Abstracts of Remediation Case Studies

Volume 9

Federal
Remediation
Technologies
Roundtable
<www.frtr.gov>

Prepared by the

Member Agencies of the
Federal Remediation Technologies Roundtable

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Federal Remediation Technologies Roundtable

Environmental Protection Agency
Department of Defense
U.S. Air Force
U.S. Army
U.S. Navy
Department of Energy
Department of Interior
National Aeronautics and Space Administration

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NOTICE

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FOREWORD

This report is a collection of abstracts summarizing 13 new case studies of site remediation applications prepared primarily by federal agencies. The case studies, collected under the auspices of the Federal Remediation Technologies Roundtable (Roundtable), were undertaken to document the results and lessons learned from technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of innovative cleanup technologies.

The Roundtable was created to exchange information on site remediation technologies, and to consider cooperative efforts that could lead to a greater application of innovative technologies. Roundtable member agencies, including the U.S. Environmental Protection Agency (EPA), U.S. Department of Defense, and U.S. Department of Energy, expect to complete many site remediation projects in the near future. These agencies recognize the importance of documenting the results of these efforts, and the benefits to be realized from greater coordination.

The abstracts are organized by technology, and cover a variety of *in situ* and *ex situ* treatment technologies and some containment remedies. The abstracts and corresponding case study reports are available through the Roundtable web site, which contains a total of 374 remediation technology case studies (the 13 new case studies and 361 previously-published case studies). Appendix A to this report identifies the specific sites, technologies, contaminants, media, and year published for the 374 case studies.

Abstracts, Volume 9, covers a wide variety of technologies, including full-scale remediations and large-scale field demonstrations of soil, groundwater, and sediment treatment technologies. Previously published versions of the Abstracts Volume are listed below. Additional abstract volumes will be compiled as agencies prepare additional case studies.

Abstracts

Volume 1:	EPA-542-R-95-001; March 1995; PB95-201711
Volume 2:	EPA-542-R-97-010; July 1997; PB97-177570
Volume 3:	EPA-542-R-98-010; September 1998
Volume 4:	EPA-542-R-00-006; June 2000
Volume 5:	EPA-542-R-01-008; May 2001
Volume 6:	EPA-542-R-02-006; June 2002
Volume 7:	EPA 542-R-03-011; July 2003
Volume 8:	EPA 542-R-04-012; June 2004
Volume 9:	EPA-542-R-05-021; July 2005

Accessing Case Studies

All of the Roundtable case studies and case study abstracts are available on the Internet through the Roundtable web site at: http://www.frtr.gov/costperf.htm. This report is also available for download at this address. The Roundtable web site also provides links to individual agency web sites, and includes a search function. The search function allows users to complete a key word (pick list) search of all the case studies on the web site, and includes pick lists for media treated, contaminant types, primary and supplemental technology types, site name, and site location. The search function provides users with basic information about the case studies, and allows users to view or download abstracts and case studies that meet their requirements. Users are encouraged to download abstracts and case studies from the Roundtable web site.

In addition to being accessible through the Roundtable web site, a limited number of copies of this document are available free of charge by mail from the National Service Center for Environmental Publications (NSCEP) (allow 4-6 weeks for delivery), at the following address:

U.S. EPA/NSCEP
P.O. Box 42419
Cincinnati, OH 45242
Phone: (513) 489-8190 or
(800) 490-9198
Fax: (513) 489-8695

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INTRODUCTION

Increasing the cost effectiveness of site remediation is a national priority. The selection and use of more cost-effective remedies requires better access to data on the performance and cost of technologies used in the field. To make data more widely available, member agencies of the Federal Remediation Technologies Roundtable (Roundtable) are working jointly to publish case studies of full-scale remediation and demonstration-scale remediation projects. At this time, the Roundtable is publishing 13 new remediation technology case studies to the Roundtable web site (http://www.frtr.gov/costperf.htm), for a total of 374 case studies, primarily focused on contaminated soil and groundwater cleanup.

The case studies were developed by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). They were prepared based on recommended terminology and procedures agreed to by the agencies. These procedures are summarized in the *Guide to Documenting and Managing Cost and Performance Information for Remediation Projects* (EPA 542-B-98-007; October 1998).

By including a recommended reporting format, the Roundtable is working to standardize the reporting of costs and performance to make data comparable across projects. In addition, the Roundtable is working to capture information in case study reports that identifies and describes the primary factors that affect cost and performance of a given technology. Factors that may affect project costs include economies of scale, contaminant concentration levels in impacted media, required cleanup levels, completion schedules, and matrix characteristics and operating conditions for the technology.

The case studies and abstracts present available cost and performance information for full-scale remediation efforts and several large-scale demonstration projects. They are meant to serve as primary reference sources, and contain information on site background, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The case studies and abstracts contain varying levels of detail, reflecting the differences in the availability of data and information about the application.

The case study abstracts in this volume describe a wide variety of *ex situ* and *in situ* soil treatment technologies for both soil and groundwater. Contaminants treated included chlorinated solvents; petroleum hydrocarbons and benzene, toluene, ethylbenzene, and xylenes; polycyclic aromatic hydrocarbons; pesticides and herbicides; metals; and radioactive materials.

Table 1 provides summary information about the technology used, contaminants and media treated, and project duration for the 13 technology applications in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information about quantity of media treated and quantity of contaminant removed. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting technology cost. (The column showing the calculated unit costs for treatment provides a dollar value per quantity of media treated and contaminant removed, as appropriate.) The cost data presented in the table were taken directly from the case studies and have not been adjusted for inflation to a common year basis. The costs should be assumed to represent dollar values for the time period that the project was in progress (shown on Table 1 as project duration).

Appendix A to this report provides a summary of key information about all 374 remediation case studies published to date by the Roundtable, including information about site name and location, technology, media, contaminants, and year the project began. The appendix also identifies the year that the case study was first published by the Roundtable. All projects shown in Appendix A are full-scale unless otherwise noted.

Table 1. Summary of Remediation Case Studies

Site Name, State (Technology)	Principal Contaminant Groups*: Volatiles-Halogenated	Semivolatiles - Nonhalogenated	BTEX and/or TPH	Pesticides/Herbicides	Metals	Media (Quantity Treated)	Project Duration	Summary
***In Situ* Soil Treatment**								
California Gulch Superfund Site, OU 11, CO (In Situ Solidification/Stabilization - Biosolids)						Soil (NP)	June 17, 1998 - August 20, 1999 (Biosolids addition: July - August 1998)	Use of in situ biosolids and lime addition to treat soil contaminated with heavy metals (cadmium, copper, lead, manganese, zinc)
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation, Various Locations (In Situ Chemical Oxidation, Monitored Natural Attenuation, Enhanced Fluid Recovery)						Soil, Groundwater (NP)	Various dates from 1999 - April 22, 2003	Use of in situ chemical oxidation to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner sites
Frontier Hard Chrome Superfund Site, WA (In Situ Chemical Reduction)						Soil (20,962 yd^3), Groundwater (185,000 gallons)	January - September 2003	Use of in situ chemical reduction to treat soil contaminated with chromium
Hunter Army Airfield, Former Pumphouse #2, GA (In Situ Thermal Treatment - Electrical Resistive Heating)						Soil (35,000 yd^3), Groundwater, LNAPLs	April 5 - August 5, 2002	Use of in situ thermal treatment to treat soil and groundwater contaminated with chlorinated solvents
Multiple (3) Dry Cleaner Sites - SVE, Various Locations (Soil Vapor Extraction)						Soil, Groundwater, DNAPLs (NP)	Various dates from January 1999 - August 2003	Use of in situ SVE to treat soil and groundwater contamination with chlorinated solvents at dry cleaner sites
Multiple (3) POL-Contaminated Sites, AK (Rhizosphere-Enhanced Bioremediation)						Soil (NP)	Various dates from summer 1998 - date unknown	Use of rhizosphere-enhanced bioremediation to treat soil contaminated with diesel and gasoline range organics
***Ex Situ* Soil/Sediment Treatment**								
T.H. Agriculture and Nutrition Site, OU2, GA (Thermal Desorption)						Soil (10,424 tons)	October - November 1999	Use of ex situ thermal desorption to treat soil contaminated with pesticides

Table 1. Summary of Remediation Case Studies (continued)

Site Name, State (Technology)	Principal Contaminant Groups*: Volatiles-Halogenated	Semivolatiles - Nonhalogenated	BTEX and/or TPH	Pesticides/Herbicides	Metals	Media (Quantity Treated)	Project Duration	Summary
***In Situ* Groundwater Treatment**								
Charleston Naval Complex, AOC 607, SC (In Situ Thermal Treatment - Electrical Resistive Heating)						Groundwater, DNAPLs (NP)	October 2001 - July 2002	Use of in situ thermal treatment to treat groundwater contaminated with halogenated volatiles
Multiple (5) Dry Cleaner sites - In Situ Bioremediation, Various Locations (In Situ Bioremediation Using Various Additives)						Soil, Groundwater, DNAPLs (NP)	Various dates from Spring 2001 - date unknown	Use of in situ bioremediation using various additives to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner sites
Multiple (4) Dry Cleaner sites - In Situ Bioremediation, Various Locations (In Situ Bioremediation Using HRC®)						Soil, Groundwater (NP)	Various dates from May 2000 - September 2002	Use of in situ bioremediation using HRC® to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner sites
Multiple (4) Dry Cleaner sites - In Situ Chemical, Various Locations Oxidation (In Situ Chemical Oxidation)						Soil, Groundwater, DNAPLs (NP)	Various dates from July 2001 - date unknown	Use of in situ chemical oxidation to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner sites
Naval Amphibious Base Little Creek, Site 11, GA (Cyclodextrin-Enhanced In Situ Flushing)						Soil, Groundwater, DNAPLs (NP)	June - September 2002	Use of in situ flushing (cyclodextrin enhanced flushing) to treat soil and groundwater contaminated with chlorinated solvents
Westover Air Reserve Base, MA (Constructed Treatment Wetlands)						Stormwater (12.2 million gallons)	August 2001 - May 2003	Use of constructed treatment wetlands to treat aircraft deicing fluid runoff

* Contaminant group focused on for the technology covered in the case study.

Key:

NP	= Not Provided	POL	= Petroleum, Oil, and Lubricants
LNAPLs	= Light Non-Aqueous Phase Liquids	AOC	= Area of Concern
OU	= Operable Unit	HRC®	= Hydrogen Release Compound
SVE	= Soil Vapor Extraction	BTEX	= Benzene, Toluene, Ethylbenzene, and Xylene

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)[1,2]	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment[1,2]	Key Factors Potentially Affecting Technology Costs
***In Situ* Soil Treatment**					
California Gulch Superfund Site, OU 11, CO (In Situ Solidification/Stabilization - Biosolids)	D - $3,477,697 (includes $1,738,750 for investigation and characterization, and $1,738,947 for construction and cleanup)	NP	NP	NP	Number of samples required to provide statistically significant results to evaluate the effectiveness of the treatment system
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation, Various Locations (In Situ Chemical Oxidation, Monitored Natural Attenuation, Enhanced Fluid Recovery)	NP	Spin City: Soil - 172 yd^3	NP	NP	Use of other technologies, such as enhanced fluid recovery, to reduce the amount of chemicals required for in situ chemical oxidation
Frontier Hard Chrome Superfund Site, WA (In Situ Chemical Reduction)	Source area: C - $398,000 AO - $2,021,500 ISRM wall: C - $350,300; AO - $679,700	Soil: 20,962 yd^3 Groundwater: 185,000 gallons	NP	Source area: \$124/yd^3 of soil treated ISRM wall: \$330/ft^2 of wall	Clay and moisture content of soil, and pH and flow rate of groundwater
Hunter Army Airfield, Former Pumphouse #2, GA (In Situ Thermal Treatment - Electrical Resistive Heating)	T - $1,300,000 (includes $1,042,129 for design, mobilization/demobilization, installation, and O&M for four months); $259,000 for electrical service connection	Soil: 35,000 yd^3	44,000 lbs of VOCs (from April to August 2002)	NP	Limited amount of time that PCU was loaned to DoD for the remediation
Multiple (3) Dry Cleaner Sites - SVE, Various Locations (Soil Vapor Extraction)	ABC: Soil: T - $521,463; Groundwater: T - $2,262,900 Parisian: T - $202,531 (includes DI - $72,458) Randolf's: DI - $298,500	NP	NP	NP	Parisian: Good soil sampling under the building leading to good design of SVE system
Multiple (3) POL-Contaminated Sites, AK (Rhizosphere-Enhanced Bioremediation)	Total for 3 sites: D - $8,650 (includes C - $7,250 and AO - $1,400)	NP	NP	NP	Monitoring, frequency of monitoring, and the duration of the monitoring period

Table 2. Remediation Case Studies: Summary of Cost Data (continued)

Site Name, State (Technology)	Technology Cost ($)[1,2]	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment[1,2]	Key Factors Potentially Affecting Technology Costs
***Ex Situ* Soil/Sediment Treatment**					
T.H. Agriculture and Nutrition Site, OU2, GA (Thermal Desorption)	T - $1,058,230 (includes C - $566,184 and AO - $492,046)	10,424 tons	NP	$102/ton of soil treated	Functional equivalency (as demonstrated by the vendor) of the thermal desorption system used at OU2 with the thermal desorption system used at OU1, thereby eliminating the need for a performance test
***In Situ* Groundwater Treatment**					
Charleston Naval Complex, AOC 607, SC (In Situ Thermal Treatment - Electrical Resistive Heating)	T - $1,250,000 (includes C - $373,000 and AO - $473,000)	NP	NP	NP	Slower groundwater heating than was projected in the design stage, especially in the deeper portions of the saturated zone
Multiple (5) Dry Cleaner sites - In Situ Bioremediation, Various Locations (In Situ Bioremediation Using Various Additives)	Blacks: DI - $30,000; estimated AO - $35,000 (for injection of electron donor and bacterial treatment) and $20,000 per year for on-going groundwater, soil gas, and indoor air monitoring Carousel: D - $75,000 Former 60: C - $107,500; DI - $32,300; AO - $140,200	NP	NP	NP	Former 60: Choice of injectant, ethyl lactate, was cheaper to obtain than ethanol Carousel: Additive provided by the vendor at no cost
Multiple (4) Dry Cleaner sites - In Situ Bioremediation, Various Locations (In Situ Bioremediation Using HRC®)	Ted's Cleaners: D - $110,000	NP	NP	NP	Former Prestonwood: Fracturing at high pressures, resulting in unseating of straddle packers at some locations
Multiple (4) Dry Cleaner sites - In Situ Chemical, Various Locations Oxidation (In Situ Chemical Oxidation)	Niles Finest: DI (includes post-injection sampling) - $32,285 Springvilla: DI - $103,000; AO - $3,000	NP	NP	NP	Niles Finest: Tight clay soils making remediation via chemical oxidation, especially with permanganate, difficult
Naval Amphibious Base Little Creek, Site 11, GA (Cyclodextrin-Enhanced In Situ Flushing)	D - $863,000 (includes C - $448,000, AO - $409,000, and other technology-specific costs)	NP	NP	NP	Soil delisted (using contained-in policy) and disposed of as solid waste at a Subtitle D landfill instead of being handled as listed hazardous waste

Table 2. Remediation Case Studies: Summary of Cost Data (continued)

Site Name, State (Technology)	Technology Cost ($)[1,2]	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment[1,2]	Key Factors Potentially Affecting Technology Costs
Westover Air Reserve Base, MA (Constructed Treatment Wetlands)	D - $332,900 (includes C - $326,000 and AO - $6,900)	12.2 million gallons	NP	NP	System built on a slope, requiring additional excavation to achieve the proper bed bottom level

1 Actual full-scale costs are reported unless otherwise noted.
2 Cost abbreviation: T = Total costs, AO = Annual operation and maintenance (O&M) costs, C = Capital costs, DI = Design and implementation costs, D = Demonstration-scale costs, P = Projected full-scale costs.

Key:

NP	= Not Provided	SVE	= Soil Vapor Extraction
OU	= Operable Unit	PCU	= Power Converter Unit
ISRM	= *In Situ* Redox Manipulation	HRC®	= Hydrogen Release Compound
BTEX	= Benzene, Toluene, Ethylbenzene, and Xylene	PCU	= Power Converter Unit

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IN SITU SOIL TREATMENT ABSTRACTS

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In Situ Biosolids and Lime Addition at the California Gulch Superfund Site, OU 11, Leadville, Colorado

<table>
<tr><td colspan="2">Site Name:
California Gulch Superfund Site, OU 11</td><td colspan="2">Location:
Leadville, Colorado</td></tr>
<tr><td colspan="3">Period of Operation:
June 17, 1998 - August 20, 1999 (Biosolids addition: July - August 1998)</td><td>Cleanup Authority:
CERCLA</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
Field demonstration of in situ biosolids and lime treatment of mine tailing deposits contaminated with heavy metals, including cadmium, copper, lead, manganese, and zinc.</td><td>Cleanup Type:
Field demonstration</td></tr>
<tr><td colspan="3">Contaminants:
Heavy metals (cadmium, copper, lead, manganese, zinc)</td><td>Waste Source:
Mine tailings and acid mine drainage from mine operations</td></tr>
<tr><td>Contacts:

Environmental Response Team Contacts:
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Telephone: 303-312-6607
Email:
holmes.michael@epa.gov</td><td colspan="3">Technology:
Solidification/Stabilization - In situ biosolids and lime additions
• Biosolids - EPA Class B anaerobically digested cake with a 17% solids content
• Biosolids application rate of 100 dry tons/acre
• Lime application rate of 3/8" agricultural lime at 100 tons/acre
• Incorporation depth of 4 to 12 inches</td></tr>
</table>

Type/Quantity of Media Treated:
- Soil classified as mining tailings with high mineral content
- Quantity not provided

Regulatory Requirements/Cleanup Goals:
The goals of the field demonstration were to 1) reduce metals bioavailability, 2) increase the pH of the tailings, and 3) promote vegetation.

Results:
The application of biosolids and lime:
- Did not appear to dilute the COC concentrations in the tailings; no consistent trend in COC concentrations was observed before and after treatment.
- Appeared to reduce the availability of COCs, based on a decrease in extractable metals in treated tailings, including water leachable, exchangeable, weak acid extractable, TCLP, and MEP metals in treated tailings.
- Appeared to improve soil quality, based on an increase in pH, TOC, water holding capacity, total nitrogen, phosphorous, and chloride, as well as percent saturation in cation exchange capacity by potassium and sodium after treatment.
- Increased plant and soil microbial activity based on the high biogeochemical activity of the treated soil.
- Reduced soil toxicity, based on the results of plant and earthworm assays.
- Reduced the dietary exposure risk for higher trophic organisms, based on the results of several preliminary dietary exposure models.

Costs:
The total cost for the one-year field demonstration was $3,477,697. This cost included $1,738,750 for investigation and characterization and $1,738,947 for construction and cleanup.

Description:
Mining operations at the California Gulch Superfund Site, located in Leadville, Colorado, resulted in the release of large volumes of mine waste and acid mine drainage. California Gulch was placed on the National Priorities List (NPL) in 1983, and the primary contaminants of concern (COCs) at the site are cadmium, copper, lead, manganese, and zinc. The site is divided into 12 operable units (OUs). This report focuses on a field demonstration conducted at OU 11, the Arkansas Floodplain, where tailings have been deposited into and along the banks of the Upper Arkansas River.

Biosolids and lime were added to several tailing locations in a one-year study (July to August 1998). The biosolids used in the study were EPA Class B anaerobically digested cake with a solids content of 17%. Tailings were treated at a rate of 100 dry tons per acre of biosolids cake and 100 tons per acre of 3/8" agricultural grade lime. The results of the one-year study indicated that this treatment:
- Did not appear to dilute the COC concentrations in the tailings; no consistent trend in COC concentrations was observed before and after treatment.
- Appeared to reduce the availability of COCs, based on a decrease in extractable metals in treated tailings, including water leachable, exchangeable, weak acid extractable, TCLP, and MEP metals in treated tailings.
- Appeared to improve soil quality, based on an increase in pH, TOC, water holding capacity, total nitrogen, phosphorous, and chloride, as well as percent saturation in cation exchange capacity by potassium and sodium after treatment.
- Increased plant and soil microbial activity based on the high biogeochemical activity of the treated soil.
- Reduced soil toxicity, based on the results of plant and earthworm assays.
- Reduced the dietary exposure risk for higher trophic organisms, based on the results of several preliminary dietary exposure models.

EPA indicated that additional investigation will be needed to evaluate the long-term effectiveness of this treatment. The results of the study were not statistically significant. EPA attributed this to the small sample size and wide variation in results.

The total cost for the one-year field demonstration was $3,477,697. This cost included $1,738,750 for investigation and characterization and $1,738,947 for construction and cleanup.

In Situ Chemical Oxidation Using Hydrogen Peroxide at Four Dry Cleaner Sites

Site Name:
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation

Location:
- Daisy Fresh: College Park, Georgia
- Former Alpine Cleaners: Friendswood, Texas
- Park Avenue Cleaners: Richardson, Texas
- Spin City: Plano, Texas

Period of Operation:
- Daisy Fresh: Phase I pilot test - April 8, 2003 and April 22, 2003; Phase II pilot test - August 25, 2003 and September 25, 2003
- Alpine: 1999
- Park Avenue: September 2000
- Spin City: September 2000

Cleanup Authority:
State

Purpose/Significance of Application:
Use of in situ oxidation technologies for remediation of chlorinated solvents in groundwater at drycleaner facilities

Cleanup Type:
Field demonstration - Daisy Fresh
Full scale - Alpine, Park Avenue, and Spin City

Contaminants:
Chlorinated Solvents
Daisy Fresh: (Groundwater) Chloroform - 33 : g/l; cis-1,2-DCE - 1,600 : g/l; PCE - 20,000 : g/l; TCE - 2,300 : g/l; vinyl chloride - 18 : g/l; xylenes - 16 : g/l (Soil) 1,1-DCE - 11 : g/kg; 1,2-DCE - 47 : g/kg; benzene - 8 : g/kg; chloroform - 44 : g/kg; cis-1,2-DCE - 12,600 : g/kg; naphthalene - 16 : g/kg; PCE - 219,000 : g/kg; TCE - 560,000 : g/kg; vinyl chloride - 600 : g/kg; xylenes - 87 : g/kg
Alpine: 1,1-DCE - 5.9 : g/l; cis-1,2-DCE - 3,100 : g/l; PCE - 2,940 : g/l; TCE - 1,400 : g/l; vinyl chloride - 300 : g/l. Contaminant concentrations in soil were below cleanup standards.
Park Avenue: (Groundwater) cis-1,2-DCE - 56 : g/l; PCE - 470 : g/l; trans-1,2-DCE - 4 : g/l; TCE - 150 : g/l; xylenes - 1 : g/l. (Soil) cis-1,2-DCE- 56 : g/kg; PCE - 44,590 : g/kg; TCE - 940 : g/kg; chlorobenzene - 19 : g/kg
Spin City: (Groundwater) cis-1,2-DCE - 900 : g/l; PCE - 2,900 : g/l; trans-1,2-DCE - 140 : g/kg; TCE - 320 : g/l. (Soil) cis-1,2-DCE - 130 : g/kg; PCE - 47,350 : g/kg; trans-1,2-DCE - 140 : g/kg; TCE - 1,500 : g/kg

Waste Source:
Waste and wastewater from drycleaning operations

Contacts:
Varied by site

Technology:
In Situ Chemical Oxidation
Daisy Fresh: Other technologies used - monitored natural attenuation, enhanced fluid recovery.
- ISOTEC's chemical oxidation process was used
- Phase I - 46 direct push (DP) points with multiple injection intervals and 12 injections wells; Phase II - 54,190 gallons of ISOTEC reagents injected

Alpine:
- Initially, an aqueous solution of ferrous sulfate and hydrochloric acid was injected.
- This was followed by hydrochloric acid and finally by a 35% solution of hydrogen peroxide; In August and September of 2001, a total of 135 gallons of a 5.5% solution of potassium permanganate was injected at the site.

Park Avenue:
- 550 gallons of a biodegradable surfactant was injected at each injection point
- 310 gallons of a proprietary catalyst solution was injected at each point
- A mixture of a proprietary acid (total of 270 gallons) and a hydrogen peroxide solution (total of 640 gallons) was injected

Spin City:
- 550 gallons of a biodegradable surfactant was injected at each injection point
- 116 gallons of a proprietary catalyst solution was injected at each point
- A mixture of a proprietary acid (total of 295 gallons) and a hydrogen peroxide solution (total of 515 gallons) was injected

In Situ Chemical Oxidation Using Hydrogen Peroxide at Four Dry Cleaner Sites (continued)

Type/Quantity of Media Treated:
- Daisy Fresh: Soil, groundwater
- Alpine: Groundwater
- Park Avenue: Soil, groundwater
- Spin City: Soil, groundwater; volume of treated soil: 172 cubic yards; groundwater treatment area: approximately 0.74 acres

Regulatory Requirements/Cleanup Goals:

Daisy Fresh:
- Groundwater: PCE and TCE - 5 : g/l; VC - 2 : g/l; Cis-1,2 DCE - 156 : g/l. Soil: PCE and TCE - 0.5 mg/kg; VC - 0.044 mg/kg; Cis-1,2-DCE - 78.2 mg/kg

Alpine:
- PCE - 5 : g/l; TCE - 5 : g/l; cis 1,2-DCE - 70 : g/l; vinyl chloride - 2 : g/l

Park Avenue:
- Groundwater: PCE - 500 : g/l; TCE - 500 : g/l. Soil: PCE -5,000 : g/kg; TCE - 5,000 : g/kg

Spin City:
- Groundwater: PCE - 500 : g/l. Soil: PCE - 500 : g/kg; TCE - 500 : g/kg

Results:

Daisy Fresh:
- Phase I - VOCs in two soil samples reduced from 105 : g/kg and 87 : g/kg to non-detect. Concentrations of VOCs in groundwater decreased by 83%
- Phase II - average VOC concentrations decreased by 89% from baseline conditions measured in April 2003.
- In two wells, concentrations of VOCs decreased at first and then increased. This was attributed to the desorption of solvents from the soil.

Alpine:
- 33% reduction in contaminant concentrations

Park Avenue:
- Soil contaminant concentrations reduced by 99% and groundwater concentrations reduced by 95-100%.

Spin City:
- Contaminant concentrations reduced by 56 to 99.9% in soils and by 83 to 100% in groundwater.

Costs:
- No cost data available

Description:

In situ chemical oxidation was conducted at four drycleaner sites contaminated with chlorinated solvents from drycleaning operations, with TCE and PCE as the primary contaminants in groundwater. The concentration of PCE and TCE varied between the two sites, ranging from 470 to 20,000 : g/L for PCE, and 150 to 2,300 : g/L for TCE. The remediation involved in situ chemical oxidation using hydrogen peroxide at full-scale at three sites and at pilot-scale at one site (Daisy Fresh).

Contaminant concentrations at all four sites were reduced following treatment. The percentage reduction ranged from 33 to 100 percent. At one site (Daisy Fresh), concentrations of VOCs decreased at first and then increased in two wells. This was attributed to the desorption of solvents from the soil. Cost data were not provided for any of the projects. At several of the sites, monitored natural attenuation will continue to be evaluated as a remediation technology following the application of in situ chemical oxidation.

In Situ Chemical Reduction at the Frontier Hard Chrome Superfund Site, Vancouver, Washington

Site Name: Frontier Hard Chrome (FHC) Superfund Site	**Location:** Vancouver, Washington

Period of Operation:
May to October, 2002 - Pilot scale test
January to September, 2003 - Full scale treatment

Cleanup Authority:
- Record of Decision for Soil/Source control (OU1) issued in December 1987
- Record of Decision for groundwater (OU2) issued in July 1988
- Record of Decisions (OU1 and OU2) amended to include in situ chemical reduction of hexavalent chromium to trivalent chromium in August 30, 2001

Purpose/Significance of Application:
To treat source area soil by reducing hexavalent chromium to trivalent chromium, and to treat migrating chromium from the source area.

Cleanup Type:
Field demonstration and full-scale treatment

Contaminants:
Heavy Metals (Chromium)
- Total chromium concentrations in soil as high as 7,500 mg/kg
- Total chromium concentration in the groundwater at the ISRM treatment wall as high as 300,000 : g/L

Waste Source:
Discharge of wastes from the chromium plating operations to an on-site dry well

Technology:
- In Situ Redox Manipulation (ISRM) to treat soil and groundwater in the source area and downgradient
- Treatment of source area proceeded in two steps - 1) ECOBOND® reagent injection to reduce hexavalent chromium to trivalent chromium, followed by 2) cement-based grout injections to provide structural strength to treated soil
- ECOBOND® is a proprietary sulfur-based reagent that reduces hexavalent chromium to trivalent chromium.
- Treatment depth at the source area ranged between 20 and 33 feet deep
- The application used a 10-foot diameter auger to perform in situ vertical auger mixing; the auger size was reduced to a 6-foot diameter to reach depths below 25 feet
- An ISRM treatment wall was installed to treat migrating chromium from the source area
- The wall consisted of a series of eight pairs of injection wells (16 wells total)
- Each pair of injection wells had one deep well (screened 28 to 33 ft bgs) and one shallow well (screened 23 to 28 ft bgs)
- Approximately 5,700 gallons of sodium dithionite reagent was mixed with water and injected into each well pair (40,000 gallons total)

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In Situ Chemical Reduction at the Frontier Hard Chrome Superfund Site, Vancouver, Washington (continued)

Type/Quantity of Media Treated:
Soil and Groundwater
- 20,962 cubic yards of contaminated soil treated
- 185,000 gallons of contaminated groundwater treated

Regulatory Requirements/Cleanup Goals:
- The cleanup goals for soil were 19 mg/kg of hexavalent chromium and 80,000 mg/kg of trivalent chromium.
- The cleanup goal for groundwater was 50 : g/L of total chromium.

Results:
The total chromium concentration in soil at the source area was reduced from as high as 7,500 mg/kg to non-detect (< 5 mg/kg), and from 300,000 : g/L to less than 800 : g/L in the groundwater. Total chromium concentration in the groundwater at the ISRM treatment wall was reduced from as high as 300,000 : g/L to 25 : g/L.

Costs:
ISRM treatment wall:
- Total capital costs in 2003 dollars were $350,300. Total operating and maintenance costs (O&M) costs were $679,700. The cost per square foot of the treatment wall was $330.

Source area treatment:
- Total capital costs in 2003 dollars were $398,000. Total O&M costs were $2,021,500. The cost per cubic yard of treated soil was $124.

Description:
The Frontier Hard Chrome (FHC) Superfund site was used for chrome plating operations from 1958 to 1983. Since 1983, the site has been leased and most recently used as a metals shop.

Discharge of wastes from the chrome plating operations resulted in soil and groundwater contamination at the site. Total chromium concentrations in soil were found to be as high as 7,500 mg/kg, and as high as 300,000 : g/L in groundwater at the treatment wall. Soil at the site was also contaminated, with chromium concentrations as high as 7,500 mg/kg. In September 1983, the site was added to the National Priorities List. Records of Decision (RODs) were issued in December 1987 for the soils/source control operable unit (OU1) and in July 1988 for the groundwater operable unit (OU2). In Situ Redox Manipulation (ISRM) was selected to treat soil and groundwater contamination at the site. From January to September 2003, the remedial action was conducted in three phases: building demolition, ISRM treatment wall installation, and source area treatment. ECOBOND®, a proprietary sulfur-based reagent was used to treat the source soil by reducing hexavalent chromium to trivalent chromium. The ISRM treatment wall was installed to treat migrating chromium from the source area.

Approximately 20,962 cubic yards of contaminated soil and 185,000 gallons of contaminated groundwater were treated at the source area. Total chromium concentrations in soil were reduced from as high as 7,500 mg/kg to non-detect (< 5 mg/kg). Total chromium concentrations in groundwater were reduced from as high as 300,000 : g/L to less than 800 : g/L (detection limit using HACH chromium test kits). At the ISRM treatment wall, total chromium concentrations in the groundwater were reduced from as high as 300,000 : g/L to 25 : g/L.

The total capital costs and O&M costs for the treatment of source area in 2003 dollars were $398,000 and $2,021,500, respectively. The cost per cubic yard of treated soil was $124. The total capital costs and O&M costs for the treatment wall in 2003 dollars were $350,300 and $679,700, respectively. The cost per square foot of the treatment wall was $330.

Electrical Resistive Heating at Hunter Army Airfield, Former Pumphouse #2, Savannah, Georgia

Site Name:
Hunter Army Airfield (Hunter AAF), Former Pumphouse #2

Location:
Savannah, Georgia

Period of Operation:
April 5, 2002 to August 5, 2002

Cleanup Authority:
State (Georgia Environmental Protection Division)

Purpose/Significance of Application:
Use of ERH to remediate PAHs in soil, groundwater, and LNAPL form

Cleanup Type:
Full scale

Contaminants:
Petroleum constituents - BTEX and PAHs

Dissolved groundwater plume covered an area of approximately 85,800 ft2. Initial area of benzene contamination in groundwater was approximately 55,500 ft2 observed in January 2002. A 1997 investigation discovered Light nonaqueous-phase liquid (LNAPL) in one of the wells which covered an area of approximately 3,825 ft2. In May 2002, LNAPL covered an area of 11,500 ft2.

Waste Source:
Leaks from underground storage tanks (USTs)

Technology:
Electrical Resistive Heating - Six-Phase Heating™ (SPH)
- A total of 111 ERH electrodes were installed at a spacing of 18 feet (ft), and to a depth of 16 ft bgs. The steel conductive interval ranged from 8 to 16 ft bgs, with the actual steel electrode extending from 9 to 16 ft bgs.
- In the area where free product (LNAPL) was located, 18 of the electrodes were installed as a combination of electrode and dual vapor extraction (DVE) wells. The conductive interval was 9 to 16 ft bgs for the DVE wells. The electrode/DVE wells served as heating elements and as contingency product-extraction points.
- A total of 23 vapor recovery wells (VRWs) were installed at a spacing of 40 ft, for a radius of influence of 25 ft. Two types of VRWs were installed in 8-inch diameter boreholes; DVE and soil vapor extraction (SVE) wells.
- To monitor the internal temperature of the treatment area, 15 temperature monitoring points (TMPs), were installed with thermocouples located at 8, 12, and 16 ft bgs.
- The average subsurface temperature was greater than 90 /C.

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Type/Quantity of Media Treated:
Soil, groundwater, and LNAPL

Approximately 35,000 cubic yards of media were treated.

Regulatory Requirements/Cleanup Goals:
The objectives of the corrective action were to remove free product (LNAPL) from the site, reduce concentrations of benzene in groundwater to less than the alternate concentration limit (ACL) of 469 micrograms per liter (: g/L), and to reduce concentrations of benzene and indeno(1,2,3-cd)pyrene in soil to below their alternate threshold levels (ATLs) of 0.44 milligram per kilogram (mg/kg) and 0.66 mg/kg, respectively.

Results:
- From April to August 2002, an estimated 44,000 pounds of volatile organic compounds (VOCs) were removed. The amount of free product was reduced from a maximum of 11,500 ft2 measured in May 2002 to no free product measured beginning in June 2002.
- Confirmatory soil samples were collected in February 2003. These samples indicated that none of the BTEX or PAH compounds exceeded their applicable ATLs.
- As of March 2004, post-treatment concentrations of benzene and other PAHs in groundwater were all below their respective ACLs.
- The site remains in a semiannual monitoring only program. If the concentrations of the constituents are below their ACLs following a year of semiannual sampling, then a no-further-action-required status will be requested for the site.

Costs:
The total cost for the ERH application at Hunter AAF was approximately $1,300,000, consisting of:
- $1,042,129 for design, mobilization/demobilization, installation, and operation and maintenance of the system for four months;
- $259,000 for electrical service connection.

This total cost does not include costs for the generator (PCU), which was provided on loan from DOE.

Description:
Hunter AAF contains a former aviation-gas fuel island (Former Pumphouse #2), which was used from approximately 1953 to the early 1970s. It consisted of ten 25,000-gal USTs. The pumphouse was inactive from the early 1970s to 1995. In 1995, eight of the ten 25,000-gal USTs were removed from the ground. Leakage from USTs resulted in the contaminant plume. The site is being remediated under Georgia Environmental Protection Division, Underground Storage Tank Management Program.

Site investigations carried out in 1996 and 1997 identified petroleum contaminants in soil and groundwater, including BTEX and PAHs. The investigation identified the dissolved groundwater plume as covering an area of approximately 85,800 ft2. The 1997 investigation also discovered LNAPL in one of the wells which covered an area of approximately 3,825 ft2. The ERH implementation was initiated in April 2002 and continued for four months. Approximately 35,000 cubic yards of media were treated.

Site-specific ACLs for groundwater and ATLs for soil were developed for contaminants at the site. The objectives of the treatment were to remove LNAPL from the site, reduce concentrations of benzene in groundwater to less than the ACL of 469 : g/L, and reduce concentrations of benzene and indeno(1,2,3-cd)pyrene in soil to below their ATLs of 0.44 mg/kg and 0.66 mg/kg, respectively. From April to August 2002, an estimated 44,000 pounds of volatile organic compounds (VOCs) were removed. The amount of free product was reduced from a maximum of 11,500 ft2 measured in May 2002 to no free product measured beginning in June 2002. Confirmatory soil samples collected in February 2003 indicated that none of the BTEX or PAH compounds exceeded their applicable ATLs. As of March 2004, post-treatment concentrations of benzene and other PAHs in groundwater were all below their respective ACLs.

The total cost for the ERH application at Hunter AAF was approximately $1,300,000, consisting of $1,042,129 for design, mobilization/demobilization, installation, and operation and maintenance of the system for four months; and $259,000 for electrical service connection. This total cost does not include costs for the generator (PCU), which was provided on loan from DOE.

Soil Vapor Extraction at Three Dry Cleaner Sites, Various Locations

Site Name:
Multiple (3) Dry Cleaner Sites - Soil Vapor Extraction

Location:
- ABC One-Hour Cleaners: Jacksonville, North Carolina
- Parisian Cleaners: Orlando, Florida
- Randolf's Cleaners and Alterations: Tallahassee, Florida

Period of Operation:
- ABC One-Hour Cleaners: Soil - April 2000. Groundwater - January 1999
- Parisian Cleaners: July 9, 2002
- Randolf's Cleaners and Alterations: August 21, 2003

Cleanup Authority:
State

Purpose/Significance of Application:
Use of SVE to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner facilities

Cleanup Type:
Full scale

Contaminants:
Chlorinated Solvents, Petroleum Hydrocarbons

- ABC:
(Groundwater) 1,2-DCE - 1,200 : g/L; PCE - 5,400 : g/L; TCE - 640 : g/L; VC - 110 : g/L. (Soil) 1, 2 DCE - <31,000 : g/kg; PCE - 2,100,000 : g/kg; TCE - 33,000 : g/kg; VC - <31,000 : g/kg
- Parisian:
(Groundwater) 1,2,4-trimethylbenzene - 365 : g/L; 1,3,5-trimethylbenzene - 120 : g/L; PCE - 320 : g/L; TCE - 4.4 : g/L. (Soil) 1,2,4-trimethlybenzene - 410 : g/kg; naphthalene - 570 : g/kg; PCE - 130 : g/kg; xylenes - 188 : g/kg
- Randolf's:
(Groundwater) cis-1,2-DCE - 840 : g/L; PCE - 47,760 : g/L; DCE - 7 : g/L; TCE - 275 : g/L; VC - 27 : g/L. (Soil) PCE - 18,000 : g/kg; TCE - 54 : g/kg; Toluene - 199 : g/kg; TPH - 12,000 : g/kg

Waste Source:
Waste and wastewater from dry cleaning operations.

At ABC One-Hour Cleaners, prior disposal of PCE wastes and still bottoms as pothole fill may also have contributed to the contamination.

Contacts:
Varied by site

Technology:
Soil Vapor Extraction (SVE)
- ABC: Six extraction wells installed in April 2000. In July 2002, two additional wells installed and three others shut down. For treatment of contaminated groundwater, five extraction wells installed, with four in the surficial aquifer and one is the Castle Hayne Aquifer.
- Parisian: Two vertical extraction wells installed for the SVE system. One well placed inside the building and other well placed next to the building.
- Randolf's: SVE system consisted of a 50 HP blower designed to operate at an extraction rate of approximately 480 SCFM at a vacuum of 16 inches of mercury. Extracted vapors treated in two GAC units.

Type/Quantity of Media Treated:
Soil, Groundwater, DNAPL
ABC:
- Depth to Groundwater: 15 ft bgs; Conductivity: 10.3; Gradient: 0.13 ft/ft

Parisian:
- Depth to Groundwater: 12.5 ft bgs; Gradient: 0.003 ft/ft to 0.004 ft/ft

Randolf's:
- Depth of Groundwater: 45-55 ft bgs; Conductivity: 3 ft/day; Gradient: 0.024 ft/ft

Regulatory Requirements/Cleanup Goals:
- ABC: Soil remediation goals based on soil to groundwater leachability. Groundwater cleanup goals equivalent to groundwater standards.
- Parisian: Groundwater: PCE - 3 : g/L; TCE - 3 : g/L; naphthalene - 20 : g/L; 1,2,4-trimethylbenzene - 10 : g/L; 1,3,5-trimethylbenzene - 10 : g/L. Soil (leachability): PCE - 0.3 mg/kg; TCE - 0.3 mg/kg; naphthalene - 1.7 mg/kg; 1,2,4 trimethylbenzene - 0.3 mg/kg; 1,3,5-trimethylbenzene - 0.3 mg/kg
- Randolf's: Groundwater: PCE - 3 : g/L; TCE - 3 : g/L; cis 1,2-DCE - 70 : g/L; VC 1 : g/L. Soil: PCE - 30 : g/kg; TCE - 30 : g/kg; TPH - 340,000 : g/kg

Soil Vapor Extraction at Three Dry Cleaner Sites, Various Locations (continued)

Results:

- ABC: Contaminant concentrations in soil decreased since installation of extraction wells in April 2000, but remedial objectives have not been met. Contaminant concentrations in groundwater decreased since installation of extraction wells in January 1999, but remedial goals have not been met in the surficial aquifer. Contamination in the Castle Hayne aquifer has migrated beyond the zone of extraction well influence.
- Parisian: Contaminant concentrations in soil and groundwater decreased since using the SVE system. No further action (NFA) is the final remedy for both soils and groundwater.
- Randolf's: After one year of operation, an estimated 345 pounds of chlorinated ethenes were recovered. Approximately 90 percent of this contaminant mass were recovered from soil vapor. Approximately 1.6 million gallons of groundwater have been recovered and treated. Except for one well, contaminant concentrations in groundwater samples produced by recovery wells are the same order of magnitude since system startup with PCE concentrations in 4 of the 6 recovery wells ranging from 1,300 to 4,300 : g/L. PCE concentrations in groundwater samples collected from monitor wells however, have dropped by one order of magnitude from 10s of mg/L to less than 10 mg/L. The SVE system operation rate has been 73% and the groundwater recovery system operation rate has been 87%. Downtime has been due to power interruptions, air stripper upsets, and broken drive belts on the SVE system. Hydraulic capture of the contaminant source area also has been achieved.

Costs:

- ABC: \$521,463 for treatment of contaminated soil and \$2,262,900 for treatment of contaminated groundwater
- Parisian: Assessment - \$92,120.30; design and implementation - \$72,458; operation and maintenance - \$29,264; monitoring - \$8,689; total cost - \$202, 531.
- Randolf's: Assessment - \$147,800; design and implementation - \$298,500; operation and maintenance - \$64,500 (includes monitoring and utility payments.

Description:

Soil vapor extraction was conducted at three dry cleaner sites contaminated with chlorinated solvents from leaks, spills, or dumping of dry cleaning solvents or wastewaters. The concentration of contaminants varied by site with levels of PCE in groundwater as high as 47,760 : g/L and 1,2-DCE as high as 1,200 : g/L. Levels of TCE in soil were as 33,000 : g/kg and PCE as high as 2,100,000 : g/kg. At all three sites remediation was carried out at full scale.

At the ABC One-Hour Cleaners site, the SVE system is being expanded with an additional two to three wells, since the remedial objectives have not been met. Additional monitoring wells are being installed for treatment of groundwater and monitored natural attenuation will be investigated as a viable option. An important lesson learned at this site was that after more than a decade of soil and groundwater remediation, neither the soil nor the groundwater remediation goals have been attained. Soil excavation may have been a more expensive alternative than SVE; however, source removal would have been accomplished. The removal of the dominant source may have allowed the pump and treat system a better chance at remediation. An important lesson learned at the Parisian Cleaners site was that good soil sampling under the building provided a good design of the SVE system. Lessons learned at the Randolph's Cleaners and Alterations site were that in low permeability sediments, considerable contaminant mass can be trapped in unsaturated zone, capillary zone, and the upper most portion of the saturated zone. Also, a seasonal rise in the water table at the site resulting in an order of magnitude increase in contaminant concentrations in monitor well groundwater samples, indicates the presence of DNAPL in and near the capillary zone at the site.

Rhizosphere-Enhanced Bioremediation of Petroleum, Oil and Lubricant (POL)-Contaminated Soils at Three Sites in Alaska

Site Name:
Multiple (3) POL-Contaminated Sites

Location:
- Annette Island site, Former U.S. Army Air Force Landing Field, Metlakatla, Alaska
- Galena/Campion site, Former Air Force Station, Galena, Alaska
- Barrow sites, Former Tank Farm, and Former Dry Cleaning Facility, Barrow, Alaska

Period of Operation:
- Demonstrations at Annette Island and Galena/Campion began in Summer 1998 with site installation including soil preparation and seeding
- Soil preparation and seeding at Barrow began in Summer 1999
- Performance data available through Summer 2000

Cleanup Authority:
Not applicable

Purpose/Significance of Application:
- To demonstrate remediation of POL-contaminated surface soils in cold climates using cold-tolerant plants
- To determine relative effectiveness of fertilized and planted areas versus unfertilized areas and unplanted areas
- To study relationship between contaminant degradation and root-zone microbes.
- To study microbial population and composition

Cleanup Type:
Field demonstration

Contaminants:
Diesel range organics (DRO) and gasoline range organics (GRO)
- Annette Island: Soil - fuel-related contaminants - specific information not available
- Galena/Campion: Soil - DRO (1995 data) - 36 mg/kg to 75,000 mg/kg; GRO (1995 data) - 59 mg/kg to 7,500 mg/kg
- Barrow:
  - Dry Cleaning Facility:
    – Soil (1995 data) - DRO - 230 mg/kg to 810 mg/kg; GRO - below detection limit to 85 mg/kg; PCE
  - Tank Farm:
    – Soil (1994 data) - Total petroleum hydrocarbons - 47 mg/kg to 9,400 mg/kg; lead - 8.1 mg/kg to 365 mg/kg; BTEX, halogenated aliphatics, PAHs, phenolics, solvents and inorganic compounds were also detected

Waste Source:
- Annette Island: Presumed to be from operations involving a fuel storage tank farm
- Galena/Campion: Presumed to be from operations involving a heating fuel storage tank farm
- Barrow: From operations related to a former dry cleaning facility and former bulk fuel tank farm; bulk fuel tanks contained diesel fuel, gasoline, Mogas and JP-5 jet fuel

Contacts:
Varied by site

Technology:
Rhizosphere-enhanced bioremediation
- Used a seed mixture of three species of cold-tolerant grasses
  - Annual ryegrass (10% to 15%)
  - Arctared red fescue (60% to 70%)
  - White clover (20% to 25%)
- Minimal soil preparation prior to seeding
- Surface-applied seeds with handheld seeders and pressed seed into soil
- Added maximum permissible (less than 2,000 mg nitrogen/kg of soil) quantity of standard agricultural fertilizer
- Prepared control area with fertilizer but no seeds
- Prepared control area with seeds but no fertilizer

Type/Quantity of Media Treated:
Soil
- Barrow:
  - Surface soils, mainly coarse sand and gravel marine beach deposits, but silty in vegetated areas
  - An estimated 7,000 cubic yards of petroleum contaminated soil present
  - Soils remain frozen through most of the year, but thaw to a maximum depth of 55 inches in August or September and refreeze by late October
  - Groundwater occurs only in the thawed zone above the permafrost, and there is no significant flow

Regulatory Requirements/Cleanup Goals:
- Short term goal - to achieve reduction in contaminant concentrations; long-term goal - to restore Native American lands contaminated by DoD
- Quantitative cleanup goals were not provided

Results:
- Contaminant concentration were reduced (quantitative results were not available)
- Significant plant growth was observed in fertilized areas
- Long term cleanup goals are anticipated to be achieved only after continued remediation during future thaw periods

Costs:
- Capital cost - $7,250; operation and maintenance - $1,400 per year
- Other costs - $6,000 per year (includes long-term monitoring, regulatory oversight, compliance testing/analysis, excavation , and disposal of residues
- Total cost (based on a 10,000-ft^2 treatment area, 2-ft treatment depth, and 10-year period of operation) - $27,250

Description:
Rhizosphere-enhanced bioremediation was demonstrated at field-scale at three sites (Annette Island, Galena/Campion and Barrow) in Alaska. The contaminants at the sites were mainly petroleum hydrocarbons, including gasoline range organics (GRO) and diesel range organics (DRO). Barrow also had trace-level tetrachloroethene (PCE) and daughter products in the soil as a remnant of a removal action at a former dry cleaning facility. Demonstrations at all three sites included fertilizing and seeding of contaminated areas with a mixture of three cold-tolerant grasses. Installation at Annette and Galena/Campion, including soil fertilization and seeding, was conducted in Summer 1998. At Barrow, soil fertilization and seeding was completed during the next thaw-period in Summer 1999. Progress was monitored at all three sites at least until Summer 2000. Satisfactory plant growth was observed in fertilized and seeded areas and contaminant concentrations were reduced in these areas. Quantitative cleanup goals were not provided for the demonstration. The capital cost for the was $7,250, and the O&M cost was $1,400 per year.

EX SITU SOIL/SEDIMENT TREATMENT ABSTRACTS

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Thermal Desorption at the T.H. Agriculture and Nutrition Site, OU2, Albany, Georgia

Site Name:
T.H. Agriculture and Nutrition (THAN) Site, OU2

Location:
Albany, Georgia

Period of Operation:
October to November 1999

Cleanup Authority:
CERCLA

Purpose/Significance of Application:
Use of thermal desorption to treat soil contaminated with pesticides and inorganic contaminants.

Cleanup Type:
Full scale

Contaminants:
Organochlorine and organophosphorus pesticides including DDT, toxaphene, methyl parathion, and ethylene dibromide, as well as inorganics.

Waste Source:
Pesticide formulation and packaging

Contacts:

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Technology:
Thermal Desorption
- Thermal treatment system was a low temperature thermal desorption (LTTD) system.
- System included a feed system, rotary dryer, baghouse, wet quench, air mix chamber, and granulated activated carbon beds.
- Countercurrent rotary dryer, approximately 31 feet long and 6.5 feet in diameter, was direct-fired using a 32 million BTU/hr burner.
- Excavated soil was screened to 2 inches in diameter.
- System processed an average of 15 tons of soil/hr, with a typical soil exit temperature of 975°F.
- Off-gas was passed through a baghouse to remove particulates, cooled using flash evaporation of water in a spray tower quench chamber, passed through a mist eliminator, cooled in an on-line mix chamber where ambient air was added, and reheated prior to being sent to the carbon beds.
- Treated soil was combined with baghouse dust and water, discharged to a soil stacking area, and finally sent to a verification holding area for sampling.

Type/Quantity of Media Treated:
Soil
- 10,424 tons

Regulatory Requirements/Cleanup Goals:
- Cleanup goals were - DDT - 94 mg/kg; Toxaphene - 29 mg/kg; Methyl Parathion - 17 mg/kg; Ethylene Dibromide - 0.006 mg/kg
- Maximum stack gas total hydrocarbon (THC) levels were limited to 118 parts per million by volume (ppmv)
- Emissions had to meet state ambient air concentration levels for organic emissions
- Carbon beds removal efficiency >90%

Results:
- 10,424 tons of soil were treated in 18 batches
- All but one batch met the cleanup goals after initial treatment in the thermal desorber (the batch that was out of compliance met cleanup goals after the second treatment)
- Treated soil was backfilled on site
- There were no exceedances of the state ambient air limits
- Results of analyses of the removal efficiency of the carbon beds indicated that changeout of the carbon beds was not necessary

Costs:
- Actual costs for this application - $1,058,230, including $566,184 for capital costs and $492,046 for O&M costs
- Unit cost of $102 per ton, based on 10,424 tons of treated soil

Description:
The THAN site, in Albany Georgia, operated from the 1950s until 1982 to formulate and package pesticides. Operations at the site resulted in contamination of soil and groundwater. The site was listed on the National Priorities List in 1989. During remedial investigations, it was discovered that the groundwater plume from the THAN parcel had migrated beneath an adjacent property owned by Larry Jones (Jones Property). The 5-acre Jones Property was the site of a former pesticide formulation and packaging facility (operated from 1964 to the 1970s). EPA divided the THAN site into two operable units (OU). OU1 addresses soil and groundwater from the original THAN site (western parcel). OU2 addresses soil contamination at the Jones Property (eastern parcel). This report addresses the remediation of OU2.

A record of decision (ROD) for OU2 was signed in 1996. The ROD specified excavation of contaminated soil and treatment using low temperature thermal desorption. Contaminants found in soil at the Jones Property included organochlorine and organophosphorus pesticides including DDT, toxaphene, methyl parathion, and ethylene dibromide, as well as inorganics. From October to November 1999, thermal desorption treated 10,424 tons of pesticide-contaminated soil to below cleanup goals. All but one batch met the cleanup goals after the initial treatment in the thermal desorber. The batch that was out of compliance met cleanup goals after the second treatment. All treated soil was backfilled on the site. The cost for thermal desorption at this site was $1,058,230 or $102 per ton of soil treated.

IN SITU GROUNDWATER TREATMENT ABSTRACTS

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Electrical Resistive Heating at Charleston Naval Complex, AOC 607, North Charleston, South Carolina

Site Name:
Charleston Naval Complex, AOC 607

Location:
North Charleston, South Carolina

Period of Operation:
October 2001 to July 2002

Cleanup Authority:
Resource Conservation and Recovery Act (RCRA) - Corrective Action

Purpose/Significance of Application:
Use of ERH to remediate chlorinated solvents and PCE DNAPL in groundwater.

Cleanup Type:
Full scale

Contaminants:
Chlorinated Solvents - PCE Dense Non-Aqueous Phase Liquid (DNAPL), TCE, cis-1,2-DCE, 1,1-DCE, VC

Initial maximum contaminant concentrations:
- Total volatile organic compounds (VOCs) - 18,000 : g/L
- PCE - 8,090 : g/L

Waste Source:
Use, storage, disposal, and accidental release of chlorinated solvents at a former dry cleaning facility

Contacts:

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Technology Vendor
Mr. Greg Beyke, P.E.
Thermal Remediation Services, Inc.
Phone: (615) 791-5772
Email: gbeyke@thermalrs.com

Technology:
- Electrical Resistive Heating - Six-Phase Heating™ (SPH) for subsurface heating
- Soil Vapor Extraction (SVE) system for vapor recovery
- Above-ground treatment system to process vapor and liquid wastes generated by SVE
- ERH system:
  - Two 500 kilowatt (kW) power control units (PCU) operating 101 electrodes.
  - Electrodes installed to a depth of approximately 10 to 10.5 feet below ground surface (bgs) with a lateral spacing of approximately 14 feet.
  - PCU 1 began operating on October 3, 2001 in the more contaminated "southern" portion of the Target Treatment Area (TTA).
  - PCU 2 began operating in the "northern" portion of the TTA on December 13, 2001.
  - From April 15 to May 15, 2002, the entire ERH system operated using 101 electrodes, twelve 8-inch diameter steel piles, six Geoprobe electrodes, and 310 ¾-inch diameter ground rods.
  - To optimize performance, both PCUs cycled with 50 minutes of operation followed by 10 minutes of shut-down, to allow "re-wetting" of the electrodes and prevent the drying of soils close to the electrodes.
  - The average weekly power input during the nine-month ERH operation was approximately 278 kilowatts (kW), with a maximum power input of 520 kW that occurred during the week immediately following the start-up of PCU-2. The ERH system was shut down on July 8, 2002.
  - A condenser (to remove water vapor), a cooling tower (to cool condensate), and granular activated carbon (GAC) adsorption units (to treat dry vapor prior to atmospheric release).
- Following completion of the ERH in July 2002, TTA monitoring continued until March 2004.

Type/Quantity of Media Treated:
Groundwater and DNAPL

Approximately 4,300 cubic yards of media were treated. This volume is based on a 7-foot deep (saturated zone: 4 feet bgs to 11 feet bgs treatment zone) over a 16,525 square feet (ft^2) TTA.

Regulatory Requirements/Cleanup Goals:
The objective of the ERH treatment was to reduce the amount of chlorinated volatile organic compounds (CVOC) DNAPL present in the aquifer, thereby reducing its potential to act as a continuing source for dissolved-phase contamination. A quantifiable cleanup objective was not established during this remediation action.

Electrical Resistive Heating at Charleston Naval Complex, AOC 607, North Charleston, South Carolina (continued)

Results:
- In general, ERH resulted in a decrease in the area of the plume and a decrease in the number of high concentration zones.
- In March 2004 (22 months after ERH shutdown), PCE was detected in a monitoring well at a concentration of 283 : g/L. This suggested a 95 percent reduction in concentration compared to the pre-treatment baseline.
- Total volatile organic compounds concentration decreased by 83 percent.
- Total CVOCs and PCE mass recovered during ERH system operation was calculated at 247 and 234 lbs respectively.

Costs:
The total cost for the full-scale application was approximately $1,250,000. Costs were divided into the following categories:
- Capital costs - $373,000, including $71,000 for mobilization/demobilization
- Operational costs - $473,000
- Retrofit (electrode installation and well replacement) - $60,000
- Monitoring (laboratory analytical services) - $50,000
- Project oversight - $215,000

Description:
Charleston Naval Complex area of concern (AOC) 607 consisted of a former dry cleaning facility. PCE was one of the primary chemicals that was used, stored, disposed of, and accidentally released at the site.

A RCRA Facility Investigation conducted in 1996 and 1997 detected dissolved-phase chlorinated solvents in the saturated zone including PCE, TCE, cis-1,2-DCE, 1,1-DCE and VC. In addition, PCE in the form of DNAPL appeared to have migrated into the shallow saturated zone. Initial maximum contaminant concentrations included 18,000 : g/L of total VOCs and 8,090 : g/L of PCE. The site was remediated under the RCRA Corrective Action Program. Operation of the ERH system was initiated in October 2001 and continued until July 2002. Approximately 4,300 cubic yards of media were treated. This volume is based on a 7-foot deep (saturated zone: 4 feet bgs to 11 feet bgs treatment zone) over a 16,525 square feet (ft2) TTA.

The objective of the ERH treatment was to reduce the amount of DNAPL present in the aquifer, thereby reducing its potential to act as a continuing source for dissolved-phase contamination. A quantifiable cleanup objective was not established during this remediation action.

In general, ERH resulted in a decrease in the area of the plume and a decrease in the number of high concentration zones. PCE concentrations reduced by about 95 percent in concentration compared to the pre-treatment baseline. Total VOCs decreased by 83 percent. Total CVOCs and PCE mass recovered during ERH system operation was calculated at 247 and 234 lbs respectively.

The total cost for the full-scale application was approximately $1,250,000. Costs were divided into the following categories:
- Mobilization/demobilization costs - $71,000
- Capital costs - $373,000
- Operational costs - $473,000
- Retrofit (electrode installation and well replacement) - $60,000
- Monitoring (laboratory analytical services) - $50,000
- Project oversight - $215,000

One of the main issues that arose during the ERH treatment at AOC 607 was that the treatment took longer than anticipated, mainly due to slower heating of the groundwater in deeper portions of the saturated zone. The ERH system was enhanced by using additional electrodes to achieve adequate heating.

In Situ Bioremediation Using Various Additives at Five Dry Cleaner Sites, Various Locations

Site Name:
Multiple (5) Dry Cleaner Sites - In Situ Bioremediation

Location:
- Blacks Cleaners - Portland, Oregon
- Boone Dry Cleaners - Jackson, Tennessee
- Carousel Cleaners - Oregon City, Oregon
- Former 60 Minute Cleaners - Ft. Myers, Florida
- Village Green Shopping Center - Rockledge, Florida

Period of Operation:
- Blacks - Summer 2002 to present (Full-scale)
- Boone - April to December 2002
- Carousel - Spring 2001 to Winter 2003
- Former 60 - March 13, 2004 to date unknown
- Village Green - November 12, 2002 to February 13, 2003

Cleanup Authority:
State

Purpose/Significance of Application:
Use of in situ bioremediation using various additives to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner facilities.

Cleanup Type:
- Full scale - Blacks, Boone, Former 60, and Village Green
- Field demonstration - Carousel

Contaminants:
- Blacks (Groundwater) cis-1,2-DCE - 39 mg/L; dichlorobenzenes - 0.003 mg/L; PCE - 8.7 mg/L; TCE - 10.4 mg/L; vinyl chloride 0.35 mg/L; xylenes 0.05 mg/L
  (Soil) cis-1,2-DCE - 10.9 mg/kg; PCE - 1,100 mg/kg; TCE - 91.6 mg/kg; vinyl chloride - 0.14 mg/kg
- Boone (Groundwater) 1,1-DCE - 2.7 :g/L; benzene - 32,100 :g/L; cis-1,2-DCE - 1780 :g/L; m-xylene - 16,300 :g/L; PCE - 89,800 :g/L; trans-1,2-DCE - 6.0 :g/L; TCE - 610 :g/L; vinyl chloride - 220 :g/L.
  (Soil): cis-1,2-DCE - 156 :g/kg; lead - 151 mg/kg; m-xylene - 283 :g/kg; PCE - 6,090 mg/kg; trans-1-2-DCE - 13 :g/kg; TCE - 39 :g/kg
- Carousel (Groundwater) PCE - up to 25,700 :g/L; (Soil) PCE - up to 7,000 mg/kg
- Former 60 (Groundwater) 1,1-DCA - 8.6 :g/l; 1,1-DCE - 1,050 :g/l; benzene -150 :g/l; cis-1,2-DCE - 2,321 :g/l; MTBE - 29.5 :g/l; PCE - 6,820 :g/l; trans-1,2-DCE - 150 :g/l; TCE - 2,040 :g/l; vinyl chloride - 150 :g/l
  (Soil): PCE - 1,800 :g/kg; TCE - 2.97 :g/kg
- Village Green (Groundwater) cis-1,2-DCE - 8,550 :g/L; PCE - 27,300 :g/L; TCE - 7,900 :g/L; vinyl chloride - 780 :g/L
  (Soil) PCE - 564,000 :g/kg; TCE - 5,007 :g/kg

Waste Source:
Waste and wastewater from dry cleaning operations

Contacts:
Varied by site

Technology:
In situ bioremediation - various additives
- Blacks - In-situ bioremediation using sodium lactate followed by emulsified soybean oil. System includes three horizontal injection points beneath building footprint, a horizontal injection system in former source area, and several vertical injection wells between dry cleaner facility and adjacent apartment building.
- Boone - In-situ bioremediation using corn syrup, Simple Green®, and vegetable oil.
  - Twelve 4" injection wells and eight 2" pilot test monitoring wells installed to a depth of 18 ft.
- Carousel - In situ bioremediation using BioRem H-10
- Former 60 - In situ bioremediation using ethyl lactate injection/groundwater withdrawal and re-injection.
  - A total of 110 gallons injected in a 1-2% solution.
- Village Green - In situ bioremediation using ethyl lactate
  - 12 injection points and 7 recovery wells installed in the source area for the bioremediation
  - In dissolved phase portion, 4 shallow and 5 deep injection wells were installed.
  - A total of 880 gallons of ethyl lactate were pumped into the 12 injection points above the source area.

Type/Quantity of Media Treated:
Soil, groundwater, DNAPL
- Blacks: Groundwater, soil, DNAPL; depth to groundwater: varies seasonally from 6 to 12 feet
- Boone: Groundwater, soil; depth to groundwater: 10.11 ft (shallow); 45.87 (intermediate); 65.85 (deep)
- Carousel: Groundwater, soil; depth to groundwater: seasonally varies from 10 to 20 ft bgs
- Former 60: Groundwater, soil; depth to groundwater: 4 ft bgs
- Village Green: Groundwater, soil, DNAPL; depth to groundwater: 4 ft bgs

Regulatory Requirements/Cleanup Goals:
- Blacks: Cleanup goals primarily based on vapor intrusion into buildings; preliminary remediation goals (PRGs) for groundwater: 1 : g/L PCE; 100 : g/L TCE; and 20 : g/L vinyl chloride.
- Boone: Soil - EPA Region 9 PRGs; Groundwater - MCLs
- Carousel: Final cleanup goals yet to be established. Likely cleanup goals for groundwater and soil will be based on vapor intrusion modeling, and protection of deep aquifer at the MCL of 5 : g/L for PCE.
- Former 60: Groundwater - PCE - 3 : g/L, TCE - 3 : g/L, cis-1,2-DCE - 70 : g/L, trans-1,2-DCE - 100 : g/L; 1,1-DCE - 7 : g/L; vinyl chloride - 1.0 : g/L. Soil: PCE - 30 : g/kg; TCE - 30 : g/kg
- Village Green: Groundwater - PCE - 3 : g/L, TCE - 3 : g/L, cis-1,2-DCE - 70 : g/L. Soil (leachability): PCE - 30 : g/kg; TCE - 30 : g/kg

Results:
- Blacks - Not available
- Boone -
  - Wells with greatest PCE impact indicated an 85-95% decrease by August 2002.
- Carousel -
  - BioRem H-10 was able to degrade PCE without generation and accumulation of more toxic daughter products, namely TCE and vinyl chloride.
- Former 60 -
  - There was a rapid decrease in PCE concentrations in system influent in the first quarter of system operation, coupled with an increase in cis-1,2-DCE in groundwater influent concentrations.
- Village Green -
  - The site is currently in natural attenuation monitoring with semi-annual dilute ethyl lactate dosing.
  - Confirmatory soil sampling revealed that maximum PCE contaminant concentrations in soil decreased from 564,000 : g/kg to 2,300 : g/kg.

Costs:
- Blacks: Cost for design and implementation was approximately $30,000; costs for operation and maintenance are estimated to be $35,000 per year for the periodic injection of electron donor and bacterial treatment, and $20,000 per year for on-going groundwater, soil gas, and indoor air monitoring.
- Boone and Village Green: Cost data unavailable
- Carousel: 2-year pilot demonstrations costs were $75,000 for the injection system and monitoring. BioRem contributed the H-10 bacteria product for the study.
- Former 60: Design costs were $32,300, and construction costs were $107,500; operation and maintenance costs for the first year (includes ethyl lactate, injection, monitoring, and reporting) was $140,2000.

Description:
In situ bioremediation was conducted at five drycleaner sites contaminated primarily with chlorinated solvents from drycleaning operations. PCE, TCE, DCE, and vinyl chloride were the main contaminants of concern in soil and groundwater. At two sites (Blacks and Village Green), DNAPLs were present. The remediations, including full-scale and pilot-scale bioremediation, involved the subsurface injection of various additives such as sodium lactate, soybean oil, corn syrup, Simple Green®, vegetable oil, BioRem H-10, and ethyl lactate.

Results of the bioremediation were available for four of the five sites. Reductions in PCE and TCE concentrations and increases in PCE and TCE biodegradation products were reported for all four sites. At Boone, the remedy of corn syrup, Simple Green, and vegetable oil caused the vegetable oil to float on top of water. A lesson learned from this application was that remedial designs that call for injections of oil containing nutrient-enriched emulsions should consider the separation of oil from the emulsion.

In Situ Bioremediation Using Hydrogen Release Compound (HRC®) at Four Dry Cleaner Sites, Various Locations

<table>
<tr><td colspan="2">Site Name:
Multiple (4) Dry Cleaner Sites - In Situ Bioremediation</td><td>Location:
• <u>Arlington:</u> Arlington, TX
• <u>Former Colony:</u> Richardson, TX
• <u>Former Prestonwood:</u> Dallas, TX
• <u>Ted's Cleaners:</u> Nashville, TN</td></tr>
<tr><td colspan="2">Period of Operation:
• <u>Arlington</u>: 2 HRC® injections - May 2000 and August 2002.
• <u>Former Colony</u>: Single injection - October 2000.
• <u>Former Prestonwood</u>: Single injection - June 2001.
• <u>Ted's Cleaners</u>: Single injection - September 2002.</td><td>Cleanup Authority:
State</td></tr>
<tr><td colspan="2">Purpose/Significance of Application:
Use of in situ bioremediation using HRC® to treat soil and groundwater contaminated with chlorinated solvents at dry cleaner facilities.</td><td>Cleanup Type:
• Full scale (Arlington, Former Colony, Former Prestonwood)
• Field demonstration (Ted's)</td></tr>
<tr><td colspan="2">Contaminants:
Chlorinated Solvents: PCE; TCE; DCE; Cis-1,2-DCE; Trans-1,2-DCE; 1,1-DCE; 1,1,1-TCA; Vinyl Chloride; Dichlorobenzenes; Ethylbenzene
• <u>Arlington:</u> (Groundwater) cis-1,2-DCE - 7.3 g/L; PCE - 4.5 g/L; TCE - 7.3 g/L; VC - 0.87 g/L
• <u>Former Colony</u>: (Groundwater) cis-1,2-DCE - 3.85 g/L; trans-1,2-DCE - 0.18 g/L; PCE - 0.63 g/L; TCE - 2.6 g/L; VC - 0.008 g/L; dichlorobenzenes - 0.006 g/L. (Soil) cis-1,2-DCE - 0.4 g/kg; PCE - 7.4 g/kg; TCE - 0.84 g/kg; ethylbenzene - 0.04 g/kg.
• <u>Former Prestonwood</u> (Groundwater) 1,1-DCE - 0.005 g/L; cis-1,2-DCE - 1.08 g/L; trans-1,2-DCE - 0.55 g/L; PCE - 2.35 g/L; TCE - 0.429 g/L; 1,1,1-TCA - 0.012 g/L. (Soil) PCE - 53 g/kg
• <u>Ted's Cleaners</u>: (Groundwater) cis-1,2-DCE - 2.33 g/L; trans-1,2-DCE - 0.021 g/L; PCE - 22 g/L; TCE - 0.82 g/L; VC - 0.001 g/L. (Soil) cis-1,2-DCE - 0.0410 mg/kg; PCE - 0.0640 mg/kg; TCE - 0.0025 mg/kg</td><td>Waste Source:
• Waste and wastewater from dry cleaning operations.

• At one site (Ted's Cleaners), prior disposal of PCE wastes, still bottoms, and spent filter cartridges in a dumpster located at the facility, may also have contributed to the contamination.</td></tr>
<tr><td>Contacts:
Varied by site</td><td colspan="2">Technology:
In Situ Bioremediation - HRC®
• <u>Arlington:</u> In May 2000, approximately 7,000 lbs of HRC® were injected into 45 borings in the vicinity of the source zone covering an area of approximately 3,000 ft^2. A second injection was performed in August 2002.
• <u>Former Colony:</u> A single injection event of HRC® occurred in October 2000. The compound was injected at depths of 6 to 12 ft bgs via direct push at 5 locations up gradient of the source zone. Four lbs/ft were injected for a total of 50 lbs/injection point (total of 250 lbs).
• <u>Former Prestonwood:</u> The limestone subsurface was fractured by injecting HRC® at high pressure at depths of 15 to 25 ft bgs. At shallower depths of 5 to 15 ft bgs, slightly less pressure (40-60 psi) was used. A total of 3,400 lbs was injected.
• <u>Ted's Cleaners:</u> In September 2002, HRC® was injected at nine injection points. The free product from the wells was removed by bailing in May 2003. Groundwater monitoring events were conducted in November 2002; January 2003; May 2003; and June 2004.</td></tr>
<tr><td colspan="3">Type/Quantity of Media Treated:
Soil, Groundwater
• <u>Arlington:</u> depth to groundwater: 7 ft bgs; subsurface geology: Predominantly medium to dark gray shale
• <u>Former Colony:</u> depth to groundwater: 13 to 15 ft bgs; subsurface geology: Clay at 15 ft bgs, limestone (Austin Chalk) at 15 ft bgs
• <u>Former Prestonwood:</u> depth to groundwater: 5 ft bgs; subsurface geology: Fill material, clay lenses, limestone
• <u>Ted's Cleaners:</u> depth to groundwater: 3.2 to 10.7 ft bgs; subsurface geology: Limestone bedrock is overlain by sand and gravel alluvium in a matrix of silt and clay. Overburden varies from 5.7 ft to 22.5 ft bgs.</td></tr>
</table>

In Situ Bioremediation Using Hydrogen Release Compound (HRC®) at Four Dry Cleaner Sites, Various Locations (continued)

Regulatory Requirements/Cleanup Goals:
- Arlington: (Groundwater) PCE - 500 : g/L; TCE - 500 : g/L; cis-1,2-DCE - 7,000 : g/L; VC - 200 : g/L. (Soil) PCE - 7 mg/kg; TCE - 0.5 mg/kg; cis-1,2-DCE - 0.5 mg/kg; VC - 0.2 mg/kg
- Former Colony: Cleanup goals not specified
- Former Prestonwood: (Groundwater) PCE - 500 : g/L. (Soil): PCE - 50,000 : g/kg
- Ted's Cleaners: Remove or reduce contaminant source area. No site specific cleanup goals were established.

Results:
- Arlington: Sampling conducted in January and April 2002 indicated that PCE concentrations exceeded the cleanup goal in one monitoring well, leading to a second HRC® injection event. Following the second injection, the dissolved contaminants remained below cleanup goals. Confirmatory soil samples indicated that cleanup goals for the soil were not exceeded. A certificate of completion was issued for this site.
- Former Colony: Contaminant concentrations in groundwater have decreased since HRC® injection in October 2000. Groundwater monitoring is being continued at the site.
- Former Prestonwood: Two years after HRC® injection, PCE concentration in one monitoring well increased from 15,000 : g/L to 23,500 : g/L. Additional groundwater monitoring has been recommended for the site.
- Ted's Cleaners: As of the June 2004 monitoring results, no effect of HRC® injection had been observed on down gradient contaminant concentrations approximately 5 ft away. Additional testing is being done at the site, including the polymerase chain reaction test.

Costs:
- Arlington, Former Colony, and Former Prestonwood: No cost data available
- Ted's Cleaners: $7,500 (remedy selection report); $35,000 (pilot study injection); $110,000 (total project cost to date including monitoring)

Description:
In situ bioremediation using HRC® was conducted at four dry cleaner sites contaminated with chlorinated solvents. The concentration of contaminants varied by site with levels of cis-1,2-DCE and TCE as high as 7.3 g/L and PCE as high as 22 g/L. Levels of TCE, and PCE in soil were as high as 0.8 g/kg, and 53 g/kg, respectively. At three sites (Arlington, Former Colony, and Former Prestonwood), remediation was carried out at full scale while at Ted's Cleaners, a pilot scale operation was performed.

At the Arlington site, HRC® was injected in two events. Following these injections, the concentrations of dissolved contaminants were reduced to below the cleanup goals and a certificate of completion was issued for the site. An important lesson learned at this site was that contaminant concentrations can rebound with use of HRC®. Monitoring should be continued for at least a year after injection to ensure that cleanup levels for various contaminants are not exceeded. At the Former Colony site, HRC® injection was used to stimulate biodegradation. A single injection was carried out in October 2000, where 250 lbs was injected into the contaminated source area. PCE concentrations have steadily declined since the injection. Monitoring is ongoing at the site. At the Former Prestonwood site, excavation of contaminated soil had been carried out prior to HRC®. Injection in June 2001. At this site, limestone subsurface had to be fractured using a higher pressure injection of HRC® at greater depths and a lower pressure injection at shallower depths. Approximately 136 lbs were injected into 25 boreholes, for a total injection of 3,400 lbs of HRC® at the site. PCE concentration increased from 15,000 : g/L to 23,500 : g/L approximately two years after the first injection. Additional monitoring has been recommended at the site. At the Ted's Cleaners site, HRC® was selected for a pilot test, where it was injected at 9 points in the target area in a grid-like pattern. As of June 2004, no change in groundwater contaminant concentrations had been observed, and additional monitoring is being carried out at the site for natural attenuation parameters in addition to polymerase chain reaction tests. The total cost of the project including monitoring costs was about $ 110,000.

In Situ Chemical Oxidation at Four Dry Cleaner Sites, Various Locations

Site Name:
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation

Location:
- Former Cowboy Cleaners: Broomfield, CO
- Niles Finest Cleaners: Niles, IL
- Rummel Creek Shopping Center: Houston, TX
- Springvilla Dry Cleaners: Springfield, OR

Period of Operation:
- Former Cowboy Cleaners: September 2001 to February 2003
- Niles Finest Cleaners: May 2004 to date unknown
- Rummel Creek Shopping Center: July 17, 2001 to date unknown
- Springvilla Dry Cleaners: October 11, 2004 to date unknown

Cleanup Authority:
State

Purpose/Significance of Application:
Use of in situ oxidation technologies for remediation of chlorinated solvents in groundwater at drycleaner facilities.

Cleanup Type:
Full scale

Contaminants:
Chlorinated Solvents: cis-1,2-DCE; PCE; TCE; 1,2-dichloropropane; trans-1,2-DCE); 1,1-DCE; 1,1,1-TCA); Vinyl Chloride
- Former Cowboy Cleaners: PCE - 1,900 : g/L
- Niles Finest: (Groundwater) PCE - 1 mg/L; TCE - 0.015 mg/L. (Soil) 1,1,1-TCA - 5.61 mg/kg; 1,1-DCE - 3.5 mg/kg; PCE - 1,300 mg/kg; trans-1,2-DCE - 0.865 mg/kg; TCE - 18 mg/kg; VC - 2.84 mg/kg; Chromium - 0.0015 mg/L
- Rummel Creek: (Groundwater) 1,1-DCE - 9.7 : g/L; cis-1,2-DCE - 2600 : g/L; PCE - 2,200 : g/L; trans-1,2-DCE - 20 : g/L; TCE - 610 : g/L; VC - 12 : g/L
- Springvilla: (Groundwater) 1,1-DCE - 6.8 : g/L; cis-1,2-DCE - 4 : g/L; PCE - 7,800 : g/L; TCE - 48 : g/L. (Soil) cis-1,2-DCE - less than 5 : g/kg; PCE - 130,000 : g/kg; TCE - 50 : g/kg

Waste Source:
Waste and wastewater from dry cleaning operations

Contacts:
Varied by site

Technology:
In situ chemical oxidation
- Former Cowboy: A total of 12 nested injectors were installed in the source area. Upon setting of the grout, a 10% (by weight) solution of permanganate was introduced under pressure into each injector. Up to 300 gallons per day of 1-2% solution were fed into the system during remediation. A series of injectors was installed downstream to control PCE that was mobilized into groundwater from soil in the source area.
- Niles Finest: A 10 percent (by weight) of sodium permanganate (NaMnO4) solution was injected into the surface of the 200-ft2 area on a 24-point grid pattern. 15-19 gallons of the NaMnO4 were injected at each injection point.
- Rummel Creek: A 0.5 to 2% KMnO4 solution was injected into the perched water bearing zone using direct push technologies. Injections were carried out four times over a one year period. A total of 837 pounds of KMnO4 was injected. Each injection point received injections at two depths: one approximately 5 ft from the bottom of the transmissive zone, and the other five to 10 ft above the first.
- Springvilla: The treatment technologies used at this site include ISCO, monitored natural attenuation, carbon adsorption, removal, and SVE. On October 11, 2004, 100 gallons of 4% sodium permanganate solution was injected through lower infiltration piping in source area excavation. Groundwater monitoring is ongoing. Injection of electron donor to initiate bioremediation is planned for 2005.

Type/Quantity of Media Treated:
Soil, Dense non-aqueous phase liquid (DNAPL), Groundwater
- Former Cowboy: Depth to groundwater: 25 ft bgs
- Niles Finest Cleaners: Depth to groundwater: 3.74 ft bgs (average); conductivity: 0.101 ft/day; gradient: 0.034 ft/ft
- Rummel Creek: Depth to groundwater: 18 to 23 ft bgs; conductivity: 4.2 to 9.2 ft/day; gradient: 0.0045 ft/ft
- Springvilla: Depth to groundwater: 5 to 13 ft bgs; conductivity: 5 to 10 ft/day (for gravel); gradient: 0.003 ft/ft

Regulatory Requirements/Cleanup Goals:
- Former Cowboy Cleaners: Cleanup goals were not identified.
- Niles Finest Cleaners: Soil remediation objective for PCE was 704.1 mg/kg. Contaminants found in groundwater were below the groundwater remediation objectives.
- Rummel Creek Shopping Center: PCE - 5 : g/L; TCE - 5 : g/L; cis-1,2-DCE - 70 : g/L; trans-1,2-DCE - 100 : g/L; VC - 2 : g/L
- Springvilla Dry Cleaners: Reduce contaminant mass beneath building to reduce/remove soil source of groundwater contamination and to reduce vapor intrusion potential.

Results:
- Former Cowboy Cleaners:
  - Initial PCE concentration in the source area was 1,900 : g/L; after eight months of treatment, the concentration was
  - In February 2003, the State of Colorado issued a No Action Determination Approval
- Niles Finest Cleaners:
  - For groundwater, results of post injection sampling indicated that PCE contamination increased to 56 : g/L 30 days after injection, and to 150 : g/L 60 days after injection.
  - Post-injection soil sampling showed a decrease in PCE contamination. However, the 60-day post-injection sampling showed much higher concentrations, ranging from 2,000 mg/L to 2,800 mg/L, near the original hot-spot area
  - Even though the rebound of groundwater contamination can be addressed by injecting additional $NaMnO_4$, the Illinois Fund Administrator and the consultant decided to abandon the use of $NaMnO_4$.
  - Based on post-injection sampling, excavation has been proposed to address the soil contamination
- Rummel Creek Shopping Center:
  - The maximum concentrations observed at the source wells prior to the injection of permanganate were 2,200 : g/L for PCE and 610 : g/L for TCE.
  - The first KMnO4 injection reduced the concentrations in the source wells which ranged from non-detect to 79 : g/L for PCE and non-detect to 74 : g/L for TCE.
  - The TCE and PCE concentrations were found to vary across the non-source wells, but the concentrations were generally decreasing.
  - At the downgradient wells, the concentrations had either remained stable or had decreased.
- Springvilla Dry Cleaners:
  - Following the excavation of contaminated soil, PCE concentration observed in a monitoring well closest to the treatment area was approximately half the pre-injection concentration.
  - Evidence of permanganate (manganese dioxide) has been observed at wells >300 ft downgradient of the treatment area.
  - Groundwater monitoring will continue and an evaluation of the remediation system will be performed to determine whether to inject additional permanganate or to switch to a bioremediation approach using simple electron donor added to infiltration gallery. Additional injection to infiltration gallery is planned for summer or fall 2005.

Costs:
- Former Cowboy Cleaners and Rummel Creek Shopping Center: Cost data unavailable
- Niles Finest Cleaners: Design and implementation, including post-injection sampling: $32,285
- Springvilla Dry Cleaners:
  - Design and Planning: $8,000
  - Implementation (through soil treatment and initial permanganate treatment): $95,000
  - Cost for Operation and Maintenance (O&M): Approximately $3,000/year for vapor recovery system monitoring and analytical costs

Description:
ISCO using either sodium or potassium permanganate was conducted at five dry cleaner sites contaminated with chlorinated solvents, primarily PCE and TCE. The concentration of contaminants in groundwater varied by site with levels of PCE as high as 110,000 : g/L and TCE as high as 610 : g/L. The remediation involved in situ chemical oxidation at full-scale at both sites. The remediation involved in situ chemical oxidation at full-scale at all four sites.

Reductions in contaminant concentrations following treatment were observed at all the sites except one (Niles Finest Cleaners). At the Niles site, a rebound in PCE concentrations was observed in both soil and groundwater after the injection of oxidant. Excavation has been proposed for the contaminated soil as an alternative to chemical oxidation. A lesson learned with this application is that when utilizing chemical oxidation, rebound or increase of chlorinated solvents in groundwater should be carefully monitored, even where contamination in soil was the only initial concern.

Cyclodextrin-Enhanced *In Situ* Removal of Organic Contaminants from Groundwater at Site 11, Naval Amphibious Base Little Creek, Virginia Beach, Virginia

Site Name:
Naval Amphibious Base Little Creek, Site 11

Location:
Virginia Beach, Virginia

Period of Operation:
June to September 2002

Cleanup Authority:
CERCLA

Purpose/Significance of Application:
Field demonstration of CDEF to recover chlorinated solvent DNAPLs from soil and groundwater.

Cleanup Type:
Field demonstration

Contaminants:
VOCs - TCE, 1,1,1-TCA, 1,1-DCE, and chloroform

Waste Source:
Waste generated from metal plating operations

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Technology:
Flushing (in situ) - cyclodextrin-enhanced flushing (CDEF).
- Flushing system consisted of eight 4-inch PVC injection/extraction wells - five for both injection and extraction and the other three for extraction only. Wells were screened in the lower 5 feet of the surficial aquifer.
- System operated at an average flow rate of 7,200 gallons per day.
- Cyclodextrin solution (20% by weight) was stored in a 6,500 gallon storage tank and gravity fed into the injection/extraction wells.
- Groundwater extraction wells were used to capture the injectate flushed through the contaminated media.
- Extracted groundwater was passed through a 2 µm sand filter to remove fines.
- Filtered groundwater was then passed through an air stripper to remove TCE from the cyclodextrin-TCE complex.
- A pervaporation unit was also used for TCE removal. The unit operated only for a limited period of time to field test it as an alternative to air stripping.
- The stripped cyclodextrin solution was then recycled using an ultrafiltration unit and reinjected.
- The gas-phase waste stream from the air stripper was passed through an activated carbon unit prior to atmospheric discharge.

Type/Quantity of Media Treated:
Groundwater, soil
- Surficial aquifer is composed primarily of poorly sorted sand with lenses of clay, silt, sand, peat, and shell fragments. The aquifer is generally unconfined and is underlain by a clay confining unit.
- Water table was encountered 7 to 8 feet below ground surface.
- Hydraulic conductivity of the aquifer in the remediation zone was 8×10^{-4} centimeters per second.

Regulatory Requirements/Cleanup Goals:
To achieve greater than 90 percent reduction in DNAPL mass and greater than 99 percent reduction in aqueous TCE concentrations.

Results:
Mass reduction in subsurface DNAPL was between 70 and 81 percent. This corresponded to a mass of 39 kilograms and a volume of 30 liters. The average TCE concentration in groundwater was reduced by 78 percent.

Costs:
The total cost of the demonstration was $863,000, consisting of a capital cost of $448,000, an operation and maintenance cost of $409,000, and other technology-specific costs.

Description:
Site 11, Naval Amphibious Base Little Creek (NABLC), Virginia Beach, Virginia encompassed a former plating shop that was operated by the NABLC, School of Music. Chlorinated solvents and other industrial liquids that were stored in tanks at this facility leaked and migrated into the underlying surficial aquifer. Impacted soils, tanks and piping were removed in 1996. The site was listed on the NPL on May 10, 1999. The contaminants of concern at this site include chlorinated solvents such as TCE, 1,1,1-TCA, 1,1-DCE and chloroform. A demonstration of CDEF was conducted at the site to evaluate the effectiveness of the technology to treat the contaminants of concern. The demonstration began in June, 2000 and continued until September, 2000. Treatment goals for the demonstration were to achieve greater than 90 percent reduction in DNAPL mass and greater than 99 percent reduction in aqueous TCE concentrations.

CDEF achieved 70 to 81 percent DNAPL mass reduction and approximately 78 percent reduction in the average concentration of TCE in groundwater. The total capital cost for constructing the CDEF system was $448,000, and the total cost of operation and maintenance for the period of the demonstration was $409,000.

Some problems were encountered during the demonstration. One of the problems was that aeration of the injectant caused iron present in the groundwater to precipitate inside the air stripper, increasing the air stripper's maintenance frequency. In addition, injection wells became clogged by the precipitation of iron in the injectant. These problems were solved by storing the injectant in tanks long enough to allow the injectant's natural oxidant demand to consume any dissolved oxygen.

Enhanced Biological Attenuation of Aircraft Deicing Fluid Runoff Using Subsurface Flow Constructed Wetlands at the Westover Air Reserve Base, Chicopee, Massachusetts

Site Name: Westover Air Reserve Base (ARB)	**Location:** Chicopee, Massachusetts
Period of Operation: August 2001 to May 2003 (performance data available from December 2002)	**Cleanup Authority:** Not applicable
Purpose/Significance of Application: Demonstration of SSF CTW for treatment of aircraft deicing fluids-contaminated storm water runoff at the Westover ARB.	**Cleanup Type:** Field demonstration
Contaminants: Nonhalogenated semivolatiles: aircraft deicing fluids - propylene glycol, ethylene glycol and additives • On average, 10,000 gallons of aircraft deicing fluid used annually at Westover ARB • 50,000 gallons of aircraft deicing fluid used during period of demonstration (2002 - 2003) • Peak influent biochemical oxygen demand (BOD) concentrations ranged from 974 to 15,098 mg/L in 10 deicing events during 2002	**Waste Source:** Aircraft deicing operations resulting in contamination of storm water runoff
Contacts: Jeff Karrh Project Manager Naval Facilities Engineering Service Center Robert L. Knight Wetland Solutions, Inc. 2809 N.W. 161 Court Gainesville, FL 32609 Phone: (386) 462-1003 Email: bknight@wetlandsolutionsinc.com	**Technology:** Subsurface Flow (SSF) Constructed Treatment Wetlands (CTW) • A passive system operating under gravity flow that treats storm water runoff from a 162 acre watershed. • Approximately 3 feet deep and consists of *phragmites* sp. rhizomes growing on a sand and gravel bed. 2,000 rhizomes were planted on 3-foot centers in a 3-inch layer of ¾-inch gravel. • Can handle a mean flow of 100,000 gpd, and maximum flow of 400,000 gpd. • Constructed over a low elevation 0.6-acre area and has a trapezoidal cross section. • Hydraulically isolated from surrounding soils by a 30 mil PVC liner. • Perforated inlet and outlet pipes buried in subsurface coarse rock layers that run along opposing inside edges of the SSF CTW. The inlet pipe runs close to the surface and the outlet pipe runs close to the base liner. • Storm water to be treated enters the SSF CTW through the perforated inlet pipe, flows horizontally through the root zone in the granular media and exits through the perforated outlet pipe.

Type/Quantity of Media Treated:
Stormwater
- Approximately 12.2 million gallons of storm water was treated between December 2002 and May 2003.

Regulatory Requirements/Cleanup Goals:
Compliance with NPDES permit requirement - monthly mean BOD in effluent less than 30 mg/L.

Results:
- Results are based on performance between December 2002 and May 2003.
- Average monthly influent BOD ranged from 165 to 2,655 mg/L. Average monthly effluent BOD ranged from 100 to 1,667 mg/L. BOD reduction ranged from 11.2 to 78 percent.
- The NPDES permit requirement for BOD was not met during the demonstration. However, the NPDES permit changed from individual to multi-sector during the project. It was therefore suggested that comparison of demonstration results to individual permit criteria was not valid.
- Other parameters measured were chemical oxygen demand (COD), methyl-1H-benzotriazole (deicing fluid additive), dissolved oxygen (DO), pH, redox, temperature and turbidity. Significant changes in average influent and effluent pH were observed. The average pH of influent and effluent was 7.58 and 9.54 respectively.

Costs:
- Capital cost for the demonstration totaled $326,000. The cost included design, mobilization, equipment purchase, construction, management, permitting and demobilization.
- Operation and maintenance cost during the demonstration totaled $6,900. The cost included labor, utilities, equipment and equipment maintenance.
- Projected annual cost for operation and maintenance was $2,000. The cost included analytical testing.

Description:
Westover ARB, located in Massachusetts, is situated approximately 2 miles east of the Connecticut River, and is traversed and bounded by Cooley and Stony Brooks. The Base performs deicing and anti-icing on its aircrafts and runways during snow storms and freezing rain events. This generates contaminated storm water runoff that can impact adjacent surface waters.

The demonstration of CTW was performed to evaluate it as an alternative for treating runoff from Westover ARB. A passive SSF CTW was constructed over 0.6 acres of land to handle an average flow of 100,000 gpd and a maximum flow of 400,000 gpd. The CTW consisted of *phragmites* sp. rhizomes grown over a sand and gravel base. Stormwater runoff was delivered to the CTW through a perforated inlet pipe and exited it through a perforated outlet pipe.

The regulatory goal of the demonstration was to comply with the NPDES permit requirement of a monthly mean BOD in effluent of less than 30 mg/L. The CTW treated almost 12.2 million gallons of water during the demonstration. The average monthly influent BOD ranged from 165 to 2,655 mg/L, and the average monthly effluent BOD ranged from 100 to 1,667 mg/L. The regulatory goal was not met. Noncompliance with the goal was attributed to its inapplicability to the multi-sector permit for this site.

The capital cost for the demonstration totaled $326,000, which included design, mobilization, equipment purchase, construction, management, permitting, and demobilization costs. The O&M cost totaled $6,900, which included labor, utilities, equipment and equipment maintenance.

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Soil Vapor Extraction (41 Projects)						
Basket Creek Surface Impoundment Site, GA	18	SVE	Soil	TCE; Volatiles-Halogenated; Ketones; Volatiles-Nonhalogenated; Heavy Metals	1992	1997
Camp Lejeune Military Reservation, Site 82, Area A, NC	32	SVE	Soil	BTEX; PCE; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated	1995	1998
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA	45	SVE	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1992	1995
Davis-Monthan AFB, Site ST-35, AZ	51	SVE	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1995	1998
Defense Supply Center Richmond, OU 5, VA	52	SVE (Field Demonstration)	Soil	PCE; TCE; Volatiles-Halogenated	1992	1998
East Multnomah County Groundwater Contamination Site, OR	370	SVE; Air Sparging; Pump and Treat	Soil; Groundwater; LNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1991	2004
Fairchild Semiconductor Corporation Superfund Site, CA	68	SVE	Soil	PCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1989	1995
Fort Lewis, Landfill 4, WA	84	SVE; Air Sparging	Soil	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1994	1998
Fort Richardson, Building 908 South, AK	88	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998
Fort Greely, Texas Tower Site, AK	82	SVE; Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1994	1998
Hastings Groundwater Contamination Superfund Site, Well Number 3 Subsite, NE	104	SVE	Soil	TCE; Volatiles-Halogenated	1992	1995
Holloman AFB, Sites 2 and 5, NM	108	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Intersil/Siemens Superfund Site, CA	117	SVE	Soil	TCE; Volatiles-Halogenated	1988	1998
Luke Air Force Base, North Fire Training Area, AZ	145	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; Ketones	1990	1995
McClellan Air Force Base, Operable Unit D, Site S, CA	154	SVE (Field Demonstration)	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1993	1995
Multiple (2) Dry Cleaner Sites - *In situ* SVE, Various Locations	366	SVE	Soil; Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1994	2004
Multiple (3) Dry Cleaner Sites - *In Situ* Treatment, Various Locations	363	SVE; Chemical Oxidation/Reduction (*in situ*); Thermal Treatment (*in situ*)	Soil; Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	2001	2004
Multiple (3) Dry Cleaner Sites - SVE/Air Sparging, Various Locations	317	SVE; Air Sparging	Soil; Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Various years - starting 1995	2003
Multiple (3) Dry Cleaner Sites - SVE/MNA, Various Locations	320	SVE; Monitored Natural Attenuation; Pump and Treat	Soil; Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Various years - starting 1996	2003
Multiple (4) Dry Cleaners - SVE and SVE Used with Other Technologies, Various Locations	365	SVE; Air Sparging; Chemical Oxidation/Reduction (*in situ*); Pump and Treat; Monitored Natural Attenuation; Multi Phase Extraction	Soil; Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1997	2004
Multiple (6) Dry Cleaner Sites, Various Locations	345	SVE	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1992	Various years - 2002, 2003
Multiple (7) Dry Cleaner Sites	176	SVE; Pump and Treat	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Various years - starting 1998	Various years - 2001, 2002
Multiple (7) Dry Cleaner Sites - P&T/SVE/MPE, Various Locations	349	SVE; Multi Phase Extraction; Pump and Treat	Soil; Groundwater; DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1991	Various years - 2002, 2003
Multiple (3) Dry Cleaner Sites, Various Locations	379	SVE	Soil; Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1999	2005

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
NAS North Island, Site 9, CA	183	SVE (Photolytic Destruction) (Field Demonstration)	Soil	PCE; TCE; DCE; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1997	1998
Patrick Air Force Base, Active Base Exchange Service Station, FL	214	SVE (Biocube™) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	2000
Patrick Air Force Base, Active Base Exchange Service Station, FL	215	SVE (Internal Combustion Engine) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1993	2000
Rocky Mountain Arsenal Superfund Site (Motor Pool Area - Operable Unit #18), CO	237	SVE	Soil	TCE; Volatiles-Halogenated	1991	1995
Sacramento Army Depot Superfund Site, Tank 2 (Operable Unit #3), CA	241	SVE	Soil	Ketones; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1992	1995
Sacramento Army Depot Superfund Site, Burn Pits Operable Unit, CA	240	SVE	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1994	1997
Sand Creek Industrial Superfund Site, Operable Unit 1, CO	242	SVE	Soil; LNAPLs	PCE; TCE; Volatiles-Halogenated; Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1997
Seymour Recycling Corporation Superfund Site, IN	258	SVE; Containment - Caps; Bioremediation (*in situ*) Enhanced Bioremediation	Soil	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Shaw AFB, OU 1, SC	261	SVE; Free Product Recovery	Soil; Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
SMS Instruments Superfund Site, NY	264	SVE	Soil	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1992	1995
Stamina Mills Superfund Site, RI	273	SVE; Multi Phase Extraction (Field Demonstration)	Soil; Off-gases	TCE; Volatiles-Halogenated	1999	2001
Tyson's Dump Superfund Site, PA	285	SVE	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1988	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy, Portsmouth Gaseous Diffusion Plant, OH	292	SVE; Chemical Oxidation/Reduction (*in situ*); Solidification/Stabilization; Thermal Treatment (*in situ*) (Field Demonstration)	Soil	TCE; DCE; Volatiles-Halogenated	1992	1997
U.S. Department of Energy, Savannah River Site, SC	295	SVE (Flameless Thermal Oxidation) (Field Demonstration)	Soil; Off-gases	PCE; TCE; Volatiles-Halogenated	1995	1997
U.S. Department of Energy, Savannah River Site, SC, and Sandia, NM	251	SVE; In-Well Air Stripping; Bioremediation (*in situ*) ALL; Drilling (Field Demonstration)	Soil; Groundwater	Volatiles-Halogenated	1988	2000
Vandenberg Air Force Base, Base Exchange Service Station, CA	306	SVE (Resin Adsorption) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	2000
Verona Well Field Superfund Site (Thomas Solvent Raymond Road - Operable Unit #1), MI	307	SVE	Soil Light Non-aqueous Phase Liquids	Ketones; BTEX; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated	1988	1995
Other *In Situ* Soil/Sediment Treatment (43 Projects)						
Alameda Point, CA	5	Electrokinetics (Field Demonstration)	Soil	Heavy Metals	1997	2001
Argonne National Laboratory - West, Waste Area Group 9, OU 9-04, ID	12	Phytoremediation (Field Demonstration)	Soil	Heavy Metals	1998	2000
Avery Dennison, IL	329	Thermal Treatment (*in situ*)	Soil; DNAPLs	Volatiles-Halogenated	1999	2003
Beach Haven Substation, Pensacola, FL	20	Electrokinetics (Field Demonstration)	Soil	Arsenic	1998	2000
Brodhead Creek Superfund Site, PA	24	Thermal Treatment (*in situ*)	Soil; DNAPLs	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated; Arsenic	1995	1998
California Gulch Superfund Site, OU 11, CO	373	Solidification/Stabilization (Field Demonstration)	Soil	Heavy Metals	1998	2005

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Castle Airport and Various Sites, CA	361	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated;	1998	2004
Castle Airport, CA	35	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	BTEX; Volatiles-Nonhalogenated	1998	1999
Confidential Chemical Manufacturing Facility, IN	330	Thermal Treatment (*in situ*)	Soil; DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated	1997	2003
Crooksville/Roseville Pottery Area of Concern (CRPAC), OH	327	Solidification/Stabilization (Field Demonstration)	Soil	Heavy Metals	1998	2002
Dover Air Force Base, Building 719, DE	57	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	TCE; DCE; Volatiles-Halogenated	1998	2000
Eielson Air Force Base, AK	64	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1991	1995
Ensign-Bickford Company - OB/OD Area, CT	66	Phytoremediation	Soil	Heavy Metals	1998	2000
Former Mare Island Naval Shipyard, CA	75	Thermal Treatment (*in situ*) (Field Demonstration)	Soil	PCBs; Semivolatiles-Halogenated	1997	2000
Fort Richardson Poleline Road Disposal Area, OU B, AK	89	Thermal Treatment (*in situ*); SVE (Field Demonstration)	Soil	PCE; TCE; Volatiles-Halogenated	1997	2000
Frontier Hard Chrome Superfund Site, WA	381	Chemical Oxidation/Reduction (*in situ*)	Soil; Groundwater	Heavy Metals	2003	2005
Hill Air Force Base, Site 280, UT	106	Bioremediation (*in situ*) Bioventing	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1990	1995
Hill Air Force Base, Site 914, UT	107	Bioremediation (*in situ*) Bioventing; SVE	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1988	1995

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Hunter Army Airfield, Former Pumphouse #2, GA	382	Thermal Treatment (*in situ*)	Soil; Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated PAHs; Semivolatiles-Nonhalogenated	2002	2005
Idaho National Engineering and Environmental Laboratory, ID	114	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Volatiles-Halogenated	1996	2000
Koppers Co. (Charleston Plant) Ashley River Superfund Site, SC	350	Solidification/Stabilization	Sediment; DNAPLs	PAHs; Semivolatiles-Nonhalogenated	2001	2003
Lowry Air Force Base, CO	143	Bioremediation (*in situ*) Bioventing	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995
Magic Marker, NJ and Small Arms Firing Range (SAFR) 24, NJ	146	Phytoremediation (Field Demonstration)	Soil	Heavy Metals	Magic Marker - 1997; Fort Dix - 2000	2002
Missouri Electric Works Superfund Site, MO	160	Thermal Treatment (*in situ*) (Field Demonstration)	Soil	PCBs; Semivolatiles-Halogenated	1997	1998
Morses Pond Culvert, MA	351	Chemical Oxidation/Reduction (*in situ*)	Soil	Heavy Metals	2001	2004
Multiple Air Force Test Sites, Multiple Locations	180	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	2000
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation, Various Locations	380	Chemical Oxidation/Reduction (*in situ*)	Soil; Groundwater	DCE; PCE; TCE; Volatiles-Halogenated BTEX; Volatiles-Nonhalogenated Semivolatiles-Nonhalogenated	Various years-starting 1999	2005

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple (3) POL-Contaminated Sites, AK	376	Phytoremediation; Bioremediation (*in situ*) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated PAHs; Semivolatiles-Nonhalogenated; PCE; Volatiles-Halogenated; Heavy Metals	Various years - starting 1998	2005
Naval Air Weapons Station Point Mugu Site 5, CA (USAEC)	188	Electrokinetics (Field Demonstration)	Soil; Sediment	Heavy Metals	1998	2000
Naval Air Weapons Station Point Mugu Site 5, CA (USEPA)	189	Electrokinetics (Field Demonstration)	Soil	Heavy Metals	1998	2000
Paducah Gaseous Diffusion Plant (PGDP) Superfund Site, KY	328	Lasagna^{TM}	Soil	TCE; Volatiles-Halogenated	1999	2002
Parsons Chemical/ETM Enterprises Superfund Site, MI	212	Vitrification (*in situ*)	Soil; Sediment	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals; Dioxins/Furans	1993	1997
Portsmouth Gaseous Diffusion Plant, X-231A Site, Piketon, OH	225	Fracturing (Field Demonstration)	Soil; Groundwater	TCE; Volatiles-Halogenated	1996	2001
Sandia National Laboratories, Unlined Chromic Acid Pit, NM	246	Electrokinetics (Field Demonstration)	Soil	Heavy Metals	1996	2000
Savannah River Site 321-M Solvent Storage Tank Area, GA	337	Thermal Treatment (*in situ*) (Field Demonstration)	Soil; DNAPLs	PCE; TCE; Volatiles-Halogenated	2000	2003
Twin Cities Army Ammunition Plant, MN	283	Phytoremediation (Field Demonstration)	Soil	Heavy Metals; Arsenic	1998	2000
U.S. Department of Energy, Savannah River Site, SC, and Hanford Site, WA	296	Thermal Treatment (*in situ*) (Field Demonstration)	Soil; Sediment	PCE; TCE; Volatiles-Halogenated	1993	1997
U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY	291	Lasagna^{TM} (Field Demonstration)	Soil; Groundwater	TCE; Volatiles-Halogenated	1995	1997
U.S. Department of Energy, Portsmouth Gaseous Diffusion Plant, OH and Other Sites	293	Fracturing (Field Demonstration)	Soil; Groundwater; DNAPLs	TCE; Volatiles-Halogenated	1991	1997

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy, Multiple Sites	288	Drilling (Field Demonstration)	Soil; Sediment	-	1992	1997
U.S. Department of Energy, Hanford Site, WA, Oak Ridge (TN) and Others	289	Vitrification (*in situ*)	Soil; Sludge; Debris/Slag/ Solid	Pesticides/Herbicides; Heavy Metals; Arsenic; Dioxins/Furans; Semivolatiles-Halogenated PCBs; Radioactive Metals	Not Provided	1997
White Sands Missile Range, SWMU 143, NM	313	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Soil	Heavy Metals	1998	2000
Young-Rainy Star Center (formerly Pinellas) Northeast Area A, FL	355	Thermal Treatment (*in situ*)	Soil; Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated DCE; PCE; TCE; Volatiles-Halogenated	2002	2004
Incineration (on-site) (18 Projects)						
Baird and McGuire, MA	15	Incineration (on-site)	Soil; Sediment	Dioxins/Furans; Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Arsenic; Heavy Metals; Volatiles-Halogenated	1995	1998
Bayou Bonfouca, LA	19	Incineration (on-site)	Soil; Sediment	PAHs; Semivolatiles-Nonhalogenated	1993	1998
Bridgeport Refinery and Oil Services, NJ	23	Incineration (on-site)	Soil; Debris/Slag/ Solid; Sediment; Organic Liquids; Sludge	PCBs; Semivolatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated	1991	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Celanese Corporation Shelby Fiber Operations, NC	36	Incineration (on-site)	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated; Heavy Metals; BTEX	1991	1998
Coal Creek, WA	43	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; Heavy Metals	1994	1998
Drake Chemical Superfund Site, Operable Unit 3, Lock Haven, PA	59	Incineration (on-site)	Soil	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1998	2001
FMC Corporation - Yakima, WA	72	Incineration (on-site)	Soil; Debris/Slag/ Solid	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals	1993	1998
Former Nebraska Ordnance Plant - OU 1, NE	76	Incineration (on-site)	Soil; Debris/Slag/ Solid	Explosives/Propellants	1997	1998
Former Weldon Springs Ordnance Works, OU 1, MO	79	Incineration (on-site)	Soil; Debris/Slag/ Solid	Explosives/Propellants; Heavy Metals; PCBs; Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated	1998	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
MOTCO, TX	165	Incineration (on-site)	Soil; Sludge; Organic Liquids	PCBs; Semivolatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1990	1998
Old Midland Products, AR	206	Incineration (on-site)	Soil; Sludge	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Volatiles-Nonhalogenated; Volatiles-Halogenated	1992	1998
Petro Processors, LA	217	Incineration (on-site)	Soil; Organic Liquids; DNAPLs	PAHs; Semivolatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated	1994	1998
Rocky Mountain Arsenal, CO	236	Incineration (on-site)	Soil; Organic Liquids	Pesticides/Herbicides; Heavy Metals; Arsenic	1993	1998
Rose Disposal Pit, MA	238	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated	1994	1998
Rose Township Dump, MI	239	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; Heavy Metals; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated; PAHs; Ketones	1992	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Sikes Disposal Pits, TX	262	Incineration (on-site)	Soil; Debris/Slag/ Solid	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Times Beach, MO	280	Incineration (on-site)	Soil; Debris/Slag/ Solid	Dioxins/Furans; Semivolatiles-Halogenated	1996	1998
Vertac Chemical Corporation, AR	308	Incineration (on-site)	Soil; Debris/Slag/ Solid; Organic Liquids	Dioxins/Furans; Semivolatiles-Halogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Thermal Desorption (30 Projects)						
Anderson Development Company Superfund Site, MI	8	Thermal Desorption (*ex situ*)	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1992	1995
Arlington Blending and Packaging Superfund Site, TN	13	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated; Arsenic	1996	2000
Brookhaven National Laboratory (BNL), NY	325	Thermal Desorption (*ex situ*) (Field Demonstration)	Soil	Heavy Metals	Not provided	2002
Cape Fear Superfund Site, NC	33	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated; Arsenic; Heavy Metals; Volatiles-Nonhalogenated; BTEX	1998	2002
FCX Washington Superfund Site, NC	69	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated	1995	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Fort Lewis, Solvent Refined Coal Pilot Plant (SRCPP), WA	86	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated	1996	1998
Fort Ord, CA	354	Thermal Desorption (*ex situ*) (Field Demonstration)	Debris/Slag/Solid; Off-gas	Heavy Metals	2002	2004
Industrial Latex Superfund Site, NJ	348	Thermal Desorption (*ex situ*)	Soil; Off-gases	Pesticides/Herbicides; Semivolatiles-Halogenated; PAHs; PCBs; Arsenic	1999	2002
Letterkenny Army Depot Superfund Site, K Areas, OU1, PA	135	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated; Heavy Metals	1993	2000
Lipari Landfill, Operable Unit 3, NJ	137	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Arsenic; Heavy Metals; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	2002
Longhorn Army Ammunition Plant, Burning Ground No. 3, TX	138	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated	1997	2000
McKin Superfund Site, ME	155	Thermal Desorption (*ex situ*)	Soil	BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated	1986	1995
Metaltec/Aerosystems Superfund Site, Franklin Borough, NJ	156	Thermal Desorption (*ex situ*)	Soil	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1994	2001
Naval Air Station Cecil Field, Site 17, OU 2, FL	182	Thermal Desorption (*ex situ*)	Soil	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998
New Bedford Harbor Superfund Site, New Bedford, MA	197	Thermal Desorption (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Outboard Marine Corporation Superfund Site, OH	209	Thermal Desorption (*ex situ*)	Soil; Sediment	PCBs; Semivolatiles-Halogenated	1992	1995
Port Moller Radio Relay Station, AK	223	Thermal Desorption (*ex situ*)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
Pristine, Inc. Superfund Site, OH	227	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals	1993	1995
Re-Solve, Inc. Superfund Site, MA	230	Thermal Desorption (*ex situ*)	Soil	PCBs; Semivolatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; TCE; Volatiles-Halogenated	1993	1998
Reich Farm, Pleasant Plains, NJ	228	Thermal Desorption (*ex situ*)	Soil	Volatiles-Halogenated; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	2001
Reilly Industries Superfund Site, Operable Unit 3, IN	229	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated	1996	2002
Rocky Flats Environmental Technology Site, Mound Site, Golden, CO	234	Thermal Desorption (*ex situ*)	Soil	PCE; TCE; Volatiles-Halogenated	1997	2001
Rocky Flats Environmental Technology Site, Trenches T-3 and T-4, CO	235	Thermal Desorption (*ex situ*)	Soil; Debris/Slag/Solid	TCE; Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; Radioactive Metals	1996	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Sand Creek Superfund Site, OU 5, CO	243	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Arsenic	1994	2000
Sarney Farm, Amenia, NY	248	Thermal Desorption (*ex situ*)	Soil	TCE; DCE; Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated	1997	2001
Site B (actual site name confidential), Western United States	333	Thermal Desorption (*ex situ*)	Soil; Off-gases	Pesticides/Herbicides; Semivolatiles- Halogenated; Semivolatiles-Nonhalogenated	1995	2003
TH Agriculture & Nutrition Company Superfund Site, GA	277	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides	1993	1995
Waldick Aerospaces Devices Superfund Site, NJ	310	Thermal Desorption (*ex situ*)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated; Heavy Metals	1993	1998
Wide Beach Development Superfund Site, NY	314	Thermal Desorption (*ex situ*); Chemical Oxidation/Reduction (*ex situ*)	Soil	Semivolatiles-Halogenated; PCBs	1990	1995
TH Agriculture and Nutrition Site, OU2, GA	374	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles- Halogenated; Semivolatiles-Nonhalogenated	1999	2005
Other *Ex Situ* Soil/Sediment Treatment (33 Projects)						
Bonneville Power Administration Ross Complex, Operable Unit A, WA	22	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated; Semivolatiles-Halogenated	1994	1998
Brookhaven National Laboratory, NY	25	Physical Separation	Soil	Radioactive Metals	2000	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Brown Wood Preserving Superfund Site, FL	27	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated	1989	1995
Burlington Northern Superfund Site, MN	29	Bioremediation (*ex situ*) Land Treatment	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated	1986	1997
Dubose Oil Products Co. Superfund Site, FL	60	Bioremediation (*ex situ*) Composting	Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated	1993	1997
Fort Polk Range 5, LA	87	Acid Leaching; Physical Separation (Field Demonstration)	Soil	Heavy Metals	1996	2000
Fort Greely, UST Soil Pile, AK	83	Bioremediation (*ex situ*) Land Treatment	Soil	BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated	1994	1998
French Ltd. Superfund Site, TX	91	Bioremediation (*ex situ*) Slurry Phase	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; PCBs; Semivolatiles-Halogenated; Arsenic; Heavy Metals	1992	1995
Hazen Research Center and Minergy GlassPack Test Center, WI	358	Vitrification (*ex situ*) (Field Demonstration)	Sediment	PCBs; Dioxins/Furans; Semivolatiles-Halogenated; Heavy Metals	2001	2004
Idaho National Environmental and Engineering Laboratory (INEEL), ID	116	Physical Separation	Soil	Radioactive Metals	1999	2001
Joliet Army Ammunition Plant, IL	121	Bioremediation (*ex situ*) Slurry Phase (Field Demonstration)	Soil	Explosives/Propellants	1994	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
King of Prussia Technical Corporation Superfund Site, NJ	125	Soil Washing	Soil; Sludge	Heavy Metals	1993	1995
Los Alamos National Laboratory, NM	141	Physical Separation	Soil; Debris/Slag/ Solid	Radioactive Metals	1999	2000
Lowry Air Force Base, CO	144	Bioremediation (*ex situ*) Land Treatment	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995
Massachusetts Military Reservation, Training Range and Impact Area, Cape Cod, MA	152	Solidification/Stabilization	Soil	Heavy Metals	1998	2001
Naval Construction Battalion Center Hydrocarbon National Test Site, CA	190	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1996	1998
New Bedford Harbor Superfund Site, New Bedford, MA	198	Vitrification (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001
New Bedford Harbor Superfund Site, New Bedford, MA	195	Solidification/Stabilization (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1995	2001
New Bedford Harbor Superfund Site, New Bedford, MA	196	Solvent Extraction (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001
Novartis Site, Ontario, Canada	199	Bioremediation (*ex situ*) Land Treatment (Field Demonstration)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated	1996	1998
Oak Ridge National Laboratory, TN	201	Vitrification (*ex situ*) (Field Demonstration)	Sludge	Heavy Metals; Radioactive Metals	1997	2000
Pantex Plant, Firing Site 5, TX	211	Physical Separation	Soil; Debris/Slag/ Solid	Radioactive Metals	1998	2000
Peerless Cleaners, WI; Stannard Launders and Dry Cleaners, WI	216	Bioremediation (*ex situ*) Composting	Soil	PCE; TCE; DCE; Volatiles-Halogenated; Semivolatiles-Nonhalogenated	Not Provided	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
RMI Titanium Company Extrusion Plant, OH	231	Solvent Extraction (*ex situ*) (Field Demonstration)	Soil	Radioactive Metals	1997	2000
Sandia National Laboratories, ER Site 16, NM	245	Physical Separation	Soil	Radioactive Metals	1998	2000
Sandia National Laboratories, ER Site 228A, NM	244	Physical Separation	Soil	Radioactive Metals	1998	2000
Scott Lumber Company Superfund Site, MO	254	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated	1989	1995
Southeastern Wood Preserving Superfund Site, MS	270	Bioremediation (*ex situ*) Slurry Phase	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated	1991	1997
Sparrevohn Long Range Radar Station, AK	272	Solvent Extraction (*ex situ*)	Soil	PCBs; Semivolatiles-Halogenated	1996	1998
Stauffer Chemical Company, Tampa, FL	275	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Pesticides/Herbicides	1997	2001
Tonapah Test Range, Clean Slate 2, NV	282	Physical Separation	Soil; Debris/Slag/Solid	Radioactive Metals	1998	2000
Umatilla Army Depot Activity, OR	300	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Explosives/Propellants	1992	1995
Umatilla Army Depot Activity, OR	301	Bioremediation (*ex situ*) Composting	Soil	Explosives/Propellants	1994	1997
Pump and Treat (50 Projects)						
Amoco Petroleum Pipeline, MI	7	Pump and Treat; Air Sparging	Groundwater; LNAPLs	BTEX; Volatiles-Nonhalogenated	1988	1995

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Baird and McGuire Superfund Site, MA	16	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated; Pesticides/Herbicides; Semivolatiles-Halogenated	1993	1998
Bofors Nobel Superfund Site, OU 1, MI	21	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Volatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	1998
Charnock Wellfield, Santa Monica, CA	37	Pump and Treat; Chemical Oxidation/Reduction (*ex situ*) (Field Demonstration)	Drinking Water	MTBE; Volatiles-Nonhalogenated	1998	2001
City Industries Superfund Site, FL	41	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated; Ketones; Semivolatiles-Nonhalogenated	1994	1998
Coastal Systems Station, AOC 1, FL	44	Pump and Treat (Field Demonstration)	Groundwater	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1997	1998
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA	46	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1988	1995
Commencement Bay, South Tacoma Channel Superfund Site, WA	47	Pump and Treat; SVE	Groundwater; Soil; DNAPLs; LNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1998	2001
Des Moines TCE Superfund Site, OU 1, IA	54	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1987	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Former Firestone Facility Superfund Site, CA	73	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1986	1998
Fort Lewis Logistics Center, WA	85	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	2000
Ft. Drum, Fuel Dispensing Area 1595, NY	81	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	BTEX; Volatiles-Nonhalogenated	1992	1995
JMT Facility RCRA Site (formerly Black & Decker RCRA Site), NY	119	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1988	1998
Keefe Environmental Services Superfund Site, NH	122	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1993	1998
King of Prussia Technical Corporation Superfund Site, NJ	126	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated Heavy Metals	1995	1998
Lacrosse, KS	127	Pump and Treat	Drinking Water	BTEX; Petroleum Hydrocarbons; MTBE; Volatiles-Nonhalogenated	1997	2001
Langley Air Force Base, IRP Site 4, VA	128	Pump and Treat	Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995
LaSalle Electrical Superfund Site, IL	129	Pump and Treat	Groundwater	PCBs; Semivolatiles-Halogenated; TCE; DCE; Volatiles-Halogenated	1992	1998
Lawrence Livermore National Laboratory (LLNL) Site 300 - General Services Area (GSA) Operable Unit, CA	134	Pump and Treat	Groundwater; Soil; DNAPLs	TCE; Volatiles-Halogenated	1991	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Marine Corps Base, OU 1 and 2, Camp Lejeune, NC	149	Pump and Treat	Groundwater	PCBs; Semivolatiles-Nonhalogenated; Pesticides/Herbicides; Heavy Metals; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	2001
Marine Corps Base, Campbell Street Fuel Farm, Camp Lejeune, NC	150	Pump and Treat	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated	1996	2001
McClellan Air Force Base, Operable Unit B/C, CA	153	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1988	1995
Mid-South Wood Products Superfund Site, AR	158	Pump and Treat	Groundwater	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals; Arsenic	1989	1998
Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility - Volatile Halogenated Organic (VHO) Plume, WY	181	Pump and Treat; SVE	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1994	1998
Naval Air Station, Brunswick, Eastern Groundwater Plume, ME	185	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1995	2001
Odessa Chromium IIS Superfund Site, OU 2, TX	204	Pump and Treat	Groundwater	Heavy Metals	1993	1998
Odessa Chromium I Superfund Site, OU 2, TX	203	Pump and Treat	Groundwater	Heavy Metals	1993	1998
Offutt AFB, Site LF-12, NE	205	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; TCE; DCE; Volatiles-Halogenated	1997	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Old Mill Superfund Site, OH	207	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1989	1998
Ott/Story/Cordova Superfund Site, North Muskegon, MI	208	Pump and Treat	Groundwater	PCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; PCBs; Semivolatiles-Halogenated; Pesticides/Herbicides	1996	2001
Paducah Gaseous Diffusion Plant, KY	344	Pump and Treat (Field Demonstration)	Groundwater	Radioactive Metals	1999	2002
Pinellas Northeast Site, FL	219	Pump and Treat (Membrane Filtration - PerVap^{TM}) (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	1998
Pope AFB, Site SS-07, Blue Ramp Spill Site, NC	222	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1998
Pope AFB, Site FT-01, NC	221	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1998
Rockaway, NJ	233	Pump and Treat	Drinking Water	MTBE; BTEX; Volatiles-Nonhalogenated; TCE; Volatiles-Halogenated	1980	2001
SCRDI Dixiana Superfund Site, SC	255	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1992	1998
Shaw AFB, Sites SD-29 and ST-30, SC	260	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Shaw AFB, Site OT-16B, SC	259	Pump and Treat	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1995	1998
Sol Lynn/Industrial Transformers Superfund Site, TX	265	Pump and Treat	Groundwater	TCE; Volatiles-Halogenated	1993	1998
Solid State Circuits Superfund Site, MO	266	Pump and Treat	Groundwater; DNAPLs	TCE; DCE; Volatiles-Halogenated	1993	1998
Solvent Recovery Services of New England, Inc. Superfund Site, CT	267	Pump and Treat; Containment - Barrier Walls	Groundwater	Semivolatiles-Nonhalogenated; PCBs; Semivolatiles-Halogenated; Heavy Metals; TCE; DCE; Volatiles-Halogenated	1995	1998
Sylvester/Gilson Road Superfund Site, NH	276	Pump and Treat; Containment - Barrier Walls; Containment - Caps; SVE	Groundwater; LNAPLs	Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1982	1998
Tacony Warehouse, PA	278	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1998	2000
Twin Cities Army Ammunition Plant, MN	284	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1987	1995
U.S. Department of Energy Kansas City Plant, MO	290	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Semivolatiles-Halogenated PCBs; Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1983	1995
U.S. Aviex Superfund Site, MI	286	Pump and Treat	Groundwater; DNAPLs	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1993	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy Savannah River Site, A/M Area, SC	297	Pump and Treat	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1985	1995
Union Chemical Company Superfund Site, ME	302	Pump and Treat; Chemical Oxidation/Reduction (*in situ*); SVE	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated	1996	2001
United Chrome Superfund Site, OR	303	Pump and Treat	Groundwater	Heavy Metals	1988	1998
Western Processing Superfund Site, WA	312	Pump and Treat; Containment - Barrier Walls	Groundwater; LNAPLs; DNAPLs	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals	1988	1998
***In Situ* Groundwater Bioremediation (44 Projects)**						
Abandoned Manufacturing Facility - Emeryville, CA	2	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals	1997	2000
Altus Air Force Base, Landfill 3 (LF 3), OK	338	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	2000	2003
Avco Lycoming Superfund Site, PA	14	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1997	2000
Balfour Road Site, CA; Fourth Plain Service Station Site, WA; Steve's Standard and Golden Belt 66 Site, KS	17	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
Brownfield Site, Chattanooga, TN (specific site name not identified)	28	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1999	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Contemporary Cleaners, Orlando. FL	49	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Cordray's Grocery, Ravenel, SC	50	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1998	2001
Dover Air Force Base, Area 6, DE	56	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2000
Dover Air Force Base, Area 6, DE	55	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1996	2002
Edwards Air Force Base, CA	63	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1996	2000
Former Industrial Property, CA	372	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated	2000	2004
French Ltd. Superfund Site, TX	92	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Volatiles-Halogenated; Volatiles-Nonhalogenated	1992	1998
Gas Station, Cheshire, CT (specific site name not identified)	94	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated	1997	2001
Hanford Site, WA	96	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	Volatiles-Halogenated	1995	2000
Hayden Island Cleaners, Portland, OR	105	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Idaho National Engineering and Environmental Laboratory, Test Area North, ID	115	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1999	2002
ITT Roanoke Site, VA	118	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	DCE; Volatiles-Halogenated	1998	Not Provided
Lawrence Livermore National Laboratory, CA	133	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater; Soil	MTBE Volatiles-Nonhalogenated	Not Provided	2001
Libby Groundwater Superfund Site, MT	136	Bioremediation (*in situ*) Enhanced Bioremediation; Pump and Treat	Groundwater	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated	1991	1998
Moffett Field Superfund Site, CA	162	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	Volatiles-Halogenated	1986	2000
Moss-American Site, WI	369	Bioremediation (*in situ*) Enhanced Bioremediation; Permeable Reactive Barrier	Groundwater	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated,	2000	2004
Multiple Dry Cleaner Sites	174	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001
Multiple (4) Dry Cleaner Sites - *In Situ* Bioremediation, Various Locations	346	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Volatiles-Nonhalogenated; BTEX; MTBE	Various years - starting 2002	2003
Multiple (4) Dry Cleaner sites - In Situ Bioremediation, Various Locations	384	Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater	DCE; PCE; TCE; Volatiles-Halogenated; Volatiles-Semihalogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 2000	2005

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple (5) Dry Cleaner sites - In Situ Bioremediation, Various Locations	383	Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	Various years - starting 2001	2005
National Environmental Technology Test Site, CA		Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	MTBE	2001	2004
Naval Weapons Station Seal Beach, CA	194	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1997	2000
Naval Air Station New Fuel Farm Site, NV	360	Bioremediation (*in situ*) Bioventing; Free Product Recovery	Groundwater	Petroleum Hydrocarbons; LNAPLs	Not Provided	2004
Naval Weapons Industrial Reserve Plant (NWIRP) , TX	315	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE, Volatiles-Halogenated	1999	2002
Naval Base Ventura County, CA	352	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated	1999	2004
Offutt Air Force Base, NE	339	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	Not provided	2003
Pinellas Northeast Site, FL	218	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; DNAPLs	TCE; DCE; Volatiles-Halogenated	1997	1998
Savannah River Site Sanitary Landfill (SLF), SC	362	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated	1999	2004
Savannah River Site, SC	250	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Sediment	PCE; TCE; Volatiles-Halogenated	1992	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Service Station, CA (specific site name not identified)	256	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Service Station, Lake Geneva, WI (specific site name not identified)	257	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Site A (actual name confidential), NY	263	Bioremediation (*in situ*) Enhanced Bioremediation; Pump and Treat; Air Sparging; SVE	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
South Beach Marine, Hilton Head, SC	268	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	PAHs; Semivolatiles-Nonhalogenated; BTEX; MTBE; Volatiles-Nonhalogenated	1999	2001
Specific site name not identified	304	Bioremediation (*in situ*) Enhanced Bioremediation (Bench Scale)	Groundwater; Soil	MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Texas Gulf Coast Site, TX	279	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals	1995	2000
U.S. Navy Construction Battalion Center, Port Hueneme, CA	299	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1998	2001
U.S. Department of Energy Savannah River Site, M Area, SC	298	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Sediment	PCE; TCE; Volatiles-Halogenated	1992	1997
Vandenberg Air Force Base, Lompoc, CA	305	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1999	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Watertown Site, MA	311	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil	PCE; TCE; Volatiles-Halogenated	1996	2000
Other *In Situ* Groundwater Treatment (80 Projects)						
328 Site, CA	1	Multi Phase Extraction; Fracturing	Groundwater; Soil	TCE; Volatiles-Halogenated	1996	2000
A.G. Communication Systems, IL	332	Thermal Treatment (*in situ*)	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1995	2003
Aberdeen Proving Grounds, Edgewood Area J - Field Site, MD	3	Phytoremediation (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1996	2002
Amcor Precast, UT	6	In-Well Air Stripping; SVE	Groundwater; Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated	1992	1995
Brookhaven National Laboratory, NY	26	In-Well Air Stripping (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1999	2002
Butler Cleaners, Jacksonville, FL	30	Chemical Oxidation/Reduction (*in situ*) ($KMnO_4$)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Not Provided	2001
Camp Lejeune Marine Corps Base, Bldg 25, Camp Lejeune, NC	31	Flushing (*in situ*) (SEAR and PITT)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1999	2001
Cape Canaveral Air Force Station, Launch Complex 34, FL	340	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil; DNAPLs	TCE; Volatiles-Halogenated	1999	2003
Cape Canaveral Air Force Station, Launch Complex 34, FL	341	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater; DNAPLs	TCE; Volatiles-Halogenated	1999	2002

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Carswell Air Force Base, TX	34	Phytoremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1996	2002
Charleston Naval Complex, AOC 607, SC	378	Thermal Treatment (*in situ*)	Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated	2001	2005
Clear Creek/Central City Superfund site, CO	326	Phytoremediation (Field Demonstration)	Groundwater	Heavy Metals	1994	2002
Confidential Manufacturing Facility, IL	48	Thermal Treatment (*in situ*)	Groundwater; Soil; DNAPLs	TCE; DCE; Volatiles-Halogenated	1998	2000
Defense Supply Center, Acid Neutralization Pit, VA	53	Multi Phase Extraction (Field Demonstration)	Groundwater; Soil	PCE; TCE; DCE; Volatiles-Halogenated	1997	2000
Del Norte County Pesticide Storage Area Superfund Site, CA (Air Sparging and Pump and Treat)	359	Air Sparging; SVE	Groundwater	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals	1990	2004
Eaddy Brothers, Hemingway, SC	61	Air Sparging; SVE	Groundwater; Soil	BTEX; MTBE Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1999	2001
Edward Sears Site, NJ	62	Phytoremediation (Field Demonstration)	Groundwater	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1996	2002
Eight Service Stations, MD (specific sites not identified)	65	Multi Phase Extraction	Groundwater; Soil; LNAPLs	BTEX; MTBE Volatiles-Nonhalogenated	1990	2001
Fernald Environmental Management Project, OH	70	Flushing (*in situ*) (Field Demonstration)	Groundwater	Heavy Metals	1998	2001
Former Sages Dry Cleaners, Jacksonville, FL	78	Flushing (*in situ*) (Ethanol Co-solvent)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Former Nu Look One Hour Cleaners, Coral Springs, FL	77	In-Well Air Stripping (NoVOCs^{TM})	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Former Intersil, Inc. Site, CA	74	Permeable Reactive Barrier; Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	1998
Fort Devens, AOCs 43G and 43J, MA	80	Monitored Natural Attenuation	Groundwater; Soil; LNAPLs	BTEX; Volatiles-Nonhalogenated	1997	2000
Fort Richardson, AK	331	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil; DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1999	2003
Four Service Stations (specific site names not identified)	90	Air Sparging	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated	1993	2001
Fry Canyon, UT	93	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Radioactive Metals; Heavy Metals	1997	2000
Gold Coast Superfund Site, FL	95	Air Sparging; Pump and Treat	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1994	1998
Hanford Site, 100-H and 100-D Areas, WA	101	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater	Heavy Metals	1995	2000
Hunter's Point Ship Yard, Parcel C, Remedial Unit C4, CA	357	Chemical Oxidation/Reduction (*in situ*)	Groundwater; DNAPLs	TCE; Volatiles-Halogenated	2002	2004
ICN Pharmaceuticals, OR	334	Thermal Treatment (*in situ*); SVE	Groundwater; Soil; DNAPLs	TCE; DCE; Volatiles-Halogenated	2000	2003
Johannsen Cleaners, Lebanon, OR	120	Multi Phase Extraction	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Keesler Air Force Base Service Station, AOC-A (ST-06), MS	123	Monitored Natural Attenuation	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated; Heavy Metals	1997	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Kelly Air Force Base, Former Building 2093 Gas Station, TX	124	Monitored Natural Attenuation	Groundwater; Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1997	2000
Lawrence Livermore National Laboratory Gasoline Spill Site, CA	130	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated	1992	1995
Louisiana Army Ammunition Plant, LA	142	Monitored Natural Attenuation	Groundwater	Explosives/Propellants	Not Provided	2001
Marshall Space Flight Center, AL	336	Chemical Oxidation/Reduction (*in situ*); Fracturing; Permeable Reactive Barrier (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	2000	2003
Massachusetts Military Reservation, CS-10 Plume, MA	159	In-Well Air Stripping (UVB and NoVOCs) (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2002
McClellan Air Force Base (AFB), OU A, CA	151	Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated	1999	2001
Miamisburg, OH	343	Air Sparging; SVE	Groundwater; Soil	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1997	2001
Milan Army Ammunition Plant, TN	157	Phytoremediation (Field Demonstration)	Groundwater	Explosives/Propellants	1996	2000
Moffett Field Superfund Site, CA	163	Permeable Reactive Barrier (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2000
Moffett Federal Airfield, CA	161	Permeable Reactive Barrier (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1996	1998
Monticello Mill Tailings Site, Monticello, UT	164	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Metals	1999	2001

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple Dry Cleaner Sites	171	Air Sparging; SVE	Groundwater; Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001, 2002
Multiple (10) Sites - Air Sparging, Various Locations	342	Air Sparging	Groundwater; Soil	TCE; PCE; DCE; Volatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenat ed; BTEX; Volatiles-Nonhalogenated; MTBE; Petroleum Hydrocarbons	Various years	2002
Multiple Air Force Sites	177	Multi Phase Extraction (Field Demonstration)	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	Not Provided	2001
Multiple Air Force Sites	178	Monitored Natural Attenuation (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1993	1999
Multiple Air Force Sites	179	Monitored Natural Attenuation (Field Demonstration)	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1993	1999
Multiple DoD Sites, Various Locations	347	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Volatiles-Halogenated	Various years	2003
Multiple (2) Dry Cleaner Sites, Various Locations	324	Chemical Oxidation/Reduction (*in situ*)	Groundwater; Dense Non-aqueous Phase Liquids (DNAPLs)	PCE; TCE; Volatiles-Halogenated	Various years - starting 1998	2003
Multiple (2) Dry Cleaners - In Well Air Stripping	364	In-Well Air Stripping	Soil; Groundwater	PCE; TCE; Volatiles-Halogenated	1994	2004

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple Dry Cleaner Sites	175	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1999	2001, 2002
Multiple Dry Cleaner Sites	173	Multi Phase Extraction; Pump and Treat	Groundwater; Soil; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001, 2002
Multiple Sites	167	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1991	2002
Multiple Sites	166	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals; Radioactive Metals; Arsenic	1997	2002
Multiple Sites	169	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Radioactive Metals; Arsenic	1995	2002
Multiple Sites	170	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Radioactive Metals; Pesticides/Herbicides	1995	2002
Multiple Sites	168	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Heavy Metals; Radioactive Metals	1995	2002

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple Dry Cleaner Sites	172	Flushing (*in situ*); Thermal Treatment (*in situ*); In-Well Air Stripping (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001
Multiple (4) Dry Cleaner sites - In Situ Chemical Oxidation	385	Chemical Oxidation/Reduction (*in situ*)	Groundwater; Soil; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; Heavy Metals	Various years - starting 2001	2005
Naval Air Station, Pensacola, FL	187	Chemical Oxidation/Reduction (*in situ*)	Groundwater	TCE; DCE; Volatiles-Halogenated	1998	2001
Naval Submarine Base, Kings Bay, GA	193	Chemical Oxidation/Reduction (*in situ*); Monitored Natural Attenuation	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1999	2001
Naval Submarine Base, Kings Bay, GA	192	Chemical Oxidation/Reduction (*in situ*)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1998	2000
Naval Air Engineering Station (NAES) Site (Area I), NJ	353	Chemical Oxidation/Reduction (*in situ*)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	2002	2004
Naval Amphibious Base Little Creek, Site 11, GA	375	Flushing (*in situ*) (Field Demonstration)	Groundwater; Soil	DCE; TCE; Volatiles-Halogenated	2002	2005
Naval Air Station, North Island, CA	186	In-Well Air Stripping (NoVOCs) (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1998	2000
Naval Air Station, Pensacola, OU 10, FL	184	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1998	2000
Oak Ridge National Laboratory, TN	202	Permeable Reactive Barrier - Funnel and Gate Configuration and Trench (Field Demonstration)	Groundwater	Radioactive Metals	1997	2002

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Pinellas Northeast Site, FL	220	Thermal Treatment (*in situ*) - Dual Auger Rotary Steam Stripping (Field Demonstration)	Groundwater; Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1996	1998
Portsmouth Gaseous Diffusion Plant, X-701B Facility, OH	226	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater; DNAPLs	TCE; Volatiles-Halogenated	1988	2000
RMI Titanium Plant, Ashtabula Environmental Management Project, OH	232	Flushing (*in situ*) (WIDE) (Field Demonstration)	Groundwater; Soil	TCE; Volatiles-Halogenated; Radioactive Metals	1999	2001
Scotchman #94, Florence, SC	253	Multi Phase Extraction; Air Sparging; SVE	Groundwater; Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; MTBE; Volatiles-Nonhalogenated	1998	2001
Site 88, Building 25, Marine Corps Base Camp Lejeune, NC	147	Flushing (*in situ*) (SEAR) (Field Demonstration)	Groundwater; DNAPLs; LNAPLs	Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated	1999	2001
South Prudence Bay Island Park, T-Dock Site, Portsmouth, RI	269	Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Volatiles-Nonhalogenated	1998	2001
Sparks Solvents/Fuel Site, Sparks, NV	271	Multi Phase Extraction	Groundwater; LNAPLs	BTEX; MTBE; Volatiles-Nonhalogenated; PCE; TCE; Volatiles-Halogenated	1995	2001
Tinkham's Garage Superfund Site, NH	281	Multi Phase Extraction	Groundwater; Soil	PCE; TCE; Volatiles-Halogenated	1994	2000
U.S. Coast Guard Support Center, NC	287	Permeable Reactive Barrier	Groundwater; DNAPLs	TCE; Volatiles-Halogenated; Heavy Metals	1996	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy Savannah River Site, A/M Area, SC	294	In-Well Air Stripping; Pump and Treat (Field Demonstration)	Groundwater; Soil; DNAPLs	PCE; TCE; Volatiles-Halogenated	1990	1995
Visalia Superfund Site, CA	309	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater	Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1997	2000
Westover Air Reserve Base, MA	377	Phytoremediation; Bioremediation (*in situ*) (Field Demonstration)	Stormwater	Semivolatiles-Nonhalogenated	2001	2005
Debris/Solid Media Treatment (28 Projects)						
Alabama Army Ammunition Plant, AL	4	Thermal Desorption (*ex situ*) (Field Demonstration)	Debris/Slag/ Solid	Explosives/Propellants	1995	1998
Argonne National Laboratory - East, IL	9	Physical Separation (Scabbling) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	Not Provided	2000
Argonne National Laboratory - East, IL	11	Physical Separation (Concrete Demolition) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000
Argonne National Laboratory, IL	10	Solidification/Stabilization (Phosphate Bonded Ceramics) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Heavy Metals	Not Provided	2000
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	38	Physical Separation (Centrifugal Shot Blast) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	39	Physical Separation (Rotary Peening with Captive Shot) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	40	Physical Separation (Roto Peen Scaler with VAC-PAC[R] System) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	1998

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Clemson University, SC	42	Solidification/Stabilization (Sintering) (Bench Scale)	Debris/Slag/ Solid	Heavy Metals	1995	2000
Envirocare of Utah, UT	67	Solidification/Stabilization (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	1998
Fernald Site, OH	71	Physical Separation (Soft Media Blasting) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	2000
Hanford Site, C Reactor, WA	102	Solidification/Stabilization (Polymer Coating) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Hanford Site, WA	97	Physical Separation(Concrete Grinder) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000
Hanford Site, WA	98	Physical Separation (Concrete Shaver) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000
Hanford Site, WA	99	Physical Separation (Concrete Spaller) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1998	2000
Hanford Site, WA	100	Solidification/Stabilization (Polyester Resins) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Radioactive Metals; Heavy Metals; Arsenic	Not Provided	2000
Hanford Site, WA	103	Physical Separation; Solvent Extraction (Ultrasonic Baths) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1998	1998
Idaho National Engineering and Environmental Laboratory, ID	110	Solidification/Stabilization (Innovative Grouting and Retrieval) (Full scale and Field Demonstration)	Debris/Slag/ Solid; Soil	Radioactive Metals	1994	2000
Idaho National Engineering and Environmental Laboratory, ID	109	Solidification/Stabilization (DeHg^{SM} Process) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	1998	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Idaho National Engineering and Environmental Laboratory, ID	113	Physical Separation (Wall Scabbler) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	2000	2001
Idaho National Engineering and Environmental Laboratory, ID	112	Vitrification (*ex situ*) (Graphite Furnace) (Field Demonstration)	Debris/Slag/ Solid; Organic Liquids; Soil	Heavy Metals; Radioactive Metals	1997	2000
Idaho National Engineering and Environmental Laboratory, Pit 2, ID	111	Solidification/Stabilization (Polysiloxane) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Heavy Metals	1997	2000
Lawrence Livermore National Laboratory, CA	132	Chemical Oxidation/Reduction (*ex situ*) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	PCE; TCE; Volatiles-Halogenated PCBs; Semivolatiles-Halogenated; Explosives/Propellants	Not Provided	2000
Los Alamos National Laboratory, NM	139	Solidification/Stabilization (ADA Process) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	1998	2000
Los Alamos National Laboratory, Technical Area 33, NM	140	Solidification/Stabilization (Field Demonstration)	Sludge	Heavy Metals; DCE; Volatiles-Halogenated; Radioactive Metals	1997	2000
Pacific Northwest National Laboratory, WA	210	Solidification/Stabilization (Sol Gel Process) (Bench Scale)	Debris/Slag/ Solid; Groundwater	Heavy Metals	Not Provided	2000
Portsmouth Gaseous Diffusion Plant, OH	224	Solidification/Stabilization (ATG Process) (Field Demonstration)	Organic Liquids	Heavy Metals; Radioactive Metals	1998	2000
Savannah River Site, SC	249	Acid Leaching (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	2000

EXHIBIT A-1. SUMMARY OF 374 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
STAR Center, ID	274	Vitrification (*ex situ*) (Plasma Process) (Field Demonstration)	Debris/Slag/ Solid; Soil; Sludge	Heavy Metals; Radioactive Metals	1993	2000
Containment (7 Projects)						
Dover Air Force Base, Groundwater Remediation Field Laboratory National Test Site, Dover DE	58	Containment - Barrier Walls (Field Demonstration)	Groundwater	-	1996	2001
Lawrence Livermore National Laboratory (LLNL) Site 300 - Pit 6 Landfill OU, CA	131	Containment - Caps	Debris/Slag/ Solid	TCE; Volatiles-Halogenated; Radioactive Metals	1997	1998
Marine Corps Base Hawaii, HI	148	Containment - Caps (Field Demonstration)	Soil	-	1994	1998
Naval Shipyard, CA	191	Containment - Caps (Field Demonstration)	Soil	BTEX; Volatiles-Nonhalogenated	1997	1998
Oak Ridge National Laboratory, TN	200	Containment - Barrier Walls (Field Demonstration)	Soil; Sediment; Groundwater	Radioactive Metals	1996	2000
Sandia National Laboratory, Albuquerque, NM	247	Containment - Caps (Field Demonstration)	Soil	-	1995	2001
U.S. Department of Energy, SEG Facilities, TN	252	Containment - Barrier Walls (Field Demonstration)	Soil	-	1994	1997

* Full scale unless otherwise noted
† Technology focused on in case study listed first, followed by other technologies identified in the case study

Key:

DNAPLs	= Dense Non-Aqueous Phase Liquids	TCE	= Trichloroethene
SVE	= Soil Vapor Extraction	PCE	= Tetrachloroethene
BTEX	= Benzene, Toluene, Ethylbenzene, and Xylene	DCE	= Dichloroethene
PAHs	= Polycyclic Aromatic Hydrocarbons	LNAPLs	Light Non-Aqueous Phase Liquids
PCBs	= Polychlorinated Biphenyls	MTBE	= Methyl tert-butyl ether

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