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SCFA PROGRAM OVERVIEW

"The Subsurface Contaminants Focus Area is committed to continued support to the DOE problem holders in identifying timely alternatives to costly, inefficient baseline technologies. We will continue to involve the end users in program planning and decision making to ensure that the highest priority problems are addressed with the available resources."

Jim Wright
Subsurface Contaminants Focus Area Lead

BACKGROUND

After years of designing, manufacturing, and testing nuclear weapons, the U.S. Department of Energy (DOE) is faced with the challenge of cleaning up the hazardous waste left behind.

- More than 5,700 known DOE ground-water plumes have contaminated more than 600 billion gallons of water and 200 million cubic meters of soil.
- DOE landfills contain more than 3 million cubic meters of buried waste contaminating the surrounding environment.
- Radioactive and hazardous contaminants in the soils and ground water at all DOE sites in the complex require cost-effective and timely technology systems to replace baseline technologies.

MISSION

To develop, demonstrate, and deploy innovative systems that accomplish containment and long-term isolation of leaking buried waste areas and remediation of dispersed contamination including dense nonaqueous-phase liquids (DNAPLs), metals, and radionuclides in the subsurface. These systems will reduce the risks to health, safety, and the environment and the costs of remediation while meeting compliance requirements.
STRATEGY

In support of its vision for technological excellence, the SCFA has identified three strategic goals. These goals are reviewed annually to ensure consistency with DOE’s national strategy and stakeholder priorities. Specific objectives in support of these goals are identified in deployment plans and program scopes of work. The three strategic goals of the SCFA are

- Contain and/or stabilize contamination sources that pose an imminent threat to surface and ground waters
- Delineate DNAPL contamination in the subsurface and remediate DNAPL-contaminated soils and ground water
- Remove a full range of metal and radionuclide contamination in soils and ground water

To meet the challenges of remediating subsurface contaminants in soils and ground water, SCFA funded more than 40 technologies in fiscal year 1997. These technologies are grouped according to the following product lines:

- Dense Nonaqueous-Phase Liquids
- Metals and Radionuclides
- Source Term Containment
- Source Term Remediation

This report briefly describes the SCFA 1997 technologies and showcases a few key technologies in each product line.

21 Field Applications of New Technologies in 1997
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Disposal of chemicals that have low water solubility and a density greater than water results in the formation of distinct areas of pure residual contamination in soils and ground water. These chemicals are typically chlorinated solvents and are collectively referred to as dense nonaqueous-phase liquids (DNAPLs). Because of their relatively high density, they tend to move downward through soils and ground water, distributing small amounts along the migratory pathway, until they reach a low-permeability layer, where they can collect in discrete pools if sufficient DNAPL is available.

Once the DNAPLs have reached a low-permeability layer, they tend to move laterally under the influence of gravity and to slowly dissolve into the ground water, providing a long-term source for contamination of ground water. Because of its movement patterns, DNAPL contamination is difficult to detect, characterize, and remediate. The SCFA is developing a number of technologies to address the problems inherent to this class of chemical contaminants. The strategic goal of the DNAPLs product line is to demonstrate the ability to delineate DNAPL contamination in the subsurface and remediate DNAPL-contaminated soils and ground water in varying hydrogeological settings.

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**Fenton's Reagent**

The Fenton's Reagent process is an in situ oxidation method to destroy DNAPLs in ground water. Fenton's chemistry, developed by H. J. H. Fenton in the 1890s, has been widely used by the wastewater industry for treatment of organic wastes. Hydrogen peroxide is the active ingredient in the oxidation of organic compounds. The hydroxyl radical is the reactive species in this process and is more than 100 times as powerful as oxygen or ozone alone. Fenton's reagent is used to convert DNAPLs to carbon dioxide, chlorine, and water. The hydrogen peroxide and catalyst (ferrous sulfate) are injected into the groundwater zone where the targeted DNAPL zone is located. The oxidation reaction accelerates cleanup activities by destroying contaminants in situ, eliminating undesired downward movement of DNAPLs. A full-scale demonstration of in situ destruction of DNAPLs by Fenton's Reagent, attended by 79 end users, regulators, and vendors, was completed at the Savannah River Site A/M Area in April 1997. The effects of the reaction on biological and geochemical conditions will be evaluated in 1998.
LASAGNA™

The LASAGNA™ process, so named for its layered structure of electrodes and treatment zones, is an integrated in situ treatment technology in which established geotechnical methods are used to install treatment zones and electrodes directly into low-permeability soil (clays). Power is then applied to the electrodes, and electro-osmosis is used to move the contaminants dissolved in ground water through the treatment zones, where they are either adsorbed or destroyed in situ. The process remediates hard-to-treat, low-permeability soils at a very low cost compared to pump-and-treat and soil vapor extraction technologies, which are inefficient in such soils. LASAGNA™ technology currently costs approximately $175/cubic yard for a 1-acre site vs $500/cubic yard for applying baseline technologies, which generate secondary wastes that require treatment, storage, or disposal. A full-scale demonstration at the Paducah Gaseous Diffusion Plant was completed in August 1997. EM-40 at Paducah is funding the subsequent LASAGNA™ application there for full-scale cleanup of the Solid Waste Management Unit.

Optimization of Enhanced Soil Mixing

In Situ Enhanced Soil Mixing (ISESM) encompasses a number of in situ soil treatment technologies for remediating soils contaminated with volatile organic compounds, especially in fine-grained soils, which are difficult to treat with other remediation technologies. Soils are mixed with a single-blade or multiple augers. Enhancements include injection of heated air with vapor extraction, injection of oxidants, and injection of grout. ISESM was demonstrated at the Portsmouth Gaseous Diffusion Plant in 1992 and the Kansas City Plant in 1996 and deployed at the Argonne 317 Area French Drain in 1997.

Separation, Recovery, and Recycling for Surfactant Solutions

Surfactant flushing has been demonstrated at a number of federal and commercial sites for removal of residual DNAPL contamination. However, for this process to become economically attractive to DOE and other end users, a means must be found to economically separate the contaminants from the waste stream, recondense the surfactant solution, and reinject it into the subsurface. Air stripping is an effective method of removing volatile contaminants from the waste stream, and ultrafiltration is capable of concentrating the solution. The recovery technology was demonstrated in FY97 at the Tinker Air Force Base in Oklahoma City.
**RTDF Bioremediation**

The Remedial Technologies Development Forum (RTDF) Bioremediation subgroup demonstrates, validates, and establishes implementation principles and practices handbooks for three bioremediation technologies for the cleanup of chlorinated organic contaminants in situ: accelerated anaerobic biodegradation, intrinsic remediation, and cometabolic bioventing. The multidisciplinary design includes the efforts of hydrogeologists, microbiologists, geochemists, and engineers. Technology handbooks for efficient application are being developed in conjunction with field studies at Dover Air Force Base.

**LLNL Site 300 Building 834 DNAPL Remediation**

DNAPL contamination has been found underneath buildings and structures at several DOE sites. The sites have expressed a need for special technologies that can be implemented without disruption of the facilities. Under Site 300, Building 834, at Lawrence Livermore National Laboratory two bioremediation studies are under way to evaluate the remediation of DNAPLs and light nonaqueous-phase liquids. The 1997 studies evaluated bioremediation in field conditions to determine whether these compounds could be remediated simultaneously, with no toxic by-product that would disturb the facility or prevent regulatory compliance.

**In Situ Chemical Oxidation Using KMnO₄**

In Situ Chemical Oxidation using potassium permanganate (KMnO₄) was field-tested in low-permeability soils at the Kansas City Plant in 1996 using soil mixing and in 1997 in an aquifer at the Portsmouth Gaseous Diffusion Plant using a ground-water recirculation technology. This technology enables oxidant migration to be controlled within the treatment zone. A tour of the Portsmouth facility was conducted in July 1997. One hundred end users, regulators, and contractors attended this tour and engaged in productive discussion on deployment of the technology at their sites.
**DNAPLs in Low-Permeability Media**

Four test cells to compare various methods of removing DNAPL from low-permeability media (clay) were installed at the Portsmouth Gaseous Diffusion Plant in 1997. Horizontal fractures were generated in each test cell using hydraulic fracturing techniques developed in the oil industry. The fractures in two cells were propped open with a sand slurry, allowing access by steam and hot air. Another cell used iron filings for a proppant, resulting in in situ dechlorination; and fractures in the final cell were propped open with potassium permanganate grout, providing in situ oxidation. Initial findings in the side-by-side field tests showed that the cell using potassium permanganate grout produced the most promising results. This field test was one of several technologies highlighted at a tour conducted at the Portsmouth Gaseous Diffusion Plant in July 1997.

**In Situ Hydrous Pyrolysis/Oxidation**

Hydrous Pyrolysis/Oxidation (HPO) provides a combination of both rapid mass removal of DNAPLs and in situ destruction of residual contamination. It is projected that these technologies may result in significant cost savings by eliminating long-term use of an expensive pump-and-treat method. Large-scale cleanup of DNAPL sources using HPO/DUS may be used to treat large volumes of contaminated soils and sediments and may result in clean closure of a site.

In a unique partnership with Southern California Edison, this SCFA technology was deployed in a full-scale cleanup of the telephone pole manufacturing plant in Visalia, California, in 1997–98. DUS/HPO outperformed the previous product recovery method (conventional pump and treat) by recovering 50,000 gallons of DNAPL in the first 6 months of operation in comparison to 500 gallons per year recovered by the older baseline technology.
Recirculating Well Treatment of Trichloroethylene and Technetium-99

Recirculating well technology treats mixed (radioactive/metalllic and hazardous) ground-water contaminants found in a thin water-bearing zone not easily targeted by traditional vertical wells. The recirculation system uses a pair of horizontal wells—one for ground-water extraction and treatment and the other for reinjection of treated ground water—to set up a recirculation flow field that establishes a sweeping action for the removal and treatment of ground-water contaminants. A field demonstration at Portsmouth Gaseous Diffusion Plant in 1996–97 showed that a mixed waste stream containing chlorinated solvents and technetium-99 can be treated simultaneously using palladized iron to dechlorinate solvents and sorb technetium-99.

In Situ Bioremediation for Hanford Tetrachloride Plume

In situ anaerobic bioremediation is being developed to destroy volatile organic compounds, nitrates, and other hazardous chemicals less expensively than the baseline pump-and-treat method. The objective is to achieve complete contaminant transformation to carbon dioxide, water, and nitrogen gas while generating no secondary waste. Nutrients are delivered using an injection/extraction well network that enhances mixing. The technology was selected by the DOE-EM Advisory Board for accelerated deployment at Hanford.
METALS AND RADIONUCLIDES PRODUCT LINE

Radionuclides contamination is prevalent in the DOE complex. Heavy metal contaminants behave similarly to radionuclides in environmental media and so are included in this product line. Recent studies have identified 59 waste sites at 14 DOE facilities across the nation that exhibit radionuclide contamination in excess of established limits. The rapid and efficient characterization and remediation of these sites and the areas surrounding them represent a technological challenge with no existing solution. Current methods used to remove these contaminants from soils and ground water are expensive, may have a high degree of risk, and may produce a secondary-waste problem. Depending upon the concentration, type of contaminants, depth of contamination, and area to which the contamination has spread, currently available technologies such as excavation, treatment, and disposal may not be technically feasible or publicly acceptable. The strategic goal of the metals and radionuclides product line is to establish a second generation of in situ treatment systems that bring together advanced characterization and treatment technologies. Current activities are working to extend existing innovative technology systems to address broader classes of subsurface contamination. These technologies include in situ chemical treatment, in situ redox manipulation, electrokinetics, and separations technologies.

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ACT*DE*CON™ Soil Processing

The ACT*DE*CON™ process uses a chelant, a carbonate, and an oxidant to dissolve radionuclides in soil or other contaminated solid media. The oxidant raises the oxidation state of the contaminant to a soluble level, and the chelant assists formation of the carbonate complex. Following the separation of the liquid and solid components of the soil slurry, the carbonate complexes are selectively removed from the liquid phase. This process is typically accomplished by the MAG*SEP™ technology, which uses selective adsorbers on the surface of magnetically susceptible particles. These particles are finally removed from the spent ACT*DE*CON™ by electromagnetic separation and are either regenerated or stabilized as final waste, allowing recycling of the spent ACT*DE*CON™ solution. Future work will finalize the secondary waste (spent ACT*DE*CON™) treatment and design and construct a functional pilot-scale testing system to provide a reasonably accurate simulation of the processing conditions in the field. The technology’s benefit is volume reduction of radioactive/transuranic waste generated in the cleanup of contaminated soil and sediment. A pilot-scale treatment system on both plutonium- and thorium-contaminated soil at the Mound Plant demonstrated the removal of plutonium to be below levels detectable by the soil screening instruments. The ACT*DE*CON™ and MAG*SEP™ technologies are proprietary to Selective Environmental Technologies, Inc. (Selentec). Their application to the Mound site is being developed
under a joint project between Selentec and Argonne National Laboratory. Based on a successful
demonstration, ACT*DE*CON™ has been selected for deployment at Mound under the Accelerated Site
Technology Deployment Program.

Enhanced Uranium Recovery

This project is investigating the application of commercial in situ solution mining
technologies for the remediation and containment of uranium ground-water
contamination. Ground-water reinjection is an integral part of the in situ mining process.
Enhanced uranium recovery will be accomplished by increasing the contaminant
flushing process and limiting the ground-water drawdown where most of the uranium is
located. This project will address technical uncertainties related to the application of
injection technology. The potential exists to significantly reduce the duration of aquifer
remediation projects. For instance, at Fernald the potential reduction in time to remediate
the Great Miami Aquifer is 15 years or more. This translates into a potential savings of
$60 million. A large-scale demonstration of water injection is proposed to evaluate the
improvement in performance over the baseline ground-water remediation strategy
(pump and treat). Modeling identified key geochemical parameters of the aquifer prior to
investigating and mapping the aquifer's geochemical properties. Nine “early start” extraction wells were
installed for use during pilot-scale injectivity tests and during the full-scale demonstration.

Smart Sampling™

Smart Sampling™ integrates sampling and characterization with programmatic, economic, and
regulatory performance objectives to assist in evaluating remediation options. This process provides a
real-time analysis tool for decision makers and field personnel and allows for the evaluation of
sampling strategies vs cost and performance objectives. Using easy-to-understand graphics and simple
economic functions, the Smart Sampling™ process helps program managers and stakeholders to
visualize the characterization and sampling data coming from a specific site. Smart Sampling™ is
divided into three integrated technical product lines: information
management and visualization, advanced geostatistical applications, and
economic risk-based decision analysis. Smart Sampling™ uses geostatistical
simulation to generate maps or three-dimensional pictures that display the
likelihood of exceeding a regulatory action level for a particular
contaminant. Emphasis is on integrating the use of Smart Sampling™ with
existing hardware and software systems at individual sites. The process
decreases information management and analysis times by an order of
magnitude and produces technically defensible, state-of-the-art site
sampling and decision strategies. The project attained full-scale use of the
technique at Fernald. Technology transfer activities are under way at
Mound, Sandia, Weldon Spring, Fernald, and the Ohio Environmental
Protection Agency.
GeoFlow Treatment System

The GeoFlow Treatment System uses natural hydraulic gradients to pass contaminated ground water through a treatment cell. Several variations of the GeoFlow Treatment System design are possible depending on site characteristics and the best remediation strategy. One design uses an impermeable barrier and partially penetrating interceptor well to collect contaminated ground water and direct it to the GeoFlow treatment cell, which contains a removable/interchangeable treatment media canister and sampling ports for head measurements and sampling. The technology is versatile and adaptable to most site conditions by providing permeable or impermeable reaction walls; cut-off walls; interceptor trenches; upgradient and downgradient site boundary protection; landfill containment, monitoring, and leachate collection; enhanced funnel and gate-type designs; and landfill methane containment and collection.

Resource Recovery Project

The Resource Recovery Project (RRP) addresses three problems identified by DOE: extraction and removal of heavy metals (ex situ), containment of heavy metals (in situ), and development and demonstration of technologies for radionuclide extraction and removal. The RRP's objective is to test and evaluate technology on a comparable basis and to provide cost and performance data to end users. The project will use contaminated surface water from the Berkeley Pit, a large Superfund site (former mining site), which contains high concentrations of heavy metals, sulfate, and low pH. At the completion of each demonstration, a Technology Evaluation Report reports the technology's ability to meet compliance, technical viability, and engineering/constructability.

Subsurface Reactive Barriers

Passive reactive barriers are engineered structures emplaced in the subsurface to capture and treat an advancing ground-water contamination plume. The natural hydraulic pressure gradient in the aquifer drives the plume through the reactive zone. The reactive media are selected and designed specifically for each site because their choice is a function of contaminant type and concentration, background ground-water chemistry, and co-contaminants. Mixtures of contaminants can be remediated. Various designs are possible, including impermeable barriers that funnel ground water through an in situ treatment “gate” and excavated and backfilled trenches consisting of permeable reactive media. Passive reactive barriers may generate smaller quantities of waste material requiring disposal and are expected to significantly lower ground-water remediation costs and risks than the baseline of pump and treat. In FY97, SCFA evaluated reactive media, designed, and began construction of two different types of barriers, one at Rocky Flats Environmental Technology Site and the other at the Oak Ridge Y-12 Plant. SCFA also cooperated with Oak Ridge Environmental Restoration in the installation and testing of a reactive trench design.


**Gaseous Reduction of Chromate**

This project tests the feasibility of treating unsaturated soils contaminated with heavy metals and radionuclides by injection of reactive gases. The process diminishes human exposure and is relatively inexpensive to install and operate. The first contaminant tested will be chromate (Cr-VI). Chromate-contaminated soil samples collected at the Sandia National Laboratories Chemical Waste Landfill were tested. Engineering design and gas flow modeling activities have been conducted to develop approaches for ensuring the control of reactive gases and effectively treating large masses of contaminated soil. A skid-mounted prototype gas treatment system was designed, built, tested, and transported to the White Sands Missile Range in New Mexico in preparation for field-testing.

**In Situ Redox Manipulation**

In Situ Redox Manipulation creates a treatment zone in the subsurface for remediation of redox-sensitive contaminants in ground water, including chromate, uranium, technetium, some chlorinated solvents, and some explosive compounds. Aquifer sediments are chemically manipulated (reduced) so that they become the reactive media. The process places treatment capacity in the most permeable regions of the subsurface, in the path of the migrating contaminants. After a full-scale field injection test at the Hanford site, the technology, which is relatively inexpensive to install and operate, has been incorporated into the 2006 Plan as a treatability study for the Hanford 100-HR-3 Operable Unit.

**Biomass Remediation System**

The Biomass Remediation System is demonstrating the feasibility of using plants to remediate soils, sediments, and surface waters contaminated by heavy metal, radionuclides, and organics. Phytoremediation—the uptake of metals and radionuclides from soil and concentration in the leaf-stalk biomass—is especially suited to areas of land or water where low concentrations of contaminants are widespread. Several field trials have been completed to evaluate preliminary candidate species, provide accurate estimates of the rate of phytoremediation at the site, and validate field and laboratory test protocols. Fernald site field protocols are under development for the use of native, crop, and weedy plant species to remediate uranium-contaminated soil.

Under an agreement with central and eastern Europe, phytoremediation was used at an abandoned coal mine in Poland. Other activities will include bioremediation of an oil waste lagoon at the Czechowicz oil refinery, demonstrating the workability of expedited site characterization. Functional design criteria for an in situ bioremediation system based on treatability study results have been delivered. A workshop on bioremediation of the oil refinery site was held at the Warsaw '96 Symposium in September 1996. The demonstration was conducted at the oil refinery in Katowicz, Poland in 1997 with favorable results to be documented in 1998.
SOURCE TERM CONTAINMENT PRODUCT LINE

Virtually all DOE facilities have landfill sites. Contaminant leaching from landfills provides a major source of contamination to soils and ground water outside of the landfill. To eliminate this migration, the SCFA has developed a strategy that emphasizes source containment as its first step. Containment controls the extent of the contaminant plume and the concentration of contaminants until the landfill can be treated or further stabilized pending later treatment. Containment technologies are crucial to the success in keeping existing contamination problems at their current level. When remediation technologies are deployable, containment may become part of the permanent solutions. Containment technologies include landfill covers, impermeable barriers installed beneath existing landfills, and permeable barriers installed beneath or around existing landfills which contain only the contaminants and allow the passage of uncontaminated material. The product line’s strategic goal is to demonstrate the ability to contain contamination sources that pose an imminent threat to surface and ground waters.

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Close-Coupled Jet Grout Barrier

The Close-Coupled Jet Grout Barrier places an impermeable, dual barrier beneath an existing waste site. The barrier is composed of a composite grouting material that is jet-injected at high pressure and velocity without disturbing the waste form. This action completely destroys the soil structure. The grout and the soil are intimately mixed into a homogeneous mass. Two grouting materials (cement and a high-molecular-weight polymer) form the composite (“close-coupled”) barrier. The less expensive cement is used as the base for the more expensive polymer lining. This dual barrier system saves costs by using cement but still has the superior physical attributes necessary to withstand nearly any waste form at the polymer lining. A field-scale jet-grout demonstration at Hanford emplaced a cone-shaped, close-coupled barrier beneath a simulated waste form. In a full-scale demonstration at Brookhaven National Laboratory, a v-trough-shaped cementitious barrier was emplaced beneath a mixed waste pit. After the composite barrier cured, the waste was stabilized within the barriers using jet grouting at low pressure to form a stabilized waste monolith. The large monolith was then fractured in situ into manageable smaller units for later disposal.
**SEAttrace™ Gaseous Tracers**

SEAttrace™ is a quantitative subsurface barrier assessment system using harmless and inexpensive gaseous tracers to verify impermeable barrier emplacements in the vadose zone. The system integrates autonomous, multipoint soil vapor sampling with a data analysis system using an inverse global optimization code to pinpoint leak sources, sizes, and start times. Gaseous tracers provide a conservative assessment of barrier integrity after emplacement and provide a long-term integrity monitoring function.

**Alternative Landfill Cover**

The Alternative Landfill Cover Demonstration (ALCD) project is developing technologies to improve upon current landfill cover systems, providing alternatives to the EPA's landfill cover designs that will be more effective and less difficult and expensive to install in arid and semiarid climates. The project is also working to improve regulatory acceptance of alternative landfill cover designs. Some of the alternative designs emphasize unsaturated hydraulic conductivity, increased water storage potential to allow for eventual evaporation, and increased transpiration through engineered vegetative covers. The alternative covers were designed to take advantage of local materials to allow for easier construction of covers at substantial cost savings. Four alternative covers have been designed. The test plots for each design, along with standard RCRA covers as a baseline, were constructed and instrumented. The Western Governors Association and the Committee to Develop On-Site Innovative Technologies are working with Sandia National Laboratories to promote interstate cooperation.

One of the alternative designs is being constructed at Warren Air Force Base in Cheyenne, Wyoming. Another of the alternative designs, Capillary Barrier, is a project that involves design, demonstration, and analysis of capillary barrier landfill cover concepts at the Lee Acres landfill near Farmington, New Mexico, in cooperation with the Bureau of Land Management. The technology saves money by emphasizing use of natural processes for evapotranspiration and uses natural materials and configurations in construction to increase stability. A demonstration-level project was installed in May 1997.
Frozen Soil Barrier

This technology induces soil freezing artificially to reduce hydraulic conductivity and contain contaminant plumes inside the waste site boundaries of the freeze. In conjunction with the barrier application, it implements a systems approach to ensure that verifiable and transferable results are obtained. The system consists of multiple thermoprobes, an active air-cooled refrigeration condensing unit, a two-phase working fluid, an interconnecting supply and return piping network, and a control system. This hybrid system can function simultaneously in both passive and active modes. When the ambient temperatures are sufficiently low, energy costs are reduced accordingly. The system provides subsurface containment for a variety of sites and wastes including underground tanks, nuclear waste sites, hazardous mixed waste sites, plume control, burial trenches, and chemically contaminated sites. It can be rapidly installed and removed, does not degrade or weaken over time, is repairable in situ, uses benign materials, and leaves no lasting effects. Electropotential studies utilizing frozen soil’s low electrical conductivity properties showed low ionic transport across the frozen soil barrier, indicating the barrier is an effective deterrent to ionic transport. Diffusion studies conducted by the Los Alamos National Laboratory confirmed barrier integrity. A hot-site demonstration is in progress at Oak Ridge National Laboratory and is being evaluated as an EPA site evaluation.

Diaphragm Barrier, Dover Air Force Base

Working through an interagency agreement with EPA, the U.S. Air Force, and the DuPont Corporation, DOE successfully demonstrated the Diaphragm Barrier technology at the Dover Air Force Base, Dover, Delaware. This barrier was initially developed in Italy and is being tested for application in the United States. The technology constructs a thin-walled (4–8 inches) barrier wall using a modified jet grout approach. The demonstration constructed a thin-walled barrier to a depth of 40 feet, totally containing the test area. The barrier is easily installed in congested facility areas and is applicable in unstable soil conditions, which normally preclude slurry wall construction.

Verification and Monitoring Subsurface Barriers

DOE is developing a technology system to evaluate the construction and continuity of subsurface barriers, with near real time results. Using a suite of technologies, DOE successfully evaluated the hydraulic conductivity, areal extent, and continuity of two subsurface barriers. The two barriers include the viscous liquid barrier at Brookhaven National Laboratory and the diaphragm barrier at Dover Air Force Base. In this innovative approach, the technology system uses traditional geotechnical testing methods, geophysics, and gaseous tracers to evaluate the subsurface barrier. The geotechnical
methods are used to evaluate both material and barrier hydraulic continuity. The geophysics includes ground-penetrating radar, electrical, and seismic methods and is used to map the areal extent and continuity; the gaseous tracers are used to identify construction errors with centimeter precision.

**Buried Waste Containment System**

The Buried Waste Containment System constructs a continuous barrier beneath an existing structure or waste site, without intruding upon or disturbing the overburden materials. Permanent sensor access ports for performance monitoring are simultaneously installed into the barrier during construction. This technological system successfully conducted two proof-of-principle tests, demonstrating the technology's viability. These tested demonstrated the ability to excavate a continuous 1-foot slot, at a depth of 25 feet over a 30 x 50 foot area. The second test demonstrated the ability to continuously emplace materials within this slot, while providing enough strength to support the overburden pressures.

**Viscous Liquid Barrier**

Viscous liquid barriers are constructed using permeation grouting to place inert liquids that increase their viscosity as a function of time. With the use of multiple injection locations, an impermeable wall is constructed without disturbing the soil matrix or damaging structural features like tanks, pipes, and cables. Lawrence Berkeley National Laboratory, funded by OST, is investigating multiple materials, including colloidal silica and polysiloxane. These materials are mixed with a brine solution to design the material set time for emplacement. This technology was successfully demonstrated at the Brookhaven National Laboratory in FY97.

**Smart Geomembrane**

Incorporating sensors developed in the “smart structures” applications of the defense and space programs, the Geosynthetic Membrane Monitoring System can measure subsidence, moisture content, and fluid levels; detect tears in the membrane and local subsidence where drums and waste boxes may have collapsed; determine hill slope stability; and monitor road and runway stability. The sensors use optical fibers that are virtually nonreactive to corrosive chemicals. Insusceptibility to stray electrical noise and lightning minimizes false readings. Pilot-scale and field tests were conducted in 1997 at Sandia National Laboratories.
SOURCE TERM REMEDIATION PRODUCT LINE

A number of existing landfill disposal sites were established and closed under old waste-disposal practices. Continuing concerns over long-term performance of these landfills demand that some of this buried waste be either treated or moved to a more up-to-date disposal site. The SCFA is working on technologies to remove pockets of buried transuranic waste and investigating in situ stabilization techniques as alternatives to retrieval, treatment, and storage. In FY98, the Source Term Remediation product line is combined with the Source Term Containment Product Line to form the Source Term Containment/Remediation Product Line.

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Digface Characterization

The goal of this project is to develop and demonstrate a field-ready mobile platform that contains geophysical, chemical, and radiological sensors to provide constant surveillance and screening for all categories of hazards at the digface during retrieval excavation. This system is also available in a more portable system called the Warthog. As waste retrieval proceeds, sensors are continuously deployed to characterize the remaining waste. Remediation proceeds methodically as characterization data are interpreted in real time to support the retrieval process. The system not only reduces environmental, health, and safety risks during cleanup of buried waste sites, but also saves money by eliminating unnecessary sampling and analysis of soils and the generation of large amounts of clean, excavated soil that must be assumed to be contaminated based on existing sampling protocol. A track-mounted, trolley-platform, digface-characterization system was demonstrated at the EG&G Mound Laboratory in Ohio in 1995 to monitor a $20 \times 20 \times 5$ ft excavation of a radiologically contaminated site. The spatial information produced by the digface system directed excavation into areas containing the contaminants, saving the time and cost of unnecessary excavation. It was also used to develop options for handling the remaining excavation after the digface system was removed. The system was deployed at the Mound facility in August 1997 to provide real-time radiation (plutonium-238) mapping of the Miami–Erie Canal soils.
**In Situ Stabilization**

In situ grouting injects stabilization agents under high pressure into buried waste, encapsulating contaminants into a monolith that is impervious to water migration. The technique can solidify waste to prevent aerosolization during future retrieval, if necessary, and can stabilize old landfills to enhance landfill covers. After curing, the monolithic grouted block can be left in place as a containment option or can be fractured for subsequent removal. The isolation wall concept was demonstrated at Idaho National Engineering and Environmental Laboratory (INEEL) Cold Test Pit. Grouting was successfully performed as a CERCLA Treatability Study at the Acid Pit site at INEEL in September 1997.

**Subsurface Structure Stabilization**

This project is demonstrating an innovative three-step process for buried waste retrieval in a field environment. First, grouting the waste serves to agglomerate fine soil particles that may have become contaminated. Next, the grouted monolith is fractured using a demolition grout. Finally, the debris is excavated in a relatively dust-free environment with remotely controlled equipment. The system can also create a grout wall around a hot spot in the waste, which can then be excavated without the surrounding waste sloughing into the pit. The method contains the spread of contamination and reduces control costs without jeopardizing worker safety.

**Hot-Spot Remediation System**

This ground-penetrating radar holographic three-dimensional imaging system has the potential to significantly reduce the cost of remediation through increased understanding of the risk of subsurface waste containment in waste units and landfills. The technology addresses areas designated as “Contamination Level Undetermined” by determining whether buried objects are present and whether there is contamination present from buried objects or nearby waste sites. The technique addresses cultural concerns in areas of archeological significance. It also protects health and safety during remediation by delineating hot-spot contamination and predetermining levels of personnel protective equipment required for excavation of buried objects. The system was successfully demonstrated at the Savannah River Site during January 1997 for soil contaminated with cesium-137.
Fiscal Year 1997
Technologies by Site
Total $33,261K

Funding Distribution of
Technology Development by Site
and Product Line

Fiscal Year 1997
Technologies by Product Line
Total $33,261K
## 1997 SCFA Technologies

<table>
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<tr>
<th>TECHNOLOGIES</th>
<th>TMS</th>
<th>SITE</th>
<th>FY 1997 FINAL FUNDING ($K)</th>
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* TMS = Technology Management System
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