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Examples of Groundwater Remediation at NPL Sites

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Cover pictures from top, clockwise: Groundwater treatment facility at Pemaco Superfund Site; In situ thermal treatment at Fort Lewis Logistics Center Superfund Site; Treatment Plant #1 at Holingsworth Solderless Terminal Superfund Site; Treatment building and air stripper tower at Tabernacle Drum Dump Superfund Site.

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List of Acronyms and Abbreviations

Bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Contaminant of Concern
DCE	dichloroethene
DNAPL	Dense Non-aqueous Phase Liquid
DUS	Dynamic Underground Stripping
EPA	U.S. Environmental Protection Agency
ERD	Enhanced Reductive Dechlorination
ERH	Electrical Resistance Heating
ESD	Explanation of Significant Differences
ISCO	In Situ Chemical Oxidation
ISCR	In Situ Chemical Reduction
ISTT	In Situ Thermal Treatment
LNAPL	Light Non-aqueous Phase Liquid
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
OSRTI	Office of Superfund Remediation and Technology Innovation
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCE	Tetrachlorothene
ppm	Parts per million
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RPM	Remedial Project Manager
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
SWRAU	Sitewide Ready for Anticipated Use
TCE	trichloroethene
TSD	Treatment, Storage and Disposal
UST	Underground Storage Tank
UXO	Unexploded Ordnance
VEB	Vertical Engineered Barrier
VOC	Volatile Organic Compound

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Executive Summary

This report documents where innovative and established technologies have been used to restore groundwater to beneficial use. This report includes a select number of example National Priorities List (NPL) sites where the remedial action objective (RAO) and associated cleanup levels were to restore groundwater for use as a source of drinking water. Groundwater was restored for use as drinking water at 17 NPL sites and significant progress toward groundwater restoration has been made at an additional 13 NPL sites where contaminants remain above safe drinking water levels in only a few groundwater wells. The RAO of restoring groundwater for beneficial use was achieved under the Superfund program, including the successful treatment of groundwater to federal and state maximum contaminant levels for drinking water. These sites are examples of where the Superfund program overcame difficult remediation challenges, such as groundwater contaminated with chlorinated solvents (including the presence of dense non-aqueous phase liquids [DNAPLs]) and complex hydrogeologic settings.

The NPL sites discussed in this report were selected based on several criteria, including the use of innovative cleanup technologies or approaches to remedy concentrated groundwater plumes. The most commonly occurring contaminants of concern at these sites were chlorinated volatile organic compounds, which were present at 26 of the 30 sites. The less frequently occurring contaminants included metals, non-chlorinated volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons, with dioxins or pesticides only present at one site.

The restoration of groundwater was achieved most often by combining remedial technologies. For example, soil excavation and groundwater extraction and treatment (i.e., pump-and-treat) were used to restore groundwater at 17 of the 30 NPL sites. Given that many of these sites were cleaned up during the period from 1983 to 2000, the remedies used at these sites represented state of the art technologies at that time. These traditional technologies were often modified or replaced with innovative technologies such as in situ bioremediation, in situ chemical oxidation (ISCO), in situ thermal treatment (ISTT) or monitored natural attenuation (MNA) at some sites. The application of remedial technologies at these sites decreased contaminant concentrations from 90% up to 99.99% (i.e., one to more than four orders of magnitude).

DNAPLs were found or suspected at eight of the 30 sites. A combination of excavation and pump-and-treat was used most often to remediate these sites along with at least one other technology or approach such as vertical engineered barrier, air sparging, in situ bioremediation, ISTT, or MNA. Of the eight DNAPL sites, groundwater was restored for use as drinking water at three sites and significant progress towards restoration has been made at five sites. These findings indicate that the Superfund program has achieved the cleanup of sites with DNAPLs.

The time required to restore groundwater for use as drinking water at the 17 NPL sites ranged from three to 27 years with a median time of eight years. Cleanup time generally increased as the amount of contaminant removed increased with the exception of four sites where contaminant concentrations were decreased by nearly 99.99% in less than eight years. Cleanup times were generally shorter for sites with less complex hydrogeologic settings with the exception of three sites with mild heterogeneity that required more than 15 years to restore groundwater. Also, in most cases, cleanup times were shorter for lesser reductions in concentration.

All of the 30 sites, with the exception of two, have achieved the status of sitewide ready for anticipated reuse (SWRAU), and 12 of these sites have been returned to use either in whole or in part. Reuse includes industrial and commercial redevelopment, recreational use, alternative energy use, and lifting of groundwater use restrictions.

1. Purpose and Scope

The report is intended for federal and state agency personnel, potentially responsible parties, cleanup consultants, and remediation site managers to demonstrate where innovative and established technologies have been used to restore groundwater to beneficial use. As such, this report documents a select number of example NPL sites where the remedial action objective (RAO) and associated cleanup levels were to restore groundwater for use as a source of drinking water. Cleanups that only addressed contaminated soils are not included. However, soil cleanup is covered where it was part of the effort to restore groundwater.

The NPL sites in this report contained contaminants of concern (COCs) such as chlorinated and non-chlorinated volatile and semivolatile organic compounds (VOCs and SVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals. This report excludes sites that were primarily contaminated with petroleum hydrocarbons, contained unexploded ordnance (UXO) or radioactive contamination.

Groundwater contamination at these sites resulted from operations including landfills or dumps, chemical production, manufacturing, metal works or plating, waste storage and disposal, and wood treatment facilities. The sites are in residential neighborhoods, industrial parks or former factories, and at federal facilities.

This report is not intended to be a remedial technology primer and does not contain general descriptions of the technologies applied. More information about the breadth of technologies, contaminant groups, and remedies is addressed in other documents such as the Superfund Remedy Report, Fifteenth Edition[1] and the Contaminated Site Clean-Up Information (CLU-IN[2]) website.

1.1 Remedial Action Objectives and Associated Cleanup Levels

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) RAOs specify "contaminants and media of concern, potential exposure pathways, and remedial goals."[3] Consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), "RAOs provide a general description of what the cleanup will accomplish (*e.g.,* restoration of groundwater to drinking water levels)."[4] Groundwater remedies will often have a restoration RAO based on the NCP expectation that groundwater will be restored to its beneficial use within a reasonable timeframe.[5] Drinking water is most often the beneficial use of groundwater, but non-potable use is possible if groundwater is determined to be unsuitable for human consumption[6]. Sites with multiple types of contaminated media, unusual media, or a very large extent of contamination are often addressed with multiple types of RAOs.

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[1] http://www.clu-in.org/asr/

[2] http://www.clu-in.org/

[3] 40 CFR 300.430(e)(2)(i)

[4] EPA. 1999a. A Guide to Preparing Superfund Proposed Plans, Records of Decision and Other Remedy Selection Decision Documents. OSWER Directive No. 9200.1-23P.

[5] *"EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site. When restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction"* 40 CFR 300.430(a)(1)(iii)(F).

[6] Groundwater Use Policy (55 FRN 8732)

RAOs may include specific cleanup levels for the media and the objective addressed.[7] Examples of cleanup levels include maximum contaminant levels (MCLs), which are drinking water standards established under the Safe Drinking Water Act. Federal MCLs are often Applicable or Relevant and Appropriate Requirements (ARARs) for groundwater remedies at NPL sites. The RAOs for each of the 30 NPL sites included in this report are presented in Table A.6. This report does not assess every cleanup RAO and associated cleanup level for all of the NPL sites presented. For example, the report does not discuss some RAOs and cleanup levels for soil if they are not related to the groundwater cleanup. In order to simplify the discussion of remedy performance, the report only includes cleanup levels for a subset of contaminants of concern, for instance those with the highest initial concentrations or that are representative of the cleanup progress.

1.2 Site Selection Process

To determine which sites to include in this report, the following information sources were reviewed:

- List of sites deleted from the NPL.
- Recommendations from EPA, state, and other federal Remedial Project Managers (RPMs), EPA regional technical staff and headquarters staff.
- Databases accessed through online sources such as Federal Remediation Technologies Roundtable[8] (FRTR), Interstate Technology & Regulatory Council[9] (ITRC), and CLU-IN.
- EPA Superfund site profile websites and fact sheets.

Out of this review approximately 175 sites were identified as candidates for inclusion in this report. From these, the final sites were selected based on one or more of the following criteria:

- Achieved groundwater restoration.
- Groundwater plume with initial contaminant concentrations of greater than 100 micrograms per liter (µg/L or ppb).
- Utilized innovative cleanup technologies or approaches.
- Site was redeveloped or ready for reuse and redevelopment.

In addition, an attempt was made to represent a range of contaminant types, remedies used, and hydrogeologic complexity. Sites with an ongoing cleanup were included if they fit the above criteria and where contaminants remain above cleanup levels in only a few groundwater wells. These sites have achieved significant progress towards groundwater restoration.

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[7] 40 CFR 300.430(e)(2)(i)

[8] https://frtr.gov/

[9] http://www.itrcweb.org/

2. Observations and Analysis of Cleanups

This report addresses groundwater remedies at 30 NPL sites, including 17 remedies that have achieved groundwater restoration (Table 2.1) and 13 that have achieved significant progress towards groundwater restoration (Table 2.2). The cleanups that achieved groundwater restoration were listed on the NPL between 1983 and 1990, and all but two were deleted from the NPL between 1996 and 2011 with a total time listed on the NPL ranging from 11 to 25 years (Table 2.1).

Table 2.1 NPL Sites that Achieved Groundwater Restoration

Site	Year Listed	Years on NPL	Cleanup Levels
1. Del Norte County Pesticide Storage, CA (OU 1)	1984	18	Fed MCL†
2. Firestone Tire and Rubber, CA (OU 1)	1987	18	State MCL/ Risk Based
3. Frontier Hard Chrome, Inc., WA (OU's 1 and 2)	1983	*	Fed MCL/ State MCL
4. Gold Coast Oil Corp., FL (OU 1)	1983	13	Fed MCL
5. Island Chemical Corp/V.I. Chemical Corp, Virgin Islands (OU 1)	1996	13	Fed MCL
6. Mannheim Avenue Dump, NJ (OU 1)	1983	24	State MCL
7. Odessa Chromium II, TX (OU's 1-3)	1986	18	Fed MCL
8. Pasley Solvents and Chemicals, Inc., NY (OU 1)	1986	25	Fed MCL
9. Rochester Property, SC (OU 1)	1989	18	Fed MCL
10. SMS Instruments, NY (OU 1)	1986	24	Fed MCL/ State MCL
11. Southern California Edison, Visalia Pole Yard, CA (OU 1)	1989	20	Fed MCL‡
12. Tabernacle Drum Dump, NJ (OU 1)	1984	24	State MCL
13. Tri-State Plating, IN (OU 1)	1986	11	Fed MCL
14. Vestal Water Supply Well 4-2, NY (OU 1)	1983	16	Fed MCL
15. Waverly Groundwater Contamination, NE (OU 1)	1986	20	Fed MCL
16. Western Pacific Railroad Co., CA (OU 1)	1990	11	Fed MCL/ Sate MCL
17. Western Processing, WA (OU 2), Offsite Trans Plume	1983	**	Fed MCL

Notes:
†Technical Impracticability (TI) waiver for MCL in 2002, EPA plans to amend TI waiver to allow for unrestricted use.
* Deletion anticipated in 2018, pending review of all criteria.
‡Covenant between Southern California Edison and the California Department of Toxics Substance Control (DTSC) prohibits installation of water wells for any purpose.
** Offsite trans plume achieved RAOs, however, other OUs at Western Processing still undergoing cleanup; therefore, the site remains on the NPL.

The sites where contaminants remain above cleanup levels in only a few wells were listed on the NPL between 1983 and 1996 (Table 2.2).

Table 2.2 NPL Sites that Achieved Significant Progress towards Groundwater Restoration

Site	Year Listed	Cleanup Levels
1. Browns Battery Breaking, PA (OU's 1 and 2)	1986	Fed MCL/ State MCL
2. Dover AFB - SS07/Area 2, DE (OU 15)	1989	State MCL
3. Eastern Surplus Company, ME	1996	Fed MCL
4. Fort Lewis Logistics Center, WA (East Gate Disposal Yard, Landfill 2)	1989	Fed MCL
5. Hollingsworth Solderless Terminal, FL (OU 1)	1983	Fed MCL
6. King of Prussia, NJ (OU's 1-3)	1983	Risk Based/ Fed MCL
7. LeHillier/Mankato Site, MN (OU 1)	1983	Fed MCL
8. Letterkenny Army Depot (Southeast Area), PA (OU 10)	1987	Fed MCL
9. Malvern TCE, PA (OU's 1-4)	1983	Fed MCL
10. Mystery Bridge Road/Highway 20 (Dow/DSI), WY (OU's 1 and 2)	1990	Fed MCL
11. NCR Corp., DE (OU 1)	1987	Fed MCL
12. Pemaco, CA (OU 1)	1999	Fed MCL
13. US Aviex, MI (OU 1)	1983	Risk Based/ Fed MCL

The cleanup levels for sites with multiple contaminants can be based on federal MCLs for one contaminant and state MCLs for another. Some contaminants have cleanup levels based on equivalent federal and state MCLs. Four cleanups achieved a state-based MCL that was more stringent than the federal MCL, including:

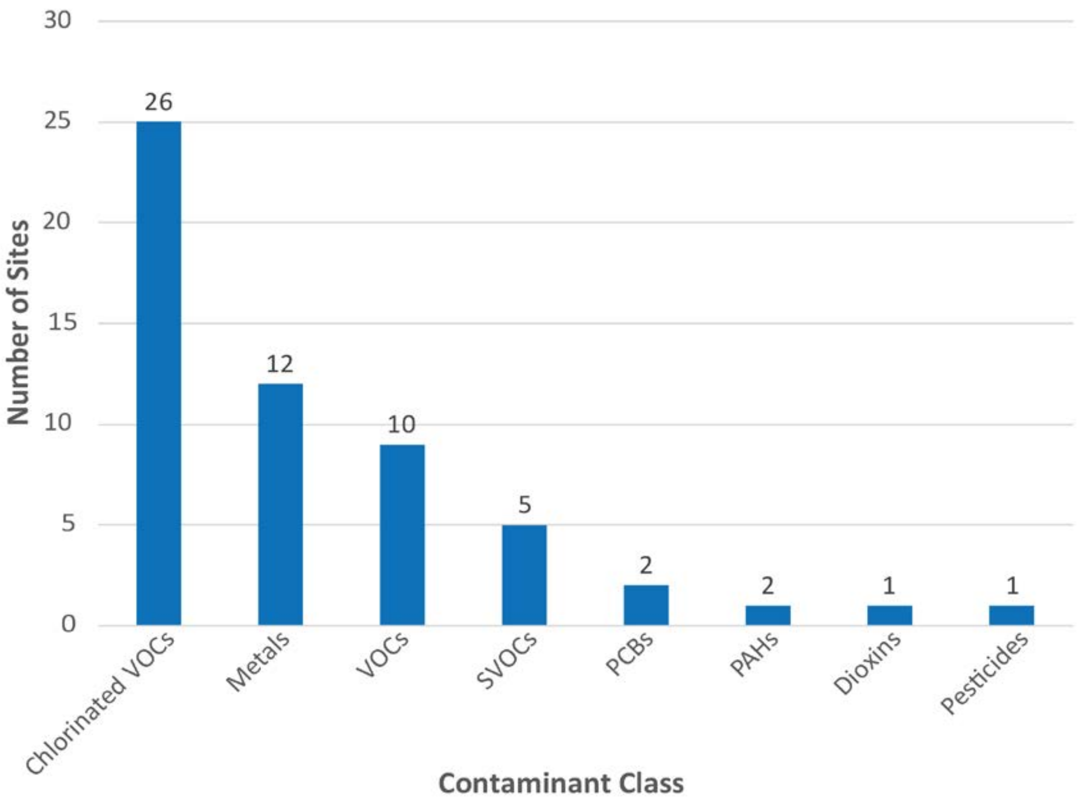
- Firestone Tire and Rubber site in California where 1,1-dichloroethene (1,1-DCE) was reduced from a maximum of 120 ppb to less than the California cleanup level of 6 ppb (Federal MCL of 70 ppb).
- Mannheim Avenue Dump site in New Jersey where trichloroethene (TCE) was reduced from a maximum of 140 ppb to less than the New Jersey cleanup level of 1 ppb (Federal MCL of 5 ppb).
- Tabernacle Drum Dump site in New Jersey where trichloroethane (TCA) was reduced from a maximum of 1,000 ppb to less than the New Jersey cleanup level of 26 ppb (Federal MCL of 200 ppb).
- SMS Instruments site in New York where total dichlorobenzene was reduced from a maximum of 570 ppb to below the New York cleanup level of 3 ppb (Federal MCLs of 600 ppb for o-dichlorobenzene and 75 ppb for p-dichlorobenzene).

The most commonly occurring COCs were chlorinated VOCs, which were present at 26 of the 30 sites (Figure 2.1). Metals were also prevalent, and were COCs at 12 of the 30 sites. The less frequently occurring contaminants included non-chlorinated VOCs, SVOCs, and PCBs.

The presence of DNAPL was observed as a separate phase in groundwater monitoring wells or groundwater samples at two sites including:

- Fort Lewis Logistics Center, WA (East Gate Disposal Yard, Landfill 2)
- Southern California Edison, Visalia Pole Yard (OU 1)

Figure 2.1 Frequency of Contaminant Classes at 30 NPL Sites



DNAPL was suspected to be present based on contaminant concentrations being above one percent of their aqueous solubility limit[10] at the following sites:

- Dover AFB - SS07/Area 2 (OU 15)
- Gold Coast Oil Corp. (OU 1)
- Malvern TCE (OU’s 1-4)
- Pasley Solvents and Chemicals, Inc. (OU 1)
- NCR Corp. (OU 1)
- Pemaco (OU 1)

The groundwater restoration remedies presented in this report were implemented at sites that represent a wide range of hydrogeologic environments. As shown in Table 2.3, the sites have been categorized into one of four different hydrogeologic settings, from granular media (e.g., sand) with mild to high heterogeneity (Types I and III) to more heterogeneous fractured media (Types IV and V). These hydrogeologic settings correspond to how contaminants are stored and released in the subsurface where regions with higher storage potential generally equate to longer cleanup times[11].

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[10] USEPA. Estimating Potential for Occurrence of DNAPL at Superfund Sites. OSWER Publication 9355.4-07FS. January 1992.

[11] *Contaminants in the Subsurface: Source Zone Assessment and Remediation*, Committee on Source Removal of Contaminants in the Subsurface, National Research Council, 2004 (http://www.nap.edu/catalog/11146.html).

Table 2.3 Hydrogeologic Setting and Contaminant Phase

Hydrogeologic Setting	Contaminant Phase	
	Dissolved Phase	DNAPL or Suspected DNAPL
Granular Media with Mild Heterogeneity (Type I)	• Del Norte County Pesticide Storage, CA (OU 1) • Hollingsworth Solderless Terminal, FL (OU 1) • LeHillier/Mankato Site, MN (OU 1) • SMS Instruments, NY (OU 1) • Tabernacle Drum Dump, NJ (OU 1) • Tri-State Plating, NJ (OU 1) • Waverly Groundwater Contamination, NE (OU 1)	• Gold Coast Oil Corp., FL (OU 1) • Pasley Solvents and Chemicals, NY (OU 1)
Granular Media with Moderate to High Heterogeneity (Type III)	• Browns Battery Breaking, PA (OU's 1 and 2) • Eastern Surplus Company, ME (OU 1), Southern PCE Plume • Firestone Tire and Rubber, CA (OU 1) • Frontier Hard Chrome, Inc., WA (OU’s 1-2) • Island Chemical Corp/V.I. Chemical Corp, Virgin Islands (OU 1) • King of Prussia, NJ (OU's 1-3) • Mannheim Avenue Dump, NJ (OU 1) • Mystery Bridge Road/Highway 20 (Dow/DSI), WY (OU's 1 and 2) • US Aviex, MI (OU 1) • Vestal Water Supply Well 4-2, NY (OU 1) • Western Pacific Railroad Co., CA (OU 1) • Western Processing, WA (OU 2, Offsite Trans Plume	• Dover AFB, SS07/Area 2, South Management Unit (OU 15) • Fort Lewis Logistics Center, WA - East Gate Disposal Yard (Landfill 2) • Pemaco, CA (OU 1) • NCR Corp. (OU 1) • Southern California Edison, Visalia Pole Yard, CA (OU 1)
Fractured Media with Low Matrix Porosity (Type IV)	None	• Malvern TCE (OU’s 1-4)
Fractured Media with High Matrix Porosity (Type V)	• Letterkenny Army Depot (Southeast Area), PA (OU 10) • Odessa Chromium II, TX (OU’s 1-3) • Rochester Property, SC (OU 1)	None

Notes:
(1) None of the sites in this report had hydrogeology described as granular media with mild heterogeneity and low permeability (Type II).
(2) LNAPL also present at Fort Lewis East Gate Disposal Yard.

The following sections discuss the technologies applied to restore contaminated groundwater (2.1), the technologies used at sites where DNAPL was observed or suspected (2.2), the decrease in contaminant levels achieved by the cleanup (2.3), and the time required to accomplish the cleanup (2.4). Appendix A contains several tables summarizing the detailed site information which served as the basis for the following sections. Appendix B contains case summaries for 17 of the 30 NPL sites. These case summaries include a brief description and history of the site, the extent of contamination, the remedial technologies used, and the successes achieved. This information was gathered from site-specific documents such as Five-Year Reviews, Record of Decisions (RODs), ROD Amendments, Explanations of Significant Differences, Remedial Investigation Reports, Feasibility Studies, Remedial and Removal Action Reports and Long Term Monitoring Reports.

2.1 Technologies Applied to Restore Groundwater

Figure 2.2 shows the number of times a technology was used at a NPL site and is based on the summary tables presented in Appendix A (Table A.1 and Table A.2). The technologies applied to restore groundwater at the 30 NPL sites fit into 12 categories as summarized in Figure 2.2. The categorization of technologies was done for the sake of this analysis and contains some assumptions. For example, hydrogen peroxide was injected while operating a pump-and-treat system at some sites and this was categorized as pump-and-treat rather than as in situ chemical oxidation (ISCO) and pump-and-treat. This was because the hydrogen peroxide was added to improve contaminant recovery by degrading organic carbon rather than degrading the contaminant of concern. The category excavation/removal includes both the excavation of soil and removal of drums or debris. Some of these technologies only addressed contaminated groundwater (e.g., pump-and-treat), others were used to remove contaminants only from soil (e.g., soil vapor extraction or SVE), while some were used to remove contaminants from groundwater and soil (e.g., in situ thermal treatment). Given that contaminated soil can serve as the long-term source of groundwater contamination, this report includes all the technologies that were applied at a given site to restore groundwater, even if the technology only addressed contaminated soil.

Figure 2.2 Remedial Technologies and Approaches Associated with 30 NPL Sites

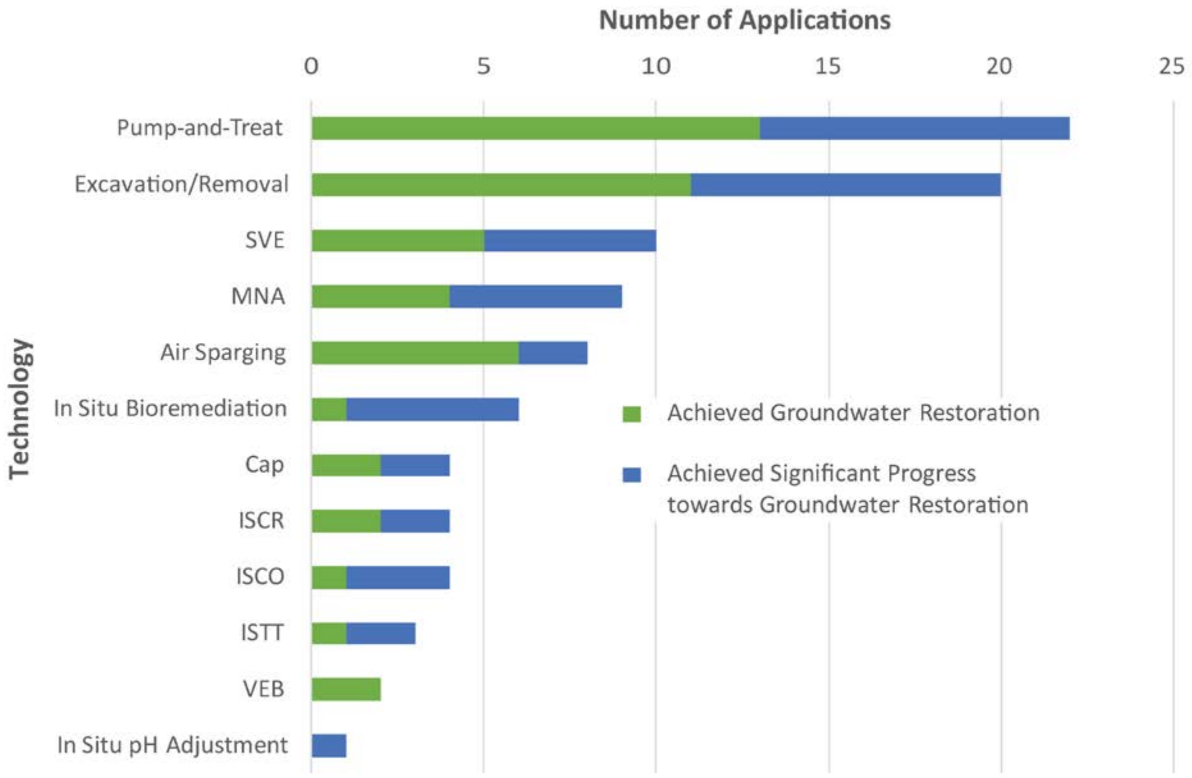


Figure 2.2 shows that pump-and-treat and excavation/removal were the most commonly applied technologies at the 30 NPL sites. Some sites had more than one pump-and-treat system, but were counted as only one application for this report. Other technologies implemented at sites with groundwater cleanups included SVE, monitored natural attenuation (MNA), capping, air sparging, in situ bioremediation, ISCO, in situ chemical reduction (ISCR), in situ thermal treatment (ISTT), and in situ pH adjustment. Vertical engineered barriers (VEB) were used to temporarily contain contaminated groundwater at two sites as part of groundwater restoration efforts.

The four ISCO applications used ozone, sodium permanganate or hydrogen peroxide to remediate chlorinated VOCs. Among the three ISTT applications, electrical resistance heating (ERH) was used at two sites, and dynamic underground stripping (DUS) with steam (a form of ISTT similar to steam enhanced extraction) was used at one site. Two of the ISCR applications were conducted to remediate hexavalent chrome (Cr^{6+}) contamination. At both sites Cr^{6+} was reduced to Cr^{3+} using sodium dithionite or ferrous sulfate as the reducing agent.

Figure 2.2 shows the total number of technologies used to restore groundwater at the 30 NPL sites. When viewed from a site-specific perspective, multiple technologies were used in combination to restore groundwater. For example, at the Gold Coast Oil Corp. site, excavation was initially used to remove soil contaminated with VOCs, followed by four years of pump-and-treat (P&T), and finally excavation and air sparging were used to remove regions suspected to contain DNAPL (Figure 2.3). Thus, three technologies (excavation, pump-and-treat, and air sparging) were used to restore groundwater at the Gold Coast Oil Corp. site in a period of six years (1989 to 1995).

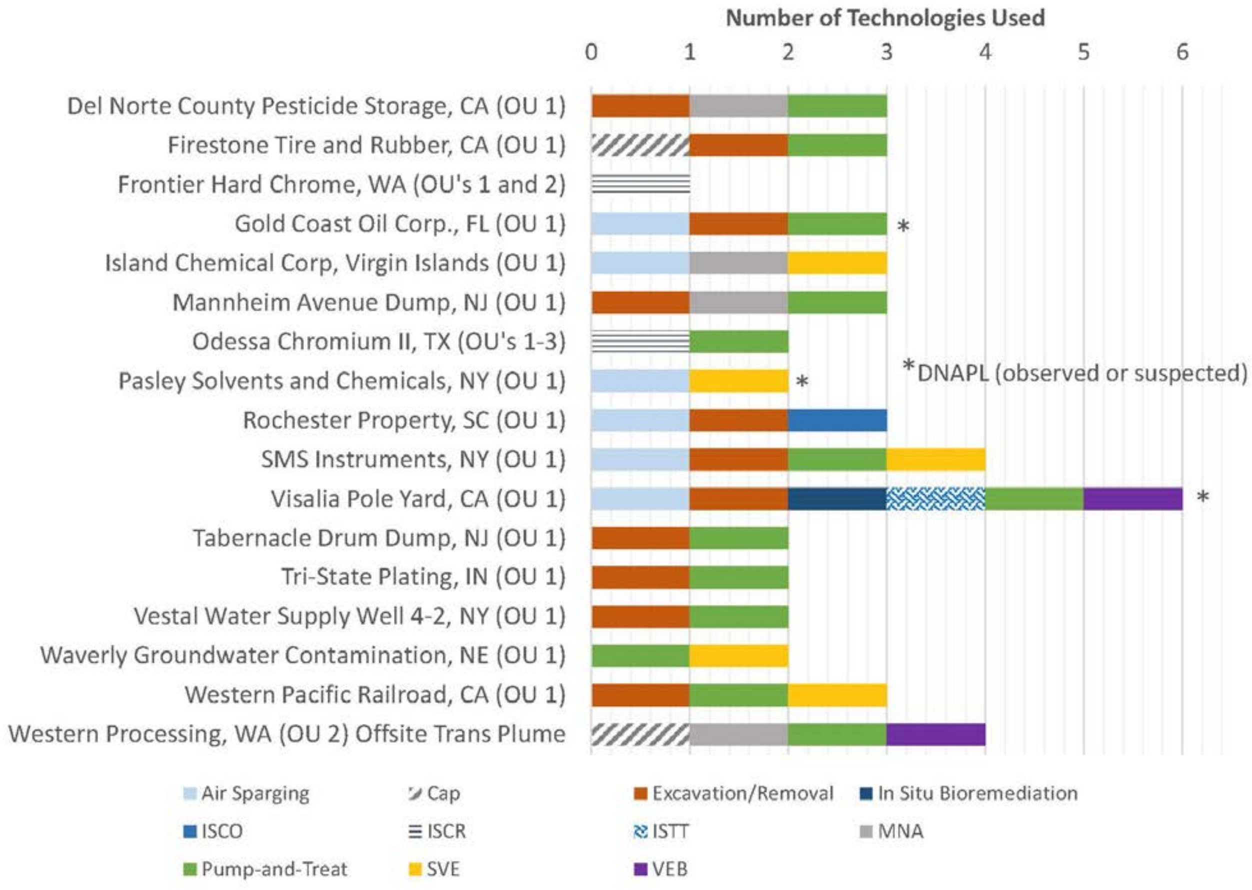
Figure 2.4 shows that the number of technologies used at the sites that achieved groundwater restoration ranged from one to as many as six, and was most commonly the combination of two or three technologies. Importantly, Figure 2.4 is not a timeline indicating the order in which these technologies were used at a site. The most frequently used technology combination was excavation/removal and pump-and-treat, which was used at 10 of the 17 sites. Given that many of these sites were cleaned up during the period from 1983 to 2000, these remedies represented state of the art technologies at that time.

Gold Coast Oil Corporation Superfund Site:
Achieved Groundwater Restoration in Six Years

The Gold Coast Oil Corp. Superfund site is a 2-acre property that operated as an oil and solvent reclamation and bulk storage facility from the early 1970s until 1982. Remedial actions included the excavation and disposal of visibly contaminated soil in 1989, followed by extracting groundwater from five wells and treating with air stripping towers beginning in 1990. There were two efforts to enhance contaminant extraction during pump-and-treat operation, first hydrogen peroxide was injected into two monitoring wells that were located in an area suspected to contain DNAPL. Second, the groundwater extraction system was shut down periodically. The pump-and-treat system was permanently shut down in 1994 and additional soil excavation and air sparging of groundwater (without pump-and-treat) in two areas of suspected DNAPL were subsequently performed in 1995. This approach reduced groundwater concentrations to below federal, state, and county cleanup levels. Overall, the RAOs and cleanup levels were achieved in approximately six years. The site was deleted from the NPL in October 1996.

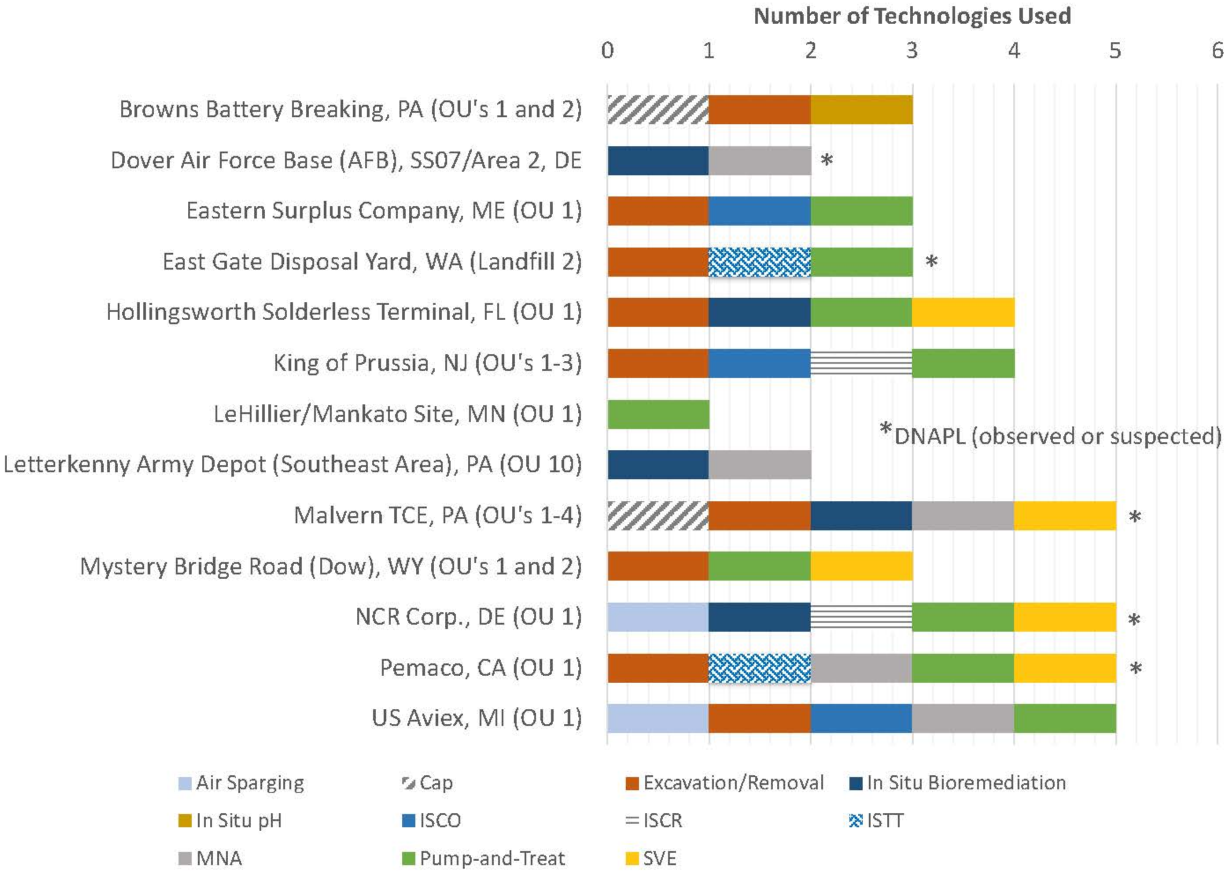
Figure 2.3 Remediation Timeline for Gold Coast Oil Corporation

Figure 2.4 Number of Technologies used to Achieve Groundwater Restoration



While traditional technologies such as pump-and-treat and air sparging were able to achieve groundwater restoration at some sites (e.g., Gold Coast, Firestone Tire and Rubber, Tabernacle Drum Dump, Tri-State Plating), there are examples of where these technologies were modified or replaced in an effort to meet cleanup levels. As detailed in Table A.3, the air sparging system at the Rochester Property was modified to include ozone to address increasing TCE concentrations. At the Mannheim Avenue Drum Dump site, after 18 months of operating a pump-and-treat system, influent TCE concentrations had decreased to less than 1 ppb. However, after the pump-and-treat system was shut down, TCE concentrations in two of the 32 monitoring wells remained above the New Jersey cleanup level of 1 ppb. Thereafter, MNA was employed for six years to achieve the cleanup level of 1 ppb in all monitoring wells.

Figure 2.5 Number of Technologies at Sites that Achieved Significant Progress towards Groundwater Restoration



The combination of excavation/removal and pump-and-treat was also used frequently at the sites that achieved significant progress towards groundwater restoration (Figure 2.5). However, compared to the sites that achieved groundwater restoration (Figure 2.4), the combination of five technologies was the most frequent indicating these sites used additional technologies. For example, at Hollingsworth Solderless, it was determined that a pump-and-treat system was no longer effective at decreasing concentrations of TCE, *cis*-1,2-DCE and vinyl chloride after two years of operation (Table A.3). After a successful pilot test of in situ bioremediation, a ROD Amendment was issued in 2008 modifying the site remedy from pump-and-treat to in situ bioremediation (i.e., enhanced reductive dechlorination). As of 2016, only four out of the 24 wells being monitored exceed the State of Florida standard of 1 ppb for vinyl chloride.

Sufficient information was available in the case studies presented in Appendix B to identify 11 groundwater restoration remedies that were changed or optimized after the initial remedies specified in the decision document were implemented. The remedy changes described in Table A.3 include those where a groundwater restoration remedy technology or approach was changed after implementation, or a formal optimization review was conducted, such as an EPA Remediation System Evaluation (RSE)[12].

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[12] For more information on RSEs at Superfund sites, see [Cleanup Optimization at Superfund Sites](#).

2.2 Technologies Used at DNAPL Sites

Groundwater restoration was achieved at three sites where DNAPL was observed or suspected (Gold Coast Oil Corp., Pasley Solvents and Chemicals, and Southern California Edison Visalia Pole Yard) (Table 2.4). Significant progress toward groundwater restoration was achieved at five sites where DNAPL was observed or suspected (Dover AFB – SS07/Area 2, Fort Lewis Logistics Center [Landfill 2], Malvern TCE, NCR Corp., and Pemaco). Excavation/removal and pump-and-treat were the technologies most often used at these sites, followed by SVE, in situ bioremediation, air stripping, MNA, ISTT, with one application of capping, VEB, or ISCR.

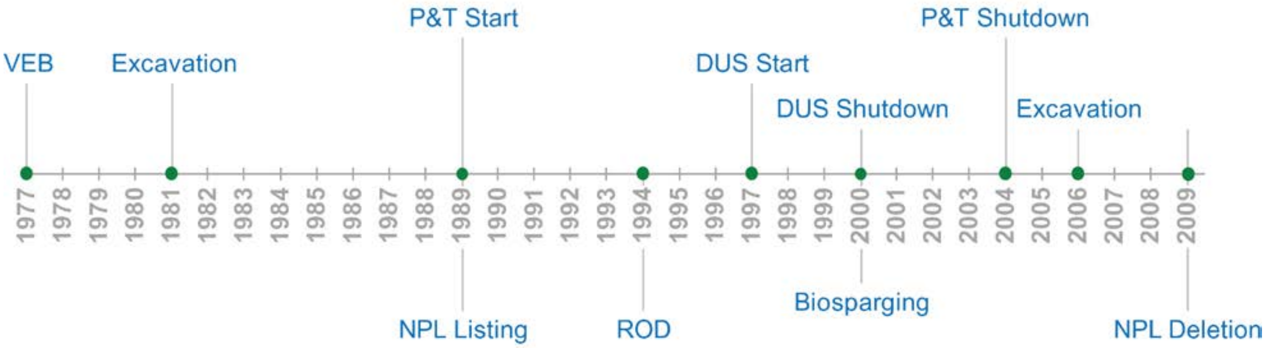
Table 2.4 Remedial Technologies Applied at DNAPL Sites

Site	DNAPL	Remedial Technologies Applied										Remedy Achieved
		Excavation/Removal	Pump-and-Treat	Capping	SVE/MPE	In Situ Bioremediation	Air Sparging	MNA	VEB	ISCR	In Situ Thermal Treatment	
Gold Coast Oil Corp., FL	Suspected	•	•				•					Unrestricted Use/ Unrestricted Exposure
Pasley Solvents and Chemicals, Inc., NY	Suspected				•		•					
Southern California Edison, Visalia Pole Yard, CA	Observed	•	•			•	•		•		•	MCLs‡
Dover AFB – SS07/Area 2, DE	Suspected					•		•				Significant Progress
Fort Lewis Logistics Center, WA (East Gate Disposal Yard, Landfill 2)	Observed	•	•								•	
Malvern TCE, PA	Suspected	•		•	•	•		•				
NCR Corp., DE	Suspected		•		•	•	•			•		
Pemaco, CA	Suspected	•	•		•			•			•	
Total		5	5	1	4	4	4	3	1	1	3	

Note: ‡Covenant between Southern California Edison and California Department of Toxics Substance Control (DTSC) prohibits installation of water wells for any purpose.

At the Visalia Pole Yard, pools of DNAPL were observed at the bottom of the shallow and intermediate aquifers. As shown in the timeline in Figure 2.6, a number of technologies were used to restore these aquifers. Initial efforts involved installing a VEB to slow the lateral migration of contaminants in the shallow aquifer and excavating contaminated soil. This was followed by the installation of a pump-and-treat (P&T) system which operated for 15 years. While the P&T system was operating, an ISTT system (DUS) was employed followed by biosparging. Overall, approximately 1.33 million pounds of contaminants were removed using the combination of technologies shown in Figure 2.6. Although groundwater contaminant concentrations at the Visalia Pole Yard were reduced to below MCLs, Southern California Edison and the California Department of Toxic Substances Control signed a covenant which prohibits the installation of water wells for any purpose.

Figure 2.6 Remediation Timeline for Southern California Edison Co., Visalia Pole Yard



2.3 Cleanup Magnitude

One measure of cleanup is based on comparing the maximum contaminant concentration before cleanup to the maximum concentration after cleanup. For example, at the Gold Coast Oil Corp. Superfund site, the maximum concentration of tetrachloroethene (PCE) in groundwater prior to remediation was 100,000 ppb whereas after applying excavation/removal, pump-and-treat and air sparging, PCE concentrations were below the federal MCL of 5 ppb, which represents a decrease in PCE concentration of greater than 20,000 times. This indicates that the PCE concentration at the Gold Coast Oil Corp. site decreased by greater than four orders of magnitude (i.e., base 10 logarithm of 20,000 is 4.3). Figure 2.7 shows the magnitude of contaminant decreases for the 17 sites that achieved groundwater restoration, which ranged from just over one order at Firestone Tire and Rubber to more than four orders at the Island Chemical Corp. and Gold Coast Oil Corp. The remedies that demonstrated the greatest contaminant concentration decreases included:

- The Frontier Hard Chrome cleanup resulted in the maximum concentration of hexavalent chromium of 300,000 ppb being reduced to below the federal MCL of 50 ppb—a nearly four orders of magnitude reduction.

- The Gold Coast Oil Corp., FL remedy reduced initial maximum PCE concentrations of 100,000 ppb to less than 3 ppb (and below the EPA MCL of 5 ppb)—a four orders of magnitude reduction.

- The Island Chemical Corp. cleanup resulted in the total toluene/ ethylbenzene/xylene maximum concentration of 176,000 ppb being decreased to 13 ppb (with all individual contaminant concentrations below their federal MCLs)—a four orders of magnitude reduction.

- The Western Processing cleanup resulted in the maximum *cis*-1,2-DCE concentration 10,000 ppb in the offsite “trans” plume being decreased to non-detectable levels that were below the federal MCL of 70 ppb—a three orders of magnitude decrease.

Figure 2.7 Magnitude of Contaminant Concentration Decreases at Sites that Achieved Groundwater Restoration

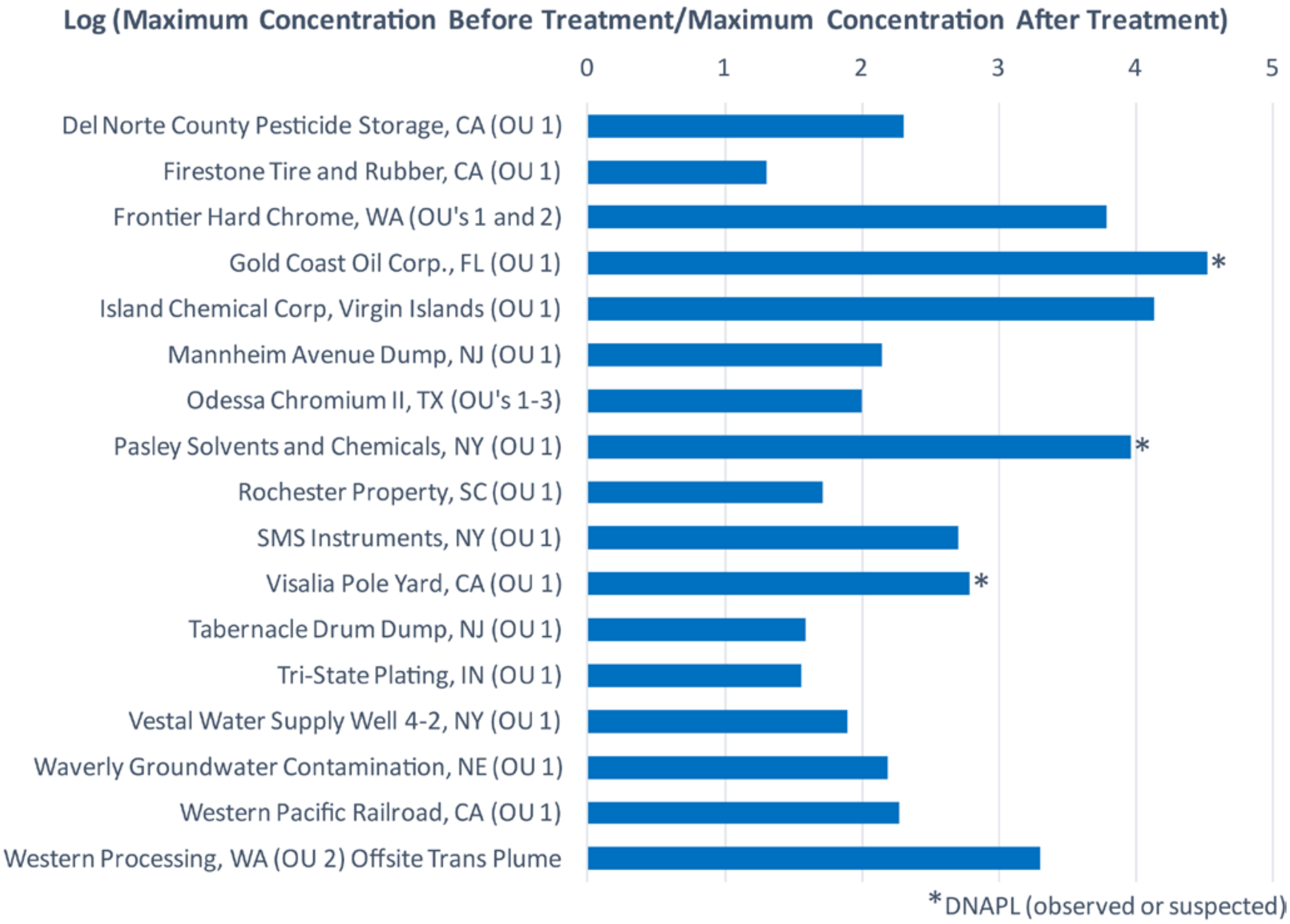


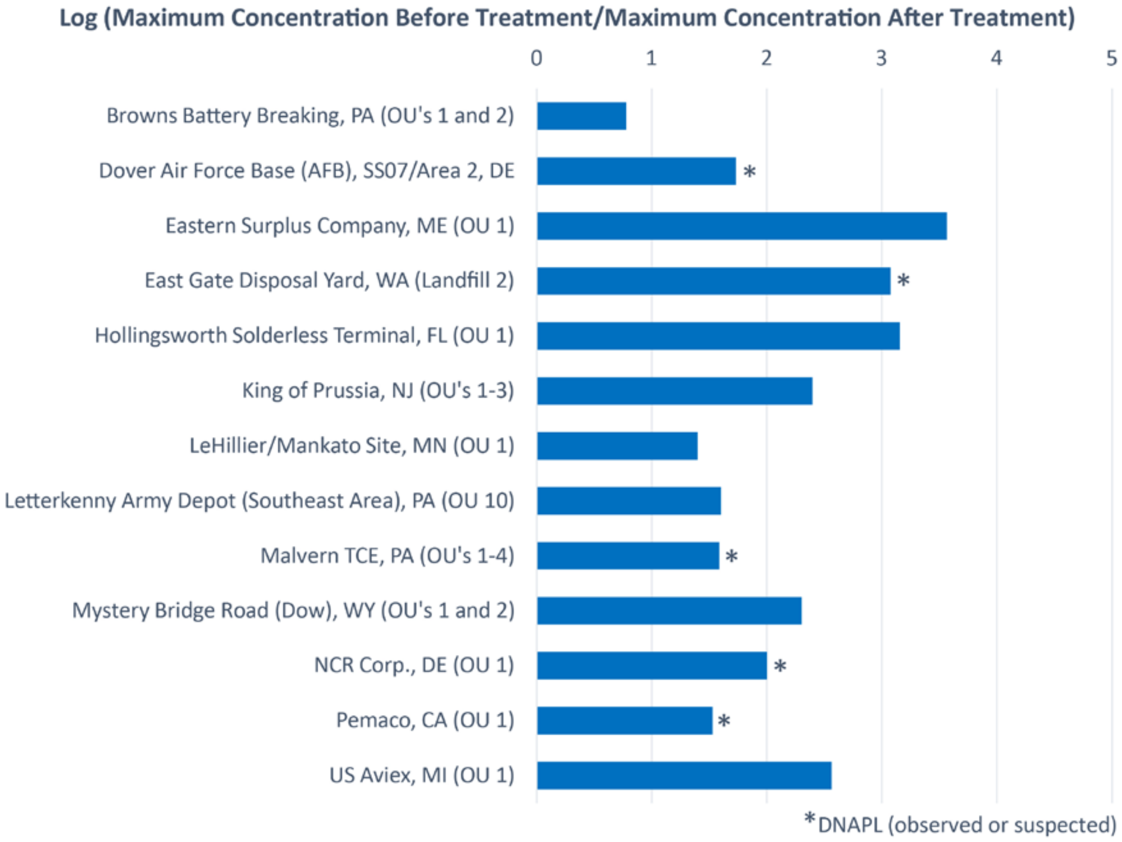
Figure 2.8 shows the magnitude of contaminant decreases for the 13 groundwater restoration sites that achieved significant progress toward groundwater restoration, which ranged from just under one order at Browns Battery Breaking site to more than three orders at the Eastern Surplus Company site. The remedies that demonstrated the greatest contaminant concentration decreases included:

- TCE at the Fort Lewis Logistics Center, WA East Gate Disposal Yard (Landfill 2) was reduced from a maximum of 250,000 ppb to less than 220 ppb maximum—a three orders of magnitude reduction.
- TCE at Hollingsworth Solderless was reduced from 4,300 ppb to below cleanup level of 3 ppb—a three orders of magnitude reduction.

Significant Progress towards Groundwater Restoration and Associated Cleanup Levels at the Fort Lewis Logistics Center

Remedial actions at the Fort Lewis Logistics Center East Gate Disposal Yard (Landfill 2) included the cleanup of chlorinated VOCs and petroleum hydrocarbons from soil and groundwater. This contamination resulted from an industrial landfill operated from 1946 to the early 1970's, where degreasers from the Logistics Center were transferred to drums and buried in trenches. Chlorinated solvents were being released into the City of Tillicum's public water supply. The remedy included pump-and-treat, drum removal, and ISTT (ERH) to treat source zones. These actions reduced TCE concentrations by three orders of magnitude, from 250,000 ppb to 220 ppb based on the most current information available at the time this report was prepared.

Figure 2.8 Magnitude of Contaminant Concentration Decreases at Sites that Achieved Significant Progress towards Groundwater Restoration



There was no obvious trend when the number of technologies used (Figure 2.4 and Figure 2.5) was compared to the magnitude of contaminant decrease (Figure 2.7 and Figure 2.8). For example, at the Frontier Hard Chrome site, a 3.8 order decrease in hexavalent chrome concentration was achieved using a single technology (ISCR) whereas six technologies were employed at the Visalia Pole Yard site to achieve a 2.8 order decrease in pentachlorophenol concentration. Also, there was no attempt to determine the order of magnitude decrease in contaminant concentration achieved by each technology because the goal of the Superfund program is to clean up sites. At some sites, this goal can be accomplished using a single technology (e.g., Frontier Hard Chrome site); at other sites a combination of technologies was required to achieve cleanup levels (e.g., Visalia Pole Yard).

2.4 Cleanup Time

The sites considered in this section are the 17 that achieved groundwater restoration (Table 2.1). Cleanup time is given in Table A.4 and was defined as the time from the first application of a remedial technology during the Superfund remedial action phase to the time when cleanup levels were first reported as having been met. Cleanup time does not include the time for Superfund removal actions, attainment monitoring, or the time required to propose and achieve delisting a site from the NPL because these times are unrelated to remedial technology performance. Cleanup time ranged from three years at Tri-State Plating (OU 1) to 27 years at Del Norte Pesticide Storage with a median time of eight years. At the majority of sites (12 of the 17 sites), groundwater restoration was achieved within 10 years while five sites required greater than 15 years to achieve groundwater restoration.

Cleanup time generally increased as cleanup magnitude increased (Figure 2.9). From Tri-State Plating (OU1), where a cleanup of less than one order of magnitude contaminant concentration reduction was completed in 3 years, to Western Processing (Offsite Trans Plume), where a cleanup of over 3 orders of magnitude contaminant concentration reduction was completed in 24 years. The exceptions to this trend were the four sites where contaminant concentrations decreased by nearly four orders of magnitude in less than eight years (Frontier Hard Chrome, Gold Coast Oil Corp., Island Chemical, and Pasley Solvents and Chemicals) and one site, Del Norte, where concentrations decreased by over 2 orders of magnitude, but cleanup time was 27 years. The exact reason for the faster cleanup time at these four sites is not known. However, the hydrogeologic setting is thought to play a key role in the time required to achieve groundwater restoration[13]. In the case of Del Norte, the longer remediation time might be due to the more recalcitrant contaminants (pesticides and herbicides combined with CVOCs). The hydrogeologic setting for each of the 17 sites is also presented in Figure 2.9 and was determined from field investigation reports. Of the 17 sites, eight have hydrogeologic settings that are generally less complex (Type I: mild heterogeneity and moderate to high permeability), seven have more complexity (Type III: moderate to high heterogeneity and moderate to high permeability), and two have hydrogeologic settings best described as being similar to fractured media with high secondary porosity (Type V).

Cleanup times were generally shorter for sites with less complex hydrogeologic settings (Type I), including Gold Coast Oil Corp. and Tri-State Plating sites where fewer than six years were required to meet cleanup levels after remedial action was initiated. This was true for sites where DNAPL was suspected to be present (Gold Coast Oil Corp. and Pasley Solvents) and sites with smaller plumes (Tabernacle Drum Dump and Tri-State Plating). In addition, fewer technologies were employed (i.e., fewer than three) to achieve groundwater cleanup levels for sites with less complex hydrogeologic settings (Type I). However, there are exceptions to this trend. For example, SMS Instruments (OU1) required 16 years and the application of four technologies to achieve groundwater restoration even though the hydrogeologic setting consisted of fine- to coarse-grain sand with moderate to high permeability. In addition, two other Type I sites, Del Norte and Waverly Groundwater Contamination, took 27 and 15 years respectively.

As the hydrogeologic setting became more complex (Type III and V), the time to achieve cleanup levels generally increased. The cleanup time for the seven completed groundwater restoration remedies that involved moderate to high heterogeneity and moderate to high permeability (Type III) ranged from six years at Firestone Tire and Rubber to 24 years at Western Processing (OU 2, Offsite Trans Plume). These sites had plumes of varying sizes (up to 2.5 miles long), depths (up to 250 feet bgs), and contaminant groups (chlorinated VOCs, non-chlorinated VOCs, SVOCs or metals). However, the initial contaminant concentrations and overall contaminant decreases for these sites were typically lower than for the Type I sites. Sites with Type III setting and lower initial concentrations included:

- At Firestone Tire and Rubber, an initial 1,1-DCE concentration of 120 ppb was reduced to less than 6 ppb in a 2.5-mile long plume in six years.
- At the Mannheim Avenue Dump site, an initial TCE concentration of 140 ppb was reduced to below 1 ppb in a plume measuring 1,000 feet by 1,000 feet in area and extending 55 feet deep in eight years.

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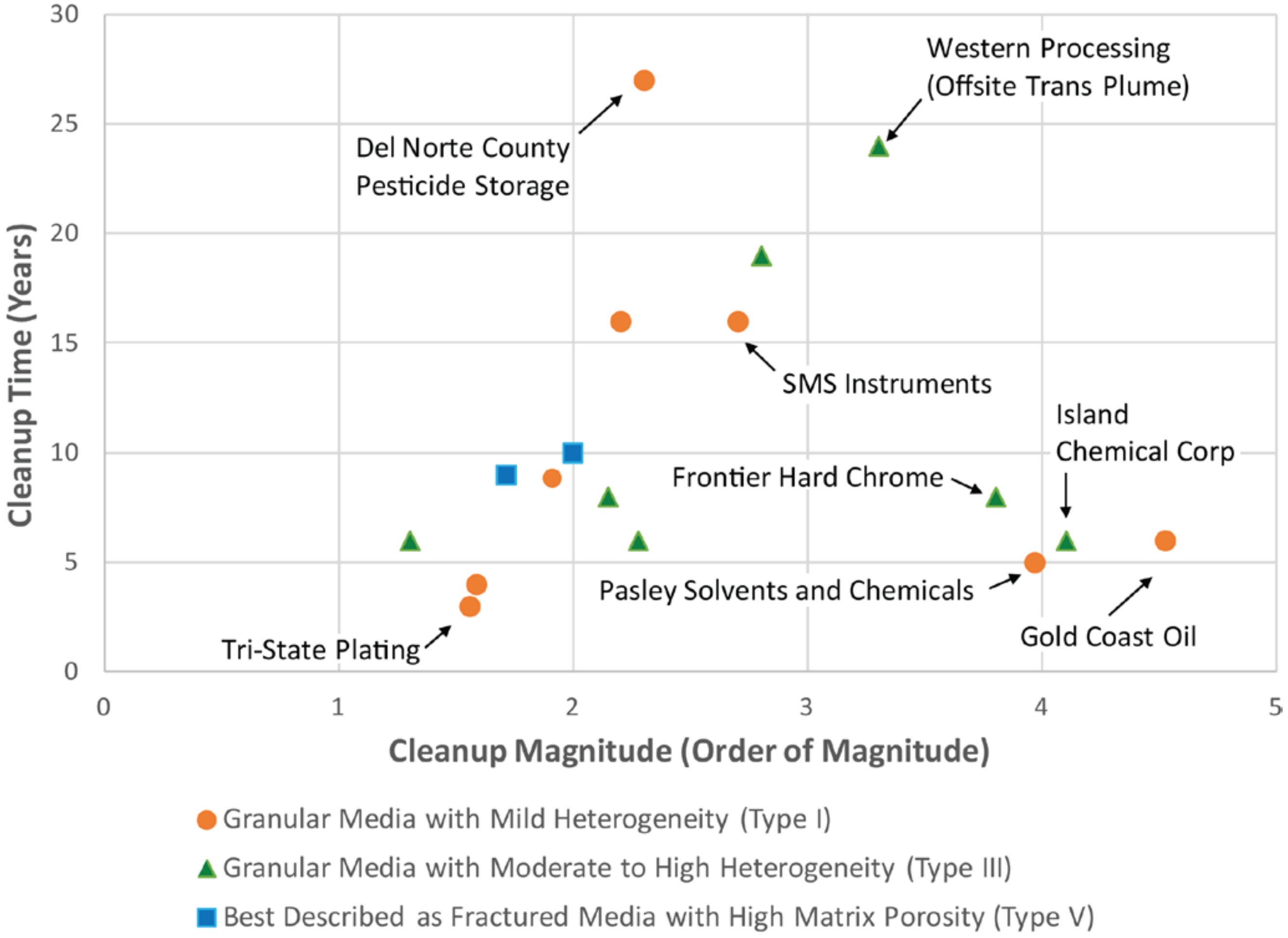
[13] *Contaminants in the Subsurface: Source Zone Assessment and Remediation*, Committee on Source Removal of Contaminants in the Subsurface, National Research Council, 2004 (http://www.nap.edu/catalog/11146.html)

Figure 2.9 Cleanup Time and Magnitude for Sites that Achieved Groundwater Restoration



The one exception was the Western Processing site, which required 24 years to cleanup a plume with an initial contaminant concentration of 10,000 ppb 1,1-DCE, a higher initial concentration than the other Type III sites, but lower than two of the Type I sites (Pasley Solvents and Gold Coast Oil Corp.).

The Rochester Property site in South Carolina, which consisted of a saprolite aquifer with silt and varying amounts of fine to coarse sand and clays (Type V), achieved cleanup levels in nine years using air and ozone sparging. Compared with the other sites shown in Figure 2.9, the Rochester Property site had a relatively small contaminant plume (0.33 acres) and lower initial contaminant concentration (TCE concentration of 180 ppb).

In terms of remedial technologies, the sites with a Type I hydrogeologic setting (Gold Coast Oil Corp., Pasley Solvents, Vestal, and Tabernacle Drum Dump) involved the remediation of chlorinated VOC plumes (ranging in size from as small as 0.87 acres to approximately 3,000 feet long) using one or more of the following: pump-and-treat, SVE and air sparging technologies. Several of the sites with a Type III hydrogeologic setting (Firestone Tire and Rubber, Mannheim Avenue Dump, and Western Pacific Railroad) also involved the application of pump-and-treat, SVE and air sparging technologies to remove dissolved phase plumes that had affected at least two separate aquifer units of varying thickness and composition. These data show that traditional technologies (pump-and-treat, SVE and air sparging) have been effective at cleaning up dissolved phase contaminant plumes (e.g., chlorinated VOCs) and their sources in permeable aquifers with mild to high heterogeneity.

3. Sites Returned to Use

Superfund Redevelopment[14] operates as a nationally coordinated effort to ensure that at every Superfund site, EPA and its partners have an effective process and the necessary tools and information needed to return the country's most hazardous sites to productive use. Most of the sites (except Vestal Water Supply Well 4-2 and Western Processing), have achieved the status of Sitewide Ready for Anticipated Use (SWRAU). As described below, 12 of the 30 sites have been returned to use either in whole or in part. This reuse has generated jobs, positively impacted local economies, and improved the quality of life for neighboring communities. As shown in Table 3.1, and discussed below, the types of reuses that have been implemented at the sites included in this report include industrial/commercial, recreational/wildlife habitat/agricultural, mixed use, alternative energy development, and other reuses.

3.1 Industrial/Commercial Reuse

Industrial and commercial redevelopment was performed at eight of the sites included in this report. The areas reused at these sites range from small single buildings (Browns Battery Breaking, PA) up to very large land areas for industrial parks and mixed-use purposes (Firestone Tire and Rubber, CA). Specific examples include:

- Browns Battery Breaking, PA – one-story automobile and truck service and repair facility.
- Firestone Tire and Rubber, CA – 256-acre industrial park for several small- and medium-size businesses.
- Norwood PCBs, MA – two single-story retail buildings, totaling 56,000 square feet.
- SMS Instruments, NY – kitchen, bathrooms, and utensil manufacturer on a 1.5-acre parcel.

Norwood PCBs Site, MA - Commercial Redevelopment

3.2 Recreational Use

Two sites have been reused as recreational parks (Pemaco, CA and LeHillier/Mankato, MN).

3.3 Alternative Energy Development

Under the RE-Powering America's Land Initiative[15], which was launched in 2008, EPA and DOE have encouraged renewable energy development on current and formerly contaminated land and mine sites. The initiative identifies the renewable energy potential of these sites and provides useful resources for communities, developers, industry, state, and local governments interested in reusing these sites for renewable energy development. One of the Superfund sites evaluated in this report

PV Green Remediation at Pemaco, CA Superfund Site

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[14] For more information about the Superfund Redevelopment Initiative, see https://www.epa.gov/superfund-redevelopment-initiative

[15] RE-Powering America's Land Initiative encourages renewable energy development on current and formerly contaminated lands, landfills, and mine sites when such development is aligned with the community's vision for the site, see https://www.epa.gov/re-powering

participated in the RE-Powering Initiative in an effort to implement green and sustainable remedies.

- Pemaco, CA – installed a 3.4-kilowatt solar photovoltaic (PV) system in 2007 to help meet total electricity demands of a high-vacuum dual-phase extraction system that removes TCE from perched groundwater and upper vadose soil, and an ERH system that removes TCE from lower vadose soil and groundwater. The solar PV system saves nearly $3,000 annually in electricity costs, and reduces the site's greenhouse gas emissions by 3.3 tons each year.

3.4 Other Reuses

As shown in Table 3.1, a range of other reuses have also been implemented at the sites included in this report. For example, the 5-acre Eastern Surplus Superfund Site in Maine, a former Army surplus and salvage operation, includes a major archeological research site. During cleanup activities in the late 1990s, EPA encountered a trove of American Indian artifacts and an archaeological site estimated to be thousands of years old. EPA, in cooperation with the Passamaquoddy Tribe, Maine Department of Environmental Protection, University of Maine, and the Maine Historic Preservation Commission, is preserving the historical and cultural integrity of this property, including the collection of hundreds of stone tools, drills, pottery shards, and scrapers typical of early eastern woodland tribes. At Western Processing, the cleanup of the offsite plume led to surface water restoration.

Table 3.1 Sites Returned to Use

Reuse	Number of Sites	Sites
Industrial/Commercial	8	Browns Battery Breaking, PA (OUs 1 and 2) Firestone Tire and Rubber, CA (OU 1) SMS Instruments, NY (OU 1) Del Norte County Pesticide Storage, CA (OU 1) Hollingsworth Solderless Terminal, FL (OU 1) NCR Corp., DE (OU 1) Norwood PCBs, MA (OU 1) Pasley Solvents and Chemicals, Inc., NY (OU 1)
Recreational Use	2	Pemaco, CA (OU 1) LeHillier/Mankato Site, MN (OU 1)
Alternative Energy	1	Pemaco, CA (OU 1)
Archaeological Research Site	1	Eastern Surplus Company, ME
Surface Water Restored	1	Western Processing, WA (OU 2), Offsite Trans Plume

4. Conclusions

As detailed in this report, the Superfund program has overcome a range of challenges to achieve the restoration of groundwater. The following are highlights from the previous sections:

- The most commonly occurring contaminants were chlorinated VOCs, which were present at 26 of the 30 sites in this report. Metals were also prevalent, and were COCs at 12 of the 30 sites. The less frequently occurring contaminants included non-chlorinated VOCs, SVOCs, and PCBs.

- The technologies applied to address groundwater contamination at the 30 NPL sites fit into 12 categories with pump-and-treat and excavation/removal the most commonly applied. Other technologies associated with groundwater cleanups included SVE, MNA, capping, air sparging, in situ bioremediation, ISCO, ISCR, ISTT, in situ pH adjustment, and VEBs.

- A combination of technologies was applied to address different media, multiple contaminants, or a range of contaminant concentrations at 28 of the 30 sites. The most frequently used technology combination was excavation/removal and pump-and-treat, which was used at 17 of the 30 sites. Given that many of these sites were cleaned up during the period from 1983 to 2000, these remedies represented state of the art technologies at that time.

- While traditional technologies such as pump-and-treat and air sparging achieved groundwater restoration at some sites (e.g., Gold Coast, Firestone Tire and Rubber, Tabernacle Drum Dump, Tri-State Plating), these technologies were modified or replaced with innovative technologies such as in situ bioremediation, MNA, ISCO, and ISTT at some sites.

- The magnitude of contaminant concentration decreases for the sites that achieved groundwater restoration ranged from just over one order at Firestone Tire and Rubber to more than four orders at the Island Chemical Corp. site and Gold Coast Oil Corp. site. The magnitude of contaminant decreases for the sites that have achieved significant progress toward groundwater restoration ranged from just under one order at Browns Battery Breaking site to more than three orders at the Eastern Surplus Company site.

- Although a combination of technologies was generally employed to achieve cleanup levels, there was no obvious trend between the number of technologies used and the order of magnitude decrease in contaminant concentration. At the Frontier Hard Chrome site, a single technology (ISCR) was used to decrease hexavalent chromium by nearly four orders of magnitude. While at the Visalia Pole Yard site, six different technologies were used to decrease pentachlorophenol concentrations by nearly three orders of magnitude.

- The cleanup times for the 17 sites that achieved groundwater restoration ranged from three years at Tri-State Plating (OU 1) to 27 years at Del Norte Pesticide Storage with a median time of eight years. Cleanup time generally increased as cleanup magnitude increased at 12 of the 17 sites except for four sites where contaminant concentrations were decreased by nearly four orders in less than eight years. Cleanup times were generally shorter for sites with less complex hydrogeologic settings apart from three sites that have mild heterogeneity and required more than 15 years to achieve groundwater restoration. Also, in most cases, cleanup times were shorter for lesser reductions in concentration.

- Most of the 30 sites, (except Vestal Water Supply Well 4-2 and Western Processing), have achieved the of Sitewide Ready for Anticipated Use (SWRAU), and 12 of the 30 sites have been returned to use either in whole or in part. Reuse includes industrial and commercial redevelopment, recreational use, alternative energy use, archaeological research, surface water restoration, and lifting of groundwater use restrictions.

Appendix A: Site Information Summary Tables

Table A.1 Location, Industry Type, Contaminant Group, and Remedial Technology for NPL Sites that Achieved Groundwater Restoration

Site	Industry Type								Contaminant Group					Technology											
	Landfill/Dump	Chemical Production	Manufacturing	Metal Works/Plating	Waste TSD	Military/Federal	Wood Treatment	Other	Chlorinated VOCs	Metals	Non-chlorinated VOCs	PCBs/Pesticides/Dioxins/ Furans	PAHs/SVOCs/	Excavation/Removal	Pump-and-Treat	Capping	SVE/MPE	In Situ Bioremediation	Air Sparging	MNA	VEB	ISCO	ISCR	In Situ Thermal treatment	In Situ pH Adjustment
Del Norte County Pesticide Storage, CA (OU 1)		•							•			•		•	•					•					
Firestone Tire and Rubber, CA (OU 1)			•						•		•			•	•	•									
Frontier Hard Chrome, Inc., WA (OUs 1 and 2)				•						•													•		
Gold Coast Oil Corp., FL (OU 1)					•				•		•			•	•				•						
Island Chemical Corp/V.I. Chemical Corp, USVI		•							•	•	•						•		•	•					
Mannheim Avenue Dump, NJ	•								•	•				•	•					•					
Odessa Chromium II, TX (OUs 1-3)			•							•					•								•		
Pasley Solvents and Chemicals, Inc., NY		•							•		•						•		•						
Rochester Property, SC (OU 1)	•								•	•			•	•					•			•			
SMS Instruments, NY			•						•		•			•	•		•		•						
Southern California Edison, Visalia Pole Yard, CA (OU 1)							•					•	•	•	•			•	•		•			•	
Tabernacle Drum Dump, NJ	•								•					•	•										
Tri-State Plating, IN (OU 1)				•						•				•	•										
Vestal Water Supply Well 4-2, NY		•							•					•	•										
Waverly Groundwater Contamination, NE (OU 1)								•	•						•		•								
Western Pacific Railroad, Co., CA (OU 1)								•	•	•			•	•	•		•								
Western Processing, WA (OU2), Offsite Trans Plume					•				•	•					•	•				•	•				
Restoration Totals	**3**	**4**	**3**	**2**	**2**	**0**	**1**	**2**	**13**	**8**	**5**	**2**	**3**	**11**	**13**	**2**	**5**	**1**	**6**	**4**	**2**	**1**	**2**	**1**	**0**

Table A.2 Location, Industry Type, Contaminant Group, and Remedial Technology for NPL Sites that Achieved Significant Progress towards Groundwater Restoration

Site	Industry Type								Contaminant Group					Technology											
	Landfill/Dump	Chemical Production	Manufacturing	Metal Works/Plating	Waste TSD	Military/Federal	Wood Treatment	Other	Chlorinated VOCs	Metals	Non-chlorinated VOCs	PCBs/Pesticides/Dioxins/ Furans	PAHs/SVOCs/	Excavation/Removal	Pump-and-Treat	Capping	SVE	In Situ Bioremediation	Air Sparging	MNA	VEB	ISCO	ISCR	In Situ Thermal Treatment	In Situ pH Adjustment
Browns Battery Breaking, PA (OUs 1 and 2)				•						•				•		•									•
Dover AFB - SS07/Area 2, DE						•			•									•		•					
Eastern Surplus Company, ME								•	•	•		•		•	•							•			
Fort Lewis Logistics Center, WA (East Gate Disposal Yard, Landfill 2)						•			•		•			•	•									•	
Hollingsworth Solderless Terminal, FL (OU1)			•						•					•	•		•	•							
King of Prussia, NJ					•					•	•		•	•	•							•	•		
LeHillier/Mankato Site, MN (OU 1)	•								•						•										
Letterkenny Army Depot (Southeast Area), PA (OU10)						•			•		•							•		•					
Malvern TCE, PA (OUs 1-4)					•				•		•	•		•		•	•	•		•					
Mystery Bridge Road/Highway 20 (Dow/DSI), WY (OUs 1 and 2)								•	•		•			•	•		•								
NCR Corp., DE			•						•						•		•	•	•				•		
Pemaco, CA (OU 1)		•							•	•			•	•	•		•			•				•	
US Aviex, MI (OU 1)		•							•		•			•	•				•	•		•			
Restoration Totals	**1**	**2**	**2**	**1**	**2**	**3**	**0**	**2**	**11**	**4**	**6**	**2**	**2**	**9**	**9**	**2**	**5**	**5**	**2**	**5**	**0**	**3**	**2**	**2**	**1**

Table A.3 Summary of Technologies Applied to Restore Groundwater

Site	RAO / Cleanup Goal Status	Technologies Used
Gold Coast Oil Corp., FL (OU 1)	Achieved	Initial remedial actions included the excavation/removal and disposal of visibly contaminated soil, followed by installation of a groundwater pump-and-treat system. Attempts to enhance contaminant reduction during pump-and-treat operation, first by the addition of hydrogen peroxide and then by pulsed pumping, were unsuccessful. The pump-and-treat system was shut down and additional soil excavation/removal and air sparging of groundwater (without pump-and-treat) in two areas of suspected DNAPL were subsequently performed. Several adjustments, both successful and unsuccessful, were made to the pump-and-treat system to optimize and speed cleanup. Some groundwater extraction wells were enlarged to increase extraction rates in the most contaminated area of the plume. Additionally, hydrogen peroxide was injected into these two wells in an unsuccessful attempt to oxidize TCE and PCE. The groundwater extraction system was shut down periodically (or pulsed) for periods of 30 and 60 days in an attempt to increase TCE and PCE desorption from aquifer materials in area groundwater. Contaminant concentrations were not significant reduced and the pump-and-treat system was permanently shut down. The soil was then excavated in suspected hot spots. Finally, air sparging was used in suspected hot spots to reduce residual contamination to below cleanup levels.
Odessa Chromium II, TX (OUs 1-3)	Achieved	The initial remedy included the extraction of chromium-contaminated groundwater with ex situ electrochemical treatment of groundwater with chromium concentrations greater than the MCL. At the time of the initial remedy, the cleanup level for total chromium was 0.05 ppm, but was later raised to 0.10 ppm. Treated groundwater was re-injected. The treatment system was expanded to remediate an additional contaminant plume and the treatment type was changed from electrochemical to ion exchange to reduce costs. Two wells remained above cleanup levels after five years of extraction and treatment. ISCR using Fe(II)SO4 treatment was applied at the two remaining wells to speed the remediation process, reducing concentrations to below cleanup levels.
Rochester Property, SC (OU 1)	Achieved	An air sparging system was operated at the site for four years to treat TCE, when it was determined that groundwater on-site met cleanup levels. However, groundwater sampling and analysis found increasing contaminant concentrations in a down gradient well off-site. The air sparging system was then modified to include ozone sparging. The air/ozone sparging system reduced off-site groundwater contaminant concentration to below cleanup levels.
Southern California Edison, Visalia Pole Yard, CA (OU 1)	Achieved	Remedial actions at the site included installing a VEB (slurry wall) around the contaminated area and excavation/removal of contaminant sources. A groundwater pump-and-treat system was also operated for 19 years to remediate the groundwater plume. In situ thermal treatment using DUS was installed to increase the rate of recovery of contaminants and reduce cleanup costs. After the DUS system was shut down, in situ bioremediation (including vadose zone bioventing and saturated zone biosparging) was applied with pump-and-treat. The bioremediation phase took advantage of the elevated subsurface temperatures to enhance the biological degradation process. A post-remediation soil investigation indicated that TCDD was detected slightly above the cleanup level at four locations. As a result, soil within the TCDD “hot spot” areas was removed. This combination of remedies achieved all cleanup levels.
Western Pacific Railroad Co., CA (OU 1)	Achieved	A pump-and-treat system was used at this site to treat groundwater contaminated with CVOCs. The pump-and-treat system was modified multiple times during the cleanup, including replacing GAC units with an air stripper to remove contaminants from extracted groundwater, and adding a new extraction well. SVE was also added to expedite and optimize contaminant removal. This approach achieved all cleanup levels.

Site	RAO / Cleanup Goal Status	Technologies Used
Browns Battery Breaking, PA (OUs 1 and 2)	Significant Progress	In situ injection of sodium bicarbonate was used to lower metal concentrations in both alluvial and upper bedrock groundwater through 2013, but additional reductions were not observed from 2013 through 2016. Pneumatic fracturing of wells occurred in March 2017 to increase the delivery of sodium bicarbonate the aquifer. Additional information about the effect of hydro-fracturing was not yet available at the time this report was published.
Eastern Surplus Company, ME (OU 1), Southern TCE Plume	Significant Progress	A removal action included excavation/removal and off-site disposal of contaminated soil and sediment and groundwater pump-and-treat with reinjection of the treated water. Addition of permanganate to the reinjected water was done to enhance the remedy, which began during the removal action phase. A later ROD selected this remedy and it continued in the remedial action phase. Six additional extraction wells were added to increase flushing of the plume, and sodium permanganate solution was injected in direct push wells with additional permanganate solution added to re-circulating wells. PCE concentrations increased after permanganate injections, and then declined for five consecutive sampling events. The groundwater pump-and-treat system was shut down for a short period to evaluate how contaminant concentrations would change or rebound in response to ISCO. The system was restarted after groundwater sampling data indicated that concentrations had increased in both plumes. Extraction wells located within the southern plume were shut down after VOC concentrations later decreased to the cleanup levels.
Fort Lewis Logistics Center, WA (East Gate Disposal Yard, Landfill 2)	Significant Progress	A pump-and-treat system was used at this site to remove TCE from groundwater. The pump-and-treat system was updated by decommissioning and replacing the original extraction wells and reconfiguring the extraction well and reinjection networks to optimize plume containment and contaminant mass removal. In addition, in situ thermal treatment was performed using ERH. The ERH enhanced contaminant removal by volatilizing chemicals and decreasing fluid viscosity, which allowed for extraction of LNAPL and DNAPL. An additional pump-and-treat system was installed and continues to operate along with the original pump-and-treat system.
Hollingsworth Solderless Terminal, FL (OU 1)	Significant Progress	A groundwater pump-and-treat system was operated for two years, when it was determined that the system was no longer effective at further reducing concentrations of TCE, *cis*-1,2-DCE and VC. Subsequent groundwater monitoring results showed a rebound of contaminant concentrations. An in situ pilot test for enhanced bioremediation was completed in September, 2007. Additional soil excavation/removal was conducted, and in situ bioremediation (potassium lactate injections and bioaugmentation) was implemented in 2013. The most recently available groundwater monitoring data (June 2016) indicates that VC is the only contaminant exceeding cleanup levels. Only 1 out of the 24 wells being monitored exceeds the State of Florida VC standard of 1 ppb, with concentrations measuring 45ppb.
King of Prussia, NJ (OUs 1-3)	Significant Progress	A pump-and-treat system was used to initially capture contamination but concentrations of some chlorinated VOCs and metals remained above cleanup levels. In March 2013, ISCR was conducted with carbon impregnated zero valence iron substrate. From October 2002 through September 2003 ISCO with hydrogen peroxide and ferrous sulfate was applied in a separate area. Contaminant concentrations are continuing to diminish, and monitoring at the site is ongoing.

Site	RAO / Cleanup Goal Status	Technologies Used
Pemaco, CA (OU 1)	Significant Progress	Soil excavation/removal and an SVE system were installed to remediate chlorinated and non-chlorinated VOCs. However, community concerns about potential dioxin emissions from thermal oxidation treatment of extracted vapors led to the shutdown of the SVE system. A high vacuum dual-phase extraction (HVDPE) pump-and-treat system which used granulated activated carbon (GAC) for groundwater treatment and flameless thermal oxidation (FTO) and GAC for treatment of vapors was installed. In addition, ERH was used to treat the deeper vadose soils and groundwater from 32 to 100 feet bgs, followed by groundwater pump-and-treat and MNA. EPA conducted an RSE in 2011 to optimize the system, and issued an RSE report in July 2011, which contained recommendations for reducing sampling, and optimizing system design and equipment, but did not contain recommendations for changing the remedy. Many of the recommended optimizations have been implemented[16]. However, groundwater cleanup levels are not being met as contamination levels have been increasing since 2011 because the full extent of TCE contamination has not been determined.

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[16] Appendix to the Groundwater Remedy Optimization, Progress Report: 2010 – 2011

Table A.4 Time to Meet RAOs and Hydrogeologic Complexity for Sites that Achieved Groundwater Restoration

Site Name	Groundwater Contaminant Groups (Contaminants with Highest Concentrations)	Remedies that Contributed to Groundwater Cleanup	Areal Extent of Plume	Hydrogeologic Complexity of Contaminated Aquifer	Years to Meet Cleanup Levels
Del Norte County Pesticide Storage, CA (OU 1)	Pesticides, Herbicides, Chlorinated VOCs (1,2-DCP, 2,4-D)	Excavation, Pump-and-Treat, MNA	Not available	*Type I:* moderately well-sorted fine sands, silts, and clays with generally moderate groundwater permeability.	27
Firestone Tire and Rubber, CA (OU 1)	Chlorinated VOCs, Non-chlorinated VOCs (Benzene, 1,1-DCE, 1,1-DCA, PCE, Toluene, TCE, Xylene)	Pump-and-treat	2.5 mile long plume	*Type III*: Three aquifers (shallow, intermediate, and deep) each with sands and gravels, and conductivity of >100 ft day. Each aquifer is separated from the neighboring aquifer by discontinuous clay aquitards, which consist of impermeable silt and clay units. Groundwater extracted from each of the three aquifers.	6
Frontier Hard Chrome, Inc., WA (OU's 1 and 2)	Metals (Trivalent and Hexavalent Chromium)	In situ redox manipulation treatment wall to reduce Cr6 (injection of sodium dithionite reagent).	Not available	*Type III:* Upper zone is low permeability silty sandy gravel, underlain by high permeability sandy gravel and sand silt leaky aquitard. Lower zone is moderate to high permeability sandy gravels.	8
Gold Coast Oil Corp., FL (OU 1)	DNAPL, Chlorinated VOCs, Non-chlorinated VOCs (PCE, TCE, *trans*-1,2-DCE, 1,1-DCA, Methylene Chloride, Toluene)	Excavation, pump-and-treat, air sparging	0.87 acre areal extent and up to 10 feet thick	*Type I*: Unconfined aquifer of white to light tan, fine-grained sand with high permeability.	6
Island Chemical Corp/V.I. Chemical Corp, Virgin Islands (OU 1)	Non-chlorinated VOCs, Chlorinated VOCs, Metals (Methylene chloride, Chloroform, Ethylbenzene, Xylenes, Toluene, Acetone)	SVE, air sparging, MNA	Not available	*Type III*: Brown and gray clay-rich alluvial sediments. Local lenses of permeable gravel and sand are located at approximately 30 to 40 ft bgs. Underlying the alluvium is the white to light brown and gray, lime-rich, stiff clay of the Kinphill Formation.	6
Mannheim Avenue Dump, NJ (OU 1)	Chlorinated VOCs, Metals (TCE, Lead)	Excavation, pump-and-treat, MNA, [Point of entry treatment systems installed in 1993,	Plume measuring 1,000 feet x 1,000 feet in area and extending 55 feet deep	*Type III*: The aquifer underlying the site consists of shallow and deep zones, each comprised of sand and gravel, separated by an approximately 3 to 5 feet thick semi-permeable clay layer.	8
Odessa Chromium II, TX (OUs 1-3)	Metals (Hexavalent Chromium)	Pump-and-treat, ISCO with ferrous sulfate	Approximate 40 acre plume	*Type V*: Sandstone and conglomerate rock overlaid by soil and caliche	10

Site Name	Groundwater Contaminant Groups (Contaminants with Highest Concentrations)	Remedies that Contributed to Groundwater Cleanup	Areal Extent of Plume	Hydrogeologic Complexity of Contaminated Aquifer	Years to Meet Cleanup Levels
Pasley Solvents and Chemicals, Inc., NY (OU 1)	DNAPL, Non-chlorinated VOCs, Chlorinated VOCs (*trans*-1,2-DCE, TCA, 1,1-DCA, Chlorobenzene, Toluene, Ethylbenzene, Xylenes)	SVE, air sparging	400-foot-long plume, depths up to 60 feet	*Type I*: Unconsolidated sand and gravel	5
Rochester Property, SC (OU 1)	Chlorinated VOCs, PAH, Metals [TCE, *cis*-1,2-DCE, *bis*(2-ethylhexyl)phthalate) manganese]	Excavation, air sparging, ISCO using ozone sparging.	0.33 acres	*Type V:* Saprolite aquifer with silt and varying amounts of fine to coarse sand and clays.	9
SMS Instruments, NY (OU 1)	Chlorinated VOCs, non-chlorinated VOCs (TCE, Chlorobenzenes, Xylene)	pump-and-treat, SVE, air sparging	Not available	*Type I:* moderate to high permeability, Stratified fine- to coarse-grained sand and light to dark tan or brown gravel	16
Southern California Edison, Visalia Pole Yard, CA (OU 1)	DNAPL, CSVOCs, SVOCs, PCP, Dioxins [Benzo(a)pyrene, TCDD]	In situ thermal treatment, enhanced in situ bioremediation (air sparging and bioventing), pump-and-treat, VEB (slurry wall), excavation	SVOC plume covers 2.1 acres and extends from water table to depth of approximately 145 feet	*Type III*: Three aquifers (shallow, intermediate, and deeper) consisting of unconsolidated sediment lie beneath the site, ranging in depth from 30 to 180 feet bgs. Aquitards consisting of a relatively impermeable silt layer separate these aquifers	19
Tabernacle Drum Dump, NJ (OU 1)	Chlorinated VOCs (TCA, 1,1-DCE)	Removal of drums, excavation of soil, pump-and-treat	Plume extended ~ 3,000 feet from source area	*Type I*: Generally homogeneous sand that becomes coarser with depth and an average value of hydraulic conductivity of 343.5 gpd/sq ft (SEMS 56482)	4
Tri-State Plating, IN (OU 1)	Metals (Chromium)	Pump-and-treat, excavation, drum removal, decontamination and demolition of site buildings	200-foot long plume	*Type I*: Unconfined aquifer composed of alternating sequences of sand and gravelly sands with high permeability where hydraulic conductivity values ranged from 1 to 7 x 10-2 cm/sec and averaged about 3.5 x 10-2 cm/sec (SEMS 221436)	3
Vestal Water Supply Well 4-2, NY (OU 1)	Chlorinated VOCs (TCA, TCE, PCE)	Pump-and-treat	Not available	*Type I:* Glaciofluvial sand and gravel deposits	9
Waverly Groundwater Contamination, NE (OU 1)	Chlorinated VOCs (Carbon Tetrachloride, Chloroform)	SVE, pump-and-treat	Not available	*Type I:* Site is underlain by about 13 feet of loess and over 80 feet of sand in two layers separated by approximately 5 feet of clay, contamination was in upper aquifer (SEMS 40193838). Estimated transmissivity values range from 25,000 to greater than 100,000 gallons per day per foot. (SEMS 40184729)	16

Site Name	Groundwater Contaminant Groups (Contaminants with Highest Concentrations)	Remedies that Contributed to Groundwater Cleanup	Areal Extent of Plume	Hydrogeologic Complexity of Contaminated Aquifer	Years to Meet Cleanup Levels
Western Pacific Railroad Co., CA (OU 1)	Chlorinated VOCs (1,1-DCE, 1,1-DCA, TCE)	Pump-and-treat, SVE	700-foot long plume extending 60 feet bgs	*Type III*: Interbedded clays, sands, and gravels, which vary in thickness and composition, both horizontally and vertically across the site	6
Western Processing, WA (OU 2), Offsite Trans Plume	Chlorinated VOCs, Metals (TCE, *cis*-1,2-DCE, vinyl chloride, Zinc)	Pump-and-treat, slurry wall, capping, MNA.	Not available	*Type III:* A fairly continuous fine to medium sand with intermittent silty zones existing below 40 feet. This sand unit extends to a depth of 150 feet below ground surface. Conductivity of 10 to 100 feet/day (FRTR Case Study)	24

Notes:

(1) Hydrogeologic complexity and extent of plume are based on the information provided in the resources used to develop this report.

(2) Restoration time presented in this report begins when the first Superfund Remedial Action phase began, including source removals such as excavation or drum removal. For completed restorations, the restoration time ends when the concentration goals were first reported as being met.

(3) Hydrogeologic categories are described in *Contaminants in the Subsurface: Source Zone Assessment and Remediation*, Committee on Source Removal of Contaminants in the Subsurface, National Research Council, 2004 (http://www.nap.edu/catalog/11146.html).

Table A.5 Time to Achieve Significant Progress and Complexity for Selected Sites that Achieved Significant Progress towards Groundwater Restoration

Site Name	Groundwater Contaminant Groups (Contaminants with Highest Concentrations)	Remedies that Contributed to Groundwater Cleanup	Areal Extent of Plume	Hydrogeologic Complexity of Contaminated Aquifer	Years to Meet Cleanup Levels
Dover Air Force Base (AFB), DE (SS07/Area 2, South Management Unit)	DNAPL, Chlorinated VOCs (PCE, TCE, *cis*-1,2-DCE, Vinyl Chloride)	ERD/Accelerated anaerobic biodegradation, MNA	Approximately 2,800 feet long by 650 feet wide	*Layered/Interbedded*: Four (4) aquifers beneath site with varying compositions including mixtures of gravel, sand, and silt with clay and gravel lenses	11+
Eastern Surplus Company, ME (OU 1), Southern TCE Plume	Chlorinated VOCs (PCE, TCE)	Soil excavation and waste removal, pump-and-treat, ISCO with sodium permanganate injections	1.5 acre southern chlorinated VOC plume; depths up to 20-30 feet bgs	*Layered/Interbedded*: Overburden consisting of stratified beds of gravel, sand, and mixed sands and silt, and shallow bedrock	11
Fort Lewis Logistics Center, WA (East Gate Disposal Yard (EGDY) OU1)	DNAPL, LNAPL, Chlorinated VOCs, Petroleum Hydrocarbons (TCE)	Pump-and-treat, drum removal, in situ thermal treatment (ERH)	TCE groundwater plume extended 2 to 2.5 miles long and 3,000 to 4,000 feet wide, with 60-to-100-foot contaminant thickness	*Layered/Interbedded*: Complex hydrostratigraphy generally consisting of glacial sand and gravel deposits with till layers overlying a finer-grained nonglacial deposit	25+
Hollingsworth Solderless Terminal, FL (OU 1)	Chlorinated VOCs (TCE, *cis*-1,2-DCE, Vinyl Chloride)	Excavation, pump-and-treat, SVE, in situ ERD (with potassium lactate and bacteria injections)	Approximate 200-foot radius area (or about 3 acres), with the highest concentrations found at the 50-to-75-foot depths	*Homogeneous, Medium to High Permeability*: Site overlies Biscayne aquifer, which is highly permeable, unconfined, and composed of a fine- to-medium grained sand, sandstone, and limestone sequence	26+
Letterkenny Army Depot (Southeast Area), PA (OU 10)	Chlorinated VOCs (TCE, *trans*-1,2-DCE, Vinyl Chloride)	ERD using sodium lactate injections, MNA	Chlorinated VOC groundwater plume extends to springs located approximately 1.5 to 2 miles off-site	*Fractured*: Fractured and weathered karstic bedrock, with large cavities formed by dissolution of limestone rock	18+
Pemaco, CA (OU 1)	DNAPL, Chlorinated VOCs (PCE, TCE, *cis*-1,2-DCE, Vinyl Chloride), Non-chlorinated VOCs	SVE, in situ thermal treatment (ERH), high-vacuum dual phase extraction, pump-and-treat, and MNA	Chlorinated VOC groundwater plume approximately 1,300 feet by 750 feet in deep aquifer, extended 200 feet offsite in perched aquifer	*Layered/Interbedded*: Six discrete groundwater zones, including perched aquifer and five underlying zones made up of silty sands separated by less permeable clay-rich strata	10+

Notes:
(1) For ongoing remedies that have not yet met RAOs, the time in years to meet them is followed by a “+”.

Table A.6 Site Information Summary Table

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Eastern Surplus Company, ME EPA Region 1	Other (Salvage/ Storage Yard/ Re-sale)	Groundwater Soil Sediment	Chlorinated VOCs, Metals, PCBs (PCE, TCE, Manganese, Lead, PCBs)	Restore groundwater to meet MCLs or Maine Maximum Exposure Guidelines (MEGs) (PCE 3 ppb). Prevent additional sediment contamination and offsite migration. ***Significant progress has been made.***	Soil excavation and waste removal, pump-and-treat, ISCO with sodium permanganate injections.	Removed approximately 120 transformers, 4,650 gallons of waste oil, and 2,400 gallons of PCB oil.	PCE concentrations in 1.5 acre Southern Plume reduced from 1,100 ppb to below cleanup level. Chlorinated VOC concentrations in Northern Plume are still above cleanup levels. Current site use includes a major archaeological research site for the history of the Passamaquoddy people.	Listed 06/17/1996; Not yet deleted	*See Case Summary for full list of information sources.* 1. EPA Web site: Eastern Surplus Company Site Profile
King of Prussia, NJ (OUs 1-3) EPA Region 2	Waste TSD	Soil/ Groundwater	Chlorinated VOCs, Metals, SVOCs (PCE, TCE, DCE, Chloroform, Beryllium, Copper, Chromium, Nickel, Phthalates)	Remediate soils through either treatment or excavation and offsite disposal to meet EPA risk-based cleanup levels, and restore groundwater to state and federal MCLs (PCE 1 ppb, TCE 1 ppb). ***Significant progress has been made.***	Pump-and-treat, excavation, ex situ soil washing, ISCR with carbon impregnated zero valance iron substrate, ISCO with hydrogen peroxide and ferrous sulfate.	Disposed of 2 tankers and over 500 drums/ containers holding contaminated materials. Over 19,000 tons of metals-contaminated soils treated with soil washing. Over 729 million gallons of groundwater treated with pump-and-treat system, removing 1.27 tons of chlorinated VOCs and 5.6 tons of metals.	Soil remedy achieved risk-based cleanup levels and eliminated a major source of groundwater contamination. Pump-and-treat is providing capture but concentrations of some chlorinated VOCs and metals (chromium and beryllium) remain above cleanup levels. In 2014, average PCE concentrations were 18 ppb. Average TCE concentrations were 10.2 ppb. ISCO reduced VOC concentrations in monitoring and recovery wells by 81% to 97%.	Listed 09/01/1983; Not yet deleted	1. EPA Web site: King of Prussia Site Profile 2. Five-Year Review Report, King of Prussia Superfund Site (Sept 2010): 3. Five-Year Review Report, King of Prussia Superfund Site (June 2015)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Mannheim Avenue Dump, NJ (OU 1) EPA Region 2	Landfill/ Dump	Soil/ Groundwater	Chlorinated VOCs, Metals (TCE, Lead)	Restore groundwater to a NJDEP TCE cleanup level of 1 ppb. ***RAOs have been achieved.***	Excavation, pump-and-treat, MNA.	Over 25,000 pounds of contaminated sludge and 2,700 CY of contaminated soil removed. RAOs met in approximately 8 years of combined pump-and-treat and MNA.	TCE in groundwater reduced from 140 ppb to less than cleanup level. Eliminated TCE plume initially measuring 1,000 feet x 1,000 feet in area and extending 55 feet deep.	Listed 09/01/1983; Deleted 08/28/2007	*See Case Summary for full list of information sources.* 1. EPA Web site: Mannheim Avenue Dump Site Profile
Tabernacle Drum Dump, NJ (OU 1) EPA Region 2	Landfill/ Dump (Rural area with a one-time dumping of solvents, paints, and paint sludge)	Soil/ Groundwater	Chlorinated VOCs (TCA, DCE)	Restore groundwater to meet state MCLs (TCA 26 ppb, DCE 2 ppb). ***RAOs have been achieved.***	Removal of drums, excavation of soil, pump-and-treat.	Removed and disposed of 40 CY of drummed material, 8 truckloads of soil, and 3,000 gallons of liquid material. Seven million gallons of impacted groundwater treated per month, achieving RAOs in just over 4 years of pump-and-treat.	TCA reduced from 1,000 ppb to less than NJDEP MCL, and DCE reduced from 180 ppb to less than NJDEP MCL. Eliminated chlorinated VOC plume that initially extended ~ 3,000 feet from the source area.	Listed 09/21/1984; Deleted 05/08/2008	*See Case Summary for full list of information sources.* 1. EPA Web site: Tabernacle Drum Dump Site Profile
Pasley Solvents and Chemicals, Inc., NY (OU 1) EPA Region 2	Chemical Production (Oil/Solvent Storage and Distribution)	Soil/ Groundwater/ DNAPL (suspected)	VOCs, Chlorinated VOCs (DCE, TCA, DCA, Chlorobenzene, Toluene, Ethylbenzene, Xylenes)	Restore groundwater to MCLs (DCE 100 ppb, TCA 200 ppb). Treat soil to residential risk levels (1 ppm). ***RAOs have been achieved.***	SVE, air sparging.	Over 15,000 pounds of contaminants removed from soil and groundwater. Cleanup levels achieved within 5 years of AS/SVE system startup.	Soil cleanup levels met. Total VOC concentrations in groundwater dramatically reduced from 37,000 ppb to 4 ppb. DCE reduced from 25,000 ppb to below MCL. TCA reduced from 3,600 ppb to below MCL. 400-foot long plume reduced to below MCLs.	Listed 06/10/1986; Deleted 09/26/2011	*See Case Summary for full list of information sources.* 1. EPA; DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved; pps. 47-48; 2009b. 2. Second Five-Year Review Report for Pasley Solvents and Chemicals Site; 2009.

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
SMS Instruments, NY (OU 1) EPA Region 2	Manufacturing (Military Aircraft Components -Industrial Wastes)	Soil/ Groundwater	Chlorinated VOCs, non-chlorinated VOCs (TCE, Chlorobenzenes, Xylene)	Restore groundwater to meet federal and state MCLs. ***RAOs have been achieved.***	Tank removal, pump-and-treat, SVE, air sparging	6,000 gallon underground tank removed. 50,000 tons of soil remediated. Approximately 607 million gallons of groundwater treated.	Initial total chlorinated VOC concentrations exceeded 5,000 ppb near the source area. Post treatment, total chlorinated VOC concentrations in groundwater were reduced to around 10 ppb, with individual contaminants below their respective cleanup levels. A kitchen, bathroom, and household utensil manufacturer, operates on the site today.	Listed 06/10/1986; Deleted 09/13/2010	1. EPA Web site: SMS Instruments Inc. Site Profile 2. Third Five Year Review Report for SMS Instruments Site (May 2006)
Vestal Water Supply Well 4-2, NY (OU 1) EPA Region 2	Chemical Production (Distribution)	Soil/ Groundwater	Chlorinated VOCs (TCA, TCE, PCE)	Restore groundwater to MCLs. ***RAOs have been achieved.***	Excavation, pump-and-treat.	42 tons of contaminated materials removed. 6,950 million gallons of contaminated groundwater treated.	Initial maximum groundwater concentrations of TCA (390 ppb), TCE (239 ppb), and PCE (220 ppb) from municipal well 4-2 decreased to levels below drinking water standards. Treatment period occurred over approximately 9 years.	Listed 09/01/1983; Deleted 09/30/1999	1. Charsky, Matthew; Science and Policy Branch, Groundwater Successes at Deleted NPL Sites. (2010) 2. EPA Web site: Vestal Water Supply Well 4-2 Site Profile 3. Lee, G. W. Hydrogeological Investigation of Organic Contamination at Monarch Chemicals, Inc. Town of Vestal. (1980)
Island Chemical Corp/V.I. Chemical Corp, Virgin Islands (OU 1) EPA Region 2	Chemical Production (Pharmaceutical manufacturing and blending operations)	Soil/ Groundwater	Non-chlorinated VOCs, Chlorinated VOCs, Metals (Methylene chloride, Chloroform, Ethylbenzene, Xylenes, Toluene, Acetone)	Restrict on-site groundwater use to non-potable purposes until MCLs are achieved. ***RAOs have been achieved.***	SVE, air sparging, MNA	Removed 205 55-gallon drums, 40 85-gallon drums, 9 5-gallon drums of various chemicals, and 8,000 pounds of lab pack chemicals from buildings. 2,030 pounds of contaminants removed from groundwater.	Groundwater concentrations of total toluene, ethylbenzene and xylene reduced from a maximum of 176,000 ppb to 13 ppb. Chloroform concentrations in groundwater reduced from 2,400 ppb to 13 ppb. All contaminant concentrations meet MCL cleanup levels.	Listed 06/17/1996; Deleted 10/16/2009	1. EPA Web site: Island Chemical Corp/VI Chemical Corp. Site Profile 2. Five-Year Review Report for Island Chemical Corp. Virgin Islands Chemical Corp. Superfund Site (March 2009)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Dover Air Force Base (AFB), SS07/Area 2, South Management Unit, DE (OU 15) EPA Region 3	Military/Federal (Aircraft Maintenance)	Groundwater /DNAPL (suspected)	Chlorinated VOCs (PCE, TCE, DCE, VC)	Restore groundwater to meet state MCLs (1 ppb PCE, TCE, and VC), prevent exposure, and restrict land use to industrial until unrestricted exposure and use levels can be documented. ***Significant progress has been made.***	ERD/Accelerated anaerobic biodegradation, MNA.	Over 100,000 gallons of carbon substrate injected into subsurface through 49 injection points, resulting favorable conditions for reductive dechlorination. ERD resulted in meeting cleanup levels in most SS07 source area wells within 2 years. The plume was initially 2,800 feet long and 650 feet wide.	In 2006, PCE and TCE concentrations were 32,000ppb and 110 ppb, respectively. By 2008 nearly all wells met cleanup levels. However, the most recent semi-annual monitoring data (January 2016) indicated exceedances in 2 source area wells. In one well TCE, 1,2-DCE and VC were 86 ppb, 840 ppb and 130 ppb, respectively. At the other well TCE and VC were 23 ppb and 8.2ppb, respectively. These wells are being resampled to confirm concentrations.	Listed 03/13/1989; Not yet deleted	*See Case Summary for full list of information sources.* 1. EPA Web site: Dover Air Force Base Site Profile 2. Fourth Five-Year Review Report for Dover AFB, SS07/Area 2, South Management Unit (Sept 2013) 2 Monitoring Report Sites SS07, LF17, and LF18 South Management Unit (through October 2010) (February 2011) 4. Monitoring Report Sites SS07, LF17, and LF18 South Management Unit (through December 2014) (March 2015) 4. Dover AFB Sampling Summary Report SS07 (not yet in a report)
NCR Corp., DE (OU 1) EPA Region 3	Manufacturing (Electronic Equipment)	Groundwater/ DNAPL (suspected)	Chlorinated VOCs (TCE)	Prevent offsite migration and reduce groundwater concentrations to meet MCLs (TCE 5 ppb). ***Significant progress has been made in the Phase I and II areas of the site.***	Pump-and-treat, SVE, air sparging, in situ biological reductive dechlorination (full scale), ZVI (ISCR).	Approximately 315 CY of sludge and wastes from concrete lagoons and pits was excavated.	In situ and ex situ groundwater treatment has prevented offsite migration and substantially reduced levels of TCE in both Phase I and II areas groundwater, where TCE concentrations have been reduced from >490,000 ppb to a range from less than 5 ppb in the Phase I area and 200 ppb in the Phase II area . Contaminants still exceed cleanup levels in 3 wells.	Listed 07/22/1987; Not yet deleted	1. EPA Web site: NCR Corp. Site Profile 2. Second Five-Year Review for NCR Corporation (June 2005) 3. Third Five-Year Review Report for NCR Corporation Superfund Site (July 2010) 4. Semi-Annual Report for the Millsboro, Delaware, NPL Site, TRC Environmental Corporation (July 2013) 5. Fourth Five-Year Review for NCR Corporation Superfund Site (June 2015)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Browns Battery Breaking, PA (OUs 1 and 2) EPA Region 3	Metal Works/ Plating (Battery Recycling Facility)	Soil/ Groundwater	Metals (Lead, Zinc, Beryllium, Cadmium, Chromium, Nickel)	Relocation of residents, removal of contamination from onsite soils, restore groundwater to background levels and pH between 6-8, meet federal and state MCLs (lead 5 ppb). ***Significant progress has been made.***	Consolidation and capping soil and battery casings, excavation offsite disposal of soils, stabilization/solidification, in situ injection of sodium bicarbonate to elevate pH of groundwater. Pneumatic fracturing of wells completed in March 2017 to attempt to increase the delivery of sodium bicarbonate the aquifer.	Approximately 13,000 cubic yards of battery casings and contaminated soil consolidated and capped. Disposed of 25,000 tons of stabilized material. Treated and disposed of 43,000 tons of soil and battery casings. Between 2003 and 2007, 28 injection events and a total of 70,601 pounds of sodium bicarbonate added to the groundwater within the target area.	Soil RAOs have been met. Lead concentrations in soil have been reduced from maximum of 60,000 ppm to below cleanup level of 1,000 ppm. Cleanup levels for metals have not been met site wide, but metals plume has been reduced to 100 foot in radius. A contaminated groundwater plume remains with max lead concentrations of 17 ppb. In-situ injection of sodium bicarbonate lowered metal concentrations in both alluvial and upper bedrock groundwater through 2013, but additional reductions were not observed from 2013 through 2016.	Listed 06/10/1986; Not yet deleted	1. EPA Web site: Brown's Battery Breaking Site Profile 2. Third Five Year Review Report for Brown's Battery Site (Sept 2007) 3. Fourth Five-Year Report for Brown's Battery Site (Sept 2012) 4. Ruth Associates, Inc., Results of the February 2016 Groundwater Monitoring Event; Brown's Battery Breaking Site; April 19, 2016.

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Letterkenny Army Depot (Southeast Area), PA (OU 10) EPA Region 3	Military/ Federal (Ammunition Storage)	Groundwater	Chlorinated VOCs, Non-Chlorinated VOCs (TCE, DCE, VC, and Benzene)	Meet federal and State MCLs for groundwater and PA Water Quality Criteria (WQC) for springs. Reduce or eliminate migration of contaminated groundwater off-post and to off-post springs. Return land to beneficial use. ***Significant progress has been made.***	In situ biological treatment using ERD with sodium lactate injections, MNA.	Over an 18 year period, remedy has reduced onsite groundwater contaminant concentrations significantly. Concentrations in down gradient offsite wells and springs are below MCLs and water quality criteria, respectively.	TCE and VC concentrations reduced from a maximum of 67 ppb and 90 ppb, respectively to below MCLs. Originally, the plume was greater than 20 acres but since 2013 all chlorinated solvent concentrations are below MCLs. However, benzene exceeds the MCL in 1 well. Groundwater use restrictions were lifted from some of the on-post and off-post areas of OU 10.	Listed 07/22/1987; Not yet deleted	*See Case Summary for full list of information sources.* 1. EPA Web site: Letterkenny SE Area Site Profile 2. ESD, Southeastern (SE) Area OU Letterkenny Army Depot (Sept 2009) 3. Five-Year Review Report for Letterkenny SE Area Site (Sept 2012) 4. Annual Groundwater and Surface Water Monitoring Report for SE Area OU 10 (August 2016) 5. Five-Year Review Report for Letterkenny Army Depot (March 2017)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Malvern TCE, PA (OUs 1-4) EPA Region 3	Waste TSD (Solvent Reclamation Facility)	Soil/ Groundwater/ DNAPL (suspected)	Chlorinated VOCs, non-chlorinated VOCs, PCBs (TCE, PCE, TCA, 1,4-Dioxane)	Prevent direct contact with contaminated soils and reduce potential migration of contaminants to groundwater, prevent ingestion and inhalation of contaminants in groundwater, restore groundwater to beneficial use and to meet MCLs (FDA/MA area: TCE 5 ppb, cis-1,1-DCE 7 ppb; MPA: TCE 5 ppb, cis-1,1-DCE 7 ppb). ***Significant progress has been made.***	Structure/tank/drum and soil excavation and removal and offsite disposal, cap, SVE, in situ bioremediation recirculation system (using sodium lactate and nutrient injections), MNA.	250 poly drums, 50 steel drums, 5 tanks, 8 fire extinguishers, 2 propane tanks, and 2 pressurized cylinders were removed. 143 CY of PCB-impacted soils excavated. More than 11,000 pounds of chlorinated and non-chlorinated VOCs removed from soils by SVE system since 2005.	Chlorinated VOC concentrations in residential wells reduced below MCLs in early 2000's and have been non-detect ever since. In the FDA/MA Area concentrations of TCE (240 ppb down to 23 ppb), cis-1,2 DCE (1,000 ppb down to 100 ppb), and 1,4-dioxane (56 ppb down to 11 ppb) have decreased by about an order-of-magnitude since 2005 due to MNA. In just 2 years of operation in the Main Plant Area (MPA), the in situ bioremediation system has shown a 2-3 order-of-magnitude reduction in source area TCE and TCA groundwater concentrations. Initial TCE concentrations have been reduced from 81,400 ppb to d 2,170 ppb; *cis*-DCE concentrations have been reduced from 77,000 ppb to d 3,150 ppb; and TCA concentrations have been reduced from 6,800 ppb to d 580 ppb. COC concentrations remain above cleanup levels, although the remedial system has achieved a significant reduction of COCs. In the FDA/MA area, max VOC concentrations are 4,886 ppb, decreased from 35,146 ppb in 2007. In the MPA area, TCE concentrations are down to a max of 530 ppb. There has been an overall 76-90% reduction of VOC concentrations in the MPA area.	Listed 09/08/1983; Not yet deleted	1. EPA Web site: Malvern TCE Site Profile 2. Second Five-Year Review Report for Malvern TCE Superfund Site (Sept 2010) 3. Third Five-Year Review Report for Malvern TCE Superfund Site (Sept 2015)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Gold Coast Oil Corp., FL (OU 1) EPA Region 4	Waste TSD (Oil/Solvent Reclamation)	Groundwater/ Soil/ DNAPL (suspected)	Chlorinated VOCs, VOCs (PCE, TCE, DCE, DCA, Methylene Chloride, Toluene)	Restore groundwater to MCLs. ***RAOs have been achieved.***	Excavation, pump-and-treat, air sparging.	883 tons of contaminated soil removed. 80 million gallons of groundwater treated and 1,961 pounds of PCE and TCE removed. Met cleanup levels within 6 years of initiating remedial actions.	PCE concentrations in groundwater reduced from 100,000 ppb to below 3 ppb; TCE reduced from 48,000 ppb to below 3 ppb. Remedy reduced initial 0.87 acre plume to below cleanup levels.	Listed 09/08/1983; Deleted 10/09/1996	*See Case Summary for full list of information sources.* 1. Ryan, Serena; NNEMS, DNAPL Cleanup: Accomplishments at Twelve NPL Sites. (August 2010) 2. EPA Web site: Gold Coast Oil Company Site Profile
Hollingsworth Solderless Terminal, FL (OU 1) EPA Region 4	Manufacturing (Solderless Electrical Terminals)	Soil/ Groundwater	Chlorinated VOCs (TCE, *cis*-DCE, Vinyl chloride)	Restore groundwater to meet federal and state MCLs and risk-based cleanup levels (TCE 3 ppb, cis-DCE 70 ppb, VC 1 ppb). ***Significant progress has been made.***	Excavation, pump-and-treat, SVE, in situ bioremediation with ERD using potassium lactate and bacteria injections	Over 300 tons of contaminated soils removed. Pump-and-treat system initially removed up to 55 pounds of contaminants per day.	TCE reduced from 4,300 ppb to below cleanup level, and *cis*-DCE reduced from 10,000 ppb to below cleanup level. VC as high as 6,000 ppb have been reduced to 45 ppb. VC is the only remaining groundwater contaminant detected above state or federal standards. Most recent groundwater monitoring results (June 2016) indicate only 1 well of 24 exceed state of FL standard of 1ppb for VC.	Listed 09/08/1983; Not yet deleted	*See Case Summary for full list of information sources.* 1. EPA Web site: Hollingsworth Solderless Site Profile 2. EPA Region 4, June 2016
Rochester Property, SC (OU 1) EPA Region 4	Landfill/ Dump	Soil/ Groundwater	Chlorinated VOCs, non-chlorinated SVOCs, Metals (TCE, DCE, Bis(2-ethylhexyl)phthalate, Manganese)	Restore groundwater to MCLs (TCE 5 ppb, manganese 180 ppb, *cis*-1,2-DCE 70 ppb). ***RAOs have been achieved.***	Excavation, air sparging, ISCO using ozone sparging.	Removed 1,400 CY of contaminated soils. Air and ozone sparging achieved MCLs over 9 years	TCE reduced from 180 ppb to below 5 ppb, manganese reduced from 1,390 ppb to below cleanup level, and cis-1,2-DCE reduced from 3,600 ppb to below MCL. TCE plume eliminated from initial size of ~ 1/3 acre. Site meets criteria of "Site-Wide Ready for Anticipated Use".	Listed 10/04/1989; Deleted 10/09/2007	*See Case Summary for full list of information sources.* 1. Charsky, Matthew; Science and Policy Branch, Groundwater Successes at Deleted NPL Sites. (2010) 2. EPA Web site: Rochester Property Site Profile

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Tri-State Plating, IN (OU 1) EPA Region 5	Metal Works/ Plating (Electroplating)	Soil/ Groundwater	Metals (Chromium)	Eliminate the source and restore groundwater to federal MCLs (chromium 50 ppb). ***RAOs have been achieved.***	Pump-and-treat, excavation, drum removal, decontamination and demolition of site buildings.	27 drums of toxic materials removed. Top 1 foot of soil and visibly-contaminated areas excavated. All on-site structures demolished. 200 gpm pump-and-treat system reduced chromium concentrations to below 50 ppb cleanup level in three years of operation.	Chromium reduced from maximum concentration of 1,800 ppb to less than cleanup level. Remedy eliminated 200-foot long chromium plume. Site meets criteria for "Site-Wide Ready for Anticipated Use".	Listed 06/10/1986; Deleted 07/14/1997	*See Case Summary for full list of information sources.* 1. EPA Web site: Tri-State Plating Site Profile
US Aviex, MI (OU 1) EPA Region 5	Chemical Production (Automobile fluid production; bulk chemical repackaging)	Soil/ Groundwater	Chlorinated VOCs, Non-chlorinated VOCs (TCE, PCE, 1,1,1-TCA, Diethyl ether, 1,2-DCA, 1,1-DCE)	Restore groundwater to levels established by MDEQ and MCLs (1,2-DCA 5 ppb, diethyl ether 43 ppb, TCE 5 ppb, PCE 0.88 ppb, TCA 200 ppb). Provide onsite control of contaminated groundwater to prevent its migration offsite. ***Significant progress has been made.***	Soil excavation, pump-and-treat, air sparging, ISCO using ozone sparging, MNA.	4,817 tons of soil excavated and hauled offsite. Contaminated groundwater plume extended ~ 1 mile from facility.	As of 6/2009, in situ groundwater treatment reduced all contaminant concentrations to below MCLs with the exception of 1,2-DCA, Diethyl ether, TCE, PCE and TCA, which have been decreasing. COCs persist above cleanup levels within the contaminant plume downgradient of the site. In January 2013, EPA issued a Site-wide Ready for Anticipated Reuse (SWRAU) determination.	Listed 09/08/1983; Not yet deleted	1. EPA Web site: U.S. Aviex Site Profile 2. Third Five-Year Review Report for U.S. Aviex Superfund Site (Nov 2009) 3. Fourth Five-Year Review Report for U.S. Aviex Superfund Site (Nov 2014)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
LeHillier/ Mankato Site, MN (OU 1) EPA Region 5	Landfill/ Dump	Groundwater	Chlorinated VOCs (TCE)	Protect public from exposure to TCE, minimize migration of TCE in groundwater, and restore groundwater to federal MCLs (TCE 5 ppb). ***Significant progress has been made.***	Pump-and-treat.	Treatment of a 50-acre TCE plume in shallow unconfined aquifer over 8 years of pump-and-treat. Extraction wells designed to operate at rates up to 500 GPM.	Reduced initial TCE concentrations of up to 300 ppb to below MCL in 15 of 16 wells. Remaining well has TCE concentration of 12.6 ppb. Nearby municipal well shows no detections of TCE or chlorinated VOCs.	Listed 09/08/1983; Not yet deleted	1. EPA Web site: Lehillier/Mankato Site Profile 2. Fourth Five-Year Review Report for Lehillier/Mankato Superfund Site (June 2011) 3. Fifth Five-Year Review Report for Lehillier/Mankato Superfund Site (June 2016)
Odessa Chromium II, TX (OUs 1-3) EPA Region 6	Manufacturing (Radiator repair facility)	Groundwater	Metals (Hexavalent Chromium)	Prevent human ingestion of contaminated water and restore groundwater to meet federal MCLs (total chromium 0.1 ppm). ***RAOs have been achieved.***	Pump-and-treat, in situ chemical reduction (ISCR) with ferrous sulfate treatment	121 million gallons of groundwater pumped and treated, removing 141 pounds of chromium. ISCR with ferrous sulfate used to address residual chromium contamination in two wells. Cleanup levels achieved in less than 10 years of combined pump-and-treat and ISCR.	Total chromium reduced from 9.9 ppm to less than MCL. Remedy reduced approximate 40 acre chromium plume to below MCLs.	Listed 05/20/1986; Deleted 07/19/2004	*See Case Summary for full list of information sources.* 1. EPA Web site: Odessa Chromium II Site Profile 2. Five Year Review Report for Odessa Chromium II Superfund Site (2001)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Waverly Groundwater Contamination, NE (OU 1) EPA Region 7	Other (Grain Facility)	Soil/ Groundwater	Chlorinated VOCs (Carbon Tetrachloride, Chloroform)	Prevent exposure to contaminated groundwater, prevent future migration of contaminated groundwater plume, restore contaminated groundwater for future use as drinking water by reducing CCl4 and chloroform to below risk-based criteria (CCl4 5 ppb, chloroform 3.8 ppb). ***RAOs have been achieved.***	SVE, pump-and-treat.	GW treatment system designed to accept a flow of 400 GPM and an extraction well pumping rate of 150 GPM.	Maximum CCl4 and chloroform concentrations detected in groundwater were 400 ppb and 200 ppb, respectively. CCl4 reduced to 2.6 ppb, below cleanup level. Chloroform reduced to below cleanup level.	Listed 06/10/1986; Deleted 11/20/2006	1. EPA Web site: Waverly Groundwater Contamination Site Profile 2. Fourth Five-Year Review Report for Waverly Groundwater Contamination Site (Aug 2009) 3. Third Five-Year Review Report for Waverly Groundwater Contamination Site (Sept 2004)
Mystery Bridge Road/Highway 20 (Dow/DSI), WY (OUs 1 and 2) EPA Region 8	Other (Oil Field Services)	Soil/ Groundwater	Chlorinated VOCs, VOCs, LNAPL (PCE, Benzene, Toluene, Ethylbenzene, and Total Xylenes [BTEX])	Prevent ingestion of contaminated groundwater and restore affected aquifer by reducing contaminant concentrations to meet federal MCLs (PCE 5 ppb). ***Significant progress has been made.***	Excavation, pump-and-treat, , SVE	440 CY contaminated soil removed and disposed offsite. SVE system recovered 6,300 pounds of VOC contaminants.	Cleanup levels have been met with most recent sampling data showing that all COCs are below MCLs.	Listed 08/30/1990; Not yet deleted	1. EPA Web site: Mystery Bridge Road/Highway 20 Site Profile 2. Third Five-Year Review Report for Mystery Bridge Road/Highway 20 Superfund Site, Natrona County, Casper, Wyoming (Sept 2009) 3. Fourth Five-Year Review Report for Mystery Bridge Road/Highway 20 Superfund Site (Sept 2014) 4. Isoconcentration Map of PCE and Benzene in January 2010

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Del Norte County Pesticide Storage, CA (OU 1) EPA Region 9	Chemical Production (Storage of pesticides)	Soil/ Groundwater	Pesticides, Herbicides, Chlorinated VOCs (1,2-DCP, 2,4-D)	Restore groundwater to MCLs. Technical Impracticability waiver in 2000 ROD amendment waived the 5 ppb MCL for 1,2-DCP. The 1985 ROD established the RAO for 1,2-DCP at 10 ppb. **Soil and groundwater RAOs have been achieved for all contaminants of concern.**	Excavation and offsite disposal for soil, pump-and-treat, MNA.	Removed 290 CY of contaminated soil. 23 million gallons of groundwater has been treated over 7 years. 98% reduction of 1,2-DCP concentrations.	Reduced 1,2-DCP concentration in groundwater from 2,000 ppb to below MCL. 2,4-D reduced to below its MCL of 100 ppb through source removal alone. Upon confirmation by future sampling that 1,2-DCP concentration remains below the MCL	Listed 09/21/1984; Deleted 09/18/2002	*See Case Summary for full list of information sources.* 1. EPA Web site: Del Norte County Pesticide Storage Site Profile 2. Five-Year Review Report for Del Norte County Pesticide Storage Site (June 2015)
Firestone Tire and Rubber, CA (OU 1) EPA Region 9	Manufacturing (Tire)	Soil/ Groundwater	Chlorinated VOCs, nonchlorinated VOCs (Benzene, DCE, DCA, PCE, Toluene, TCE, Xylene)	Reduce contaminant concentrations to meet CA state drinking water cleanup levels or risk-based levels and control contaminant migration (DCE 6 ppb). ***RAOs have been achieved.***	Excavation and capping, pump-and-treat	Removed 22 storage tanks and 5,300 CY of contaminated soil. 1.8 billion gallons of groundwater treated. 496 pounds of chlorinated and non-chlorinated VOCs removed. Achieved cleanup levels in approximately 6 years of pump-and-treat.	DCE concentration reduced from 120 ppb to less than cleanup level. Remedy reduced 2.5 mile long groundwater contaminant plume to below cleanup levels. Site has been returned to productive use as an industrial park that provides space for several small and medium-size businesses.	Listed 07/22/1987; Deleted 04/21/2005	*See Case Summary for full list of information sources.* 1. EPA Web site: Firestone Tire and Rubber Site Profile

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Pemaco, CA (OU 1) EPA Region 9	Chemical Production (Blending and Distribution)	Soil/ Groundwater/ DNAPL (suspected)	Chlorinated VOCs, Non-chlorinated VOCs, SVOCs, Metals, PAHs (PCE, TCE, DCE, Vinyl chloride)	Prevent migration of COCs from soil to groundwater. Restore groundwater to MCLs (TCE 5 ppb, DCE 6 ppb). Prevent offsite migration of contaminated groundwater. Eliminate potential exposures to indoor air contamination. ***Significant progress has been made.***	Excavation and off-site disposal of soil, SVE, in situ thermal treatment (ERH), high-vacuum dual phase extraction, pump-and-treat, and MNA.	Removal and treatment of 21,500 pounds of chlorinated VOCs in vadose zone soils. DNAPL remediated.	Groundwater TCE in the in situ thermal treatment area reduced from 22,000 ppb to 660 ppb and DCE was reduced from 14,000 ppb to 440 ppb. The site was redeveloped into a park. A 3.4-kW PV system produces approximately 5,600 kWh/yr. Groundwater cleanup levels have not been met as contaminant levels have been increasing since 2011.	Listed 01/19/1999; Not yet deleted	*See Case Summary for full list of information sources.* 1. Ryan, Serena; NNEMS, DNAPL Cleanup: Accomplishments at Twelve NPL Sites. (August 2010) 2. EPA : Pemaco Maywood Profile Site 3. Groundwater Monitoring Report, 2013 June Monitoring Event (April 2014) 4. Second Five-Year Review Report, Pemaco Superfund Site, Los Angeles County, California. Sept. 2015.

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Southern California Edison, Visalia Pole Yard, CA (OU 1) EPA Region 9	Wood Treatment	Soil/ Groundwater/ DNAPL	Chlorinated and non-chlorinated SVOCs, PCP, dioxins (Benzo(a)pyrene, TCDD)	Discontinue discharge of chemicals related to pole treatment operations, extract and treat contaminated groundwater to meet MCLs (PCP 1 ppb, BaP 0.2 ppb, TCDD 0.00003 ppb), and contain the contaminant plume. ***RAOs have been achieved.***	In situ thermal treatment, enhanced in situ bioremediation (air sparging and bioventing), pump-and-treat, VEB - slurry wall, excavation.	1.33 million pounds of contaminants removed or treated by series of remedies. In situ thermal treatment removed over 99% of contamination in just three years. Cleanup levels and RAOs across site met in less than 25 years from start of remediation. Cleanup of groundwater plume covering 2.1 acres and extending from the water table to a depth of approximately 145 feet.	PCP concentration reduced from maximum concentration of 610 ppb to below MCL. BaP concentration reduced from maximum of 5 ppb to below MCL. TCDD concentration reduced from maximum of 11 ppb to MCL.	Listed 03/31/1989; Deleted 09/25/2009	*See Case Summary for full list of information sources.* 1. Ryan, Serena; NNEMS, DNAPL Cleanup: Accomplishments at Twelve NPL Sites. (August 2010) 2. EPA; DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved. (2009) 3. EPA Web site: Southern California Edison Site Profile
Western Pacific Railroad Co., CA (OU 1) EPA Region 9	Other (Rail Facility)	Soil/ Groundwater	Chlorinated VOCs, Metals, SVOCs (DCE, DCA, TCE, Arsenic, Lead, PAHs)	Restore groundwater to federal and state MCLs (DCE 6 ppb, DCA 5 ppb). ***RAOs have been achieved.***	Excavation, pump-and-treat, SVE.	2,500 tons of PAH contaminated soil removed. 127 million gallons of groundwater treated. 66 pounds of chlorinated VOCs removed from soil and groundwater. Site was deleted from NPL 11 years after remedial actions began.	DCE concentration reduced from 320 ppb to 1.7 ppb, less than CA MCL. DCA concentration reduced from 66 ppb to 1.4 ppb, less than CA MCL. Remedy eliminated initial 700-foot long chlorinated VOC contaminant plume.	Listed 08/30/1990; Deleted 08/29/2001	*See Case Summary for full list of information sources.* 1. Charsky, Matthew; Science and Policy Branch, Groundwater Successes at Deleted NPL Sites. (2010) 2. EPA Web site: Western Pacific Railroad Co Site Profile

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Fort Lewis Logistics Center, WA (East Gate Disposal Yard (EGDY)/Landfill 2 EPA Region 10	Military/ Federal (Maintenance and Disposal Yard)	Soil/ Groundwater/ DNAPL/ LNAPL	Chlorinated VOCs, Petroleum Hydrocarbons (TCE)	Restore groundwater to MCLs (TCE 5 ppb). ***Significant progress has been made.***	Pump-and-treat, drum removal, in situ thermal treatment with electrical resistive heating (ERH).	Over 125,000 pounds of chlorinated VOCs and petroleum hydrocarbons removed by ERH over three year period. 12,787 pounds of chlorinated and non-chlorinated VOCs extracted from pump-and-treat.	Maximum TCE concentrations in treatment zone fell from 250,000 ppb to a maximum concentration of 220 ppb. Site received the fiscal year 2005 Secretary of Defense Environmental Award for Environmental Restoration.	Listed 11/21/1989; Not yet deleted	*See Case Summary for full list of information sources.* 1. Ryan, Serena; NNEMS, DNAPL Cleanup: Accomplishments at Twelve NPL Sites. (August 2010) 2. EPA Web site: Fort Lewis Logistics Center Site Profile 3. 2015 Remedial Action Completion Report for Joint Base Lewis McChord Logistics Center (Aug 2015) 4. Preliminary site close-out report for Fort Lewis Logistics Center Site Profile (Sept 2015) 5. United States Department of Army; 2014 Annual Groundwater Monitoring Report. (July, 2016)
Frontier Hard Chrome, Inc., WA (O's 1 and 2) EPA Region 10	Metal Works/ Plating (Chrome Plating)	Soil/ Groundwater	Metals (Trivalent and Hexavalent Chromium)	Prevent direct exposure to chromium-contaminated soils and dust, control source area, and meet federal MCLs for chromium (50 ppb). **RAOs have been achieved for soil (OU 1) and groundwater (OU2).** Attainment assessment is underway.	In situ soil mixing with injection of reducing agent in the source area. In situ redox manipulation treatment wall to reduce Cr6 (injection of sodium dithionite reagent).	Over 180,000 gallons of groundwater treated through injection technology. 160 CY of contaminated soil excavated and disposed off site.	Initial chromium concentrations in groundwater as high as 300,000 ppb. Groundwater concentrations in all monitoring wells have been below the cleanup level since 2009.	Listed 09/08/1983; Proposed for deletion in 2017.	1. EPA Web site: Frontier Hard Chrome Inc. Site Profile 2. Five-Year Review Report for Frontier Hard Chrome, Inc (2008) 3. Long-Term Monitoring Report Event 19 for Frontier Hard Chrome Site (June 2013), Washington Department of Ecology, (Dec 2011.) 4. Five-Year Review for Frontier Hard Chrome, Inc (Jan 2013) 5. Long-Term Monitoring Report for Frontier Hard Chrome Inc. (Dec 2014)

Site Name	Industry (Site Type)	Media	Contaminant Groups (Contaminants with Highest Concentrations)	RAOs/ Cleanup Levels (RAOs Achieved or Significant Progress Made)	Remedial Technologies Used	Magnitude of Cleanup	Progress/ Accomplishments	NPL Listing; Deletion	Information Source(s)
Western Processing, WA (OU 2), Offsite Trans Plume EPA Region 10	Waste TSD	Groundwater/ Soil/ Surface Water	Chlorinated VOCs, Metals (TCE, *cis*-1,2-DCE, Vinyl Chloride, Zinc)	Prevent offsite migration of contaminated groundwater through containment (1995 ESD). Performance standard for "*trans*" plume groundwater is MCLs for *cis*-1,2-DCE (70 ppb). Restore surface water to Federal Ambient Water Quality Criteria (AWQC) (or background-derived concentrations where upstream concentrations approach or exceed the AWQC). ***RAOs have been achieved.***	Pump-and-treat, slurry wall, capping, MNA.	"Trans" plume actively remediated by pump-and-treat for 12 years (1988 - 2000) and MNA from 2000 to present. 40-foot deep slurry wall installed to prevent contaminants from migrating offsite. 13-acre RCRA cap placed over site. As of 2010, over 11,000 pounds of TCE, 5,500 pounds of DCE, 1,000 pounds of vinyl chloride, and 81,000 pounds of metals have been extracted from the groundwater.	Slurry wall, pump-and-treat, and MNA program reduced "trans" plume groundwater concentrations outside slurry wall to safe drinking water levels. No chlorinated VOCs were detected in "trans" plume monitoring wells in 2010. Last detection of TCE in 1992, 1,2-DCE in 2002, and vinyl chloride in 2006. Initial maximum groundwater DCE and vinyl chloride concentrations in "trans" plume wells were approximately 10,000 ppb and 500 ppb, respectively. Surface water contaminants have met cleanup levels since 1993.	Listed 09/08/1983; Not yet deleted	1. Ryan, Serena; NNEMS, DNAPL Cleanup: Accomplishments at Twelve NPL Sites. (August 2010) 2. EPA Web site: Western Processing Co. Site Profile 3. Fourth Five-Year Review Report for Western Processing Superfund Site (July 2008): 4. 2010 Annual Report Western Processing Kent, Washington, Landau Associates (June 2011) 5. Fifth Five-Year Review Report for Western Processing Superfund Site (Sept. 2013)

Appendix B: Case Summaries

Table B- 1. Industry Type, Media, Contaminant, and Technology for 19 Remedies with Case Summaries

Site	Page Number	Industry (Site Type)	Media Type	Contaminant Groups (Contaminants with Highest Concentrations)	Technology
Region 1					
Eastern Surplus Company, ME (OU 1), Southern TCE Plume	B-6	Other (Salvage/Storage Yard/Re-sale)	Groundwater/Soil/Sediment	Chlorinated VOCs, Metals, PCBs (PCE, TCE, Manganese, Lead, PCBs)	Soil and sediment excavation and waste removal, pump-and-treat, ISCO with sodium permanganate injections.
Region 2					
Mannheim Avenue Dump, NJ (OU 1)	B-9	Landfill/Dump	Soil/Groundwater	Chlorinated VOCs, Metals (TCE, Lead)	Excavation, pump-and-treat, MNA.
Tabernacle Drum Dump, NJ (OU 1)	B-11	Landfill/Dump (Rural area with a one-time dumping of solvents, paints, and paint sludge)	Soil/Groundwater	Chlorinated VOCs (TCA, DCE)	Removal of drums, excavation of soil, pump-and-treat.
Pasley Solvents and Chemicals, Inc., NY (OU 1)	B-13	Chemical Production (Oil/Solvent Storage and Distribution)	Soil/Groundwater/DNAPL (suspected)	Non-chlorinated VOCs, Chlorinated VOCs (DCE, TCA, DCA, Chlorobenzene, Toluene, Ethylbenzene, Xylenes)	SVE, air sparging.
Region 3					
Dover Air Force Base (AFB), SS07/Area 2, South Management Unit, DE	B-17	Military/Federal (Aircraft and Vehicle Maintenance)	Groundwater/DNAPL (suspected)	Chlorinated VOCs, Non-chlorinated VOCs (PCE, TCE, DCE, Vinyl Chloride, Benzene)	ERD/Accelerated anaerobic biodegradation, MNA.
Letterkenny Army Depot (Southeast Area), PA (OU 10)	B-21	Military/Federal (Ammunition Storage)	Groundwater	Chlorinated VOCs (TCE, DCE, Vinyl Chloride)	In situ biological treatment using ERD with sodium lactate injections, MNA.
Region 4					
Gold Coast Oil Corp., FL (OU 1)	B-25	Waste TSD (Oil/Solvent Reclamation)	Groundwater/Soil/DNAPL (suspected)	Chlorinated VOCs, Non-chlorinated VOCs (PCE, TCE, DCE, DCA, Methylene Chloride, Toluene)	Excavation, pump-and-treat, air sparging.

Site	Page Number	Industry (Site Type)	Media Type	Contaminant Groups (Contaminants with Highest Concentrations)	Technology
Hollingsworth Solderless Terminal, FL (OU 1)	B-29	Manufacturing (Solderless Terminals)	Soil/Groundwater	Chlorinated VOCs (TCE, cis-DCE, Vinyl Chloride)	Excavation, pump-and-treat, SVE, in situ bioremediation with ERD using potassium lactate and bacteria injections.
Rochester Property, SC (OU 1)	B-33	Landfill/Dump	Soil/Groundwater	Chlorinated VOCs, SVOCs, Metals (TCE, DCE, Bis(2-ethylhexyl)phthalate, Manganese)	Excavation, air sparging, ISCO using ozone sparging.
Region 5					
Tri-State Plating, IN (OU 1)	B-35	Metal Works/Plating (Electroplating)	Soil/Groundwater	Metals (Chromium)	Pump-and-treat, excavation, drum removal, decontamination and demolition of site buildings.
Region 6					
Odessa Chromium II, TX (OUs 1-3)	B-37	Manufacturing (Radiator repair facility)	Groundwater	Metals (Hexavalent Chromium)	Pump-and-treat, ISCR with ferrous sulfate treatment.
Region 9					
Del Norte County Pesticide Storage, CA (OU 1)	B-39	Chemical Production (Storage of pesticides)	Soil/Groundwater	Pesticides, Herbicides, Chlorinated VOCs (1,2-DCP, 2,4-D)	Excavation and offsite disposal for soil, pump-and-treat, MNA.
Firestone Tire and Rubber, CA (OU 1)	B-43	Manufacturing (Tire)	Soil/Groundwater	Chlorinated VOCs, Non-chlorinated VOCs (Benzene, DCE, DCA, PCE, Toluene, TCE, Xylene)	Excavation and capping, pump-and-treat.
Pemaco, CA (OU 1)	B-45	Chemical Production (Blending and Distribution)	Soil/Groundwater/DNAPL (suspected)	Chlorinated VOCs, Non-chlorinated VOCs, SVOCs, Metals, PAHs (PCE, TCE, DCE, Vinyl Chloride)	Excavation and off-site disposal of soil, SVE, in situ thermal treatment (ERH), high-vacuum dual phase extraction, pump-and-treat, and MNA.

Site	Page Number	Industry (Site Type)	Media Type	Contaminant Groups (Contaminants with Highest Concentrations)	Technology
Southern California Edison, Visalia Pole Yard, CA (OU 1)	B-49	Wood Treatment	Soil/Groundwater/DNAPL	SVOCs, CSVOCs, PCP, dioxins (Benzo(a)pyrene, TCDD)	In situ thermal treatment, enhanced in situ bioremediation (air sparging and bioventing), pump-and-treat, VEB (slurry wall), excavation.
Western Pacific Railroad Co., CA (OU 1)	B-53	Other (Rail Facility)	Soil/Groundwater	Chlorinated VOCs, Metals, PAHs (DCE, DCA, TCE, Arsenic, Lead)	Excavation, pump-and-treat, SVE.
Region 10					
Fort Lewis Logistics Center, WA (East Gate Disposal Yard (EGDY) OU1)	B-57	Military/Federal (Maintenance and Disposal Yard)	Soil/Groundwater/DNAPL/LNAPL	Chlorinated VOCs, Petroleum Hydrocarbons (TCE)	Pump-and-treat, drum removal, electrical resistive heating (ERH).

Notes:
(1) Not all remedies and contaminants are presented for each site.
(2) Remedies listed are specific to the media, contaminant, and operable unit that are the subject of this report.
(3) One primary site type selected for each site.
(4) Other site type includes two transformer/electrical facilities, one grain facility, one rail facility, one textile mill, one oil field one oil field services facility, and one salvage/storage yard/retail facility.

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Eastern Surplus Company Superfund Site, Southern Plume

Site Location: Meddybemps, Washington County, ME, Region 1

EPA ID#: MED981073711

Regulatory Agency: U.S. EPA, Maine Department of Environmental Protection (MEDEP)

Site Summary: Remedial actions at the Eastern Surplus Company NPL site included the cleanup of chlorinated volatile organic compounds (VOCs), metals, and PCBs from groundwater and soils. Key site contaminants of concern (COCs) included tetrachloroethene (PCE), trichloroethene (TCE), manganese, lead, and polychlorinated biphenyls (PCBs). MEDEP initiated several removal actions starting in 1985, and the site was listed on the NPL in 1996. After being listed on the NPL, contaminated surface and subsurface soils were excavated and shipped off-site for disposal. In addition, sediment from Dennys River contaminated with elevated concentrations of PCBs was removed along with the soils. Contaminated groundwater was discovered in two separate plumes, identified as the northern and southern plumes. A combined groundwater pump-and-treat and an in situ chemical oxidation (ISCO) remedial program were implemented at both plumes. VOC contaminant concentrations within the southern plume have decreased to below concentration goals, which are based on EPA maximum contaminant levels (MCL) or Maine's Maximum Exposure Guidelines (MEG), whichever is lower for the contaminant of concern (EPA, 2011). However, the majority of the contamination remains in the northern plume which will be addressed using enhanced in situ bioremediation.

Eastern Surplus NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including PCE and TCE, metals including manganese and lead, and PCBs; highest concentrations in groundwater included 6,700 ppb PCE (northern plume) and 1,100 ppb PCE (southern plume)
- **Media:** Groundwater, soil, sediment, DNAPL (suspected in northern plume), fractured bedrock
- **Plume:** Approx. 1 acre northern chlorinated VOC plume; approx. 1.5 acre southern chlorinated VOC plume; depths up to 20–30 feet bgs
- **Technologies:**
  - Groundwater pump-and-treat with carbon filtration and ion exchange treatment of extracted groundwater
  - ISCO (sodium permanganate)
- **Major Successes:**
  - Remediated source of soil, groundwater, and sediment contamination within 10 years
  - Southern plume groundwater contaminant concentrations reduced to below MCLs
  - Current site use includes a major archaeological research site for the history of the Passamaquoddy people

Site History: The Eastern Surplus Company site operated from 1946 to 1976 as a salvage and storage yard to store and re-sell supplies, materials, and equipment from the U.S. Department of Defense (DOD). An inspection by MEDEP in 1984 noted chemical odors, leaking electrical transformers, hundreds of deteriorating drums and containers, compressed gas cylinders, 16,000 pounds of calcium carbide, and numerous areas of stained soil. The northern portion of the site covers approximately 4–5 acres, and the southern portion covers approximately 2–3 acres. The site is bounded by residential properties, Meddybemps Lake, the Dennys River, and undeveloped land. The overburden soils consist of stratified beds of gravel, sand, and mixed sands and silt and range from 5 to 20 feet in thickness in the northern plume and 10 to 30 feet in the southern plume. Depth to groundwater in the southern plume ranges from 12 to 20 feet below ground surface (bgs), while the overburden in the northern plume is only seasonally saturated. Bedrock at the site is a combination of Meddybemps granite with a gabbro-diorite intrusion (EPA, 1990).


Treatment Building (EPA, 2011)

The MEDEP initiated a removal action in 1985 to stabilize the site by removing approximately 120 transformers, 4,650 gallons of waste oil, and 2,400 gallons of PCB oil. In 1986, EPA took over the removal action, which involved the inspection, evaluation, and removal of thousands of leaking drums and cans, and over 2,000 compressed gas cylinders (EPA, 2006). The site was listed on the NPL in June 1996, and a non-time critical removal action (NTCRA) was completed in 1999 and 2000. The NTCRA involved soil excavation and disposal, and the installation of a source control groundwater extraction system (EPA, 2006). The Remedial Investigation/Feasibility Study (RI/FS) was also completed in 1999, and a record of decision (ROD) was issued in September 2000 (EPA, 2000) which selected pump-and-treat for the two groundwater plumes, enhancement of the system through flushing and/or ISCO to facilitate the removal of contamination, and land use restrictions to prevent ingestion of groundwater and disturbance of archaeological resources. Beginning in 2001, EPA enhanced the groundwater component of the ROD by implementing ISCO with sodium permanganate. Three five-year reviews have been performed to date (EPA, 2006, 2011, and 2016) EPA performed a bench-scale study in 2011 and a pilot study in 2012-2013 of enhanced in situ bioremediation (EISB) in the northern plume. Based on the positive impact, EPA is preparing to expand to a full-scale implementation of EISB.

Extent of Contamination: Two distinct groundwater VOC plumes were identified at the site, an approximate 1 acre northern plume and an approximate 1.5 acre southern plume. PCE was detected in the northern plume at a maximum concentration of 6,700 µg/L (ppb). Because this concentration is greater than 1 percent of PCE's solubility in water, it indicates the possible presence of a DNAPL at this site (EPA, 1992). Other VOCs were detected in the northern plume above cleanup goals including TCE, *cis*-1,2-dichloroethene (*cis*-DCE), 1,1,2-trichloroethane, xylene, and methylene chloride. The ROD-specified groundwater cleanup goals are based on MCLs or Maine's MEG including 3 ppb for PCE (MEG), 5 ppb for TCE (MCL), 70 ppb for *cis*-DCE (MCL), 3 ppb for 1,1,2-trichloroethane (MEG), 600 ppb for xylene (MEG), and 5 ppb for methylene chloride (MCL). The southern plume contained PCE at a maximum concentration of 1,100 ppb and PCBs detected at a concentration of 3 ppb. Both plumes were believed to be discharging to the Dennys River. A majority of contamination in the northern plume was located in fractured bedrock with possible DNAPL, whereas the southern plume was located in overburden and shallow bedrock.


Extraction wells at Eastern Surplus Company Superfund Site (EPA, 2006)

Cleanup Approach: Remedial actions for both contaminated groundwater plumes began in 1999 as part of the NTCRA. The northern plume groundwater extraction system came online in January 2000 and the southern plume extraction system came online in September 2000. The interim system completed during the NTCRA was augmented with additional extraction wells and injection wells which were used to enhance the flushing of the plume to the extraction wells. A total of 10 extraction wells were installed in the northern plume and six extraction wells in the southern plume. The treatment system for the extracted groundwater consisted of filtration of suspended solids, liquid-phase granular activated carbon (GAC) for removal of VOCs, and ion exchange to remove metals of concern. After a two-phase pilot study from July 2000 until June 2001, a full scale ISCO application was implemented from August 2002 through January 2003 using sodium permanganate. Sodium permanganate solution was injected in direct push wells within both plumes with additional permanganate solution added to re-circulating wells. Results indicated that sodium permanganate was effective in destroying dissolved PCE in bedrock in the northern plume, but needed to be effectively delivered into the bedrock fractures to ensure adequate contact with the PCE (EPA, 2006). Sodium permanganate injections in the southern plume indicated that PCE concentrations increased after full scale permanganate injections (which could indicate dissolution of sorbed DNAPL), then declined for five consecutive sampling events. The groundwater pump-and-treat system operated full-scale until January 2003, and was shut down for a short period to evaluate how contaminant concentrations would change or rebound. The system was restarted in August 2003 after groundwater sampling data indicated that concentrations had increased. Extraction wells located within the southern plume were shut down in late 2010 as VOC concentrations had decreased to below the cleanup goals (MCLs and MEGs) (EPA, 2011).

Cleanup Success: The southern contaminated groundwater plume was successfully treated using a conventional pump-and-treat system supplemented by the injection of sodium permanganate (ISCO) to accelerate degradation of contaminants. As a result of this approach, combined with source removal during the NTCRA, the approximately 1.5 acre southern plume was cleaned up to drinking water standards, and extraction wells located within the southern plume were shut down in late 2010. Remediation continues, however, within the northern plume where concentrations are still above MCLs due to the more complex geology and higher (DNAPL range) initial concentrations in groundwater. Current site use includes a major archaeological research site for the history of the Passamaquoddy people.

Table 1. Summary of PCE Concentration in Southern Plume at the Eastern Surplus NPL Site

Treatment Phase	PCE Maximum Concentration (ppb)
Initial Maximum Concentration in Overburden	1,100*
Before ISCO Pilot Study	570 (overburden)* 200 (bedrock)*
After ISCO Pilot Study (July 200 –June 2001)	160 (overburden) 77 (bedrock)
After Full-Scale ISCO (August 2002– January 2003)	25 (overburden)* 22 (bedrock)*
April 2006	9 (overburden)* 6 (bedrock)*
Current Maximum Concentration	Below MCL and MEG**

Sources: * EPA, 2006 and ** EPA, 2011
ppb = parts per billion

References

United States Environmental Protection Agency; Third Five Year Review, Eastern Surplus Company Superfund Site, Washington County, Maine. September 28, 2016.

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United States Environmental Protection Agency; Second Five Year Review, Eastern Surplus Company Superfund Site, Meddybemps, Maine. September 29, 2011.

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United States Environmental Protection Agency; Record of Decision, Eastern Surplus Company Superfund Site, September 28, 2000.

United States Environmental Protection Agency. Estimating Potential for Occurrence of DNAPL at Superfund Sites. OSWER Publication 9355.4-07FS. January 1992.

Mannheim Avenue Dump NPL Site

Site Location: Galloway Township, NJ, Region 2

EPA ID#: NJD980654180

Regulatory Agency: U.S. EPA, New Jersey Department of Environmental Protection (NJDEP)

Site Summary: Remedial actions at the Mannheim Avenue Dump NPL site included cleanup of lead and trichloroethene (TCE) in soil and TCE in groundwater. The soil remedy included the excavation and off-site incineration of contaminated soil (EPA, 1990). Groundwater cleanup involved a pump-and-treat groundwater system with air stripping of extracted groundwater for 18 months (EPA, 1999). Pump-and-treat was followed by monitored natural attenuation (MNA). The cleanup level of 1 µg/L (ppb) for TCE in groundwater was met by 2002 (EPA, 2004). The site was deleted from the NPL in 2007 (EPA, 2010).

Mannheim Avenue Dump NPL Site
Remediation Highlights

- **Contaminants:** TCE in groundwater and TCE and lead in soil; highest concentration in groundwater was 140 ppb TCE.
- **Media:** Groundwater, Soil
- **Plume:** TCE in groundwater covered an area of 1,000 feet by 1,000 feet and extended 55 feet deep
- Technologies:
  - Drum, sludge, and soil removal
  - Groundwater pump-and-treat with air stripping treatment
  - MNA
- Major Success:
  - Over 25,000 pounds of contaminated sludge and 2,700 cubic yards of contaminated soil removed
  - Remedy met stringent NJDEP cleanup level of 1 ppb for TCE in approximately eight years of combined pump-and-treat and MNA

Site History: The Mannheim Avenue Dump was a sand and gravel pit, which ceased operation in 1964. Beginning in 1964, the site was used by Lenox China to dispose of industrial wastes from manufacturing and by Galloway Township to dispose of municipal wastes. The aquifer underlying the site consists of shallow and deep zones, each comprised of sand and gravel, separated by an approximately 3-to-5-foot thick semi-permeable clay layer. The depth to shallow groundwater is approximately 35 feet below ground surface (bgs). Groundwater flows in a northwesterly direction in the shallow zone and in a northeasterly direction in the deeper zone (EPA, 2004).

In 1981, an industrial survey report from Lenox China notified the NJDEP that hazardous waste could have been disposed of on-site, including 55-gallon drums of TCE degreasing sludge. A subsequent NJDEP investigation revealed the presence of exposed 55-gallon drums in deteriorating conditions. Drum samples were collected and indicated the presence of VOCs and heavy metals. The site was placed on the NPL in 1983. Sludge and soil removal actions began in 1985, and a Remedial Investigation/Feasibility Study (RI/FS) and a record of decision (ROD) were completed in 1990 (EPA, 1990). The groundwater remedy began in 1994 and in eight years, TCE concentrations in all wells were below the NJDEP Drinking Water Standard cleanup level of 1 ppb (EPA, 2004). The second five-year review was completed in 2004 (EPA, 2004) and the site was deleted from the NPL in 2007 (EPA, 2010).

Extent of Contamination: The highest concentration of lead in soil was 48,000 ppm (EPA, 1999). The highest concentration of TCE in sludge was 2,000 ppm (ATSDR, 1993). TCE contamination was detected in both the shallow and deep aquifer zones. Initial TCE concentrations of 140 ppb in groundwater were found onsite after initial cleanup efforts. Following the sludge and soil removal actions, TCE was still detected at concentrations up to 29 ppb and 47 ppb in the shallow and deep aquifers, respectively. The TCE plume in excess of 1 ppb in the shallow aquifer zone was estimated to be 100 feet long, 400 feet wide, and 15 feet deep, while the plume in the deep aquifer zone was estimated to be 1,000 feet long, 1,000 feet wide, and 55 feet deep (EPA, 1990).

Cleanup Approach: In 1985, initial cleanup of the site involved the removal of 25,000 pounds of degreasing sludge and treatment of the sludge using off-site incineration. In 1989, 2,700 cubic yards (CY) of lead-contaminated soil from 35 soil piles was excavated and incinerated off-site (EPA, 2010). The groundwater remedy involved a pump-and-treat system consisting of three extraction wells, one screened in the shallow aquifer and two screened in the deep aquifer. The contaminated groundwater was pumped to the treatment system at a rate of 40 gallons per minute (gpm) where VOCs were removed using air stripping. The treated groundwater was then re-injected into the aquifer. The treatment system operated for 18 months from

August 1994 to April 1996, when it was determined that TCE concentrations in the influent had dropped below the 1 ppb cleanup level. The pump-and-treat system was shut down, and was followed by MNA. A total of 30 million gallons of contaminated groundwater were treated during pump-and-treat system operation (EPA, 2010). Long term monitoring data indicated that TCE concentrations in the 32 monitoring wells were steadily declining, and had reached levels lower than the NJDEP Drinking Water Standard cleanup level of 1 ppb in all but two wells. MNA continued since the TCE concentration in one well remained as high as 22 ppb. By 1999, only one well had a concentration above cleanup levels, at around 4 ppb (EPA, 1999). Monitoring data demonstrated that all well concentrations were below the cleanup level by 2002, and remained so through 2003 (EPA, 2004). Table 1 demonstrates the reduction in the maximum TCE concentrations in groundwater at the site as a result of the implemented remedy.

Cleanup Success: The cleanup at the Mannheim Avenue Dump NPL site incorporated two large contaminant source area removals, followed by pump-and-treat and MNA of groundwater. The source removals helped to expedite the cleanup of the groundwater. After operating the pump-and-treat system for only 18 months, followed by approximately six years of MNA, the sizable TCE plumes in both the shallow and deep aquifer zones were remediated to below the NJDEP cleanup levels. The site was deleted from the NPL in 2007.

Table 1. Concentration Reduction in Groundwater at the Mannheim Avenue Dump NPL Site

Timeframe	Maximum TCE Concentration (ppb)
Investigations in 1985/1986	140*
Investigations for RI/FS 1989/1990; After Removal Actions	47*
After 18 Month of Pump-and-Treat System Operation 1996	22**
After ~ 3 Years of MNA 1999	4**
After Another 3 Years of MNA 2002	<1***

Source: * = EPA, 1990; ** = EPA, 1999; * = EPA, 2004**
ppb = parts per billion

References

Agency for Toxic Substances and Disease Registry; Public Health Assessment for Mannheim Avenue Dump, Galloway Township, Atlantic County, New Jersey; November 5, 1993.

United States Environmental Protection Agency, Region 2; Mannheim Avenue Dump Site Profile; 2010.

United States Environmental Protection Agency; Second Five-Year Review for Mannheim Avenue Dump Site; 2004.

United States Environmental Protection Agency; Five-Year Review Report, Mannheim Avenue Dump Superfund Site; 1999.

United States Environmental Protection Agency; EPA Superfund Record of Decision: Mannheim Avenue Dump; 1990.

Tabernacle Drum Dump NPL Site

Site Location: Tabernacle Township, NJ, Region 2

EPA ID#: NJD980761357

Regulatory Agency: U.S. EPA, New Jersey Department of Environmental Protection (NJDEP), Burlington County Health Department (BCHD)

Site Summary: Remedial actions at the Tabernacle Drum Dump NPL site were handled in two stages. A time critical removal action was conducted to remove leaking storage containers holding waste paint, paint sludge, and solvents and the resulting contaminated soil. A subsequent long-term remedial phase focused on cleanup of groundwater using a pump-and-treat system with air stripping to remove chlorinated volatile organic compounds (VOCs) from the extracted groundwater. Key contaminants of concern in groundwater included 1,1,1-trichloroethane (1,1,1-TCA) and its breakdown product, 1,1-dichloroethene (1,1-DCE). The pump-and-treat system was successful in reducing contaminant levels for TCA and 1,1-DCE to below their NJDEP maximum contaminant levels (MCLs) in just over four years (EPA, 2010).

Tabernacle Drum Dump
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including 1,1,1-TCA and breakdown product 1,1-DCE; highest concentrations in groundwater included 1,000 ppb 1,1,1-TCA and 180 ppb 1,1-DCE
- **Media:** Groundwater, Soil
- **Plume:** VOCs in groundwater extended approximately 3,000 feet from the source location
- Technologies:
  - Emergency removal action to remove damaged and leaking drums and affected soil
  - Groundwater pump-and-treat system with air stripping to treat extracted groundwater
- Major Successes
  - Soil contaminant concentrations below cleanup levels after emergency action
  - 1,1,1-TCA concentrations reduced from 1,000 ppb to below NJDEP cleanup level of 26 ppb
  - Groundwater cleanup levels achieved with just over four years of pump-and-treat

Site History: The Tabernacle Drum Dump was a 1-acre wooded site which was used by Atlantic Disposal Services (ADS) to illegally dispose of approximately 200 containers of waste solvent, paint, and paint sludge on an approximately 2,000-square-foot portion of the property in 1976 or 1977. Two aquifers exist beneath the site, separated by an intermittent, 20-foot thick clay layer. The upper water-bearing source is the Cohansey aquifer, which consists of up to approximately 100 feet of highly permeable soils, and supplies the majority of residents living in the vicinity. In some areas, the Cohansey aquifer is hydraulically connected to the underlying Kirkwood aquifer, which is not typically used as a source of potable water. The direction of groundwater flow is southeasterly, and the principal threat posed at the site was the potential ingestion of groundwater by down gradient residents (EPA, 1988).

The containers were discovered by the Tabernacle Township in 1982. In 1984, EPA issued an administrative order to ADS to perform an emergency removal action of waste containers, drummed materials, contaminated soil, and liquid materials. In September 1984, the site was finalized for inclusion on the NPL. EPA completed a Remedial Investigation/Feasibility Study (RI/FS) and signed a record of decision (ROD) in 1988. Installation of a groundwater pump-and-treat system was completed in July 1993 and operated until 1997, when cleanup levels were achieved. The site was deleted from the NPL in May 2008 (EPA, 2010).

Extent of Contamination: The area of surface contamination covered approximately 2,000 square feet of the 1-acre site. Initial maximum concentrations of 1,1,1-TCA and 1,1-DCE in groundwater were 1,000 µg/L (ppb) and 180 ppb, respectively, with concentrations of 1,1,1-TCA significantly exceeding the NJDEP MCL of 26 ppb in six of the eight wells on the site (EPA, 1988). The plume extended 3,000 feet southeast of the original dump location (EPA, 2010). The maximum initial concentration detected in groundwater and concentration ranges during post-remedial monitoring are shown in Table 1.

Cleanup Approach: The initial remedial action at the Tabernacle Drum Dump NPL site was conducted by ADS in 1984, under the supervision of EPA, and consisted of surface cleanup. This action included removal and off-site disposal at a hazardous waste facility of 40 cubic yards (CY) of drummed material, eight truckloads of excavated soil, and approximately 3,000 gallons of liquid material (EPA, 2010). The RI/FS completed by EPA in 1988 showed that the contaminant plume was migrating to the southeast of the original dump location in the direction of residential drinking water wells, and a ROD was signed later that year. A groundwater pump-and-treat system was constructed and began operation in 1993. The system pumped groundwater, treated it with air stripping to remove VOCs, and re-injected it into the aquifer at a rate of approximately seven million gallons per month (EPA, 2010). Quarterly groundwater sampling that began in October 1993 and continued throughout the program showed decreasing concentrations of contaminants. In December 1997, the pump-and-treat system was shut down, as EPA concluded contaminant concentrations had decreased below cleanup levels (EPA, 1998). Five years of post-remediation monitoring 1999–2005) verified that the RAOs and cleanup levels were met. In 2005, the pump-and-treat system was dismantled and monitoring wells were abandoned. The site was deleted from the NPL in May 2008 (EPA, 2010).

Treatment building and air stripper tower (Waste Technology, 1999)

Cleanup Success: The Tabernacle Drum Dump NPL site was successfully remediated using a combination of a time-critical source removal of leaking drums and contaminated soil with a subsequent pump-and-treat groundwater remedy. Groundwater cleanup levels were met in just over four years of pump-and-treat operation. The pump-and-treat system reduced 1,1,1-TCA concentrations from 1,000 ppb to less than 2 ppb, and 1,1-DCE concentrations from 180 ppb to less than 1 ppb. Five years of post-remediation monitoring verified that cleanup levels were met and the site was deleted from the NPL in 2008 (EPA, 2010).

Table 1. Pre- and Post-Remediation Contaminant Concentrations in Groundwater

Contaminant of Concern	Initial Maximum Concentration (ppb) – July 1985	Remedial Goal (ppb) (NJDEP MCL)	Concentration Ranges During Monitoring (1996-1997)
1,1,1-Trichloroethane	1,000	26	0.5-2.0
1,1-Dichloroethene	180	2	0.2-1.0

Source: EPA, 1998
NJDEP = New Jersey Department of Environmental Protection
MCL = Maximum Contaminant Level
ppb = parts per billion

References

United States Environmental Protection Agency, Region 2; Site Overview, Tabernacle Drum Dump; 2010.

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Waste Technology, Inc.; Biannual Inspection Report for the Tabernacle Drum Dump Site. August 10, 1999.

Pasley Solvents and Chemical NPL Site

Site Location: Hempstead, NY, Region 2

EPA ID#: NYD991292004

Regulatory Agency: U.S. EPA, New York State Department of Environmental Conservation (NYSDEC), Nassau County Department of Health (NCDH)

Site Summary: Remedial actions at the Pasley Solvents and Chemical NPL site included the cleanup of halogenated and non-halogenated volatile organic compounds (VOCs) from groundwater and soil. Key contaminants included chlorobenzene, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), toluene, ethylbenzene, and xylenes. The remedy included in situ treatment of groundwater and soil using air sparging (AS) and soil vapor extraction (SVE). All cleanup levels were met within five years after completing construction of the remedy (EPA, 2009a).

Pasley Solvents and Chemical NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including chlorobenzene, 1,1-DCA, 1,1-DCE, *trans*-1,2-DCE, and 1,1,1-TCA, and VOCs including toluene, ethylbenzene, and xylenes; highest concentrations in groundwater included 37,000 ppb *trans*-1,2-DCE
- **Media:** Groundwater, Soil
- **Plume:** Groundwater DCE plume extended approximately 400 feet southwest of the source and reached depths of 60 feet
- **Technologies:**
  - SVE
  - AS
- **Major Success:**
  - Large reduction of total volatile organic index compounds in groundwater in first two years (from 37,000 ppb to 4 ppb)
  - Over 15,000 pounds of contaminants removed from soil and groundwater
  - Cleanup levels achieved within five years of AS/SVE system startup
  - Deleted from the NPL in 2011

Site History: The Pasley Solvents and Chemical Company is a former tank farm that stored and distributed oil, solvents, and other chemicals. The facility operated from 1969 to 1982. Leaking tanks contaminated soil and groundwater at the site. There are two distinct geological/hydrological formations at the site, the Upper Glacial aquifer and the Magothy aquifer. The Upper Glacial aquifer consists of up to 60 feet of unconsolidated sand and gravel, while the Magothy formation consists of up to 400 to 500 feet of thick fine sands with thin, discontinuous layers of silt and clay. The groundwater in these aquifers flows in a south to southwesterly direction, depending upon depth (EPA, 2009a). In 1980, inspection by the NCDH revealed soils contaminated with VOCs (EPA, 2009a). In 1981, the company had five groundwater monitoring wells installed, and groundwater samples indicated the presence of VOCs, including benzene, tetrachloroethene (PCE), toluene, and xylene, above State Drinking Water Standards (EPA, 1992). In 1982, operations at the site ceased, and it was placed on the NPL in 1986. Removal of the tank farm was conducted in 1988, a Remedial Investigation and Feasibility Study (RI/FS) was completed, and a record of decision (ROD) was issued in 1992. The ROD selected remediation of groundwater by extraction, treatment, and recharge of the treated groundwater into the aquifer, and SVE to treat contaminated soils. A ROD Amendment was issued in 1995 to allow groundwater treatment via in situ AS instead of constructing the original ROD-selected treatment system. Remedial construction was completed and the system became operational in November 1997. The system operated for five years, and was followed by post-remediation monitoring demonstrating all remedial action objectives (RAOs) had been met. The final Close Out Report was signed in 2005 (EPA, 2009a). The site was deleted in September of 2011.

Extent of Contamination: The highest concentration of total VOCs detected in surface soil was 603,000 µg/L (ppb). VOCs detected in soil at 6 to 12 inches below ground surface (bgs) were also generally present in the groundwater. *Trans*-1,2-DCE concentrations, the most prevalent contaminant in groundwater at the site, were as high as 37,000 ppb (EPA, 2009b). The groundwater plume was located in the Upper Glacial aquifer at depths up to 60 feet bgs, and extended to the southwest for approximately 400 feet (EPA, 1992).

Contamination detected in a cluster of up gradient wells indicated that contamination was entering the site from the adjacent Roosevelt Field Superfund site. Because the Roosevelt Field site was suspected to be contributing TCE and PCE to the upper aquifer, the up gradient well cluster was not used to define the plume for the site. The sum of these VOCs was labeled as total volatile organic index compounds (TVOICs) and included chlorobenzene, 1,1-DCA, 1,1-DCE, ethylbenzene, toluene, *trans*-1,2-DCE, 1,1,1-TCA, and xylenes (EPA, 1992). The TVOIC compounds were found to contribute a major part (88 percent) of the contamination found in the monitoring well cluster located on-site. TCE and PCE are not considered to have originated at the site and are not TVOIC compounds. Maximum concentrations of TCE and PCE were detected at 320 ppb and 27 ppb, respectively. The use of index compounds allowed identification of a well-defined contaminant plume for the site (EPA, 1992).

Cleanup Approach: Initial cleanup of the site involved the removal of the tank farm in 1988, followed by the removal of contaminants from water and soil using AS and SVE, respectively. For the groundwater remedy, a total of 34 2-inch AS wells were installed and screened at 50 to 52 feet, both on-site and off-site. For SVE, 13 2-inch wells and eight 4-inch wells were placed in contaminant source areas, and were screened at either 5 to 10 feet or 15 to 20 feet. The collected vapors were treated with activated carbon. The AS/SVE system construction was completed and started operating in 1997. It operated for five years (1997–2002) as required by a Consent Decree (EPA, 2009b). There were four onsite monitoring wells that were monitored during the remedy, with 19 rounds of samples collected on a semi-annual basis (EPA, 2009a). These samples showed TVOIC concentrations in three wells had been reduced non-detectable levels after only two years of treatment (EPA, 2009b). The fourth well, MW-2S, required five years of treatment and the implementation of contingency measures before the TVOICs (specifically xylene) were reduced below the cleanup levels. Contingency measures included shutting off the east side air sparging wells and diverting air to the area around MW-2S, installing two more AS wells near MW-2S, and adding inorganic nutrients (in the form of a commercial garden fertilizer) to the west side well in an attempt to accelerate biological activity for further chemical reduction. Table 1 lists the pre-remediation and post-remediation TVOIC concentrations from the on-site monitoring well MW-2S. All individual TVOICs were below their cleanup levels at shutdown of the system in 2002 and during subsequent rounds of monitoring (EPA, 2009a). Both soil and groundwater cleanup objectives were met within five years of the start of the AS/SVE treatment (EPA, 2009a), removing approximately 15,461 pounds of contaminants from the site.

Cleanup Success: The Pasley Solvents and Chemical NPL site was treated for both soil and groundwater contamination. An AS/SVE system was operated on-site and off-site for five years, reducing TVOICs in groundwater and contaminants in soil below cleanup levels. The SVE system reduced soil contamination over a period of five years, while the AS system reduced very high TVOIC concentrations in groundwater from 37,000 ppb before remediation to 4 ppb within only two years (EPA, 2009a). The completed remediation of the site allowed for beneficial reuse. The Metropolitan Transit Authority (MTA) leased the property and currently uses it for a police station (EPA, 2009c). The site was deleted from the NPL in 2011.

Table 1: Reduction in TVOIC Concentrations in Upper Aquifer Groundwater Monitoring Well MS-2S – Pasley Solvents and Chemical NPL Site

	Onsite Monitoring Well MW-2S		Federal Drinking Water Standard
Chemical	March 1990* (ppb)	August 2005** (ppb)	(ppb)
Chloroform	33	ND	NS
1,1-Dichloroethene	62	ND	7
1,1-Dichloroethane	300	2J	NS
trans-1,2-Dichloroethene	25,000	ND	100
1,1,1-Trichloroethane	3,600	2J	200
Ethylbenzene	510	ND	700
Toluene	1,100	ND	1,000
Chlorobenzene	510	ND	100
Xylene	1,100	ND	10,000

*** Source: EPA, 1992, ** Source: EPA, 2009a; ppb = parts per billion, ND = Non-detect ; NS = No Standard**

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Dover Air Force Base (AFB), SS07/Area 2, South Management Unit, NPL Site

Site Location: Dover, DE, Region 3

EPA ID#: DE8570024010

Regulatory Agency: U.S. EPA, State of Delaware Department of Natural Resources and Environmental Control (DNREC)

Site Summary: Remedial actions at the South Management Unit SS07/Area 2 site at the Dover AFB included the cleanup of petroleum and chlorinated solvents in groundwater from historic aircraft maintenance activities. Key contaminants of concern include tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichlorethene (*cis*-1,2-DCE), and vinyl chloride in groundwater. Remedial actions included the injection of a combination of slow-release (emulsified vegetable oil) and soluble (sodium lactate) substrates to achieve enhanced reductive dechlorination (ERD) and induce accelerated anaerobic biodegradation (AAB) to treat source area groundwater contamination. Monitored natural attenuation (MNA) was used to address the remainder of the chlorinated solvent plume. A record of decision (ROD) was signed in December 2005, and by the end of March 2006, over 100,000 gallons of carbon substrate-amended water had been injected into the source area subsurface through 49 injection points, resulting in favorable conditions for reductive dechlorination. ERD resulted in meeting remediation standards in most SS07 source area wells within 2 years. By 2008 nearly all wells met the groundwater remediation standards established in the 2005 ROD were the federal maximum contaminant levels (MCLs) of 5 ppb for PCE and TCE. In 2014 the Air Force revised the remediation standards to be the State of Delaware MCLs of 1 µg/L (ppb) for PCE, TCE, and vinyl chloride (USAF, 2014). The most recent available semi-annual monitoring data (January 2016) indicated exceedances in 2 source area wells. In one well TCE, *cis*-1,2-DCE and vinyl chloride were 86 ppb, 840 ppb and 130 ppb, respectively. At the other well TCE and vinyl chloride were 23 ppb and 8.2ppb, respectively. These wells are being resampled to confirm concentrations. (USAF, 2013, USAF, 2016).

Dover Air Force Base, South Management Unit, NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including PCE, TCE, *cis*-1,2-DCE, and vinyl chloride; highest concentrations in groundwater included 32,000 ppb PCE and 110 ppb TCE
- **Media:** Groundwater, DNAPL
- **Plume Size:** Chlorinated VOC groundwater plume approximately 2,800 feet long by 650 feet wide
- **Technologies:**
  - ERD
  - AAB
  - Natural attenuation
- **Major Successes:**
  - Injection of over 100,000 gallons of carbon substrate into subsurface
  - ERD reduced contaminants of concern in most source area wells to below cleanup levels within two years
  - Natural attenuation is effectively lowering contaminant concentrations in adjacent plumes
  - Off-site migration of contaminated groundwater prevented, MCLs achieved in groundwater at the Base property line

SS07 at Dover Air Force Base (USAF, 2008)

Site History: Dover AFB was listed on the NPL in March 1989 and contains 20 OUs, each with a corresponding ROD. As part of the overall site cleanup strategy for the Base, Dover AFB was divided into four management units for the purpose of conducting remedial investigations and feasibility studies. OU15, also known as the South Management Unit (SMU), contains the SS07/Area 2 site and three additional sites. The three additional sites include LF17 (a former landfill used for disposal of general refuse), FT01 (a former fire training area), and LF18 (a former landfill used for disposal of general refuse and industrial shop waste). The ROD selected remedies for these three additional sites included MNA with periodic monitoring and land use controls (LUCs). These three additional areas are not the focus of this Site Summary, and will not be discussed further.

The SS07/Area 2 site was used as a hazardous waste storage area since 1981 and industrial activities were conducted there since the 1940s. Although there were no documented releases of contaminants at SS07, signs of surface spills were evident during remedial investigations of the site, and solvents that were historically used in aircraft maintenance activities and petroleum were the primary contaminants within the Area 2 groundwater plume (USAF, 2006). SS07 is the primary source of contaminants that form the Area 2 groundwater plume. A ROD was signed in December 2005, and five-year-reviews were performed in 2008 and 2013 stating that the remedy performed at SS07/Area 2 was protective of human health and the environment (USAF, 2008 and 2013).

Extent of Contamination: Chlorinated solvents were present in shallow groundwater from a source area (SS07), which is part of the OU 15 SMU of the Dover AFB. The Columbia aquifer at the site is not a source of drinking water; however, the potential existed for contaminant constituents to migrate off base, where the aquifer is a potential drinking water source. MCL exceedances of chlorinated solvents in groundwater, which triggered the need for remedial action, formed a long, narrow plume referred to as Area 2. The Area 2 chlorinated solvent plume extended from the SS07 source area approximately 2,800 feet down gradient. Elevated PCE and TCE concentrations (32,000 and 110 ppb, respectively) were discovered in shallow groundwater, approximately 10 to 15 feet below ground surface (bgs). The site has four aquifers beneath it with varying compositions including mixtures of gravel, sand, and silt with clay and gravel lenses (USAF, 2008).

Cleanup Approach: Remedial actions began in 2005 with monitoring to determine if any undefined source areas were located up gradient of the SS07/Area 2 plume, and to provide information for the design and optimal location for injecting ERD substrate, including the feasibility of using permanently installed injection/extraction wells to deliver the substrate into the subsurface. It was determined that the subsurface formation did not have the permeability necessary for permanent injection wells. In March 2006, a combination of slow-release (emulsified vegetable oil) and soluble (sodium lactate) substrates and nutrients (dibasic ammonium phosphate [DAP]) were added to potable water at a ratio of 50/50 and injected into the subsurface to stimulate the biodegradation of chlorinated solvents. Approximately 2,100 gallons of amended water was injected into each direct-push borehole at four separate depth intervals between approximately 5 and 25 feet bgs. Injections occurred at 49 locations within the source area, with a total of approximately 103,000 gallons of amended water injected for the entire SS07 site. Additional monitoring wells were installed to expand the existing well network to monitor the effectiveness of the ERD remedy. The entire SS07/Area 2 plume was monitored to assess the progress of natural attenuation in reducing contaminant concentrations. Based on delineation sampling for a suspected source area, in July and August 2012 additional injections were conducted up gradient of the single well where contaminant concentrations remained above MCLs. Twenty temporary wells at depths ranging between 5 and 25 feet bgs were injected with 139,000 gallons of water amended with 825 gallons of sodium lactate and 2,000 gallons of emulsified vegetable oil.

Injection/Extraction Well Remediation
(EPA, 2011)

Cleanup Success: The SS07/Area 2 groundwater contamination was treated using an innovative ERD method to stimulate the biodegradation of chlorinated solvents. Dramatic decreases in contaminant concentrations have been documented in semi-annual sampling programs. Since the AAB injections in 2006, concentrations of both PCE and TCE have decreased three to four orders of magnitude, and since April 2007, neither PCE, TCE, nor breakdown products (*cis*-1,2-DCE and vinyl chloride) have exceeded the MCLs in any SS07 source area wells (USAF, 2011). Reducing conditions are stable in the source area and the presence of ethane in several wells within and just down gradient of the source area indicates that complete dechlorination is occurring (USAF, 2011). ERD resulted in meeting remedial standards in most

SS07 source area wells within 2 years. By 2008 nearly all wells met cleanup levels. In 2014 the Air Force revised the remediation standards to be the State of Delaware MCLs of 1 ppb for PCE, TCE, and VC (USAF, 2014). The most recent available semi-annual monitoring data (January 2016) indicated exceedances in 2 source area wells. In one well TCE, *cis*-1,2-DCE and vinyl chloride were 86 ppb, 840 ppb and 130 ppb, respectively. At the other well TCE and vinyl chloride were 23 ppb and 8.2 ppb, respectively. These wells are being resampled to confirm concentrations. (USAF, 2013; USAF, 2016).

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Letterkenny Army Depot Southeast Area NPL Site, OU 10

Site Location: Chambersburg, PA, Region 3

EPA ID#: PA6213820503

Regulatory Agency: US EPA

Site Summary: Remedial actions at the Letterkenny Army Depot Southeast Area NPL site at OU 10 included the cleanup of chlorinated volatile organic compounds (VOCs) from a leaking industrial wastewater sewer and non-chlorinated VOCs from a leaking underground storage tank return line. Key contaminants of concern include trichloroethene (TCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), 1,1-dichloroethene (1,1-DCE), vinyl chloride, and benzene. The remedial action at OU 10 included in situ enhanced reductive dechlorination (ERD) using injections of a sodium lactate solution. In addition, monitored natural attenuation (MNA) and land use controls were put in place during the remedial activities. The site has not yet been deleted from the NPL, however significant progress has been made at OU-10.

Letterkenny Army Depot Southeast Area NPL Site,
OU 10
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including TCE, *trans*-1,2-DCE, and vinyl chloride; highest concentrations in groundwater included 200 ppb TCE, 59 ppb, *trans*-1,2-DCE, and 90 ppb vinyl chloride
- **Media:** Groundwater
- **Plume Size**: Chlorinated VOC groundwater plume extends to springs located approximately 1.5 to 2.0 miles off-site
- **Technologies:**
  - ERD using sodium lactate injections
  - MNA
- **Major Successes:**
  - Use of innovative in situ remedy reduced key groundwater contaminant concentrations to below MCLs for all CVOCs in fractured and karstic bedrock
  - Remediated 20 acre contaminant plum
  - Groundwater use restrictions were partially lifted

Site History: The Letterkenny Army Depot began operating in 1942 for ammunition storage. In 1947, the Army expanded operations to include testing, maintenance, and overhaul of military vehicles and missiles, as well as the storage and transportation of industrial chemicals. These operations consisted of cleaning, stripping, painting, lubrication, and plating activities, which involved the use of solvents, blast media (such as sand from sandblasting operations), paints, petroleum products, and metals. The site was later included in the 1995 Base Realignment and Closure Act (BRAC), which designates land for transfer to the private sector for local redevelopment. Contamination at the site was first detected in 1983 in the southeast area of the site. VOCs and metals were detected in at least six major areas, including contaminated soil, surface water, and groundwater. At OU 10, VOC-laden wastewater associated with solvent-use stations inside Building 37 leaked through breaks in a deteriorated industrial wastewater sewer, causing groundwater contamination (USAEC, 2006). The contaminated aquifer that lies beneath OU-10 consists of fractured and weathered karstic bedrock, with large cavities formed by dissolution of limestone rock. Groundwater flows in a general east-southeast direction; however the karst nature of the aquifer makes it difficult to predict localized flow direction and migration of contaminants (USAEC, 2006). The Letterkenny Army Depot Southeast Area NPL site was listed on the NPL in July 1987. A record of decision (ROD) for OU 10 was signed in September 2006, which included institutional controls. Four site-wide five-year reviews have been completed in 2001, 2008, 2015, and 2017. An explanation of significant difference (ESD) was signed in September 2009, which included lifting groundwater use restrictions across most of the OU 10 area (EPA, 2011).

Extent of Contamination: Dissolved phase contaminants (TCE and breakdown products) were present in the karst aquifer and eventually migrated off-site to residential areas, and to springs located approximately 1.5 to 2.0 miles off-site (USAEC, 2006). Maximum initial onsite groundwater contaminant concentrations in 1994 for TCE, *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride were 200 µg/L (ppb), 59 ppb, 13 ppb, and 90 ppb, respectively (Table 1). Sampling of off-site wells and springs between 1991 and 1996 identified VOC concentrations in excess of EPA maximum contaminant levels (MCLs) for groundwater and Pennsylvania Water Quality Criteria (WQC) for springs. The primary VOCs detected in off-site wells were TCE (up to 13.9 ppb) and 1,1-DCE (up to 16.2 ppb). The primary VOCs detected in off-site springs were TCE (up to 6.4 ppb), *trans*-1,2-DCE (up to 5 ppb), and 1,1-DCE (up to 4.5 ppb) (USAEC, 2009). From the early 1980s through 1992, the Army installed alternate potable water supplies at a number of offsite residences where OU 10 site-related VOC contamination had reached domestic supply wells at concentrations exceeding MCLs (USAEC, 2006).

Cleanup Approach: The first remedial activities at OU 10 at the Letterkenny Army Depot Southeast Area NPL site took place in 1999 when a pilot study was initiated to inject a sodium lactate solution into the plume to serve as a carbon and energy source and promote ERD of the chlorinated VOCs. As a result of the initial pilot study success, the Army continued with sodium lactate injections as part of the Focused Feasibility Study (FFS), and ultimately selected ERD in the ROD as the preferred groundwater remedy at OU 10. A total of three additional separate, month-long sodium lactate nutrient injections were performed (August/September 2004, May/July 2005, and April/May 2007) at the site to enhance the biodegradation of the remaining VOCs within the bedrock aquifer source area. Following these injections, groundwater monitoring was implemented to continue to monitor the reduction of contaminant concentrations. Post remediation data available through 2015 indicate that while some CVOCs were reduced to below MCL cleanup levels, TCE, vinyl chloride, and benzene remain above MCL cleanup levels in a few wells (USAEC, 2017).

Cleanup Success: The Letterkenny Army Depot Southeast Area NPL Site OU 10 was treated using in situ ERD involving multiple injections of sodium lactate to stimulate the microbial degradation of chlorinated VOCs in the groundwater. Since the start of the remedy in 1999, VOC concentrations in on-site wells have decreased significantly. The VOC plume has been remediated, with the exception of TCE, vinyl chloride, and benzene in several wells. The groundwater use restrictions have been partially lifted in some areas that are currently outside the extent of the contaminant plume. Groundwater monitoring will continue at the site until MCLs have been met and the aquifer has been restored to drinking water quality (USAEC, 2015a; USAEC 2015b).

Table 1. Summary of Remediation of Groundwater at Letterkenny Army Depot Southeast Area NPL Site, OU-10

Contaminant of Concern	Initial Maximum Concentration (ppb) *	Maximum Concentration (April 2010) (ppb) **	Percent Reduction
TCE	200	11	94.5%
Trans-1,2-DCE	59	< 1.0	> 99%
1,1-DCE	13	0.34	97.4%
Vinyl Chloride	90	2.3	97.4%

Source: * EPA, 2006; ** EPA, 2010
MCL = EPA Maximum Contaminant Level
ppb = parts per billion
ND = non-detect

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Gold Coast Oil Corporation NPL Site

Site Location: Miami, Florida, Region 4

EPA ID#: FLD071307680

Regulatory Agency: U.S. EPA, Florida Department of Environmental Protection (FDEP), Department of Environmental Resource Management of Miami Dade County (DERM)

Site Summary: Remedial action at the Gold Coast Oil Corporation National Priority List (NPL) site included the cleanup of chlorinated and non-chlorinated volatile organic compounds (VOCs) that resulted from the direct discharge of oil/solvent reclamation blowdown to the soil and improper storage of waste. Key contaminants included tetrachloroethene (PCE), trichloroethene (TCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), 1,1-dichloroethane (1,1-DCA), methylene chloride, and toluene (USACE, 2001). Remedial actions included the excavation and disposal of visibly contaminated soil, followed by a groundwater pump-and-treat system outfitted with two air stripping towers. Attempts to enhance contaminant reduction during pump-and-treat operation, first by the addition of hydrogen peroxide and then by pulsed pumping, did not result in achieving the cleanup level. Therefore, the pump-and-treat system was shut down and additional soil excavation and air sparging of groundwater (without pump-and-treat) in two areas of suspected dense non-aqueous phase liquid (DNAPL) were subsequently performed. This approach reduced groundwater concentrations to below federal, state, and county cleanup levels in approximately six years from the beginning of remedial activities (USACE, 2001). The site was deleted from the NPL in October 1996 (EPA, 2011).

Gold Coast Oil Corporation NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated and non-chlorinated VOCs including PCE, TCE, *trans*-1,2-DCE, 1,1-DCA, methylene chloride, and toluene; highest concentrations in groundwater included 100,000 ppb PCE and 48,000 ppb TCE
- **Media & Waste:** Groundwater, Soil, DNAPL (suspected)
- **Plume:** Contaminated groundwater plume approximately 0.87 acre areal extent and up to 10 feet thick
- **Technologies:**
  - Soil excavation and disposal
  - Pump-and-treat system with air stripping
  - Localized air sparging of groundwater
- **Major Successes:**
  - Removal of 883 tons of contaminated soil
  - 80 million gallons of water treated and 1,961 pounds of PCE and TCE removed
  - Concentrations of *trans*-1,2-DCE, 1,1-DCA, methylene chloride, and toluene below cleanup levels within first year of pump-and-treat
  - PCE and TCE achieved federal, state, and county cleanup levels within four years of pump-and-treat implementation by use of localized air sparging
  - Site deleted from the NPL in October 1996

Gold Coast Oil Site (EPA, 2011)

Site History: The Gold Coast Oil site is a 2 acre property that operated as an oil and solvent reclamation and bulk storage facility from the early 1970s until 1982. The property was owned by CSX Transportation, but leased to Gold Coast Oil Corporation until it lost its lease in 1982 due to regulatory violations (EPA, 2011). Two aquifers lie beneath the site, the Biscayne Aquifer, which is the sole source of drinking water for Miami-Dade County, and the deep Floridan Aquifer. The Biscayne Aquifer (where contamination was present) ranges from 5 to 110 feet below ground surface (bgs), and the Floridian is at depths below 700 feet. The Biscayne and Floridan Aquifers are not hydraulically connected (EPA, 1987). Soil and groundwater contamination in the Biscayne Aquifer, which is an unconfined aquifer with high permeability, was first detected by the FDEP in 1980. Investigations were conducted by FDEP, DERM, and EPA in 1981, and the facility ceased operations in 1982. The site was placed on the NPL in 1983 and a record of decision (ROD) was issued in 1987 (EPA, 1987) while additional remedial investigations continued. Soil and groundwater remedial actions were performed from 1989 until

1995. A Site Closeout Report (Clark, 1995) documented that the remedial actions met the ROD cleanup standards for soil and groundwater (USACE, 2001).

Extent of Contamination: Approximately 883 tons of visibly contaminated soil was removed from the site between 1989 and 1990 before site investigations commenced. The initial area of the groundwater contaminant plume was estimated to be 0.87 acres (based on 1990 plume maps). Based on the plume thickness of approximately 10 feet and a porosity of 30 percent, the initial plume was estimated to be over 2.8 million gallons (Clark, 1995). As shown in Table 1, the initial concentrations of TCE and PCE detected in the groundwater were greater than 1 percent and 60 percent of TCE and PCE solubility, respectively, indicating the likely presence of a DNAPL (EPA, 1992).

Cleanup Approach: Preliminary site cleanup began with the excavation and off-site disposal of 683 tons of soil contaminated with VOCs in March 1989, and an additional 200 cubic yards in March 1990 (USACE, 2001). The pump-and-treat system was constructed and began operation in July 1990, pumping at approximately 44 gallons per minute (gpm). The extraction system included five on-site wells located in the Biscayne Aquifer. Three extraction wells were installed at 15 feet bgs and two wells were installed 30 feet bgs, with two of the three shallow wells (MW-11 and MW-13) located in an area suspected to contain DNAPL. The two deep wells were placed in the same source zone area as MW-13, and the third shallow well was located down gradient of the plume. The treatment system contained two 36-foot air stripping towers. Effluent was injected back into the aquifer by way of three injection wells (Clark, 1995).

Several adjustments, both successful and unsuccessful, were made to the pump-and-treat system to optimize and speed cleanup. In July 1991, wells MW-11 and MW-13 were enlarged from 2-inch to 4-inch wells to increase extraction rates in the most contaminated area of the plume. Additionally, hydrogen peroxide was injected into these two wells from March to July 1993, in an unsuccessful attempt to oxidize TCE and PCE, which were still elevated (at 10 and 30 µg/L or ppb, respectively) relative to their cleanup levels. From August 1993 until early 1994, the groundwater extraction system was shut down periodically (or pulsed) for periods of 30 and 60 days in an attempt to increase TCE and PCE desorption from aquifer materials in area groundwater. This effort was also unsuccessful, and the pump-and-treat system was permanently shut down in May 1994. From November 1994 until February 1995, the soil surrounding MW-11 and MW-13 was excavated under suspicion that DNAPL may have been present. TCE and PCE were not detected in excavated soil. Finally, with the pump-and-treat system shut down, the groundwater in the areas of MW-11 and MW-13 was sparged using a portable air sparging unit in early 1995 (USACE, 2001). The aquifer was sampled over the next three months, and showed no exceedance of contaminant cleanup levels, which were derived from FDEP, DERM, and EPA MCLs. The cleanup levels were 3 ppb for PCE and TCE, 70 ppb for *trans*-1,2-DCE, 5 ppb for 1,1-DCA and methylene chloride, and 340 ppb for toluene (USACE, 2001).

Cleanup Success: At the Gold Coast NPL site, source removal, combined with groundwater pump-and-treat and air sparging over a six year period, successfully reduced concentrations of chlorinated solvents to below cleanup levels based on MCLs and other state and county standards. The pump-and-treat system removed 1,961 pounds of TCE and PCE from 1991 to 1994, and treated a total of 80 million gallons of groundwater. Through an iterative cleanup process, “hot spots” of residual contaminant were identified and subsequently effectively treated.

Table 1. Reduction of PCE and TCE in Groundwater at the Gold Coast Oil Corp. NPL Site

Treatment Phase	PCE Concentration (ppb)	TCE Concentration (ppb)
Initial Maximum Concentration	100,000	48,000
Before Pump-and-Treat (January 1990) – Average Concentration	176	88
After Completion of Pump-and-Treat – Average Concentration	8	9
After Completion of Localized Air Sparging – All Concentrations	<3	<3

Sources: Clark, 1995; EPA, 1998

References

Edward E. Clark Engineers-Scientists, Inc. (Clark); Site Closeout Report, Gold Coast Oil NPL Site; January 1995.

United States Army Corps of Engineers; Superfund Five-Year Review Report, Gold Coast Oil Company, Inc.; August 2001.

United States Environmental Protection, Region 4; Gold Coast Oil Corp, Site Summary; 2011.

United States Environmental Protection Agency; Cost and Performance Report, Pump and Treat and Air Sparging of Contaminated Groundwater at the Gold Coast Superfund Site, Miami, Florida; September 1998

United States Environmental Protection Agency. Estimating Potential for Occurrence of DNAPL at Superfund Sites. OSWER Publication 9355.4-07FS. January 1992.

United States Environmental Protection Agency; EPA Superfund Record of Decision, Gold Coast Oil Corp.; 1987.

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Hollingsworth Solderless Terminal (OU 1)

Site Location: Fort Lauderdale, Florida, Region 4

EPA ID#: FLD004119581

Regulatory Agency: U.S. EPA, Florida Department of Environmental Protection (FDEP) formerly the Florida Department of Environmental Regulation (FDER), Broward County Environmental Quality Control Board (BCEQCB)

Site Summary: Remediation of the Hollingsworth Solderless Terminal NPL site involved the application of a number of remedial technologies, including soil excavation and off-site disposal, pump-and-treat for groundwater, SVE, and enhanced reductive dechlorination (ERD). The key contaminants at the Site are trichloroethene (TCE) and its breakdown products *cis*-1,2-dichlorethene (*cis* -1,2-DCE) and vinyl chloride in groundwater and TCE in soil. Following an initial failed attempt at soil excavation, SVE was used to remove soil contaminants, followed by groundwater pump-and-treat with air stripping of the extracted groundwater. This was followed by removal of soils in two additional areas of contamination that were not addressed in the original remediation, and ERD of contaminated groundwater by the injection of potassium lactate and augmentation with *Dehalococcoides ethenogenes* (DHE) bacteria. Total chlorinated volatile organic compound (VOC) concentrations in groundwater have been reduced by up to 98 percent in just over two years after integrating in-situ ERD into the remedial approach.

Hollingsworth Solderless Terminal NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including TCE, *cis*-1,2-DCE, and vinyl chloride in groundwater; TCE in soil; highest concentrations in groundwater included 4,300 ppb TCE, 10,000 ppb *cis*-1,2-DCE, and 6,000 ppb vinyl chloride
- **Media:** Groundwater, Soil
- **Plume:** Approximate 200-foot radius area (or about 3 acres), with the highest concentrations found at the 50 to 75 foot depths
- **Technologies:**
  - Soil excavation and off-site disposal
  - Groundwater pump-and-treat with air stripping
  - SVE
  - In situ ERD with potassium lactate and *Dehalococcoides ethenogenes* bacteria injections
- **Major Successes:**
  - Initial groundwater remedy removed up to 55 pounds of contaminants each day
  - Over 300 tons of contaminated soils removed
  - Chlorinated VOC concentrations in groundwater reduced up to 98 percent in just over two years using ERD
  - Vinyl chloride is the only remaining groundwater contaminant detected above cleanup levels.

Site History: The Hollingsworth Solderless Terminal Company operated from 1968 to 1982, manufacturing small, solderless electrical connectors. The manufacturing process included heat treatment in molten salt baths, degreasing, and electroplating. The company disposed of wash water and process wastewater contaminated with TCE and heavy metals into drain fields and an injection well located onsite, resulting in contamination of soil and groundwater. The site overlies the Biscayne aquifer, which is highly permeable, unconfined, and is composed of a fine- to-medium grained sand, sandstone, and limestone sequence. The City of Fort Lauderdale's water supply wells are located within a quarter mile to a half mile of the Hollingsworth Site. In the vicinity of the Site, the top of the aquifer is near ground surface and its base is approximately 200 to 250 feet below ground surface (bgs).

In 1980, during a routine inspection, BCEQCB discovered that Hollingsworth was disposing of process wastes into an onsite injection well. In 1981, Hollingsworth filed for bankruptcy and ceased operations the next year. EPA conducted a Site Assessment and developed a Remedial Action Master Plan in 1982, and the Site was listed on the NPL in 1983. In 1986, EPA finalized a feasibility study (FS) and issued a record of decision (ROD) for the Site. A groundwater extraction and treatment system was installed in 1992 and operated until 1994 (EPA, 2008). An explanation of significant difference (ESD) was signed in 2001 which authorized the additional removal of contaminated soil and a septic tank from two areas that were not treated during the original remediation. A ROD Amendment was issued in 2008 changing the groundwater remedy from pump-and-treat to in-situ ERD (EPA, 2008). In April 2011, electron donor (Regenesis 3DMe^{TM}) was injected in the immediate vicinity of two of the drain fields. Long term groundwater monitoring continues at the site, a fourth five-year review was released in 2011 and a fifth five-year review in 2016.

Extent of Contamination: The VOC contaminated soil in the East Drainfield area that was treated with SVE was estimated to be 14 feet long, 12 feet wide, and 12 feet deep, and contained total VOC concentrations as high as 17 mg/kg (ppm) before treatment (EPA, 1996). The cleanup level for the soil was 1 ppm for TCE. About 300 tons of contaminated soil and sludge were also excavated from the South and West Drainfields and disposed of off-site (EPA, 2002). The extent of groundwater chlorinated VOC contamination was estimated to be an approximate 200-foot radius area (or about 3 acres), with the highest concentrations found at the 50-to-75-foot depths (EPA, 1986). Documents do not indicate the presence of dense non-aqueous phase liquid (DNAPL) at the site. The established groundwater cleanup levels were 1 ppb for vinyl chloride and 70 ppb for *trans*-1,2-DCE were based on the EPA proposed maximum contaminant levels (MCLs) and 3.2 ppb for TCE was based on a 10^{-6} life-time cancer risk factor (EPA, 1986). Subsequent investigations determined that *cis*-1,2-DCE was more prevalent than *trans*-1,2-DCE (EPA, 2011a).

Cleanup Approach: The cleanup approach in the ROD included excavation, ex situ aeration, and replacement of soil in the area of excavation. The ROD also specified extraction, treatment with air stripping technology, and re-injection of groundwater into the aquifer. Due to water levels reaching historically high levels in the late 1980s, the soil excavation and replacement could not be completed without re-contamination, and was replaced by in-situ SVE (Weston, 1996). The SVE system began operation in January 1991, and by July 1991 the soil cleanup level of TCE concentrations less than 1 ppm was achieved (Ebasco, 1993). Construction of the groundwater pump-and-treat system was completed in December 1991, and brought online in July 1992. The system removed large volumes of VOCs at an estimated rate of over 55 pounds per day from three recovery wells during the initial weeks of operation (EPA, 2002). The system operated until August 1994, when it was determined that the system was no longer effective at further reducing concentrations of TCE, DCE, and VC, and the system was dismantled and removed from the site under EPA direction (EPA, 2008).

Subsequent groundwater monitoring results showed a rebound of contaminant concentrations indicating that residual contamination sources were present on two areas of the site. An ESD was signed by EPA in 2001, authorizing the removal of additional contaminated soil in the South Drainfield and a septic tank in the West Drainfield (EPA, 2008). In February 2002, soil from a 60-foot by 40-foot parcel of the South Drainfield area was excavated to a depth of two feet below the water table (6 to 8 feet bgs). At the West Drainfield, the septic tank was cut open, and approximately 300 tons of sludge and soil were excavated, mixed with Portland cement, and disposed of offsite. Groundwater monitoring showed that although chlorinated VOC concentrations had been reduced in shallow groundwater, a similar decline had not occurred in deeper groundwater. A pilot study was performed at both the South and West Drainfields from April 2005 to September 2007 to test the ability of in situ ERD to reduce groundwater contamination using potassium lactate injections and bioaugmentation. At each area, one central recovery well was installed, screened from 6 to 36 feet bgs, and was surrounded by a ring of eight injection wells screened from 10 to 30 feet bgs. Groundwater was extracted from the recovery wells, mixed with potassium lactate solution, amended with DHE bacteria, and injected into the aquifer. Over the course of treatment during the pilot study, total chlorinated VOC concentrations were reduced from a high of 3,067 ppb to 599 ppb at the West Drainfield, and from 60,171 ppb to 733 ppb at the South Drainfield. Specific contaminant concentration reductions are shown in Table 1. Plume migration also ceased during the study. Due to the success of the pilot study showing a site wide decrease in contaminant concentrations, a ROD Amendment was issued in 2008, modifying the Site remedy to in-situ ERD with potassium lactate injection (EPA, 2008). The ROD Amendment proposed additional injections of a carbon substrate to address the remaining unacceptable concentrations in two areas, and possible bioaugmentation with DHE bacteria. In April 2011, an additional injection of substrate was accomplished in the two areas to address the remaining unacceptable concentrations of groundwater contaminants (EPA, 2001b). The most recently

Treatment Plant #1, Hollingsworth Solderless
(EPA, 2011a)

available groundwater monitoring data (2016) indicates that four out of the 24 wells being monitored exceed the State of Florida standard of 1 ppb for vinyl chloride. Vinyl chloride remains the only remaining groundwater contaminant detected above state or federal standards (EPA, 2016).

Cleanup Success: The combination of source area treatment, pump-and-treat, and in situ ERD has shown significant progress in the remediation of the approximate 3-acre chlorinated VOC plume at the Site. The initial groundwater pump-and-treat system removed up to 55 pounds of VOCs per day during the first weeks of operation. Application of SVE technology to soils contaminated with TCE at concentrations up to 17 ppm was successfully treated in six months, reducing TCE concentrations to less than the cleanup level of 1 ppm (Ebasco, 1993). The subsequent removal of 300 tons of soil and sludge in two areas further reduced groundwater VOC concentrations (EPA, 2002), and the implementation of in-situ ERD using injections of potassium lactate in the two most contaminated areas of the site reduced total VOC concentrations up to 98 percent in just over two years (EPA, 2008). Recent data indicate VC is the only remaining groundwater contaminant detected above cleanup levels.

Table 1. Reduction in Chlorinated VOC Concentrations at Hollingsworth Solderless NPL Site

	TCE (ppb)	*cis*-1,2-DCE (ppb)	Vinyl Chloride (ppb)
Cleanup Levels	3	70	1
Maximum Initial Concentration (from 1986 ROD) [a.]	4,300	9,700	6,000
After Pump-and-Treat (1995–1998 Data) [b.]	0.8	10,000	2,500
Following 2002 Soil Removal (August 2002 Data) [b.]	260	9,400	3,400
Following Pilot Study – Enhanced Reductive Dechlorination (February and August 2007 Data) [c.]	4.7	430	720
Current Maximum Concentrations	<3 [d.]	<70 [d.]	45 [d.]

Sources: a. EPA, 1986; b. EPA, 2005; c. EPA, 2008; d. EPA, 2016

References

Ebasco; Final Remedial Action Report for the Hollingsworth Solderless Terminal Company Site; 1993.

Jackson, Galo; e-mail to Linda Fiedler with attached data from most recent Hollingsworth site sampling. August 29, 2013.

Roy F. Weston, Inc.; Five-Year Review Report, Hollingsworth Solderless Terminal Company; 1996.

United States Environmental Protection Agency; Sampling Investigation Report, Hollingsworth Solderless Terminal Company Superfund Site, SESD Project Identification Number: 16-0363. 2016.

United States Environmental Protection Agency; Fifth Five-Year Review Report for Hollingsworth Solderless Terminal. September 2016.

United States Environmental Protection Agency; Fourth Five-Year Review Report for the Hollingsworth Solderless Terminal Site; 2011a.

United States Environmental Protection Agency Hollingsworth Solderless Site Profile site; 2011b.

United States Environmental Protection Agency; Record of Decision Amendment, Hollingsworth Solderless Terminal Company Superfund Site; 2008.

United States Environmental Protection Agency; Third Five-Year Review Report for the Hollingsworth Solderless Terminal Site; December 2005.

United States Environmental Protection Agency; Remedial Action Report for the Hollingsworth Solderless Terminal Site; 2002.

United States Environmental Protection Agency; Record of Decision, Hollingsworth Solderless Terminal Company Superfund Site; 1986.

Rochester Property NPL Site

Site Location: Travelers Rest, SC, Region 4

EPA ID#: SCD980840698

Regulatory Agency: U.S. EPA

Rochester Property NPL Site
Remediation Highlights

- **Contaminants:** TCE, *cis*-1,2-DCE, bis(2-ethylhexyl)phthalate, and manganese; highest concentrations in groundwater included 180 ppb TCE, 3,600 ppb *cis*-1,2-DCE, 33 ppb bis(2-ethylhexyl)phthalate, and 1,390 ppb manganese
- **Media:** Groundwater, Soil
- **Plume:** TCE groundwater plume approximately 1/3 acre in size
- **Technologies:**
  - in situ air sparging
  - ISCO by ozone sparging in groundwater
  - Excavation of soil and offsite disposal
- **Major Successes:**
  - Groundwater cleanup levels (MCLs) achieved at all locations over nine years
  - Removal of 1,400 cubic yards of contaminated soils
  - Successful treatment approach using innovative in situ technologies to accelerate cleanup

Site Summary: Remedial actions at the Rochester Property NPL site included the cleanup of chlorinated and non-chlorinated volatile organic compounds (VOCs) and metals, which resulted from the dumping of contaminated materials. Key contaminants of concern include trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), bis(2-ethylhexyl)phthalate, and manganese. The initial remedial actions included an in situ air sparging system through the saturated portion of the aquifer. This was later followed by chemical oxidation by adding ozone to the air sparging system (EPA, 2005). The site was added to the NPL on October 4, 1989 and deleted from the NPL on October 9, 2007 (EPA, 2011). EPA maximum contaminant levels (MCLs) have been achieved in groundwater site-wide for all contaminants. Key contaminant concentrations have been reduced by at least 82 percent or more site-wide (EPA, 2005).

Site History: The Rochester Property NPL site was used in the early 1970s as a dump site for the disposal of various wastes including wood glue, print binders, powder materials, natural guar gums, and adhesives. The site contains four trenches, each approximately 40 feet long, 3 feet wide, and 10 feet deep. The site is relatively flat and is part of the Piedmont physiographic province of South Carolina. Sands, silts, clays and underlying bedrock make up the geology at the site and depth to water ranges from 5 feet below ground surface (bgs) to 23 feet bgs (EPA, 1993). During a 1984 inspection, chlorinated and non-chlorinated VOCs and metals were detected during a waste analysis (EPA, 2005). Rochester Property was listed on the NPL in 1989 and deleted from the NPL in 2007 (EPA, 2011). EPA issued a record of decision (ROD) in 1993 to address contamination at the site and select a remedy, which was followed by an explanation of significant difference (ESD) in 2002 to modify the remedy. To date, two five-year reviews have been released in 2000 and 2005, respectively. A second ESD was released in 2006 after the second five-year review to address a change in remedial goals for TCE and bis(2-ethylhexyl)phthalate. Manganese was removed as a remedial goal from this 2006 ESD due to a change in EPA's Integrated Risk Information System (IRIS) manganese risk values.

Extent of Contamination: Dissolved phase contaminants were present in the groundwater at Rochester Property with maximum TCE, *cis*-1,2-DCE, bis(2-ethylhexyl)phthalate, and manganese concentrations of 180 µg/L (ppb), 3,600 ppb, 33 ppb, and 1,390 ppb, respectively (EPA, 1993). The horizontal extent of TCE contamination was delineated to approximately 145 feet long by 100 feet wide and the extent of *cis*-1,2-DCE contamination was delineated to approximately 135 feet long by 85 feet wide during site investigations (EPA, 2005). Initial and current groundwater contaminant concentrations are shown in Table 1.

Cleanup Approach: The first remedial actions at the Rochester Property NPL site took place in 1990 when 1,400 cubic yards of waste were excavated and disposed of off-site in a hazardous waste landfill. After the ROD was signed in 1993, an in situ dual trench air sparging system was constructed and operated from June 1995 until July 1999, when it was determined that the wells with the highest concentrations no longer exceeded remedial goals. In 2000 however, groundwater sampling and analysis found increasing contaminant concentrations in a down gradient well off-site, which was later purchased by Rochester Property. The air sparging system was then modified in 2002 to include ozone sparging, which along with air, improved treatment efficiency by chemically oxidizing the contaminants. The air/ozone sparging system was shut down in 2004 to assess potential rebound effects and continue groundwater monitoring (EPA, 2005).

Cleanup Success: The Rochester Property NPL site was treated using an innovative in situ remedial technology which employed a chemical oxidation method by combining ozone with the original air sparging system. Dissolved phase contaminants in groundwater were addressed and remediated successfully using this in situ method. Overall, the key contaminants of concern were removed from the groundwater and no longer exceed MCLs. Manganese was originally determined to exceed cleanup levels; however, the 2006 ESD removed manganese as a contaminant of concern due to a change in EPA's IRIS manganese risk values. There have been no exceedances of MCLs since sampling in November 2004. The air sparging system was turned off in July 2004 and the final groundwater monitoring event was conducted in November 2006, due to consistent contaminant concentrations below the MCLs. EPA has determined that the site meets criteria for "Site-Wide Ready for Anticipated Use" and was deleted from the NPL in October, 2007. Since cleanup was completed to levels which are sufficient for unrestricted use and exposure, there will be no more five-year reviews for this site (EPA, 2011).

Table 1. Summary of Remediation of Groundwater at Rochester Property NPL Site

Contaminant of Concern	Initial Maximum Concentration (ppb)	Remedial Goal (ppb) (MCL)	Current Maximum Concentration (ppb)	Percent Reduction
TCE	180	5	<MCL	>97%
cis-1,2-DCE	3,600	70	<MCL	>97%
Bis(2-ethylhexyl)phthalate	33	6	<MCL	>82%

Sources: EPA, 1993; EPA, 2005
MCL = U.S. EPA Drinking Water Maximum Contaminant Level
ppb = parts per billion

References

United States Environmental Protection Agency; Superfund Site Progress Profile, Rochester Property. Updated March 1, 2011.

United States Environmental Protection Agency; Explanation of Significant Differences: Rochester Property. 2006

United States Environmental Protection Agency, Region 4; Superfund Five-Year Review Report: Second Five-Year Review Report for Rochester Property Superfund Site, Travelers Rest, South Carolina. 2005.

United States Environmental Protection Agency; Explanation of Significant Differences: Rochester Property. 2002.

United States Environmental Protection Agency; Five-Year Review Report (Type 1), Rochester Property Site, Travelers Rest, South Carolina. 2000.

United States Environmental Protection Agency; Record of Decision: Rochester Property. 1993.

Tri-State Plating NPL Site

Site Location: Columbus, IN, Region 5

EPA ID#: IND006038764

Regulatory Agency: US EPA

Site Summary: Remedial actions at the Tri-State Plating National Priority List (NPL) site included the cleanup of metals from electroplating activities. The key contaminant of concern at the site was chromium. The initial remedial actions included disposal of drums containing inorganic materials. Later, soil was excavated and the onsite buildings were decontaminated and demolished. Groundwater contamination was addressed by a pump-and-treat system using existing extraction wells. The site was deleted from the NPL in July, 1997 after all cleanup levels had been met. During cleanup, the total chromium concentration in groundwater was reduced below its cleanup level of 50 µg/L (ppb) and the aquifer was restored for unrestricted use (EPA, 1997).

Tri-State Plating NPL Site
Remediation Highlights

- **Contaminants:** Chromium; highest concentration in groundwater 1,800 ppb.
- **Media:** Groundwater, Soil
- **Plume:** Contaminant plume extended for at least 200 feet
- Technologies:
  - Groundwater pump-and-treat
  - Excavation and off-site disposal of soil and drums
  - Decontamination and demolition of site buildings
- Major Successes:
  - Groundwater cleanup levels for chromium were achieved in just three years of pump-and-treat system operation
  - Determined that site meets criteria for “Site-Wide Ready for Anticipated Use,” including unlimited use and unlimited access
  - Protected a municipal well field and surface water located 800 feet from the site
  - Deleted from the NPL in 1997

Site History: The Tri-State Plating site operated from 1946 to 1981 as Hull Industries and Quality Plating Service Company and was bought by Tri-State Plating in 1981. From 1981 to 1984, electroplating operations were the primary activity at the 0.36-acre site. The site used chromium for plating activities. Contamination was first detected in 1983 in both soil and groundwater after the death of six birds that drank from a pool onsite. In 1984, after finding that Tri-State Plating was discharging contaminated wastewater to the city's sewer system, the City of Columbus instructed the company to install a treatment system to control the contamination. Later in 1984, when a treatment system had not been installed, the city blocked off the sewers leading from the Tri-State Plating facility and shut off the company's water supply. Tri-State Plating discontinued operations in 1984. The Tri-State Plating site was listed as final on the NPL in 1986. A record of decision (ROD) was signed in 1990 and the site was deleted from the NPL in 1997 (EPA, 2011).

Extent of Contamination: Contaminants were present in the surface and subsurface soils and eventually migrated to the underlying aquifer. Maximum initial and final monitoring groundwater contaminant concentrations for chromium are shown in Table 1. The total extent of the groundwater plume was not available from the information sources used for this case summary, however, elevated levels of chromium were found in a groundwater well located 200 feet south of the site.

Cleanup Approach: The first remedial actions at Tri-State Plating took place in 1987 when 27 drums of waste were transported and disposed of off-site. Later that year, decontamination of site buildings occurred and the top one foot of soil and several areas of visible contamination were excavated site wide, followed by further excavation in 1989. Also in 1989, all on-site structures were demolished and soil was re-vegetated and graded. A groundwater extraction system was installed to remediate the chromium plume and operated from 1992 until the groundwater remediation goals were met in 1995 (EPA, 1997; Tetra Tech, 1992). The system used three groundwater extraction wells at depths of up to 60 feet below ground surface (bgs). It was determined that a pump rate of 200 gallons per minute (gpm) created an effective capture zone which prevented offsite contaminant migration. The extracted groundwater was treated by the existing City of Columbus waste water treatment plant prior to discharge (Tetra Tech, 1992). The site groundwater was sampled for a two-year period to assure that the groundwater cleanup goals were achieved permanently, and the remedial activities were deemed complete in 1996 (EPA, 1997).

Cleanup Success: The Tri-State Plating site was effectively remediated using source control (drum and soil removal) followed by the operation of a groundwater pump-and-treat system for a period of about three years. Following remedial activities, it was determined that groundwater remedial action objectives (RAOs), including the cleanup level of 50 ppb for chromium, were achieved and no further remediation would be required (EPA, 1997).

Table 1. Summary of Remediation of Groundwater at Tri-State Plating NPL Site

Contaminant of Concern	Initial Maximum Concentration (ppb)	Cleanup Level (ppb)	Final Maximum Concentration (ppb)	Percent Reduction
Chromium (Total)	1,800	50	<50	>98%

Source: EPA, 1990; EPA, 1997
ppb = parts per billion

References

Tetra Tech, Inc.; Remedial Action Report for Tri-State Plating Site, Columbus, Indiana. 1992.

United States Environmental Protection Agency; Superfund Site Progress Profile, Tri-State Plating. Updated April 4, 2011.

United States Environmental Protection Agency; Notice of Intent for Deletion, Tri-State Plating Superfund Site from the National Priorities List. 1997.

United States Environmental Protection Agency; Superfund Record of Decision: Tri-State Plating. 1990.

Odessa Chromium II NPL Site

Site Location: Odessa, TX, Region 6

EPA ID#: TXD980697114

Regulatory Agency: US EPA, Texas Commission of Environmental Quality (formerly Texas Natural Resource Conservation Commission)

Site Summary: Remedial actions at the Odessa Chromium II NPL Site included the cleanup of total chromium and hexavalent chromium [Cr(VI)] contamination in groundwater, caused by radiator repair work conducted on the site from 1960 to the early 1970s. The initial remedy began in 1993 and included the extraction of chromium-contaminated groundwater, with ex situ electrochemical (South Plume) and ion exchange (North Plume) treatment of groundwater that exceeded the EPA maximum contaminant level (MCL) for total chromium of 0.10 mg/L (ppm). Secondary in situ chemical reduction (ISCR) treatment was conducted in 1999 by injecting a concentrated ferrous sulfate [$Fe(II)SO_4$] solution to expedite cleanup of a small area (two wells) that remained above remediation goals after five years of pump-and-treat. Overall, the site achieved its cleanup goals in less than 10 years of treatment.

Odessa Chromium II NPL Site
Remediation Highlights

- **Contaminants:** Chromium and hexavalent chromium (CrVI); highest concentrations in groundwater included 9.9 ppm total chromium
- **Media:** Groundwater
- **Plume Size**: Chromium contamination in more than a 40-acre portion of the Trinity-Edwards aquifer
- **Technologies:**
  - Groundwater pump-and-treat with ex situ ion-exchange treatment of North Plume and electrochemical treatment of South Plume
  - ISCR using ferrous sulfate ($Fe(II)SO_4$) treatment
- Major Successes:
  - Pump-and-treat: six wells in Trinity Aquifer and two wells in the perched zone achieved concentrations <0.10 ppm
  - Pump-and-treat: 141 pounds of chromium removed from groundwater via pump-and-treat
  - ISCO: two additional wells that were above 0.10 ppm achieved the cleanup goal with only two rounds of treatment
  - Successful treatment train approach using pump-and-treat followed up by innovative ISCR to accelerate cleanup and achieve MCLs in less than 10 years

Site History: Basin Radiator & Supply operated a radiator repair facility at the site from 1960 to the early 1970s. Wastewater containing corrosion inhibitors, including Cr(VI), was discharged to unlined ponds and radiator sludge was buried at the site. Two aquifers at the site were affected (perched and Trinity) with depth to groundwater ranging from 35 to 45 feet below ground surface (bgs) (EPA, 2005). Groundwater contamination was first detected in 1977 when the Texas Natural Resource Conservation Commission (TNRCC) discovered elevated levels of chromium in groundwater in response to citizen complaints of contaminated well water (EPA, 2004). The Odessa Chromium II site was added to the state Superfund list in 1981, and listed on the NPL in 1985 (EPA, 2005). A record of decision (ROD) was signed in 1988 and two explanation of significant differences (ESD) documents were filed in 1999 and 2003. The site was deleted from the NPL in 2004 (EPA, 2005).

Extent of Contamination: Total chromium contamination was present in both the perched aquifer and the Trinity-Edwards sole-source aquifer with the highest concentrations of 9.9 and 3.3 ppm, respectively (EPA, 2004). More than a 40-acre portion of the Trinity-Edwards aquifer showed contamination (EPA, 2011). The Trinity-Edwards aquifer is 60 to 100 feet thick and lies in sandstone and conglomerate rock overlaid by 20 to 60 feet of soil and caliche (EPA, 2011). Maximum initial and final cleanup groundwater contaminant concentrations are shown in Table 1.

Cleanup Approach: The initial remedy began in 1993 and included the extraction of chromium-contaminated groundwater from the South Plume, with ex situ electrochemical treatment of groundwater with chromium concentrations greater than the MCL. At the time of the initial remedy, the cleanup goal for total chromium was 0.05 ppm, but was raised to 0.10 ppm in 1999. Treated groundwater was re-injected into the Trinity-Edwards aquifer. By December 1997, all six wells in the Trinity-Edwards aquifer and two wells in the perched zone exhibited total chromium concentration less than 0.10 ppm, and 141 pounds of chromium had been removed from area groundwater (EPA, 2005). However, two wells in the perched zone remained above cleanup levels after five years of extraction and treatment. In December 1998, both of the remaining wells were treated with a concentrated solution of $Fe(II)SO_4$. The wells were continuously sampled and one of the two wells was shut down in February 1999 after three months of continuous concentrations below the cleanup level. The second well received a second Fe(II)SO_4 treatment in April 1999 as its concentration had dropped below the cleanup level right after the first treatment but did not stay below the cleanup level during the subsequent 90-day period. Concentrations at the second well remained below cleanup levels during the 90-day period after the second treatment.The first ESD was filed in 1999 as the PRP agreed to expand the remedy to the North Plume and petitioned EPA to change the treatment type from electrochemical to ion exchange, claiming lower projected remedial costs (EPA, 2005). The ESD added ISCR using Fe(II)SO_4 treatment to the two remaining wells to speed the remediation process. In September, 2003 a second ESD was filed to remove requirements for long-term monitoring since cleanup goals had been achieved. A Closeout Report verifying the success of the Odessa Chromium II, North and South Plume remedy remediation was signed by EPA in September 2003.

Cleanup Success: The Odessa Chromium II NPL Site was treated using a pump-and-treat system with ex situ electrochemical and ion exchange treatment technologies. The system treated 121 million gallons of water, removing 141 pounds of total chromium in two aquifers over a five-year period, leaving only two perched zone wells with residual chromium concentration in excess of the cleanup goal (EPA, 2005). The remaining two wells were treated successfully by ISCR to help reduce chromium concentrations to levels below the cleanup goal. EPA issued an ESD on September 10, 2003, which contained sampling results from more than eight years of quarterly monitoring. Upon evaluation of the data, it was determined that the 30-year monitoring period requirement could be discontinued. EPA, with concurrence from the TCEQ, determined that all appropriate responses under CERCLA had been completed and no further action was necessary. The site was deleted from the NPL in July 2004 (EPA, 2004).

Table 1. Summary of Remediation of Groundwater at Odessa Chromium II NPL Site

Contaminant of Concern	Initial Maximum Concentration (ppm)	Remedial Goal (ppm) (MCL)	Current Maximum Concentration (ppb)
Chromium, Total	9.9	0.1	<MCL

Source: EPA, 2011
MCL = U.S. EPA Drinking Water Maximum Contaminant Level
ppm = parts per million

References

United States Environmental Protection Agency, Region 6; Odessa Chromium #2, North and South Plumes Status Report; 2011.

United States Environmental Protection Agency; Cost and Performance Report, Pump and Treat and In Situ Chemical Treatment of Contaminated Groundwater at the Odessa Chromium II South Superfund Site, Operable Unit 2, Odessa, Texas; 2005.

United States Environmental Protection Agency; Federal Register Notice, Notice of Direct Final Action; Volume 69, Number 98; 2004.

Del Norte Pesticide Storage Area, OU 1

Site Location: Crescent City, Del Norte County, CA, Region 9

EPA ID#: CAD000626176

Regulatory Agency: U.S. EPA, State of California, Department of Toxic Substances Control (DTSC), Del Norte County Health and Human Services Public Health Branch

Site Summary: Remedial actions at the Del Norte Pesticide Storage Area included the cleanup of 1,2-dichloropropane (1,2-DCP) and 2,4-dichlorophenoxyacetic acid (2,4-D) from soil and groundwater as the result of improper storage and disposal of pesticides on the site from 1970 to 1981 (EPA, 1985). The remedy included excavation and offsite disposal of contaminated soil and pump-and-treat of contaminated groundwater, followed by monitored natural attenuation (MNA) to address residual contamination. These actions reduced 2,4-D concentrations in groundwater to below the EPA maximum contaminant level (MCL) cleanup goal, and significantly reduced 1,2-DCP concentrations to below the MCL cleanup goal in all but one monitoring well (EPA, 2010a).

Del Norte Pesticide NPL Site
Remediation Highlights

- **Contaminants:** Pesticides and herbicides including 1,2-DCP and 2,4-D; highest concentrations in groundwater included 2,000 ppb 1,2-DCP
- **Media:** Groundwater, Soil
- **Plume Size:** Contaminant plume size approximately 12,000 square feet and extended approximately 170 feet off-site
- **Technologies:**
  - Groundwater pump-and-treat with carbon adsorption and air sparging
  - MNA for residual 1,2-DCP
- **Major Successes:**
  - 2,4-D concentration reduced below MCL in groundwater through source removal alone
  - 98 percent reduction of 1,2-DCP after only four years of pump-and-treat
  - MNA further reduced 1,2-DCP concentrations in groundwater from 40 to 6.5 ppb

Site History: The Del Norte Pesticide Storage Area site accepted containers from local agricultural and forestry related industries from 1970 until 1981. The site is approximately 200 feet long and 100 feet wide, or 0.5 acres. The site was used as an interim or emergency storage area for pesticide containers that had been triple-rinsed and punctured. It was later determined that wastes and rinse water were improperly disposed of in an unlined sump (EPA, 2010a). Area groundwater is shallow and ranges from 3 to 10 feet below ground surface (bgs) on a seasonal basis, and the thickness of the upper aquifer is approximately 30 feet. The site lies on a 1.5-mile wide marine terrace shelf, consisting of moderately well sorted fine sands, silts, and clays with generally moderate groundwater permeability. Initial site investigations were performed from 1981 to 1983, when 1,600 containers were removed from the site for proper disposal. The site was placed on the NPL in 1983, and a remedial investigation and feasibility study (RI/FS) was conducted in 1985 which showed that a 1,2-DCP and 2,4-D plume in groundwater extended approximately 170 feet southeast of the site. A record of decision (ROD) was signed in 1985 and an explanation of significant differences (ESD) in 1989 determined that the chromium contaminant of concern identified in the 1985 ROD was naturally occurring and did not require remediation (EPA, 2015). In 2000, a ROD amendment concluded that the remedial objective of restoring contaminated groundwater to the MCL for 1,2-DCP would not be met because no technology existed that was capable of reaching drinking water levels and a Technically Impracticable (TI) waiver was issued (EPA, 2015). The site was deleted from the NPL in September 2002, and four Five-Year Reviews have been performed, the last in June 2015. The most recent groundwater monitoring results show that all

Del Norte Pesticide Storage Site (right) and Adjacent Airport (left) (EPA, 2010b) contaminants of concern are below their MCLs and all remedial action objectives have been achieved (EPA, 2015).

Extent of Contamination: The soil and groundwater at the site were contaminated with 1,2-DCP and 2,4-D. Approximately 290 cubic yards (CY) of soil required excavation and removal from the site as part of the remedial action. The groundwater plume of 1,2-DCP, the principal contaminant, was approximately 12,000 square feet and extended 170 feet southeast of the site, with concentrations of 1,2-DCP as high as 2,000 µg/L (ppb) before remediation (EPA, 2010a). There are no private residences or water supply wells within 2,000 feet from the plume. Concentration reductions of 1,2-DCP, by treatment phase, are shown in Table 1.

Cleanup Approach: The cleanup initially included the removal of about 290 CY of contaminated soil in 1987. The soil removal alone reduced 2,4-D concentrations in underlying groundwater to below its 100 ppb cleanup goal at the time (EPA, 2000a). A pump-and-treat system was installed in 1990, and operated from April 1990 to December 1994. During the period of operation, 1,2-DCP concentrations were reduced to 40 ppb, which was still above the cleanup goal of 5 ppb based on the EPA MCL adopted in 1992. With 1,2-DCP still above its cleanup goal in groundwater, an attempt to optimize the system to further reduce 1,2-DCP concentrations was conducted by adding air sparging and performing pulsed-pumping for extended periods of time to determine what effect it would have on contaminant concentrations. However, the entire system was shut down in 1997 as there were no discernible changes to the 1,2-DCP concentrations. Monitoring data indicated that 1,2-DCP concentrations decreased at the same slow rate during air sparging and pulsed-pumping as they had during operation of the pump-and-treat system alone. In 2000, a ROD Amendment was issued, changing the remedy for the site to plume containment through MNA, continued groundwater monitoring, and institutional controls. This Amendment also waived the cleanup goal for 1,2-DCP through a Technical Impracticability Waiver (EPA, 2000b). As of October 2009, two monitoring wells had detectable concentrations of 1,2-DCP, with only one of the wells in exceedance of the MCL (5 ppb) at a concentration of 6.5 ppb (EPA, 2010a).

Cleanup Success: Pesticide concentrations in groundwater at the Del Norte Pesticide Storage NPL site were significantly reduced through a combination of contaminant source removal, pump-and-treat, and MNA. The pump-and-treat system treated 23 million gallons of groundwater in seven years of operation, and achieved 98 percent contaminant reduction (1,2-DCP) in just its first four years (EPA, 2010a). Subsequent MNA has further reduced 1,2-DCP concentrations to below the MCL in all monitoring wells (EPA, 2015). The Technical Impracticability provision of the 2000 ROD Amendment will be addressed through an appropriate Decision Document once the confirmation is received and formal documentation of unrestricted use and unrestricted exposure status is complete (EPA, 2015).

Table 1. Reduction of 1,2-DCP Concentrations in Groundwater at Del Norte Pesticide Storage Area NPL Site

Treatment Phase	1,2-DCP Concentration (ppb)
Initial Concentration Before Remediation – Maximum Concentration	2,000
After Soil Removal (1989) – Maximum Concentration	600
After Initial 4 Years of Pump-and-Treat (1990-1994) – Maximum Concentration	37
After 3 Years Air Sparging (1995-1997) – Maximum Concentration	40
Natural Attenuation (by 1999) – Maximum Concentration	23
Natural Attenuation (by 2002) – Maximum Concentration	11
Natural Attenuation (by 2014) – Concentration Range in the Two Wells Where 1,2-DCP is Still Detectable	2 - 4

Sources: FRTR, 2004; EPA, 2000a; EPA, 2010b; EPA, 2015

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Firestone Tire and Rubber Company NPL Site

Site Location: Salinas, California, Region 9

EPA ID#: CAD990793887

Regulatory Agency: U.S. EPA

Site Summary: Remedial action at the Firestone Tire and Rubber Company NPL site included cleanup of chlorinated and non-chlorinated volatile organic compounds (VOCs) that resulted from the spillage of production chemicals during the manufacturing process. Key contaminants included benzene, 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), tetrachloroethene (PCE), toluene, trichloroethene (TCE), and xylene. Remedial actions included the removal of storage tanks, excavation of contaminated soil, and the operation of an oil/water separator and a groundwater pump-and-treat system with air stripping and carbon adsorption treatment (FRTR, 1998a and 1998b). The pump-and-treat system operated for six years and cleanup goals were achieved across the site. The Final Closeout Report was issued in 2004 and the site was deleted from the NPL in April 2005 (EPA, 2009).

Firestone Tire and Rubber NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated and non-chlorinated VOCs including benzene, 1,1-DCE, 1,1-DCA, PCE, toluene, TCE, and xylene; highest concentrations in groundwater included 120 ppb 1,1-DCE
- **Media:** Groundwater, Soil
- **Plume Size:** Contaminant groundwater plume extended 2.5 miles off-site
- **Technologies:**
  - Soil removal
  - Oil/water separation
  - Pump-and-treat with air stripping and carbon absorption treatment technologies
- **Major Successes:**
  - Removal of 22 storage tanks and 5,300 CY of contaminated soil
  - 1.8 billion gallons of groundwater treated and 496 pounds of VOCs removed
  - 1,1-DCE concentration reduced by 75 percent after two years of pump-and-treat system operation
  - All contaminants of concern below cleanup goals in six years of pump-and-treat operation

Site History: The Firestone Tire and Rubber Company operated a 43-acre tire manufacturing plant on this 256-acre site from 1965 to 1980. Three aquifers (shallow, intermediate, and deep) lie beneath the site, with depths ranging from near ground surface to 90 feet below ground surface (bgs), 100 to 140 feet bgs, and 200 to 500 feet bgs, respectively. Each aquifer is separated from the neighboring aquifer by discontinuous clay aquitards, which consist of impermeable silt and clay units. Groundwater and soil contamination was first detected during pre-closure investigations of the facility's solid waste management units in 1983 (FRTR, 1998a). The site was placed on the NPL in July 1987 and a record of decision (ROD) was signed in September 1989 (EPA, 2009). Remediation and monitoring activities began in 1983 and continued until 1998, and the site was deleted from the NPL in April 2005 (FRTR, 1998b).

Extent of Contamination: 1,1-DCE was the principal contaminant at the site, and was selected during the design process as the index compound for the remedial action. The maximum concentration of 1,1-DCE detected on-site was 120 ppb. A VOC plume was identified in groundwater that extended nearly 2.5 miles off-site. The extent of the plume was heavily influenced by local high-volume agricultural wells which yielded very high hydraulic conductivities, ranging from 100 to 1,200 feet/day (FRTR, 1998a). Contaminants migrated from the shallow aquifer to the intermediate and deep aquifers by seeping through gaps in the silt and clay aquitards separating the aquifers (FRTR, 1998b). Changes in 1,1-DCE concentrations during the remedy are included in Table 1.

Cleanup Approach: During the pre-closure investigations conducted at the site, 11 areas of potential contamination were identified, which led to the removal of 22 storage tanks and excavation and removal of 5,300 CY of soil contaminated with various organic and inorganic contaminants in 1983 and 1984. It was later determined, however, that the tanks and soil removed had not been the only sources of groundwater contamination. In 1985 a multi-component pump-and-treat system was installed, and both on-site and off-site groundwater pumping was initiated to reduce further migration of contaminants. The extraction system initially comprised 25 wells located on- and off-site, with 15 wells in the shallow aquifer and five wells each in the intermediate and deep aquifers. The pump-and-treat system was not only designed to extract and treat contaminated groundwater, but also to prevent off-site migration by placing a number of shallow wells at the perimeter of the facility boundary (FRTR, 1998b).

The pump-and-treat system began operation in February 1986, pumping at 550 gallons per minute (gpm) (FRTR, 1998b). Two areas of groundwater required pre-treatment before entering the main pump-and-treat system, due to high levels of either oil and grease or chlorinated solvents. High levels of oil and grease were treated using an oil/water separator, followed by an initial pass through two fixed-bed adsorbers. Groundwater with high levels of chlorinated solvents was pre-treated in an air stripper using an airflow of 750 cubic feet per minute (cfm), removing 98 percent of chlorinated solvents. All other groundwater was mixed with water output from the fixed-bed adsorbers and the air stripping units, before passing through the carbon filters at 550 gpm. The treated groundwater was aerated in tanks before being discharged to the Salinas River. The pump-and-treat system operated for over six years until June 1992, when cleanup levels for the contaminants of concerned were met. The cleanup levels were 6 ppb for 1,1-DCE, 5 ppb for 1,1-DCA, 3.2 ppb for TCE, 0.7 ppb for PCE and benzene, 20 ppb for toluene, and 70 ppb for xylene (EPA, 1989).

Cleanup Success: The Firestone Tire & Rubber Company NPL site remedy included source area soil removal followed by groundwater pump-and-treat. The pump-and-treat system operated for approximately six years, treating 1.8 billion gallons of water and removing 496 pounds of total VOCs. The decline in concentrations of 1,1-DCE were dramatic, dropping from 120 ppb to an average of 61 ppb after the first year of pump-and-treat system operation, halved again to an average of 30 ppb after the second year of treatment, and dropping to 4.8 ppb by 1994. The remedial system was decommissioned in 1995 with confirmation sampling continuing in 10 wells until 1998 (FRTR, 1998b). The Final Closeout Report was issued in 2004 and the site was deleted from the NPL in April 2005 (EPA, 2009).

Table 1. Reduction of 1,1-DCE in Groundwater at the Firestone Tire & Rubber Company NPL Site

Treatment Phase	1,1-DCE Concentration (ppb)
Initial Maximum Single Concentration – During Site Investigations	120
After First Year of Pump-and-Treat (1987) – Average Concentration	61
After Second Year of Pump-and-Treat (1988) – Average Concentration	~30
By 1994: After Completion of Pump-and-Treat – Average Concentration	4.8

Source: FRTR, 1998b **1,1-DCE cleanup level = 6 ppb**

References

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Pemaco NPL Site

Site Location: Maywood, CA, Region 9

EPA ID#: CAD980737092

Regulatory Agency: U.S. EPA

Site Summary: Remedial actions at the Pemaco NPL site included the cleanup of chlorinated volatile organic compounds (VOCs), non-chlorinated VOCs, semi-volatile organic compounds (SVOCs), PAHs, metals, and dense non-aqueous phase liquids (DNAPLs) from chemical blending and distribution activities. Key contaminants of concern in the exposition groundwater zones include tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and vinyl chloride. The initial remedial actions included contaminated soil excavation and removal of underground and above ground storage tanks and drums, and building demolition. These actions were later followed by soil-vapor extraction (SVE), groundwater pump-and-treat using granulated activated carbon (GAC) treatment, and electrical resistance heating (ERH) using high-vacuum dual-phase extraction (HVDPE) and flameless thermal oxidation (FTO). The site was added to the NPL on January 19, 1999 and has not yet been deleted; however significant progress towards achieving remedial action objectives has been made. Groundwater contaminant concentrations have been reduced from as high as 22,000 µg/L (ppb) TCE to below EPA maximum contaminant levels (MCLs) in many locations. In the most successful area, eleven of 18 wells have achieved VOC concentrations below MCLs. Additionally, contaminant concentrations in soil met cleanup levlels in nearly all post-remediation samples (EPA, 2010). However, increasing levels of contamination since 2011 indicate that the full lateral and vertical extent of TCE contamination has not been fully delineated (EPA 2015).

Pemaco NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including PCE, TCE, *cis*-1,2-DCE, and vinyl chloride; non-chlorinated VOCs; SVOCs including PAHs, and metals; highest concentrations in the exposition groundwater zone included 1,100 ppb PCE, 22,000 ppb TCE, 14,000 ppb DCE, and 780 ppb vinyl chloride
- **Media:** Groundwater, Soil, DNAPL (suspected)
- **Plume Size:** VOC groundwater plume approximately 1,300 feet by 750 feet in deep aquifer, extended 200 feet offsite in perched aquifer
- **Technologies:**
    - High-vacuum dual phase extraction
    - ERH
    - Groundwater pump-and-treat (GAC/UV Ox)
    - Excavation and off-site disposal of soil
- **Major Successes:**
    - Groundwater and soil cleanup levels achieved at most locations; reduced groundwater contaminant concentrations to below MCLs at most locations
    - Removal and treatment of 21,500 pounds of VOCs in vadose zone soils
    - Remediation of DNAPL
    - Successful treatment approach using innovative, in situ technologies to accelerate cleanup
    - Redevelopment of the site into a park

Site History: Pemaco operated from the 1940s to 1990s as a chemical blending and distribution facility until the owner abandoned the site in 1991. The site used chlorinated and aromatic solvents, oils, and other flammable liquids, which were stored on-site. The main warehouse, which is the principal source of contamination on-site, was destroyed by a fire in 1993 (EPA, 2011). The 4.1-acre site is relatively flat and consists of six discrete groundwater areas. A perched aquifer zone ranges from 30-35 feet below ground surface (bgs) and the remaining five underlying zones range from 3 feet to 15 feet thick at depths ranging from 75-175 feet bgs. There is a 1-10-foot impermeable clay layer that lies directly beneath the perched zone, separating the upper and lower aquifers. The five underlying zones are made up of silty sands separated by less permeable clay-rich strata and are stratigraphic equivalents to the regional Exposition Aquifer (EPA, 2010). Pemaco was listed on the NPL in 1999 and has not yet been deleted (EPA, 2011). A site Feasibility Study (TN&A, 2004) was issued in 2004 and a record of decision (ROD) (EPA, 2005) was signed in 2005. The First Five-Year Review Report was completed in 2010 and a second Five-Year Review Report was completed in 2015.


Groundwater Treatment Facility at Pemaco Superfund Site (EPA, 2010)

Extent of Contamination: Dissolved phase contaminants and DNAPL were present in the perched aquifer, with VOC concentrations exceeding 10,000 ppb. The lateral extent of contamination within this aquifer extended off-site over 200 feet from site boundaries. Contaminants migrated to the upper zones of the deeper "Exposition Aquifers" where DNAPL was suspected due to the presence of TCE at greater than 1 percent of its solubility (EPA, 1992). The deeper plume extended laterally over an area of 1,300 feet by 750 feet, with a thickness of 1.5 to 10 feet, with VOC concentrations at a maximum of 22,000 ppb in the source area (EPA, 2010). Initial and subsequent groundwater contaminant concentrations as of 2011 are shown in Table 1.

Table 1. Summary of Remediation of Groundwater at Pemaco NPL Site

Contaminant of Concern	Initial Maximum Concentration (ppb)	Remedial Goal (ppb) (MCL)	2011 Maximum Concentration (ppb)*	Percent Reduction
PCE	1,100	5	120	89%
TCE	22,000	5	650	97%
cis-1,2-DCE	14,000	6	450	97%
Vinyl Chloride	780	0.5	16	98%

Sources: EPA, 2005; EPA, 2010
MCL = U.S. EPA Drinking Water Maximum Contaminant Level
ppb = parts per billion

*Concentrations have increased since 2011 because the full extent of contamination has not been determined.

Cleanup Approach: The first remedial actions at the Pemaco NPL site took place from 1991 to 1999, when emergency removal activities were initiated. These activities included soil excavation and removal of underground and above ground storage tanks and drums. In 1997, an SVE system was installed as an interim treatment method. It remained operational until 1998, when it was shut down due to community concerns about dioxin emissions from the SVE system which could have been produced as a byproduct of the thermal oxidation treatment of extracted vapors. By the time the SVE system was removed, it had treated over 21,500 pounds of hydrocarbons from vadose zone soils. After the ROD was signed in 2005, construction began on additional selected remedies. These remedies, which began in 2007, included a HVDPE pump-and-treat system which used GAC for groundwater treatment and FTO/GAC for treatment of vapors. In addition, ERH was used to treat the deeper vadose soils and groundwater at depths from 32 feet to 100 feet bgs, which was to be followed by groundwater pump-and-treat and monitored natural attenuation (MNA) (EPA, 2005; EPA, 2011). A bioremediation pilot study was also initiated in 2006, and has shown favorable conditions for reductive dechlorination of TCE. EPA is evaluating potential optimization opportunities, including additional bioremediation treatment, reduced pumping rates, and or pulsed pumping. In 2007, the site also performed an in situ bioremediation pilot study using enhanced reductive dechlorination (ERD), both alone and in conjunction with thermal treatment using ERH.

Cleanup Success: The contaminated vadose and saturated zones at the Pemaco NPL site were treated using several innovative remedial technologies. Dissolved phase contaminants, DNAPL, and soil vapor were addressed using these technologies. The site was separated into various areas (northern, which included pump-and-treat and SVE, and southern, which included ERH and source zones). While all areas have shown significant progress, the southern ERH target zone has shown the most success. In this area, the HVDPE system removed 70 percent of the contaminant mass, which was followed by removal of the remaining 30 percent by ERH. Eleven of 18 wells in the southern area have shown TCE concentrations below the MCLs, however, there are still wells that have not achieved MCLs (although only three of the wells in this area have concentrations above 25 ppb). However, increasing levels of contamination since 2011 indicate that the full lateral and vertical extent of TCE contamination has not been fully delineated (EPA 2015). Nearly all soil samples taken post-ERH have concentrations below 10 ppb TCE, achieving the cleanup level of 60 ppb for soil. The Pemaco site has not yet been deleted and groundwater pump-and-treat and MNA will continue until groundwater MCLs are met site-wide. However, the Maywood Riverfront Park, which includes the redeveloped Pemaco site, officially opened in May 2008 and offers soccer fields, playground equipment, handball courts, and basketball courts for area residents.

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Southern California Edison Co., Visalia Pole Yard NPL Site

Site Location: Visalia, CA, Region 9

EPA ID#: CAD980816466

Regulatory Agency: U.S. EPA, State of California Department of Toxic Substances Control

Visalia Pole Yard NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated and non-chlorinated SVOCs including benzo(a)pyrene, PCP, and TCDD; highest concentrations in groundwater included 5 ppb benzo(a)pyrene, 610 ppb PCP, and 11 ppb TCDD
- **Media & Waste:** Groundwater, Soil, DNAPL
- **Plume Size:** SVOC groundwater plume covers 2.1 acres and extends from the water table to a depth of approximately 145 feet
- **Technologies:**
  - In situ thermal treatment (DUS)
  - In situ bioremediation (air sparging and bioventing)
  - Groundwater pump-and-treat
  - VEB (slurry wall)
  - Excavation and off-site disposal of soil
- **Major Successes:**
  - All groundwater and soil cleanup levels achieved; reduced groundwater contaminant concentrations to below MCLs
  - Removal or treatment of 1.33 million pounds of contaminants
  - Remediation of DNAPL
  - Successful treatment train approach using innovative, in situ technologies to accelerate cleanup

Site Summary: Remedial actions at the Southern California Edison (SCE) Visalia Pole Yard NPL site included the cleanup of chlorinated and non-chlorinated SVOCs from wood treatment activities. Key contaminants of concern include benzo(a)pyrene, pentachlorophenol (PCP), and tetrachlorodibenzo-p-dioxin (TCDD), an impurity in the PCP used at the site. The initial remedial actions included installation of a vertical engineered barrier (VEB) (slurry wall) to keep contaminants from migrating offsite, contaminated soil removal and groundwater pump-and-treat. To enhance the removal of contaminants, an in situ thermal treatment system using steam injection in a dynamic underground stripping (DUS) process was implemented, followed by in situ bioremediation using air sparging and bioventing. The site was deleted from the NPL in September 2009 after all remedial action objectives (RAOs) had been met. Overall, approximately 1.33 million pounds of contaminants were removed or treated during remedial actions, reducing groundwater contaminant concentrations, which ranged from 5 ppb to 610 ppb, to below EPA MCLs. Contaminant concentrations in soil also met cleanup levels as determined in the ROD (Eaker, 2010).

Site History: The SCE Visalia Pole Yard operated from 1925 to 1980 as a utility pole treatment facility. The site used creosote compounds and PCP dissolved in diesel oil from 1968 to 1980. Leaks from pipes and underground storage tanks (USTs) contaminated soil and groundwater at the site. Three aquifers (shallow, intermediate, and deeper) consisting of unconsolidated sediment lie beneath the site, ranging in depth from 30 to 180 feet below ground surface (bgs). Aquitards consisting of a relatively impermeable silt layer separate these aquifers (EPA, 1994). Groundwater contamination was first detected in 1966 in an onsite well. The Southern California Edison Visalia Pole Yard was added to the state Superfund list in 1985, then was listed on the NPL in 1989 and deleted in 2009 (EPA, 2011). A record of decision (ROD) was signed in 1994 and three five-year reviews have occurred to date (2005, 2010, and 2015). The Remedial Action Completion Report (SCE, 2008) documented that the post-remediation groundwater monitoring and soil removal actions performed met the ROD cleanup standards for soil and groundwater. A Remedial Action Report and a final close out report were signed in 2009 (EPA, 2009).

Contaminants in a dissolved air flotation tank at Visalia Pole Yard (Walter, 1998)

Extent of Contamination: Dissolved phase contaminants were present in the shallow aquifer and eventually migrated to the intermediate and deeper aquifers. Contaminant migration also occurred laterally along the aquitards and pools of DNAPL settled at the bottom of the shallow (50 feet bgs) and intermediate (100 feet bgs) aquifers. Contaminants migrated into the deep aquifer to a maximum depth of 145 feet bgs (EPA, 1994). Maximum initial and subsequent groundwater contaminant concentrations as of 2007 are shown in Table 1.

Cleanup Approach: The first response actions at Visalia took place in 1977, when a 60-foot deep VEB (slurry wall) was built around the contaminated area in an attempt to slow the lateral migration of contaminants in the shallow aquifer. In 1981, 2,300 cubic yards of contaminated soil were disposed of offsite as an initial remediation effort. A groundwater extraction and treatment system was installed and operated from 1985 through 2004 to remediate the groundwater plume. The system pumped, treated, and discharged an average of 0.36 to 0.5 million gallons per day of contaminated groundwater. In 1997, a DUS system was installed using technology developed by the Lawrence Livermore National Laboratory with the University of California, Berkeley (EPA, 2005). The DUS system was implemented to increase the rate of recovery of contaminants, resulting in a faster and less expensive cleanup of the site. The DUS system ran for 36 months and injected 660 million pounds of steam into the saturated zone through 14 injection wells. The liquid and vapors were extracted through four extraction wells, separated, cooled, and then treated. Daily contaminant mass recovery rates reduced from 13,000 pounds per day initially to about 4 pounds per day by June 2000. Steam injection was halted due to the diminishing recovery rate. After the DUS system was shut down in 2000, in situ bioremediation (including vadose zone bioventing and saturated zone biosparging) and pump-and-treat continued until 2004. The bioremediation phase took advantage of the elevated subsurface temperatures to oxidize contaminants that were not removed or destroyed by the DUS process, which enhanced the biological degradation process. Overall, approximately 1.33 million pounds of contaminants were removed during the remedy, including 239,000 pounds by vapor phase extraction, 678,000 pounds by free phase extraction, 199,500 pounds by aqueous phase extraction, and 212,200 pounds by in situ hydrous pyrolysis oxidation (Eaker, 2010). A post-remediation soil investigation in November 2004 indicated that TCDD was detected slightly above the cleanup standards at four locations. As a result, approximately 20 cubic feet within the TCDD “hot spot” area (soil between zero and 10 feet below grade) was removed in July 2006 (EPA, 2010).

Cleanup Success: The SCE Visalia Pole Yard site was treated using an innovative steam remediation system, coupled with enhanced in situ bioremediation and pump-and-treat. While SCE estimated that the pump-and-treat system combined with in situ bioremediation would take 120 years to clean up the site (Walter, 1998), cleanup levels were met in less than 25 years from start of remediation and 15 years from ROD signature. The in situ steam remediation removed over 99 percent of the contamination in just three years. Quarterly groundwater monitoring was conducted from 1985 through June 2007, which verified that all groundwater cleanup levels were met.

A covenant between SCE and the California Department of Toxics Substance Control prohibits use of the site for residences, hospitals, schools, and day care centers as well as prohibiting the installation of water wells for any purpose (EPA, 2009). EPA determined that the site meets criteria for “Site-Wide Ready for Anticipated Use” (EPA, 2011). The Visalia Pole Yard was deleted from the NPL in 2009.

Table 1. Summary of Remediation of Groundwater at Southern California Edison Visalia Pole Yard NPL Site

Contaminant of Concern	Initial Maximum Concentration (ppb)	Remedial Goal (ppb) (MCL)	Maximum Concentration (ppb) (2007)	Percent Reduction
Benzo(a)pyrene	5	0.2	<MCL	>96%
PCP	610	1	<MCL	>99%
TCDD (Dioxin)	11	0.00003	<MCL	>99%

Source: EPA, 2005
MCL = U.S. EPA Drinking Water Maximum Contaminant Level
ppb = parts per billion

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Western Pacific Railroad NPL Site

Site Location: Oroville, CA, Region 9

EPA ID#: CAD980894679

Regulatory Agency: US EPA, California Regional Water Quality Control Board (CRWQCB)

Site Summary: The remediation of the Western Pacific Railroad NPL site involved an initial removal action addressing a waste pond and a leaking underground storage tank (UST); the installation and operation of groundwater pump-and-treat and soil vapor extraction (SVE) systems, and a subsequent soil removal action. Key contaminants were chlorinated volatile organic compounds (VOCs) including 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), and trichloroethene (TCE) in groundwater and subsurface soil, and polycyclic aromatic hydrocarbons (PAHs) in surface soil. Many of the response actions were expedited and occurred prior to the signing of the record of decision (ROD). Ultimately, the remedial action objectives (RAOs) and groundwater cleanup levels [(EPA and California maximum contaminant levels (MCLs)] were met and the site was deleted from the NPL only four years after the ROD was issued and 11 years after removal actions began.

Western Pacific Railroad NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including 1,1-DCA, 1,1-DCE, and TCE in groundwater; PAHs, arsenic, and lead in surface soil; highest concentrations in groundwater 320 ppb 1,1-DCE and 66 ppb 1,1-DCA
- **Media:** Groundwater, Soil
- **Plume:** VOC plume extended approximately 700 feet long at a depth of 60 feet bgs
- Technologies:
  - Soil removal
  - Groundwater pump-and-treat with air stripping and GAC
  - SVE
- Major Successes:
  - 2,500 tons of PAH contaminated soil removed
  - 127 million gallons of groundwater treated
  - 66 pounds VOCs removed from groundwater and soil
  - Groundwater cleaned up below EPA and California MCL
  - Site deleted from the NPL 11 years after removal actions began and only four years after ROD was issued

Aerial Photo (CH2M Hill, 2008)

Site History: The 90-acre Western Pacific Railroad facility operated as a fueling and maintenance rail yard from the 1880s until 1970. Western Pacific Railroad and its subsequent owner, Union Pacific Railroad (UPRR), leased the property to Solano Railcar Company, which conducted sandblasting, painting, welding, and railcar repairs until 1991. In the course of the fueling, machining, and repairing of locomotives and railcars, spills contaminated soils and groundwater. A leaking UST in the fueling area was the source of VOC contamination in the groundwater. The subsurface of the site is composed of interbedded clays, sands, and gravels, which vary in thickness and composition, both horizontally and vertically across the site. The depth to the shallow aquifer is approximately 60 feet below ground surface (bgs) with a general groundwater flow direction to the west-southwest toward the Feather River. A shallow clay aquitard is located approximately 110 feet bgs at the site. In 1989, the California Regional Water Quality Control Board (CRWQCB) issued an order to UPRR to investigate groundwater and an on-site waste pond. The site was listed on the NPL in 1990, and UPPR signed an Administrative Consent Order in 1993 to contain the VOC plume. The Remedial Investigation (RI) and Feasibility Study (FS) was completed and a ROD was signed in 1997 (EPA, 1997). Response actions were performed through the 1990s, and the site was deleted from the NPL in 2001 (EPA, 2003).

Extent of Contamination: During the RI, surface soils were found to be contaminated primarily with PAHs and heavy metals, including arsenic and lead. Maximum concentrations detected were 28 mg/kg (ppm)

PAHs, 73 ppm arsenic, and 810 ppm lead (EPA, 1997). Removal of approximately 2,500 cubic yards (CY) of contaminated soil was required to reach the PAH soil cleanup level of 0.41 ppm (expressed as benzo(a)pyrene [B(a)P] equivalents). In groundwater 1,1-DCA, 1,1-DCE, and TCE were detected at concentrations as high as 66 µg/L (ppb), 320 ppb, and 13 ppb, respectively (Dames & Moore, 1989). The groundwater chlorinated VOC plume spread approximately 700 feet down gradient from the site UST towards a California Water Service (CWS) public drinking water well (CWS-1). PAHs were not detected in groundwater.

Cleanup Approach: Cleanup at the Western Pacific Railroad NPL site started in 1989 when the waste pond was excavated and backfilled with clean fill, groundwater monitoring wells were installed in the fueling area, and the leaking UST in the fueling area was removed (URS, 2001). In 1994, a time-critical removal action was conducted that involved the installation of a groundwater pump-and-treat system in the upper aquifer to prevent migration of contaminants to a nearby public water supply well (CWS-1). The pump-and-treat system consisted of a single extraction well, a bag filter, an air stripper, two granulated activated carbon (GAC) units, and one injection well (EPA, 2001). The pump-and-treat system was modified at two different times during the cleanup. In 1996, EPA allowed removal of the GAC units as use of the air stripper was successful in removing contaminants. In 1997 a new extraction well and an SVE unit was added to expedite and optimize contaminant removal (EPA, 2003).

By 1997, only three years after beginning pump-and-treat, and before signing of the ROD, groundwater concentrations had reached their cleanup levels, which were based on EPA and California MCLs (whichever was lower). The TCE cleanup level was based on the EPA MCL of 5 ppb while the 1,1-DCA and 1,1-DCE cleanup levels were based on the California MCLs of 5 ppb and 6 ppb, respectively. As part of the ROD, treatment and monitoring continued over the next two years to ensure that groundwater concentrations remained below these cleanup levels. Additionally, in accordance with the ROD, a soil removal action was conducted in 1998 over a six-day period that removed the top 1 foot of soil over a one-acre area (approximately 2,500 CY) with the highest levels of PAH contamination. The groundwater pump-and-treat and SVE systems were shut down in November 1999, and a final round of groundwater sampling conducted in July 2000 confirmed that all contaminants remained below the cleanup levels. More than 127 million gallons of groundwater were treated during the remedy, with over 66 pounds of VOCs removed from groundwater and soil via the groundwater pump-and-treat and the SVE systems (URS, 2001). The final closeout report for the site was signed by EPA in June 2001 (EPA, 2001).

Cleanup Success: The successful remediation of the Western Pacific Railroad NPL site involved a combination of source removal of the waste pond, contaminated soil, and a leaking UST, followed by the operation and optimization of a groundwater pump-and-treat and SVE system to contain and clean up a 700-foot long chlorinated VOC plume. Ultimately, the groundwater met its federal and state cleanup levels, and the site was deleted from the NPL 11 years after removal actions began and only four years after the ROD was signed (URS, 2001).

Table 1. Western Pacific Railroad NPL Site Groundwater Contaminant Levels

Concentrations at MW-89-2	**1,1-DCA (ppb)**	**1,1-DCE (ppb)**	**TCE (ppb)**
1989 (Prior to NPL listing)	66	320	13
2002 (Five Year Review)	1.4	1.7	Not Detected
Cleanup Levels	5 (CA MCL)	6 (CA MCL)	5 (EPA MCL)

Sources: Dames & Moore, 1989 (1989 data); EPA, 2003 (2002 data)

References

Agency for Toxic Substance and Disease Registry; Public Health Assessment Western Pacific Railroad, Oroville, Butte County, California; 1992

Dames and Moore; Fueling Area Progress Report; 1989.

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Fort Lewis Logistics Center East Gate Disposal Yard (EGDY) OU1

Site Location: Pierce County, Washington, Region 10

EPA ID#: WA7210090067

Regulatory Agency: U.S. EPA, Washington State Department of Ecology

Site Summary: The 87,000-acre former Fort Lewis Army facility (now called Joint Base Lewis-McChord) contains 16 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites. The Logistics Center is the largest and most affected area at the facility, and consists of three major contaminated waste units, including the East Gate Disposal Yard (EGDY), the Solvent Refined Coal Pilot Project (SRCPP) area, and Landfill 4. The focus of this case summary is the EGDY (OU 1), which is a former industrial landfill used for disposing of equipment cleaning wastes and degreasing wastes. Trichloroethene (TCE) and petroleum hydrocarbons are the primary contaminants at the site, often occurring as light non-aqueous phase liquids (LNAPL) and dense non-aqueous phase liquids (DNAPLs), respectively. The remedial action at the EGDY involved connecting private drinking water wells to clean water sources, excavation and removal of over 1,000 buried waste drums, in situ thermal treatment of DNAPL using electrical resistance heating (ERH), and construction and operation of pump-and-treat systems to remediate volatile organic compounds (VOCs) in groundwater (EPA, 2011). While not yet deleted from the NPL, the remedy has shown significant progress towards restoring groundwater to EPA maximum contaminant levels (MCLs) (U.S. Army, 2007). TCE concentrations have been decreasing, with TCE exceeding the MCL cleanup level in one well and at the MCL in one well. All other monitoring wells are below the MCL (U.S. Army, July, 2016).

Fort Lewis Logistics Center NPL Site
Remediation Highlights

- **Contaminants:** Chlorinated VOCs including TCE and petroleum hydrocarbons; highest concentrations in groundwater included 250,000 ppb TCE
- **Media & Waste:** Groundwater, Soil, DNAPL
- **Plume:** TCE groundwater plume extended 2 to 2.5 miles long and 3,000 to 4,000 feet wide, with 60 to 100-foot contaminant thickness
- **Technologies:**
  - ERH
  - Pump-and-treat system with air stripping treatment
  - Drum waste removal
- **Major Successes:**
  - Over 125,000 pounds of chlorinated VOCs and petroleum contaminants removed by ERH in approximately three years
  - 12,787 pounds of VOCs (TCE and DCE) extracted by pump-and-treat beginning in 1995
  - Maximum groundwater TCE concentrations reduced from over 100,000 ppb to less than 300 ppb in the source area since 2005
  - Received 2005 Secretary of Defense Environmental Award for Environmental Restoration

Site History: The Logistics Center is a 650-acre area located within the Fort Lewis Army facility. The facility was built in the early 1940s, and is an industrial complex comprised of warehouses, motor pools, maintenance facilities, and an equipment disposal yard. A 1986 groundwater investigation by the Department of Defense (DoD) discovered TCE contamination, originating from the Logistics Center. The source of TCE contamination was from the disposal of cleaning and degreasing wastes at the 23-acre EGDY (also known as Landfill 2). The TCE contaminated the unconfined Vashon Aquifer and eventually migrated to the deeper Sea Level Aquifer (SLA). While the hydrostratigraphy at the site is extremely diverse and complex, the unconfined Vashon Aquifer generally consists of glacial sand and gravel deposits with till layers overlying a finer-grained nonglacial deposit (Kitsap Formation). The Kitsap Formation separates the unconfined Vashon Aquifer from the SLA. The water table is between 7 and 35 feet below ground surface (bgs) at the site (EPA, 1990).

The Logistics Center was listed on the NPL in 1989 and a Federal Facility Agreement (FFA) was signed in 1990 between EPA, the Army, and the State of Washington Department of Ecology. The Remedial Investigation (RI) and Feasibility Study (FS) were completed in 1988 and 1990, respectively, and a record of decision (ROD) was signed in 1990. Remedial activities began in the early 1990s and continue today. Due to additional groundwater contamination identified in the lower SLA, a 2007 explanation of significant differences (ESD) was developed, and in October 2009 the Army completed installation of an additional pump-and-treat system for the SLA. Pump-and-treat and long term monitoring continue as of late 2016. (EPA, 2016).

Extent of Contamination: The Logistics Center TCE groundwater plume within the Vashon Aquifer extends from southeast to northwest for about 2 miles, is between 3,000 to 4,000 feet wide, and has a contaminated thickness of 60 to 100 feet (EPA, 1990; U.S. Army, 2007). Partway down the plume, the Vashon Aquifer plume divides into an Upper Vashon Aquifer plume and a Lower Vashon Aquifer plume. About halfway down the Vashon Aquifer plume, TCE also migrated into the SLA via a hydrogeologic preferential pathway, which created a plume that extends for approximately 2.5 miles. The 23-acre EGDY source area historically contained TCE in groundwater at maximum concentrations exceeding 100,000 ppb (and as high as 250,000 ppb) prior to treatment. Three separate NAPL source areas covered approximately 2.2 acres at depths ranging from 28 to 47 feet bgs (USACE, 2002). The maximum initial and available groundwater contaminant concentrations as of 2015 are shown in Table 1.

Cleanup Approach: Remedial action at the Logistics Center NPL site started in 1992 with the construction of one pump-and-treat system at the EGDY and one down gradient pump-and-treat system (Interstate 5 system) near the leading edge of the plume to contain the Vashon Aquifer plume. As of 2011, the EGDY system has eight extraction wells and the Interstate 5 system has 15 extraction wells. The Interstate 5 system extracts water only from the Upper Vashon Aquifer, so the extent to which it helps contain the Lower Vashon Aquifer plume is unknown. The two pump-and-treat systems began operating in 1995 with a combined design flow rate of 2,400 gallons per minute (gpm). The systems use air stripping towers to remove VOCs, and treated groundwater is reinjected into the aquifer through infiltration galleries and injection wells. Between 2000 and 2001, the Army excavated and removed over 1,000 buried drums containing TCE wastes from the EDGY. Between 2003 and 2006, the EGDY pump-and-treat system was updated by decommissioning and replacing the original extraction wells and reconfiguring the extraction well and reinjection networks to optimize plume containment and contaminant mass removal. The Army also optimized the monitoring locations and sampling frequency as needed, including the use of passive diffusion bag samplers for the majority of monitoring locations (U.S. Army, 2007). Between 2003 and 2007, in situ thermal treatment was performed in three separate source areas at EGDY using ERH. During each ERH application an array of electrodes spaced about six meters apart heated the subsurface both above and below the water table. The ERH enhanced contaminant removal by volatilizing chemicals and decreasing fluid viscosity, which allowed for extraction of LNAPL/DNAPL. Three areas, totaling over 69,000 cubic yards of material, were treated up to 16 feet bgs, covering a total area of approximately 1.5 acres. Liquid and vapor recovered from the subsurface was separated by phase and treated with thermal oxidation. The ERH remediation system removed and treated an estimated 9,900 pounds of TCE, 2,000 pounds of *cis*-1,2-dichoroethene (*cis*-1,2-DCE), and 114,400 pounds of petroleum hydrocarbons (U.S. Army, 2007). Construction of the lower SLA pump-and-treat system began in 2007, was completed in 2009, and continues along with the EGDY and Interstate 5 pump-and-treat systems. The SLA pump-and-treat system is unique in that the discharge from the treatment tower is pumped to Madigan Army Medical Center, where the water is used for cooling in the heating and ventilating system. A number of land use controls (LUCs), including restricting the use of groundwater on-site and off-site, were also implemented as components of the remedy and remain in place. The pump-and-treat system continues to operate with quarterly long-term groundwater monitoring at the SLA system and semiannual long-term monitoring at the EGDY and Interstate 5 systems.

In situ thermal treatment of DNAPL using electrical resistive heating (ERH) at Fort Lewis Logistics Center NPL Site (Thermal Remediation Services, 2008)

Cleanup Success: Through targeted source area remedial actions (drum removal and in situ thermal treatment) combined with optimized pump-and-treat systems, the Fort Lewis Logistics Center NPL site has made significant progress towards meeting its cleanup levels. ERH treatment was successful at removing significant contaminant mass and LNAPL/DNAPL from the source zones. The optimized pump-and-treat systems have extracted and treated approximately 12,787 pounds of VOCs, and source area groundwater TCE concentrations have been reduced to less than 210 µg/L (ppb) from a maximum of 250,000 ppb prior to the remedy (Knadle, 2011). As a result of the successful remediation program, Fort Lewis received the fiscal year 2005 Secretary of Defense Environmental Award for Environmental Restoration.

Table 1. Groundwater TCE Concentration Reductions within ERH Treatment Areas

Cleanup Level	Pre-ERH Concentrations *		Post-ERH Concentration	
	Maximum	*Average*	*Maximum*	*Average*
TCE: 5 ppb	250,000 ppb	>1,000 ppb	210 ppb (2015**)	Not calculated, exceeded MCL in only one well

Sources: * U.S. Army, 2007; ** U.S. Army, 2016.

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