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Savannah River Site

Soil and Groundwater Closure Projects Technology Descriptions

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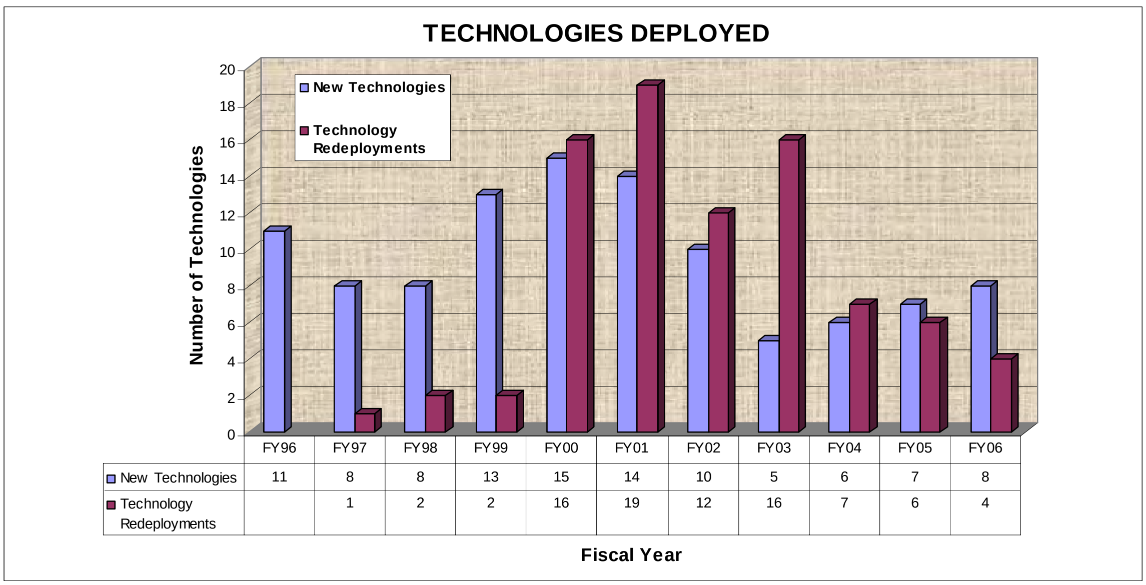
Washington Savannah River Company LLC
Aiken, South Carolina

INTRODUCTION

Welcome to the Savannah River Site Technology Description Book for the Soil and Groundwater Closure Projects. This book summarizes those technologies that have been implemented to facilitate process improvements, operable unit characterizations, and remedial actions at the Savannah River Site (SRS) over the last 15 years.

Overall, 105 new technologies have been applied to the environmental program at the Savannah River Site (SRS). Many of these technologies have been redeployed for use at other operable units; and in a number of cases, some technologies have been institutionalized as the standard mode of operations. The following figure depicts the number of new technology and technology redeployments from 1996 to 2006. The number of technologies redeployed is accounted by a reuse following the initial deployment.



As shown on the figure, beginning in the mid-1990s, many of the technologies deployed were new as the program was in its infancy, moving from document production to field work upon regulatory approval. With more field activities ongoing, lessons learned and implementation of numerous technologies, allowed for many technologies that were initially deployed to be redeployed. This is evident as the environmental program matured into the early 21st century. After FY03, the number of field activities diminished resulting in a reduction in the number of technologies deployed. However, the program is still active in all aspects of environmental restoration and is actively promoting the use of new technologies and redeployment of technologies that expedite field work and operable unit closure while reducing cost and improving schedule efficiencies.

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ACRONYM LIST

1, 2-DCE	1, 2-dichloroethylene
ABRP	A Area Burning/Rubble Pits
ADS	Analytical Development Section
bls	below land surface
Bq/L	Becquerel/liter
CBRP	C Area Burning/Rubble Pit
CCl4	Carbon Tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfm	cubic feet per minute
CLSM	Cementatious Low Strength Material
cm	centimeter
cm/sec	Centimeter per second
CMP	Chemical Metals and Pesticides Pits
COC	Contaminant of Concern
CP	Cone Penetrometer
cpm	counts per minute
CPRB	Coal Pile Runoff Basin
CPT	Cone Penetrometer Technology
CVOC	Chlorinated Volatile Organic Compounds
DACPRB	D Area Coal Pile Runoff Basin
DAS	diode array spectrophotometers
DCPRB	D Area Coal Runoff Basin
DDT	dichlor diphenyl trichlor
DNAPL	Dense Nonaqueous Phase Liquid
DOE	Department of Energy
DOT	Department of Transportation
DPT	direct push technology
DTNF	Disc Tube Nano Filtration
DUS	Dynamic Underground Stripping
EBF	Electromagnetic Borehole Flowmeter
EMWD	Environmental Measurement While Drilling
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERT	Electrical Resistance Tomography
ESC	Expedited Site Characterization
ETV	Environmental Technology Verification
FDTAS	Field Deployable Tritium Analysis System
FDR	Frequency Domain Reflectometry
FID	Flame Ionization Detector
FFA	Federal Facility Agreement
FLUTE	Flexible Liner Underground technologies
FRB	F-Area Retention Basin

ft	feet
FY	Fiscal Year
g	gram
GC	Gas Chromatograph
gpm	gallons per minute
GPS	global positioning system
HOPS	Heuristic Optimized Processing System
HPO	Hydrous Pyrolysis Oxidation
HPT	Health Physics Technology
Hz	Hertz
IAPP	Interim Action Proposed Plan
ICP	Inductively Coupled Plasma
ID	inner diameter
IDW	Investigated Derived Waste
ISOCS	In-Situ Object Counting System
ISPV	In-Situ Plasma Vitrification
L/min	Liter/minute
LANL	Los Alamos National Laboratory
LED	Light Emitting Diode
LIF	Laser Induced Fluorescence
LLNL	Lawrence Livermore National Laboratory
LSC	Liquid scintillation counter
m	meter
MCA	Multichannel Analyzer
MCL	Maximum Contamination Level
MDL	Method Detection Level
MIP	Membrane Interface Probe
mL	milliliter
mL/min	milliliter/minute
MNA	Monitored Natural Attenuation
MS	Mass Spectroscopy
MWMF	Mixed Waste Management Facility
NAPL	Nonaqueous Phase Liquid
NPDES	National Pollutant Discharge Elimination System
OD	outer diameter
OU	Operable Unit
ORWBG	Old Radioactive Waste Burial Ground
OST	Office of Science and Technology
PCB	polychlorinated biphenyl
PCR	Principle Component Regression
PCE	Tetrachloroethylene
pCi/L	pico curie per liter
PDWS	Primary Drinking Water Standards
PHA	Pulse Height Analysis

PID	Photoionization Detector
PLS	Partial Least Squares
ppb	part per billion
ppm	part per million
PRB	permeable reactive barrier
psi	pounds per inch
PWMS	Purge Water Management System
QA	Quality Assurance
QC	Quality Control
RADMAPS	Real Time Sodium Iodide Gamma Detector
RO	Reverse Osmosis
ROD	Record of Decision
ROST	Rapid Optical Sensor Technology
RMS	Remote Monitoring System
S/S	Solidification and Stabilization
SAM	Surveillance and Measurement System
SBIR	Small Business Innovative Research
SCAPS	Site Characterization and Analysis Penetrometer System
SCDHEC	South Carolina Department of Health and Environmental Control
SGCP	Soil and Groundwater Closure Project
SGI	sol-gel indicators
SPE	Solid Phase Extraction
SRB	sulfate reducing bacteria
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SVE	Soil Vapor Extraction
TAL	Target Analyte List
TCE	Trichloroethylene
TCL	Target Compound List
TCO	Thermal Catalytic Oxidation
TDEM	Time Domain Electromagnetic Induction
TEOS	tetraethylothrosilicate
TVA	Tennessee Valley Authority
UC	University of California
UC-Berkeley	University of California-Berkeley
VOC	Volatile Organic Compounds
VZCOMML	Vadose Zone Contaminant Migration Multi-Layered Software
WSRC	Washington Savannah River Company
WTU	Water Treatment Unit

Chapter 1: Characterization Technologies

1.1-Soil

1.1.1-Real Time Soil Moisture Measurement

Deployment Date: 1QFY01

Study Area/Project: D Area Phytoremediation Plots

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Tim Smail (timothy.smail@srnl.doe.gov)

Description: Savannah River National Laboratory (SRNL) and Soil and Groundwater Closure Projects (SGCP) installed a real-time soil moisture monitoring system in the D-Area Phytoremediation plots. The soil moisture system, from ADCON Telemetry, consists of ten wells with two sensors per well, ten remote telemetry units, and one radio data logger. The soil moisture probes work on the principle of Frequency Domain Reflectometry (FDR). The radio data logger requests readings from the remote telemetry units every fifteen minutes and stores the data.

The system is designed for monitoring the wetting pattern of three drip emitters in one of the control plots. The overall objective is to have the soil moisture monitoring system control the irrigation system to optimize performance of the phytoremediation.

1.1.2- Real Time Remote Sampling for Early Removal Actions (Dig Face Monitoring)

Deployment Date: 2QFY97

Study Area/Project: Ford Building Waste Unit

SGCP Contact: Tom Gaughan (thomas.gaughan@srs.gov)

Description: Dig face characterization is a concept for improving the safety and efficiency of hazardous waste retrieval. A dig face characterization system consists of onsite hardware for collecting detailed information on the changing chemical, radiological, and physical conditions in the subsurface soil during the entire course of a hazardous site excavation. The dig face characterization concept originated at the Idaho National Engineering Laboratory and has been under development there since 1992. During August 1995, a prototype dig face system was taken to Mound Laboratory, Ohio, for a first attempt at monitoring a hazardous excavation. Mound Area 7 was the site of historical disposals of Thorium-232, Actnium-227, and assorted debris. The dig face characterization system was used to monitor a 20-ft x 20-ft x-5-ft deep excavation aimed at removing Actnium-227 contaminated soils. Radiological, geophysical, and topographic sensors were used to scan across the excavation dig face at four successive depths as soil was removed in 1-ft to 2-ft lifts. The geophysical and topographic sensors mapped the dig face topography and the location of metallic debris in great detail as the excavation advanced. The radiation sensors produced high fidelity images showing the location of radioactive contaminants and clearly identified and delineated separate Thorium-232 and Actnium-227 plumes. By combing the radiation data from all four levels, a 3-D image of the contamination plumes were developed. The radiation sensor data indicated that only a small portion of the excavated soil volume was contaminated. This conclusion could not be verified by routine sample collection procedures because it was impossible to reconstruct the spatial position of the collected samples. The spatial information produced by the dig face system was used to direct the excavation activities into the area containing the Actnium-227 and to evaluate options for handling the separate Thorium-232 plume. Demonstration of this technology was performed at the Ford Building Waste Site at Savannah River Site (SRS).

1.1.3-Electra/Endura Survey Instrument

Deployment Date: 1QFY01

Study Area/Project: L Area Hot Shop, Site Wide

SGCP Contact: Greg Joyner (greg.joyner@srs.gov)

Description: This survey instrument has widespread applicability for Soil and Groundwater Closure Projects (SGCP) and has significant savings potential over traditional measurement techniques (i.e., smearing and lab analysis). The Electra is a microprocessor based rate meter with selectable dose rate and count rate scales. It has a fixed lower threshold and adjustable upper threshold and is compatible with most externally connected Geiger-Mueller or scintillation Health Physics probes.

The Endura™ probes are designed for monitoring alpha and beta radiations. Endura™ phosphors include a light tight layer coated with a proprietary compound. These coatings replace traditional think foils and their weight is similar. These probes are much more resilient than their thin foil equivalent, but with no loss in sensitivity. Radiation detection efficiencies and traditional equivalents are identical, within design tolerances, for most nuclides.

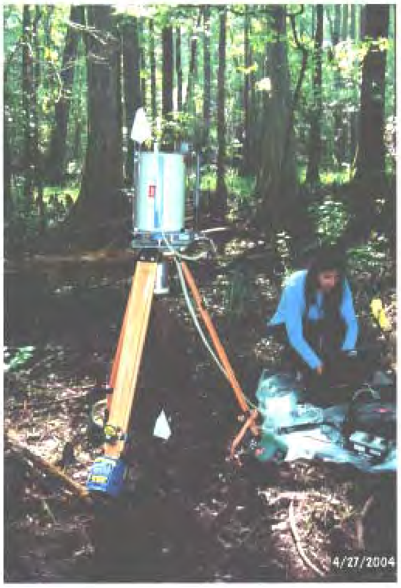
1.1.4-In-Situ Object Counting System (ISOCS)

Deployment Date: 1QFY02

Study Area/Project: Old Radioactive Waste Burial Ground, Site Wide

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
John Adams (john.adams@srs.gov)
Aparajita Morrison (aparajita.morrison@srs.gov)

Description: In-Situ Object Counting System (ISOCS) is a Germanium detector gamma ray characterization system that can identify specific nuclei, and quantitatively determine the corresponding radioactive inventory *In Situ*. Health Physics Technology (HPT) has supported Soil and Groundwater Closure Projects (SGCP) field radiological assessment efforts using ISOCs. The gamma detection system allows for a quick *In Situ* setup that assesses approximately 1.2 metric tons of soil/debris with a single measurement. Typically, ISOCS measurements for environmental soils have been 10-15 minutes to achieve the desired sensitivity. Data handling (spectral files merged with calibration data) and evaluation typically requires another 10-15 minutes per measurement. The benefits of using ISOCS over conventional laboratory analysis include:

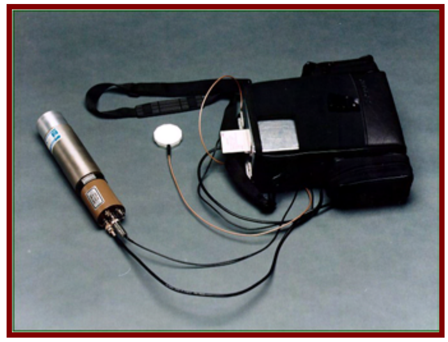


- Large surface areas can be measured quickly saving time over conventional sampling and lab analysis;
- Measurement of remote source locations up to 50 meters from the detector at any angle in all directions;
- Reduces health and safety hazards associated with collecting samples, packaging, transportation and handling in laboratory;
- Ability to model complex geometries;
- Cost savings of thousands of dollars per waste site when compared with sampling efforts and laboratory analysis; and
- Cost savings associated with timely assessment of potential radiological hazards in area prior to start of removal/remediation actions.

1.1.5-Real Time Sodium Iodide Gamma Detector (RADMAPS Application)

Study Area/Project: Site Wide

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Ken Hofstetter (kenneth.hofstetter@srnl.doe.gov)



Description: Real Time Sodium Iodide Gamma Detector (RADMAPS) is a portable system for detecting, locating and characterizing nuclear material. The portable field unit records gamma or neutron radiation spectra and its location, along with the date and time, using an imbedded Global Positioning System. RADMAPS is advancement in data fusion, integrating several off the shelf technologies with new computer software in a product that is simple to use and requires very little training. The existing technologies employed in this system include: Global Positioning System satellite data, radiation detection (scintillation detector), pulse height analysis, Flash Memory Cards, Geographic Information System software and laptop or personal computers with CD-ROM supporting digital base maps.

The software developed at Savannah River National Laboratory (SRNL) eliminates costly, error prone, manual data entry. It is easy for a novice investigator to use with only brief training, while the data it provides is precise and reliable.

An initial screening survey is performed to establish the level of naturally occurring (background) radiation. This screening survey becomes the point of reference as the detailed survey continues, looking for radiation 'spectra' (fingerprints). All pertinent data, including the time each spectrum is accumulated, is stored as the investigator moves through the survey site.

Information collected during an investigation is transferred to a personal or laptop computer via Flash Memory Card technology. On the computer, the spectral data is analyzed, correlated with position and presented as a graphic display using a commercial Geographic Information System.

Using commercially available digital maps, satellite or aerial photos, site plans or other custom graphics, RADMAPS shows the user the radiation type, location and intensity. The analysis clearly differentiates between man made and background radiation. RADMAPS is capable of pinpointing the ground location of the radioactive material to within six feet.

RADMAPS principle application is in mapping contaminated areas both in the US and worldwide. The number of radioactive sites worldwide is conservatively estimated to be in the thousands. Each of these sites will require a detailed survey before and after cleanup efforts. RADMAPS can play an essential and cost effective role in that effort.

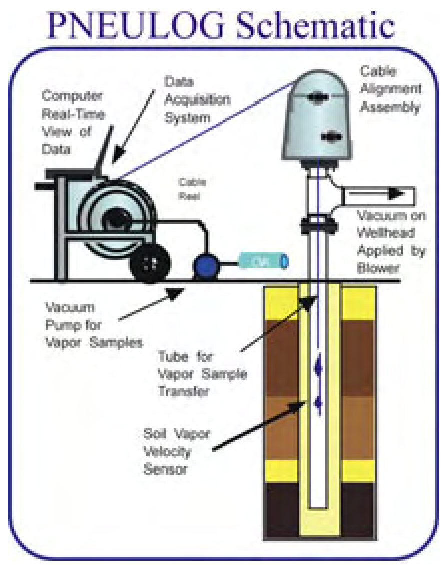
1.1.6-Pneulog Depth Discrete Contaminant Flux Measurement

Deployment Date: 4QFY02

Study Area/Project: C Burning Rubble Pit

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: A new characterization technique that reduces long term operational costs and to accelerate cleanup by optimizing soil vapor extraction (SVE) systems. The technology, known as Pneulog^{TM}, utilizes in well instrumentation to continuously measure air permeability and contaminant production along a well screen during vapor extraction. Data from several wells across a site are then used to optimize a remedial strategy and estimate operation times to meet closure requirements. This method f expedited characterization enables the rapid deployment of an efficient SVE system. By targeting the contaminant producing soil layers the wasteful collection and treatment of clean soil gas is minimized. Pneulog provides data for predicting ass removal as a function of time. The predicted mass removal allows calculation of an optimal extraction rate.



1.1.7-Characterization and Monitoring of DNAPL (SEAMIST by FLUTE)

Deployment Date: 3QFY97

Study Area/Project: A/M Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)

Description: Researchers from Savannah River National Laboratory (SRNL) in collaboration with Flexible Liner Underground Technologies (FLUTE), Ltd. installed the first two inch diameter, multiple ports flexible membrane wells in cone penetrometer technology (CPT) pushed holes at the A/M Area of SRS. The entire installation (including CPT push) of the 100 foot long membranes took less than three hours for the first well and less than two hours for the second well. The Department of Energy Site Characterization and Penetration System (SCAPS) truck was used to push the CPT hole.

The rugged, yet lightweight membranes are deployed in an open hole by incrementally inverting them using air pressure (5-15 psi). When fully inverted, the membranes make a tight and continuous seal with the walls of the hole. Sampling ports are pushed against the walls in direct contact with the subsurface formation, eliminating mixing of sampling zones. The sampling ports are connected to the surface via small diameter tubing which can be accessed for soil gas or pressure measurements. Other sampling methods (e.g., sorbent samplers) can also be deployed using this technology.

The membranes at Savannah River Site (SRS) have nine ports at different depths in the vadose zone for pressure and soil gas monitoring. Initial work at SRS will involve depth-discrete pressure measurements at one site to monitor the zone of influence of a vadose zone extraction unit currently removing chlorinated organic contaminants and depth discrete soil gas measurements at another site to identify high concentration and potential dense nonaqueous phase liquid (DNAPL) zones.

1.1.8-VOC Headspace Sampling

Deployment Date: CY1987

Study Area/Project: Site Wide

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)

Description: Headspace analysis is the analysis of the vapor above a given solution. In volatile organic compound (VOC) headspace sampling, borings are drilled to various depths and sol samples are collected using a split spoon sampler. Within seconds a sub-sample of soil is placed in a vial, suspending solution is added, and a Teflon lined septum is used to cap the vial. A gas chromatograph is used for analysis of the headspace for VOC. The headspace analysis method was developed to generate an accurate and rapid delineation of the vertical and horizontal distribution of VOC in the subsurface.

1.1.9-Surveillance and Measurement System (SAMS) 935

Deployment Date: 3QFY04

Study Area/Project: TNX Outfall Delta

SGCP Contact: Aparajita Morrison (aparajita.morrison@srs.gov)

Description: The Surveillance and Measurement System (SAM) 935 is a hand-held radiation detector used as a screening tool to determine the presence of contaminants. The SAM 935 uses a thallium-activated sodium iodide detector to provide isotopic identification. The size of the thallium sodium crystal is 1.5 inch x 2 inches. The system is capable of displaying gamma spectra, count rates and dose rates.

The SAM 935 possesses the following advantages for field sampling:

- It provides instant results. Real time analytical results allow the project team members to make informed decisions in the field;
- It decreases the number of samples sent to the laboratory for analysis by identifying "suspect" areas of contamination;
- It lowers the potential dose to the sampler by decreasing exposure time;
- It decreases waste generation during sampling. *In situ* analyses require less field equipment, generate less investigative derived waste and reduce the need for tighter radiological controls than conventional invasive sampling;
- *In situ* analyses eliminated the need for extensive mobilization planning (coordinating laboratory analyses, creating chain of custody forms, handling sample containers, etc.); and
- Fewer sample locations were needed than would have been the case if traditional soil sampling methods had been employed.

1.1.10-Rapid Hydrophobic Sampling (FLUTE)

Deployment Date: 4QFY98

Study Area/Project: 321-M Solvent Storage Tank

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)
SRNL Contact: Brian Riha (brian.riha@srnl.doe.gov)

Description: The Rapid Hydrophobic Sampling (i.e., FLUTE) is a flexible membrane sampling device that provides detailed delineation of dense nonaqueous phase liquids (DNAPL) in a borehole. It is deployed via a reusable nylon liner, with a hydrophobic ribbon impregnated with dye, that when inverted into a borehole creates a tight contact with the wells of the borehole. When deployed, the ribbon will absorb the DNAPL that is in contact with the membrane causing a color change in the dye. Upon removal, the membrane is turned inside out and the ribbon is retrieved from the membrane. The presence of DNAPL is indicated by brilliant red marks on the hydrophobic ribbon. Sections of ribbon can also be sent for laboratory analysis to identify the specific nonaqueous phase liquid (NAPL) compounds that are present.

Advantages:

- The FLUTE Hydrophobic Flexible Membrane can be deployed in small diameter cone penetrometer technology (CPT) holes;
- *In situ* sampling eliminates the need for drilling and collection of soil samples to determine DNAPL locations;
- The FLUTE membrane is relatively inexpensive and is reusable;
- Minimal time is needed to deploy and retrieve membrane;
- The FLUTE membrane is lightweight and easily transported with no need for special vehicles or equipment; and
- Use of the FLUTE in the initial characterization phase can be used to optimize subsequent drilling and sampling resulting in significant time and cost savings.

The hydrophobic flexible membrane was used at SRS in FY98 beneath M Area Solvent Storage Tanks to determine a vertical profile of NAPL in the subsurface.

1.2-Groundwater

1.2.1-Depth-Discrete Sampling (KABIS Sampler)

Deployment Date: 3QFY97

Study Area/Project: Southern Expansion Area of the Non Radioactive Waste Disposal Facility

SGCP Contact: Martha Thompson (martha.thompson@srs.gov)

Description: The KABIS Sampler is a self contained, stainless steel sampling device, designed to be lowered to any specific depth for sample collection. The samples collected during the demonstration will be analyzed and compared wit those collected during a routine sampling event. The KABIS Sampler does not require well purging and reduces the amount of investigated derived waste (IDW) associated with routine sampling events. The sampler is currently being deployed at Hanford where a cost analysis versus conventional methods indicated a substantial savings through the elimination of well purging and associated purge water costs.

Representatives from Department of Energy (DOE) and Environmental Protection Agency (EPA) were on hand June 11, 1997 to observe a demonstration of the KABIS Sampler in the Southern Expansion area of the Non Radioactive Waste Disposal Facility.

1.2.2-Fiber Optic Chemical Sensors

Deployment Date: CY1990

Study Area/Project: Site Wide

SGCP Contact: Martha Thompson (martha.thompson@srs.gov)

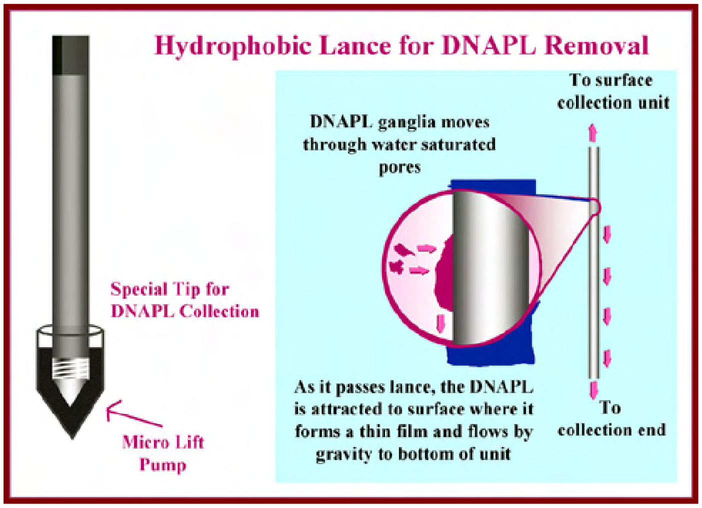
Description: Fiber optic chemical sensors provide real time capabilities for stream monitoring and down well groundwater and waste processing. Fiber optic chemical sensors have been developed to monitor carbon tetrachloride (CCl4) and trichloroethylene (TCE). Fiber optic chemical sensor technology detects carbon tetrachloride at parts per million levels and trichloroethylene at parts per billion levels. This technology provides real time analysis versus one week lab analysis.

1.2.3-Hydrophobic Lance

Deployment Date: 4QFY98

Study Area/Project: M Basin

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)



Description: The hydrophobic lance is a technology for collecting and removing isolated masses of dense nonaqueous phase liquids (DNAPLs) from the subsurface. It relies on direct push technology to drive a small diameter pipe of a hydrophobic material into the soil at depths up to about 150 feet. The technology is based on the fact that DNAPLs are attracted to surfaces that are less polar than water. The lance surface is made of hydrophobic, oleophilic materials—like Teflon—which repel water but have an affinity for oil. As the lance is driven into the soil, it attracts DNAPLs preferentially. The DNAPLs wet the surface of the lance and run to the bottom, where they can be collected and removed through screening and pumping systems.

1.2.4-Well Head Analyzer (Sniffer)

Deployment Date: 4QFY97

Study Area/Project: A/M Area

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)

Description: Utilizing the Environmental Technology Verification Program (ETV) SRS partnered with public and private third party testing organizations to acquire a robust, reliable, cost effective technology to allow at the wellhead analysis of groundwater samples. Such capability will allow for significant reduction in the "out year mortgage" for site cleanup and improve the data acquisition process.

Specifically, in one area of Savannah River Site (SRS), there are approximately 350 wells of which, 334 require semi-annual sampling and the remaining 16 wells require weekly process samples for trichloroethylene (TCE) and tetrachloroethylene (PCE). Other organic solvent contamination areas exist at the site. In addition, periodic treatability and feasibility studies require numerous fast and inexpensive analyses for aqueous phase organic solvents.

To address these needs, the following preliminary data quality objectives have been prepared:

- The demonstrated technology must be safe to human health and the environment. The analyses required will be TCE and PCE; range of sample concentration is 3 part per billion (ppb) to 10 part per million (ppm);
- The demonstrated technology must run on portable power supplied by Honda, gas powered generators. Output power rating is 5 kV;
- The technology must be capable of being operated by a field technician with a high school diploma;
- The technology must be able to complete the analysis in 20 minutes or less;
- The technology must be capable of electronic downloading of the data into an Oracle database or other standard electronic output format;
- Must operate under field conditions ranging from 20 to 110 degrees Fahrenheit, with relative humidity ranging from 20 to 100%; and
- The cost of analysis for both PCE and TCE combined must be less than $100 per sample, including all operating and maintenance costs.

The Visitor's Day for the Well Head Monitoring Technology Demonstration at SRS Integrated Demonstration Site was held on September 11. Five vendors participated, demonstrating a wide range of field portable instrumentation for measurement of chlorinated volatile organics in groundwater. This demonstration was co-sponsored by the US EPA Environmental Technology Verification Program and the Department of Energy.

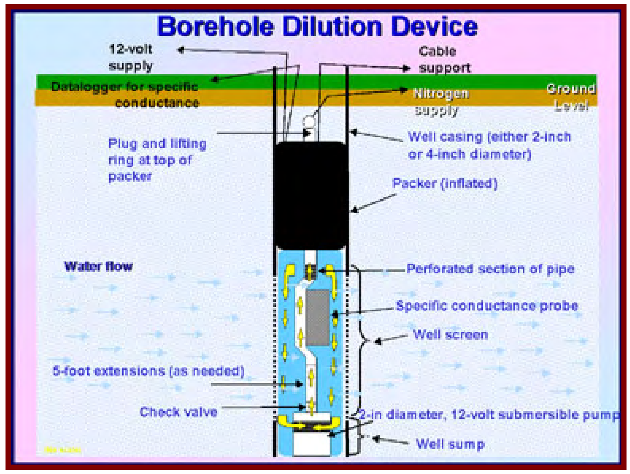
1.2.5-Borehole Dilution Test

Deployment Date: 2QFY01

Study Area/Project: R-Area

SGCP Contact: Eric Schiefer (eric.schiefer@srs.gov)

Description: The borehole dilution test is a new approach to obtain estimates of groundwater velocity in the vicinity of test wells. This method is based upon the rate of dilution of a tracer that is initially placed within the well screen zone below a packer. The rate of dilution is proportional to the ambient velocity of groundwater moving through the well screen. Estimates of groundwater velocity are being evaluated as an alternative to the large scale pump test to evaluate area hydraulic conductivity.



1.2.6-Passive Sampler (Diffusion Sampler) for TCE in Monitoring Wells and Wetland Soils

Deployment Date: 1QFY00, 2QFY00

Study Area/Project: A/M Area Southern Sector, C-BRP

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
Roger White (roger.white@srs.gov)
SRNL Contact: Dennis Jackson (dennis.jackson@srnl.doe.gov)

Description: Chlorinated solvents in the subsurface are one of the most significant environmental problems at Department of Energy (DOE) sites. Conventional sampling protocol requires purging monitoring wells (2-4 times the volume of groundwater in the well casing) before a sample is taken. When screening data are needed for a limited suite of contaminants, representative data can be obtained with passive samplers. Passive samplers (sometimes referred to as diffusion samplers) consist of sealed polyethylene bags filled with deionized water. The bags are suspended directly in a well screen for a period of approximately 14 days. During this time, the bag is exposed to the natural groundwater flow through the screen zone. Representative amounts of trichloroethylene (TCE) and tetrachloroethylene (PCE) have been demonstrated to diffuse from the groundwater into the deionized water in the bags. The deionized water can then be sampled and analyzed using conventional methods. No pumping of groundwater is required and sampling labor costs and purge water disposal costs are significantly reduced.

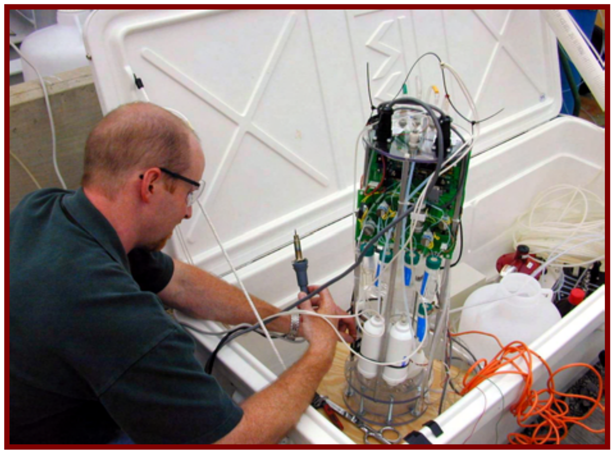
This concept has also been used at Savannah River Site (SRS) to obtain cost effective screening data along extended seeplines adjacent to surface streams. The bags are buried directly in seepline sediments along the stream. The data provides the basis for placing monitoring wells up gradient of areas where plumes may outcrop to the streams. This sampling tool is also appropriate for collecting tritium samples.

1.2.7-Burge Real Time TCE Sensor

Deployment Date: 1QFY02

Study Area/Project: TNX

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Tim Smail (timothy.smail@srnl.doe.gov)
Scott McWhorter (scott.mcwhorter@srnl.doe.gov)



Description: The Analytical Development Section (ADS) Sensor and Analyzer Group collaborated with Soil and Groundwater Closure Projects (SGCP) to test and develop a commercial in line trichloroethylene sensor. The task entailed evaluating the analytical performance of the sensor in a laboratory setting, ensuring that the sensor is adequately ruggedized to place in a process stream setting in the field and evaluating its performance in the field setting.

The sensor system is an in line trichloroethylene sensor developed by Burge Environmental. The system is based upon measuring the change in absorbance of a colored reaction product that is formed after the reaction of trichloroethylene in a headspace vessel. The sensor system contains a series of electrically actuated valves and tubing for fluidic manipulation plus a headspace analysis vessel which contains the absorbance detection scheme. Before deploying this system in a field setting, verification of the analytical detection capabilities must be accomplished, along with appropriately packaging the instrument to ensure ruggedness in the field.

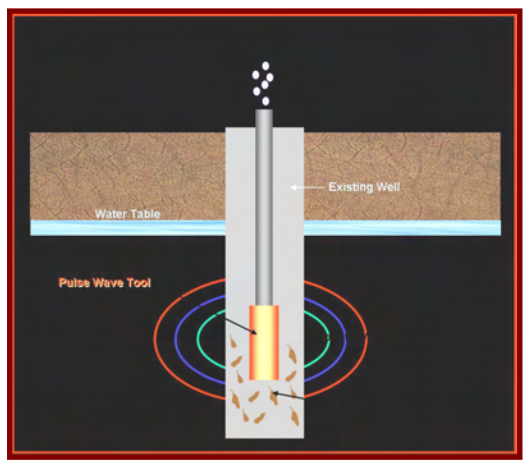
1.2.8-Pulse Wave Well Tool

Deployment Date: 1QFY99 and 4QFY00

Study Area/Project: Vicinity of M Basin, A/M Area

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)

Description: Pulse wave technology uses pressurized nitrogen to improve the performance of wells. The gas is delivered to a special head in the well via tubing. A chamber is filled at a controlled rate and the gas is released rapidly when the target chamber pressure develops. The result is a controllable series of pressure release events that have been shown to be effective in improving the efficiency of wells. Pulse Wave technology was originally developed and tested in Russia and has been used in the oil and gas industry in the United States.



Pulse Wave technology has several features that make it promising for use in improving the performance of various environmental remediation activities. The technology used only nitrogen which is nontoxic, widely available and inexpensive. The bulk of the well development (performance improvement) results form in well generated pulse waves during this portion of the work, no IDW is generated. No injection of clean water is made into a contaminated site and most of the nitrogen pulse exits the well head, minimizing the potential to “spread” contaminants. Past results document typical increase in well productivity are greater than 2 to 5 times. Another significant advantage for environmental remediation is that selected zones either in the well can be preferentially developed based on depth discrete contaminant profiles. This allows maximum mass removal with only modest increases in water treatment volume.

Implementation of the technology is straightforward and inexpensive. Thus, selective deployment of the technology for environmental remediation has a high probability of success and a large return on investment.

Pulse Wave technology has not previously been applied to environmental remediation. Currently, theory and experience is applicable to wells below the water table. However, Savannah River Site (SRS) deployed this technology on one vadose zone well and one groundwater well.

The Pulse Wave System uses less fluid and generates less investigated derived waste (IDW) than typical methods, introduces no excess liquid into contaminated sites, and used no chemical solutions. Alternate ultrasonic and fluid jet systems are more complicated and expensive and generate higher frequencies that have limited penetration.

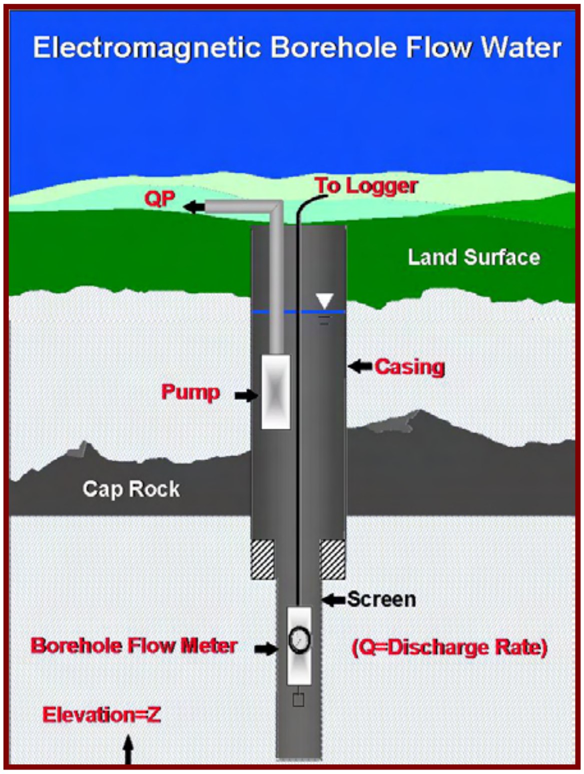
1.2.9-Borehole Flowmeter

Deployment Date: 2QFY99

Study Area/Project: Burial Ground Complex, Southwest Plume Area

SGCP Contact: Tom Gaughan (thomas.gaughan@srs.gov)
Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)
Greg Flach (gregory.flach@srnl.doe.gov)

Description: Multiple well or single aquifer pumping tests are normally conducted to determine horizontal conductivity of an aquifer. These tests can be time consuming and costly. An alternate method using an Electromagnetic Borehole Flowmeter (EBF) was used to calculate the same parameters. To evaluate the technology, a test of the EBF was conducted at an existing well field where a long term pumping test was just conducted.



A multiple well pumping test was conducted at the Southwest Plume Test Pad near the Burial Ground Complex. The tests provide reliable estimates of horizontal conductivity averaged over aquifer thickness, and a relatively large horizontal zone of influence. To complement these results, EBF testing was performed to determine the vertical variation of horizontal conductivity about the average determined from the conventional aquifer testing.

The term "borehole Flowmeter" refers to any instrument that measures the vertical flow inside a well casing. Various types of borehole flowmeters have been used in field applications, including heat pulse, tracer release and impeller (spinner) designs. Researchers at the Tennessee Valley Authority (TVA) developed, patented and commercialized a robust, highly sensitive, borehole Flowmeter based on electromagnetic principles. The EBF operates according to Faraday's Law of Induction, which states that the voltage induced by a conductor moving at right angles through a magnetic field is directly proportional to the velocity of the moving conductor. Groundwater acts as the moving conductor, an electromagnet generates the magnetic field, and electrodes measure the induced voltage.

Two varying sizes of the EBF were evaluated. The ½-inch ID EBF has a threshold flowrate of about 5 mL/min, which is 1000 times more sensitive than the typical impeller Flowmeter. Flowrates up to about 10 L/min can be measured, giving the ½-inch ID EBF outstanding range. The 1-inch ID EBF can measure flows from about 40 mL/min to 40 L/min.

With the data collected a depth discrete flow field profile of the well can be established. Additionally, from the flow data collected the horizontal and vertical hydraulic conductivity can be determined. These data allow for a better understand of contaminant pathways in a heterogeneous subsurface.

1.2.10-Field Deployable Tritium Analysis (FDTAS)

Deployment Date: CY2000

Study Area/Project: Site Wide

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: A remotely operated, field deployable tritium analysis system (FDTAS) for measuring tritium in contaminated surface and groundwater in near real time has been developed and tested at SRS. The FDTAS prototype includes an automated sampling and purification system coupled with a stop/flow radiation detector utilizing liquid scintillation counting technology to achieve tritium sensitivities at environmental levels (25 Bq/L) for a 10 minute count. A multiport, limited volume sampler (50 mL) is used to obtain a sample from a well or surface water source, followed by in line purification through a single use filtration and ion exchange column, and then sent to a special cell for mixing the purified sample with liquid scintillation cocktail (LSC). The LSC sample mixture is pumped into a special quartz analysis cell where it is counted for a preset interval for analysis. A minimum volume of associated waste is generated through the use of small bore tubing and minimum flushing protocols. The radiation detector consists of standard LS coincidence counting electronics plus special bismuth germinate windows for active background suppression (<1.5 cpm in the tritium windows).

A 1:1 cocktail to sample mixture is used to achieve a tritium detection efficiency of >25%. The system has been calibrated in the laboratory using standard sources and has been tested in the field on lake, river and well water samples. It has also been tested on an environmental remediation air stripper which is used to remove organic solvents form contaminated groundwater. The operation of the FDTAS is controlled from a remote computer connected to the system through a standard modem. The status of the system is monitored form the remote station during all phases of operation and displays real time tritium spectral data as it is being generated. The FDTAS permits the automated screening and monitoring of tritium plumes in ground and surface waters at levels rivaling traditional sampling and laboratory analysis methods.

1.2.11-Multilevel Sampling in Monitoring Wells (Solinst)

Deployment Date: 3QFY97

Study Area/Project: Burial Ground Complex, Southeast Plume Area (BSE 1C/D, BSE 2C/D and BSE 3C/D)

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: Multilevel sampling apparatus was installed and tested in existing wells in the Southeast Plume at the Mixed Waste Management Facility (MWMF). The multilevel sampling apparatus collects samples from discrete vertical zones with an aquifer or aquifers using a single well. The discrete zones are isolated by packers and samples are delivered to the surface via a system of sampling ports and hoses.

There are several advantages over standard monitoring well construction:

- less holes are drilled in the ground (standard wells can sample only a single vertical zone) so there are reduced costs associated with drilling and construction materials;
- less investigated derived waste (IDW) due to fewer holes being drilled;
- less IDW due to purge water since the vertical zone is isolated and the volume of water associated with the whole well need not be purged; and
- low flow sampling leads to less turbid samples and should reduce the amount of spurious metals detected when unfiltered samples are analyzed

Multilevel sampling makes use of standard monitoring wells with sand packs and low flow sampling (which provides for low turbidity samples). Multilevel sampling should reduce the incidence of spurious metals detections.

1.2.12-Multilevel Sampling in Monitoring Wells (Strata Sampler ™)

Deployment Date: 3QFY98

Study Area/Project: Barnwell County Landfill, the M Area DNAPL Characterization Project

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Ralph Nichols (ralph.Nichols@srnl.doe.gov)

Description: The StrataSampler™ is a device used for the collection of soil vapor and water samples. Multiple StrataSamplers™ can be placed in a single borehole to allow the collection of discrete samples from several different depths. The StrataSampler™ is comprised of a slotted sample chamber with an inner pass through that allows tubing to connect to deeper StrataSamplers™ in the same well casing. Benefits include:

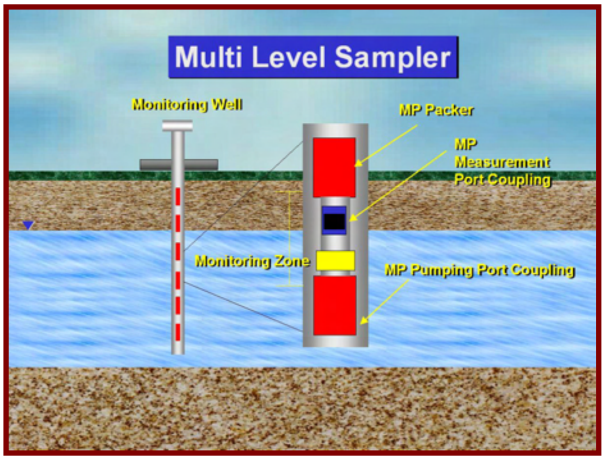
- The design of the device allows the collection of discrete samples from several depths within a single borehole, minimizing the drilling costs.
- Use of the StrataSampler™ reduces the amount of construction materials since each well screen shares casing with the overlying StrataSampler™.
- Installation of several StrataSampler™ reduces the amount of investigated derived waste (IDW) that must be generated and ultimately disposed.
- Drilling and waste collection/disposal costs are typically reduced by a factor of three to five over the conventional technology.
- This method reduces the potential for exposure to dangerous chemicals and improves safety as a result of reduced drilling.
- This technology is currently being used at the Barnwell County Landfill, the University of Miami-Ohio Experimental Well Field, the M Area dense nonaqueous phase liquid (DNAPL) Characterization Project and Lake Karachai (Russia).

1.2.13-Multilevel Sampling in Monitoring Wells (Westbay)

Deployment Date: 2QFY00

Study Area/Project: A/M Area Southern Sector

SGCP Contact: Tom McAdams (tom.mcadams@srs.gov)



Description: Defining the extent of groundwater contaminant plume in geologic materials require three dimensional analysis of sampling points at depths > 250 feet. Westbay has developed a sampling system which addresses this need. Their system embodies a modular casing system which allows a large number of monitoring zones to be established in a single borehole. Valve port couplings provide access to individual zones from a common casing. Individual screened intervals are isolated by packers. There are several key benefits associated with this system; they are significantly reduced installation costs and virtual elimination of purge water.

1.2.14-FIU VOC Indicator Sensor Array

Deployment Date: 2QFY04

Study Area/Project: C BRP

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: Groundwater remediation strategy at the Savannah River Site (SRS) is working to address the issue of intermingled groundwater plumes and how monitored natural attenuation (MNA) may be a present or future remedial alternative. To support MNA, routine groundwater monitoring, as with any remedial action, must be conducted. However, the costs for this monitoring can be high which makes MNA less attractive over the long-term. Numerous reports have described various field parameters and analytical parameters that can be analyzed which provide a basis to demonstrate that MNA is ongoing. To address the need of reduce monitoring by employing a multi-parameter system which can analyze some of the key MNA parameters, a remote monitoring system (RMS) was designed, engineered, tested and deployed. The monitoring system employs the use of a Hydrolab DataSonde 4a. The Hydrolab is capable of monitoring for pH, specific conductance, dissolved oxygen, redox potential, salinity, nitrate, and chloride. Additional capabilities of the RMS include wireless data collection, analysis, transmission, and data management. The system is powered by a marine battery that is continuously charged by a solar collection system. The system is integrated with QED Micropurge low-flow pumps and mini air compressor that is controlled by Campbell Scientific CR10X control system. The system is designed for real-time, remote detection of halogenated volatile organic compound indicator parameters in contaminated groundwater at the SRS that could be used to support MNA as a remedial action.

The RMS was deployed for six months to undergo testing and evaluation at a well cluster which is remotely located at SRS. Two wells were selected for monitoring where previous groundwater data have indicated that MNA was occurring. The RMS was programmed to collect samples from each well twice a day. The data were stored in a data logger and downloaded when accessed with a drive-by wireless modem. After six months of testing, the system operated as designed. One key problem was with a faulty chloride sensor.

1.2.15-Cone Sipper

Deployment Date: 3QFY96

Study Area/Project: Met Lab

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: Paired with a cone penetrometer technology (CPT), the Cone Sipper allows the collection of soil gas and groundwater samples of multiple depths without the need for removing and decontaminating the probe between samples. Samples are brought to the surface via small diameter plastic tubes and the device can be purged for reuse *In Situ* by injecting distilled water, air or inert gas. Its simple construction, using just three remote controlled valves, ensures reliable operation.

1.2.16-QED Low Flow Pump

Deployment Date: 4QFY02

Study Area: F Seepage Basin, M Area Basin

SGCP Contact: Eric Schiefer (eric.schiefer@srs.gov)
Mark Amidon (mark.amidon@srs.gov)

Description: The QED low flow pump is a practical solution for collecting precise, accurate ground water samples from small diameter wells. Now users of direct push technology can sample with the same EPA accepted low flow methods previously reserved for 2-inch and larger conventionally drilled wells. At 0.75-inch O.D. by 10.5-inch long, the ¾-inch QED low flow pump fits in wells as small as ¾-inch schedule 40. Disposable bladders and push in tubing replace may be replaced in seconds.

Direct push technology and low flow sampling reduce the costs of well installation, sampling and purge water handling. This pump minimizes turbidity and silting caused by the well surging of other devices such as bailers and jerk samplers and collects quality samples from small diameter wells at significant savings.

Solid stainless steel construction allows the pump to be durable with no motors, bearing or impellers to go bad. Even if the pump fills with silt, it can be put into action again with a quick, simple cleaning. Output pressure is strong and controllable.

1.2.17-QED Sample Pro

Deployment Date: 3QFY05

Study Area/Project: P Reactor Groundwater

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: The QED Sample Pro Portable MicroPurge Pump is the first pump developed specifically to bring the advantages of low-flow sampling to sites where groundwater samples are routinely collected without dedicated well pumps, from temporarily installed small diameter piezometers, and within cone penetrometer (CP) push rods. The Sample Pro pump is capable of pumping from depths up to 200 feet (61m).

The ¾-inch Sample Pro was used for groundwater sampling within cone penetrometer (CP) rods as part of determining the nature and extent of groundwater contamination at a P Area. The Sample Pro Pump is easy to disassemble, without any tools, and simple to clean to eliminate any potential cross contamination. The Sample Pro utilizes a disposable bladder, which snaps in and out without any clamps, so it can be discarded after each groundwater sampling event.

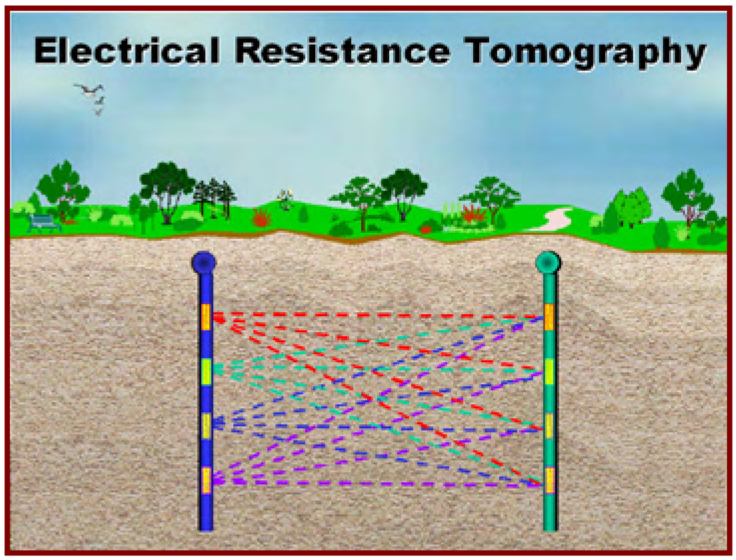
1.3-Soil and Groundwater

1.3.1-Electrical Resistance Tomography

Deployment Date: 3QFY00

Study Area/Project: 321-M Solvent Storage Tank

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)



Description: Electrical Resistance Tomography (ERT) for subsurface imaging was developed for the Department of Energy (DOE) Office of Science and Technology (OST) by Lawrence Livermore National Laboratory (LLNL). This technology can be used to obtain snapshot images of relatively static subsurface conditions for site screening or characterization. It can also be used to obtain a series of images showing the relatively rapid changes caused during environmental remediation. ERT creates 2-D or 3-D visualizations of the subsurface by generating an electrical current in the ground and measuring the potential distribution that results from the current flowing in the conductive subsurface. The images are created by interconnecting a network of boreholes. The data can be used to monitor the progress of cleanup using technologies such as air stripping, bioremediation and subsurface heating. Remediation processes such as those using subsurface heating or steam injection, can cause rapid temperature and liquid saturation changes that immediately affect electrical resistivity. Any natural or remedial process that affects electrical resistivity can readily be measured by ERT, and the results can be used to guide remediation efforts. The two or three dimensional images of the subsurface can have a scale of feet or many thousands of feet depending up on the configuration and spacing of electrode arrays. ERT is better and more economical than the drilling of more boreholes to achieve the same level of subsurface coverage. It works well in both the vadose (unsaturated) and saturated subsurface zones. The technology reduces drilling costs by at least 50 percent, accelerates the drilling phase, and does not require cross-hole interpolation of data. It also can be used to reduce the cost of full scale remediation by revealing the optimal placement of treatment wells during pilot tests. It has been successfully used to monitor the effectiveness of air permeation in air injection and vacuum extraction tests, subsurface conditions during air stripping and radio frequency heating/six phase heating tests at the Savannah River Site (SRS).

1.3.2-Expedited Site Characterization and CPT: Application of Innovative Characterization Method at SRS

Deployment Date: FY98

Study Area/Project: Site Wide

SGCP Contact: Greg Rucker (gregory.rucker@srs.gov)

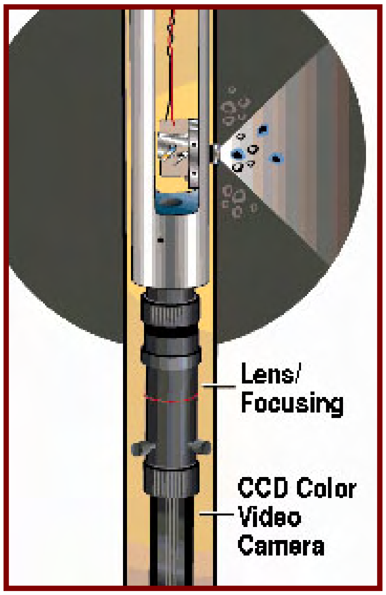
Description: Effective remediation of groundwater contamination cannot occur until the plume geometry has been thoroughly evaluated relative to the geological strata. The Expedited Site Characterization Method (ESC) combined with cone penetrometer technology (CPT) integrates multiple geophysical and analytical sampling techniques into a single approach for characterizing groundwater plumes with a higher degree of confidence compared to more traditional approaches. Application of this method has been applied in two phases at the Savannah River Site (SRS). The first phase is concerned with determining the hydrogeological framework to understand contaminant extent and migration. The second phase is an intensive, dynamic phase in which samples are collected and analyzed in a mobile laboratory. The generation of "real-time" data permits the investigation to proceed by tracking the vertical and horizontal path of contamination in the groundwater. Both the geometry can also be superimposed on top of the subsurface geology to illustrate the nature and extent of the plume relative to the strata. This method has produced three dimensional visualizations of groundwater plume geometry and increased insight of plume behavior. Application of the method has resulted in more cost effective and efficient remedial decisions and corrective measures. This method has universal application for characterizing either groundwater or soil contamination.

1.3.3-GeoVIS Probe (Soil Video Imaging System)

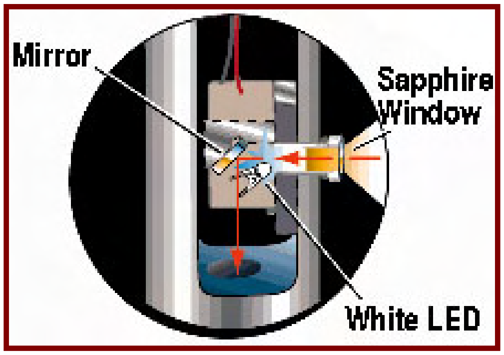
Deployment Date: 1QFY99

Study Area/Project: A/M Area, D-Area, R-Reactor

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)



Description: The GeoVIS Probe, an *In Situ* video system deployed using cone Penetrometer, is used to acquire visual information about the subsurface. The instrument consists of a CCD color camera; lens/focusing system, and a white light emitting diode (LED) illumination system. With a view port, dense nonaqueous phase liquid (DNAPL) produces a reflected color light, which can be observed visually by the video camera. The video camera is mounted inside the probe and looks out at the soil as the cone penetrometer technology (CPT) is pushed down through the suspected zone of contamination. In several field applications, the GeoVIS Probe has been used successfully to delineate DNAPL and other colored compounds in the subsurface. The GeoVIS Probe has the following advantages over conventional characterization methods:



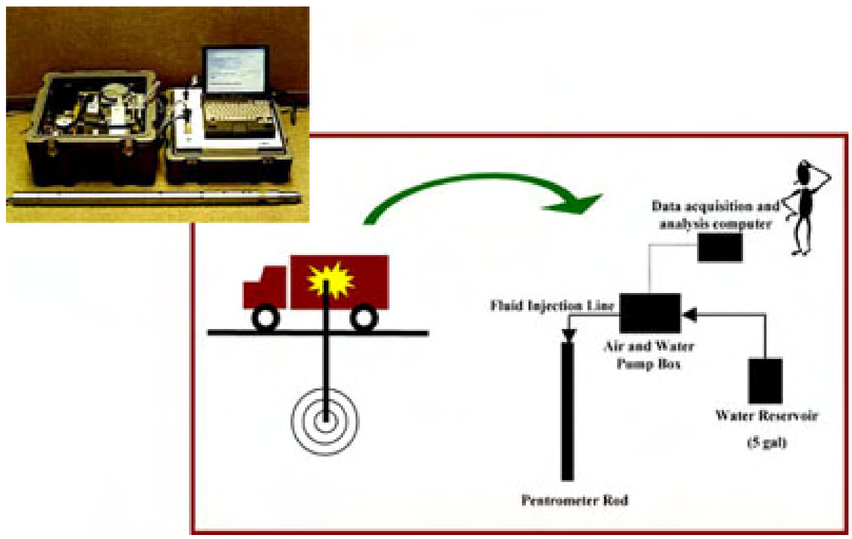
- video imaging of DNAPL using CPT would allow for quick screening of colored contaminants, in some cases DNAPL;
- use of video imaging in the initial characterization phase can be used to optimize subsequent drilling and sampling resulting in significant time and cost savings;
- the GeoVIS can be used to examine selected geologic intervals where contaminants have been identified leading to the development of a more robust conceptual model for contaminant migration;
- the GeoVIS collects data in real time, the results are used t make on site decisions;
- the GeoVIS has the capability to resolve particles as small as 10 mm;
- The GeoVIS can be used for precise delineation of the depth to groundwater using the CPT; and
- The GeoVIS Probe has been used in A/M Area, D Area and R Reactor during 1Q99 to gather information about porosity of soil matrix and presence of DNAPL.

1.3.4-In-Situ Permeability Measurements Technique

Deployment Date: 4QFY98

Study Area/Project: M-Area, Old Radioactive Waste Burial Ground

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)
SRNL Contact: Mike Serrato (mike.serrato@srln.doe.gov)



Description: The *In Situ* Permeability Measurements with Direct Push Technique is an *In Situ* permeability measurement tool using direct push technique cone penetrometer technology (CPT) to obtain a soil permeability distribution. Existing techniques for determining soil permeability distribution. Existing techniques for determining soil permeability require costly sampling and lab analysis. The *In Situ* Permeability Measurements with Direct Push Technique provides real time *In Situ* permeability in both the vadose and saturated zones using a fluid injection and monitoring system, which results in detailed vertical profiles of permeability. Science & Engineering, Inc. developed the *In Situ* Permeability Measurements with Direct Push and was field tested at the Savannah River Site (SRS). The initial field testing was focused on the Integrated Demonstration Site in M Area with field deployment at the Old Radioactive Waste Burial interim soil cover.

1.3.5-Cone Penetrometer Technology (CPT)

Deployment Date: CY1990

Study Area/Project: Site Wide

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: Cone penetrometer technology (CPT) is useful for accessing the subsurface. It is deployed by using a small diameter metal rod advanced into the ground with a hydraulic push system deployed on a heavy truck (20 to 40 tons). The tip of the CPT rod is outfitted with sensors that measure the physical parameters of the subsurface to characterize the geology of the push locations. The CPT also can be instrumented with sensors that determine chemical parameters and sampling equipment that detects water, gas and soil contamination. This technology expedites the characterization of contaminated sites.

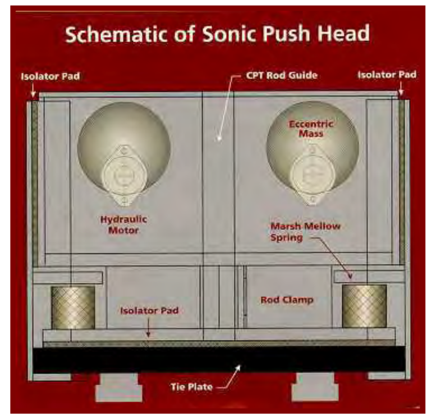
1.3.6-Cone Penetrometer Technology (CPT) Sonic Drive System

Deployment Date: 1QFY98

Study Area/Project: Site Wide

SGCP Contact: Tom Gaughan (thomas.gaughan@srs.gov)

Description: This cone penetrometer technology (CPT) Sonic Drive System allows trucks to achieve greater penetration depths beyond those achieved by standard direct push systems by reducing the required static push forces. The technology utilizes offset masses to induce vibration to supplement standard direct push technology. An advantage of the sonic CPT system is that standard CPT trucks can have the same capabilities as heavy weight CPT trucks. Both soil and water can be sampled with the sonic CPT system. Additionally, the sonic CPT system has the capability to penetrate hard layers of soil where previous standard CPT systems have met refusal.



1.3.7-Horizontal Drilling

Deployment Date: CY1998

Study Area/Project: M-Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)

Description: Horizontal drilling is used to install wells in lateral planes of the subsurface. These wells may be used for characterization, monitoring and remediation efforts involving soil and groundwater. At the Savannah River Site (SRS), horizontal wells have been used for the cleanup of chlorinated organic solvents in M Area, where waste solvents leaking from a settling basin contaminated the vadose zone and migrated into the groundwater. Horizontal wells provide a platform for implementing innovative technologies for this problem, such as *In Situ* air stripping, soil vapor extraction bioremediation with methane and PHOSter.

1.3.8-Resonant Sonic Drilling

Deployment Date: 3QFY96 (primary drilling platform for all projects since 2002)

Study Area/Project: M-Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)

Description: Resonant sonic drilling is a technique developed to access aggressive soils such as cobbles and gravel to facilitate sampling and remediation. Sonic drilling is comprised of two major components: a drill rig with a sonic head and a drill pipe. The sonic drill head uses counter rotating weights to impart energy waves at a frequency up to 150 cycles per second which expand and contract the drill pipe creating a cutting action. Deployment of instruments for subsurface characterization, monitoring and remediation provides for continuous core sampling of soils and drills at a rate 2-3 times faster than cable tool drilling systems. No cutting fluids are necessary and resonant sonic drilling can drill through any type of formation including metals, concrete and boulders.

1.3.9-EM-31 Conductivity

Deployment Date: 2QFY2004

Study Area/Project: A/M Southern Sector

SGS Contact: Randy Cumbest (randolph.cumbest@srs.gov)

Description: The EM-31 is a frequency domain electromagnetic instrument used for measurement of ground conductivity and for metal detection in that it is sensitive to conductors. The instrument functions by transmitting an electromagnetic signal at a fixed frequency. The transmitted EM signal induces "eddy currents" in nearby conductors that in turn generate a secondary electromagnetic field that is sensed by a receiver. In A/M Southern Sector, it has been employed for metal detection and to measure ground conductivity to detect a conductive tracer plume.

1.3.10-Cone Penetrometer Technology (CPT) Gamma Probe

Deployment Date: 3QFY97

Study Area/Project: R Reactor Seepage Basin

SGCP Contact: Gerald Blount (gerald.blount@srs.gov)

Description: In 3Q97, Savannah River Site (SRS) performed a technology demonstration of a direct push deployed gamma probe at the R Reactor Seepage Basins. The activity demonstrated the operational capabilities of the Site Characterization and Analysis Penetrometer System (SCAPS) spectral gamma probe. This gamma probe demonstration was a joint venture between SRS (SRNL/SGCP), Department of Energy (DOE) Office of Science and Technology, DOE Special Technologies Laboratory, Argonne National Laboratory, and the Army Corps of Engineers. The tool is intended for use as a site characterization tool at DOE sites containing radionuclides in the subsurface. *In situ* measurement of gamma emitting radionuclide concentrations in the subsurface has previously not been possible. *In situ* measurement eliminates the costs of taking a soil sample, transporting and controlling the handling of the sample and analyzing the sample. *In situ* measurement also eliminates the costs associated with the disposal of the sample, disposal of laboratory wastes and disposal of most investigation derived waste.

Comparative test work involved performing subsurface gamma spectral surveys where analytical data is available from the phase I characterization of the waste unit. Additional subsurface gamma surveys have been performed within and adjacent to the radiologically contaminated basins. The intent of the demonstration was to prove the viability of the gamma probe for future radiological waste unit characterization, and provide additional characterization data on the extent of subsurface contamination within the R Reactor Seepage Basins.

The probe consists of a sodium iodide detector, containing a 1.0x3.0 in. cylindrical sodium iodide crystal and photomultiplier tube; a temperature sensor; and a custom designed preamplifier down hole in the probe. The temperature sensor is essential to assess spectral drift due to thermal changes in the detector. During operation, analog signals are transmitted from the probe at depth to the truck where industry standard, rack mounted NIM modules are available for data processing and storage. The NIM components consist of a spectroscopy amplifier from which the signal is split into a multichannel analyzer buffer and to a rate meter. The multichannel analyzer system yields approximately 9 percent resolutions on the 662 keV line for Cesium-137. In the current configuration, the gamma energy range for 2048 channels is from approximately 200keV, but this range can be modified by simple adjustments to the NIM mounted spectroscopy amplifier within the limits of the detector. There is some distortion in the low end of the spectrum due to scatters from the D2 steel housing. Current designs for future modes are expected to overcome this low energy problem as well as giving a significant increase in resolution.

The modularity of the probe makes these improvements possible at a minimal cost and offers the field user maximum flexibility.

1.3.11-Simulprobe

Deployment Date: 4QFY97

Study Area/Project: L Area Bingham Pump Outage Pit

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: The Simulprobe groundwater sampling tool retrieves a paired groundwater and sediment sample from discrete intervals in a borehole. Permission was obtained from South Carolina Department of Health and Environmental Control (SCDHEC) to test the Simulprobe tool at L Area Bingham Pump Outage Pits borehole. During the test, the Savannah River Site (SRS) successfully used the Simulprobe Maxi to sample groundwater, in both an unassisted canister-fill mode and vacuum pump-assisted mode. In the canister fill mode, at about 65 feet subsurface, a 0.6 liter groundwater sample was collected in 30 minutes; the turbidity of this sample was 104 NTU. At another location, at approximately 45 feet subsurface, just below the water table, a low velocity pump was used to draw water into the canister. A 0.75 liter groundwater sample was obtained in 8 minutes using this method; the turbidity of the sample as 130 NTU.

The Simulprobe tool, for depth discrete groundwater sampling, works like the Hydropunch I system but has several noteworthy advantages over the Hydropunch tool. Advantages of the tool are:

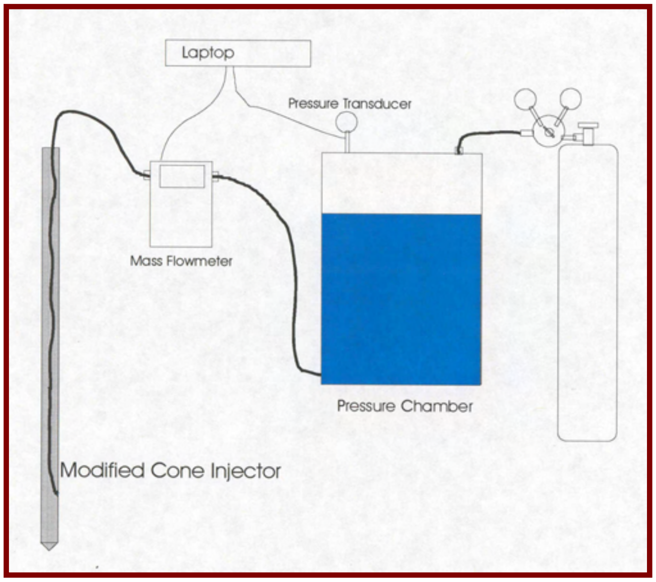
- lowered on a wire line;
- takes a paired water and sediment sample in one trip down the borehole;
- 2 liter stackable canisters (can retrieve 2, 4, 6 liter samples);
- qualitative canister fill detection;
- yields lower turbidity samples;
- more durable tool, fewer refusals, less tool deformation;
- fewer parts to decontaminate; and
- requires less time to obtain samples

1.3.12-Continuous Permeability Measurement with CPT

Deployment Date: 2QFY03

Study Area/Project: D-Area

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Greg Flach (gregory.flach@srnl.doe.gov)



Description: cone penetrometer technology (CPT) has become the preferred method of accessing the subsurface for characterization and monitoring associated with environmental restoration at SRS. However, CPT is presently deficient in characterizing permeability with both accuracy and low cost. Depth discrete permeability characterization is critical to understanding groundwater flow patterns and contaminant plume migration.

To address the accuracy and cost limitations of present CPT techniques for characterizing permeability *in situ*, the following concept for estimating permeability is being developed. The idea is to inject fluid through a CPT port at constant head during a standard "lithology" push, and continuously monitor injection flow rate. The port would be located at sufficient distance behind the continuously advancing tip to minimize dynamic effects and flow would be maintained continuously during the push to minimize the chances of clogging the injection port. The injection pressure into the formation would be maintained at approximately 10 psi above the hydrostatic/ambient pressure by adjusting the regulator at the pressure source during every rod break (adjustment every meter). Tubing and other frictional head losses would also be accounted for to maintain the 10 psi pressure into the formation. Air or nitrogen will be injected through the system on penetration and water will be injected on removal of the rods. The air injection data will be most useful in the vadose zone to predict performance of remediation systems using vapor extraction or gaseous nutrient injection, but less useful below the water table where air entry pressure may complicate results. Similarly, water injection data will be best used to evaluate formation parameters below the water table because unsaturated hydraulic conductivity will complicate response in the unsaturated zone. However, both sets of fluid injection data will be used to interpret the permeability response of the formation, particularly in the capillary fringe where varying saturation conditions could produce confusing results for each individual injection fluid. Currently available cone Penetrometer tools will be modified to accommodate a small diameter (1-3 cm) port through which fluid will be injected. Pressure and flow transducers will be selected for the anticipated ranges and will be capable of being electronically logged. A regulated nitrogen cylinder will provide the pressure source to a chamber containing the injection fluid. Investigations will be conducted to a maximum depth of approximately 60 feet below the water table to facilitate the acquisition of high resolution pressure data.

It is anticipated that the injection flow rate will be largely proportional to the permeability/conductivity of the sediment, and that a quantitative estimate of permeability can be made through analysis and calibration of the technique to other existing measurements. The proposed test is anticipated to be significantly more accurate than inferring permeability from the standard CPT push and dissipation tests, and be much less expensive than Cone Permeameter™ testing because a separate CPT push and long test times are avoided. The proposed technique will generate a continuous profile of permeability variation with depth. The technology, of proven effective, would have widespread applicability both on site, where accurate permeability information is vital to developing optimally functioning remediation systems and in the commercial CPT industry.

1.3.13-Spectral Gamma Logging

Study Area/Project: Site Wide

SGCP Contact: Jim Kupar (james.kupar@srs.gov)

Description: Spectral gamma logging has the potential for being the first direct find technology for dense non-aqueous phase liquid (DNAPL) locations within contaminated soils above and below the water table. This subsurface characterization technique is based on analyzing spectral gamma readings of specific elements in the test region. Uranium and thorium, elements which naturally occur in the environment, decay into radon. In substances contaminated with varying masses of DNAPLs, radon preferentially partitions into the DNAPL globules. With this technology, a spectral gamma probe is deployed into a well and gamma radiation levels are measured and logged. An analysis of the data on gamma emitting radon parents in relation to that on radon daughters makes it possible to identify DNAPL parameters as well as to characterize geologic conditions.

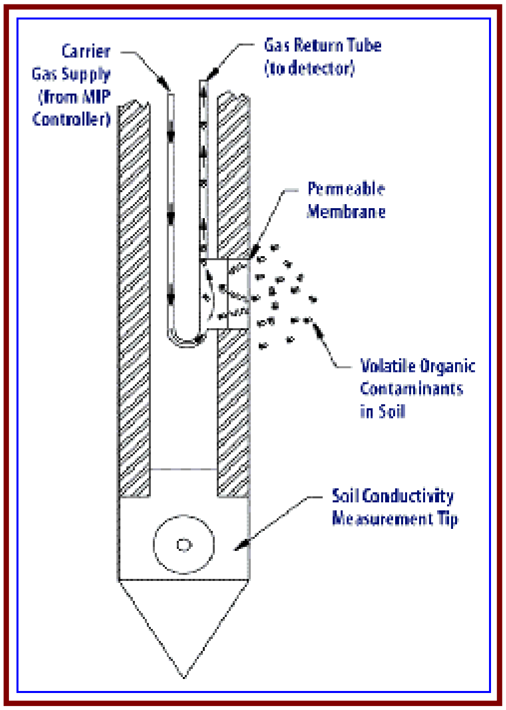
In addition, spectral gamma logging provides detailed information about DNAPL locations without requiring additional drilling and with minimal investigation derived waste.

1.3.14-Membrane Interface Probe

Deployment Date: 3QFY01

Study Area/Project: A/M Area, C-BRP

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)



Description: The Membrane Interface Probe (MIP) is a permeable membrane device used to detect volatile contaminants as it is driven to depth in soil or other unconsolidated materials. A thin film membrane is impregnated into stainless steel screen on the face of the probe. This membrane is heated to 100-120 degree centigrade which leads to quick diffusion of volatile contaminants across the membrane into the carrier gas line. The carrier gas (typically N2) transfers the contaminants to a detector (e.g., photoionization detector (PID), flame ionization detector (FID), or other) at the surface.

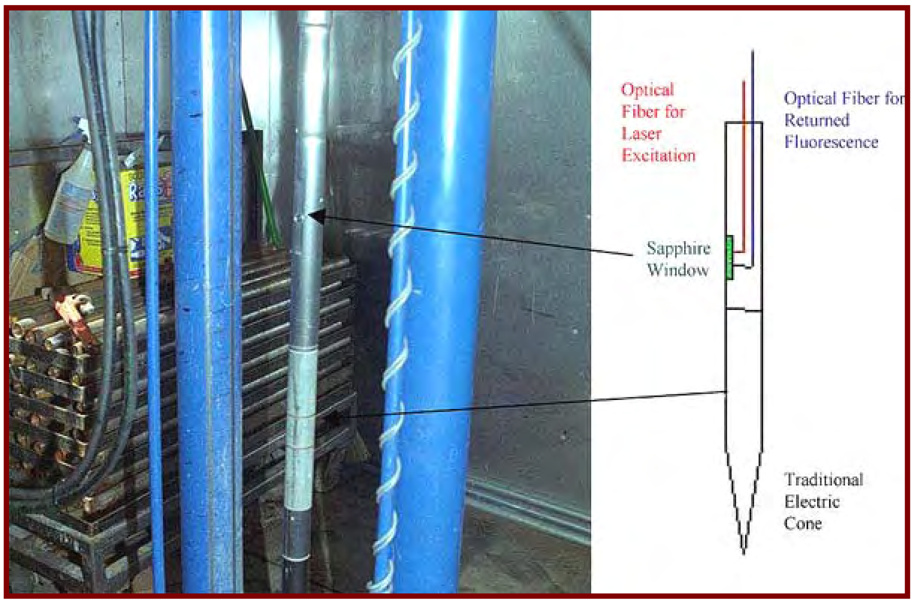
As the operator advances the MIP sensor into the subsurface, a log is displayed onscreen by the laptop computer. This log provides information about the relative volatiles concentration at depth. The real time log also provides a depth/speed graph, electrical log of the formation, and temperature log of the heated sensor onscreen. Running MIP logs on a grid or targeted pattern across the investigated area will provide the investigator with a three dimensional view of volatile contaminant distribution and lithology. Optional software allows construction of cross sections from the MIP and electric logs. The MIP log provides semiquantitative/qualitative information on contaminant levels and lets the investigator collect targeted samples from contaminated zones to define specific analytes and precise concentrations. Information from both the MIP and electric logs provides information on contaminant distribution and migration pathways. This information enhances development of an accurate site conceptual model which can significantly reduce the cost of assessment and later remediation activities, if any are required.

1.3.15-Characterization of DNAPL using Laser Induced Fluorescence (LIF) CPT

Deployment Date: 4QFY98

Study Area/Project: M Area Basin

SGCP Contact: Bob VanPelt (Robert.vanpelt@srs.gov)
SRNL Contact: Brian Riha (brian.riha@srnl.doe.gov)



Description: A cone penetrometer technology (CPT) based laser induced fluorescence (LIF) system was successfully used to detect waste chlorinated solvents at the M Area Basin at Savannah River Site (SRS). The Rapid Optical Sensor Technology (ROST) system (developed by North Dakota Technologies) was deployed by researchers from SRNL and Fugro, Inc. at a site where dense nonaqueous phase liquid (DNAPL) (tetrachloroethylene [PCE]) was recovered from two wells and where previous characterization activities had been performed (Raman spectroscopy and conventional soil coring and analysis). DNAPL was measured in both the saturated and unsaturated zones using the LIF technique. The locations were confirmed by the previous characterization activities.

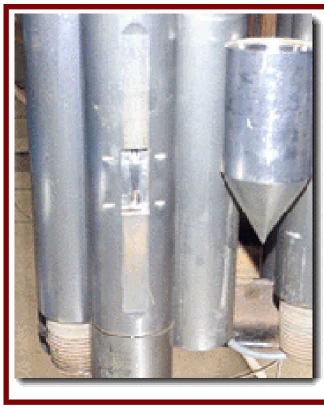
Fluorescence excitation and emission spectra are collected and analyzed. Although DNAPL themselves do not fluoresce at standard excitation wavelengths, organic matter or co contaminants that do fluoresce can leach preferentially into DNAPL. Thus the fluorescence is used to infer the presence of DNAPL. LIF can be deployed using CPT allowing for quick screening for DNAPL compounds. Use of LIF in the initial characterization phase can be used to optimize subsequent drilling and sampling resulting in significant time and cost savings. LIF screening is typically available form most commercial cone penetrometer companies.

1.3.16-Field Raman Spectrograph

Deployment Date: 1QFY99

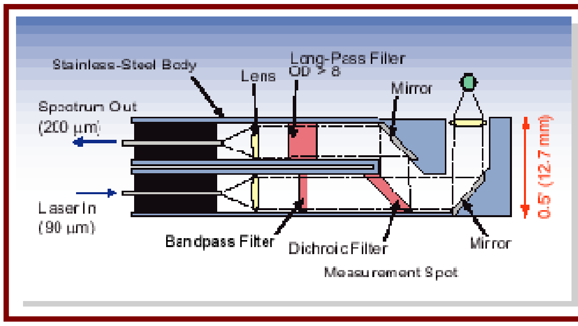
Study Area/Project: 321-M Area Basin

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)



Description: Instrumentation for on site use is needed to provide highly specific *in situ* chemical characterization and mapping of a wide variety of wastes, corrosion products and pollutants that are located in storage tanks soils and ground and surface waters at Department of Energy (DOE) sites. The history of many of the contamination sources is unknown, thus making plans for environmental restoration difficult. Concentrated wastes tend to be heterogeneous and cannot sufficiently be characterized unless multiple samples are taken.

A field hardened Raman Spectrograph has been designed which can be used to obtain "chemical fingerprints" of concentrated and dilute hazardous waste contaminants in storage tanks, soil and water. The instrument is a portable, small, analytical device capable of *in situ* measurements that can identify compounds more than 50 meters away from the spectrometer via fiber optic probes. The system is designed to be suitable for detection of highly concentrated materials and in specially designed probes, for parts per billion levels.



The field Raman Spectrograph Probe is a sensor that can be deployed with cone penetrometer technology (CPT) for i*n situ* detection and speciation of compounds including DNAPL. Raman spectroscopy is an inelastic light scattering technique that identifies specific chemical compounds by their unique spectrum. EIC Laboratories, Inc. and Lawrence Livermore National Laboratories have both designed field hardened Raman spectrographs using fiber optics that can be implemented in a CPT probe.

Advantages:

- The probe is unique as it allows for *in situ* determination of a broad range of chemicals, including DNAPL for example trichloroethylene (TCE) or tetrachloroethylene (PCE);
- It is deployed using CPT allowing for quick and accurate screening for DNAPL compounds;

- Use of the Raman Spectrography in the initial characterization phase can be used to optimize subsequent drilling and sampling resulting in significant time and cost savings; and
- The Raman system is best used for source zone characterization since it is only sensitive to very high concentration or separate phase contaminants

1.3.17-Environmental Measurement While Drilling (EMWD)

Deployment Date: 2QFY96

Study Area/Project: F-Retention Basin

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: Environmental Measurement While Drilling (EMWD) is an innovative technology developed by Savannah River National Laboratory (SRNL) to provide real time data while drilling. The sensors are located behind the drill bit and linked to a computer system above ground, while the computer functions as a data display and storage unit. During the drilling, data is collected in real time on nature and concentration of contaminants. Sensors consisted of gamma radiation detector and a Geiger-Mueller Tube. Gamma radiation detector is integrated to the drill bit. Various sensors may be attached to the drill bit to detect a wide range of contaminants.

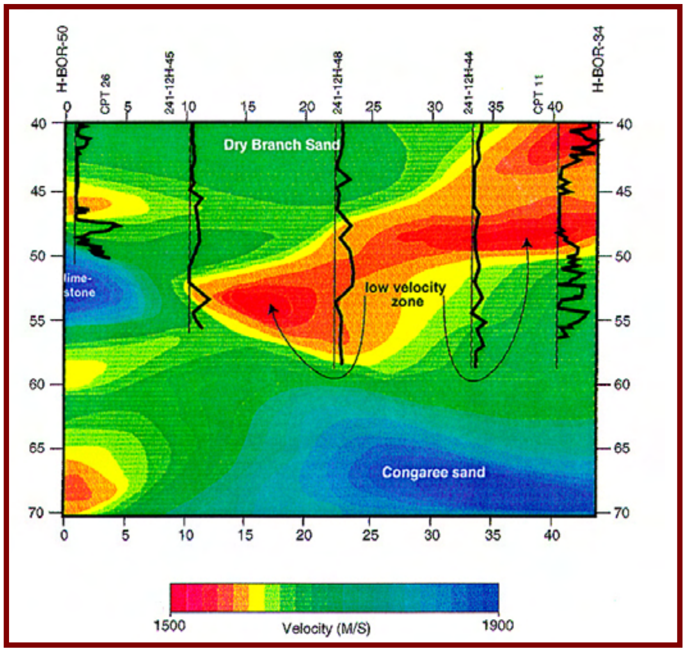
1.3.18-Seismic Tomography

Deployment Date: CY1990

Study Area/Project: Site Wide

SGS Contact: Randy Cumbest (randolph.cumbest@srs.gov)

Description: Seismic tomography is a method of generating two dimensional images of the subsurface that can be used to understand the movement of contaminants and to design/monitor appropriate remediation strategies. Seismic sources and receivers are places in boreholes and the travel times of shock waves between the two locations are collected to construct a view of rock properties and fluid content in a non-intrusive manner.



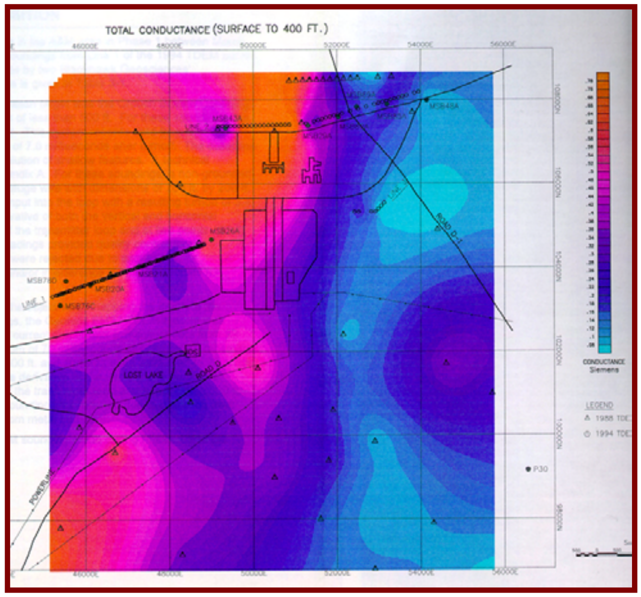
1.3.19-Geophysical Data Fusion for Subsurface Imaging

Deployment Date: 2QFY96

Study Area/Project: M-Area

SGS Contact: Randy Cumbest (randolph.cumbest@srs.gov)

Description: This methodology combines data from complementary geophysical sensors and incorporates geophysical understanding to obtain three dimensional images of the subsurface. The process focuses on the characterization of thin clay lenses (aquitards) in highly stratified sand and clay coastal geology to depths of up to 300 feet. The sensor suite used in this work includes Time Domain Electromagnetic induction (TDEM) and near surface seismic techniques.



1.4-Analytical

1.4.1-Portable Sodium Iodide Gamma Detector for Vegetation Characterization

Deployment Date: 2QFY97

Study Area/Project: C-Reactor Seepage Basin

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Frank Moore (frank.moore@srnl.doe.gov)

Description: On March 10-11, 1997 Soil and Groundwater Closure Projects (SGCP) with Savannah River National Laboratory (SRNL) applied a real time measurement method for gamma radiation emitted by the contaminated vegetation in the C Reactor Seepage Basins. Results from three trees of high, medium and low activity, indicated that the instrument could routinely detect the low emission levels that would enable segregation of the trees into clean and contaminated categories. The selection criteria between the contaminated and uncontaminated vegetation would be based on the 1000 dmp/100 cm^2 limit stated in Department of Energy (DOE) Order 5400.5, which was used in the railroad tie precedent. This represents a significant advance over the current method which relies on taking as many as 50 separate core samples per basin with chemical analysis at $3,500 per sample.

Results have been validated against chemical analysis data from the tree core samples. The results appear encouraging that we will be able to achieve significant cost savings during the current radiological vegetation removal projects.

1.4.2-Mobile Laboratories

Deployment Date: 4QFY97

Study Area/Project: B-Area

SGCP Contact: Tom Gaughan (thomas.gaughan@srs.gov)
Robert Kemmerlin (robert.kemmerlin@srs.gov)

Description: A mobile laboratory, centrally located within SRS boundary was used to perform quality analyses on soil, sediment and water. South Carolina Department of Health and Environmental Control (SCDHEC) certified organic and inorganic analytical capabilities including Target Analyte List (TAL) and Target Compound List (TCL) for 12 samples per day with appropriate quality assurance (QA)/quality control (QC) implementation. The mobile laboratories provide analytical support for a minimum of 6-8 operable units. Service provided may be either screening or definitive level data.

Chemical analyses of water, soil and sediment are required to comply with Federal and State environmental laws and regulations. It is anticipated that data and documentation generated will be subjected to regulatory and public scrutiny. Analytical services include:

- Provide new protocol precleaned sample containers with appropriate preservatives and labels;
- Provide packing materials and shipping coolers/containers;
- Transport samples from the RFI project site to the mobile lab which will be centrally located on the SRS site;
- Maintain and return original sample chain of custody;
- Handling and storage of samples following all State and Federal guidelines and regulations;
- Participate in applicable Savannah River Site (SRS), Environmental Protection Agency (EPA) and Department of Energy (DOE) QA programs;
- Analysis of the samples (for organic, inorganic constituents);
- Hard copy and electronic transmittal of analytical results in required formats
- Forward results on all audits by the EPA and all other regulatory agencies;
- Proper management of sample residual and extracts for disposal by SRS;
- Safe retention of all documents for a period of five years;
- Handling and disposal of nonradioactive hazardous waste generated by the mobile lab.

1.4.3-IRIS Inductively Coupled Plasma (ESC Application)

Deployment Date: 1QFY98

Study Area/Project: B-Area

SGCP Contact: Tom Gaughan (rhomas.gaughan@srs.gov)
Robert Kemmerlin (robert.kemmerlin@srs.gov)

Description: A technology manufactured by Thermal Gerald Ash Corporation and marketed under the name of IRIS Inductively Coupled Plasma (ICP) for detection of metals is installed in the B Area target analyte list (TAL)/target compound list (TCL) Laboratories. The IRIS ICP instrument was selected due to its' enhanced resolution that provides improvements in detection limits and reduced spectral interference's. User selected analytical wavelengths are simultaneously integrated in a manner whereby the signal to noise ratio is optimized. This allows for the spectrographic imaging of the entire spectrum in a matter of seconds. Initial Method Detection Limits (MDL) studies have indicated MDLs comparable to Furnace AA analyses but with the potential for a much greater throughput of samples. Metals to be analyzed on the IRIS include arsenic. Lead, selenium, thallium, and antimony. In soil samples these metals have shown significant interference's from earth metals using traditional techniques which will not be a problem with the IRIS ICP. The IRIS ICP represents the latest technological advancement in the metals analysis field.

1.4.4-Oak Ridge Mobile Laboratories (ESC Application)

Deployment Date: 2QFY98

Study Area/Project: F-Area

SGCP Contact: Terry Killeen (terry.killen@srs.gov)

Description: The FUSRAP program located in Oak Ridge has offered SRS a Mobile Laboratory equipped with a Gamma Pulse Height Analysis (Gamma PHA) spectrometer, and other equipment such as computers and hoods for performing analysis. This lab will provide capabilities for analyzing for gamma emitting radionuclides. Other analytical equipment such as the 3M Empore solid phase extraction disks and gas flow alpha/beta proportional counting will be installed in the mobile lab which will be deployed at the F&H water treatment facility. The equipped laboratory, valued at $250 k, will be transferred to Savannah River Site (SRS) at a shipping cost of less than $10 k.

1.4.5-Hidex Triathler Luminometer

Deployment Date: 1QFY01

Study Area/Project: F&H Treatment Units

SGCP Contact: Greg Joyner (greg.joyner@srs.gov)

Description: The Triathler Luminometer is a compact, portable, manual instrument for measuring samples in various vial sizes up to 20 mL in volume. Triathler is a revolutionary new tool for scientists involved in biotechnology, medicine, lift science research and environmental monitoring. It's a small, manual single well instrument that performs liquid scintillation counting, gamma counting and luminescence counting. It is designed for those who require instant results in their assays. Due to Triathler's extremely small size the counting is easy to perform in the field, wherever samples are collected. Triathler incorporates sophisticated alpha/beta separation electronics, which enable very low background and high efficiency alpha counting. Significant cost savings can be achieved from obtaining instantaneous clearance of samples, particularly tritium.

1.5-Sewer lines

1.5.1-Pipe Explorer System

Deployment Date: 1QFY00

Study Area/Project: R and C Area Process Sewers

SGCP Contact: Sara Mundy (sara.mundy@srs.gov)

Description: The Pipe Explorer System, developed by SEA, Inc., is a characterization technology designed to remotely access sewer pipes for the purpose of determining pipe conditions. The system operates by blowing air to insert a camera/and or detector system in a sealed plastic liner into process sewer systems. Once the camera/detector system is ready to be retrieved, it can be simply pulled back out via an attached line. More over, the front end of the liner is attached to the camera system; therefore, causing the liner to be reversed during the retrieval process. The outside of the liner becomes the inner surface and vice versa. It can be deployed under partially submerged conditions, and the plastic liner is designed to keep its contents free of contamination. This system has been successfully deployed on FUSRAP in Albuquerque New Mexico and Argonne National Laboratories sites. This technology was developed under a Department of Energy (DOE) FETC contract for the R and C Areas process sewer lines. By determining contamination levels in process sewers, decisions can be made to excavate, grout *in situ* or abandon in place. This system has proven to be a cost effective and waste minimizing technology by circumventing the high cost and risk associated with excavation and disposal without prior characterization of this type. There are potentially very large cost savings using abandon in place compared to excavation and disposal--$100-$1200/ft (Los Alamos National Laboratory cost assessment). Furthermore, a notable limitation exists in that the system cannot proceed through 90 degree pipe turns.

Chapter 2: Data Base Management/Computer Programs

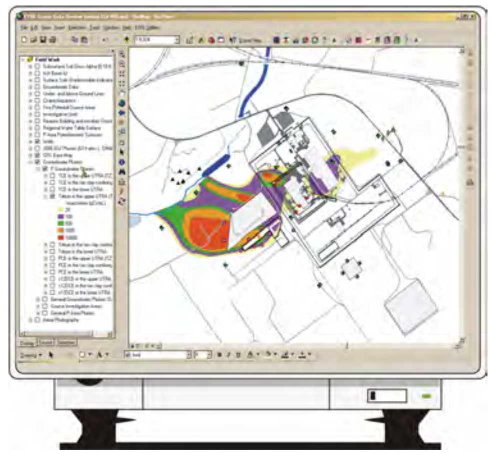
2.1.-GIS Real Time Access (ESC Application)

Deployment Date: 4QFY98

Study Area/Project: Site Wide

SGCP Contact: Tom Gaughan (thomas.gaughan@srs.gov)
EGIS Contact: Tracy McLane (tracy.mclane@srs.gov)

Description: Analytical data generated by the Mobile Lab will be linked to Savannah River Site (SRS) site computer network system providing real time access for the end user. This will allow cross linking of analytical data to geographic coverages to generate figures depicting physical as well as chemical data. This enables efficient interpretation of impacts/releases from operable units to the environment.

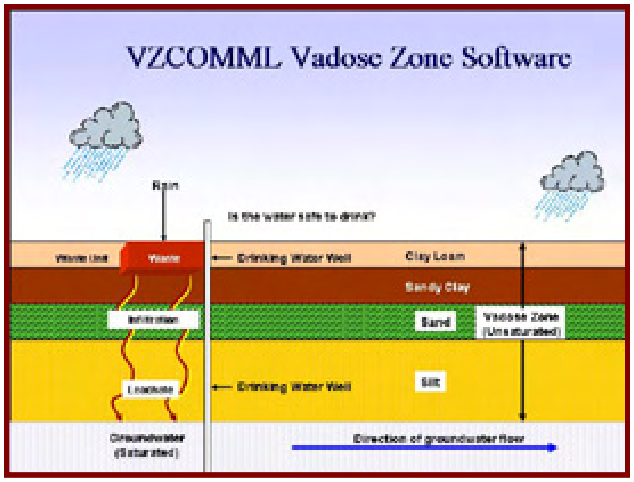


2.2-Vadose Zone Contaminant Migration Multi-Layered Software (VZCOMML)

Deployment Date: FY1999

Study Area/Project: Site Wide

SGCP Contact: Greg Rucker (gregory.rucker@srs.gov)
Cathy Lewis (catherine.lewis@srs.gov)



Description: The Vadose Zone Contaminant Migration Multi-Layered Software (VZCOMML) is innovative software developed at Department of Energy's (DOE) Savannah River Site (SRS) that automatically performs vadose zone fate and transport analyses.

The software's power is in its capability of calculating less restrictive, but still protective clean up levels for waste units. This can equate to the development of realistic clean up levels reducing overly conservative remediation goals, resulting gin significant savings for the Soil and Groundwater Closure Projects (SGCP) program. Use of the software has been implemented at SRS since 1999 in all regulatory document fate and transport assessments and is also used in DOE's Plug-In ROD for radioactive seepage basins. The model has been used on over 30 projects.

The software was designed within a simplified framework to minimize data parameter input and the need for expensive geotechnical data while optimizing useful output results. Significant cost savings are realized by the software's simultaneous calculation method and optimizing the number of chemicals per run when compared to other commercial software available on the market. The combination of the screening method and use of verified and accepted equations adds value by generating simple but powerful information for remedial project decisions.

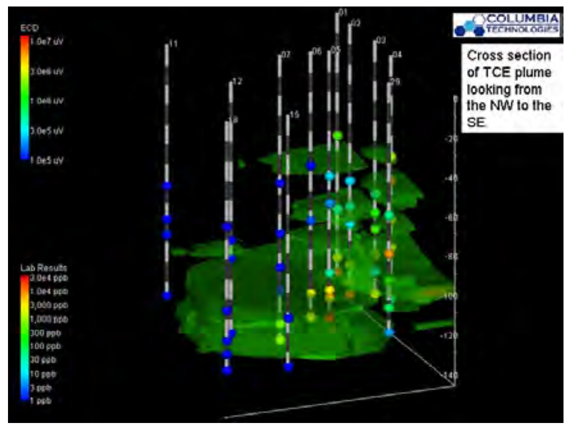
This software is copyrighted by WSRC and is currently available at no cost to any government agency or its contractors. The software has won an Intellectual Property Award and is currently being sold on a commercial basis.

2.3-Smart Data (3-D Image of Sub-Surface Contamination)

Deployment Date: 4QFY02

Study Area/Project: P-Area Groundwater

SRNL Contact: Karen Vangelas (karen.vangelas@srnl.doe.gov)



Description: Interest in characterization approaches that integrate rapid data collection, screening analysis and visualization techniques to allow additional characterization decisions to be made in the field is increasing. SmartData SM, a proprietary approach developed by COLUMBIA Technologies, LLC, integrates rapid data collection methods, rapid analysis methods, rapid computational analysis and information delivery technologies to provide decision making tools in the field. The data collection methods typically center on CPT based sensors which allow for collection of large quantities of depth discrete data in both the saturated and unsaturated zones. The data can be in the form of soil, water and soil gas samples. The analytical methods use field based instruments, such as gas chromatographs, to provide screening level data. One use of the SmartData SM approach is in characterization of the subsurface contaminated with volatile organic contaminants (VOCs). This approach expedites the characterization of contaminated sites.

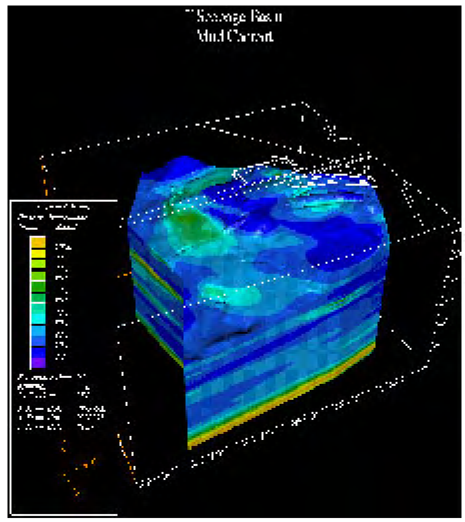
2.4-3-D Digital Imaging

Deployment Date: ~CY1998

Study Area/Project: Site Wide

SGS Contact: Randy Cumbest (randolph.cumbest@srs.gov)
SRNL Contact: Greg Flach (gregory.flach@srnl.doe.gov)

Description: Subsurface environmental data were traditionally viewed and analyzed in 2-D, using base and contour maps. 2-D visualization can obscure important vertical variations in contaminant concentration and hydrogeology. 3-D digital imaging enables the analyst to simultaneously view horizontal and vertical variation, and provides a more accurate representation of subsurface data. Data analysis using 3-D graphics on high speed workstations leads to a better interpretation of the depth, width and breadth of the dispersion of pollutants in groundwater or soil. This graphic package includes a contouring system specially designed for visualizing contaminant information at a waste site.



2.5-Data Delve-Heuristic Optimized Processing Systems (HOPS)

Deployment Date: CY1995

Study Area/Project: Integrator Operable Units

SGCP Contact: Susan Dyer (susan.dyer@srs.gov)

Description: DataDelve Client and EcoTrack Server is an environmental information system that used heuristic algorithms as a problem solving technique in which the best solution of several found by alternative methods is chosen at each stage of a program for use in the next step of the program. These algorithms were developed by Heuristic Optimized Processing Systems (HOPS) International, Inc. Personnel use the system performing environmental assessments during waste site remediation and restoration activities. The system supports activities related to the Comprehensive Environmental Response, Compensation and Liability Act.

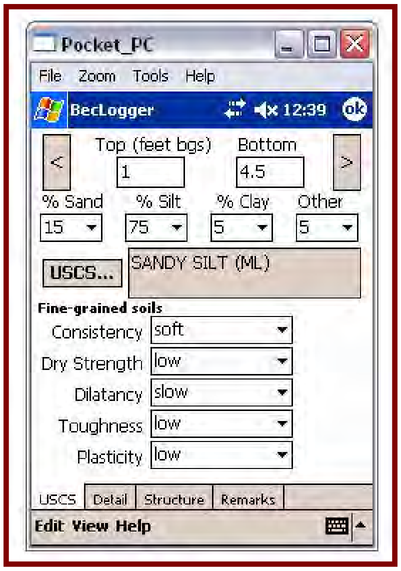
2.6-BecLogger

Deployment Date: 3QFY05

Study Area/Project: General Separation Area

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)

Description: The BecLogger is a Bechtel software program written for a personal data assistant (PDA) platform that allows a field geologist to capture core description and notes electronically. This process minimizes error and allows for the data to be electronically available for download into a database. From this database, forms and completed geotechnical logs can be generated for review and approval without the time-consuming handwritten paper copies.

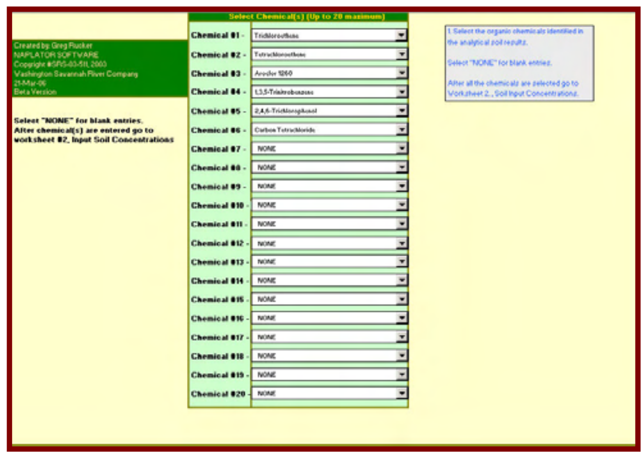


2.7-NAPL Calculator

Deployment Date: 2Q03

Study Area/Project: Site Wide

SGCP Contact: Greg Rucker (gregory.rucker@srs.gov)



Description: It is extremely important to properly characterize the magnitude of NAPL contamination in soils in order to design and construct a successful remediation system. To determine if a NAPL mixture is present in a soil sample can be an extremely complicated problem to solve. The Non-Aqueous Phase Liquid Calculator is a software program designed to determine the presence and quantity of NAPL mixtures in soil samples using routinely available soil analysis. The calculator will solve this problem by providing robust data outputs including: the mass of NAPL present in the sample (if any), effective solubility of each mixture component, phase (vapor, liquid, and solid) concentrations, phase masses, residual saturation (volumetric NAPL content), molar fraction for each mixture component, and soil saturation limits (threshold limits) for each mixture component to name a few of the more important results. The calculator will solve for both saturated and unsaturated soil samples. All the chemical parameters for over 300 organic compounds necessary for the calculations are provided in a built-in database within the software which eliminates user inputs. The model will also solve on both a wet or dry weight basis which is often overlooked in this type of calculation.

This software was first used at the C-Area Burning Rubble Pit in 2002 and at the CMP Pits in 2003. A number of copies have been sold commercially to several environmental consulting firms including Parson's Engineering and Science in New York State. The software has also been the subject of a manuscript and presentation at the National Ground Water Association Annual Conference in Houston, Texas.

2.8-Motor Current Signature Analysis

Deployment Date: 3QFY2003

Study Area/Project: Site Wide

SGCP Contact: Joseph Amari (joseph.amari@srs.gov)

Description: MCEmax is used to record "current signature analysis" of electrical equipment, such as motors and transformers. It gives an indication of equipment "health" by measuring the equipment electrical signal, which is affected in different ways by different equipment problems. One great advantage this technology provides is that measurements may be taken remotely for equipment in rad areas. For example, the status of bearings on a pump in a tank with high radionuclides can be monitored from outside the rad area using this technology.

Chapter 3: Remediation Technologies

3.1-Soil

3.1.1-In-Situ Plasma Vitrification of Contaminated Soils (Demonstration)

Deployment Date: 1QFY97

Study Area/Project: K Reactor Seepage Basin

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)

Description: The plasma torch, a source of intense (5000-10,000 degrees Celsius) heat, is being used in next-generation melter designs to convert the most difficult hazardous and radioactive wastes into stable, vitrified forms. In-situ plasma vitrification (ISPV) offers permanent, in place treatment of soils which, due to high levels of radioactive or hazardous contamination, cannot be safely exhumed for treatment. ISPV extends the capabilities of conventional in-situ vitrification since it is not dependent on soil properties and has inherent depth limitations. It is also inherently safer since void buildup and underground gas pressurization are avoided by the "bottom-up" direction of melting.

3.1.2-In-Situ Soil Stabilization Solidification

Deployment Date: 2QFY99, 4QFY99, 2QFY00

Study Area/Project: Site Wide

SGCP Contact: Mohammad Kasraii (mohammad.kasraii@srs.gov)
Amit Ganguly (amitava.ganguly@srs.gov)

Description: Solidification and stabilization (S/S) technology is currently being used to treat a wide variety of sites in the commercial waste remediation industry. During the S/S process, a special grout is mixed into the contaminated soil. This grout has a chemical affinity for the contaminants and effectively immobilizes these contaminants in place while at the same time prevents their migration into the groundwater. The grout mixture is usually Portland cement based and contains specific additives designed to react with the targeted contaminants of concern (COCs). The grout is mixed into the soil and typical additives are bentonite, zeolites, fly ash, cement kiln dust and various silicates. Proportions of this grout, water and additives area determined through a field optimization process depending on the field conditions (type of soil, moisture content, type and concentrations of contaminants). 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.

As several of the abandoned radioactive and chemical waste basins in the Soil and Groundwater Closure Projects (SGCP) are similar in contaminant concentrations, area extent and depth, it is intended that they will remediate using the in-situ grouting technique.

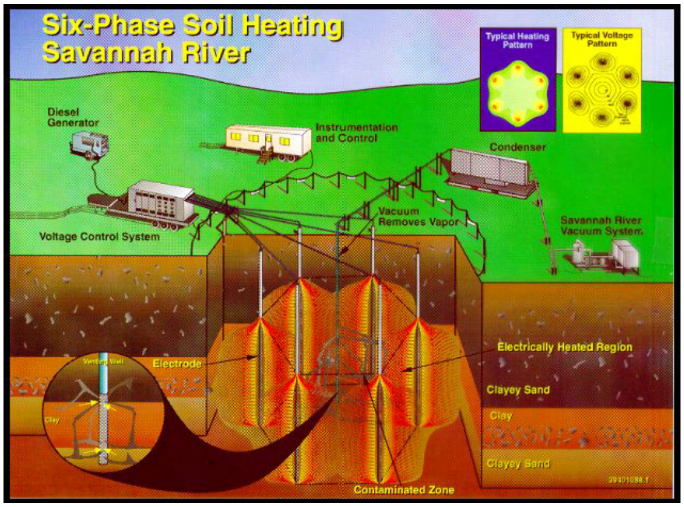
3.1.3-Thermally Enhanced Vapor Extraction (Six Phase Heating, Demonstration)

Deployment Date: 3QFY06

Study Area/Project: C-Reactor Groundwater
Future Deployment: FY08
Study Area/Project for Future Deployment: CMP Pits

SGCP Contact: Robert Blundy (bob.blundy@srs.gov)
Joe Amari (joseph.amari@srs.gov)

Description: Thermally Enhanced Vapor Extraction (also referred to as Six Phase Soil Heating or Electrical Resistance Heating [ERH]) remediates soils contaminated with volatile and semi-volatile organic compounds and is designed to enhance the removal of contaminants from the subsurface during soil vapor extraction. The technology combines of six-phase electrical heating with soil vapor extraction (SVE) to produce a more efficient *in situ* remediation system for difficult soil and/or contaminant applications.



ERH is especially suited to sites where contaminants are tightly bound to clays and are thus difficult to remove using SVE alone. By coupling ERH with SVE, large quantities of contaminants can be effectively removed in a relatively short amount of time.

ERH increases the temperature of the soil internally by passing standard AC current through the soil moisture. Heating is largely dependent on soil moisture where soils of low permeability and high water content are preferentially heated. Heating also raises the vapor pressure of volatile and semi-volatile contaminants, increasing volatilization and concomitant removal from the soil via SVE. Heating dries the soil and creates steam which 1) increases the permeability of the formation, and 2) strips contaminants that may not be removed via SVE alone.

Conventional three-phase electricity is separated into six separate electrical phases, producing an improved subsurface heat distribution. Each phase is delivered to a single electrode, each of which is placed in a hexagonal pattern. The soil vapor extraction well, which removes the contaminants, air, and steam from the subsurface, is located in the center of the hexagon.

ERH offers advantages over other heating technologies such as:

- delivers more power to a larger soil area and less at the electrodes;
- uses standard utility power transformers at a relatively low capital cost; and
- does not require permeable soils as does SVE and as do most other heating methods.

3.1.4-Soil Vapor Extraction

Deployment Date: CY 1987, 3QFY00

Study Area/Project: A/M Area, M Basin

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
John Bradley (john02.bradley@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)

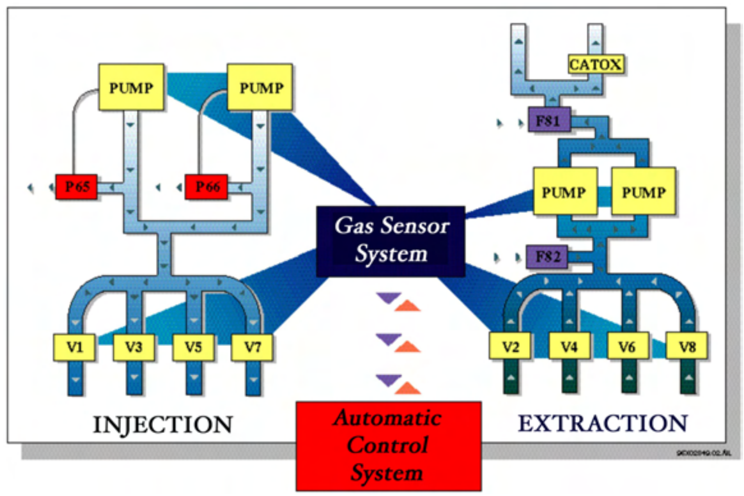
Description: Vapor extraction systems remove volatile organic compounds (VOCs) from soils above the water table through slotted well piping that can be installed vertically or horizontally. Vacuum pumps draw the VOCs through the pipes to the surface where they are removed from the air stream and destroyed. The goal is to remove the contaminants before they migrate into the water table. The Savannah River Site (SRS) was one of the first locations in the United States to deploy the technology

3.1.5-Soil Vapor Extraction Unit Control Systems (SVE Unit 5 in A/M Area)

Deployment Date: 4QFY96

Study Area/Project: A/M Area, M Basin

SGCP Contact: John Bradley (john02.bradley@srs.gov)



Description: In M Area at SRS, soil vapor extraction systems are coupled with four thermal catalytic oxidation (TCO) units for treating soil vapor streams from underground chlorinated volatile organic compounds (VOCs). Each TCO unit handles oil vapor streams from one to three wells. The technology destroys CVOC emissions in the soil vapor stream and results in water vapor, carbon dioxide, and hydrochloric acid. These products are discharged to the atmosphere at a rate per hour permitted by regulatory authorities. The concentration of CVOC emissions in the soil vapor stream is variable. To accommodate peak concentrations in the stream and to avoid exceeding discharge limits, the process throughput is "throttled back" to a level that is less than the system's theoretical capacity. This reduces the speed and efficiency of treating the soil vapor. The solution for this dilemma is to install a process control system designed to stabilize discharges at the permitted level by regulating and optimizing the process. This is a computerized system that consists of a host center and automatic control valves that monitor all four TCO units.

3.1.6-Enhanced Soil Vapor Extraction with Hydraulic Fracturing

Deployment Date: 4QFY05

Study Area/Project: MIPSL

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Brian Riha (brian.riha@srnl.doe.gov)

Description: Introducing sand-filled fractures into tight zones improves the performance of soil vapor extraction (SVE) by 1) increasing the overall permeability of the formation and thereby increasing SVE flow rates, 2) shortening diffusion pathways, and 3) increasing air permeability by improving pore water removal. The synergistic effect of the fracture well completion methods, fracture and flow geometry, and pore water removal appears to increase the rate of solvent mass removal over that of increasing flow rate alone.

A field test was conducted where a conventional well in the Savannah River Site (SRS) Upland Unit was tested before and after hydraulic fracturing. The goals of the fracturing pilot testing were to evaluate the following:

- The effect of hydraulic fractures on the performance of a conventional well. This was the most reliable way to remove the effects of spatial variations in permeability and contaminant distribution on relative well performance. It also provided data on the option of improving the performance of existing wells using hydraulic fractures.
- The relative performance of a conventional SVE well and isolated hydraulic fractures. This was the most reliable indicator of the performance of hydraulic fractures that could be created in a full-scale implementation.

The SVE well, monitoring point arrays and four fracturing wells were installed. Four fractures were successfully created. The fractures were created in an open area at the bottom of steel well casing by using a water jet to create a notch in the soil and then injecting a guard and slurry into the formation. The sand-filled fractures increase the effective air permeability of the subsurface formation and decrease diffusion path lengths for contaminant removal.

The primary metrics for evaluation were an increase in SVE flow rates in the zone of contamination and an increase in the zone of influence. Sufficient testing has been performed to show that fracturing in the Upland Unit accelerates SVE solvent remediation and fracturing can increase flow rates in the Upland Unit by at least one order of magnitude.

3.1.7-Phytoremediation –VOC Application

Deployment Date: 4QFY99

Study Area/Project: A/M Southern Sector

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
Roger White (roger.white@srs.gov)

Description: Phytoremediation is a technology that uses the ability of natural occurring plants to degrade volatile organic compounds (VOCs) released to the subsurface and at the same time minimizes risks to public 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. The use of vegetation to actively promote microbial restoration of chemically contaminated soils has been previously demonstrated at the SRS. A comparison of the environmental fate of carbon 14 labeled TCE in vegetated and on vegetated soils from a TCE contaminated field indicated increased mineralization (natural gas production) in soils containing vegetation. A pilot scale study to determine what type of vegetation is effective has commenced. This technology was deployed in the Southern Sector where a plume of TCE and tetrachloroethylene (PCE) contaminated groundwater is estimated to emerge (in the next ten years) at hydrologic boundaries such as surface streams. The emergence of the TCE/PCE plume could potentially result in the contamination of surface soils and water. Therefore, this technology is being deployed to phytoremediated the TCE and PCE moving in groundwater through the soil prior to the contaminants emerging through to the surface receptors.

3.1.8-Barometric Pumping (Baroball)

Deployment Date: 1QFY96, 2QFY96 and 4QFY98

Study Area/Project: M Basin and Miscellaneous Chemical Basin

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Riha (brian.riha@srnl.doe.gov)

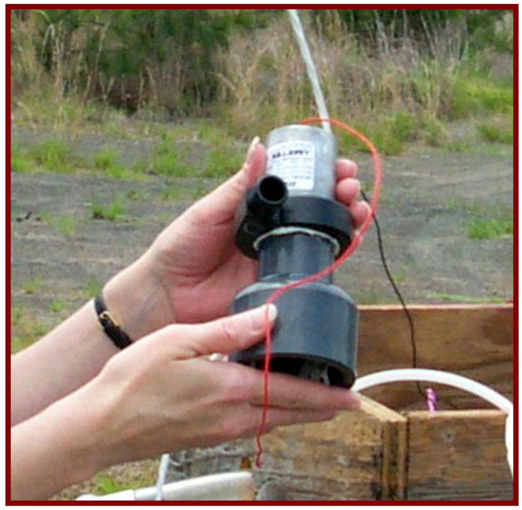
Description: Barometric pumping removes volatile organic compounds from the soil by taking advantage of changes in barometric pressure above and below ground. When the subsurface pressure is higher, contaminants naturally move upward where they can be treated/released. The Baroball significantly increases 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 disbursing the pollutant. Its design consists of a simple plastic sphere that seals the well from incoming surface air. The Met Lab BaroBalls will utilize a cone penetrometer technology (CPT) truck for well installation.

3.1.9-Microblowers

Deployment Date: 4QFY02

Study Area/Project: A Burning Rubble Pit

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Brian Riha (brian.riha@srnl.doe.gov)



Description: The A Area Burning/Rubble Pits (731-A/1A) and Rubble Pit (731-2A) (ABRP) Operable Unit (OU) is located in the northwest portion of SRS. Recently geo-referenced aerial photographs revealed a "trench/it" underlying the A Area Ash Pit (788-2A). Characterization has since revealed that elevated concentrations of tetrachloroethylene, trichloroethylene and 1, 2-dichloroethylene is present in the base of the "trench/pit" and extends into the vadose zone beneath the trench to the water table. This "trench/pit" and its associated volatile organic compound (VOC) contamination are believed to be the source of existing M Area aquifer contamination. Four borings completed during the recent trench/pit characterization effort were converted to soil vapor extraction (SVE) wells and capped until approval for use in future vadose zone remediation. The project team is proposing to evaluate three of these four wells for low flow active (microblower) extraction.

The microblower is a low flow, low power, active soil vapor extraction device which is being developed for environmental applications by Savannah River National Laboratory (SRNL). Microblowers are small pumps that are connected directly to the wellhead to remove contaminated soil gas. Microblowers can be operated either by power provided directly by a solar panel or by a solar recharged battery. At ABRP, the microblowers will be driven directly by solar power. Microblowers can also be used in conjunction with a one way valve (Baroball) in a hybrid system. During daylight hours, the microblower would operate to remove soil gas. In the afternoon/evening, when solar power is not available, barometric pumping would remove contaminated soil gas. Vacuum induced by the blower at different flow rates will be measured to determine the system characteristics of the well. These measurements will enable us to select a microblower with the appropriate performance characteristics of the well. Off-gas concentrations will be measured continuously by a portable gas chromatograph.

3.1.10-Metal Reduction by Melanin Application

Deployment Date: 3QFY05

Study Area/Project: Pond 25

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Chuck Turick (charles.turick@srnl.doe.gov)

Description: Contamination from metals and radionuclides exists throughout the Department of Energy (DOE) system including Savannah River Site (SRS). Remediation technologies exist for treating these contaminants but when metals and radionuclides are present in low concentrations with associated environmental risk, these technologies may cease to be cost effective.

A field project was performed at Pond 25 along Tim's Branch to focus on the long-term effects of using humic-type compounds of microbial origin for accelerating and maintaining metal and radionuclide stabilization. Because of their redox behavior, humics accelerate metal reduction by bacteria. Although humics are considered ubiquitous, their concentrations and redox behavior vary considerably throughout the subsurface. A portion of subsurface microbes produce humic-type compounds as extracellular metabolites. These metabolites (such as melanin) have redox cycling properties that permit bacteria to reduce metals at accelerated rates. For example melanin production by bacteria in the genus *Shewanella* accelerates the reduction rates of metal oxyanions and minerals by as much as ten times.

Work performed at SRS has demonstrated that: 1) Redox cycling metabolites are produced by bacteria in various soils at SRS; 2) Supplemental addition of tyrosine or phenylalanine to the soil stimulates production of redox cycling polymers; 3) Redox cycling polymers are "shared" for metal reduction by bacteria that do not produce these polymers; 4) Bacterial metal reduction is enhanced in soils with redox cycling bacterial metabolites; 5) U stabilization is achieved in-situ by stimulating indigenous microbes to produce and reduce pyomelanin.

3.1.11-Pug Mill

Deployment Date: 1QFY05

Study Area/Project: P Area Seepage Basins

SGCP Contact: John Bradley (john02.bradley@srs.gov)

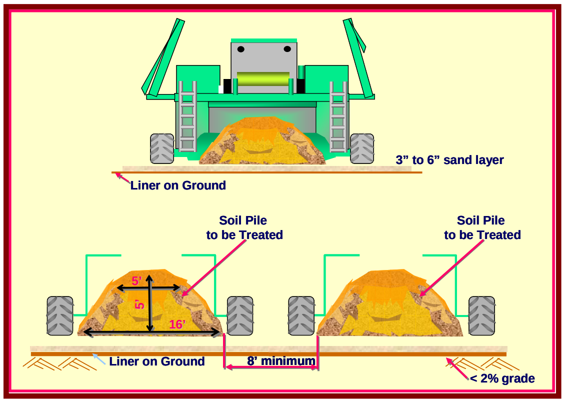
Description: The P-Area Reactor Basins were remediated in 2005 using a pug mill to achieve in-situ solidification and stabilization (S/S). Soils were transferred from the reactor seepage basins to the pug mill; the prescribed amounts of Portland cement, bentonite, and water were added to the soil; the pug mill thoroughly mixed the components; and the resulting S/S mix was transported back into the basins from which the soil originated. The S/S grout mix was approximately 15% Portland cement and approximately 5% bentonite. The amount of water added was variable, based on soil conditions during S/S operations. A programmable logic controller was utilized to control additions of the cement, bentonite, water and soil in to the pug mill.

3.1.12-Microenfractionation

Deployment Date: 1QFY02

Study Area/Project: CMP Pits

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
Sara Mundy (sara.mundy@srs.gov)



Description: H&H Eco Systems Inc. of North Bonneville, WA implemented the bioremediation treatability study by constructing windows out of 600 cubic yards of contaminated ballast area soils, then introducing organic ingredients together with inorganic supplements using a commercial window turning machine (their Microenfractionator™ process). The windows were covered between treatments to retain moisture and heat from the biochemical reactions. Periodically, the windows were sampled and process parameters measured to monitor on going process chemistry. The process was conducted over a six month period, basically in two phases. An initial aerobic phase showed a slow decrease in both pesticide and polychlorinated biphenyl (PCB) concentrations but the dichlor diphenyl trichlor (DDT) still remained elevated above the remedial goals. To accelerate the rate of DDT concentration decline, the process was converted to anaerobic operation, which resulted in almost a further order of magnitude decrease in the DDT concentration over 30 days.

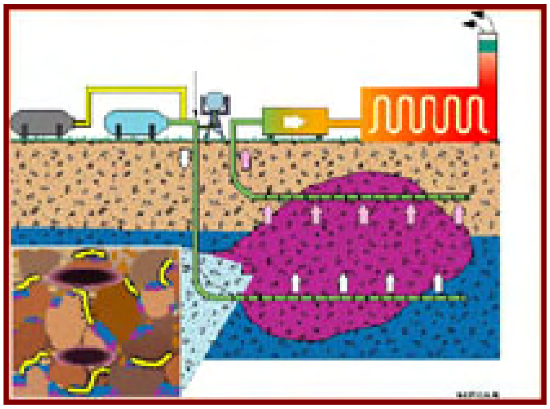
Overall measured decreased in contaminant concentrations were: destruction of the herbicide to levels below detection, up to 93% reduction for the DDT and up to 60% reduction for the PCBs below initial levels. The decline in DDT concentration during the anaerobic period coincided with measured increases in the concentrations of known DDT degradation products, which provided supplemental evidence that microbial destruction of DDT, had in fact taken place. Similar work to support the observed decline in PCB concentrations is ongoing.

3.1.13-Phosphate-Accelerated Bioremediation (PHOSter)

Deployment Date: CY1996

Study Area/Project: A/M Area

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)



Description: In bioremediation processes that are phosphorus-limited (where the amount of phosphorus determines biomass growth and reaction rates), controlled addition of the nutrient is the key to effective process control and to reducing the time needed to destroy contaminants.

Savannah River Site (SRS) scientists, in partnership with Oak Ridge National Laboratory, developed a new, improved process to control the addition of vapor-phase phosphorus to bioremediation systems, bioreactors, and other biotechnology applications. Called the PHOSter system, this technology offers significant advantages over existing technology, such as

- improved control,
- simpler design and operation,
- increased flexibility for site-specific customization,
- improved use of the phosphorus feedstock, and
- greater ability to document performance.

For example, in a bioventing process used to remediate an oil-contaminated site, air is drawn through the soil to stimulate the aerobic bacteria that break down the contaminant. The PHOSter system allows a controlled amount of phosphorus to be added to the air, providing relatively precise control of the biomass growth. Thus, the operator can maximize oil degradation without over stimulating the microbial community.

Traditional approaches to using phosphorus at remediation sites are based on adding liquid fertilizer (orthophosphate) solutions to the ground surface or to wells. Such systems have influenced only small areas and over stimulated these areas, resulting in negative consequences like formation clogging.

The addition of phosphoric acid vapor was proposed as an alternative. Like other inorganic orthophosphate-based systems, this approach tends to over stimulate relatively small areas because of the high solubility and ionizability of the acid. Moreover, full-scale process control and efficient use of phosphorus in phosphoric acid-based systems have never been demonstrated.

The PHOSter system, which has been proven effective in the laboratory and in the field, eliminates or reduces many of the short comings associated with phosphoric acid vapor.

The PHOSter system permits controlled addition of a relatively safe form of organic phosphorus (nominally triethyl phosphate) to the injected air. The liquid is added in a contractor or with an infusion pump at a rate below the vapor pressure. Research at SRS shows phosphorus in this form is available to the microorganisms, providing stimulation similar to liquid orthophosphate. Presence of the organic groups, however, reduces dissolution of the nutrient into water (similar to natural organic fertilizers used in agriculture) and provides a more uniform "time-release" stimulation.

When added to a full-scale, field demonstration using horizontal well technology, stimulation of indigenous methanotrophs with the PHOSter system resulted in major improvements in the in-situ destruction of chlorinated solvents in soil and ground water at SRS. In another test, the Gas Research Institute/Retech used the technology at a bioventing site and increased the bioremediation rate by a factor of 5 to 10.

The PHOSter system can improve the effectiveness of many environmental bioremediation and biotechnology techniques, such as bioventing and other in-situ bioremediation methods, surface bioreactors, and other processes that are phosphorus limited. PHOSter may also enhance biological-based production of chemicals and pharmaceuticals.

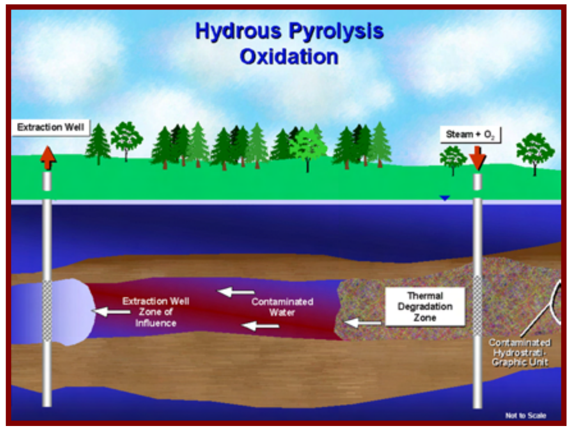
The PHOSter system was recently recognized as a leading-edge environmental technology innovation, one of the prestigious R&D 100 awards for 1996.

3.1.14-Hydrous Pyrolysis

Deployment Date: 1QFY01

Study Area/Project: 321-M Solvent Storage Tank Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)



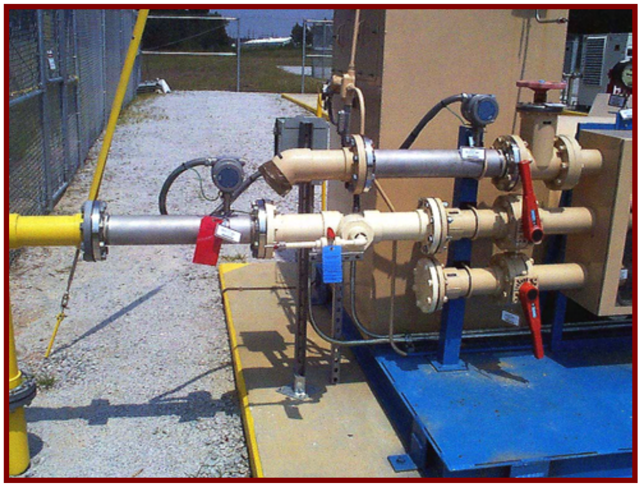
Description: Hydrous Pyrolysis Oxidation (HPO) is another name for chemical oxidation in the presence of heat. These simple reactions between oxygen and contaminants are orders of magnitude faster at or close to steam temperature than under ambient temperatures. To utilize HPO for *in situ* remediation, steam injection is first used to heat the target zone and remove the mobile nonaqueous phase liquid (NAPL). Then, steam and oxygen are injected simultaneously in a pulsed fashion, building a heated, oxygenated zone in the subsurface. When injection is stopped, the steam condenses and contaminated groundwater returns to the heated zone. The contaminants in the groundwater mix with the oxygen and condensate and in the presence of heat rapidly oxidize to form carbon dioxide and chloride ions.

3.1.15-In-Situ Air Sparging and Soil Vapor Extraction

Deployment Date: 3QFY99

Study Area/Project: C Area Burning Rubble Pit 131-C

SGCP Contact: John Bradley (john02.bradley@srs.gov)
SRNL Contact: Brian Looney (brian02.looney@srnl.doe.gov)



Description: The C Area Burning/Rubble Pit 131-C (CBRP) is a shallow, unlined excavation pit with a volume of approximately 3, 270 cubic yards. The CBRP was constructed in 1951 for use as a burning pit for oils, paper, plastics and rubber. Disposal of combustible wastes in the pit was discontinued in 1973 and the remaining pit contents were covered with a thin layer of soil. Soils within and beneath the pit are primarily contaminated with volatile organic compounds (VOCs) and low concentrations of dioxins and metals; and groundwater in the upper water table is contaminated with trichloroethylene (TCE) and lesser amounts of tetrachloroethylene (PCE) and dichloromethane. Operations at CBRP began on September 28, 1999. An interim remedial action is necessary to reduce high concentrations of TCE and to minimize the spread of groundwater VOCs from the upper water table to deeper aquifers. Therefore, an Interim Action Proposed Plan (IAPP) was prepared to establish the necessary interim remedial actions. The following remedial actions will be utilized:

- A native soil cover was installed over the CBRP to act as a barrier and to prevent soil exposure to future human and ecological receptors as well as mitigate further migration of TCE from CBRP soils to groundwater; and
- Air sparging is being utilized together with soil vapor extraction to remove the VOCs from the contaminated groundwater in the upper aquifer and from the soils located in the vadose zone. Air sparging injects compressed air at controlled pressures and volumes into the upper water table. The compressed air facilitates the removal of volatile organics from the groundwater through the physical process of volatilization. VOCs are transported through the mechanism of air channels or bubbles upward into the relatively dry soil of the vadose zone. Once the VOCs reach the vadose zone, they are extracted via vacuum wells by the soil vapor extraction system. The extracted soil vapors are processed through a liquid phase separator to remove condensate. The offgas complies with South Carolina Department of Health and Environmental Control (SCDHEC) Air Quality Control permit requirements.

After the higher concentration areas targeted by this interim action become remediated to concentrations amendable to bioremediation, nutrients may be added to the air sparging system to enhance biodegradation. The soil vapor extraction system will utilize an existing on site soil vapor extraction (SVE) unit manufactured by NEPCCO Equipment Division, Ocala, Florida. This unit is an integrated 500 scfm soil vapor extraction and catalytic oxidizer unit.

3.1.16-Dynamic Underground Stripping (DUS)

Deployment Date: 3QFY00

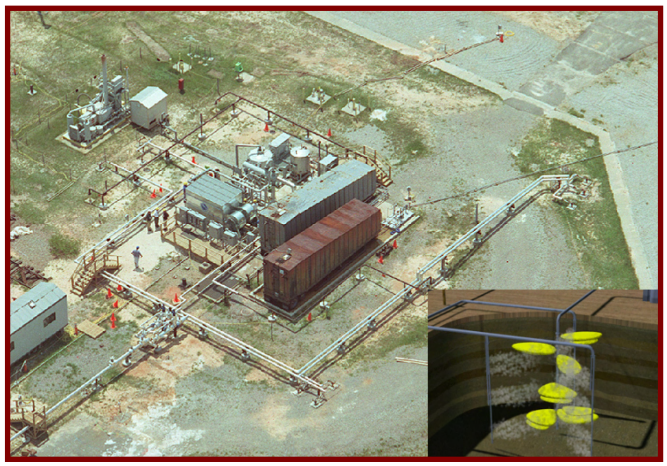
Study Area/Project: 321-M Solvent Storage Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)

Deployment Date: FY06

Study Area/Project: M-Area Settling Basin

SGCP Contact: Jim Kupar (james.kupar@srs.gov)



Description: Dynamic underground stripping (DUS) is a 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 vacuum extraction and condensed into a liquid product at the surface. This new DUS process can reduce remediation schedules at several Department of Energy (DOE) Complex locations by decades or more over traditional pump and treat methods.

Lawrence Livermore National Laboratory (LLNL) and University of California (UC)-Berkeley originally developed the DUS process. After successful demonstrations at LLNL and the Southern California Edison Pole yard Superfund Site, LLNL licensed the process to three California firms for commercial deployment. SRS committed to providing resources to implement DUS at the 321-M solvent tank storage area in FY 2000, and DOE-Portsmouth deployed DUS at one holding pond in FY99.

The DUS process offers a significant improvement over baseline processes by greatly increasing remediation speed and completeness, and by gaining tight control over the process. Continuous adjustments of the rate and location of steam flow at several injection wells fosters more direct migration of product towards the extraction wells and helps prevent both horizontal migration of VOCs outside of the steam zone and vertical migration into deeper aquifers. The improvements and advantages offered by the DUS process are derived from the following features:

- steam injection at the treatment area's periphery heats permeable subsurface areas beyond contaminant boiling points, vaporizes VOCs trapped between soil particles, and rapidly drives contaminants to a central vacuum extraction well.
- contaminants trapped in less permeable clays and sediments can be removed by an electrical heating system to vaporize them and drive them into the steam zone.
- underground imaging and temperature monitoring engenders a controlled process. The temperature monitor delineates the heated area and the imaging system tracks the steam fronts to facilitate total cleanup and precise process control.
- effluent vapors, condensed VOCs, and water are treated onsite for complete remediation.

The effectiveness of the DUS process somewhat depends on the geology at the target location. To prevent migration of the contamination downwards during the heating process, it is preferable to have an impermeable confining layer below the region of contamination. From the 321-M solvent tanks storage area operation, the final condensed product will be a mixture of trichloroethylene (TCE) and tetrachloroethylene (PCE) condensed product contaminated with other trace organics, inorganics and water.

3.2-Groundwater

3.2.1-In-Situ Bioremediation

Deployment Date: 3QFY99

Study Area/Project: Sanitary Landfill

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Dennis Altman (denis.altman@srs.gov)

Description: Scientific studies at the Savannah River Site (SRS) have shown 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 cost, 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 at the Sanitary Landfill project. One plume contained trichloroethylene (TCE) as its major contaminant of concern and the other plume contained vinyl chloride as its major constituent. Site 1 and Site 2 were also significantly different in terms of contaminants of concern (COCs), dissolved oxygen, chloride, nitrite, and nitrate concentrations, and response to nutrient stimulation, thus 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 situ* by the addition of oxygen (as compressed air), nutrients, and methane to the contaminated zone. Biostimulation at both sites resulted in undetectable levels of the COCs and many other organics in both the groundwater and vadose zone.

The remediation system incorporates two horizontal injection zones along the south and west sides of the landfill, respectively. Based on the optimization test and probable future leaching changes both injection systems inject at a depth of 30-45 feet below the water table. This provides a sparge zone that biotreats all current and future leachate since the configuration and prevailing groundwater flow would contain any leachate from these areas. Each horizontal well is over 1400 feet long with one having a screen zone of 800 feet and the other 900 feet. Bioremediation via *in situ* stimulation of indigenous microorganisms is an efficient and cost effective long term means of obtaining ultimate groundwater restoration at the SRS Sanitary Landfill.

3.2.2-Phytoremediation of Tritium

Deployment Date: 4QFY00

Study Area/Project: Burial Ground and Southwest Plume Area

SGCP Contact: Mohammad Kasraii (mohammad.kasraii@srs.gov)
Mark Amidon (mark.amidon@srs.gov)

Description: Phytoremediation uses either naturally occurring or genetically engineered plants to remediate contaminated soils, sediments and water. Plant systems and their associated rhizospheric microorganisms are used to remove, degrade or stabilize a wide variety of environmental contaminants. Phytoremediation targets currently include contaminating metals, metalloids, petroleum hydrocarbons, pesticides, explosives, radionuclides, chlorinated solvents, industrial by-products, and excess nutrients.

This technology has been implemented as part of a system to reduce the discharge of tritium from the Burial Ground Complex Southwest Plume (i.e., Mixed Waste Management Facility), into Four Mile Branch. The system is a combination of hydraulic control and enhanced evaportranspiration. Tritium contaminated water is collected, moved to a location up-gradient of the discharge point, and used to irrigate an established pine forest.

3.2.3-Phytoremediation of TCE Using Drip Irrigation

Deployment Date: 4QFY00

Study Area/Project: D-Area

SGCP Contact: Jeff Ross (j.ross@srs.gov)
SRNL Contact: Robin Brigmon (r03.brigmon@srnl.doe.gov)

Description: Phytoremediation uses the natural processes associated with plants to remediate contaminated media. Certain plants along with rhizosphere microorganisms have been found to degrade low concentrations of chlorinated solvents such as trichloroethylene (TCE) in contaminated groundwater. A phytoremediation system consisting of a drip irrigation system and a tree plantation (loblolly pines and cottonwoods) have been deployed to evaluate the effectiveness of phytoremediation to restore the TCE-contaminated Upper Three Runs Aquifer. Cottonwoods have not yet been planted; however, they will be planted in the spring. TCE-contaminated groundwater is pumped from recovery wells in the Upper Three Runs Aquifer and distributed via a drip-irrigation system to each of the tree plots. Two new wells have been installed and will be operational soon. Over time as phytoremediation occurs, the level of contamination in the groundwater decreases.

3.2.4-Oleophilic Filtration

Deployment Date: 3QFY96

Study Area/Project: M-Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
Roger White (roger.white@srs.gov)

Description: Oleophilic filtrations are an effective pump and treat method for cleaning dense nonaqueous phase liquids (DNAPLs) from contaminated ground water. This technique uses a patented ceramic substrate onto which water repelling and oil attracting derivative of ammonia has been grafted by a permanent, chemical substitution process. In the system, DNAPL contaminated water is processed through a specially designed container with a filtration bed of these hydrophobic, oleophilic ceramic granules. Water passes through, but hydrocarbons adsorb to the granules. The granules are capable of removing a wide variety of hydrocarbons from water. Clean water is discharged, and the trace oil in discharge streams is consistently below 15 parts per million, as required by AFNORT 90 203 measurement standards. At a preset, pressure drop threshold across the bed, an automatic backwash begins and releases from the bed any captured hydrocarbons and suspended solids from recovery or disposal. The system design is simple, automatic, and requires minimal maintenance, with few moving parts. This technology will be used with alcohol injection/extraction testing.

3.2.5-In-Situ Chemical Oxidation (Fenton's Chemistry)

Deployment Date: 3QFY97

Study Area/Project: A/M Area

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)
SRNL Contact: Karen Vangelas (karen.vangelas@srnl.doe.gov)
Brian Looney (brian02.looney@srnl.doe.gov)

Description: *In Situ* chemical oxidation is a patented method for treating volatile organic compound contaminated soils and groundwater through injection wells. The technique uses specially designed equipment and injectors to diffuse and disperse a powerful solution of oxidizers, catalysts, and other nonhazardous and environmentally safe compounds to the subsurface environment. The process increases the permeability of most subsurface soils and then chemically destroys the organic contamination within the treatment region *In Situ*. Upon completion of the process, the organic contaminants are converted to carbon dioxide and water or reduced to a level below regulatory limits. Remaining reagents from the injection program are converted into oxygen and water or continue to be used as nutrients by microorganisms in the soil and groundwater.

The technology has received permitting from and full support of the New Jersey Department of Environmental Protection. The South Carolina Department of Health and Environmental Control are actively interested in the deployment of this technology at M Area of the SRS.

The Geo-Cleanse technology utilizes strong oxidizing agents and other amendments which convert various organic contaminants into harmless, natural compounds. This process has been proven effective in remediation of both loose and tight soils (i.e., silts and clays) contaminated with organic contaminants.

Remediation of soil contaminated with discharges of organic contaminants is accomplished by injecting a mixture of strong oxidizers, trace metallic salts, stabilizers and surfactants in an aqueous based solution. Prior to injection, the hydrogeological parameters of the soils and groundwater are defined. In addition to the horizontal and vertical extent of the contaminants with their respective characteristics and concentration gradients, are defined and determined. A pilot program is conducted to determine the quantity and formulation of the injection mix. This is necessary to qualify the quantity of reagent needed for injection and the proper spacing of the injector to permit remediation over the entire affected area.

Once the contaminant region has been defined and delineated, the optimal reagent volumes and concentrations are determined.

The Geo-Cleanse system is then mobilized to the site and the injection program is initiated, requiring several days to several weeks to complete, depending upon the extent of contamination. Upon completion of the injection program, the installations and equipment are removed from the site. Post remedial sampling and analysis is performed to document destruction of the contaminants.

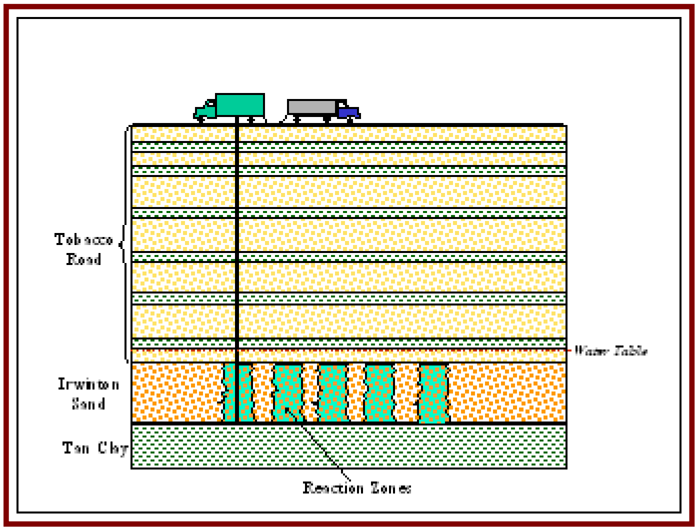
Following the treatment, the organic contaminants will have been substantially reduced or altogether eliminated by this process. The organic contaminants are quickly and naturally converted to carbon dioxide and water. Any remaining oxidizer from the injection program is either converted to water or oxygen and may be utilized by the soil and groundwater microorganisms. Depending on the extent of contamination, the entire program from permitting to cleanup can be completed in approximately 4-6 months.

3.2.6-Base Injection

Deployment Date: 2QFY01

Study Area/Project: F-Seepage Basin F-Area

SGCP Contact: Gerald Blount (gerald.blount@srs.gov)



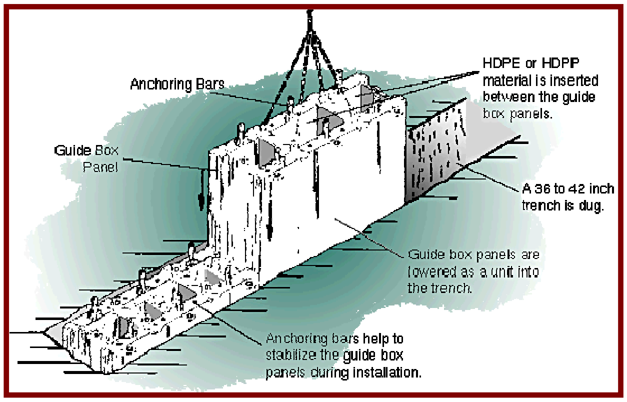
Description: The primary objective of the base injection field test in F Area is to reduce aluminum concentration in the groundwater by raising aquifer pH. Currently, aluminum is a major hindrance to waste treatment unit (WTU) operations in F Area and its removal by precipitation and flocculation significantly increases water treatment waste generation. Sodium hydroxide and trisodium phosphate have been selected as the base amendments to raise the pH of the aquifer in the F Area base injection field test. Each amendment will be injected in a separate test plot up gradient of FEX 10 and FEX 11 wells. The target zone will be just above the Tan Clay in the Irwinton sand. Amendments will be place either pneumatically (compressed air) or hydraulically (pressurized fluids) and usually involve some degree of formation fracturing Formation fracturing is typically achieved in materials that are low in permeability and are not prone to rapid dissipation of injection pressures. The Irwinton Sand is relatively high in permeability (2.5E-2 cm/sec) and would be prone to rapid dissipation of injection pressures. Therefore, significant fracturing o the formation is not expected. The pattern of injection will be five to six injection locations in each test plot, forming a picket fence configuration perpendicular to groundwater flow. The reaction zone at each injection location will approximate a column of amendment solution with undisturbed areas between columns. The purpose of this pattern is to minimize any alteration of groundwater flow paths if significant permeability loss were to occur in the target zone. Monitoring of groundwater conditions will be accomplished using a network of existing and proposed monitoring wells.

3.2.7-Sulfate Reduction of Metals in Contaminated Groundwater

Deployment Date: 3QFY02

Study Area/Project: D-Area

SGCP Contact: Jeff Ross (j.ross@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)



Description: D Area was one of the earliest operating areas constructed at SRS producing process steam and electricity and extracting heavy water for use in the site's nuclear reactors. The coal fired 484 D Powerhouse was place in operation in 1951 to provide steam and electricity for several SRS facilities. Runoff from the D Area coal pile is collected in a network of drainage ditches and flows into the D Area Coal Runoff Basin (DCPRB). Due to the contaminated runoff from the D Area coal pile to DCPRB, a low pH/metals/sulfate, groundwater contaminant plume emanates from DCPRB. A treatability study will be conducted to assess the potential of *In Situ* sulfate reduction to serve as a remedial technology for this groundwater plume in support of the feasibility stuffy for the D area Expanded Operable Unit. *In situ* sulfate reduction by sulfate reducing bacteria (SRB) involves the oxidation of an organic carbon by the SRB for energy and growth and the use of sulfate as an electron donor, which results in the production of sulfide and the subsequent *In Situ* precipitation of metal sulfides. *In situ* sulfate reduction is an innovative technology based upon the results of ex situ sulfate reduction in continuously stirred batch reactor bioreactors. The use of ex situ biobarriers allows a high degree of control over mixing, reaction conditions, and amendment addition, whereas *in situ* remediation provides challenges regarding control of these items. A phased treatability study, consisting of both laboratory testing and field studies (pilot scale demonstrations), will be conducted to determine the ability and address the requirements necessary to promote *in situ* remediation of the plume by sulfate reduction. To promote *in situ* sulfate reduction, an organic substrate will be injected into the DCPRB low pH/metals/sulfate plume. Sulfate reduction remediation will require modification of the contaminated aquifer geochemical conditions in order to sustain and enhance the growth of SRB populations and to promote subsequent sulfate reduction. Additionally, base and micronutrient amendments (nitrogen and/or phosphate) may also be required for optimization.

3.2.8-In-situ Oxidation of VOCs With Ozone (Lynntech)

Deployment Date: 1QFY00

Study Area/Project: A/M Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Karen Vangelas (Karen.vangelas@srnl.doe.gov)

Description: Savannah River National Laboratory (SRNL) was approached by Lynntech, to provide a test site and technical assistance in the demonstration of a new technology they have developed for subsurface treatment of organics. They are in Phase II of a Department of Energy (DOE) funded Small Business Innovative Research (SBIR) project and have subcontracted SRNL and other site services. The technology involves injection of ozone into the vadose zone with extraction into an off gas treatment unit employing photocatalytic oxidation. The test targeted a site in the A/M area wit chlorinated solvent contaminated soils. The ozone begins to react with and breakdown the organics *in situ* and has been shown to enhance the release of solvent over simple air injection. The current plans required a site with shallow (< 50 ft bls) contamination. The treatment area has an approximate radius of influence of 15 to 20 feet, and consists of a single injection well with two or four vapor extraction wells. Start up began in December 1999 and was completed in March 2000.

The Lynntech system requires 208 Volt/3 phase power at 100 amps, a potable water source (500-1000 gallon tank is suitable), and a dedicated phone line. The system uses a 5 lb/day electrochemical (water cracking) ozone generator that can produce a 15 weight percent ozone in oxygen stream at a flow rate of 15 to 20 liters/min (approximately 0.5-0.7 cfm). The photocatalytic reactor may treat contaminated vapor at a flow rate of 5 scfm. Therefore, use of an existing thermal catalytic off gas treatment unit (SVE-Catox) in parallel wit the Lynntech system will be required to obtain and treat the total flow rates of from 50 to 100 scfm needed to meet the desired treated radius of influence. Due to the low ozone production rate, the demonstration employs a pulsed injection extraction approach in which ozone is injected continuously with periodic extraction and vapor treatment. The pulsed extraction periods has been chosen to allow sufficient time to flood the pre spaces in the treatment area ozone. Ozone has a half life of 15-20 minutes, and it is anticipated that all of the ozone will be consumed in the subsurface.

Other than the co-production of hydrogen wit the ozone, air emissions are similar in composition to the existing permits for the SVE-Catox units. Mass removal and stack gas concentrations are well within existing permits levels due to the smaller extraction rates in the demonstration versus normal operations for the SVE-Catox systems (typically 300 to 800 scfm).

3.2.9-Alcohol Injection/Extraction (Demonstration)

Deployment Date/Demonstration Date: 3QFY96

Study Area/Project: M-Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Karen Vangelas (karen.vangelas@srnl.doe.gov)

Description: The alcohol injection/extraction test is a measurement of the presence of dense non-aqueous phase liquids (DNAPLs) within a defined probe zone. The small scale solubilization test uses existing wells to access the subsurface and identify locations of DNAPL contamination. In this test, a small volume of water is injected a small distance into the well formation and then extracted. Samples of the extracted water are analyzed for concentrations of organic contaminant. Next, a small volume of an alcohol and water solution is injected the same distance into the formation and then extracted. The extracted sample is analyzed and compared to the previous sample. The alcohol and water solution increases the solubility of the DNAPL, making it possible to capture solvent in the sample and determine the level of contamination. Importantly, it accomplishes this without reducing the surface tension of the DNAPL to a point that would mobilize the globule. This innovative process has been approved by South Carolina Department of Health and Environmental Control (SCDHEC).

3.2.10-Permeable Reactive Barrier/GeoSiphon Treatment System

Deployment Date: 4QFY99

Study Area/Project: D Area Coal Pile Runoff Basin-CPRB)

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)

Description: SRS D Area Coal Pile Runoff Basin (DCPRB) groundwater is contaminated with low pH, iron, aluminum, sulfate, chromium and nickel with lesser amounts of trichloroethylene, cadmium, and lead. The DCPRB required remediation per CERCLA process in accordance with the Federal Facility Agreement (FFA) for the Savannah River Site (SRS). An investment at the dCPRB was made during FY 1994 through 1996 in the design, installation and testing of an EnviroWall Barrier System within the most contaminated portion of the D Area CPRB plume. This TTP involved the selection of permeable treatment media for *in situ* passive testament for the DCPRB contaminated groundwater, and the modification of the existing EnviroWall Barrier System at the DCPRB to produce a demonstration *in situ* reactive treatment system which utilizes the selected treatment media. The following two tasks were performed to accomplish the overall objectives of the Technical Plan:
Task A: Ex Situ Treatment Media Evaluation
Task B: Design, Installation and Testing.

The existing EnviroWall Barrier System at the DCPRB was modified to produce a demonstration *in situ* reactive treatment system which utilizes the selected treatment media or combination of media determined from Task A. The fact that the existing Interceptor Well acts as a drain for groundwater flow from the upper to the deeper soils will be utilized in this application. The conceptual design for the D Area GeoFlow/EnviroWall Treatment System consists of the following major subsystems:

- Intercept Trench
- Treatment Cell
- Redistribution System (existing Interceptor Well EnviroWall Barrier System)

The interceptor trench consisted of a perforated pipe in a gravel bed for the collection of the contaminated groundwater and transport to the treatment cell. The gravel bed consisted of permeable treatment media such as dolomite, limestone, concrete, rock phosphate (apatite), blast furnace slag or iron to provide an initial treatment prior to the treatment cell itself. The treatment cell consisted of a flow through, removable, treatment media canister with media as selected from Task A.

The existing EnviroWall Barrier (D-Area Interceptor Well, DIW-1) was utilized as the redistribution system. However, rather than performing as an extraction system, the EnviroWall Barrier performed the reverse function and performed as a system to redistribute the treated groundwater back into the aquifer. The treatment cell was directly connected to the EnviroWall Barrier through a pipeline to one of the existing six inch stainless steel screens on the EnviroWall barrier. This produced an integrated groundwater interception, treatment and redistribution system. Both treatability and hydraulic evaluations of the system were conducted.

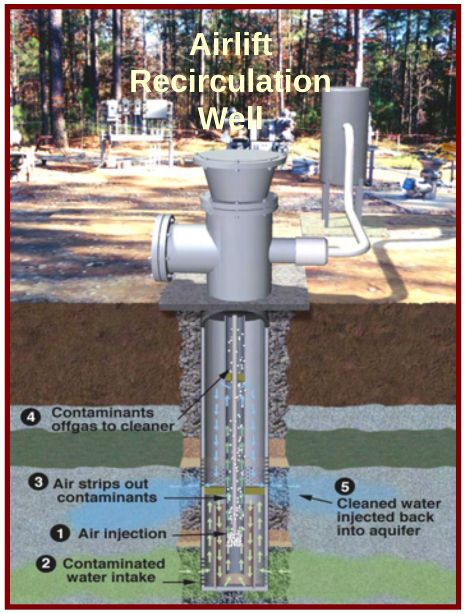
3.2.11-Recirculation Wells (in-well vapor stripping)

Deployment Date: 4QFY96

Study Area/Project: 2 wells at A/M Area

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
Roger White (roger.white@srs.gov)

Description: In well vapor stripping is a technology used for the treatment of groundwater contaminated with volatile organic compounds. The technology uses air injected into a groundwater well to strip contaminants form the water and to induce an upward flow of groundwater within the well. The treated groundwater that has been lifted upward in the well is then discharge directly back into the ground without ever leaving the well.



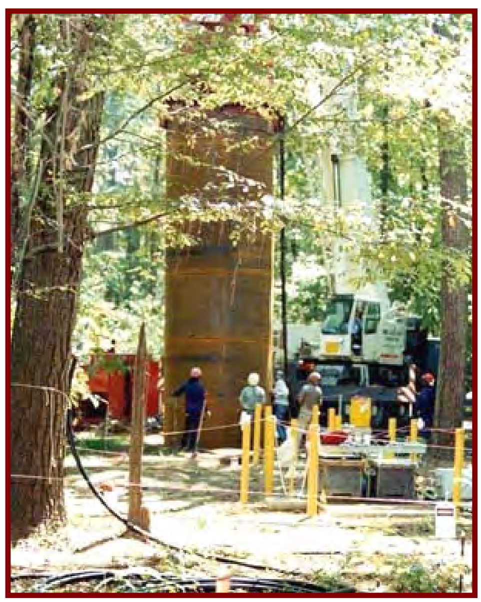
3.2.12-GeoSiphon Cell

Deployment Date: 4QFY97, 4QFY98

Study Area/Project: TNX Area, Phase II Deployment at TNX Area in 1998

SGCP Contact: Joao Cardoso (joao.cardoso-neto@srs.gov)
Sara Mundy (sara.mundy@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)

Description: Zero valence iron enhanced abiotic degradation of chlorinated volatile organic compounds (CVOCs) is essentially a reductive dechlorination process, which uses granular cast iron as the reducing agent, and produces final reaction products such as methane, ethane, ethane, and chloride ions. This treatment media has been developed and patented by the University of Waterloo. The exact pathway for this reductive dechlorination process has not yet been determined. However, it appears that it is a surface activated reaction, which may require the adsorption of the CVOCs onto specific active surface sites on the iron. During the reaction the iron is oxidized, water dissociates to form hydrogen ions and gas, and the chlorine on the CVOCs is replaced with hydrogen (CVOCs reduced). The reduction of the CVOCs is not a step wise dechlorination process. Therefore while some intermediate reaction products are produced, the mass of intermediates is substantially less than the original CVOC mass. Theses intermediate reaction products are subsequently degraded. During this treatment process, the Eh decreases and the pH increases. This treatment process may be dependent upon the pH, it may be inhibited by elevated nitrate levels, and it may reach a dichloromethane endpoint in the degradation of carbon tetrachloride.



A laboratory study has been performed to address the applicability of zero valent iron enhanced abiotic degradation to the TNX flood plain contamination. The laboratory study demonstrated that zero valent iron can treat the chlorinated volatile organic compound contaminated groundwater in the TNX flood plan to below the Primary Drinking Water Standards (PDWS), while producing less toxic final degradation products such as ethane, ethane, and methane. Additionally the process reduces the nitrates to below the PDWS. Neither chemical precipitation nor biofouling appear to be significant problems relative to plugging the pore space, based upon this study and existing field applications and demonstrations. The long term continued activity of the iron to perform treatment is currently unknown; however an *In Situ* demonstration conducted by the University of Waterloo has been in operation for five years with no observed reduction in degradation rates. Based upon these favorable results a field demonstration of zero valent iron treatment as applied through a GeoSiphon Cell will be conducted in the TNX flood plain.

The GeoSiphon (under patent consideration by WSRC) Cell utilizes granular cast iron to treat TNC flood plain CVOC contaminated groundwater *in situ*. The GeoSiphon Cell is essentially a large diameter well which 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 head difference between the cell and the Savannah River. The passively induced flow draws contaminated groundwater through the treatment cell where the iron filings reduce the CVOCs to ethane, ethane, methane and chloride ions. The treated water is subsequently discharged to the Savannah River. The GeoSiphon Cell should be less intrusive, less expensive, more efficient and less susceptible to precipitation pluggage than the use of funnel and gate or continuous permeable wall systems. This demonstration was conducted in two phases:

- Phase I, GeoSiphon Cell Pump/Treatability Tests: Flow through the GeoSiphon Cell(s) will be induced by pumping, and the treated water will be discharged to the TNX National Pollutant Discharge Elimination System (NPDES) X-08 outfall. This will allow the creation of steady state conditions so that *in situ* degradation half lives for the CVOCs and the radius of influence can be determined.

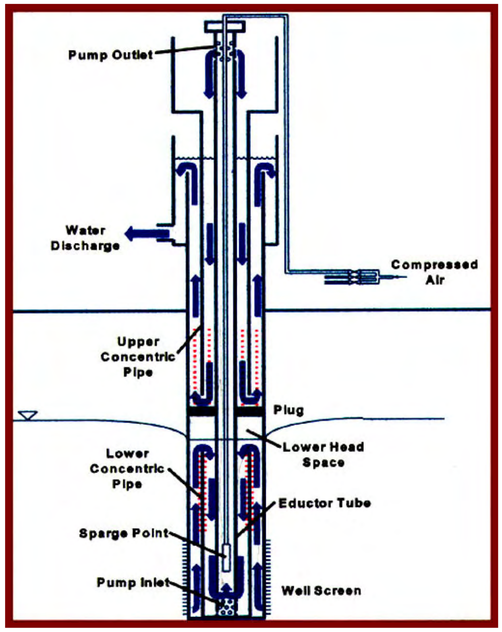
- Phase II, GeoSiphon Cell Siphon/Treatability Tests: Flow through the GeoSiphon Cell(s) will be induced by siphon for direct discharge to the Savannah River. This phase will demonstrate the overall concept.

3.2.13-Multistage In Well Aerator

Deployment Date: 4QFY98

Study Area/Project: M-Area

SGCP Contact: Bob VanPelt (robert.vanpelt@srs.gov)
Roger White (roger.white@srs.gov)



Description: Conceptually, a recirculation well removes volatile organic compounds (VOCs) from groundwater without bringing any contaminated water to the surface. The well casing is screened at two levels. The lower level screen is placed within the contaminated groundwater plume and the upper screen is placed at a level either within the aquifer, or above the water table. Compressed air is injected down a central pipe into the water at the bottom of the well. Air bubbles emerge and rise up through the column of water; the air exist the water within the well, and leaves the well casing at the ground surface. The rising air performs two functions. First, the air bubbles strip VOCs from the water and carriers the volatilized contaminants up the well casing to be discharged into the atmosphere. Second, the rising air acts as a lift pump, effectively pumping the contaminated water up from the lower screen, discharging the cleaned water back into the aquifer at the upper screen.

The multi-stage in-well aerator is designed to maximize both air/water contact time and interfacial surface area by employing double airlift stages, in conjunction with enhanced air sparging at each stage. The multi-stage in-well aerator contains an additional concentric tube and also a plug, which separates the upper and lower stages. Water enters the lower well screen and passes up and over the inner concentric weir and down to the airlift pump. Air is sparge from a porous plate at the bottom of the casing, which performs the VOC stripping action in the lower stage. The lift pump raises the water from the lower to the upper stage, where it flows down to the upper screen while it is sparged fro the second time with air from the upper porous plate/plug. This multiple pass and sparging system creates high VOC removal efficiencies.

The patented multi-stage in-well aerator was developed, and is currently being deployed, at the University of California, Davis, for remediation and hydraulic control of a large VOC (chloroform, carbon tetrachloride and trichloroethylene) contaminated groundwater plume, emanating from a waste site on the university campus. Commercial deployment of this technology has been formally assigned to Davis Environmental, a start up company managed by the inventor of the aerator. A prototype unit is also being tested at the Air National Guard Base in Portland, WA for removal of trichloroethylene and tetrachloroethylene. VOC removal efficiencies in excess of 90% are being recorded at both locations.

3.2.16-Macrocapsules

Deployment Date: 3QFY05

Study Area/Project: D Area Coal Pile Runoff Basin

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
Jeff Ross (j.ross@srs.gov)

Description: This technology involves the binding of a buffering solution with a polymer that can be designed to release a buffering solution at a given pH thereby raising and maintaining the pH at a desired pH level. Lab work has determined that by binding a buffering solution in a polymer allows for a more controlled delivery mechanism to raising and maintaining the pH. Additional work is planned to evaluate macroencapsulation in a field setting.

Many groundwater metal plumes are attributed to low pH groundwater. By raising the pH, metals will precipitate out into the formation and bind with existing clays. Additionally, with low pH groundwater, other metals that are normally found in sediments (i.e., aluminum, sodium, calcium, etc…) are in high concentrations as a result of low pH. These metals can foul a treatment system if they are not removed prior to adjusting the groundwater to remove the heavy metals. To precipitate these metals out into the formation, a limestone wall or direct base injection is employed. Macroencapsulation is being evaluated as an alternative to these technologies.

The macrocapsules (1-cm O.D.) are composed of a basic salt (K_2HPO_4) and a pH sensitive wall material (Eudragit polymer) that dissolves in pH less than 7.0. Laboratory column and box studies at the University of South Carolina have shown the potential for the use of macrocapsules for pH control of groundwater. Laboratory studies using macrocapsules and SRS sediment and groundwater showed that the macrocapsule wall material slowly dissolved and released the phosphate buffer and increased the pH from 2.8 to approximately 7.0 in small volumes of SRS groundwater.

A sequential series of passive injections (calcite [limestone] and macro-encapsulated phosphate buffer) were performed in a single groundwater well at the Savannah River Site (SRS) to assess pH control effectiveness near the D-Area Coal Pile Runoff Basin (DACPRB). In addition, the tests were to determine the effectiveness of the limestone and macrocapsules for raising the low pH groundwater, the longevity of the limestone and macrocapsules during the test, and what effects occurred as a result of raising the groundwater pH. The demonstration involved the packing of the macrocapsules and limestone chips into a 1-inch x 3-feet porous container (Soak-Ease canister). The canister was placed in the well monitored for approximately three weeks.

pH was measured real-time using an In-Situ Troll 9000 probe. Groundwater samples were collected to analyze for metal concentrations.

Results of the field tests indicated that the macrocapsule treatments increased groundwater pH from approximately 2.5 to just above 6.0 within the first 6 to 8 hours of treatment. By the end of the two-week period, there was minimal macrocapsule material remaining in the canisters. Metal concentrations remained unchanged during these treatments. Phosphate concentrations increased indicating successful release of the phosphate buffer contained in the macrocapsule.

The limestone treatments were not effective in increasing pH as significantly as were the macrocapsule treatments. The first limestone treatment was carried out with limestone chips and increased pH up to 3.0. The second limestone treatment did not change pH noticeably. Metal concentrations remained unchanged during these treatments. Visual inspection of the limestone on completion of both limestone treatments indicated significant armoring on the limestone, presumably caused by of iron oxide formation, which may have decreased the effectiveness of the limestone.

The macrocapsule treatments were more effective in increasing pH than the limestone treatments in these trials. However, the macrocapsule mass (~320 g) did not maintain a desired pH of approximately 5.0 to 6.0 for long time periods. As expected a greater mass of macrocapsules would be necessary for longer-term pH effects due to relatively high ground-water flow rates.

3.2.17-In-Situ Soil Mixing Barrier Wall

Deployment Date: CY2004

Study Area/Project: F&H Seepage Basins

SGCP Contact: Michael Hartz (michael.hartz@srs.gov)
Jeff Thibault (jeffrey.thibault@srs.gov)

Description: Deep soil mixing was used as a groundwater corrective action for a low level radioactive plume. The F and H seepage basins received low-level, acidic waste solutions from approximately 33 years of processing of uranium slugs and irradiated fuel. More than 99 percent of the radioactive releases to the basins are attributable to tritium. Low permeability covers were placed over the basins in 1991. Active remediation systems were used to address hot spots and contain tritium as much as possible. Operation of these systems was labor intensive and generated significant amounts of low level waste. Barriers were selected as next phase of corrective action because they provided a practical, clean, inexpensive technology for dealing with large volumes of tritium contaminated water. In H area, the barriers provide containment around a hot spot basin. In F area, the barriers take advantage of troughs in the first confining layer. Hot spot secondary sources were found in the troughs. Groundwater originally flowing along the troughs is intercepted by the barriers. The soils have a high horizontal/vertical conductivity ratio so the barriers trap the more contaminated water in the troughs. The longer travel time allows for more decay and the slower release rate reduces the concentration of tritium in nearby streams.

Deep soil mixing was used to mix an inert, low permeability grout with existing soils to form a low permeability barrier wall. The grout contains attapulgite, a clay resistant to high ionic strength solutions and organics. It also has a low diffusion coefficient, which is important for large area barriers. The soil mixing equipment consists of three counter-rotating hollow-stem augers mounted on a track vehicle. The three hollow stem mixing shafts mix soil from the surface to the target depth. Each shaft rotates in a direction opposite of the neighboring shaft, creating a panel of three overlapping columns. The triple shaft equipment was eliminates unsatisfactorily mixed zones between columns produced by single auger equipment. The shafts are long enough to mix an entire column without adding or removing auger flights.

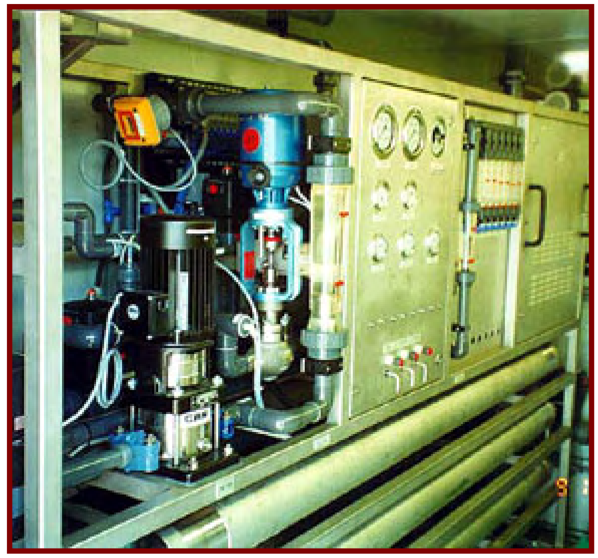
When constructing walls, each triple auger panel is placed so that the outer augers overlap completely with the outer auger holes of adjacent panels. Each auger is supplied by an independent, computer controlled grout pump with flow meter. Programmed injection rates were developed from pilot testing and were dependent on rotation rate and penetration speed. Quality assurance included sampling of the barrier as well as a permeability test cell constructed during the pilot. This technology has been used to install panels over 120 ft deep.

3.2.18-Nano Filtration

Deployment Date: 4QFY96

Study Area/Project: F-Area

SGCP Contact: Brad Davis (brad.davis@srs.gov)



Description: This demonstration will evaluate the waste minimization potential of Disc Tube Nano Filtration (DTNF) compared to the current F&H Area Phase I system of reverse osmosis (RO) and chemical precipitation with filter press and drying technologies. The new innovative technology is manufactured and marketed under the name of ROCHEM DTF Membrane Module System and is referred to as Nano-filtration. This technology is similar to typical RO technology but utilizes a water membrane system. The use of this technology has yielded dramatic results on landfill leachate. In one example, the treatment of 100 gallons of leachate has produced 97 gallons of clean water plus 3 gallons of solids and brine.

DTNF, when used in conjunction with an RO system, should produce clean water and a concentrated amp solids fraction. In the Pilot demonstration, only filter bag "collection-drying" system will be employed as a result of the very low column of solids that will be produced. In an on line system, a small filter press would be a utilized combination. It is believed that substantial savings in chemical consumption and the production of secondary waste could be realized. In particular, savings for nonhazardous secondary waste could approach >80%. For example, in the secondary waste projections for the currently designed F Area Water Treatment Unit (WTU), rather than producing about 24 cubic feet of secondary waste per day, the new technology could produce less than 5 cubic feet per day.

The environmental impact of the new technology could reduce waste production by >25,000 cubic feet over the projected five year lift of the F Area Waste Treatment Unit (WTU) with similar saving potential in H Area.

The modular systems are housed in two portable sea vans. One sea van houses a 16 gpm RO, mounted complete with pumps and support equipment (catalog number RORo-1532 DT7) to pre-concentrate the groundwater. Following the RO System, permeate is fed to a portable effluent tank and the concentrate is fed to the DTNF filtration unit contained in the second sea van (catalog number RONF 9742).

The field pilot system is complete with a 5,000 gallon feed tank, forwarding pump, a portable sea van with the RO system, a portable sea van with the DTNF system, 5, 000 gallon surge and permeate tanks, a 6,500 gallon tank to accommodate the transport of effluent to the Colloid Test area holding tank, a bag filter, a resin polishing vessel and a portable generator to supply power to the entire system. A portable office field lab is also located at the demonstration site.

3.2.19-Ion Exchange Membrane

Deployment Date: 2QFY98

Study Area/Project: Site Wide

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Donna Beals (donna.beals@srnl.doe.gov)

Description: Ion Exchange Membrane for Environmental Sampling as used for well head application: Ion specific resin is embedded in a Teflon support (3M Empore™ technology). The Empore™ disks are housed in an ISCO modified automatic sampler. Water to be sampled is pumped through the disks in the field; only the disk is returned to the counting lab for analysis (no additional chemical preparation is required). The membrane was developed jointly by Savannah River National Laboratory (SRNL), 3M Corporation and ISCO, Inc. Benefits are:

-reduced sample analysis cost and turnaround time and
-75% reduction in cost

Deployment Date: 2QFY98

Study Area/Project: F&H Groundwater Treatment Facility

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Donna Beals (donna.beals@srnl.doe.gov)

Description: Ion Exchange Membrane as used for RAD Lab application: The analysis of Tc-99, Sr-90, Cs-137 and Ra-226, -228 will be completed using commercial and noncommercial 3M Empore™ sold phase extraction (SPE) disks and gas flow alpha/beta proportional counting. These new methods consist of passing the water sample through the SPE disk at a flow rate of 30-50 mL/minute. The SPE disks are selective for only the analyte chosen thus requiring no further chemical separation prior to counting. The disks are dried and then counted directly for 20 minutes each for the selected analyte allowing for a sample turnaround time of a single shift.

Existing methods for these analytes do not provide the rapid turnaround time required for the F&H Groundwater Treatment Facility. For example, the current method of analysis for Tc-99 is to heat a one liter sample in the presence of hydrogen peroxide for one hour, cool the sample, and then pass it through an extraction chromatography column (the column flow rate is less than one mL/minute requiring overnight to complete). The new method requires only 20-30 minutes for the Tc-99 extraction on the SPE disk, and the sample does not have to be pretreated with hydrogen peroxide. A similar time savings is achieved for the analysis of Sr-90. The current method uses selective precipitation and column extraction, generating significant quantities of waste, and takes about 2 days; the new method will require 20-30 minutes for a one liter sample, with only 20 mL of waste generated.

The current method for the analysis of Cs-137 requires no chemical separation. A one liter sample is counted directly by gamma spectrometry (for 100 minutes) giving a detection limit of about 10 pCi/L. A gamma ray detector will not be available on the mobile lab platform thus requiring a new procedure. 3M has prepared a non commercial SPE disk for the extraction on Cs-137 from solution. This disk allows the Cs-137 to be extracted from a one liter sample (in 20-30 minutes) and counted by beta proportional counting (for 20 minutes) giving a detection limit approximately of 8 pCi/L.

The current method of analysis for the isotopes of radium requires extensive chemical separation. Ra-228 is determined by counting the Ac-228 daughter three days after sample preparation. Ra-226 is determined by counting the Rn-222 daughter one week after sample preparation. This turnaround time is not acceptable for the groundwater treatment laboratory. The new procedure uses the Empore^{TM} disk to collect the radium from solution (20-30 minutes for one liter). The sample is then counted immediately on the alpha/beta proportional counter. The Ra-226 activity will be calculated based on the alpha counts; the Ra-228 will be calculated based on the beta counts.

The gross alpha/gross beta activity of the water will also be determine din the on site laboratory. Current procedures require the evaporation of 0.5-1 liter of water in a glass beaker. The beaker with the sample residue is rinsed with dilute acid and the rinsate is evaporated onto a planchet for gas flow proportional counting. Typical sample turnaround time is a day. The counting efficiency of samples prepared this way is dependent on the amount of dissolved solids in the water, and varies from less then 10% to no more than 30%. A new method makes uses of EIChroM Industries “Actinide” resin. The resin is added directly to the sample, and mixed for 3-4 hours. The resin is then filtered from solution and transferred to a liquid scintillation vial. The resin extracts all elements of interest. The liquid scintillation counting provides a constant counting efficiency of about 90%. The new procedure thus provides faster turnaround and also a lower detection limit

3.3-Soil and Groundwater

3.3.1-In-Situ Bioremediation Enhanced with Nutrient/Air Stimulation

Deployment Date: FY1997

Study Area/Project: A/M Area Integrated Demonstration Site

SGCP Contact: Jim Kupar (james.kupar@srs.gov)
SRNL Contact: Robin Brigmon (r03.brigmon@srnl.doe.gov)

Description: This patented process injects a mixture of air and nutrients through a horizontal well to stimulate the growth of naturally occurring microbes that degrade volatile organic compounds, notable trichloroethylene and vinyl chloride, in soils and groundwater. An enzyme manufactured by the microbes accomplishes the degradation. *In situ* treatment reduces exposure of personnel to potential risk and prevents surface release of contaminants.

3.3.2-MNA for Chlorinated VOCs

Deployment Date: 2QFY00

Study Area/Project: D Area Oil Seepage Basin

SGCP Contact: Jeff Ross (j.ross@srs.gov)

Description: There are several criteria for use of the natural attenuation application. Some of which include:

- demonstration that the source has been removed, remediated, and/or contained to minimize additional contamination of the aquifer and/or prevent exposure to any receptor;
- demonstration that groundwater contamination has been completely characterized by establishing types and concentration of contaminants that exist at the site;
- definition of the horizontal/vertical extent of soil and/or groundwater contamination and plume movement;
- demonstration that contaminates will remain confined in a shallow geologic unit until attenuation to standards (i.e., maximum concentration limits) occurs; and
- demonstration through a monitoring program was proposed to show compliance with mixing zone requirements

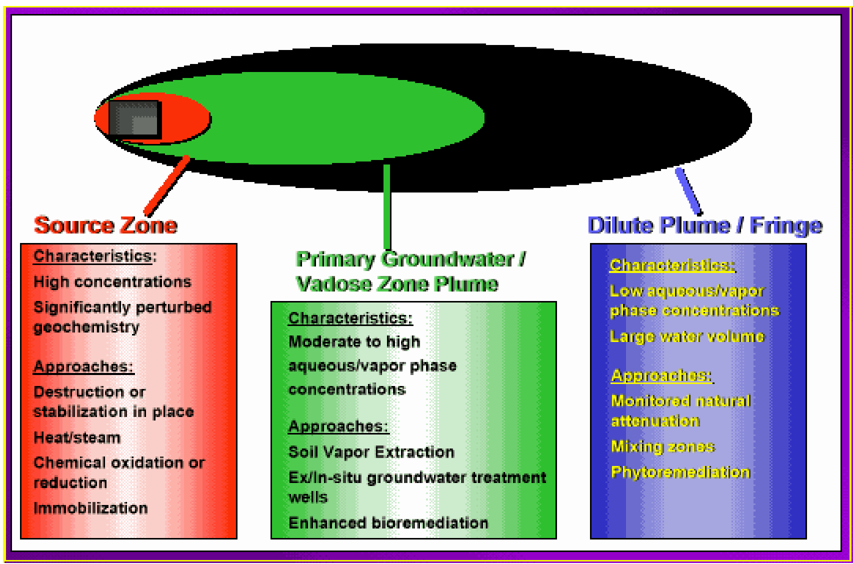
The final remedial decision was designated as monitored natural attenuation/groundwater mixing zone with institutional controls for the groundwater in order to attain drinking water standards. Implementation of this remedial action entailed the installation of 9 new wells and monitoring a total of 12 groundwater wells to ensure that the final remedy achieves its goals. No remedial action was required for the surface soils, sediments and surface water and no further action was required for the subsurface soils since the remedial action objectives were met by the Interim Remedial Action.

3.3.3-MNA for Metals

Deployment Date: 3QFY02

Study Area/Project: D-Area

SGCP Contact: Jeff Ross (j.ross@srs.gov)
SRNL Contact: Dan Kaplan (daniel.kaplan@srnl.doe.gov)
Steve Serkiz (steven.serkiz@srnl.doe.gov)

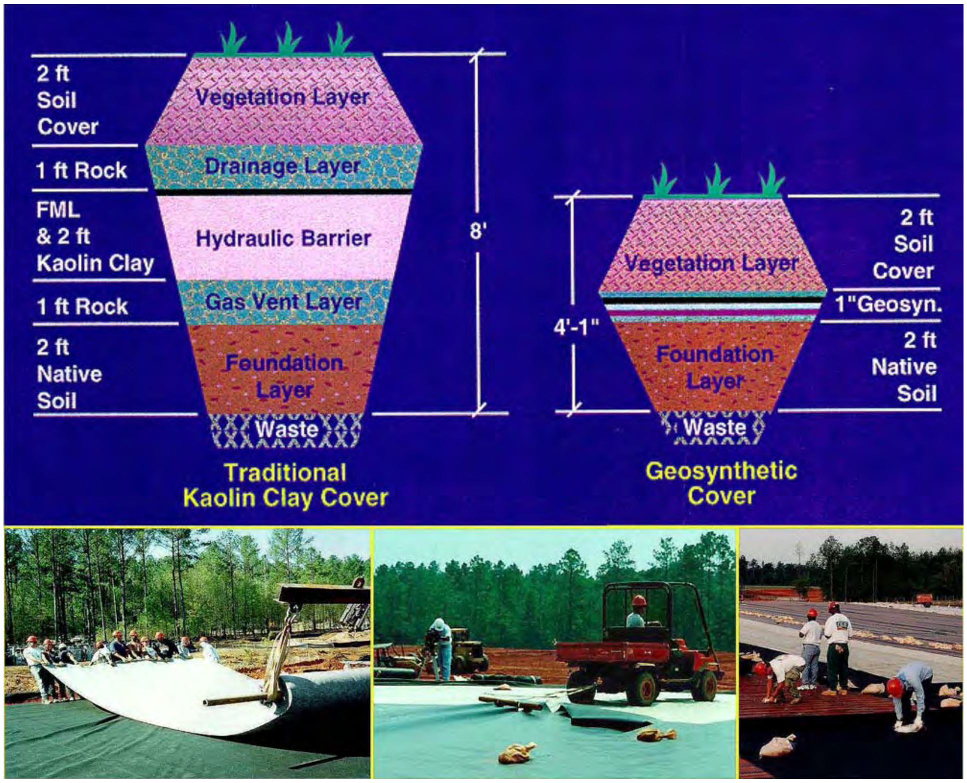


Description: Groundwater in D Area is contaminated with heavy metals that have been leached from coal and ash residues left over from 50 years of operations at the D Area boiler plant. The D Area Coal Pile Run-off Basin and 488-D Ash Basin, both contain large quantities of ash and coal fines which contain sulfur and heavy metals such as iron, chromium, nickel, manganese etc. Under oxidizing conditions in the subsurface, the groundwater becomes acidic, which in turn dissolves the residual metals in the ash to create a large groundwater plume which exceeds maximum concentration limits.

The pH and redox conditions near the source are un-naturally low, which encourages metal dissolution. However as the plume migrates westwards away from the sources, subsurface pH and redox conditions gradually revert back to more normal levels, and the solubility of these heavy metals effectively decreases and natural precipitation occurs. This effectively stabilizes these metals in place downstream of the source locations in D-Area. Research to data by the Savannah River National Laboratory (SRNL) into the subsurface conditions in D-Area has confirmed that natural attenuation of metals is indeed occurring to a significant degree and information is being gathered to provide documented verification that monitored natural attenuation (MNA) can be used in a future remediation closure action

3.4-Capping/Stabilization

3.4.1-Geosynthetic Cap



Deployment Date: 1QFY96

Study Area/Project: LLRWDF and NRWBG

SGCP Contact: Bob Blundy (robert.blundy@srs.gov)
SRNL Contact: Mike Serrato (michael.serrato@srnl.doe.gov)

Description: The first geosynthetic cap used at SRS approved in the state of South Carolina was at the Nonradioactive Disposal Facility. This geosynthetic cap technology was used instead of traditional kaolin clay caps. The closure plan was approved by the South Carolina Department of Health and Environmental Control (SCDHEC) in 1995. This work was done by Soil and Groundwater Closure Projects (SGCP) and managed by Bechtel and Westinghouse Savannah River Companies. The flexibility and ease of installation with geosynthetic capping shortens installation and construction time. Millions of dollars are saved compared to the conventional kaolin clay cap closure. The geosynthetic cap also provides greater protection of groundwater than conventional caps.

3.4.2-Solvent Tank Grouting

Deployment Date: 1QFY02

Study Area/Project: Old Radioactive Waste Burial Ground

SGCP Contact: Brad Davis (brad.davis@srs.gov)
SRNL Contact: Tim Smail (tim.smail@srnl.doe.gov)

Description: The 22 inactive underground Old Solvents Tanks (OSTs) located in the Old Radioactive Waste Burial Ground (ORWBG) are being closed in place by first solidifying the small amounts of residual liquids and then adding concrete like material to prevent tank collapse. This is done by completely filling the tanks with grout through existing vent pipes. When all of the tanks are grouted, the area will be protected with a cover system as part of the final closure of ORWBG. The OSTs temporarily stored low level radioactive liquids from 1955 to 1974. By 1981, all the tanks were emptied with only small amounts of liquid and/or solids remaining. They are constructed of thin walled milled steel and are equipped wit either one or two vent pipes. Placement and verification of grout into the tanks resulted in engineering of a grout injection tool fitted with a color camera. Other engineering applications included the development of a low cost camera that allowed for color photography with 0-90 degree tilt and zoom capabilities. In place closure of the tanks is being accomplished under an Interim Record of Decision.

3.4.3-Jack and Bore Horizontal Earth Boring

Deployment Date: 2QFY97

Study Area/Project: Old Radioactive Burial Ground

SGCP Contact: Gerald Blount (gerald.blount@srs.gov)

Description: The auger boring ("jack and bore") method of horizontal earth boring is a process of simultaneously jacking casing through the earth while removing the soil inside the encasement by means of a rotating auger. Steer able cutting heads on the end of the boring casing along with a grade sensing device will allow for extreme accuracy in holding grade tolerances. The casing also serves to support the soil around it as the soil is removed.

This technology was recently selected and successfully used for installation of a portion of the Old Radioactive Waste Burial Ground (ORWBG) Interim Action stormwater drainage system modifications. Drainage to the new Southwest Settlement Basin crosses E Road at the west end of the ORWBG. Due to the required depth of the crossing and the presence of numerous buried utilities and process lines, normal excavation for installation of this 48 inch diameter storm sewer line would have entailed extensive hand excavation, shoring, potential outages and extended road closure. The successful application of this technology, the first at SRS for large bore piping, avoided any outages, impacts to other facilities or disruption of traffic and was completed in much less time and at lower costs than could have been achieved by normal practices.

3.4.4-Vegetative Cover for Ash Basins

Deployment Date: 2QFY01

Study Area/Project: 488-D Ash Basin

SGCP Contact: Jeff Ross (j.ross@srs.gov)

Description: The 488-D Ash Basin Vegetative Cover is a pilot-scale field demonstration being conducted to evaluate the effectiveness of the vegetative cover. The treatability study will demonstrate the ability of loblolly pines and various grass species to successfully reduce infiltration of rainwater into the 488-D Ash Basin, which contains coal rejects, by increasing evaportranspiration rates. The decrease in infiltration will assist in lowering the level of the saturated zone within the 488-D Ash Basin. When the level is lowered, the rate of acid generation and transport is reduced, thereby, reducing the source of the acidity and heavy metals contaminants in the groundwater. The vegetative cover would need to be used in conjunction with other remedial alternatives (i.e. constructed wetlands, barrier walls) to be effective in remediating the basin. The trees and grasses selected for the cover will be planted in an approximately 4 acre area within the 488-D Ash Basin and monitored for several growing seasons (2 to 3 years). Greenhouse and mesocosm studies have been performed to determine the best grass species to plant and oil amendments to use. In addition, the surface water in and around the basin was characterized to provide valuable data for further studies and design of remediation systems such as constructed wetlands. In addition, ash from a Savannah River Site (SRS) ash basin is being used in the study for potential beneficial reuse.

Chapter 4: Waste Management Technologies

4.1-Soft Sided Lift Liners (vegetation/soils)

Deployment Date: 1QFY00

Study Area/Project: SRL Seepage Basin

SGCP Contact: Ron Socha (ron.socha@srs.gov)

Description: Transport Plastics Inc. Lift Liner's soft sided waste packaging system includes a 25-mil woven and coated outer polypropylene fabric shell with a 40-mil high density polyethylene inner liner. The outer shell is equipped with 18 lifting straps made of two inch polyester seat belt webbing material. The containers meet the DOT requirements for transport of low specific activity and surface contaminated objects. The system also includes a lading frame used to support the shell and inner liner during loading and a lifting/spreading bar. The lifting/spreader bar attaches to the lifting strap for hoisting the container from the loading frame onto a transport vehicle. The empty bags are light and compact enough to move by hand. A small forklift can move the empty loading frame and lifting/spreader bar. Each container has a capacity of 260 cubic feet and holds up to 24,000 lbs. This is about 6 times the capacity of a B-12 metal waste box. There is a one time cost of approximately $7,000 for the loading frame and lifting/spreader bar. The cost of the soft sided containers is $380 per bag. This result in savings of about $1,100-$2,000 in container costs for each bag filled versus filling six metal boxes. These containers reduce disposal volume, disposal container costs, shipping costs and disposal costs.

4.2-Purge Water Management System

Deployment Date: FY99

Study Area/Project: Site Wide (tank)

SGCP Contact: Eric Schiefer (eric.schiefer@srs.gov)

Description: The Purge Water Management System (PWMS) is a "closed loop" non contact system used to collect purge water from a groundwater monitoring well and return it to the originating aquifer after the sampling event without significantly altering he water quality. Standard procedures for obtaining protocol groundwater monitoring samples at SRS call for extracting or "purging" sufficient quantities of groundwater to allow removal of stagnant water from the well and to allow certain key indicator parameters to stabilize prior to collection of eh samples. The water extracted from a well prior to sample collection is termed "purge water" and must be managed in an approved fashion if it contains hazardous and/or radiological constituents that exceed the specified, health based limits. Purge water management include the containerization, transportation, treatment, and disposal at Clean Water Act permitted facility.

The PWMS consists of an above ground tank, a dual use supply and return piping system and a non metallic electronic flow meter attached to the existing well heads at groundwater monitoring wells. A submersible pump, located within the monitoring well, pumps groundwater through the supply piping to the tank. After a sufficient quantity of groundwater has been purged from the well, typically two to four well volumes, a protocol groundwater sample is obtained from the well sampling port. The purge water held in the tank is returned to the monitoring well through the same piping that supplied the purge water to the tank.

Deployment Date: 4QFY02

Study Area/Project: Site Wide (tankless)

SGCP Contact: Eric Schiefer (eric.schiefer@srs.gov)

Description: A "Tankless" Purge Water Management System (PWMS) has been successfully installed in two groundwater monitoring wells. These two deployments are part of a 3-well Pilot Study to determine the effectiveness of the Tankless apparatus and whether representative samples of groundwater are obtained when this equipment is utilized. The PWMS Tankless system allows the collection of representative groundwater samples, while eliminating the generation of Investigated Derived Waste (IDW). The PWMS Tankless unit utilizes the well itself to temporarily store purge water until the groundwater sample is obtained. In contrast, the PWMS Tank units temporarily store the IDW in above ground tanks. With both technologies, the purge water is kept in the "close loop" system and is returned to the originating aquifer through the well once the sample is collected. This technology reduces costs associated with obtaining groundwater samples by avoiding the disposal costs associated with the contaminated purge water. As part of the ongoing evaluation, a new design for this apparatus includes a custom made flow through packer and a new well head configuration that utilizes a rotometer to monitor flow rate. The rotometer performance is being compared to the performance of the electronic flowmeter that had been utilized in previous designs. The design changes reduce the fabrication cost of the Tankless unit by nearly $2,000, compared to previous models. To date, the field tests show very positive results.

4.3-Filter-Screening (Demonstration)

Deployment Date/Demonstration Date: 4QFY96

Study Area/Project: F&H Seepage Basins

SGCP Contact: Carlos Lucha (carlos.lucha@srs.gov)

Description: A conventional slurry filtering technology can potentially reduce the volume of investigated derived waste (IDW) generated and effectively separate solid and liquid components of the waste stream to facilitate the treatment of the wastewater. A filtering system incorporating screens and sediment traps is mobile and can be installed temporarily in the field where IDW is generated with simple and efficient modular systems, and scaled to fit the volume of IDW needed to be managed.

Chapter 5: Other Technologies Considered for Deployment

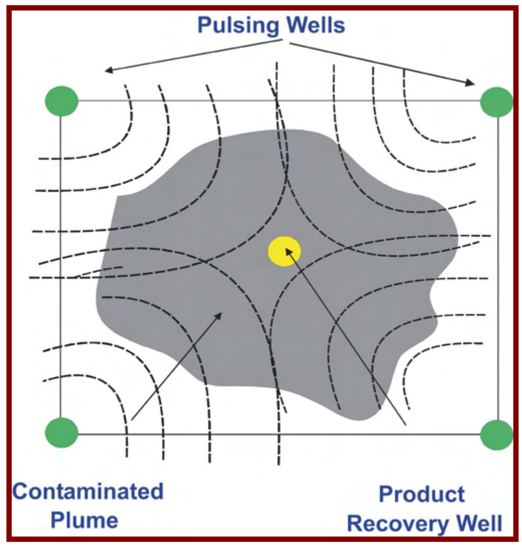
5.1-Groundwater

5.1.1-Pressure Pulse Technology

Deployment Date: TBC

Study Area/Project: Open to Potential Projects

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
Sean Bohrer (sean.bohrer@srs.gov)



Description: Recovery of groundwater contaminants via traditional pump and treat remediation systems eventually becomes less efficient over the long term as much of the contamination that remains is confined within fine grained sediments. These contaminants are hard to recover and make pump and treat systems more expensive to operate. A new technology that was developed for the oil industry addresses the need to increase the extraction of groundwater contaminants.

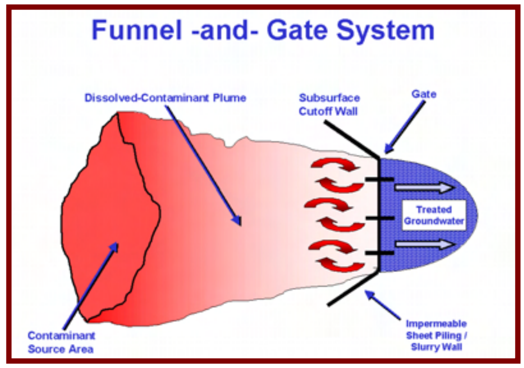
Pressure Pulse Technology involves a pulsing action within a well or series of wells to instigate porosity dilation wave in porous media. The porosity dilation wave is slow moving and is controlled by alternating the amplitude and frequency of the pulsing action. The resultant wave causes the sediments to vibrate thereby creating a mini pumping action or porosity dilation of the sediments that begins to move the contaminants whereby they can be removed via the existing pump and treat system. This project is being evaluated for deployment to increase volatile organic compound (VOC) removal near an existing pump and treat system

5.1.2-Funnel and Gate

Deployment Date: TBC

Study Area/Project: Open to Potential Projects

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)



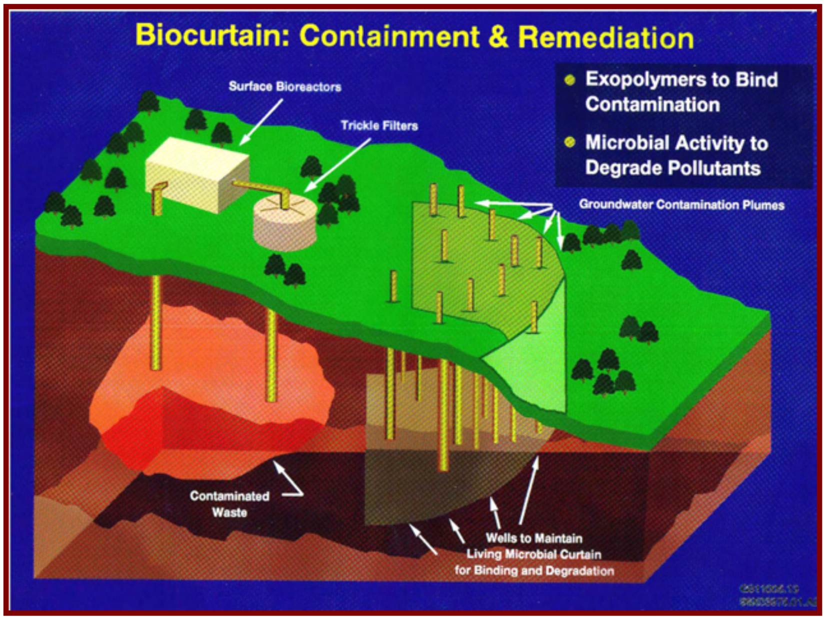
Description: Funnel & Gate systems isolate contaminant plumes in groundwater and funnel the plumes through *in situ* reactors. Groundwater plume is directed through the *in situ* reactors in the gates where physical, chemical or biological processes remove contaminants. Funnel and Gate systems can be built in several configurations; Straight walls with one or more gates, V shape funnel with the gate at the point, U shape funnel with several gates along the bottom of the U. For a complex contaminant plume, multiple contaminants can be treated by passing through a series of gates aligned in sequence, each containing different reactive media.

5.1.3-Biobarrier (Demonstration)

Deployment Date/Demonstration Date: TBC

Study Area/Project: Open to Potential Projects

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)



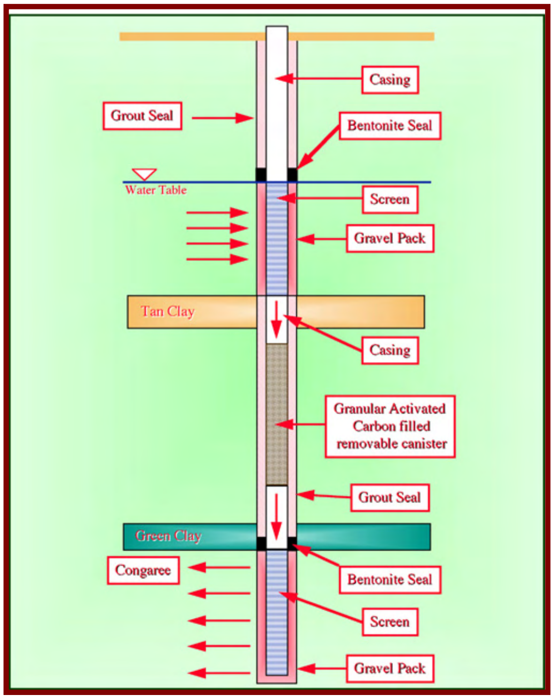
Description: The subsurface microbial barrier is a cost effective contaminant technology. It has been used in the oil industry. The microbial communities in subsurface environments will be directed to stimulate subsurface microorganisms in such a way as to provide a biological barrier for contaminant plume. This biobarrier would be maintained through a series of vertical or horizontal injection wells that would "feed" the subsurface microorganisms to maintain the biological barrier. Contaminants "trapped" in the biobarrier could be contained by maintaining the biobarrier. Once SRS reached its objectives, the subsurface could be retuned to a more "normal" habitat by lowering the nutrient concentration being delivered to subsurface community and allowing the organisms and biobarrier to die back and return to a microbial community more in line with the southeastern coastal plain sediments and groundwater.

5.1.4-Geoflow

Deployment Date: TBC

Study Area/Project: Open to Potential Projects

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Mark Phifer (mark.phifer@srnl.doe.gov)



Description: GeoFlow Cells are systems to passively induce contaminated groundwater flow through *in situ* permeable treatment media at an accelerated rate by utilizing the natural hydraulic head difference between two points. The accelerated passively induced flow can be produced through the used of open channel/pressure flow between the points of natural head difference. The up gradient initiation point is within a contaminated aquifer, and the down gradient discharge point can be to the subsurface, a surface water body or the ground surface. The permeable treatment media utilized in GeoFlow Cells can include granular cast iron, activated carbon, cation exchange resin, limestone, zeolites, etc. The permeable treatment media can be applied at any point in the passively induced flow can be applied as *in situ* or ex situ, can be configured to be either permanent or rechargeable.

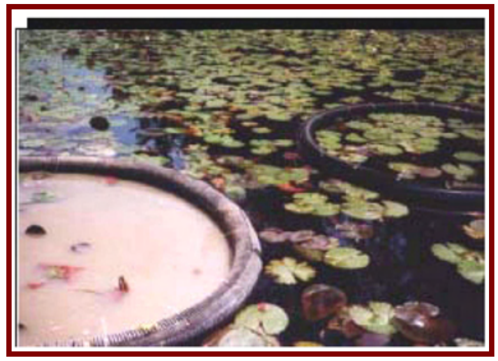
The simplest GeoFlow Cell configuration is that of a large diameter vertical well installed by conventional well drilling techniques, which contains a removable, flow through, permeable treatment media canister positioned between an upper and lower screen zone. Contaminated groundwater flow is passively induced through the treatment canister due to the head differential between the locations of the upper and lower screen zones. Groundwater flows into the screen with the higher head, through the treatment canister, and out the screen with the lower head. This can potentially be done within a single aquifer or between aquifers. Other configurations including the use of horizontal wells are possible.

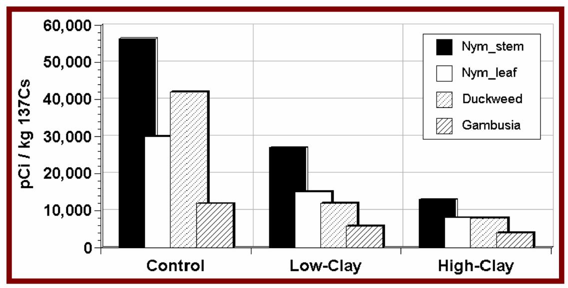
5.1.5-MNA Reduced Bioavailability of Cesium 137 in Reactor Canals

Deployment Date: TBC

Study Area/Project: R and P Reactor Discharge Canals and PAR Pond

SGCP Contact: Catherine Lewis (catherine.lewis@srs.gov)
SRNL Contact: Dan Kaplan (daniel.kaplan@srnl.doe.gov)
SREL Contact: Tom Hinton (hinton@srel.edu)





Description: Over 3000 acres of wetlands are contaminated with low levels of Cs-137 from past reactor cooling water discharge practices and present a significant remediation challenge in future years. The principal areas of contamination are the R and P reactor discharge canals and also PAR pond. Due to the immense volume of soil to be treated, physical removal and disposal would be cost prohibitive, as would stabilization in place using conventional techniques such as grouting. Migration of Cs-137 has long been known to be inhibited by the naturally occurring clays present in the soils. The Cs-137 ions are bound within the physical structure of the clay molecule by a natural ion exchange effect of significantly reducing the bioavailability of the Cs-137 and inhibiting its release into the environment. The ion exchange bonding effect can be quite strong, but depends on the type and quantity of clay present in the soil. SRS soils and sediments typically contain low quantities of kaolinite and iron oxide based clays, which have a relatively low ion exchange capacity. This is compounded by seasonal effects on the change in redox conditions in lake bed sediments, which encourage the release of the bound Cs-137 into the lake's aquatic systems, thus increasing bioavailability.

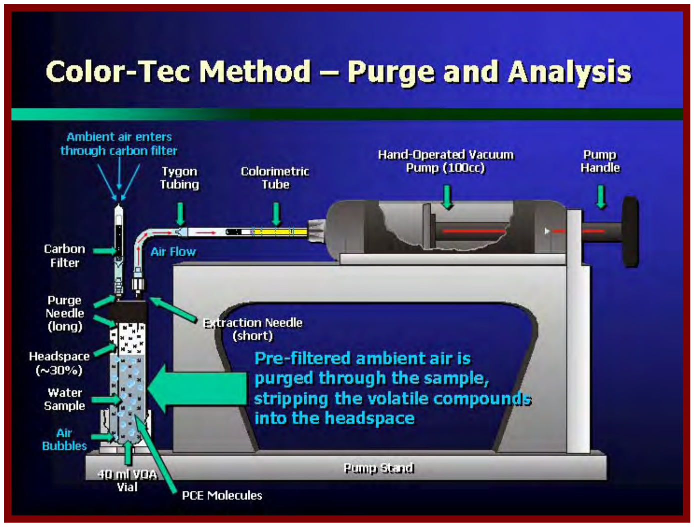
Because of their physical structure, mica type clays are known to possess a much higher ion exchange capacity, and hence have a much higher capability to bind Cs-137. The proposed process would be to introduce Illite clay from the mica clay family, onto the surface of lake beds and wetlands in and around the reactor canals. This would significantly reduce bioavailability and allow time for the Cs-137 to decay naturally. Preliminary experimental work on illite clay treatment to R discharge canal soils and PAR pond sediments, has confirmed the effectiveness of this process.

5.1.6-Color-Tec- Screening Method for Rapid Delineation

Deployment Date: TBC

Study Area/Project: TBC

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)



Description: Color-Tec is a rapid screening method that can be used to determine the presence of certain types of chlorinated alkenes and alkanes in groundwater, soil, sediment or surface water sample. This method of screening uses colorimetric tubes, similar to Dräger tubes, which provide an immediate visible sign of its presence. This indication is partially quantitative. For some analytes the Color-Tec method has a low detection. The method routinely detects tetrachloroethylene (PCE), trichloroethylene (TCE), 1,2-dichloroethylene (1,2-DCE) and vinyl chloride to near or below the Environmental Protection Agency (EPA) maximum concentration limit (MCL) in field sample gas chromatograph chromatography (GC)/mass spectroscopy (MS) data pairs.

The use of this technology is applicable to rapid field screening during pre-characterization of operable units.

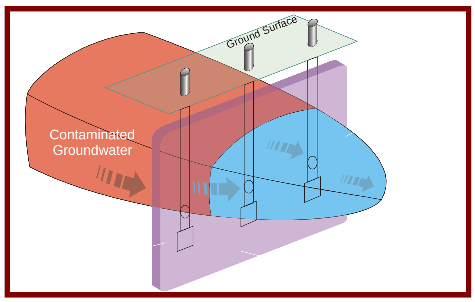
5.1.7-Trenchless Permeable Reactive Barrier-Azimuth Controlled Vertical Hydraulic Fracturing

Deployment Date: To Be Considered (TBC)

Study Area/Project: TBC

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
http://www.geosierra.com

Description: Use of zero valent iron as an effective treatment for groundwater contaminated with chlorinated halogenated organics is common place. Zero valent iron is used in both ex- and in-situ applications. The preferred method for treatment is placement of the iron in subsurface permeable reactive barrier (PRB) wall(s) whereby contaminated groundwater flows through the wall reducing the chlorinated halogenated organics into harmless daughter products. Typical barrier wall installations have been constructed by various types of trenching and slurry injections. These applications are best suited for shallow installations. However, there are drawbacks with these types of installations such as depth of installation, location, and costs.



GeoSierra has patented a revolutionary approach to barrier wall installation called azimuth controlled vertical hydraulic fracturing. This approach allows for barrier wall installation at greater depths over traditional methods. In addition, the direction of the wall can be controlled allowing for various types of configurations. The direction and depth of the wall is controlled by a series of vertical fractures that are induced between frac wells. When the vertical fracture is inducted, the iron are transported into the ground in a cross linked gel that is biodegradable. The installation of the iron reactive permeable barrier is monitored by precision weight measurement and metering of the iron filings into each frac well casing and the installed geometry of the PRB was monitored in real time by the active resistivity imaging technology. The PRB thickness is verified by inclined profiling along the PRB alignment using a soil electrical conductivity probe. High precision hydraulic pulse interference tests are conducted both pre- and post-PRB installation demonstrating that the barrier wall does not impede natural groundwater flow regimes.

The application of this technology is being considered at chlorinated halogenated contaminated groundwater plumes.

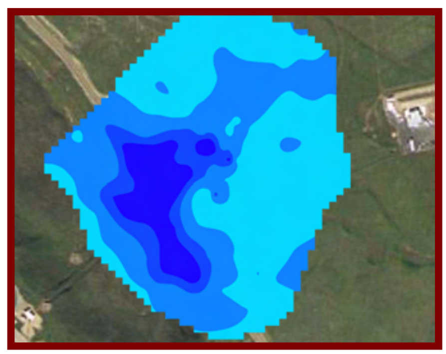
5.1.8-AquaTrak- Groundwater Mapping

Deployment Date: TBC

Study Area/Project: TBC

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Dennis Jackson (dennis.jackson@srnl.doe.gov)
SGS Contact: Randy Cumbest (randy.cumbest@srs.gov)

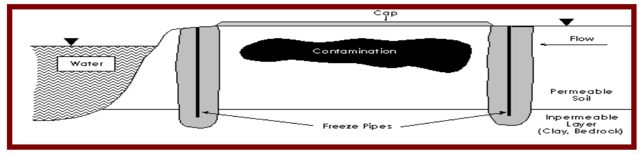
Description: AquaTrack is a geophysical technique used to map groundwater. The technique involves energizing a water-bearing zone to collect magnetic field measurements within a defined grid area. At each grid node, the magnetic field and relative global positioning system (GPS) coordinate are recorded electronically. The data are processed to generate contour maps and is correlated to other hydrogeologic data. The system operates at a frequency of 400 Hz with an inductive coil sensitivity of 60 Henrys. The use of this technology is applicable to sites where determining the saturated extent of aquifers, identifying recharge and discharge areas, mapping location of water-bearing buried stream channels, determining influence of geologic structures on groundwater flow, and evaluating hydraulic connection or separation between aquifers.

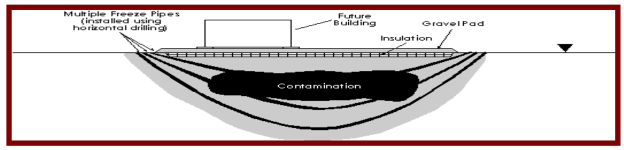


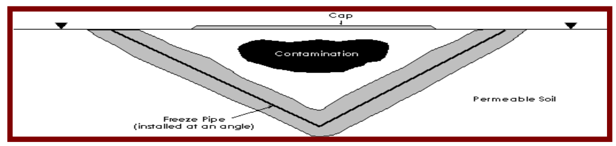
5.2-Soil

5.2.1-Soil Freeze (Cryocell) (Demonstration)

(Freeze Wall at ORNL)







Deployment Date/Demonstration Date: TBC

Study Area/Project: Open to Potential Projects

SGCP Contact: Mark Amidon (mark.amidon@srs.gov)
SRNL Contact: Mike Serrato (michael.serrato@srnl.doe.gov)

Description: Cryocell provides frozen soil barriers, a containment technology, around the contaminated waste site. It is a proven technology and has been widely used in mining and construction industries since late 1800's. Major applications have been the bonding of soil to give load-bearing strength during the construction of foundations, to seal tunnels, mining shafts, and subsurface structures against flooding, and to stabilize soil during the excavation. This technology involves the installation of rows of freeze pipes around the circumference of the site. A second set of pipes is installed 10 to 40 feet outside of the first set of pipes. These pipes then are attached to a refrigeration unit and soil around and between the pipes are frozen. Thermocouples are positioned at critical depths to monitor the frozen soil. The cooling agent is calcium chloride brine or liquid nitrogen. Frozen soil can be used to support excavations with out bracing. This method has been used to carry shafts to a depth of 3000 feet. Freeze walls can stand 6,000 psi pressure versus concrete at 3,000psi pressure. In a New York City water main distribution system a shaft 41 feet in diameter with 10 foot thick frozen soil walls was formed to a depth of 260 feet.

5.3-Other

5.3.1-Sol-Gel Indicators for Process and Environmental Measurements

Deployment Date: TBC

Study Area/Project: Site Wide

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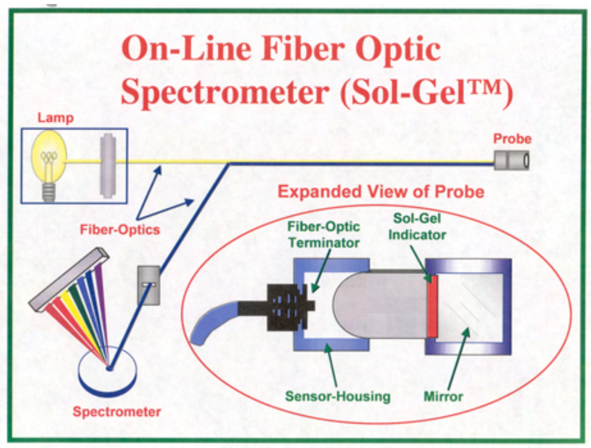

Description: Sol-gel technology extends on line fiber optic spectrophotometer capabilities. Increased emphasis in on line process and environmental analysis has fueled additional needs for field portable and remote monitoring process instrumentation. Fiber optic diode array spectrophotometers (DAS) with associated fiber optic probes provide a significant measurement capability for compounds with ultraviolet, visible or near infrared absorption. The use of fiber optics allow measurements to be made in difficult to reach or hazardous environments, with the spectrophotometer systems installed several hundred meters from the measurement point(s). The probes are used as a sample interface to allow light from the fiber optic to interact with the liquid or gas stream and return to the spectrometer.

Sol-gel indicators further extend the range and capability of this technology into a variety of additional applications for on line, real time measurement and control through the use of indicator materials trapped in a porous, sol-gel derived, glass matrix. Thin films of this material are coated onto optical components of various probe designs to create sensors for process and environmental measurements. These probes provide increased sensitivity to chemical species based upon characteristics of the specific indicator. Demonstrations have been completed for pH, metals and non metallic species. The sol-gel formulation is a mixture of tetraethylothrosilicate, ethanol and water. Indicators, such as bromophenol blue, arsenal III and congo red are dissolved in this mixture and coated onto an optical surface such as a probe lens. The product is allowed to dry at ambient temperatures or under mild heating in an oven, producing a thin film of SGI composite. Ore sizes of the sol-gel composite can be controlled during synthesis to allow the desired compounds to reach the indicator molecule, while keeping the indicator trapped within the matrix. This matrix may also screen interferences from interacting with the indicator as well.

The response range of indicators is often expanded by their inclusion into the sol-gel matrix. For example, the color response of a bromophenol blue sol-gel pH sensor from yellow (acid form) to blue (basic form) provides a response range of almost 4 pH units. This is approximately twice the response range for this indicator as traditionally used in aqueous solutions. With the bromophenol blue sol-gel indicator composite, pH differences as small as 0.1 pH unit cause marked changes in the sensors absorption spectrum. The pH sensor's response time is on the order of a few seconds to half a minute. Many indicators have a reversible response to compounds allowing the probe to be used for continuous monitoring.

Sensor responses were modeled by multivariate analysis techniques like Principle Component Regression (PCE) and Partial Least Squares using software developed at Savannah River National Laboratory (SRNL). For the bromophenol blue sensor, a PCR model based upon a training set with intervals of 0.1 pH units gave prediction accurate to +0.3 pH units on analysis of subsequent solutions. Sol-gel indicator technology has the advantage to being able to incorporate the indicator in a chemically durable matrix at room temperature, avoiding the high temperatures in conventional glass manufacture that would degrade the organic indicator molecule.

5.3.2-Fluorometer – Tool for Monitoring Plant Health During Phytoremediation and Monitored Natural Attenuation

Deployment Date: TBC

Study Area/Project: Site Wide

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Description: For phytoremediation and monitored natural attenuation (MNA) to be successful, the biotic community (plants and rhizosphere microorganisms) must remain healthy. This is analogous to keeping the pumps running in an air-stripping treatment. Maintaining the efficiency of the pumps is easily appreciated, but assessing the health and efficiency of the biota is difficult to determine. If a plant's health is affected by contaminants in soil and/or groundwater such that it grows less or dies, the results are easily recognized, but are too late. The pumps (i.e., plants) must be repaired or replaced. Therefore, to maintain maximum efficiency of phytoremediation or MNA, it is critical to be able to determine the health of the biota.

Fluorometers measure the response of chlorophyll contained in the leaf chloroplast. A short burst of a very high light intensity saturates the chlorophyll and generates a maximum fluorescence response. This value along with fluorescence values in the dark and at steady state conditions, which occurs about 4-5 minutes after the light flash are measured individually and then combined in specific ratios. Intensity of a stress is then correlated with fluorescence parameters to determine the strongest correlation. Leaf heavy metal content was strongly correlated with the fluorescence decay (a ratio involving the maximum and steady state fluorescence intensities of the leaves). Thus, determining the leaf fluorescence characteristics accurately predicts the leaf heavy metal content, which in turn can be used to determine when critical leaf toxicity concentrations would be approached.

Fluorescence is but one of a number of plant heath indicators that can be used to evaluate impact on plant health. Other characteristics such as plant metabolic functions provide additional information that can be used to evaluate plant health. The LICOR 6400 Portable Photosynthesis System is a multifunction tool that can simultaneously measure the instantaneous rates of net photosynthesis, stomatal conductance, and transpiration, as well as chlorophyll fluorescence. The information collected to some degree might explain the mechanisms for a plant’s response to stress. The obtained results can be used to determine the best action to ameliorate the stress impact, further improving phytoremediation/MNA efficiency.