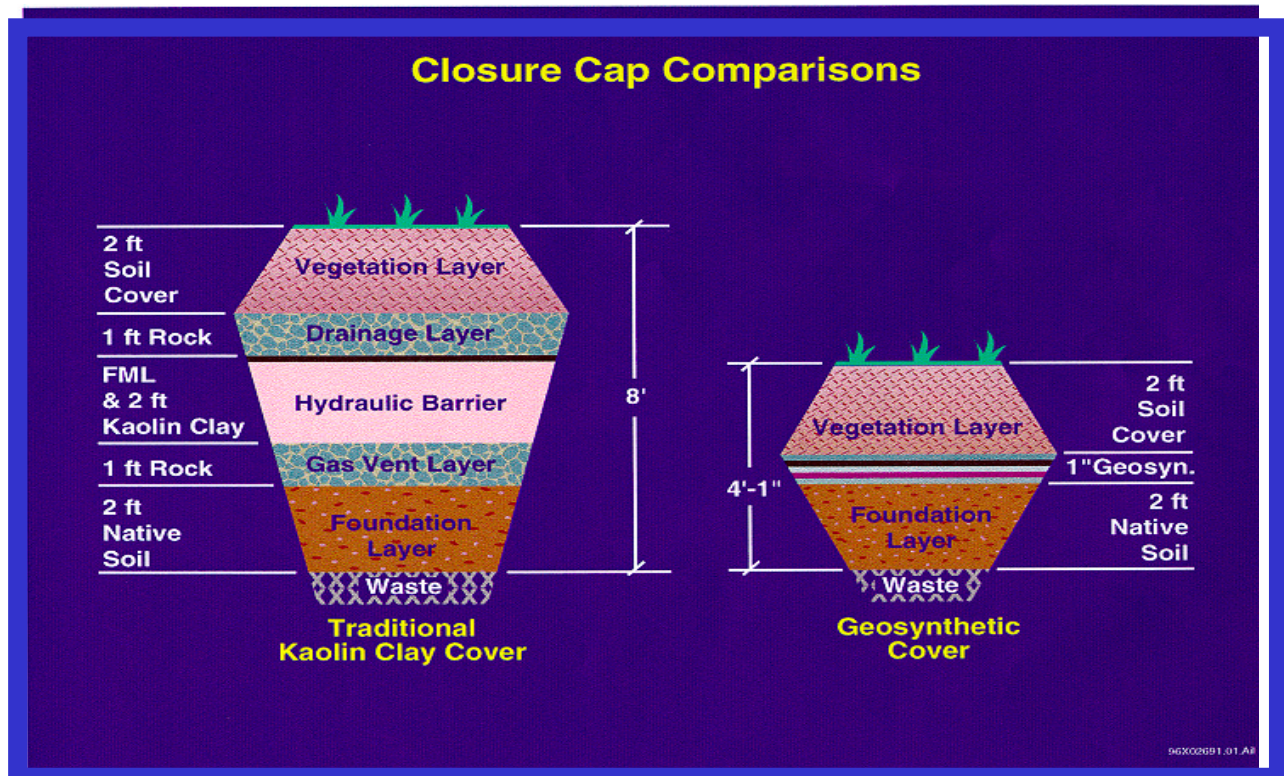


Fig. 1 – Closure Cap Comparisons

These capping approaches have proven effective in large landfill and basin remediation projects, both at radioactive waste sites and hazardous waste sites. However, many future basin sites will require that contaminants be solidified or stabilized. In these cases the treatment of the source will require a less sophisticated cap.

In-Situ Soil Stabilization Solidification

Solidification and stabilization (S/S) technology is currently being used to treat a variety of sites in the commercial waste remediation industry. Being an in-situ process, S/S is less expensive because contaminants are contained in place. During the S/S process, a special grout is mixed into the contaminated soil, which has a chemical affinity for the contaminants. Contaminants are then effectively immobilized in place, preventing their migration into the groundwater. The grout mixture is usually portland cement based and contains specific additives designed to react with the targeted contaminants. The grout is mixed at about 30 weight percent into the soil and typical additives are bentonite, zeolites, flyash, cement kiln dust and various silicates. Various mixing techniques can be employed, based on specific site conditions, soil characteristics, depth required, etc. Mixing by crane-mounted augers, rakes, high pressure jetting, low-pressure permeation and simple mixing with a backhoe have all been employed.

Since most of the abandoned radioactive and chemical waste basins in the ER program are similar in contaminant concentrations, areal extent and depth, it is intended that they will be remediated using the in-situ grouting technique. The L-Area Oil and Chemical Basin and the Old F-Area Basin are currently being remediated with this technology. (See Figure 2)

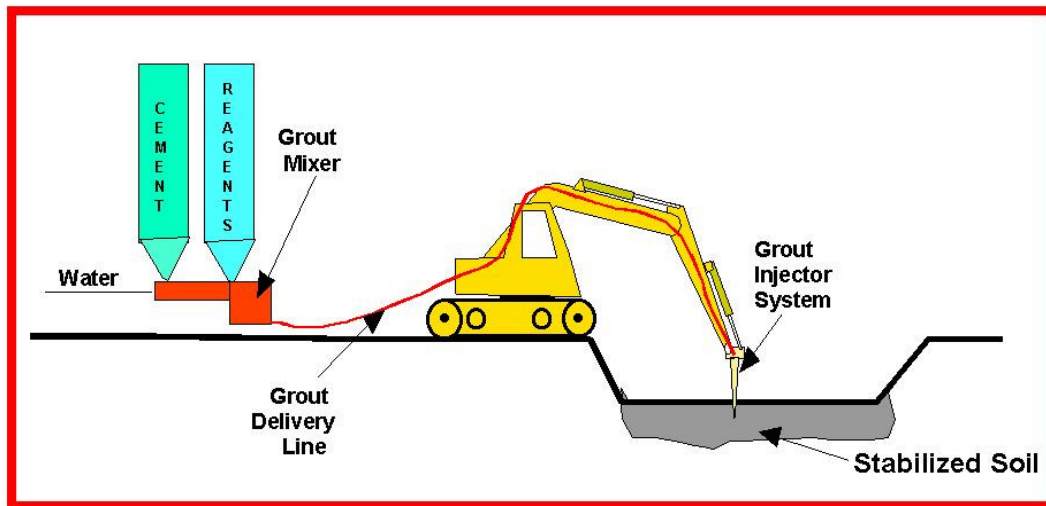


Fig. 2 - L-Area Oil and Chemical Basin Soil Stabilization Process

REMEDICATION OF GROUNDWATER/MOVEMENT TO MORE PASSIVE TECHNOLOGY

As soil basins and landfills were closed and remediated at SRS, attention was placed on several large plumes at the site where groundwater contamination was evident. Early efforts concentrated on conventional pump and treat methods of cleanup, but nowhere has there been a more pronounced evolution of technology at SRS than in groundwater cleanup where efficiency is netting tremendous cost savings.

Air stripping/Pump & Treat

SRS has used air stripping to remove solvents from groundwater for a number of years. However, the dependence on this technology is being rapidly replaced with other methods. Pump and treat air stripping is producing diminishing returns in some plume areas and still costs about \$5 per 1,000 gallons of groundwater.

Soil Vapor Extraction

The move to deploy soil vapor extraction systems increased solvent extraction by 500 percent in 1996 at SRS. Vapor extraction systems remove volatile organic compounds (VOCs) from soils above the water table through slotted well piping that can be installed vertically or horizontally. Vacuum pumps draw the VOCs through the pipes to the surface where they are removed from the air stream and destroyed. The goal is to remove the contaminants before they migrate into the water table. The Savannah River Site was one of the first locations in the U.S. to deploy the technology. It is currently in use in the A/M and C-Areas.

In-Well Air Stripping

While soil vapor extraction works well near the source of solvents, more economical air stripping is possible in dilute plumes at half the cost of traditional pump and treat air stripping. In-well vapor stripping or air recirculation wells can be operated for \$2.50 per 1,000 gallons of groundwater.

Two generations of recirculation wells have been successfully deployed at the SRS. The initial deployment entailed wells screened at two elevations in a VOC-contaminated aquifer. The contaminated groundwater is extracted through the lower screened interval and the contaminants stripped from the water by pumping compressed air into the well casing.

The permeate exits the well casing through the upper well screen and a portion of the permeate recirculates into the lower screen for advanced treatment.

The evolution of the initial deployment is the Multi-Stage In-well Aerator. These recirculation wells provide two stages of in-well stripping with each pass, increasing the efficiency of the system. When multiple wells have been deployed with proper spacing, this technology has proven to be effective in hydraulic control and remediation of large groundwater plumes. As a replacement to conventional pump-and-treat technologies, the remediation costs are reduced by approximately 50%.

Geosiphon Cell

The addition of recirculation wells to the groundwater cleanup effort at SRS denotes a move to more passive systems, which in turn are less expensive. The Geosiphon Cell is an example of a passive system. (See Figure 3)

The Geosiphon Cell is essentially a large diameter well that contains the granular cast iron and passively induces flow by use of a siphon from the cell to the Savannah River. The flow is induced by the natural hydraulic gradient between the cell and the Savannah River. The passively induced flow draws contaminated groundwater through the treatment cell where the iron filings reduce the solvents to ethane, ethene, methane, and chloride ions. The treated water is subsequently discharged into the Savannah River. The treatment media was developed and patented by the University of Waterloo. The deployment at SRS utilizes insitu treatment cells, approximately 8 feet in diameter, which collect and remediate solvent contaminated groundwater with a siphon transporting the permeate to an approved discharge location. Depending on the site hydrogeology and terrain, the system can operate without external power. Remediation costs per gallon using this technology are approximately 30% less than the cost for conventional pump-and-treat facilities.

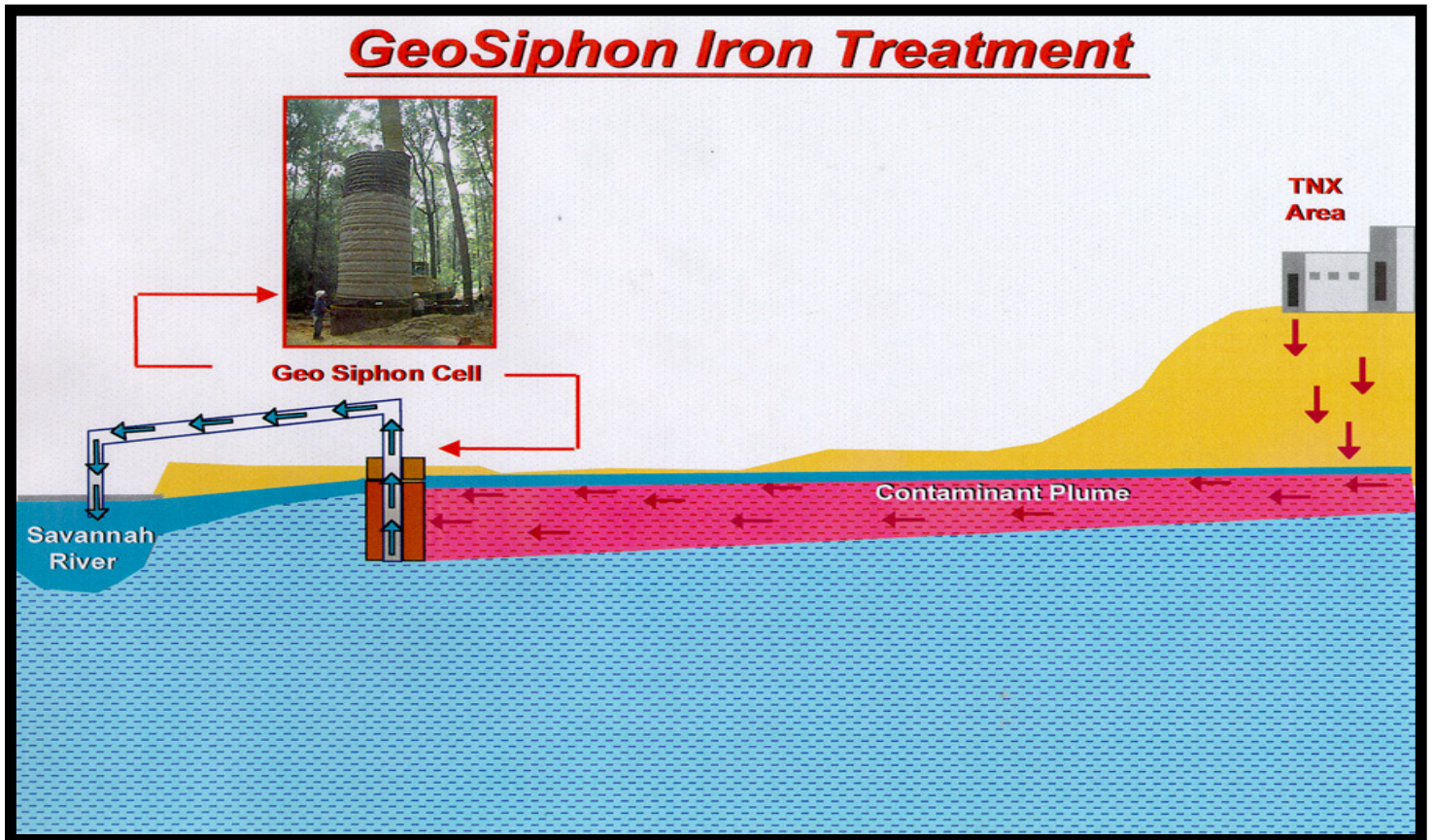


Fig. 3 – Geosiphon Iron Treatment

Bioremediation

Certainly one of the best passive methods of solvent cleanup in groundwater is bioremediation enhanced with nutrients, and stimulated through horizontal wells. This is being used at the former SRS Nonradioactive Disposal Facility where a geosynthetic cap was used to remedy the source. It was also used successfully at the D-Oil Basin.

Previous studies and on-going demonstrations at SRS revealed that normal soil bacteria are capable of degrading chlorinated solvents in situ if they are stimulated with oxygen and additional nutrients. In situ biodegradation is a highly attractive technology for remediation because contaminants are destroyed in place, not simply moved to another location or immobilized, thus decreasing costs, risks, and time, while increasing efficiency and public and regulatory acceptability. Bioremediation has been found to be among the least costly technologies in applications where it is feasible.

Historical groundwater data and landfill usage information confirmed that there existed two separate plumes of concern. One plume contained TCE as its major contaminant of concern and the other plume contained VOC as its major constituent. Sites 1 and 2 were also significantly different in terms of contaminants, dissolved oxygen, chloride, nitrate, and nitrate concentrations, and response to nutrient stimulation. Therefore, each site is considered separately. Overall, both sites were found to have indigenous microorganisms that could be stimulated to degrade chlorobenzenes, trichloroethylene and, its daughter product, vinyl chloride in site by the addition of oxygen (as compressed air), nitrous oxide, triethyl-phosphate, in both the groundwater and vadose zone.

Barometric Pumping/Baroball

The most passive method of solvent removal work is with barometric pressure. Barometric pumping removes volatile organic compounds from the soil by taking advantage of changes in barometric pressure above and below ground. When the subsurface pressure is higher, contaminants naturally move upward where they can be treated/released. The baroball significantly increases the effectiveness of barometric pumping by preventing the inflow of air into a venting well when atmospheric pressures reverse, a condition that can reduce contaminant removal by diluting and safely discharging the pollutant. Its design consists of a simple plastic sphere that seals the well from incoming surface air. Baroballs are used extensively throughout the A/M area to naturally allow solvent venting safely to the solar atmosphere.

Monitored Natural Attenuation

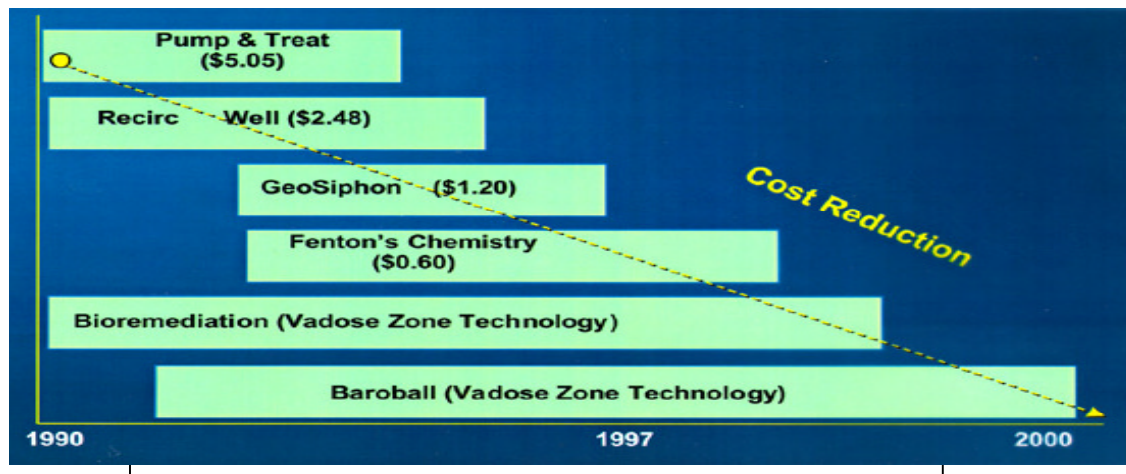
Sometimes remediation is allowed to take place naturally where appropriate. Monitored Natural Attenuation (MNA) is an appropriate remedial strategy at the SRS because the site controls access from the public. In addition, large buffering zones exist before contaminants would reach drinking water systems and other potential exposure points.

In order for the site to expand on MNA, it will become necessary to employ more cost effective and advanced methods for monitoring.

COST SAVINGS

Large cost savings are possible with the technologies just discussed. Table 3 summarizes the groundwater technologies and their costs per 1,000 gallons treated. Fenton's chemistry was not discussed as part of the SRS strategy because better dense solvent discovery technologies are needed to use the chemistry.

Table III - Costs of new technologies per 1,000 gallons treated



FUTURE CHALLENGES

Dense solvents and tritium represent some of the significant remediation challenges remaining at SRS. Each is being addressed with technologies that show promise.

Dynamic Underground Stripping

Dynamic Underground Stripping (DUS) is a new process for extracting subsurface volatile organic compounds (VOCs). This process rapidly accelerates VOC removal by injecting steam into multiple wells to heat the contaminated soil region to a point above the boiling point of the contaminants. The VOCs evaporate, become more mobile, and are removed by vacuum extraction and condensed into a liquid product at the surface. This new DUS process can shorten remediation schedules at several DOE complex locations by a decade or more.

Lawrence Livermore National Laboratory (LLNL) originally developed the DUS process. After successful demonstrations at LLNL and the Southern California Edison Pole Yard Superfund Site, LLNL licensed the process to two California firms for commercial deployment. SRS has committed to providing resources to implement DUS as a solvent tank storage area in FY 2000.

Phytoremediation

Phytoremediation is a technology that draws on the ability of naturally occurring plants to VOCs released to the subsurface, and at the same time minimize risks to public and health and the environment. Vegetation has the ability to degrade VOCs, such as trichloroethylene (TCE), present in the soils through the metabolic interactions of bacteria in the root zone or rhizosphere.

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Technology could be deployed to phytoremediate the TCE and PCE moving in groundwater through the soil prior to the contaminants emerging through the surface receptors. The end result could mean significant cost savings in the use of natural vegetation to remediate the outer fringes of the TCE/PCE plumes in the Southern Sector of A/M Area. This technology is also being pursued to capture radionuclides at the Burial Ground Complex.

CONCLUSION

Much progress has been made in soil and groundwater remediation at the Savannah River Site due in large part to new technologies. As budgets continue to tighten, environmental programs must continue to strive for innovative approaches and technological solutions to remediation efforts. The public expects it and we are being challenged to deliver.