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September 1998

Remediation Case Studies:
Groundwater Pump and Treat (Nonchlorinated Contaminants)

Volume 10

Federal Remediation Technologies Roundtable
<www.frtr.gov>

Prepared by the

Member Agencies of the Federal Remediation Technologies Roundtable

Remediation Case Studies: Groundwater Pump and Treat (Nonchlorinated Contaminants)

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Federal Remediation Technologies Roundtable

Environmental Protection Agency
Department of Defense
- U.S. Air Force
- U.S. Army
- U.S. Navy

Department of Energy
Department of Interior
National Aeronautics and Space Administration
Tennessee Valley Authority
Coast Guard

September 1998

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FOREWORD

This report is a collection of fourteen case studies of groundwater pump and treat (nonchlorinated contaminants) projects prepared by federal agencies. The case studies, collected under the auspices of the Federal Remediation Technologies Roundtable, were undertaken to document the results and lessons learned from technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of cleanup technologies.

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

The case study reports and abstracts are organized by technology in a multi-volume set listed below. Remediation Case Studies, Volumes 1-6, and Abstracts, Volumes 1 and 2, were published previously, and contain 54 case studies. Remediation Case Studies, Volumes 7-13, and Abstracts, Volume 3, were published in September 1998. Volumes 7-13 cover a wide variety of technologies, including groundwater pump and treat of nonchlorinated contaminants (Volume 10). The 14 pump and treat case studies in this report include completed full-scale remediations and large-scale field demonstrations. In the future, the set will grow as agencies prepare additional case studies.

1995 Series

Volume 1: Bioremediation, EPA-542-R-95-002; March 1995; PB95-182911

Volume 2: Groundwater Treatment, EPA-542-R-95-003; March 1995; PB95-182929

Volume 3: Soil Vapor Extraction, EPA-542-R-95-004; March 1995; PB95-182937

Volume 4: Thermal Desorption, Soil Washing, and In Situ Vitrification, EPA-542-R-95-005; March 1995; PB95-182945

1997 Series

Volume 5: Bioremediation and Vitrification, EPA-542-R-97-008; July 1997; PB97-177554

Volume 6: Soil Vapor Extraction and Other In Situ Technologies, EPA-542-R-97-009; July 1997; PB97-177562

1998 Series

Volume 7: Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption), EPA-542-R-98-011; September 1998

Volume 8: In Situ Soil Treatment Technologies (Soil Vapor Extraction, Thermal Processes), EPA-542-R-98-012; September 1998

1998 Series (continued)

Volume 9:	Groundwater Pump and Treat (Chlorinated Solvents), EPA-542-R-98-013; September 1998
Volume 10:	Groundwater Pump and Treat (Nonchlorinated Contaminants), EPA-542-R-98-014; September 1998
Volume 11:	Innovative Groundwater Treatment Technologies, EPA-542-R-98-015; September 1998
Volume 12:	On-Site Incineration, EPA-542-R-98-016; September 1998
Volume 13:	Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies, EPA-542-R-98-017; September 1998

Abstracts

Volume 1:	EPA-542-R-95-001; March 1995; PB95-201711
Volume 2:	EPA-542-R-97-010; July 1997; PB97-177570
Volume 3:	EPA-542-R-98-010; September 1998

Accessing Case Studies

The case studies and case study abstracts are available on the Internet through the Federal Remediation Technologies Roundtable web site at: http://www.frtr.gov. The Roundtable web site provides links to individual agency web sites, and includes a search function. The search function allows users to complete a key word (pick list) search of all the case studies on the web site, and includes pick lists for media treated, contaminant types, and primary and supplemental technology types. The search function provides users with basic information about the case studies, and allows them to view or download abstracts and case studies that meet their requirements.

Users are encouraged to download abstracts and case studies from the Roundtable web site. Some of the case studies are also available on individual agency web sites, such as for the Department of Energy.

In addition, a limited number of hard copies are available free of charge by mail from NCEPI (allow 4-6 weeks for delivery), at the following address:

U.S. EPA/National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242
Phone: (513) 489-8190 or
(800) 490-9198
Fax: (513) 489-8695

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INTRODUCTION

Increasing the cost effectiveness of site remediation is a national priority. The selection and use of more cost-effective remedies requires better access to data on the performance and cost of technologies used in the field. To make data more widely available, member agencies of the Federal Remediation Technologies Roundtable (Roundtable) are working jointly to publish case studies of full-scale remediation and demonstration projects. Previously, the Roundtable published a six-volume series of case study reports. At this time, the Roundtable is publishing seven additional volumes of case study reports, primarily focused on soil and groundwater cleanup.

The case studies were developed by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). The case studies were prepared based on recommended terminology and procedures agreed to by the agencies. These procedures are summarized in the Guide to Documenting and Managing Cost and Performance Information for Remediation Projects (EPA 542-B-98-007; October 1998). (The October 1998 guide supersedes the original Guide to Documenting Cost and Performance for Remediation Projects, published in March 1995.)

The case studies present available cost and performance information for full-scale remediation efforts and several large-scale demonstration projects. They are meant to serve as primary reference sources, and contain information on site background and setting, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The studies contain varying levels of detail, reflecting the differences in the availability of data and information. Because full-scale cleanup efforts are not conducted primarily for the purpose of technology evaluation, data on technology cost and performance may be limited.

The case studies in this volume describe 14 pump and treat applications used to remediate contaminated groundwater, including 11 applications used to remediate contaminated groundwater, one application used only to contain groundwater, and two applications used to recover free product. For these applications, groundwater was contaminated with a variety of contaminants including chlorinated solvents, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), pesticides/herbicides, and heavy metals (e.g., chromium). The quantity of groundwater treated in these applications ranged from 23 to 1,200 million gallons, and project durations ranged from two to 13 years. Many of these applications are ongoing, and the case studies are interim reports about these applications.

Table 1 provides a summary including information on technology used, contaminants and media treated, and project duration for the 14 pump and treat projects in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information on quantity of media treated and quantity of contaminant removed. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting technology cost. (The column showing the calculated unit costs for treatment provides a dollar value per quantity of groundwater treated and contaminant removed, as appropriate.) Cost data are shown as reported in the case studies and have not been adjusted for inflation to a common year basis. The costs should be assumed to be dollars for the time period that the project was in progress (shown on Table 1 as project duration).

While a summary of project costs is useful, it may be difficult to compare costs for different projects because of unique site-specific factors. However, by including a recommended reporting format, the Roundtable is working to standardize the reporting of costs to make data comparable across projects. In addition, the Roundtable is working to capture information in case study reports that identify and describe the primary factors that affect cost and performance of a given technology. Key factors that potentially affect project costs for pump and treat applications include economies of scale, concentration levels in contaminated media, required cleanup levels, completion schedules, matrix characteristics such as soil classification, clay content and/or particle size distribution, hydraulic conductivity, pH, depth and thickness of zone of interest, total organic carbon, oil and grease or total petroleum hydrocarbons, presence of NAPLs, and other site conditions.

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Nonchlorinated Contaminants)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Baird and McGuire Superfund Site, MA (Pump and Treat with Aeration, Air Stripping, Chemical Treatment, Clarification, and Filtration)		◐	◐	◐		◐	Groundwater (80 million gallons)	Status: Ongoing Report Covers: 4/93 - 2/97	Groundwater contaminated with a wide variety of contaminants; relatively expensive remediation, with high capital costs for treatment system
Bofors Nobel Superfund Site - OU 1, MI (Pump and-Treat with Air Stripping, Carbon Adsorption, Chemical Treatment, Filtration, and UV/Oxidation)	●						Groundwater (700 million gallons)	Status: Ongoing Report Covers: 9/94 - 10/97	The extraction system has contained the contaminant plume; the treatment system has consistently met discharge requirements since system startup in 1994
City Industries Superfund Site, FL (Pump and Treat with Air Stripping)	●	●					Groundwater (151.7 million gallons)	Status: Ongoing Report Covers: 5/94 - 5/97	The hydrogeology at this site is relatively simple and hydraulic conductivity relatively high
King of Prussia Technical Corporation Superfund Site, NJ (Pump and Treat with Air Stripping, Carbon Adsorption, and Electrochemical Treatment)	●	●				●	Groundwater (151.5 million gallons)	Status: Ongoing Report Covers: 4/95 - 12/97	Treatment system consists of a treatment train designed for removal of metals and organics
LaSalle Electrical Superfund Site, IL (Pump and Treat with Air Stripping, Carbon Adsorption, and Oil/Water Separation)	●						Groundwater (23 million gallons)	Status: Ongoing Report Covers: 12/92 - 5/97	System consists of collection trenches instead of extraction wells; relatively low groundwater flow; contaminants include PCBs and chlorinated solvents

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Nonchlorinated Contaminants) (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Mid-South Wood Products Superfund Site, AR (Pump and Treat with Carbon Adsorption, Filtration, and Oil/Water Separation)			●			●	Groundwater (100.6 million gallons)	Status: Ongoing Report Covers: 9/89 - 12/97	Groundwater contaminated with wood treating chemicals; system optimization performed after eight years of operation; groundwater contamination had been reduced to one localized area of concern
Odessa Chromium I Superfund Site, OU 2, TX (Pump and Treat with Chemical Treatment, Flocculation, Multimedia Filtration, pH Adjustment, and Precipitation)						●	Groundwater (125 million gallons)	Status: Ongoing Report Covers: 11/93 - 1/98	Includes on-site treatment for chromium; relatively low groundwater flow; contamination in one aquifer
Odessa Chromium IIS Superfund Site, OU 2, TX (Pump and Treat with Chemical Treatment, Flocculation, Multimedia and Cartridge Filtration, pH Adjustment, and Precipitation)						●	Groundwater (121 million gallons)	Status: Ongoing Report Covers: 11/93 - 12/97	Includes on-site treatment for chromium; relatively low groundwater flow; contamination in two aquifers
Pope AFB, Site FT-01, NC (Free Product Recovery)		●					Groundwater and Free Product	Status: Ongoing Report Covers: 11/93 - 11/96	Recovery of free product from groundwater
Pope AFB, Site SS-07, Blue Ramp Spill Site, NC (Free Product Recovery)		●					Groundwater	Status: Ongoing Report Covers: 11/93 - 11/96	Recovery of free product using active pumping

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Nonchlorinated Contaminants) (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Sylvester/Gilson Road Superfund Site, NH (Pump and Treat with Air Stripping, Biological Treatment, Chemical Treatment, Clarification, Flocculation, and Mixed-media Pressure Filtration; Cap; Soil Vapor Extraction; Vertical Barrier Wall)	●					●	Groundwater (1,200 million gallons)	Status: Ongoing Report Covers: 1982 - 12/95	A combination of technologies was used to remediate the site; cleanup goals were met for all contaminants with one exception (1,1-DCA) which was reported as below the detection limit
United Chrome Superfund Site, OR (Pump and Treat with Reduction and Precipitation)						●	Groundwater (62 million gallons)	Status: Ongoing Report Covers: 8/88 - 3/97	Extracted groundwater was treated on-site at the beginning of this application; however, because concentrations dropped over time, on-site treatment was discontinued
U.S. Aviex Superfund Site, MI (Pump and Treat with Air Stripping)	●						Groundwater (329 million gallons)	Status: Ongoing Report Covers: 7/93 - 12/96	Performed modeling for system optimization (MODFLOW and Randomwalk); contaminants included diethyl ether and chlorinated solvents
Western Processing Superfund Site, WA (Pump and Treat with Air Stripping and Filtration; Vertical Barrier Wall)	●		●			●	Groundwater (974 million gallons)	Status: Ongoing Report Covers: 10/88 - 12/96	Met goals for off-site plume within eight years of operation; shallow well points recently replaced with deeper wells to provide containment

* Principal contaminants are one or more specific constituents within the groups shown that were identified during site investigations.

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Baird and McGuire Superfund Site, MA (Pump and Treat with Aeration, Air Stripping, Chemical Treatment, Clarification, and Filtration)	Total: $22,726,000 C: $14,958,000 O: $7,768,000	80 million gallons	2,100 lbs	$284/1,000 gals GW $10,822/lb of cont.	Operating costs are high because of relatively high analytical costs for large number of contaminants
Bofors Nobel Superfund Site - OU 1, MI (Pump and Treat with Air Stripping, Carbon Adsorption, Chemical Treatment, Filtration, and UV/Oxidation)	Total: $13,726,000 C: $12,200,000 O: $763,000	700 million gallons	7,500 lbs	$19.61/1,000 gals GW $1,830/lb of cont.	There is a continuing source of contamination at this site; remediation focused on containing the plume
City Industries Superfund Site, FL (Pump and Treat with Air Stripping)	Total: $1,674,800 C: $1,094,800 O: $580,000	151.7 million gallons	2,700 lbs	$10.60/1,000 gals GW $590/lb of cont.	Biological growth in wells, equalization, and air stripping tower degraded system performance; in addition, optimization was performed to optimize pumping rates
King of Prussia Technical Corporation Superfund Site, NJ (Pump and Treat with Air Stripping, Carbon Adsorption, and Electrochemical Treatment)	Total: $2,816,000 C: $2,031,000 O: $785,000	151.5 million gallons	5,420 lbs	$19/1,000 gals GW $520/lb of cont.	Use of an on-site electrochemical treatment system to remove metals from groundwater increased cost
LaSalle Electrical Superfund Site, IL (Pump and Treat with Air Stripping, Carbon Adsorption, and Oil/Water Separation)	Total: $6,138,576 C: $5,314,576 O: $824,000	23 million gallons	127 lbs	$266/1,000 gals GW $48,000/lb of cont.	Contamination initially thought to be PCBs, later found to include chlorinated solvents; DNAPLs present at site
Mid-South Wood Products Superfund Site, AR (Pump and Treat with Carbon Adsorption, Filtration, and Oil/Water Separation)	Total: $1,212,600 C: $465,300 O: $747,300	100.6 million gallons	800 lbs	$13/1,000 gals GW $1,500/lb of cont.	Initial use of french drains to improve groundwater yield from fractured bedrock proved to be less effective than use of drilled extraction wells
Odessa Chromium I Superfund Site, OU 2, TX (Pump and Treat with Chemical Treatment, Flocculation, Multimedia Filtration, pH Adjustment, and Precipitation)	Total: $2,742,000 C: $1,954,000 O: $728,000	125 million gallons	1,143 lbs	$30/1,000 gals GW $2,400/lb of cont.	The ROD requirement that ferrous iron be produced on-site electrochemically limited the number of system vendors to two, increasing the cost of treatment

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

Site Name, State (Technology)	Technology Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Odessa Chromium IIS Superfund Site, OU 2, TX (Pump and Treat with Chemical Treatment, Flocculation, Multimedia and Cartridge Filtration, pH Adjustment, and Precipitation)	Total: $2,487,700 C: $1,927,500 O: $560,200	121 million gallons	131 lbs	$26/1,000 gals GW $19,000/lb of cont.	There were several startup problems including clogging of injection wells and encrusting of polishing filters; requirement to produce ferrous iron on site increased the cost of treatment
Pope AFB, Site FT-01, NC (Free Product Recovery)	Total: $355,600 C: $289,000 O: $66,600	Not provided	5,163 gals	O (average): $12.90/gal of free product	Containment system was operating efficiently and was meeting its operational objectives
Pope AFB, Site SS-07, Blue Ramp Spill Site, NC (Free Product Recovery)	Total: $490,200 C: $394,000 O: $96,200	Not provided	3,516 gals	O (average): $27.36/gal of free product	Containment system was operating efficiently and was meeting its operational objectives
Sylvester/Gilson Road Superfund Site, NH (Pump and Treat with Air Stripping, Biological Treatment, Chemical Treatment, Clarification, Flocculation, and Mixed-media Pressure Filtration; Cap; Soil Vapor Extraction; Vertical Barrier Wall)	Total: $27,600,000 C: $9,100,000 O: $18,500,000	1,200 million gallons	427,000 lbs	$23/1,000 gals GW $64/lb of cont.	An ESD required modifications to the system (adding extraction wells and SVE for toluene source control) resulted in a 15% increase in capital costs
United Chrome Superfund Site, OR (Pump and Treat with Reduction & Precipitation)	Total: $4,637,160 C: $3,329,840 O: $1,307,320	62 million gallons	31,459 lbs	$75/1,000 gals GW $140/lb of cont.	Initially used a modular treatment system rather than a more expensive permanent system; later able to discontinue use of treatment, reduced operational costs by an order of magnitude
U.S. Aviex Superfund Site, MI (Pump and Treat with Air Stripping)	Total: $1,942,000 C: $1,332,000 O: $610,000	329 million gallons	664 lbs	$5/1,000 gals GW $2,925/lb of cont.	Operation of an interim pump and treat system prior to final remediation system reduced total costs

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

Site Name, State (Technology)	Technology Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Western Processing Superfund Site, WA (Pump and Treat with Air Stripping, and Filtration; Vertical Barrier Wall)	Total: $48,730,112 C: $16,032,629 O: $32,697,483	974 million gallons	102,000 lbs	$50/1,000 gals GW $478/lb of cont.	Initial goal required use of costly pump and treat system; revised goal of containment is being achieved through use of a slurry wall

Technology Cost*
C = Capital costs
O = Operation and maintenance (O&M) costs

Calculated Cost for Treatment**
Calculated based on sum of capital and O&M costs, divided by quantity treated or removed. Calculated costs shown as "Not Calculated" if an estimate of costs or quantity treated or removed was not available. Unit costs calculated based on both quantity of media treated and quantity of contaminant removed, as appropriate.

*** For full-scale remediation projects, this identifies factors affecting actual technology costs. For demonstration-scale projects, this identifies generic factors which would affect costs for a future application using this technology.

Groundwater Pump and Treat (Nonchlorinated Solvents)

Case Studies

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Pump and Treat of Contaminated Groundwater at the Baird and McGuire Superfund Site, Holbrook, Massachusetts

Pump and Treat of Contaminated Groundwater at the Baird and McGuire Superfund Site, Holbrook, Massachusetts

<table>
<tr><td>Site Name:
Baird and McGuire Superfund site</td><td rowspan="2">Contaminants:
Volatiles - nonhalogenated (BTEX); semivolatiles - nonhalogenated; polycyclic aromatic hydrocarbons (PAHs, acenaphthene, naphthalene, 2,4-dimethylphenol); organic pesticides/herbicides (dieldrin, chlordane); heavy metals (lead); and nonmetallic elements (arsenic)
- Maximum initial concentrations measured at the site were VOCs (>1,000 ug/L), SVOCs (>10,000 ug/L); concentrations of specific contaminants not provided</td><td>Period of Operation:
Status: Ongoing
Report covers: 4/93 - 2/97</td></tr>
<tr><td>Location:
Holbrook, Massachusetts</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Metcalf & Eddy Services
Walsh Contracting
Barletta Engineering

Treatment System Operator:
Tim Beauchemin
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751
(978) 318-8616</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 6 wells, located on site, at an average total pumping rate of 60 gpm
- Extracted groundwater is treated with chemical treatment (addition of ferric chloride, lime slurry, phosphoric and sulfuric acids, and ammonium sulfate), clarification, aeration, filtration, and carbon adsorption
- Treated groundwater is reinjected through infiltration basins</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/30/86</td></tr>
<tr><td>State Point of Contact:
Harish Panchol
Massachusetts DEQE
(617) 292-5716</td><td>EPA Point of Contact:
Chet Janowski, RPM
U.S. EPA Region 1
John F. Kennedy Federal Building
One Congress Street
Boston, MA 02203
(617) 573-9623</td></tr>
<tr><td>Waste Source:
Surface impoundment/lagoon, hazardous materials storage, discharge to septic system, discharge to wetlands</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 80 million gallons treated as of February 1997
- LNAPL observed in several monitoring wells on site
- Groundwater is found at 10-15 ft bgs
- Extraction wells are located in 3 aquifers, which are influenced by a nearby surface water
- Hydraulic conductivity ranges from 0.5 to 45 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Groundwater contaminated with a wide variety of contaminants; relatively expensive remediation, with high capital costs for treatment system.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Baird and McGuire Superfund Site, Holbrook, Massachusetts (continued)

Regulatory Requirements/Cleanup Goals:

- Cleanup goals were established to be maximum contaminant levels (MCLs) as defined by the primary drinking water standards and the state of Massachusetts drinking waster quality criteria. Cleanup goals were established for benzene (5 ug/L), toluene (2,000 ug/L), ethylbenzene (680 ug/L), xylene (440 ug/L), 2,4-dimethyl phenol (2.12 ug/L), naphthalene (0.62 ug/L), acenaphthene (0.52 ug/L), dieldrin (0.000071 ug/L), chlordane (0.00046 ug/L), arsenic (0.05 ug/L), and lead (0.05 ug/L).
- Additional goals were to remediate the contaminated aquifer within a reasonable time to prevent present or future impacts to groundwater drinking water supplies, and to protect the Cochato River from future contaminant migration by establishing hydraulic containment of the plume.

Results:

- During the first two years of operation, the pump and treat system reduced average VOC and SVOC concentrations. From 1994 to 1995, average VOC concentrations decreased by 16% and average SVOC concentrations by 48%. However, contaminant concentrations in some individual wells did not decline over this period and concentrations have not been reduced to below treatment goals. As of December 1995, 2,100 pounds of organic contaminants have been removed from the groundwater.
- Contaminants have been detected in down-gradient monitoring wells and plume containment has not been achieved. A 1995 study made recommendations for achieving plume containment.

Cost:

- Actual costs for pump and treat were $22,726,000 ($14,958,000 in capital and $7,768,000 in O&M), which correspond to $284 per 1,000 gallons of groundwater extracted and $10,822 per pound of contaminant removed.
- Operating costs are relatively high because of the need to analyze for a large number of contaminants and the need for an operator to be on-site 24 hours per day.

Description:

Baird and McGuire Inc. conducted chemical mixing operations at this site from 1912 to 1983. Contamination of an on-site public drinking water well was first detected in 1982 by the town of Holbrook. Also in 1982, a citizen complaint of an oily substance in the Conchato River, which runs along the eastern boundary of the site led to an inspection by DEQE. This inspection revealed that a tank farm was not lined or diked, sewage waste, process waste, and surface water runoff were collected in an open cesspool; and a black oily substance was being discharged to on-site wetlands. During emergency removal actions by EPA in 1983 and 1985, a plume of VOCs and SVOCs was identified in the groundwater beneath the site. The site was added to the NPL in October 1982 and a ROD was signed in September 1986.

The groundwater extraction system consists of six wells placed in the part of the plume where the highest levels of contamination were detected. Groundwater treatment includes equalization and removal of free floating product, chemical treatment (with ferric chloride and lime in one stage, and phosphoric and sulfuric acids and ammonium sulfate in a second stage), flocculation/clarification, aeration, pressure filtration, and carbon adsorption, prior to discharge to infiltration basins. Above-ground biological treatment (using activated sludge) was included in the original design for this site, but was found to be not necessary, and deleted from the treatment system. After three years of operation, the system has not met the cleanup goals established for this site. In addition, the report discusses the impacts of having concurrent groundwater and soil remediation activities at this site.

SITE INFORMATION

Identifying Information

Baird and McGuire Superfund Site
Holbrook, Massachusetts

CERCLIS #: MAD001041987

ROD Date: September 30, 1986

Treatment Application

Type of action: Remedial

Period of operation: 1993 - Ongoing
(Data collected through February 1997)

Quantity of material treated during application: 80 million gallons of groundwater [9]

Background [5,6,7]

Historical Activity that Generated Contamination at the Site: Chemical mixing and batching operations

Corresponding SIC Code: 2841 (Soap and other detergents), 2879 (Pesticides and agricultural products), 2491 (Wood preserving)

Waste Management Practice That Contributed to Contamination: Surface impoundment/lagoon, hazardous materials storage, discharge to septic system, discharge to wetlands

Location: Holbrook, Massachusetts

Facility Operations:

- Baird and McGuire Inc. (BMI) conducted chemical mixing operations at this site from 1912 to 1983.
- Contamination of an on-site public drinking water well was first detected in 1982 by the Town of Holbrook. This well had to be abandoned after contamination was detected. In 1982, a citizen complaint of an oily substance in the Cochato River, which runs along the eastern property boundary, led to a DEQE inspection. This inspection revealed the following: the tank farm was not lined or diked; sewage waste, process waste, and surface water runoff were collected in an open cesspool; and a black oily substance was being discharged to on-site wetlands.
- On May 2, 1983, BMI's permit to store chemicals at the site was revoked by the Town of Holbrook. As a result, BMI was forced to cease operations.
- EPA-initiated two emergency removal actions in 1983 and 1985. During these emergency removals, a plume of volatile organic and base neutral/acid extractable compounds was identified in the groundwater beneath the site.
- BMI voluntarily implemented a series of remedial actions. These included: installing a catch basin near the tank farm; filling the cesspool with concrete; installing booms on the Cochato River; removing the wetlands discharge pipe; and constructing a clay dike around the creosote lagoon to prevent a release.
- The site was listed on the National Priorities List (NPL) in October 1982.
- An RI was conducted in 1984 and 1985. Contaminants identified in the groundwater included PAHs, halogenated and nonhalogenated organics, inorganics, and pesticides.
- Source removal actions at the site included excavation and on-site incineration of contaminated soils. These removal actions took place in 1983, 1985, and 1995 through 1997.

SITE INFORMATION (CONT.)

Background (Cont.)

Regulatory Context:

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 §121, and the National Contingency Plan (NCP), 40 CFR 300.
- A Record of Decision (ROD) was issued in September 1986.

Groundwater Remedy Selection:
The groundwater remedy initially selected for this site consisted of extraction and treatment through biological activated sludge. The treatment system has been modified, and the activated sludge tanks are currently used as air stripping units.

Site Logistics/Contacts

Site Lead: EPA

Remedial Project Manager:
Chet Janowski*
U.S. EPA Region I
John F. Kennedy Federal Building
One Congress Street
Boston, Massachusetts 02203
617-573-9623

State Contact:
Harish Panchol
Massachusetts DEQE
617-292-5716

Treatment System Vendor:
Metcalf & Eddy Services
Walsh Contracting
Barletta Engineering

Treatment System Operator:
Tim Beauchemin
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751
(978) 318-8616

*Indicates primary contact.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [5,6,7]

Primary Contaminant Groups: Halogenated and nonhalogenated volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), inorganics, and pesticides.

- Selected index contaminants at the BMI site include: arsenic, lead, BTEX, trans-1,2-dichloroethylene (trans-1,2-DCE), 4-methyl phenol, 2,4-dimethyl phenol, naphthalene, 2-methyl naphthalene, acenapthene, dibenzofuran, fluorene, phenanthrene, dieldrin, and chlordane. Attachment 1 provides a complete list of contaminants detected at the site. Maximum concentrations for individual contaminants are not provided in available documentation.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- Concentrations of contaminants at the site were greater than 10,000 µg/L for total SVOCs and greater than 1,000 µg/L for total VOCs.
- Figures 1 and 2 illustrate the contaminant contours detected in 1988 and 1995, respectively, for total VOCs.
- The areal extent of the initial plume was estimated to be more than 700,000 square feet and approximately 70 feet thick. Based on a standard porosity of 30%, the plume volume was estimated at 111 million gallons.
- A light nonaqueous phase liquid (LNAPL) has been observed in several on-site monitoring wells. The material was identified as an immiscible oily substance that floats on the water table in the 1985 RI.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [6,7]:

Four distinct hydrogeologic units have been identified beneath this site. They are:

Unit 1A	Stratified material consisting of silty sands, sand, and silt.
Unit 1B	Stratified material consisting of fine to medium, fine to course sand.
Unit 2	Unstratified glacial till.
Unit 3	Fractured bedrock.

Figure 3 shows an east-west cross-section through the site that depicts the hydrogeology of the site. The upper stratified units (Unit 1A and 1B) pinch out on the west side of the site. A bowl-shaped depression is formed by bedrock beneath the site. Shallow groundwater is found at 10 to 15 feet below ground surface. Groundwater discharges to the Cochato River along the eastern site boundary.

The toe of the plume has migrated beyond the river. However, it reached a stagnation point in 1988. Figure 4 shows the same east-west cross-section and depicts the vertical plume distribution as detected in 1985. Measured flow velocities indicate that groundwater in Units 1 and 2 can move between 50 and 500 feet per year.

MATRIX DESCRIPTION (CONT.)

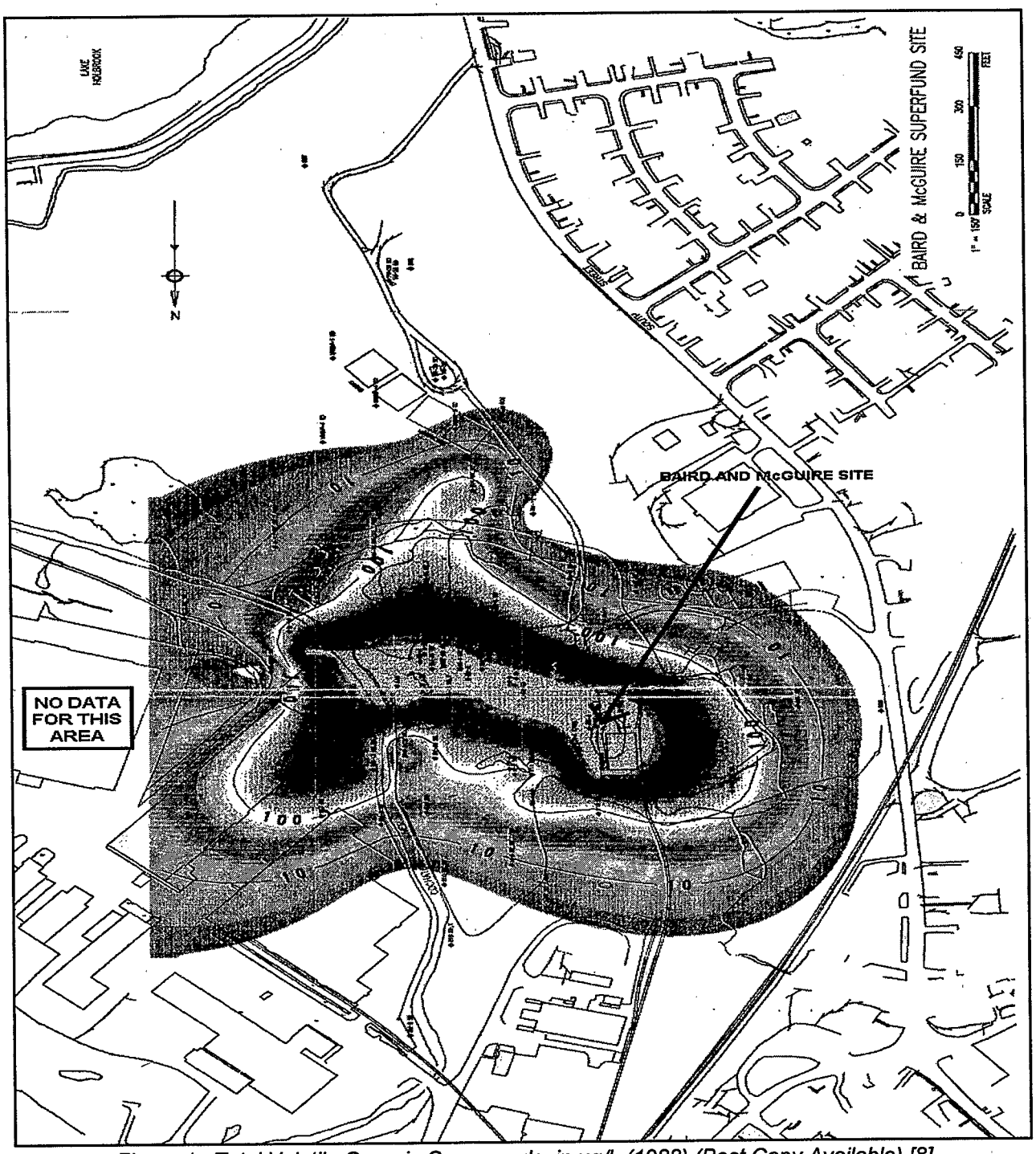

Figure 1. Total Volatile Organic Compounds, in µg/L (1988) (Best Copy Available) [8]

MATRIX DESCRIPTION (CONT.)

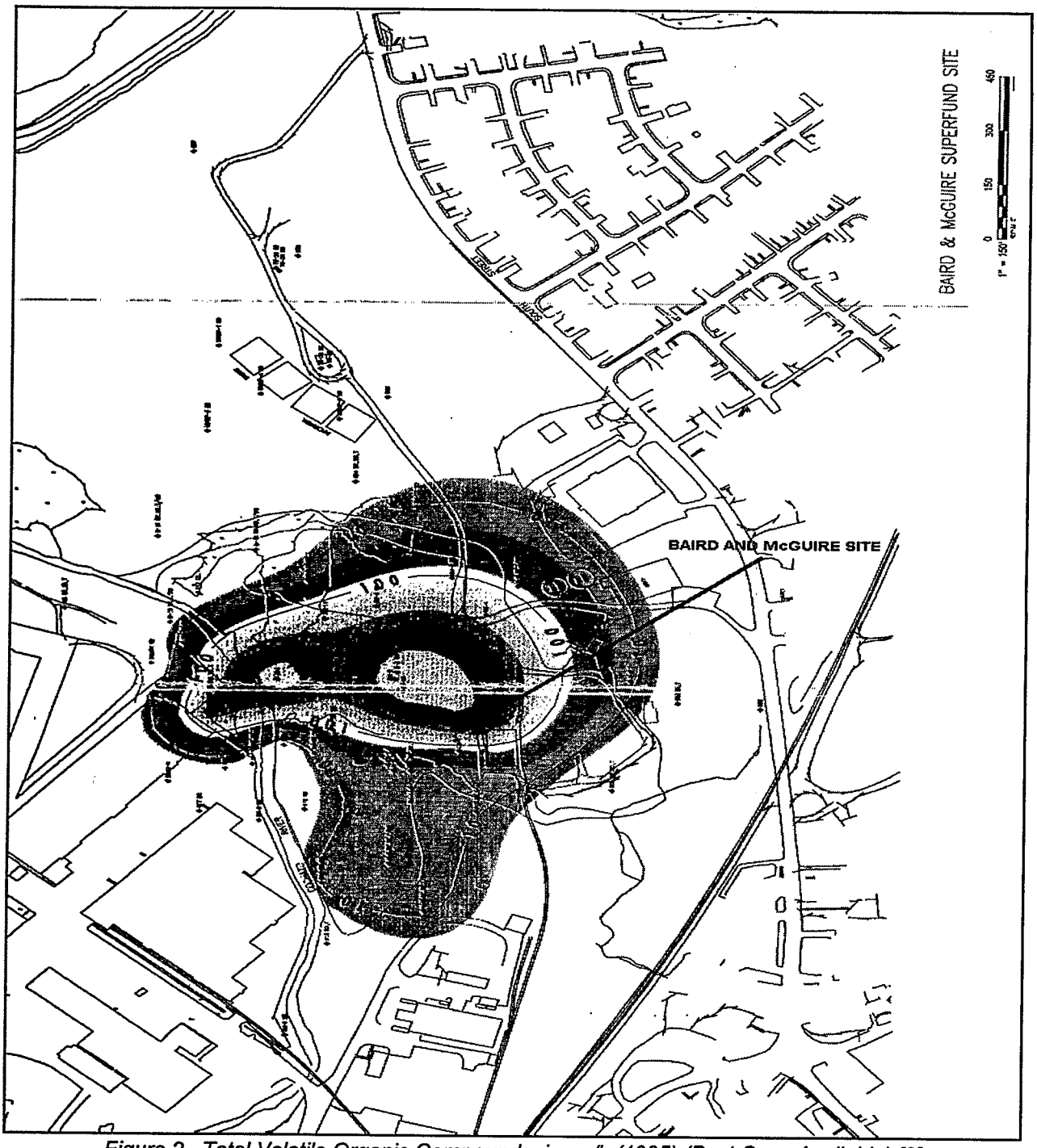

Figure 2. Total Volatile Organic Compounds, in µg/L (1995) (Best Copy Available) [8]

MATRIX DESCRIPTION (CONT.)

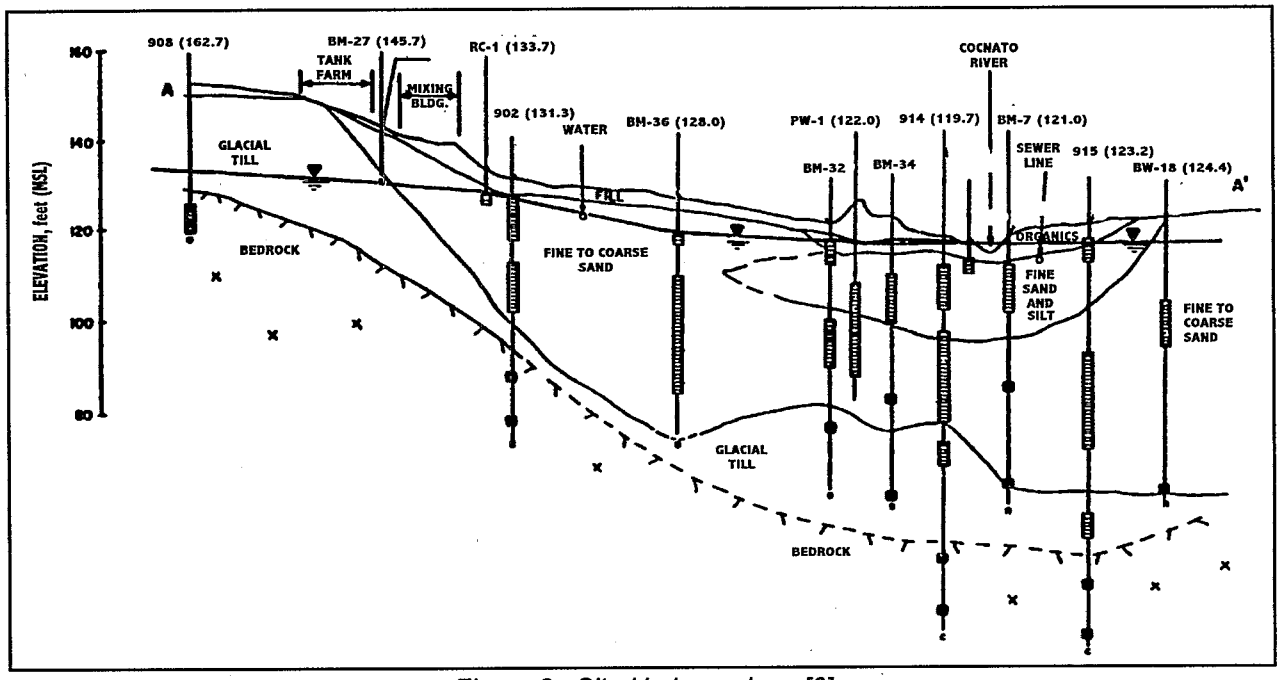

Figure 3. Site Hydrogeology [6]

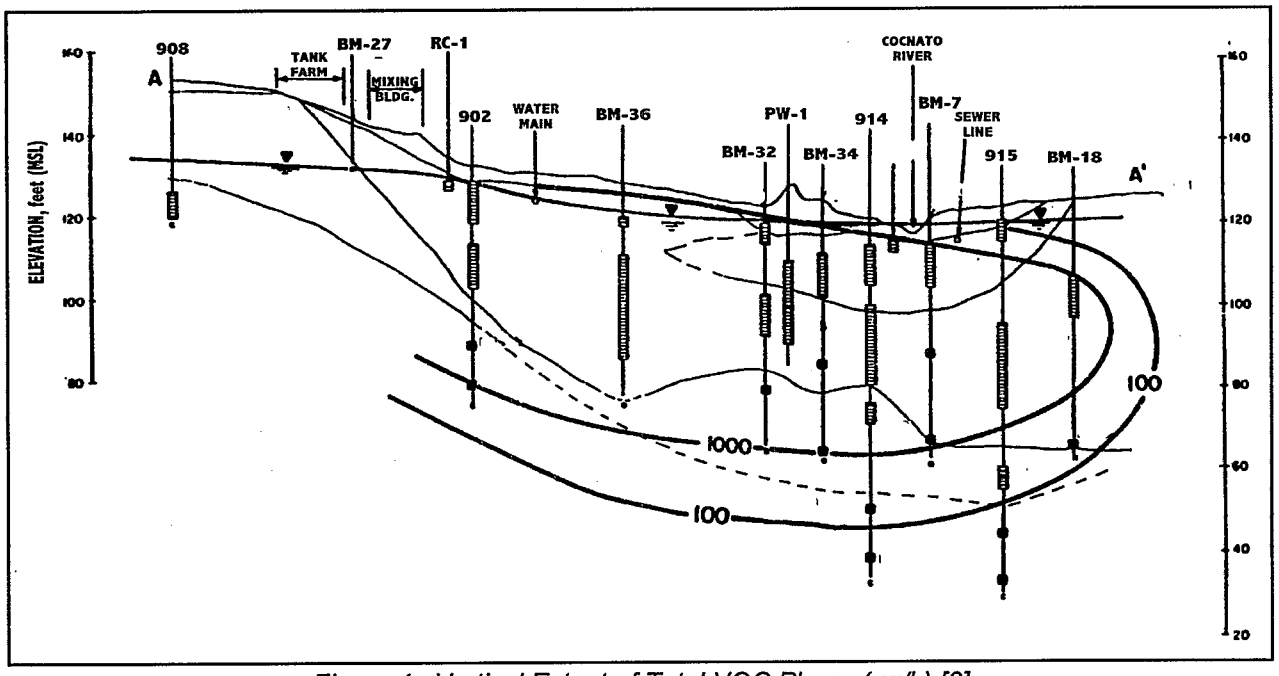

Figure 4. Vertical Extent of Total VOC Plume (µg/L) [6]

MATRIX DESCRIPTION (CONT.)

Tables 1 and 2 include technical aquifer information and technical well data. A discussion of extraction wells is included in the following section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Unit 1A	10 - 20	3	NA	East[1]
Unit 1B	25 - 50	45	0.3 - 0.7	East[1]
Unit 2	10 - 20	10	0.1 - 1.25	East[1]
Unit 3	>50	0.5	0.3 - 3	East[1]

Source: [6,7]
NA - Not characterized
[1]West side of Cochato River only; flow direction may vary on the east side of the Cochato River.

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping and hydroxide precipitation/ferric chloride treatment [3].

Supplemental Treatment Technology

Filtration, carbon adsorption, sludge dewatering [3].

System Description and Operation

Table 2. Technical Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/day)
EW-1	Units 2 and 3	64	28,800
EW-2	Unit 1B	30	43,200
EW-3	Unit 1B	38	43,200
EW-4	Units 2 and 3	84	43,200
EW-5	Unit 1B	32	28,800
EW-6	Unit 1B	30	28,800

Note: Represents initial design conditions. Average system extraction rate is 60 gpm based on the actual volume of water pumped since operations began and a 93% operation rate from April 1993 to December 1995.

Source: [3]

System Description [3,8,9]

- To accommodate soil remediation activities scheduled for 1995, the original groundwater extraction system, installed between 1990 and 1992, was constructed with temporary piping placed in contaminated soils. As discussed earlier, contaminated soils were excavated and incinerated under a separate remedial action. The temporary piping and wells had to be removed when the excavation of contaminated soils began in 1995. The following section describes the system as originally installed and operated through February 1997; however, modifications were made after soil remediation was complete in 1997.
- The extraction system consisted of six wells and associated piping. Four wells were

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

completed in the stratified material (Units 1A and 1B) and two were screened in both the till (Unit 2) and bedrock (Unit 3). The wells were placed in the part of the plume where the highest levels of contaminants were detected. The extraction system design was intended to restore the aquifer and contain the contaminant plume.

- Figure 5 shows a groundwater treatment plant flow diagram. An 8,000-gallon equalization tank is used as the first element of the treatment train to allow for constant flow rate and to remove free floating product. Two stages of hydroxide precipitation are used in the treatment system to allow for maximum metals removal efficiency at different pH levels.

- The original remedial design for the treatment system specified biological treatment of organic contaminants via an activated sludge process. However, because no biological mass existed, the biological treatment process did not achieve effluent limits. Historical analytical data indicate that sufficient organic removal rates are attained without the use of biological treatment [12].

- The activated sludge tanks are currently being used as modified air strippers. Following the air stripping step, rapid sand filtration is used to remove any suspended solids. Filtration is followed by two stages of activated carbon adsorption as a final polishing step.

- Effluent from the treatment system is re-injected into the aquifer through four gravel bed infiltration basins located upgradient of the plume.

- Off-gas generated from each of the unit operations is collected and vented to an on-site fume incinerator (separate from the soil incinerator), which destroys organics by thermal oxidation at a temperature of 1,800°F. The fume incinerator is soon to be replaced by vapor phase carbon.

- Solid waste including precipitate and activated carbon from the treatment system is disposed of off site.

- A total of 49 monitoring wells were installed in units 1B, 2, and 3 to evaluate contaminant concentration levels from 1993 to 1995. During soil excavation activities from 1995 to 1997, nearly half of the monitoring wells were damaged and not usable. The monitoring wells were replaced in 1997.

System Operation [8,9,10]

- From April 1993 to June 1995, the extraction system was operated using all six wells. After soil excavation began in June 1995, only one well, on average, was operating. Extraction wells were taken off line to allow for excavation activities, and because of poor well yield. There was no change to the treatment system until early 1997 when several upgrades were completed. Since startup, the treatment system has operated at an average extraction rate of 60 gpm, and has been unable to operate at its design rate of 150 to 200 gpm because of several problems, including undersized pumps and sludge thickener loading rates. Pumps were replaced and a larger sludge thickener installed in early 1997. These changes have enabled the treatment system to operate at its design rate since then.

- According to site engineers, at the time excavation and incineration activities began, the groundwater extraction system had not provided the required extraction rate to achieve hydraulic containment of the plume. In 1995, new well locations and screen intervals were chosen to increase the extraction rate. Other activities that were planned included replacing three of the extraction wells, installing two additional extraction wells, and retrofitting two existing extraction wells with collection equipment to enhance LNAPL removal. A groundwater model was used to optimize the extraction system. Extraction system upgrades should be completed in late 1997 when the P&T system is scheduled to resume full-scale operation.

TREATMENT SYSTEM DESCRIPTION (CONT.)

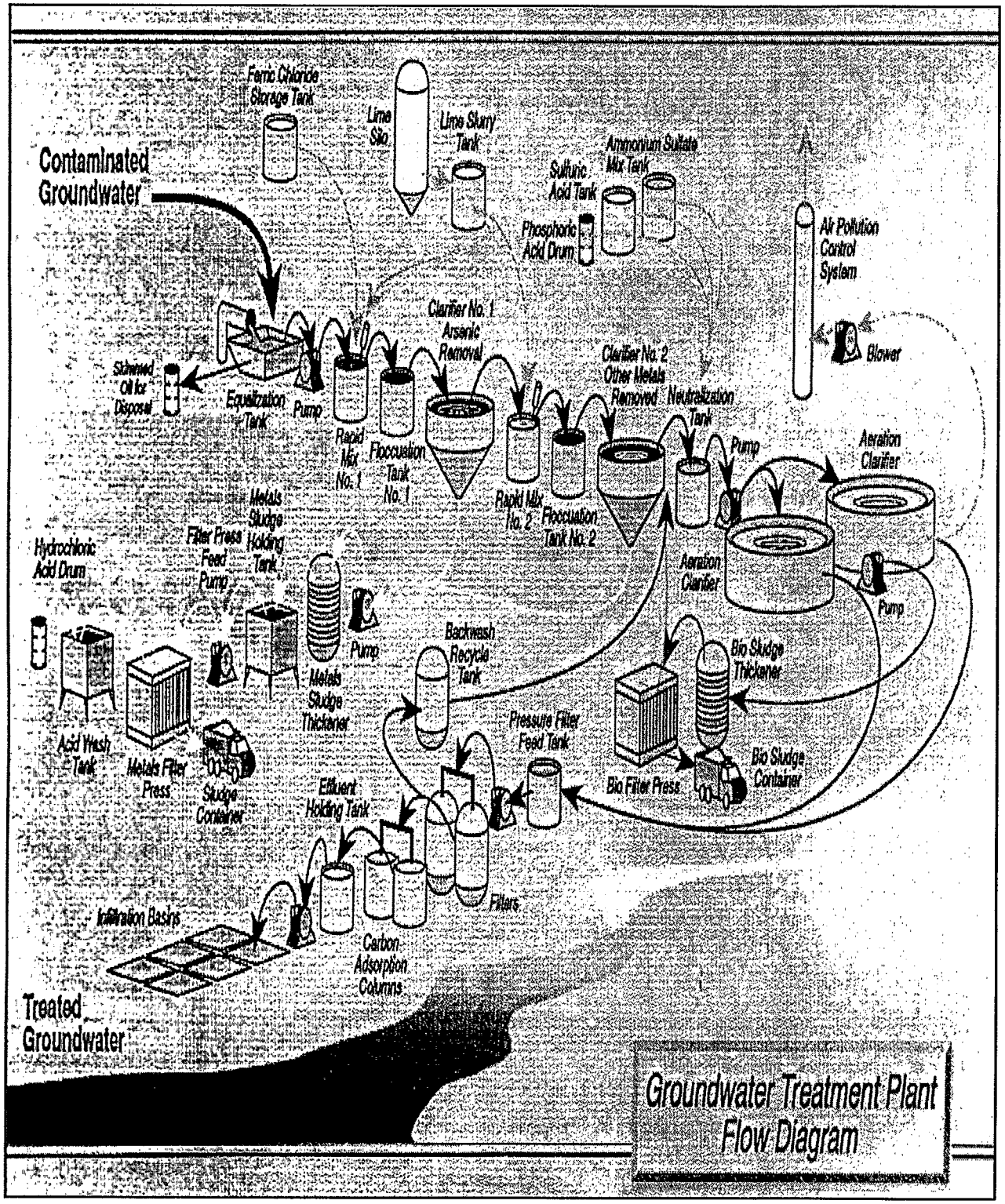

Figure 5. Groundwater Treatment Plant Flow Diagram [12]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Quantity of groundwater pumped from aquifer in gallons:

Year	Total Volume Pumped (gallons)	Unit Name
1993	18 million	1B,2,3
1994	34 million	1B,2,3
1995	28 million	1B,2,3

- As of February 1997, the treatment system has been 93% operational. Down time has been primarily due to problems with computer control instrumentation and lime buildup in feed lines.

- Excavation and on-site incineration of soils took place from 1995 to 1997. Wastewater from dewatering and incineration blowdown operations was pumped to the groundwater treatment system during this time. Since January 1996, the majority of flow to the treatment system has come from these operations.

- The wastewater generated from soil dewatering and incineration activities was estimated to be 100 gpm. The treatment system was required by contract to handle this additional wastewater flow and would reduce the volume of groundwater being sent from extraction wells if needed. However, this was not required because the groundwater extraction rate was approximately 50 gpm at that time.

- Once excavation and incineration activities began, piping and extraction wells were removed and replaced as contaminated soils were excavated and clean fill was replaced. During this time, the average extraction rate was approximately 25 gpm.

- The carbon units have been changed out approximately every two months or every eight million gallons treated. Approximately 115,000 pounds of spent carbon were regenerated or disposed of from 1993 until 1997.

- During soils excavation activities, the excavating contractor accidentally damaged or destroyed over 25 of the 49 monitoring wells. As a result, the site engineer has not been able to adequately monitor the contaminant plume during soil remediation activities. The excavation contractor will replace the damaged wells after soil remediation activities are complete.

- The long-term groundwater monitoring procedure approved by EPA stated that 20 perimeter wells would be monitored on a quarterly basis. After two consecutive sampling events from a well where no contaminants are detected, a different well nearer to the source area is chosen for the next sampling event.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

Table 3 shows operating parameters affecting cost or performance for this technology.

Table 3: Performance Parameters

Parameter	Value	
Average Extraction Rate	60 gpm	
Performance Standard (effluent) and Remedial Goal (aquifer) (µg/L)	Arsenic	0.05 µg/L
	Lead	0.05 µg/L
	Benzene	5 µg/L
	Toluene	2,000 µg/L
	Ethylbenzene	680 µg/L
	Xylene	440 µg/L
	2,4-dimethyl phenol	2.12 µg/L
	Naphthalene	0.62 µg/L
	Acenapthene	0.52 µg/L
	Dieldrin	0.000071 µg/L
	Chlordane	0.00046 µg/L

Source: [5]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
9/86	—	Date of ROD for this OU
5/87	—	Remedial design accepted
9/87	6/89	Design document prepared by Metcalf & Eddy
5/90	1/93	Construction of the groundwater treatment system
1/93	—	Groundwater treatment plant begins operations and compliance monitoring begins
6/95	5/97	Incineration activities performed
2/97	—	Groundwater treatment plant modified to increase capacity to 200 gpm
8/97	—	Anticipated date for restart of P&T full-scale operation

Source: [3, 8, 9, 10]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

Cleanup goals were established during the design phase to be maximum contaminant levels (MCL), as defined by the Primary Drinking Water Standards and the State of Massachusetts Drinking Water Quality Criteria. Specific criteria are included in Table 3. These goals must be met in all monitoring wells located on site [5].

Additional Information on Goals

In the cases where no MCL is available, the applicable regulation is EPA Ambient Water Quality Criteria for Freshwater Aquatic Organisms and Criteria for Human Consumption. Of the pollutants listed in Table 3, only arsenic, lead, and BTEX compounds have MCLs established [5].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Goals [3,5]

- To remediate the contaminated aquifer within a reasonable time to prevent present or future impacts to groundwater drinking water supplies.
- To protect the Cochato River from future contaminant migration by establishing hydraulic containment to capture the contaminant plume.

Performance Data Assessment [8,9,10,11,12]

For the purposes of this report, total contaminants refers to the broad classes of VOC and SVOC compounds detected at this site.

- During the first three years of operation, the P&T system reduced average VOC and SVOC concentration levels. The maximum concentration of contaminants detected in individual wells after three years of system operation were total SVOCs (7,967 µg/L) and total VOCs (11,870 µg/L).
- Figure 6 illustrates changes in average contaminant concentrations in the groundwater from 1994 to 1995. The data in Figure 6 show an overall decline of 16% (VOC) and 48% (SVOC) in average groundwater concentration from 1994 through 1995. However, contaminant concentrations in some individual wells did not decline over this period, and contaminant concentrations have not been reduced to below treatment goals.
- Contaminants have been detected in downgradient monitoring wells as noted in the 1995 Annual Report. On the basis of this information, plume containment has not been achieved. A 1995 groundwater study made recommendations for achieving plume containment.
- Groundwater models run by site engineers estimated that an extraction rate of approximately 150 gpm is required for plume containment. However, the treatment plant was not able to operate at its design rate of 150 to 200 gpm due to undersized pumps and sludge thickener. The extraction network also could not achieve the design extraction rate of 150 gpm due to well placement, clogging problems, and the shut-down of wells for soil remediation.
- As shown in Figure 7, the P&T system removed approximately 2,100 pounds of organic contaminant mass from the groundwater as of December 1995. Mass removed from metals precipitation units was not estimated for this report.
- Figure 7 presents the mass removal of contaminants through the treatment system from June 1994 to December 1995. A total of 80 million gallons of groundwater have been treated. The daily average treatment rate was 60 gpm as determined by the on-site contractor.
- The contaminant removal rate has fluctuated over the 1994-1995 operating period. The data presented in Figure 7 show a reduction in mass flux rate from 1994 to 1995. This decrease is due primarily to a decrease in flow rate to the treatment system. Available data indicate that influent concentrations have remained relatively constant.
- Several modifications are planned for groundwater remediation after the soils remediation activities are complete. Implementation of these modifications has reportedly begun. The first new extraction well is scheduled to be on-line by April 1998. An additional extraction well plus two LNAPL extraction wells are scheduled for later this year.

TREATMENT SYSTEM PERFORMANCE (CONT.)

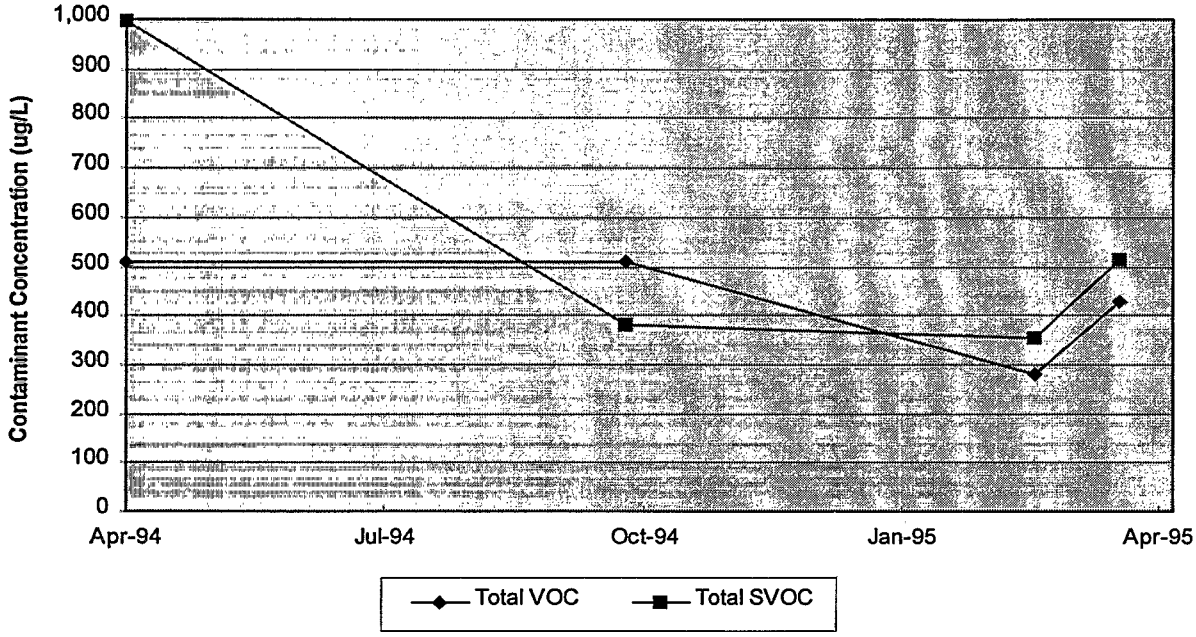

Figure 6. Average Contaminant Concentrations (1994-1995)

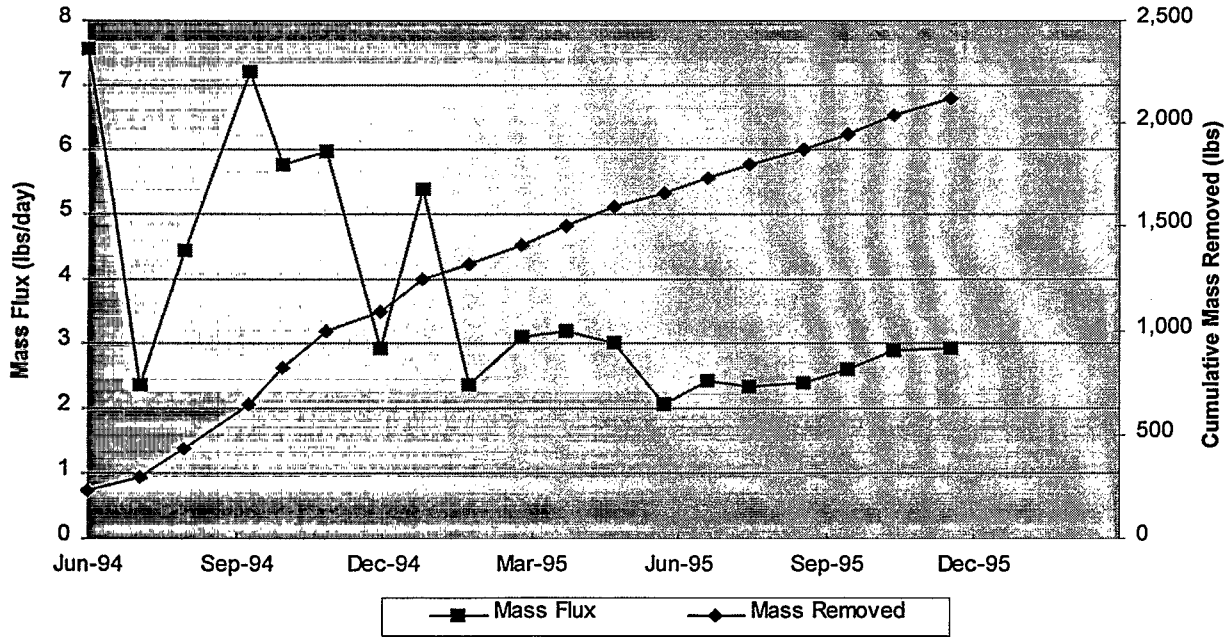

Figure 7. Mass Flux Rate and Cumulative Contaminant Removal (1994-1996)

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Performance sampling for the treatment system is completed on a weekly basis. Influent concentration, effluent concentration, flow, chemical usage, and sludge production data are available in monthly reports.
- Monthly reports for 1994 and 1995 were used for mass flux analyses performed in this report. No data were available for performance evaluation from April 1993 to June 1994.
- Contaminant mass removal was determined using analytical results from weekly influent and effluent sampling, along with average flow rate data. One weekly event per month was used for this calculation.
- Concentration data for the six extraction wells are available for April 1994, October 1994, March 1995 and April 1995 sampling rounds only. These data were used to compute the average groundwater concentration presented in Figure 6. A geometric mean was used to estimate average groundwater concentrations and provide a trend for the entire plume.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Massachusetts requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

The U.S. EPA is the lead agency for this site. The U.S. Army Corps of Engineers (USACE), N.E. Division, has been contracted to provide operations and maintenance of this site for the first ten years of operation. The New England Division of the USACE is managing all on-site activities. Metcalf & Eddy Services was awarded the contract for treatment system design and subsequently subcontracted Barletta Engineering to construct the treatment system. Metcalf & Eddy Services has been contracted to provide operation and maintenance services for the groundwater treatment system.

Cost Analysis

- All costs for remedial activities at this site were shared by the U.S. EPA and Massachusetts DEQE. The costs presented are for the groundwater pump and treat system only. No costs for the soil excavation and incineration, performed under a separate remedial action, are included.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [4,9]

Remedial Construction	
Administrative, Mobilization, and Demobilization	$3,490,595
Monitoring Wells and Sampling	$230,222
Site Work	$159,016
Ground Water Extraction/ Infiltration	$633,884
Treatment System	$9,274,652
Corps Management Costs	$1,169,292
Total Remedial Construction	**$14,957,661**

Operating Costs [4,9]

Operation and Maintenance	$4,902,878
Chemicals	$61,016
Metal Sludge Disposal	$568,670
Biological Sludge Disposal	$30,259
Carbon Regeneration/Purchase	$175,044
Utilities	$685,351
Laboratory Supplies	$772,211
Site Security	$408,159
Lab Services	$140,076
Equipment for collection and storage of LNAPL	$25,110
Total Cumulative Operating Expenses from April 1993 to February 1997	**$7,768,780**

Other Costs [4,9]

Remedial Design	
Remedial Design	$3,364,222
State Oversight	$39,911

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the Army Corps of Engineers contact for this site.

OBSERVATIONS AND LESSONS LEARNED

- Total cost for the P&T system at the BMI site was approximately $22,726,000 ($14,958,000 in capital costs and $7,768,000 in cumulative operation and maintenance costs). The unit costs for this clean-up are calculated to be $284 per 1,000 gallons of groundwater treated, and $10,822 per pound of organic contaminant removed.

- According to the site contact, substantial time and money were spent during the first year of operation in an attempt to acclimate biological organisms to the wastewater stream [4].

- Operating costs are high due to high analytical costs for the large number of contaminants and the cost for an operator to be on-site 24 hrs per day.

- The management plan to have concurrent groundwater and soil remediation activities resulted in high construction costs and logistics problems. A temporary groundwater extraction system was installed and then removed two years later when soil excavation began. In addition, monitoring wells installed across the site made it difficult to operate heavy machinery without

OBSERVATIONS AND LESSONS LEARNED (CONT.)

damaging well heads. Ultimately, over 25 monitoring wells were accidentally damaged or destroyed during the soil excavation activities. Replacement costs for these wells will be paid by the excavation contractor.

- In early 1997, plant upgrades such as pump replacement and sludge thickener unit replacement were required to achieve design capacity of 200 gpm. Upgrades were completed at a cost of $100,000 which is included in the $14.9 million [9].

- The treatment system performance data indicate that over 2,100 pounds of organic contaminants were removed from the groundwater as of December 1995. The P&T system has not met the cleanup goals, and maximum VOC and SVOC concentrations in extraction wells remain in excess of 11,000 and 7,000 µg/L, respectively.

- LNAPL material has been observed in two on-site wells, indicating the presence of a subsurface source of pollutants. Fluctuations in contaminant concentration levels were noted within several wells placed near the center of the plume. These fluctuations are also indicative of possible subsurface source zones contributing to the dissolved groundwater plume.

- During excavation and incineration activities, extraction wells and associated piping were replaced. These activities disrupted the groundwater extraction program and may have resulted in further off-site plume migration. Plume migration cannot be assessed at this time because of the interruption of the groundwater monitoring program.

- From 1993 to 1996, the overall extraction rate was 60 gpm, which is less than the design extraction rate of 150 to 200 gpm. Modifications to the extraction system will be made in 1997. According to the site engineer, the modifications will include repairing three wells and adding two new wells. The 1995 annual groundwater study and a calibrated groundwater model of the site were used to locate the two additional wells. Several wells will also be equipped to remove LNAPL material [9].

- The 1995 annual groundwater study included an optimization section which, with the aid of the groundwater model, made recommendations for enhancing the P&T system performance. Most recommendations were targeted at improving plume containment and increasing mass flux to the treatment system.

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1. Final Work Plan Focused Feasibility Study, Ebasco Services, February 1988.

2. Water Supply Feasibility Study, Ebasco Services, May 1990.

3. Remedial Action Report, Baird and McGuire Superfund Site, Holbrook, MA, Operable Unit #1, Groundwater Treatment Facility, March 1993.

4. Correspondence with Mr. Chet Janowski, Remedial Project Manager, U.S. EPA Region I, April 10, 1997.

5. Superfund Record of Decision, U.S. EPA, September 1986.

6. Remedial Investigation Report, Baird & McGuire Site, Holbrook, MA. GHR Engineering Associates, Inc., May 1985.

7. Remedial Investigation Addendum Report, Baird & McGuire Site, Holbrook, MA. GHR Engineering Associates, Inc., June 1986.

8. Evaluation of Extraction System Performance at the Baird & McGuire Superfund Site. Metcalf & Eddy Services, July 1995.

9. Correspondence with Mr. Chris Zevitas, Site Engineer, U.S. Army Corps of Engineering (USACE), April 14, 1997.

10. Monthly Process Summaries, 1994-1996, USACE.

11. Dense Nonaqueous Phase Liquids, Huling, S.G., and J.W. Weaver, U.S. EPA, March 1991.

12. Monthly Process Summary, February 1997.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

ATTACHMENT A

*Detected Compounds Listed in the ROD**

1,1-Dichloroethylene	Parius
1,2-Dichloroethane	Ethylbenzene
Aldrin	Fluoranthene
Arsenic	Lead
Benzene	Silver
Benzidine	Toluene
Benzo(a)pyrene	Xylenes (TOT)
Beryllium	Zinc
BHC-Alpha	Dibenzofuran
BHC-Beta	Total Other PAHs:
BHC-Delta (Tech)	2-Methylnaphthalene
BHC-Gamma	Acenaphthene
Cadmium	Acenaphthylene
Chlordane	Anthracene
Chloroform	Benzo(a)anthracene
Dieldrin	Benzo(b)fluoranthene
Heptachlor	Benzo(ghi)perylene
Heptachlor Epoxide	Benzo(k)fluoranthene
Nickel	Chrysene
Tetrachloroethylene	Dibenzo(a,h)anthracene
Trichloroethylene	Fluorene
Vinyl Chloride	Ideno(1,2,3-CD)pyrene
1,2-*trans*-dichloroethylene	Naphthalene
1,3-*trans*-dichloropropylene	Phenanthrene
2-Butanone	Pyrene

*Individual pollutant levels were not provided.

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UV Oxidation at the Bofors Nobel Superfund Site
Muskegon, Michigan

UV Oxidation at the Bofors Nobel Superfund Site
Muskegon, Michigan

Site Name:
Bofors Nobel Superfund Site - Operable Unit 1

Location:
Muskegon, Michigan

Cleanup Type:
Groundwater Remediation

Contaminants:
VOCs and SVOCs
- Benzene, Benzidine, 2-Chloroaniline, 1,2-Dichloroethene, Trichloroethene, 3,3-Dichlorobenzidine, Aniline, Vinyl Chloride
- Selected Maximum concentrations in ug/kg – Benzene (60,000), 2-Chloroaniline (63,000), Aniline (10,000), 3,3-Dichlorobenzidine (2,600)

Technology:
Groundwater Extraction and On-Site treatment by UV Oxidation
- Groundwater is extracted from 13 wells at the site.
- Total flow rate from the network of wells ranges from 390 to 500 gpm.
- Extracted water was initially sent through a chemical precipitation step. This step has since been removed from the system.
- Treatment steps include: dual-media filtration, UV Oxidation, GAC treatment (polishing), pH adjustment, stripping for ammonia removal and neutralization.
- Treated water is discharged to an-onsite surface water body (Big Black Creek)

Project Management:
U.S. Army Corps of Engineers
Carl Platz
Grand Haven Area Office
P.O. Box 629
Grand Haven, Michigan 49417
(616) 842-5510

Period of Operation:
- Full-Scale Treatment System Operation since September 1994.
- Treatment Currently ongoing and expected to last 50+ years.

SIC Code:
2869 (Industrial Organic Chemicals)

Cleanup Authority:
CERCLA and State
ROD date
– September 17, 1990

Vendor:
Kevin Dulle
Sverdrup Environmental
400 South 4th Street
St. Louis, Missouri 63102
(314) 436-7600

Type/Quantity of Media Treated:
Groundwater
- 700 million gallons extracted since 1994.
- 7,500 pounds of organic contaminants removed from extracted groundwater

Waste Sources:
Disposal of process wastes in 10 unlined impoundments at the site

Regulatory Requirements/Cleanup Goals:
The following list contains current discharge limits for selected contaminants. All limits have been established by MDEQ and are maximum allowable concentrations, based on weekly effluent sampling.

Purgeable Halocarbons - 5 ug/L (each)
Purgeable Aromatics - 5 ug/L (each)
Aniline - 5 ug/L
2-Chloroaniline - 10 ug/L

Purpose/Significance of Application:
The extraction and treatment system has successfully contained migration of contaminants from the site and consistently met discharge requirements since system startup in 1994.

Regulatory Points of Contact:
John Fagiolo
USEPA Region V
77 West Jackson Blvd
Mail Code: SR6J
Chicago, Illinois 60604
(312) 886-0800

Dennis Eagle
MDEQ-ERD
Knapps Centre
P.O. Box 30426
Lansing, Michigan 48909
(517) 373-8195

UV Oxidation at the Bofors Nobel Superfund Site
Muskegon, Michigan (continued)

Results:	Costs:
• The extraction and treatment system is containing the groundwater contamination plume at the site. • Contaminant concentrations in the treatment system effluent have been consistently below surface water discharge limitations for the site.	The total capital cost for construction of the treatment system was $12,200,000. Yearly O&M costs average $763,000. Over three years, the capital plus O&M costs translate to $19.61 per 1,000 gallons of groundwater treated, or $1,830 per pound of organic contaminants removed. Yearly O&M costs translate to $3.27 per 1000 gallons of groundwater treated, or $305 per pound of organic contaminants removed.

Description:

For approximately 20 years, chemical process waste liquids and sludge were routinely disposed in 10 unlined surface impoundments at the site. In addition, impoundment berms occasionally failed, releasing sludge into nearby surface water bodies. In 1978, thirteen extraction wells were installed at the site to collect contaminated groundwater down gradient of the impoundments. Collected water was treated in an existing system located at a nearby facility, and was subsequently sent the local POTW for additional treatment. A Record of Decision (ROD) was signed in September 1990, specifying construction of a new on-site treatment system with UV oxidation as the primary treatment technology.

Under direction of the USACE, treatability testing and treatment system design were performed in 1991 and 1992. In 1992 a contract was awarded for construction of the treatment system. In September 1994, construction of the system was completed and full-scale treatment was begun. The treatment system originally consisted of: metals precipitation pretreatment, dual media filtration, UV oxidation treatment for removal of organics, GAC treatment (polishing), pH adjustment, stripping to remove ammonia and neutralization. After one year of operation, the metals precipitation step was determined to be unnecessary, and was removed from the treatment train. Treated water is discharged to an on-site surface water body (Big Black Creek).

The treatment system is currently in operation and is successfully containing groundwater contamination at the site. It is estimated that significant reductions in groundwater contaminant concentrations will not be realized until the sources of contamination (impoundment soils and sludge) are removed or isolated.

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Bofors Nobel Superfund Site
Location: Muskegon, Michigan
Operable Unit: OU 1
CERCLIS #: MID006030373
ROD Date: September 17, 1990
Technology: Ultraviolet (UV) Oxidation
Type of Action: Groundwater Remediation

Figure 1 shows the location of the Bofors Nobel Superfund Site in Michigan.

TECHNOLOGY APPLICATION

Period of Operation:

September 1994 – Ongoing

Quantity of Material Treated During Application (to date):

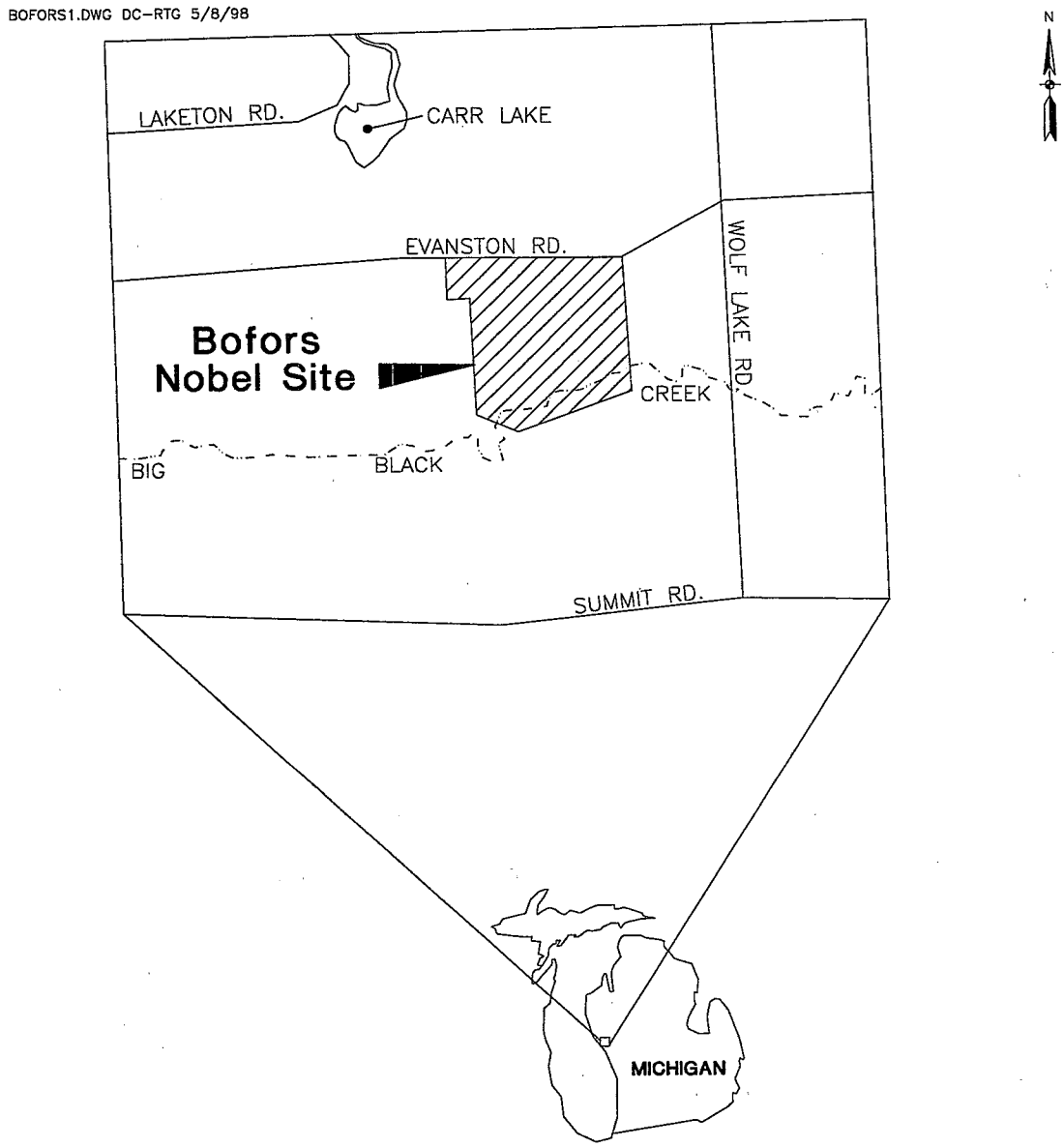
Approximately 700 million gallons of contaminated groundwater has been extracted and treated at the site. Approximately 7,500 pounds of organic compounds have been removed from the groundwater. These quantities are cumulative through October 1997.

This application is part of an ongoing project to contain contaminated groundwater at the facility. Groundwater extraction and treatment has been performed at the site since 1978. The ultraviolet (UV) oxidation treatment application has been in operation since 1994. Additional contamination in site surface water, soil, and sediment is being addressed under a later phase of this Operable Unit (OU), and is not a direct part of this application.

BACKGROUND

Site Background:

- The Bofors Nobel Superfund Site is located on 85 acres in a chemical manufacturing area six miles east of Muskegon, Michigan in Egelston Township. The site includes an operating specialty chemical manufacturing plant that is currently owned by Lomac, Incorporated. The Muskegon, Michigan area is home to a number of superfund sites as a result of past chemical manufacturing production. The geological conditions at the Bofors Nobel site include a sandy soil horizon which allowed for the rapid infiltration of contaminated liquids generated by chemical wastes which were regularly discharged to ten separate, unlined surface impoundments at the site.



NOTE: NOT DRAWN TO SCALE

Figure 1. Site Location Map, Bofors Nobel Superfund Site, Muskegon, Michigan

- Prior to 1970, the facility produced chemicals such as 3,3-dichlorobenzidine (DCB), benzidine, and azobenzene for use in alcohol based detergents and as die intermediates. Raw materials used in the production of detergents included fatty alcohol, fatty ether alcohol, sulfur dioxide, aqueous ammonia and caustic. In the production of dye intermediates, raw materials utilized included muriatic acid, sulfuric acid, nitrobenzene, methanol, benzene, caustic, sodium chloride and zinc.

- Lakeway produced a lauryl alcohol base detergent, dye intermediates, pesticides, and herbicides during the 1970s.

- In September 1977, Lakeway Chemicals merged with Bofors Industries, Incorporated to become Bofors Lakeway, Incorporated. On December 31, 1981, Bofors Lakeway, Inc. merged with Nobel Industries of Sweden and the company name was changed to Bofors Nobel, Incorporated. In December 1985, the corporation filed for bankruptcy, claiming that the company had expended in excess of $60 million dollars for environmental cleanup.

- The Bofors Nobel, Inc. assets were sold to Lomac, Inc. in March of 1987. As a part of the sales agreement, an "Agreement and Covenant Not to Sue" was entered into between the State and Lomac for site contamination caused by previous facility operators. These agreements and covenants allowed Lomac to operate the facility independently of site remediation activities.

- In March 1989, the Bofors Nobel site was placed on the National Priorities List (NPL).

Figure 2 shows the layout of the Bofors Nobel facility.

SIC Code: 2869 (Industrial Organic Chemicals)

Waste Management Practices that Contributed to Contamination:

For approximately 20 years, chemical process waste liquids and sludge were routinely disposed in ten unlined surface impoundments at the site. In addition, lagoon berms occasionally failed, releasing impoundment sludge into nearby surface water bodies.

Site Operation History:

- Lakeway Chemicals, Incorporated began producing industrial chemicals at the site in 1960. During the late 1960s and 1970s, process wastes were discharged through open trenches to ten unlined Surface Impoundments located south of the plant area.

- During the 1970s, berm failures at the impoundments resulted in the discharge of sludge directly into Big Black Creek.

- Use of the surface impoundments for waste disposal was discontinued in 1976 when the facility began discharging its liquid wastes to the Muskegon County Wastewater Treatment System. At that time, the Michigan Department of Environmental Quality (MDEQ) requested that Lakeway perform hydrogeologic tests at the site to define aquifer characteristics and define extraction well placement to prevent migration of site contamination.

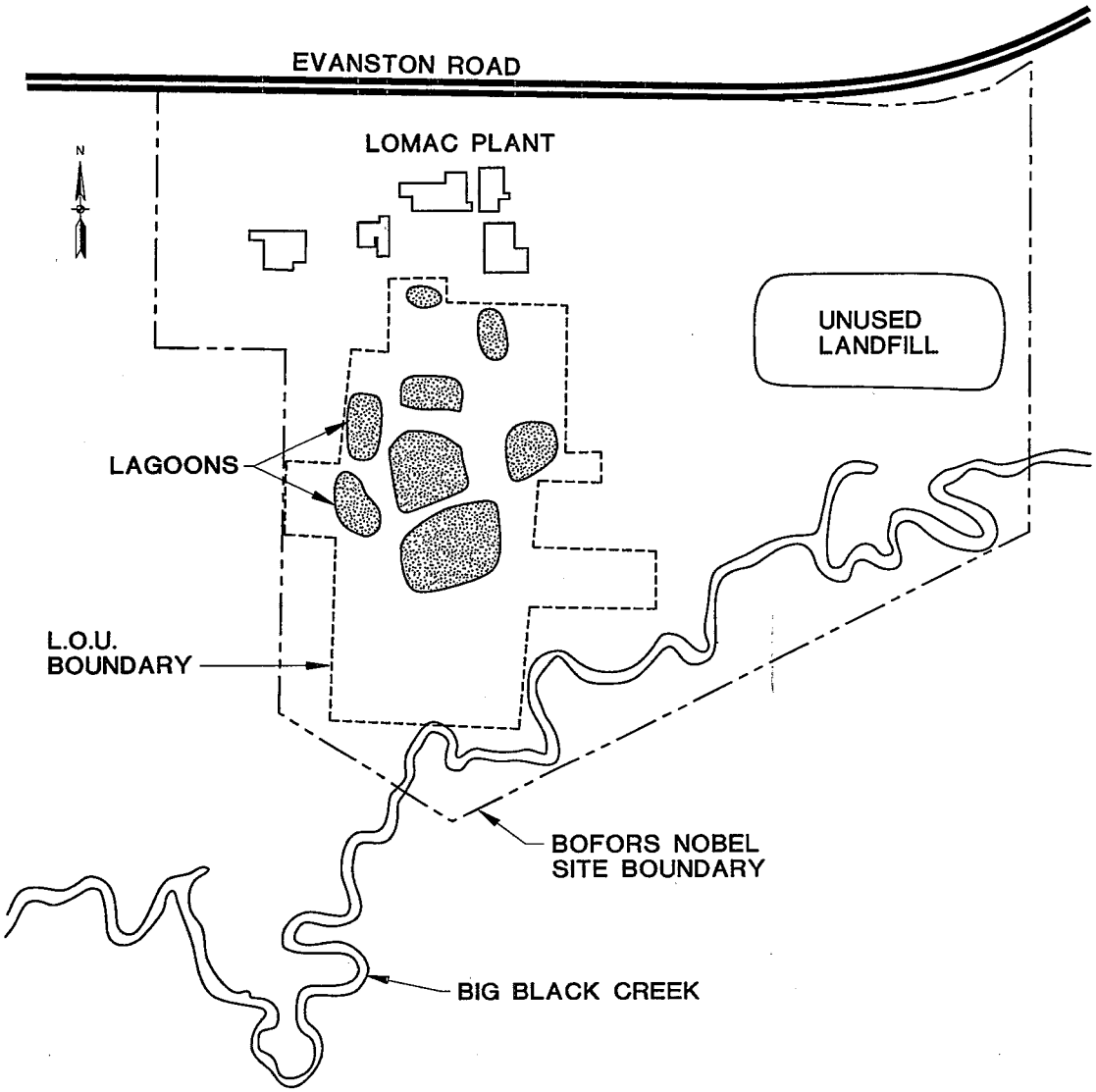


Figure 2. Layout of the Bofors Nobel Facility

- Groundwater extraction wells were installed along the southern boundary of the site and began operating in 1978.

SITE LOGISTICS/CONTACTS

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Site Investigations

- The site has been divided by the EPA into two operable units, OU 1 and OU 2. OU 1 consists of addressing soil and groundwater contamination in the lagoons area. OU 2 consists of addressing soil and groundwater contamination in the northern portion of the facility (The Lomac plant area).

- OU 1 has been subdivided into two phases. The first phase, termed the Groundwater Operable Unit (GOU), included installation of the Groundwater Treatment Plant (GWTP). The second phase, termed the Lagoon Operable Unit (LOU), will include remediation or containment of contaminated soil in the lagoons area of the facility. This report refers only to the first phase of OU 1 (The GOU).

- Because of the nature and extent of the contamination on the Bofors Nobel site, the State of Michigan contacted the U.S. EPA to evaluate the site for placement on the National Priorities List (NPL), pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA).

- The EPA conducted a site evaluation, and nominated the Bofors Nobel site to the NPL in July 1988, with listing occurring in March 1989. A Remedial Investigation/Feasibility Study (RI/FS) was initiated in August 1987 and was completed in June 1990.

- A Record of Decision (ROD) for the Bofors Nobel site was signed on September 17, 1990. The ROD addressed remediation of the sludge lagoons as well as restoration of the groundwater aquifer.

- Supplemental groundwater monitoring was performed by the USACE during the design of the GWTP and for design of an on-site landfill remedy. This monitoring was performed from March 1991 to June 1994.

MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Groundwater (ex situ)

SITE GEOLOGY/STRATIGRAPHY

The regional geology of the Bofors site can be characterized as surficial Pleistocene sediments of varying compositions above Paleozoic sedimentary bedrock occurring on the margin of the Michigan Basin. These two different depositional age sediments rest on a Pre-cambrian basement complex.

The surficial geology is comprised of material deposited by the Wisconsin advance during the glacial periods of the Pleistocene Epoch. As the Wisconsinan glacier began to recede across Michigan, it re-established a lobate character subdividing into the Michigan, Saginaw, and Lake Erie lobes. During this general retreat, end moraines developed parallel to the margins of the several lobes with some local development of interlobate moraine. The development of these moranic systems impounded meltwater behind them and initiated the first stages of the Great Lakes. Continued retreat and advances of the glacial ice created additional moranic systems and lacustrine and outwash plains. The final retreat of glacial ice left Michigan with a complex landscape generally less than 20,000 years old, developed on drift deposits. The landscape is composed of low-relief features such as outwash, till, and lacustrine plains and greater relief features including moraines, drumlins, kame, kettles, eskers, wave-cut cliffs, and dunes.

Surficial geology near the Bofors site can be characterized as Pleistocene glacio-lacustrine sands, outwash sediments, and tills overlying the lower Mississippian Marshal Sandstone and Coldwater Shale Formations. These latter two formations are part of the geologic structure known as the Michigan Basin. Surficial geology consists of alluvium comprised of laminated sand and silt with peaty and fibrous material associated with Big Black Creek, and three glacially derived zones described below:

The uppermost zone is a predominately fine to medium grained sand with generally less than five percent fines passing the No. 200 sieve. Occasional coarser-textured beds with higher percentage of fines do occur, but these beds are sporadic. Low percent of fines, good sorting, uniform texture, and consistency of occurrence characterize this zone.

The next lower sequence consists of sand deposits that are variable in texture, generally greater than five percent fines, with some units containing more than 30 percent, commonly interbedded with units of silty clay. Occasional sand beds of the uppermost zone-type occur within this zone. However, these are generally thin and sporadic. General variability and lack of uniformity characterize this sequence, with represents a highly complex pattern of sedimentation.

The basal zone of the glacial stratigraphic section is a silty clay commonly containing 60 percent or greater fines. In addition, there are local minor beds of silt and sand with gravel. This zone appears to be related to deposits of the Morainal uplands because the total thickness of the two upper zones thins adjacent to the Morainal areas, and the basal unit is encountered at progressively higher levels.

Paleozoic rocks make up the majority of the structure known as the Michigan Basin. These sedimentary formations are bowl-shaped and tend to thin towards the basin's margins. Muskegon County is located on the margin of the Michigan Basin. The upper Paleozoic rocks in this region are the Osagean and Kinderhookian Series of the lower Mississippian age, consisting of sandstones and shales. Below the

Osagean and Kinderhookian Series are Paleozoic age sedimentary rocks comprised in general of mudrocks, sandstones, carbonates, and evaporates. The bedrock topography along the western margin of the Southern Peninsula of Michigan near Muskegon County increases gradually in elevation from the Lake Michigan shoreline.

The stratigraphic column beneath the Bofors site, beginning with the youngest formation, includes:

a) Recent sediments of alluvium and swamp deposits associated with Big Black Creek.
b) Quaternary lacustrine sand formation consisting of three subunits; the upper, middle and lower units.
c) Quaternary glacial till formation.
d) Mississippian Marshall sandstone formation.

The topography at the Bofors Nobel Superfund site slopes from a high elevation of approximately 660 feet Mean Sea Level (MSL) at the northern edge of the site to Big Black Creek, which flows along the southern border of the project boundary, at an elevation of approximately 617 MSL. Groundwater beneath the site is steeply sloping, and is located between elevations 621 and 625 MSL. Depth to groundwater at the site ranges from the ground surface at Big Black Creek, to approximately 34 feet below grade at the northern edge of the site. At the extraction well points, the estimated depth to groundwater ranges from 25 to 30feet. It has been estimated that the primary aquifer at the site is 80 feet thick.

Local Climate

Regional climate characterization indicates a humid, continental climate influenced by nearby Lake Michigan. Lake Michigan influences Muskegon's climate by reducing summer maximum temperatures, and by moderating arctic air masses during winter. Strong north-westerly air flow during the winter months overrides the relatively warm water of Lake Michigan, producing snow squalls along the eastern shoreline. Consequently, snowfall in Muskegon is considerably higher than what is observed across the lake in Wisconsin or inland toward the center of lower Michigan. A thick snow cover results during winter months which may reduce the potential for wind-blown particulates. The influence of Lake Michigan is observed when comparing the Muskegon area with Grand Rapids, approximately 40 miles inland. The mean annual number of days with maximum temperatures of 90°F or greater is six at Muskegon, and thirteen at Grand Rapids. The mean number of days where minimum temperatures are below 32°F is 144 at Muskegon compared to 150 days at Grand Rapids. The mean monthly temperature in Muskegon during January is approximately 23°F, with total precipitation averaging three inches, including 33 inches of snow. Inland at Grand Rapids, the mean temperature is 21°F, with 2.5 inches precipitation, including 22 inches of snow.

CONTAMINANT CHARACTERIZATION

Primary Contaminant Groups:
Volatiles (Halogenated)
Semivolatiles (Halogenated)

Key Specific Contaminants:
Benzene
Benzidine
2-Chloroaniline
1,2-Dichloroethene
Trichloroethene
3,3-Dichlorobenzidine
Aniline
Vinyl Chloride

Over sixty contaminants have been detected in the groundwater beneath the site. The following table provides a partial list of contaminants of concern at the site.

Table 1. Partial Listing of Contaminants of Concern

Acetone	Aniline	Azobenzene
Benzene	Benzidine	2-chloroaniline
bis(2-Ethylhexyl)phthalate	Butyl Benzyl Phthalate	3-chloroaniline
Chlorobenzene	Chloroisophorone	Dichloroazobenzene
1,2-Dichlorobenzene	1,3-Dichlorobenzene	1,4-Dichlorobenzene
1,2-dichloroethane	Dichlorobiphenyl	1,2-dichloroethylene
Ethylbenzene	Isophorone	Phenols
Tetrachloroethylene	Toluene	1,1,1-Trichloroethane
Trichloroethylene	2-Methylphenol	Trimethylphenol
1,1,2,2-Tetrachloroethane	Vinyl Chloride	di-n-Propyl formamide
1,1-Dichloroethylene	Xylene	Trans-1,2-dichloroethylene
3,3'-Dichloro-2,4'-diaminobiphenyl	3,3-dichlorobenzidine isomer	

CONTAMINANT PROPERTIES

Table 2 lists selected properties for several of the most common contaminants present at the Bofors Nobel site.

Table 2. Contaminant Properties

Property	Units	Benzene	Benzidine	2-Chloro-aniline	1,2-DCE	TCE
Chemical Formula	-	C_6H_6	$C_{12}H_{12}N_2$	C_6H_6ClN	$C_2H_2C_{l2}$	C_2HCl_3
Molecular Weight	g/mole	78.11	184.23	127.57	96.95	131.5
Specific Gravity	-	0.8765	1.250	1.213	1.28 (cis) 1.26 (trans)	1.46
Vapor Pressure	mmHg	76 (20°C)	0.83 (20°C)	0.17 (20 C)	200 (trans) (14°C)	57.8 (20°C)
Boiling Point	°C	80.1	402	208.8	60 (cis) 48 (trans)	86.7
Octanol-Water Partition Coefficient (K_{ow})	-	135	65	79	123 (trans)	339

NATURE AND EXTENT OF CONTAMINATION

Several environmental investigations have been performed at the Bofors Nobel site. In 1978, Bofors Lakeway, at the direction of MDEQ, completed installation and began operation of thirteen groundwater extraction wells, primarily located along the southern boundary of the property. The wells were designed to prevent the migration of contamination beyond the site boundaries. Operation of the extraction wells has continued since that time. Prior to 1994, extracted groundwater was treated at the Lomac facility and discharged to the Muskegon County Wastewater Treatment Facility. Since 1994, groundwater treated by the UV oxidation system has been discharged directly to Big Black Creek. No groundwater contamination has been detected down gradient of the project site. Modeling has indicated that the existing extraction system is capable of retaining the plume of contamination on the project site. It is estimated that termination of extraction well operation would allow contaminant migration offsite within three days of pump cessation.

Remedial investigation field activities at the site have included:

a) Surface soil sampling
b) Subsurface soil sampling
c) Groundwater sampling
d) Geophysical investigation
e) Air monitoring

Data from hundreds of soil boring and groundwater monitoring wells has allowed the development of numerous two-dimensional contour diagrams illustrating the surface areas, groundwater elevations, and contaminant concentrations profiles. These diagrams have been used to verify that current pumping scenarios are adequate to provide capture of the site contamination.

The hydrogeologic unit located beneath the project site is consistent in composition and exhibits a range of conductivity values commonly associated with a clean sand aquifer. The mean hydraulic conductivity for the wells tested at the project site was 4.4×10^{-2} cm/sec. The transmissivity at the site ranges from 43,000 to 60,000 gpd/ft, with an average value of 48,000 gpd/ft. These values are judged to be representative of the aquifer, based upon its characterization. The storage coefficient, also felt to be consistent for a sandy aquifer, was found to be approximately 0.27. Based upon the assumption that the aquifer is 80 feet thick and the average transmissivity of 48,000 gpd/ft, the coefficient of permeability was found to be 600 gpd/ft^2, or 2.8×10^{-2} cm/sec, which correlates well with the previously stated value of 4.4×10^{-2} cm/sec.

The most prevalent and highest concentration contaminants of concern at the Bofors Nobel site include benzene, benzidine, 2-chloroaniline, 1,2-dichloroethene, trichloroethene, 3,3-dichlorobenzidine, aniline and vinyl chloride. The highest groundwater concentrations detected for each of the contaminants listed above are shown in Table 3. These concentrations are all from groundwater samples collected prior to installation of the GWTP (pre-1994).

Table 3. Highest Detected Contaminant Concentrations (Pre-1994)

Constituent	Maximum Concentration (µg/L)	Well or Well Cluster ID
Benzene	60,000	WC-27
Benzidine	1,300	MW-108
2-Chloroaniline	63,000	WC-27
1,2-Dichloroethene	1,900	LW-3
Trichloroethene	43	PW-41
3,3-Dichlorobenzidine	2,600	PW-41
Aniline	10,000	WC-27
Vinyl Chloride	1,000	W-33

The average concentrations of the most prevalent groundwater contaminants over a 16-month period from November 1994 through February 1996 are shown in Table 4.

Table 4. Average Concentrations for Selected Contaminants (1994-1996)

Compound	Average Concentration (µg/L)
Benzene	350
Benzidine	315
2-Chloroaniline	270
1,2-Dichloroethene	180
Trichloroethene	100
3,3-Dichlorobenzidine	80
Aniline	40
Vinyl Chloride	33

As of October 1997, extracted groundwater contained approximately 1.5 mg/L of total organic compounds prior to treatment. The metals concentrations in the plant influent have not exceeded the regulatory limits established by the MDEQ.

OU 01 (GOU) was intended as a remedy for contaminated groundwater at the site. To summarize the aquifer parameters discussed in the previous paragraphs, the critical aquifer characteristics have been estimated as follows:

Table 5. Aquifer Characteristics

Unit	Apparent Thickness	Hydraulic Conductivity	Transmissivity	Flow Direction
Operable Unit 1	80 feet	600 gpd/ft^{-2}	48,000 gpd/ft	Southerly

Groundwater at the southern boundary of the project site and across the entire Bofors Nobel site acts as an unconfined aquifer.

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY

Pump and Treat with UV Oxidation

SUPPLEMENTAL TREATMENT TECHNOLOGIES

Pretreatment (water) – **Chemical** (chemical precipitation) and **Filtration**
Post-Treatment (water) – **Carbon Adsorption** and **Air Stripping**
Post-Treatment (solids) – Sludge Dewatering (filter press)

TIMELINE

Table 6 shows a timeline of significant activities that have occurred on the Bofors Nobel project.

Table 6. Project Timeline

Date	Activity
September 1991	Advanced Oxidation Treatment Demonstration Testing
September 1991 through April 1992	System Design
August 1992	Bid Submittal Deadline
October 1992	Contract Award
November 1992	Construction Mobilization
June 1994	Construction Complete
September 1994	Initiate Treatment Operations

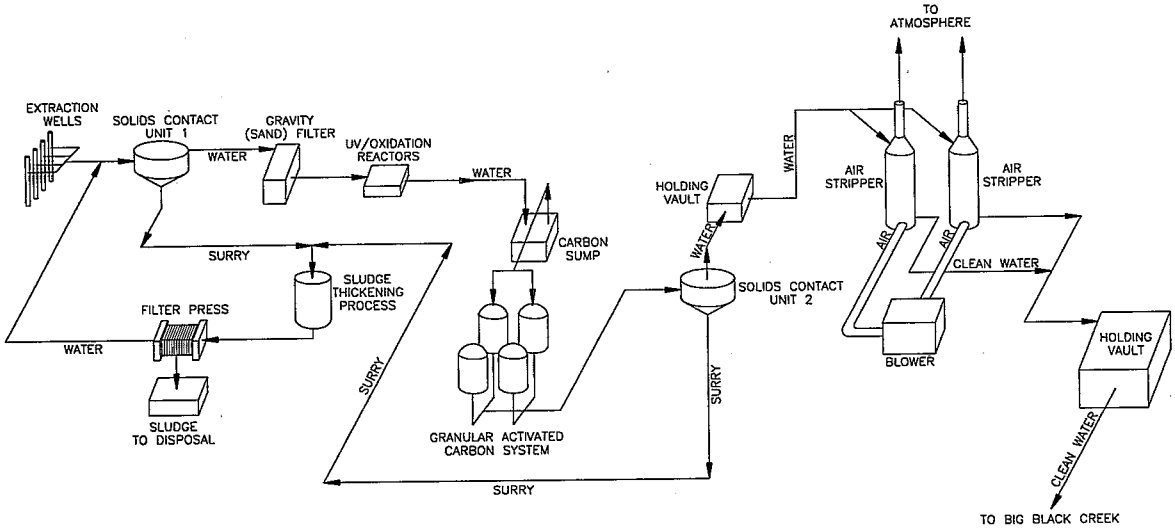
TREATMENT SYSTEM SCHEMATIC AND TECHNOLOGY DESCRIPTION AND OPERATION

Figure 3 shows a schematic diagram of the groundwater treatment system.

The extraction well network was constructed in 1978 as part of a proactive approach to site cleanup by the state of Michigan. No additional extraction wells were installed during construction of the groundwater treatment facility. Records providing extraction well details, pump types and casing/screen intervals are limited and were not available for the preparation of this document.

The facility design flow has been established as 782 gpm, with a maximum of 732 gpm derived from the wellfield, and 50 gpm as plant recycle. The current operating flow rate varies between 390 and 500 gpm, depending upon the season. Groundwater is discharged to the treatment facility from the extraction well network and was initially directed to a metals precipitation unit (solids contact unit 1) for pretreatment prior to organics removal. The metals precipitation unit was operated for approximately two years after system start-up. Because it was determined to be unnecessary at that time, it has since been taken out of service. Following solids contact unit 1, water is sent through a dual media gravity filter. Filtered water gravity flows through a UV Oxidation system to treat organic contaminants. Treated water gravity flows into a sump, from which it is pumped through four columns of granular activated carbon (GAC). GAC treatment is provided for polishing, and as a backup measure in the event the UV system is offline. Following polishing, the pH is elevated in solids contact unit 2 to convert ammonium ions (NH_4^+ - present at neutral pH) to strippable ammonia (NH_3), for removal within the ammonia stripping columns. The pH-adjusted water travels from solids contact unit 2 to the ammonia stripping sump, where it is then pumped through the ammonia stripping column. After stripping, the water is neutralized by acid addition, and the water is directed to the effluent holding vault. The holding vault also serves as a source of fire protection water at the facility. Water from the holding vault overflows through a weir and discharges to Big Black Creek at the southern edge of the site.

Solids generated in the two solids contact units are pumped to a sludge thickener. Thickened sludge is amended with lime to improve handling and dewatering, and is then pumped to a sludge filter press. The 25 to 35 percent solid sludge cake from the filter press is further processed to remove excess water using a sludge dryer. The solids content in the sludge is increased to approximately 90 percent in the sludge dryer. Sludge exiting the sludge dryer is transferred to bags and is disposed at a solid waste landfill. Water generated by the filter press is recycled to the head of the treatment facility.



• SOLIDS CONTACT UNIT 1	Removes metals from water by elevating pH and adding polymer to form a slurry mixture. Slurry sent to sludge Thickening Process; remaining water sent to Gravity Filter. Note: This unit was taken out of service in 1995 because it was not needed to meet discharge limitations.
• GRAVITY FILTER	Removes fine particles from water.
• SLUDGE THICKENING PROCESS/FILTER PRESS	Forms sludge by adding lime to slurry and forcing it through Filter Press. Sludge sent offsite for disposal, water recycled to Solids Contact Unit 1.
• UV/OXIDATION/GRANULAR ACTIVATED CARBON	Removes organic compounds from water.
• SOLIDS CONTACT UNIT 2	Elevates the pH for ammonia removal and adds a polymer to form a slurry mixture. Slurry sent to sludge Thickening Process.
• AIR STRIPPERS	Ammonia stripped from water prior to discharge to Big Black Creek.

Figure 3. Groundwater Treatment Process Schematic
Bofors Nobel Superfund Site, Muskegon, Michigan

KEY DESIGN CRITERIA

The expected operational lifetime of the treatment system is estimated to be greater than 60 years.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE

The following table lists several of the key operating parameters for the GWTP. Where possible, design values are compared to actual values.

Parameter	Units	Design Value	Actual Value (1)
Pumping Rate	gpm	782	390 - 500
Water Temperature	---	---	---
Influent	°F	NA	56
UV Oxidation Unit	°F	NA	54
Effluent	°F	NA	54
Influent and Effluent Contaminant Concentrations	---	---	---
Influent (9 Primary Contaminants)	µg/L	5,218	< 1500
Effluent (9 Primary Contaminants)	µg/L	43	< 9
Pressure Loss Through GAC Columns	PSI	1-3	NA
System pH (influent)	NA	7.0	7.3
Chemical Feed Rates	---	---	---
Caustic (50% NaOH)	gal/day	380	NA
Acid (96% H_2SO_4)	gal/day	687	NA
Polymer	gal/day	18	39
Hydrogen Peroxide	gal/day	NA	8.0
Ozone Generated	lbs/day	NA	49.7
Head Loss Through the Dual Media Filtration System	Feet	2.57	NA

(1) - 1998 Information
NA - Not Applicable

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES

The overall objective of the GOU at the Bofors Nobel Superfund Site is to control the offsite migration of contaminated groundwater, and to reduce the contaminant mass remaining in the aquifer. Limitations have been established by the MDEQ for discharge of treated groundwater from the site. Table 7 lists the MDEQ limitations for water discharged from the GWTP to Big Black Creek. Weekly sampling is required for all parameters listed in the table.

TREATMENT PLAN

The treatment strategy for OU 01 at the Bofors Nobel site is to first address the contaminated groundwater beneath the project site by preventing offsite migration. After successfully achieving this goal, the source of the site contamination (soil and sludge in the lagoons) must be addressed in order to allow the site to be remediated. Contaminated soils at the project site have not yet been addressed through any type of remediation activity, therefore, a continuous source of contaminant loading to the aquifer remains at the site. To date, alternatives that have been considered to address the contaminated soils include incineration, excavation with consolidation in an onsite landfill, and placement of a slurry

Table 7. Discharge Limitations for the GWTP

Parameter	Limitation
COD	20 mg/L
Ammonia Nitrogen	---
12/1 - 4/30	29 mg/L
5/1 - 9/30	2.0 mg/L
10/1 - 11/30	12 mg/L
Purgeable Halocarbons	---
Each	5 µg/L
Purgeable Aromatics	---
Each	5 µg/L
Aniline	10 µg/L
2-Chloroaniline	20 µg/L
Carbon Disulfide	5 µg/L
2-Butanone	500 µg/L
2-Methylphenol	5 µg/L
Benzidine	0.12 µg/L **(1)**
3,3-Dichlorobenzene	0.18 µg/L **(1)**
2,4-Dinitrophenol	29 µg/L **(1)**
1,1-Dichloroethane	5 µg/L
1,1-Dichloroethene	5 µg/L
Total Copper	62 µg/L / 38 µg/L **(1)**
Total Lead	11 µg/L **(1)**
Total Mercury	0.0013 µg/L **(1)**
Total Zinc	320 µg/L / 185 µg/L **(1)**
Dissolved Oxygen	---
5/1 - 9/30	6.5 mg/L (minimum)
10/1 - 4/30	4.0 mg/L (minimum)
pH	6.5 - 9.0 (acceptable range)

(1) - Allowable Monthly Average Concentration

wall combined with installation of an impermeable cap at the site. At the time this report was prepared, no final action had been selected to address the issue of soil and sediment contamination.

In 1991, treatability testing was performed to assess the performance of several groundwater treatment technologies. Technologies tested included: UV/peroxide oxidation, UV/ozone oxidation, and carbon adsorption. Test results indicated that UV/ozone oxidation was the superior technology for treatment of groundwater at the Bofors Nobel site.

TREATMENT PERFORMANCE DATA

The concentration of contaminants in the influent to the groundwater treatment facility has consistently been less than design values. As previously indicated, the total concentration of organic compounds in extracted groundwater is approximately 1.5 mg/L (versus a design estimate of greater than 5 mg/L), and has not varied significantly since project start-up. The consistency of the influent concentration is expected, since the source of soil and sediment contamination at the site has not yet been addressed. It is likely that future soil remediation at the site will include removal and/or capping of the contamination, ultimately leading to a reduction in the amount of contamination being carried to the site groundwater. It has been estimated that long-term cleanup of the site groundwater will take 50 to 70 years.

The groundwater treatment facility has consistently treated the target contaminants to concentrations below the limits established by the MDEQ. The site has not exceeded the permit limits for any individual contaminant since start-up in 1994. Toxicity testing was not required under the original operating contract, but has since been added to the facilities operating charter. Since initiation of toxicity testing, some difficulties have been encountered when testing 100 percent effluent on the target specie, *Daphnia magna* or *D. pulex*. Toxicity testing issues are currently being addressed at the facility, and should be closely coordinated with state regulatory personnel.

Since 1994, over 7,500 pounds of organic compounds have been removed from the groundwater at the Bofors Nobel site. The principal treatment technology employed by the groundwater treatment system at the site is UV oxidation. This technology treats organic compounds by destruction as opposed to phase transfer. Destruction treatment technologies function by converting (either by physical or chemical means) contaminants into less harmful substances, many of which can be discharged directly to the environment. Phase transfer technologies collect contaminants from one medium (e.g., water) and concentrate them in or on another medium (e.g., granular activated carbon). The concentrated contaminants are subsequently easier and less expensive to transport and dispose. Destruction technologies are typically preferable to phase transfer technologies because with destruction, the need for further handling or treatment of wastes is minimized or eliminated.

As of October 1997, the Bofors Nobel groundwater treatment facility has processed approximately 700 million gallons of contaminated groundwater without exceeding any of the discharge limitations established by the state of Michigan. The treatment facility has been operating since September 1994, effectively preventing migration of the site contaminants. The facility has treated an average of six pounds of organic compounds per day since startup, with little variation in the contaminant plume configuration. There have been no adverse air emissions caused by the operation of the treatment facility. The system is able to operate with no downtime (100% operability) as a result of system flexibility and operating flow rates below system design flow rates. During an average monthly operating cycle in 1997, the facility used between 190,000 and 200,000 kwhrs of electricity, and approximately 10,000 CCF (therms) of natural gas, depending upon ambient temperature and treatment flowpath. In 1997, treatment system chemical usage rates averaged 500 gallons per month for hydrogen peroxide, and 2500 pounds per month for ozone. Pretreatment prior to the UV oxidation system is not currently being practiced, with no adverse findings.

Since system startup, there have been periodic shutdowns for scheduled maintenance activities. The replacement of six concrete C-5000 reactor vessels with stainless steel reactor vessels has been completed. This change was required as a result of leakage that was occurring along cracks in the concrete vessels and at the piping entry points.

Hydrodynamic Performance

Thirteen extraction wells are located along the southern boundary of the project site, adjacent to Big Black Creek. All extraction wells are not operated simultaneously. Typically, nine wells are sufficient to provide capture of the contaminant plume. Selection of operating extraction wells is based on total system flow rate. The extraction wellfield has a history of problems associated with the development of biomass around the well screens and within the well packs. A proprietary rejuvenation process, blended chemical heat treatment (BCHT), has been implemented to improve flow rates in the wells. The flow rates from individual wells vary significantly, and can range from 40 to 100 gpm, depending upon the degree of fouling and aquifer characteristics. It is estimated that the contaminant plume at the site has been contained horizontally and vertically by the extraction well network.

Treatment System Cost

PROCUREMENT PROCESS

The Feasibility Study and the project ROD called for Ultraviolet Oxidation (UV Oxidation) as the selected technology for destruction of organic contaminants present in the groundwater. UV/ozone oxidation was determined to be the most appropriate treatment technology for this site based on a treatability study that evaluated UV/ozone oxidation, UV/peroxide oxidation and GAC. The ROD also directed final effluent discharge to a cold water trout stream located on site (Big Black Creek). Rapid and complete evaluation of the chosen technology was performed by the Corps to determine whether the low discharge standards established by the state could be achieved. The evaluation results indicated that the selected technology would allow the discharge limitations to be met. One of the primary concerns was the contracting effort related to the procurement of the selected treatment system. The number of vendors capable of meeting the treatment performance requirements was limited, and the proposed life cycle costs for the various vendors was an important consideration.

The relatively recent development of the oxidation technology (mid 1970s) is one of the reasons that corporate competition was limited. At the time design was initiated on the groundwater treatment facility (September 1991), only three vendors had exhibited the capabilities necessary to effectively treat a groundwater contaminated with both volatile and semivolatile constituents on a high flow rate (greater than 1 MGD) basis. Because it was anticipated that the treatment system would operate for a long period of time (greater than 30 years), it was anticipated that operation and maintenance (O&M) costs might be more significant than capital costs. Based on this, consideration was given to procurement of the UV Oxidation system based upon life cycle cost rather than capital cost. Based upon the outcome of the predesign testing, a sole source justification was used to procure the UV Oxidation vendor most appropriate for this specific groundwater application. Justification was contingent upon two primary criteria: the capability of the process to treat the contaminated groundwater to acceptable levels, and life cycle cost for the end user. The outcome of this logical progression was a "treat-off" between three vendors to allow the government to obtain the services of the vendor that could most cost effectively address the contaminants present in the site groundwater.

The contract to construct and operate the GWTP for one year was awarded on a firm fixed-price (FFP) basis to Sverdrup of St. Louis, Missouri. The O&M period was later expanded from one year to 2.5 years. At that time, the O&M contract was awarded to Ayers, Lewis, Norris and May of Muskegon, Michigan.

TREATMENT SYSTEM COST

Cost data for the Bofors Nobel project has been developed using available records at the facility. It is estimated that 7,500 pounds of organic compounds were removed from extracted groundwater between September 1994 and October 1997. It is also estimated that 700 million gallons of groundwater have been extracted from the site over the same time period. The following tables list capital and annual O&M costs for the project.

Capital Costs:

DIRECT COSTS	
System Mechanical	
Ultraviolet Oxidation System	2,200,000
Granular Activated Carbon	420,000
Ammonia Stripping	1,200,000
Solids Contact Units	600,000
Filter system	300,000
Sludge Handling	400,000
Chemical Feed	60,000
Chemical Storage	50,000
Hydrated Lime Feed System	150,000
Tankage and Pumps	150,000
System Plumbing/HVAC	900,000
Miscellaneous Equipment	250,000
Architectural/Structural	1,500,000
Electrical/Controls	800,000
Civil/Site	520,000
One Year O&M and System Startup	2,700,000
Contract Amount	**$12,200,000**

Operating Costs:

1997 Average Values	
Staffing/Labor	260,000
Offsite Laboratory Testing	160,000
Process Chemicals	70,000
Parts Replacement and Onsite Lab	20,000
Extraction Well Maintenance	10,000
Interior/Exterior Maintenance	40,000
Miscellaneous Expenses	5,000
Utility Usage	
Electricity (at $0.06 per kwh)	138,000
Natural Gas (at $0.50 per therm (CCF))	60,000
Annual Operating Cost	**$763,000**

Based on these costs, it can be calculated that $13,726,000 has been spent over the first three years of treatment system operation. This total cost translates to treatment costs of $1,830 per pound of contaminant removed, or $19.61 per 1000 gallons of groundwater treated. If removals are compared to annual O&M costs, yearly treatment costs are equal to $305 per pound of contaminant removed, or $3.27 per 1000 gallons of water treated.

REGULATORY/INSTITUTIONAL ISSUES

Surface water discharges from the treatment system are regulated by MDEQ. Discharge limitations for the site are listed in a previous section of this report (Treatment System Performance).

Groundwater cleanup criteria have not yet been established for this site. It is expected that the USEPA will develop these criteria in September 1998 in the form of a second amendment to the ROD for the site.

OBSERVATIONS AND LESSONS LEARNED

Procurement Issues:

It appeared that a FFP contract worked well overall for this project. It is possible that a cost-reimbursable contract would have allowed a higher level of responsiveness to field modifications (especially smaller modifications) to the system during the construction phase. These modifications might have been processed and implemented more rapidly under a cost-reimbursable contract.

Implementation Considerations:

A preliminary understanding of the site characteristics was obtained through the operation of the groundwater extraction system, which went online in 1978. It was recognized that until a remediation decision is made on the source of the contamination (the sludge lagoons), significant headway into reducing the volume of contamination annually treated would be difficult to achieve. It is anticipated that it will be easier to reduce the volume of contamination in the groundwater at the site following a capping or removal action. A preventive maintenance program to insure uninterrupted operation of the groundwater extraction system has been implemented to reduce downtime associated with biofouling and plugging of the well screens.

During selection of the principle treatment technology (UV Oxidation), it was recognized that water quality parameters associated with deposition of various species on the ultraviolet light quartz sheaths could impact system performance, and ultimately increase treatment cost if not addressed during system design. As a result of these concerns, pretreatment components were included in the treatment system to minimize the possibility of poor performance in the principal treatment units.

The establishment of effluent discharge criteria early in the design process is critical in order to provide a treatment system that will be capable of meeting all requirements. Toxicity testing of the plant effluent was stipulated following completion of construction. It is important that the designer be aware of the potential for chronic and acute toxicity testing, so that consideration may be given to alternative treatment schemes that may be necessary to meet toxicity requirements. At a minimum, the designer should closely consult and coordinate with the regulatory personnel responsible for developing the permit requirements to ensure that issues relative to specie selection and dilution concentrations are appropriately addressed for the specific site characteristics.

The concept of having the construction contractor perform initial (first year) O&M of the treatment system appeared to be a good idea. This allows more continuity and a smoother transition from the construction to O&M phase of the project.

Consideration should be given on future projects to the possibility that more system operators will be required during the early stages (first 2 years) of O&M. After this period, it is likely that most operational issues will have been addressed, and that less system troubleshooting will be necessary.

Technology Limitations:

Until an overall remediation strategy is developed to address contamination still present within the ten onsite lagoons, this technology is not expected to reduce the in-situ contamination in the site groundwater to below the levels required by MDEQ. The inability of the constructed system to rapidly reduce the level of site groundwater contamination is a result of the presence of a contamination source area overlying the impacted aquifer. Until the source area is addressed under a separate remediation action, contaminants will continue to leach to the groundwater. No alternative systems have been recommended or identified to improve upon what is currently in place at the Bofors Nobel superfund site for treatment of the contaminated groundwater.

While continuing plume containment appears to be successful, the overall concentrations of VOCs, SVOCs and metals have not been significantly decreased after several years of extraction and treatment.

Future Technology Selection Considerations:

The following observations were made based on conversations with the construction contractor, various vendors, the site construction manager and the using agency.

Perhaps the most important aspect of any project is communication. Maintaining open lines of communication between different agencies insures that the needs of all parties are incorporated into the final product. This aspect of the project was important not only in relation to the UV Oxidation process, but also in regard to items such as establishment of discharge criteria for the completed groundwater treatment facility. Due to the complexity and uniqueness of the selected contracting vehicle, communication was especially critical in this project.

The Treat-Off test associated with the predesign stage of the project required a concerted effort by the designer to insure that the goals of the "treat-off" were clearly communicated to the vendors. This was necessary to insure that the vendors realize that the "treat-off" test is the vehicle by which the selection of the full-scale process will be made. As a lesson learned, communication between the designer and the UV Oxidation vendors regarding the ultimate goals of the pilot testing should be emphasized.

Following selection of the most appropriate vendor for the UV Oxidation system, it was important that good communication was maintained during the design process. Items such as electrical connections, system control, cooling water requirements, system placement, foot print sizing and a host of other technical issues had to be presented to the supplier of the UV Oxidation system.

It is always important, when developing any proprietary specification, that an equitable project cost be maintained, and that cost increases following notification to the vendor of choice be minimized. During predesign activities, it should be emphasized to the prospective suppliers that the final report that they supply to the using agency will be used as the basis of selection for the finished product. It should also be emphasized that the vendor will be held to the costs presented within the report for the full-scale system, provided the final design assumptions do not change. It may be appropriate to enter into a legally binding agreement with the selected vendor to establish capital and operating costs. It should be recognized that operational costs for the full-scale system are an integral part of the projected system costs, and little can be done other than estimate the costs based upon supplier projections. The project designer should review the vendor costs for accuracy. Another potential option is to provide a fixed cost line item within the bid package, so that all prime contractors are aware of the costs associated with the UV Oxidation package.

Following award of the contract, it is important to develop a strong working relationship between the contractor, supplier, and designer, so that a quality product will be supplied. As a part of this process, it is very effective to hold pre-submittal conferences on all major equipment packages to insure that the contractor, supplier, and designer are all fully aware of the requirements of the specific process, and are aware of the responsibilities of each individual. The pre-submittal conferences will set the tone for the subsequent dealings between all of the parties.

REFERENCES

Major Sources for Each Section:

Site Characteristics:	Source #s (from list below) - 3, 4
Treatment System:	Source #s - 6, 8
Performance:	Source #s - 1, 2
Cost:	Source #s - 1, 2
Regulatory Institutional Issues:	Source #s - 4, 7
Schedule:	Source #s - 5
Lessons Learned:	Source #s - 7, 8

Chronological List of Sources and Additional References:

1. 1997 Annual Monitoring information - Facility Operations
2. Monthly Operating Reports 1994 - 1997
3. Remedial Investigation Report for the Bofors Site, Muskegon, Michigan; February 1990.
4. Phase II Remedial Investigation Report for the Bofors Site, Muskegon, Michigan; March 1990.
5. Record of Decision, Bofors Nobel Superfund Site, Muskegon, Michigan; September 1990.
6. Streckfuss, Ted H. "**Lessons Learned: Sole Source Procurement of a UV/Oxidation System and Operating Problems in a Biological Groundwater Treatment Plant.**" Third USACE Innovative Technology Transfer Workshop, June 1993.
7. Streckfuss, Ted H., Olson, Craig R. "**Innovative Contracting Strategies for Equipment Procurement, Bofors Nobel Superfund Site, Muskegon, MI.**" Fourth Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International." November 1992.
8. Streckfuss, Ted H. "**The Greening of Groundwater.**" American Society of Civil Engineers Civil Engineering. April 1995.

ACKNOWLEDGEMENTS

This analysis was originally prepared by:

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(402) 697-2560

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Pump and Treat of Contaminated Groundwater at the City Industries Superfund Site Orlando, Florida

Pump and Treat of Contaminated Groundwater at the City Industries Superfund Site Orlando, Florida

<table>
<tr><td>Site Name:
City Industries Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents and BTEX
- Initial contaminants of concern included 1,1,1-DCA, 1,1-DCE, methylene chloride, vinyl chloride, PCE, TCE, 1,1,1-TCA, benzene, toluene, ethylbenzene, acetone, MEK, MIBK, and phthalates
- Maximum concentrations detected in 1988 included 1,1-DCE (6,000 ug/L), acetone (146,000 ug/L), and MIBK (78,000 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: May 1994 through May 1997</td></tr>
<tr><td>Location:
Orlando, Florida</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Design: Jerry Peters
PEER Consultants P.C.
12300 Twinbrook Pkwy, Suite 410
Rockville, MD 20852
(301) 816-0700
Construction and O&M: ERM-EnviroClean, Inc.
250 Phillips Blvd #280
Ewing, NJ 08618
(609) 895-0050</td><td rowspan="2">Technology:
Pump and Treat with Air Stripping
- Extraction system consists of 13 recovery wells installed across the width of the initial contaminant plume
- Treatment includes an equalization/neutralization tank followed by an air stripping tower
- A network of 41 monitoring wells and 13 recovery wells are used to monitor quarterly changes in groundwater quality
- The actual average pumping rate for the system has been 195 gpm</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 3/29/90</td></tr>
<tr><td>State Point of Contact:
Don Harris
Florida DEP (FDEP)
Twin Towers Office Bldg.
2600 Blair Stone Road
Tallahassee, FL 32301
(904) 488-0190</td><td>EPA Point of Contact:
Pam Scully, RPM
U.S. EPA Region 4
345 Courtland St., N.E.
Atlanta, GA 30365
(404) 562-8898</td></tr>
<tr><td>Waste Source:
Improper disposal practices and unauthorized dumping</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 151.7 million gallons treated as of May 1997
- No NAPL have been observed in monitoring wells on site
- Extraction wells are located in one aquifer at the site
- Hydraulic conductivity reported as 6.3936 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
The hydrogeology at this site is relatively simple and hydraulic conductivity relatively high, conditions which should lead to a successful application for pump and treat technology.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the City Industries Superfund Site Orlando, Florida (continued)

Regulatory Requirements/Cleanup Goals:

- Cleanup goals are to remediate groundwater to levels set by the FDEP for the following constituents: acetone (700 ug/L), benzene (1 ug/L), 1,1-DCA (5 ug/L), 1,1-DCE (7 ug/L), cis-1,2-DCE (70 ug/L), trans-1,2-DCE (70 ug/L), ethylbenzene (700 ug/L), methylene chloride (5 ug/L), MEK (200 ug/L), MIBK (350 ug/L), PCE (3 ug/L), toluene (2,000 ug/L), 1,1,1-TCA (200 ug/L), TCE (3 ug/L), total phthalates (3 ug/L), and vinyl chloride (1 ug/L).
- The primary goal of the system is to achieve hydraulic containment of the plume.

Results:

- From May 1994 through May 1997, total concentrations of contaminants have been reduced 86% from 3,121 to 444 ug/L. However, concentrations of all VOCs remain above cleanup goals. In addition, concentrations of acetone, 1,1-DCE, and MIBK remain at persistently elevated concentrations. Through May 1997, approximately 2,700 pounds of contaminants have been removed from the groundwater.
- No contaminants have been detected in down-gradient monitoring wells since the beginning of remedial operations, and the plume has been contained.

Cost:

- Estimated costs for pump and treat were $1,674,800 ($1,094,800 in capital and $580,000 in O&M), which correspond to $10.60 per 1,000 gallons of groundwater extracted and $590 per pound of contaminant removed.

Description:

The City Industries site operated as a hazardous waste Treatment, Storage, and Disposal Facility (TSDF) from 1971 until 1983. From 1981 through 1983, EPA and county officials cited the facility for multiple violations of RCRA. In 1983, EPA, FDEP, and the county ordered the business to close, and the owner of the site abandoned the property. FDEP completed a multi-phased remedial investigation in May 1986. The site was listed on the NPL in March 1989 and a ROD was signed in March 1990.

The extraction system used at the site consists of 13 recovery wells installed across the width of the initial contaminant plume. Treatment includes an equalization/neutralization tank followed by an air stripping tower. Total concentrations of VOCs have declined 86% at this site, but remain above cleanup levels. The hydrogeology at this site is relatively simple and hydraulic conductivity relatively high, conditions which should lead to a successful application for pump and treat technology. According to the RPM, contaminant levels at the site in late 1997 and 1998 are lower than shown in the May 1997 monitoring data.

SITE INFORMATION

Identifying Information:

City Industries Superfund site
Orlando, Florida

CERCLIS #: FLD055945653

ROD Date: March 29, 1990

Treatment Application:

Type of Action: Remedial

Period of operation: 05/94 - Ongoing (Data collected through May 1997)

Quantity of groundwater treated during application: 151.7 million gallons

Background

Historical Activity that Generated Contamination at the Site: Hazardous waste handling

Corresponding SIC Code: 4953 (Hazardous Waste Material Disposal Sites)

Waste Management Practice That Contributed to Contamination: Improper disposal practices and unauthorized dumping

Location: Orlando, Florida

Facility Operations [1,2,3]:

- The City Industries site operated as a hazardous waste Treatment, Storage, and Disposal (TSD) facility from 1971 until 1983. From 1981 through 1983, U.S. EPA and Orange County officials cited the facility for multiple RCRA violations. In July 1983, EPA, the Florida Department of Environmental Protection (FDEP), and Orange County ordered the business to close under Resource Conservation and Recovery Act (RCRA) authority.

- In 1983, the owner of the site abandoned the facility. That same year, EPA and FDEP performed source control activities, including the FDEP removing 41 tons of waste drums, sludge, and liquid hazardous waste. EPA also thermally treated 1,670 tons of contaminated soil off site, and returned the clean soil to the site as fill. EPA removing 10 tons of highly contaminated soil and transported it to an off-site hazardous waste landfill. As a result of these activities, the only remaining media of concern at the site was the groundwater.

- In 1984, EPA issued an Administrative Order to City Industries requiring cleanup; however, the company ignored the order. In December 1985, the facility owner was found guilty on 17 counts of hazardous waste handling violations and other criminal charges.

- FDEP completed a multiphased Remedial Investigation (RI) in May 1986.

- In 1988, FDEP and the City Industries steering committee entered into an agreement to develop viable cleanup options. The Feasibility Study (FS) was conducted by the Potentially Responsible Parties (PRPs) under a consent agreement between the PRPs and FDEP and was completed in December 1989.

- In March 1989, the site was listed on the National Priorities List (NPL), and EPA assumed oversight responsibility from FDEP. A Record of Decision (ROD) for the site was signed on March 29, 1990.

- In 1991, EPA negotiated a consent decree with the PRPs to fund the necessary activities to clean up the site.

Regulatory Context:

- The ROD for the site was signed in 1990.

- An Explanation of Significant Differences (ESD) was signed in February 1994 to revise the selected remedy and to identify two new contaminants. The ROD called for secondary treatment of effluent to meet POTW pretreatment standards; however, the POTW refused to accept the discharge. The ESD revised the remedy to include air stripping with no secondary treatment and discharge to surface water under an NPDES permit.

SITE INFORMATION (CONT.)

Background (Cont.)

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: The selected groundwater remedy for the site is pumping and treating the contaminated groundwater through air stripping with discharge to surface water, as specified in the ROD and modified in the ESD.

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA

Remedial Project Manager:
Pam Scully*
U.S. EPA Region IV
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 562-8898

State Contact:
Don Harris
Florida Department of Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, FL 32301
(904) 488-0190

Treatment System Vendor:
Jerry Peters
PEER Consultants P.C. (Design)
12300 Twinbrook Parkway, Suite 410
Rockville, MD 20852
(301) 816-0700

Stuart Bills*
ERM-EnviroClean, Inc. (Construction & Operation/Maintenance)
250 Phillips Blvd. #280
Ewing, NJ 08618
(609) 895-0050

* Indicates primary contacts

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,3,10]

Primary Contaminant Groups: Halogenated and nonhalogenated volatile organic compounds (VOCs).

- The initial 14 contaminants of concern at the site were acetone, benzene, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), ethylbenzene, methylene chloride, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), tetrachloroethylene (PCE), toluene, 1,1,1-trichloroethane (1,1,1-TCA), trichloroethylene (TCE), and total phthalates. During construction of the treatment system in 1994, two additional contaminants of concern were identified and added to the list in the ESD: *cis*-1,2-DCE and vinyl chloride.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- The maximum concentrations of contaminants detected during a 1988 FS sampling event were acetone (146,000 µg/L), benzene (100 µg/L), 1,1-DCA (500 µg/L), 1,1-DCE (6,000 µg/L), methylene chloride (165,000 µg/L), MEK (20,000 µg/L), MIBK (78,000 µg/L), toluene (9,000 µg/L), TCE (27,000 µg/L), 1,2-DCE (24,000 µg/L), 1,1,1-TCA (430 µg/L), ethylbenzene (2,100 µg/L), and PCE (380 µg/L). The maximum concentrations of vinyl chloride and *cis*-1,2-DCE detected during 1994 were 2,400 µg/L and 38,000 µg/L, respectively.

- Based on 1986 RI data, site engineers estimated the initial plume covered approximately eight acres extending from the City Industries site toward the drainage canal east of the site. Based on an area of eight acres, a plume thickness of approximately 50 feet, and a porosity of 0.3, the initial plume volume was estimated for this report to be approximately 39 million gallons.

- Contamination has been detected in the upper aquifer (the Surficial Aquifer). Figures 1 and 2 illustrate plume distribution in the Surficial Aquifer in August 1994. Figure 1 depicts concentration contours detected in intermediate zone wells; Figure 2 depicts concentration contours detected in deep zone wells. Intermediate and deep monitoring wells are screened in the top 40 feet and lower 20 to 30 feet of the Surficial Aquifer, respectively.

- Figures 1 and 2 reveal that the majority of the contamination is in the top 40 feet of the Surficial Aquifer. The plume in the top 40 feet (Figure 1) is more concentrated than the plume in the lower 20 to 30 feet (Figure 2). The plume has migrated east of City Industries, concurrent with groundwater flow direction.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [4]

Two distinct hydrogeologic units have been identified beneath this site.

Unit 1	Surficial Aquifer	Unconfined aquifer of fine to medium-grained quartz sand with limestone, gravel, chert, and coarse-grained sand.
Unit 2	Floridan Aquifer	Interlayered clayey gravel, clayey sand, clay, and limestone.

The hydrogeology at the site consists of two units separated by a 140-foot thick aquitard. Groundwater flows in an easterly direction across the site through the 60- to 70-foot thick Surficial Aquifer. This aquifer is not used as a potable source in the vicinity of the site. Groundwater in the Floridan Aquifer has not been characterized because it is not contaminated at the site; however, the City of Winter Park draws its water from a well supply field in the Floridan Aquifer 1,900 feet west of the site. The Surficial and Floridan Aquifers are not hydraulically connected. Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Surficial Aquifer	60-70	6.3936	0.064	East
Floridan Aquifer	100	NA	NA	NA

NA - indicates not characterized
Source: [4]

MATRIX DESCRIPTION (CONT.)

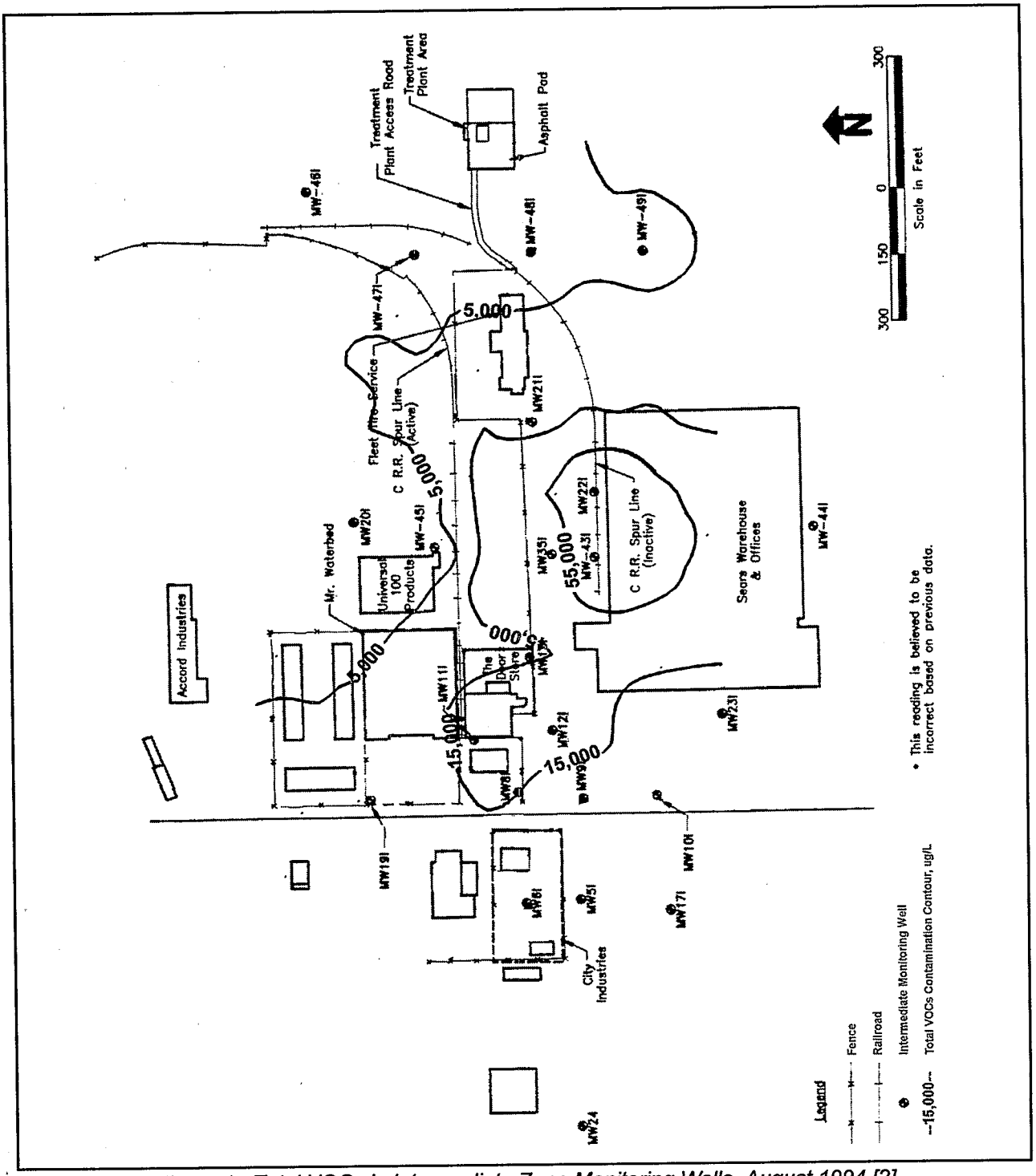

Figure 1. Total VOCs in Intermediate Zone Monitoring Wells, August 1994 [2]

MATRIX DESCRIPTION (CONT.)

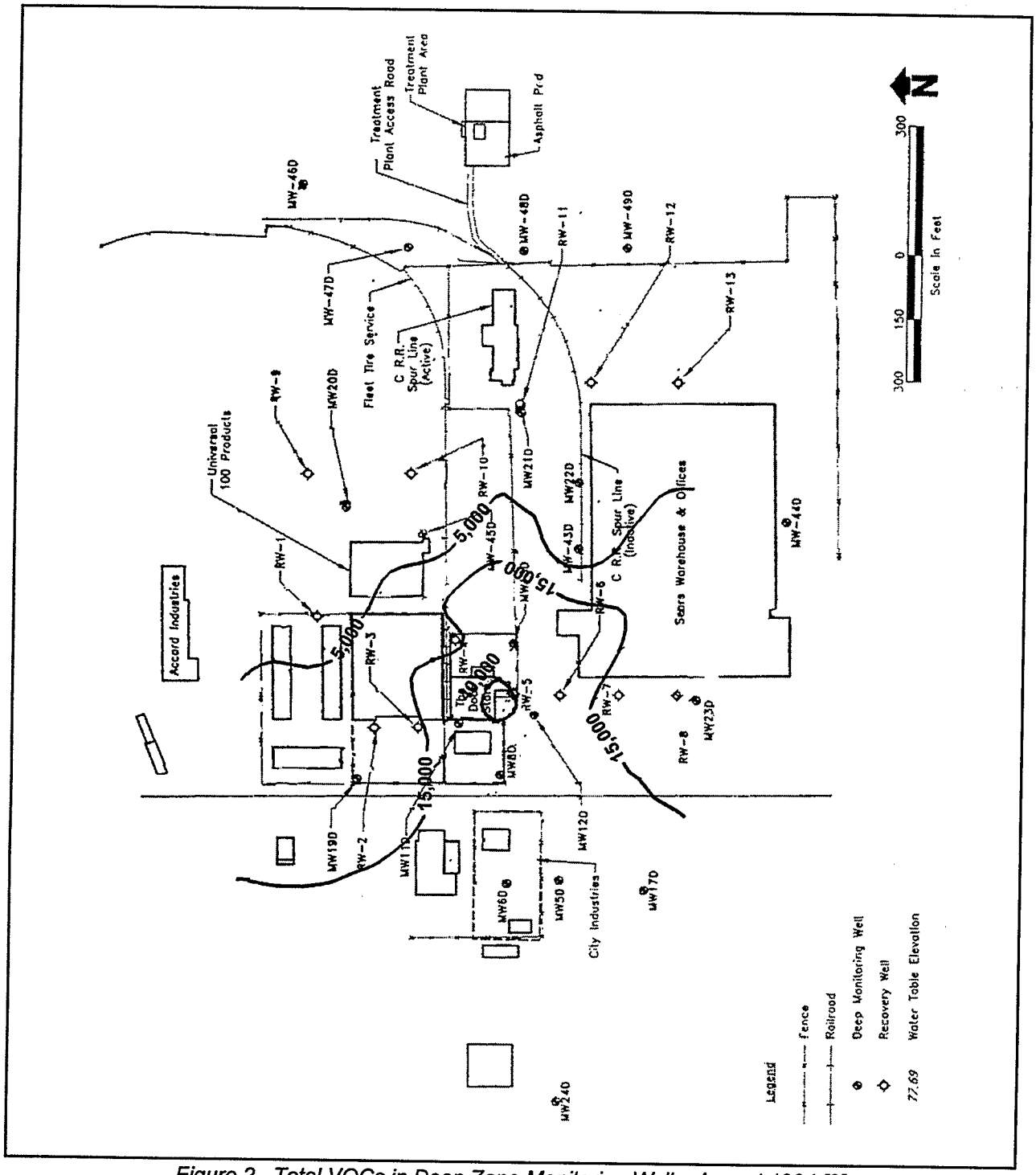

Figure 2. Total VOCs in Deep Zone Monitoring Wells, August 1994 [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with air stripping

Supplemental Treatment Technology

Equalization/neutralization prior to air stripping

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gpm)
RW-1 through RW-8	Surficial Aquifer	25-70	10
RW-9 through RW-13	Surficial Aquifer	25-70	5

Source: [2]

System Description [2]

- The groundwater extraction system consists of 13 recovery wells (RW-1 through RW-13) located on five adjacent properties east of the original site, as listed in Table 2. The recovery wells are divided into two groups, which are installed across the width of the initial contaminant plume. The well placement is designed to intercept the plume and to achieve hydraulic containment of the plume as it flows east. The first group consists of eight recovery wells (RW-1 through RW-8) which are located just downgradient from the site, perpendicular to the plume centerline, where most of the contamination has been found. The second group consists of the remaining five recovery wells (RW-9 through RW-13). These wells are located further downgradient, perpendicular to the centerline and are estimated to be at the leading edge of the contaminant plume.

- The treatment system constructed in 1994 consists of an equalization/neutralization tank followed by an air stripping tower. The 1,500-gallon equalization tank serves to settle aggregates and equalize flow to the tower. The air stripper has been designed for a 97% treatment efficiency.

- Treated water from the air stripper is transported via a gravity pipeline approximately 2,250 feet east to a county-maintained drainage canal (Crane Strand) where it is discharged in accordance with NPDES permit limits.

- A network of 41 monitoring wells and 13 recovery wells is used to measure quarterly changes in groundwater levels and concentrations. Twenty additional monitoring wells are sampled on an annual basis. The monitoring wells are screened at various depths and some are in a series of clusters of shallow, intermediate, and/or deep wells.

System Operation [2,10]

- Quantity of groundwater pumped from the aquifer in gallons:

Year	Volume Pumped (gal)
5/94-4/95	48,430,000
5/95-4/96	47,750,000
5/96-5/97	51,524,849
6/97	3,990,000

- System operations began on May 19, 1994. As of June 1997, the P&T system has been operational approximately 90% of the time.

- A primary operational concern is biological growth on pumps in the wells, in the equalization tank, and in the air stripping tower. Biological growth degrades system performance below design and permit requirements. In June 1996, the system was shut down for 24 hours and the pumps and treatment system were shocked with a high dose of chlorine, which alleviated a biological growth problem.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The air stripping tower packing continues to require cleaning approximately every six months. The air stripping media has been removed and washed with a weak acid solution four times to remove scaling: August 1994, March 1995, November 1995, and April 1996. Discharges (liquid and solid) from the cleaning operations are tested and disposed of according to applicable regulations.

- The extraction system has pumped an average of 105 gpm from May 1994 through June 1997, which meets the design requirement for plume containment.

- EPA Region 4 completed an optimization study in December 1996 to maximize plume capture during pumping. The study examined what pumping rates from all the existing wells were best to maximize zones of influence and to minimize stagnation zones. Pumping options were limited in that the total treatment capacity remained at 115 gpm; however, the study found that zones of influence would increase by decreasing pumping from wells located along the upgradient edge of the plume and increasing pumping from those at the leading edge of the plume. The following recommended changes were incorporated in June 1997: increased pumping in three wells at the leading edge of the plume from 5 to 10 gpm and decreased pumping in three other wells at the upgradient edge from 10 to 5 gpm.

- Quarterly sampling data indicates that several recovery wells are showing no contamination now. Wells with increased rates are drawing in more contaminants, but data are being analyzed to determine if stagnant zones are moving.

- In March 1998, four wells were shut down and the rates in the other wells were increased to try to increase recovery. Sampling was reduced to semi-annual. When results are available the EPA will determine if the plume is still contained or if wells need to be restarted.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the design value for this and other performance parameters.

Table 3. Performance Parameters

Parameter	Value	
Design Pump Rate	115 gpm (actual average = 105 gpm*)	
Performance Standards (Effluent)	Acetone	88,000 µg/L
	Benzene	53 µg/L
	1,1,-Dichloroethane	1160 µg/L
	1,1-Dichloroethene	303 µg/L
	c-1,2-Dichloroethene	1160 µg/L
	trans-1,2-Dichloroethene	1160 µg/L
	Ethyl Benzene	453 µg/L
	Methylene Chloride	1100 µg/L
	Methyl Ethyl Ketone	56,400 µg/L
	Methyl Isobutyl Ketone	42,800 µg/L
	Tetrachloroethylene	84 µg/L
	Toluene	175 µg/L
	1,1,1-Trichloroethane	530 µg/L
	Trichloroethylene	4,500 µg/L
	Vinyl Chloride	525 µg/L
	Xylenes, total	260 µg/L
Remedial Goals (Florida MCLs)	Acetone	700 µg/L
	Benzene	1 µg/L
	1,1,-Dichloroethane	5 µg/L
	1,1-Dichloroethene	7 µg/L
	c-1,2-Dichloroethene	70 µg/L
	t-1,2-Dichloroethene	70 µg/L
	Ethyl Benzene	700 µg/L
	Methylene Chloride	5 µg/L
	Methyl Ethyl Ketone	200 µg/L
	Methyl Isobutyl Ketone	350 µg/L
	Tetrachloroethylene	3 µg/L
	Toluene	2,000 µg/L
	1,1,1-Trichloroethane	200 µg/L
	Trichloroethylene	3 µg/L
	Total Phthalates	3 µg/L
	Vinyl Chloride	1 µg/L

Source: [1, 2]
*The average of 105 gpm was provided in the Interim Long-Term Response Action Report.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
3/90	--	ROD issued
1992	--	Final remedial design completed
2/94	--	ESD issued
5/94	---	Construction of the treatment system and extraction wells completed
5/94	ongoing	System operation begun

Source: [2]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1, 2]

Cleanup goals are to remediate groundwater to levels set by the Florida Primary Drinking Water Standards (which for this site are the same as Maximum Containment Levels (MCLs) set by the Federal Primary Drinking Water Standards). These standards are listed in Table 3 and are applied throughout the aquifer.

Treatment Performance Goals [1, 2]

- The primary performance goal of the P&T system is to achieve hydraulic containment of the plume.
- The performance goal of the treatment system is to reduce effluent contaminant concentrations to meet NPDES permit requirements listed in Table 3.

Performance Data Assessment [2, 5, 6, 9, 10]

For the purposes of this report, total VOCs consist of acetone, benzene, 1,1-DCA, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, ethylbenzene methylene chloride, MEK, MIBK, PCE, toluene, 1,1,1-TCA, TCE, total phthalates, and vinyl chloride.

- Figure 3 illustrates the trend of average total VOC concentrations from May 1994 through May 1997. Total concentrations of contaminants have been reduced 86% during this period, from 3,121 µg/L to 444 µg/L. However, concentrations of all VOCs remain above cleanup goals.
- Although concentrations have been reduced significantly, three of the VOCs show persistently elevated concentrations: acetone, 1,1-DCE, and MIBK. Nonetheless, maximum levels of acetone have decreased 84%, from 146,000 µg/L to 23,000 µg/L. Maximum levels of 1,1-DCE have declined 52% from 6,000 µg/L to 2,900 µg/L. Maximum levels of MIBK have declined 93% from 78,000 µg/L to 5,000 µg/L.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (continued) [2, 5, 6, 9, 10]

- Figures 4 and 5 illustrate contours of total VOCs detected during August 1996 sampling events in intermediate and deep monitoring wells, respectively. Compared to the plume of total VOCs detected in August 1994 (illustrated in Figures 1 and 2), the volume of total VOCs in the plume detected in August 1996 has decreased. The 55,000 µg/L contour in the intermediate wells has decreased in size from 1994 to 1996. In addition, the level of maximum VOCs has decreased in the deep wells from 40,000 µg/L in August 1994 to 8,000 µg/L in August 1996.

- No contaminants have been detected in downgradient monitoring wells since the beginning of remedial operations, and the plume has been contained. In addition, monitoring done since 1997 has shown that the plume has reduced in size. No plume map was available to demonstrate the change in size.

- Figure 6 illustrates total VOC concentrations in wells MW-13D, MW-43I, and MW-22I, where contamination is concentrated. Concentrations have decreased exponentially since operations began. In February 1996, an increase was seen in all three wells; however, concentrations have continued to decrease since 1996.

- Effluent standards for the treatment system have been met during system operation.

- From June 1994 through May 1997, the P&T system removed approximately 2,700 pounds of contaminant mass from the groundwater. Figure 7 shows mass flux rate and total contaminant removal from June 1994 through May 1997. The mass flux rate spiked in April 1996, but the spike is attributed to a high concentration of acetone detected during that sampling event.

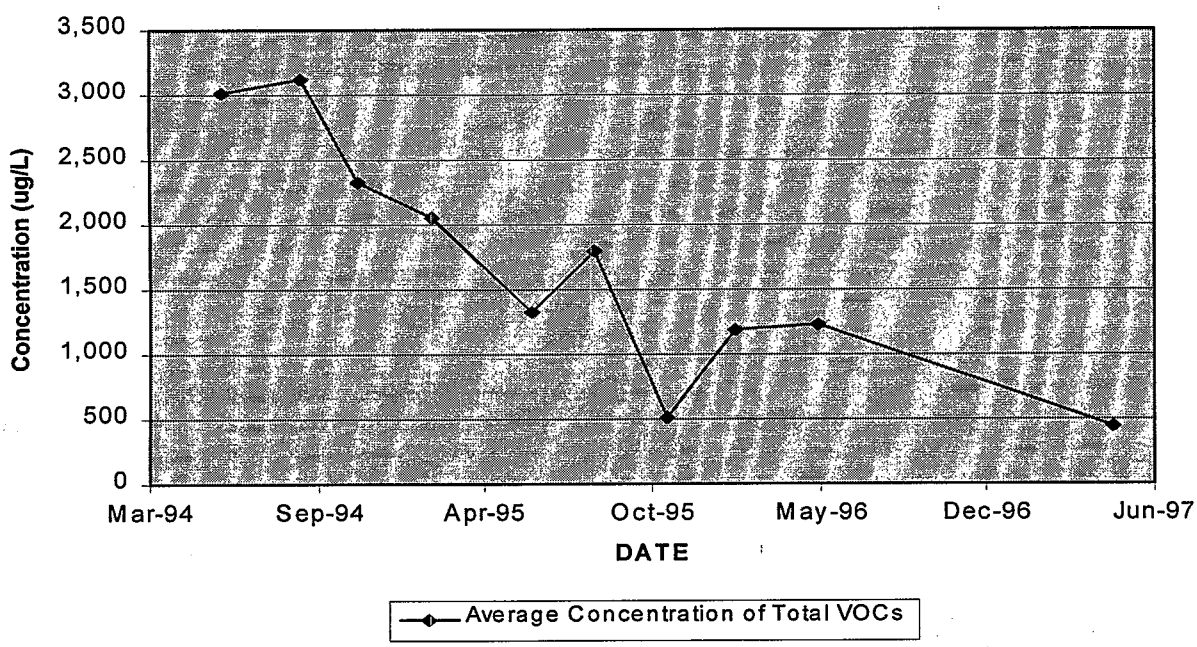

Figure 3. Average of Total VOCs in all Monitoring Wells from May 1994 through May 1997 [2,5,6,9]

TREATMENT SYSTEM PERFORMANCE (CONT.)

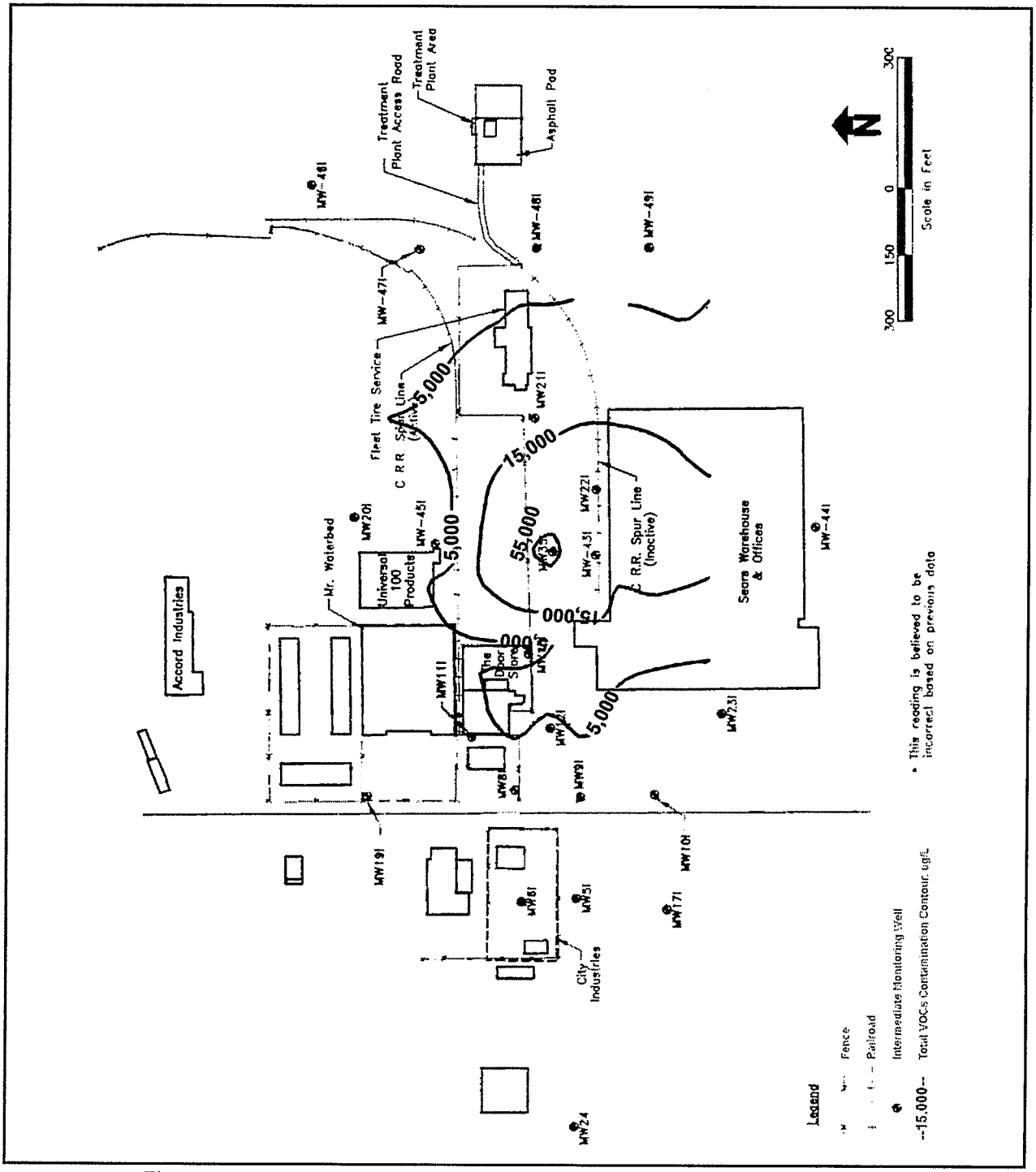

Figure 4. Total VOCs in Intermediate Zone Monitoring Wells, August 1996 [2]

TREATMENT SYSTEM PERFORMANCE (CONT.)

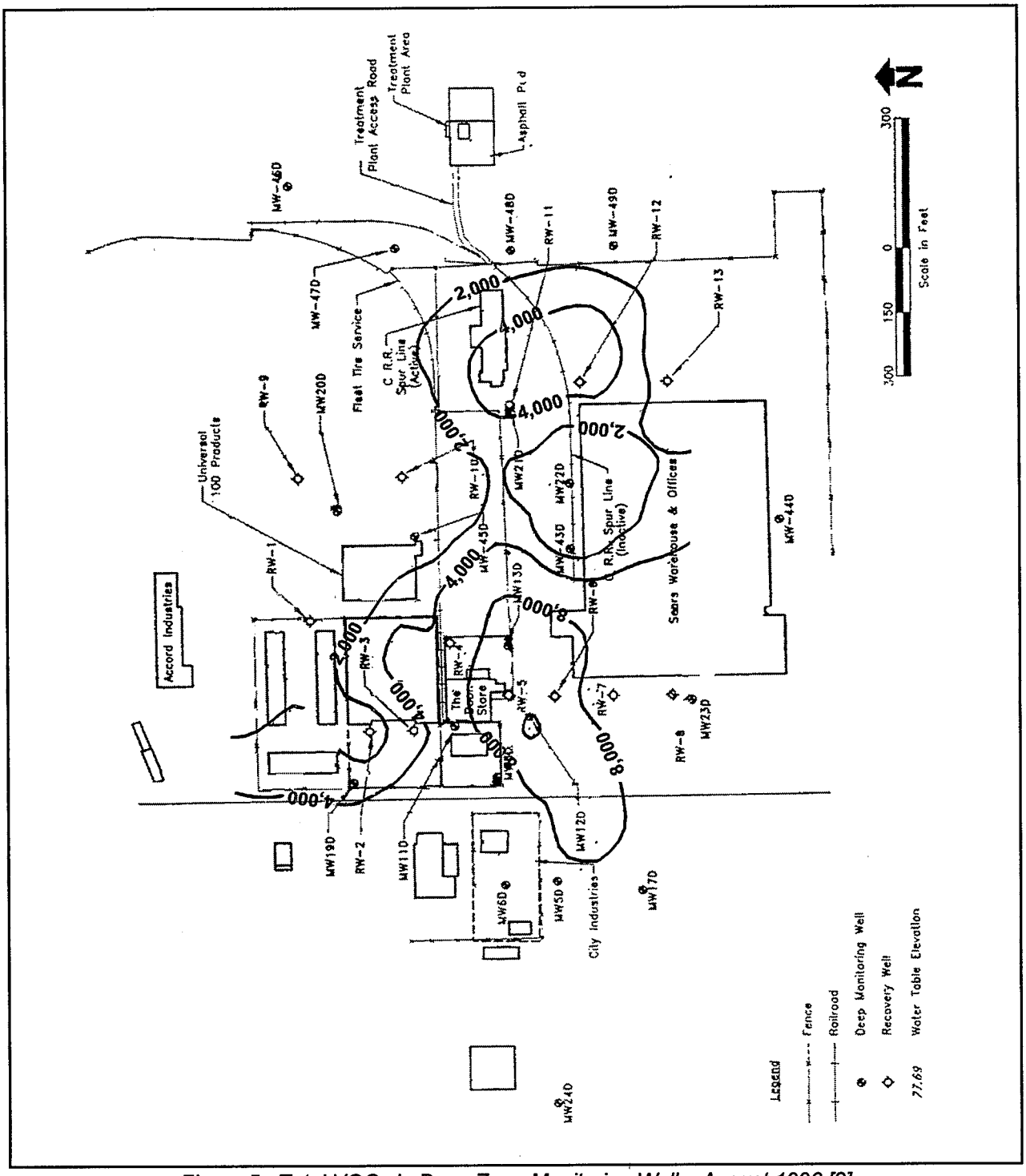

Figure 5. Total VOCs in Deep Zone Monitoring Wells, August 1996 [2]

TREATMENT SYSTEM PERFORMANCE (CONT.)

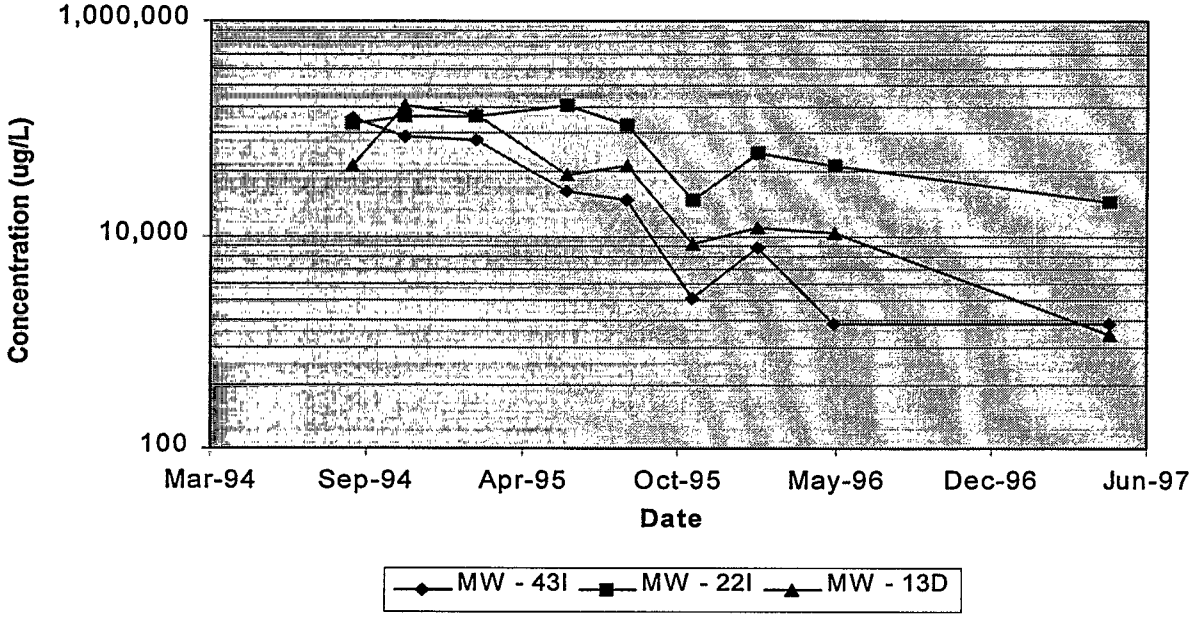

Figure 6. Total VOCs Concentrations in Highly Contaminated Wells, May 1994 through May 1997 [2,5,6,9]

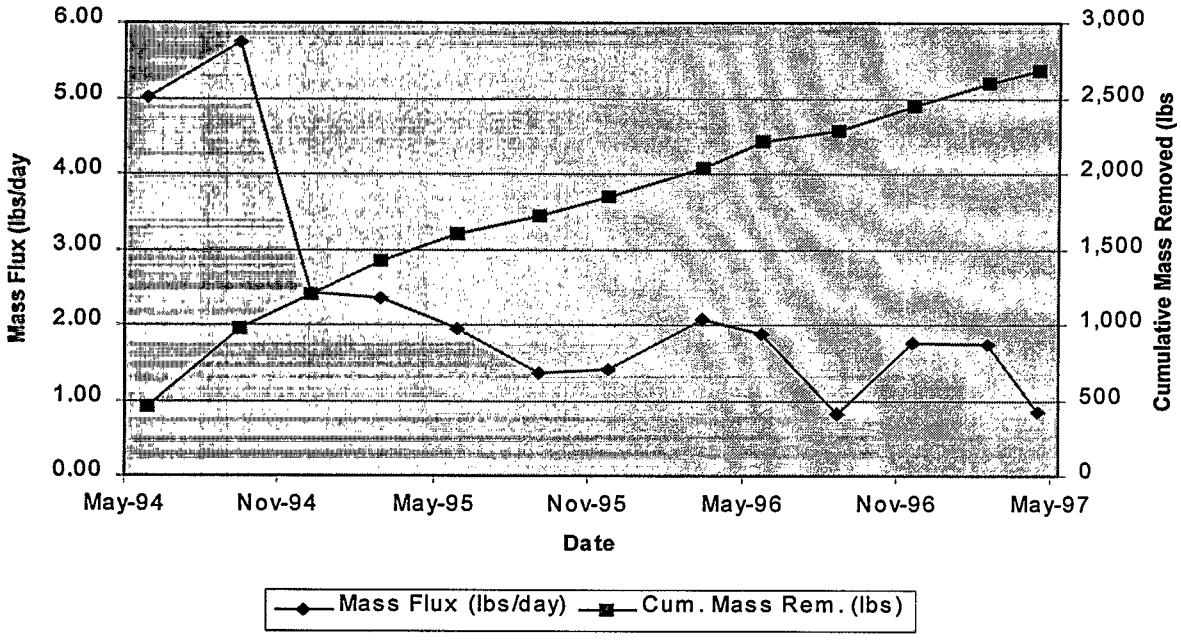

Figure 7. Mass Flux and Cumulative Mass Removal, June 1994 through May 1997 [2,6,9]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Monthly data for contaminant concentrations in monitoring and recovery wells are available for June 1994 through May 1996 in the Interim Long-Term Remedial Action Report. Quarterly data for contaminant concentrations in monitoring and recovery wells are available in monthly reports from the site operators for September 1996 through September 1997. At the time of preparation of this report, the site contact (the EPA RPM) had not received reports past May 1997. For the analyses in this report, including the average concentrations of total VOCs shown in Figures 3 and 6, quarterly data were used from June 1994 through May 1996 and annual data were used from May 1996 through May 1997.
- For Figure 3 analyses, the average concentration of total VOCs was calculated using a geometric mean of contaminant concentrations in wells within the initial contaminant plume. A geometric mean was used to show the trend of contaminant levels across the site. Where contaminant levels were below detection limits, half of the detection limit was used.
- Monthly data regarding contaminant removal through the treatment system are available for June 1994 through May 1997 in the Monthly Operations and Maintenance Reports. For the mass removal analyses in Figure 7 of this report, quarterly data were used from June 1994 through May 1997.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Florida requirements. All monitoring was performed using EPA-approved methods, and the site contact did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

EPA contracted with Peer Consultants, P.C. to design the groundwater extraction and treatment system. EPA awarded the construction, startup and O&M (2-year base period) contract to ERM-EnviroClean, Inc. FDEP was the lead agency until 1989, at which time EPA took over the lead and maintained responsibility for operation and maintenance of the treatment system.

Cost Analysis

All costs incurred for remedial activities at this site were borne by Potentially Responsible Parties (PRPs).

TREATMENT SYSTEM COST (CONT.)

Capital Costs [4]

Remedial Construction	
Mobilization and Preparatory Work	$174,700
Site Work	$68,100
Well Installation, Instrumentation, and Piping	$559,140
Install Well Manholes	$13,700
Air Stripper	$202,060
Effluent Pipeline	$27,100
Demobilization	$50,000
Total Construction	**$1,094,800**

Operating and Maintenance Costs [4,5]

5/94 - 4/95	$186,250
5/95-4/96	$186,250
5/96-5/97	$133,295
Total O&M	**$505,795**

Other Costs [4]

Remedial Design	
Remedial Design	$190,234
Preparatory Work	$90,494
Tank Removal	$74,377
Field Data Development	$147,922
Treatability Studies	$38,979
Closeout	$5,619
Remedial Oversight	$34,913
Total Design	**$582,538**
EPA Personnel	**$99,675**

Cost Data Quality

Capital and operations and maintenance cost data were supplied in a 1994 Cost Study of the site, originated from the treatment vendor, and were updated by the RPM.

OBSERVATIONS AND LESSONS LEARNED

- Approximate costs for the P&T system at this site were $1,674,800, consisting of $1,094,800 in capital costs and $580,000 in cumulative operating and maintenance costs through May 1997, which corresponds to $590 per pound of contaminants removed and $10.60 per 1,000 gallons of groundwater treated.

- Total concentrations of VOCs have declined 86% at this site, but remain above cleanup goals.

- The mass flux rate illustrated in Figure 6 is more constant over time than at many P&T sites. The hydrogeology at the site is relatively simple and hydraulic conductivity is relatively high compared to typical hydraulic conductivities [7]. In addition, no pure phase, or nonaqueous phase liquid (NAPL), has been detected at the site [5].

- Given the matrix of contaminants at this site, there is potential for cometabolic degradation. Cometabolic degradation of TCE, DCE, and vinyl chloride is supported in the presence of aromatic compounds, such as toluene [8].

- Based on conversations with the RPM for the site, contaminant levels in late 1997 and 1998 at the site are lower than the May 1997 monitoring data.

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- The site contractor did not anticipate biofouling in the air stripper in the design. According to the contractor, design specifications assumed a different temperature and alkalinity for the groundwater from actual conditions. Chlorine treatment was found to alleviate biofouling and the system has been operational 90% of the time.
- The RPM also indicated that the P&T system has lowered contaminant concentrations in extracted water to levels below effluent NPDES requirements. Thus, in the near future, the extracted water may be discharged directly to the POTW and treatment will not be necessary.

REFERENCES

1. Record of Decision, City Industries Superfund Site, U.S. EPA Region 4, March 9, 1990.
2. Interim Long-Term Response Action Report, City Industries Superfund Site, U.S. EPA Region 4, Undated.
3. Explanation of Significant Differences, U.S. EPA Region 4, February 1994.
4. Cost and Performance Profile, City Industries Superfund Site, U.S. EPA Hazardous Site Control Division Remedial Operations and Guidance Branch, unpublished.
5. Correspondence with Pam Scully, EPA RPM. April, May, and December 1997, February, March, and April 1998.
6. Monthly Operation and Maintenance Reports, June 1996 - May 1997. ERM-EnviroClean, Inc.
7. Groundwater Regions of the United States. Heath, Ralph. U.S. Geological Survey Water Supply Paper 2242, 1984.
8. Biofilm Reactor for Chlorinated Gas Treatment, Remediation Technologies, Inc. Internet publication, http://clu-in.com/site/complete/remediat.htm, May 21, 1998.
9. Twelfth Quarterly Groundwater Sampling Results; City Industries Superfund Remediation Project, ERM EnviroClean, Inc., September 19, 1997.
10. Comments on draft report provided by Pam Scully, Region 4 Remedial Project Manager, July 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. and Eastern Research Group, Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at
the King of Prussia Technical Corporation Superfund Site
Winslow Township, New Jersey

Pump and Treat of Contaminated Groundwater at the King of Prussia Technical Corporation Superfund Site Winslow Township, New Jersey

<table>
<tr><td>Site Name:
King of Prussia Technical Corporation Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents, BTEX, Heavy metals
- Contaminants of concern include 1,1-DCA, trans-1,2-DCE, 1,1,1-TCA, TCE, PCA, PCE, benzene, toluene, ethylbenzene, beryllium, chromium, copper, and nickel
- Maximum initial concentrations included PCE (2,500 ug/L), trans-1,2-DCE (12 ug/L), 1,1,1-TCA (2,200 ug/L), and chromium (1,040 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: April 1995 through December 1997</td></tr>
<tr><td>Location:
Winslow Township, New Jersey</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Treatment System Vendor: Andco Environmental Processes, Inc.
Operations: Geraghty and Miller, Inc.</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 11 wells at an average total pumping rate of 175 gpm in the upper aquifer and 25 gpm in the lower aquifer
- Extracted groundwater is treated with an electrochemical system for removal of heavy metals, and air stripping and granular activated carbon for removal of organics
- Treated groundwater is reinjected through infiltration trenches and galleries</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/9/90</td></tr>
<tr><td>Additional Contact:
Frank Opet
PRP Coordinator
Johnson Matthey
2001 Nolte Drive
West Deptford, NJ 08066
(609) 384-7222</td><td>EPA Point of Contact:
Jon Gorin, RPM
U.S. EPA Region 2
290 Broadway, 19th Floor
New York, NY 10007-1866
(212) 637-4361</td></tr>
<tr><td>Waste Source:
Discharge of waste to surface impoundment/lagoon; unauthorized dumping</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 151.5 million gallons treated as of December 1997
- Groundwater is found at 15-35 ft bgs (shallow aquifer) and from 50-250 ft bgs (deep aquifer)
- Extraction wells are located in two aquifers
- Hydraulic conductivity ranges from 55 to 100 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Treatment system consists of a treatment train designed for removal of metals and organics.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The remedial goal for the site is to reduce contaminant concentrations to below maximum contaminant levels (MCLs) set by the New Jersey Safe Drinking Water Act and the primary drinking water standards. Cleanup goals were established for beryllium (4 ug/L), cadmium (10 ug/L), chromium (50 ug/L), copper (1,000 ug/L), mercury (2 ug/L), nickel (210 ug/L), zinc (5,000 ug/L), 1,1-DCA (2 ug/L), trans-1,2-DCE (10 ug/L), 1,1,1-TCA (26 ug/L), TCE (1 ug/L), PCA (1.4 ug/L), PCE (1 ug/L), benzene (1 ug/L), toluene (2,000 ug/L), and ethylbenzene (50 ug/L).
- The extraction system was designed to create an inward hydraulic gradient to contain the plume.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the King of Prussia Technical Corporation Superfund Site Winslow Township, New Jersey (continued)

Results:

- Cleanup goals for metals and VOCs have been met in the deep aquifer and for all but some wells in the shallow aquifer (two for VOCs and four for metals). Groundwater monitoring data indicate that the plume appears to have been contained.
- From March 1995 through December 1997, the treatment system removed 1,510 pounds of organics and 3,910 pounds of metals, for a total mass removal of 5,420 pounds.

Cost:

- Actual costs for pump and treat were approximately $2,816,000 ($2,031,000 in capital and $785,000 in O&M), which correspond to $19 per 1,000 gallons of groundwater extracted and $520 per pound of contaminant removed.

Description:

The King of Prussia Technical Corporation operated as a waste disposal and recycling facility from January 1971 until early 1974, with six lagoons used to process industrial waste. EPA estimates that the company processed at least 15 million gallons of acid and alkaline wastes at this site. Drums of VOCs were buried at the site. In addition, trash and hazardous waste are suspected to have been dumped at the site illegally between 1976 and 1988 after the company stopped operations. Soil and groundwater contamination were detected by the state in 1976, and the site was added to the NPL in September 1983. A ROD was issued for this site in September 1990.

Groundwater is extracted at this site using six wells in the shallow aquifer and five wells in the deep aquifer. Extracted groundwater is treated with an electrochemical system for removal of heavy metals, and air stripping and granular activated carbon for removal of organics. Treated groundwater is reinjected through infiltration trenches and galleries. Cleanup goals for metals and VOCs have been met in the deep aquifer and for all but some wells in the shallow aquifer. As of December 1997, groundwater elevations have achieved steady-state under the current pumping scheme. The groundwater flow and contaminant transport will be reevaluated using models to evaluate remediation enhancements, including adding or removing extraction wells. In addition, the site operator is considering pumping changes.

SITE INFORMATION

Identifying Information:

King of Prussia Technical Corporation
Winslow Township, New Jersey

CERCLIS # NJD980505341

ROD Date: September 9, 1990

Treatment Application:

Type of Action: Remedial

Period of operation: April 1995 - Ongoing
Data collected through December 31, 1997

Quantity of groundwater treated during application: 151.5 million gallons

Background [1,2,3]

Historical Activity that Generated Contamination at the Site: Waste disposal and recycling

Corresponding SIC Code: 4953, Sanitary Services - Refuse Systems

Waste Management Practice That Contributed to Contamination: Discharge of waste to surface impoundment/lagoon; unauthorized dumping

Location: Winslow Township, New Jersey

Facility Operations:

- The 10-acre King of Prussia (KOP) site is located in a light industrial area and is bordered to the northeast, northwest, and southwest by a wooded state park and to the southeast by Piney Hollow Road.
- The KOP Technical Corporation operated as a waste disposal and recycling facility from January 1971 until early 1974.
- Six lagoons were used to process industrial waste. An on-site swale directed site runoff toward the Great Egg Harbor River, located approximately 1,000 feet southwest of the site.
- The swale has been designated a wetlands, and the Great Egg Harbor is used for recreational purposes.
- EPA estimates that, while in operation, the KOP Technical Corporation processed at least 15 million gallons of acid and alkaline waste at this site. Drums of VOCs were buried at the site. Also, trash and hazardous waste are suspected to have been dumped at the site illegally between 1976 and 1988 after KOP ceased operations.
- Soil and groundwater contamination were detected by the State of New Jersey in 1976. Subsequently, the KOP site was added to the National Priorities List (NPL) in September 1983. As part of initial removal actions conducted from 1985-1989, EPA excavated plastic containers and metal drums.
- Elevated levels of metals were identified in soils, lagoon sludges, swale sediment, and groundwater at the site. Elevated levels of volatile organic compounds (VOCs) were detected in soils in the drum disposal area and in the groundwater.
- Soil and sediment were remediated on site by soil washing in 1993. Tankers and buried drums were removed and disposed of off site.
- A cost and performance report entitled *Soil Washing at the King of Prussia Technical Corporation Superfund Site, Winslow Township, New Jersey* was previously prepared about the soil washing application at this site.

Regulatory Context:

- A Record of Decision (ROD) was issued for the site in September 1990 and included remedial activities for operable unit 1 (OU1) for soil and sediment contaminated with metals, OU2 for removal of contaminated soil in the area of the buried drums, and OU3 for groundwater.

SITE INFORMATION (CONT.)

Background (Cont.)

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: The selected remedy for OU4, groundwater remediation, was extraction of groundwater followed by treatment for metals and VOCs to capture the contaminated groundwater and prevent discharge of contaminants to the Great Egg Harbor River. The ROD also designated on-site groundwater treatment to remove contaminants from the collected groundwater, followed by a system to reinject treated groundwater into the aquifer.

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA

PRP Contact:
Frank Opet*
PRP Coordinator
Johnson Matthey
2001 Nolte Drive
West Deptford, NJ 08066
(609) 384-7222

*Indicates primary contacts

Remedial Project Manager:
Jon Gorin*
U.S. EPA Region 2
290 Broadway, 19th Floor
New York, NY 10007-1866
(212) 637-4361

Treatment System Vendor:
Operations: Geraghty and Miller, Inc.
Treatment System Vendor: Andco Environmental Processes, Inc.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,4]

Primary Contaminant Groups: Metals, VOCs

- The contaminants of greatest concern at this site are metals and VOCs. The metals of concern are beryllium, chromium, copper, and nickel. The VOCs of concern are 1,1-dichloroethane (1,1-DCA), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), trichloroethylene (TCE), 1,1,2,2-tetrachloroethane (1,1,2,2-PCA), tetrachloroethylene (PCE), benzene, toluene, and ethylbenzene.
- Cleanup standards are set for total chromium. Likewise, laboratory analyses test for total chromium. For these reasons, chromium levels tested and regulated at the KOP site are for total chromium.
- Figure 1 illustrates the site layout and the contaminant plumes as delineated using 1993 sampling data. Figure 1 is a compilation of drawings provided by the PRP coordinator. During the 1985-1989 remedial investigation, the metals and VOC plumes were determined to be commingled but originating from different sources.

MATRIX DESCRIPTION (CONT.)

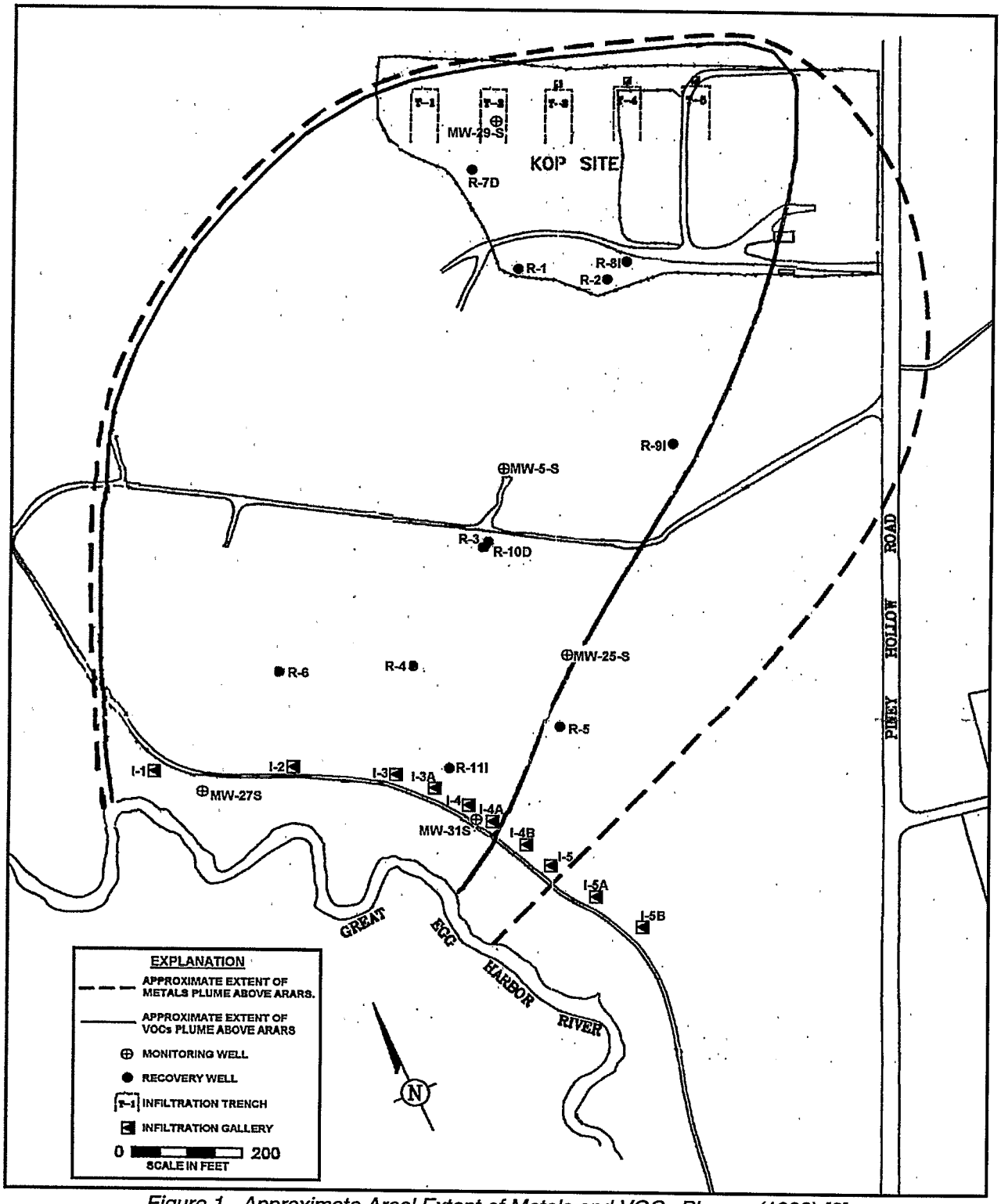


Figure 1. Approximate Areal Extent of Metals and VOCs Plumes (1993) [3]

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- The metals plume originated from wastes that were dumped throughout the site onto the soil in lagoons and in the former swale. Contamination in the metals plume is evenly distributed, with hot spots around wells 5-S (center of the plume) and 29-S (northern portion of the plume).

- The maximum initial metals concentrations detected by EPA during remedial investigations from 1985-1989 in the shallow, or upper, aquifer were 100 µg/L (beryllium), 1,040 µg/L (chromium), 12,500 µg/L (copper), and 4,670 µg/L (nickel). The metals contamination is 99% contained in the upper aquifer. Cadmium, mercury, and zinc were detected in the shallow aquifer, but at concentrations below concern.

- The upper 10 to 15 feet of the deep aquifer is referred to as the intermediate aquifer. Copper and nickel were the only two compounds that were detected at concentrations of concern in the intermediate aquifer. The maximum initial concentrations of copper and nickel detected during the 1985-1989 remedial investigation in the intermediate aquifer were 3,070 µg/L and 899 µg/L, respectively.

- Chromium was the only metal detected at levels of concern in the deep aquifer. The maximum chromium concentration detected during the 1985-1989 remedial investigation was 77 µg/L.

- The VOC plume originated at the northeastern end of the site in the shallow aquifer, in the former drums location. This area is noted in Figure 1 as the location of the infiltration trenches. Contamination in the VOC plume is concentrated in the northeastern part of the plume, with the highest contamination in well 29-S.

- The maximum initial VOC concentrations detected during the 1985-1989 remedial investigation in the shallow aquifer were 1,1-DCA at 64 µg/L; *trans*-1,2- DCE at 12 µg/L; 1,1,1-TCA at 2,200 µg/L; TCE at 940 µg/L; 1,1,2,2-PCA at 2,900 µg/L; PCE at 2,500 µg/L; benzene at 8 µg/L, toluene at 190 µg/L and ethylbenzene at 80 µg/L [1]. However, PCE was detected at levels as high as 20,000 µg/L during an April 1995 sampling event.

- TCE was the only VOC detected at levels of concern in the deep aquifer. The maximum initial concentration of TCE detected during the 1985-1989 remedial investigations in the deep aquifer was 3 µg/L.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [1]:

The site is underlain by unconsolidated Coastal Plain sediments of unconsolidated sands, gravels, and clays. Underlying the sediment formations is relatively low permeability metamorphic bedrock.

Two hydraulic units were identified in the Remedial Investigation/Feasibility Study (RI/FS) at the KOP site. Both of these aquifers are part of the regional Kirkwood-Cohansey Aquifer system. The shallow aquifer begins at 15 feet and extends to approximately 35 feet below ground surface. A 10- to 20-foot semiconfining layer separates the shallow and deep aquifers and is composed predominately of discontinuous silt and clay zones. The deep aquifer extends downward from 50 feet to approximately 250 feet below ground surface. The upper 10 to 15 feet of the deep aquifer is referred to as the intermediate aquifer.

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

The groundwater flow direction at the KOP site is southwest, towards the Great Egg Harbor River. Lateral groundwater flow in the shallow and deep aquifers is approximately 1 and 0.4 foot per day, respectively. The shallow aquifer discharges to the Great Egg Harbor River, while the deep aquifer may only discharge a minor flow component to the river. Contamination from metals and VOCs are primarily in the shallow aquifer.

There are no residential wells in the vicinity of the site. Two wells, neither of which serve as potable water supplies, are located within a half-mile radius of the site. The nearest residential water wells are located approximately one mile northeast and upgradient of the site.

Tables 1and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Linear Velocity (ft/day)	Flow Direction
Shallow	20	56-100	1.0	Southeast
Deep*	200	55-62	0.4	Southeast

*The upper 10-15 feet of the deep aquifer are referred to as the intermediate zone in some reports.

Source: [1]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with an electrochemical system and granular activated carbon treatment

Supplemental Treatment Technology

None

System Description and Operation [3,4,8]

Table 2. Technical Well Data

Well Name*	Unit Name	Depth (ft)
R-1S	Shallow	34
R-2S	Shallow	34
R-3S	Shallow	28
R-4S	Shallow	26
R-5S	Shallow	42
R-6S	Shallow	26
R-7D	Deep	95
R-8I	Deep	51
R-9I	Deep	50
R-10D	Deep	92
R-11I	Deep	57

* S denotes well screened in shallow aquifer, I denotes well screened in upper 10-15 feet of the deep aquifer (intermediate), and D denotes well screened in lower portion of the deep aquifer.

Source: [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

System Description

- The extraction well system includes 11 wells throughout the plume, as listed in Table 2.
- The shallow recovery wells are designed to pump a total of 175 gpm from the shallow aquifer. The deep and intermediate wells are designed to pump a total of 25 gpm from the deep aquifer. These pump rates were determined using the computer models MODFLOW and MT3D.
- Two recovery wells, R-1 and R-2, were placed in the shallow aquifer near the buried drums area at the northern portion of the plume. Recovery wells R-7D and R-8I were placed in the deep aquifer in the same area.
- Recovery wells R-10D and R-9I were placed in the deep aquifer at the center of the plume, where the greatest metals contamination is located. Recovery well R-3 was placed in the shallow aquifer in the same area.
- Recovery wells R-4, R-5, and R-6 were placed in the shallow aquifer and R-11I in the deep aquifer at the toe of the plume.
- Groundwater is pumped through the wells to an equalization tank to regulate flow. It is then fed into an electrochemical treatment system.
- The electrochemical system, developed by Andco Environmental Processes, Inc.. is a heavy metals removal process that can be applied to chromium-, copper-, and nickel-contaminated groundwater. A direct current is conducted through a cell containing carbon steel electrodes, which generates ferrous iron, reducing Cr^{+6} to Cr^{+3}. Trivalent chromium then complexes with hydroxyl groups to form chromium hydroxide, which is insoluble in water. The electrodes are consumed in generating the ferrous ions and require periodic replacement. The reaction occurs at a pH of six to nine. Copper and nickel form insoluble hydroxides and precipitate out at a pH of six to nine. The electrochemical system reduces the chromium and copper concentrations to less than 10 µg/L, and nickel concentrations to less than 20 µg/L.
- After metals treatment, the water passes through an inclined plate clarifier for sludge separation. Sludge is pumped out, dewatered, and disposed off-site. Clarified water is sent through a set of multimedia filters.
- Filtered water is passed through two packed air stripping towers to remove organics. GAC units were added because TCA, PCE, and TCE did not meet effluent requirements. Since the addition of GAC, the effluent meets requirements.
- Treated effluent is tested for effluent contaminant criteria. Of the effluent, 40% is reinjected through five infiltration trenches upgradient of the plume and 60% is reinjected through 10 infiltration galleries downgradient of the plume.
- Reinjected water works to recharge the aquifer as well as to desorb contaminants from the aquifer material into the groundwater.
- Groundwater is monitored according to the Long Term Monitoring Plan (LTMP), which requires quarterly testing of five monitoring wells and annual monitoring of 13 monitoring wells.

System Operation

- Quantity of groundwater pumped from the aquifer in gallons:

	Total Gallons Pumped	Aquifer
3/95-3/31/96	55.1 million	Shallow and deep
4/1/96-3/31/97	55.5 million	Shallow and deep
4/1/97-12/31/97	40.9 million	Shallow and deep

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The order of treatment units was optimized for efficiency and minimal operational problems. Metals removal is followed by air stripping and carbon polishing for organics.

- The treatment system has been operational approximately 76% of the time. The major downtime occurred between February 10, 1997 and April 1, 1997 to repair a crack in one filter. Also, during this shutdown, multimedia filter tanks were emptied to allow re-engineering of the system in all tanks and installation of new media in the proper order for maximum filtration [2].

- The agreed time frame of two years and eight months of monitoring under the Long Term Monitoring Plan has ended, and a new proposal will be provided by the PRPs to EPA for sampling in the future [2]. The past monitoring plan will be used until a new one is developed [3].

- According to operations contractor, Geraghty and Miller, Inc., as of December 1997, the groundwater elevations at the site have achieved steady-state under the current pumping scheme. At this point, the groundwater flow and contaminant transport at the site will be reevaluated using MODFLOW and MT3D to evaluate remediation enhancements, including adding or removing extraction wells [5]. The site operator is considering pumping changes.

- Monitoring data indicate that contaminant levels in the deep aquifer are below cleanup criteria [2]. According to the PRP representative, the redeveloped monitoring plan and remediation enhancements may focus on remediation of the shallow aquifer [3]. The requested change is awaiting EPA approval.

- The PRP contact also indicated that, after cleaning the well and changing a pump, pump rates in R-1 were increased in 1998. The organics concentrations in the area of MW-29S decreased as a result of the higher pumping rates.

Operating Parameters Affecting Treatment Cost or Performance

A major operating parameter affecting cost or performance for pump and treat is the extraction rate. Table 3 presents design values for this and other performance parameters.

Table 3. Performance Parameters [1,3]

Parameter	Value	
Design Pump Rate	175 gpm, upper aquifer 25 gpm, lower aquifer	
Performance Standard (Effluent)	Be	4.0 µg/L
	Cd	10 µg/L
	Cr	50 µg/L
	Cu	1,000 µg/L
	Mercury (Hg)	2 µg/L
	Ni	210 µg/L
	Zn	5,000 µg/L
	1,1-DCA	2 µg/L
	trans-1,2-DCE	10 µg/L
	1,1,1-TCA	26 µg/L
	TCE	1 µg/L
	1,1,2,2-PCA	1.4 µg/L
	PCE	1 µg/L
	Benzene	1 µg/L
	Toluene	2,000 µg/L
	Ethylbenzene	50 µg/L
Remedial Goal (Aquifer)	same as Performance Standards	

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4. Timeline

Start Date	End Date	Activity
9/29/90	---	ROD signed
8/94	---	Remedial Design completed
3/93	11/93	Soil washing performed
4/95	Ongoing	Groundwater extraction, treatment, and quarterly monitoring
Ongoing	---	Recalibration of groundwater models, reanalysis of extraction well placement, consideration of remedial alternatives

Source: [1-3]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

The remedial goal for the site is to reduce concentrations of contaminants at the site to below the Maximum Contaminant Levels (MCLs) set by the New Jersey Safe Drinking Water Act and the Primary Drinking Water Standards. The required cleanup levels are listed above in Table 3 and are applied throughout both the shallow and deep aquifers, as measured in all monitoring wells [1].

Treatment Performance Goals

- Effluent discharged from the treatment system must meet the remedial goals listed in Table 3 for reinjection [1].
- The extraction system is designed to create an inward hydraulic gradient to contain the plume [1].

Performance Data Assessment [2,3]

For the purpose of this analysis, metals include beryllium, cadmium, chromium, copper, mercury, and zinc and total VOCs include 1,1-DCA, trans-1,2-DCE, 1,1,1-TCA, TCE, 1,1,2,2-PCA, PCE, benzene, toluene, and ethylbenzene.

- Cleanup goals for metals and VOCs appear to have been met in the deep aquifer. Cleanup goals for metals and VOCs have not been met overall in the shallow aquifer; however, cleanup goals for VOCs have been met in all but two wells in the shallow aquifer.
- Figures 2 and 3 depict the trend of metals and VOC concentrations, respectively, in the shallow aquifer groundwater.
- Based on groundwater monitoring data, the plume appears to have been contained.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

Metals

- Metals concentrations in the shallow aquifer have been reduced to levels below cleanup goals in some wells. Metals goals have been met at the southwest end of the plume.
- Figure 2 illustrates metals concentrations in individual wells with contamination above cleanup goals and the average metals concentrations in the shallow aquifer from September 1994 to March 1997. The concentrations of metals decreased in all wells from September 1994 to April 1995; however, concentrations fluctuated in wells 25-S and 5-S. Well 5-S, located at the center of the site, has the highest concentrations of metals.
- Below are the remaining constituents above cleanup goals in the shallow aquifer:
  - The maximum concentration of beryllium has been reduced by 35%, from 100 µg/L in April 1994 to 65 µg/L in December 1997, above the cleanup goal of 4 µg/L.
  - The maximum concentration of chromium has been reduced by 87%, from 1,040 µg/L detected during the 1985-1989 remedial investigation to 137 µg/L in December 1997, above the cleanup goal of 50 µg/L.
  - The maximum concentration of copper has been reduced by 77%, from 12,500 µg/L detected during the 1985-1989 remedial investigation to 2,900 µg/L in December 1997, above the cleanup goal of 1,000 µg/L.
  - The maximum concentration of nickel has been reduced by 62%, from 1,100 µg/L detected during the 1985-1989 remedial investigation to 680 µg/L in December 1997, above the cleanup goal of 210 µg/L.

VOCs

- In the shallow aquifer, VOC contaminant levels have decreased overall.
- VOC contamination is concentrated in the source areas of wells 5-S and 29-S. Figure 3 illustrates that the VOC concentrations in wells 5-S and 29-S fluctuate, primarily because of fluctuating PCE and 1,1,1-TCA concentrations in the former drum area.
- Wells 5-S and 29-S are the only wells with elevated levels of *trans*-1,2-DCE and 1,1,1-TCA. The remainder of the wells show low levels of TCE, 1,1,2,2-PCA, PCE, and TCE, but no detectable levels of the other organics of concern.
- Below are data on individual VOCs in the shallow aquifer:
  - The concentrations of 1,1-DCA in the shallow aquifer have met cleanup goals. The maximum concentration of 1,1-DCA in the shallow aquifer was reduced from 64 µg/L detected during the 1985-1989 remedial investigation to levels below detection limits in December 1997 (cleanup goal is 2 µg/L).
  - The maximum concentration of *trans*-1,2-DCE in the shallow aquifer has increased from 12 µg/L detected during the 1985-1989 remedial investigation to 160 µg/L in December 1997 (cleanup goal is 10 µg/L).
  - The maximum concentration of 1,1,1-TCA fluctuated from 2,200 µg/L detected during the 1985-1989 remedial investigation to 4,670 in September 1997 to 2,420 in December 1997 (cleanup goal is 26 µg/L).
  - The maximum concentration of 1,1,2,2-PCA has been reduced from 2,900 µg/L detected during the 1985-1989 remedial investigation to 190 µg/L in December 1997 (cleanup goal is 1.4 µg/L).

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- The maximum concentration of PCE has fluctuated from 2,500 µg/L detected during the 1985-1989 remedial investigation, to 20,000 µg/L in April 1995, to 15,000 µg/L in February 1996, and most recently to 8,160 µg/L in December 1997, above the cleanup goal of 1 µg/L.

- The maximum concentration of TCE in the shallow aquifer has been reduced from 980 µg/L detected during the 1985-1989 remedial investigation to 310 µg/L in December 1997, above the cleanup goal of 1 µg/L.

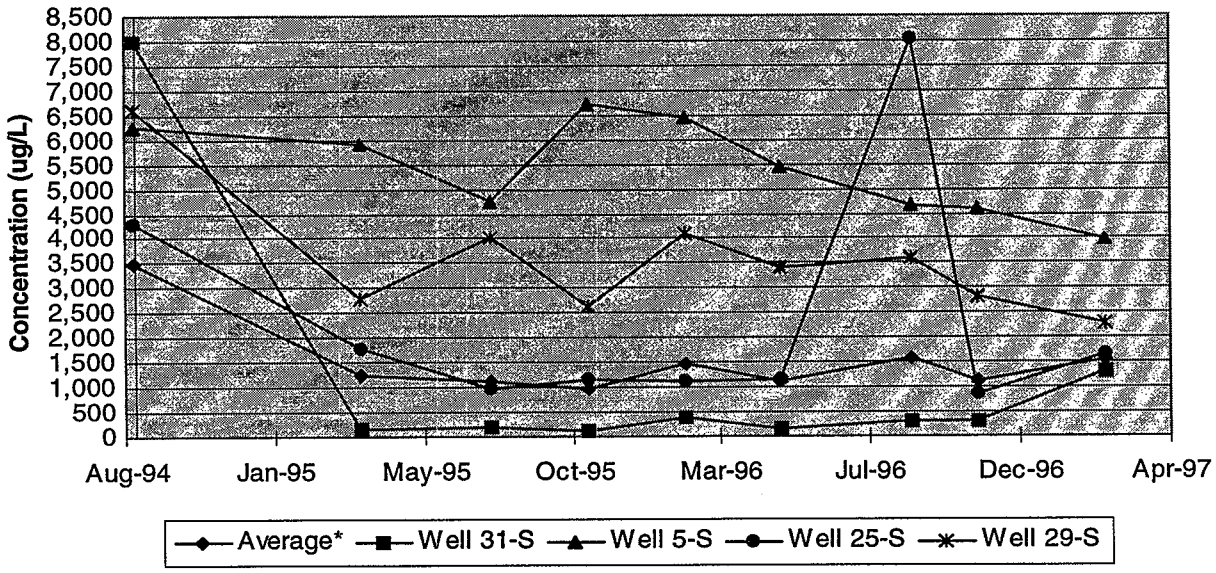
- Benzene, toluene, and ethylbenzene have been detected solely in well 29-S. In December 1997, ethylbenzene was detected at a concentration of 1,130 µg/L, above the cleanup goal of 50 µg/L. Benzene was detected at levels below detection limits, below the cleanup goal of 1 µg/L. Toluene was detected at 1,130 µg/L, below the cleanup goal of 2,000 µg/L.

Treatment System

- Effluent monitoring results indicate that during January 1997, VOC concentrations in the treatment effluent were slightly above treatment performance goals. After maintenance during treatment system shutdown, treatment performance goals have been met.

- Figure 4 illustrates concentrations of contaminants in the influent to the treatment system. The metals concentration in the influent varied from 20 µg/L in March 1995 to 5,591 µg/L in July 1996 to 2,532 in October 1997. The VOCs concentration in the influent increased from March to June 1995, from 1,236 to 2,170 µg/L, and primarily declined from June 1995 to October 1997.

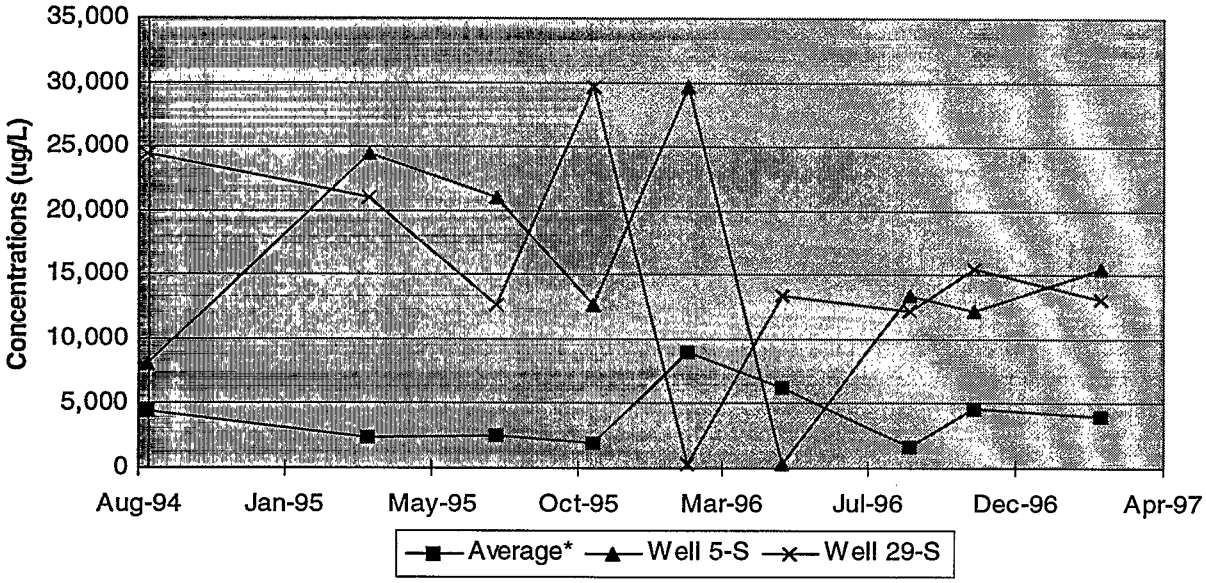
- During operation from March 1995 through December 1997, the treatment system removed 1,510 lbs of organics and 3,910 lbs of metals, for a total mass removal of 5,420 lbs. The rate of mass removal declined as the mass in the influent declined.



*Average concentrations include wells 5-S, 25-S, 27-S, 29-S, and 31-S

Figure 2. Metals Contaminant Concentrations in the Shallow Aquifer (September 1994 - March 1997) [2]

TREATMENT SYSTEM PERFORMANCE (CONT.)



*Average concentrations include wells 5-S, 25-S, 27-S, 29-S, and 31-S

Figure 3. VOC Contaminant Concentrations in the Shallow Aquifer (September 1994 - March 1997) [2]

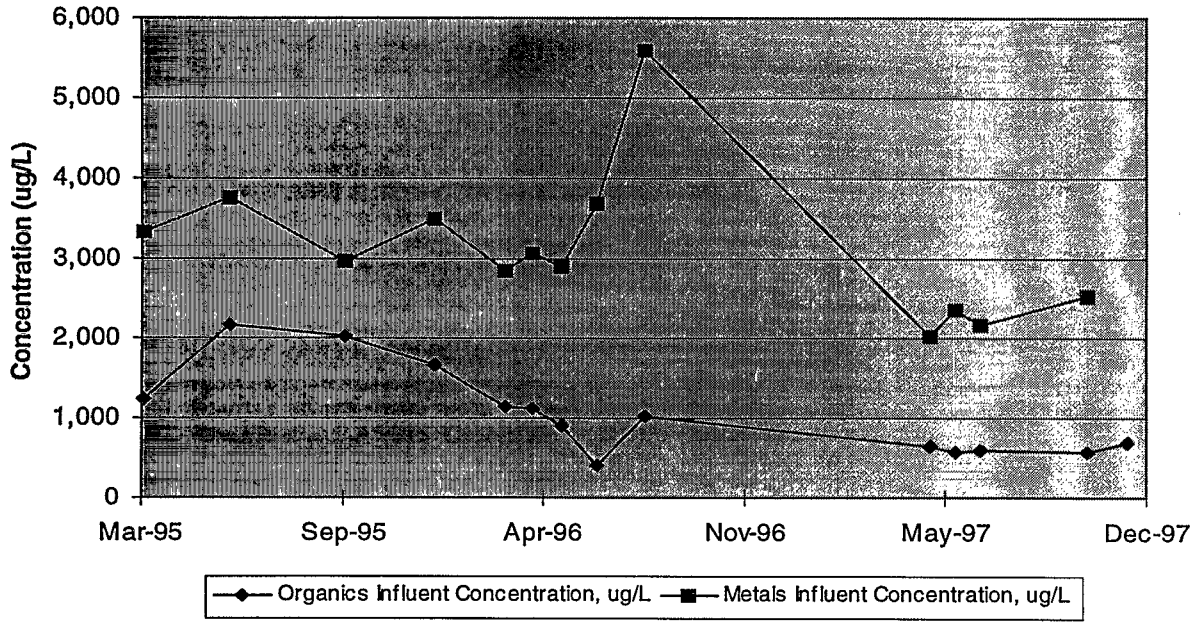


Figure 4. Influent Concentrations to the Treatment System (March 1995 - November 1997) [2]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- For the contaminant concentrations shown in Figures 2 and 3, quarterly monitoring data were used from September 1994 through March 1997. Annual monitoring data from a separate subset of wells are available from the PRP site contact. However, because the annual data used in conjunction with the quarterly data would not have represented a continuous data set for analysis, these data were not used for Figure 2 and 3 analyses.
- A geometric mean of contaminant concentrations was used to represent the trend of contaminant concentrations across the site for Figures 2 and 3.
- Contaminant concentrations in the influent shown in Figure 4 were reported in quarterly monitoring reports for March 1995 through November 1997.
- Mass removal calculations were reported in quarterly monitoring reports for March 1995 through November 1997.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of New Jersey requirements. All monitoring was performed using EPA-approved methods, and the site contact did not note any exceptions to the QA/QC protocols [2].

TREATMENT SYSTEM COST

Procurement Process

- The PRPs contracted with Geraghty & Miller, Inc. to construct and operate the remedial system, under the oversight of EPA. Geraghty & Miller, Inc. contracted with Andco Environmental Processes, Inc. to provide and install the treatment system.

Cost Analysis

- All costs for investigation, design, construction and operation of the treatment system at this site were borne by the PRPs.

Capital Costs [3]

Remedial Construction	
Groundwater Treatment	**$1,743,563**
Equipment	$927,127
Permits	$31,637
Construction Management	$234,548
SOP/D&M Manual	$63,681
Electrical System Construction	$130,424
Other Subs	$194,003
Plant Construction	$131,924
Cultural Resources	$30,219
Groundwater Control	**$287,703**
Well Construction	$116,166
Recovery System Construction	$171,707
Total Construction	**$2,031,430**

Operating Costs (1995-1997) [3]

Labor	$325,760
Travel	$14,325
Disposal (Sludge and Water)	$2,432
Chemicals	$49,226
Lab Supplies	$1,017
Health & Safety Supplies	$3,941
Administrative Expenses	$46,950
Maintenance	$159,542
Utilities	$181,501
Total Operations	**$784,694**
Operations By Year	
March 1995 - April 1995	$74,230
May 1995 - April 1996	$393,740
May 1996 - April 1997	$284,131
May 1997 - April 1998	$281,298*

*June 1997 - April 1998 costs of $251,443 not included in unit costs

TREATMENT SYSTEM COST (CONT.)

Other Costs [3]

Groundwater Investigations	$250,860
Groundwater Modeling	$140,718
Western Plume Boundary	$40,652
Treatability Study	$87,247
Treatment System Design	$304,145
Overall Design Management	$379,473
Well Installation Costs	$279,617
Total Other	**$1,482,712**

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the PRPs for this application.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the P&T application at the KOP site were approximately $2,816,000 ($2,031,000 in capital costs and $785,000 in operating and maintenance costs), which corresponds to $520 per pound of contaminants removed and $19 per thousand gallons of groundwater treated, based on cost incurred and treatment performed through December 31, 1997.

- Cleanup goals have been met in the deep aquifer, but not the shallow aquifer. Two shallow wells, in source areas, remain contaminated with VOCs. Four wells remain contaminated with metals.

- The concentrations of VOCs and metals in treatment system influent have decreased faster than concentrations in shallow monitoring wells. Concentrations of PCE and 1,1,1-TCA in these wells were higher during the November 1997 sampling than in the baseline sampling, and concentrations of other contaminants in the wells fluctuated, spiking above baseline sampling levels.

- There are several possible explanations for why treatment influent concentrations are falling faster than concentrations in the shallow monitoring wells. Two conditions would allow extracted water to circumvent the more contaminated areas. One is the tendency of contaminants in the groundwater to travel through preferential pathways, as observed at some Superfund sites [6]. Another possible factor is stagnation zones, which develop where low hydraulic gradients are created in overlapping zones of influence from recovery wells and/or from low permeability zones [7]. Stagnation zones and preferential pathways can be counteracted by adjusting the location and pumping rates of the extraction wells. The PRPs are evaluating P&T performance and will consider such adjustments to optimize mass removal and contaminant reduction [3,5].

- While no dense nonaqueous phase liquid (DNAPL) has been directly observed during sampling, high initial concentrations of TCE and PCE indicated its likely presence. If DNAPL is present at this site, it will lead to persistent plumes, as it dissolves continuously into the aqueous phase. Elimination of possible DNAPL sources, if present, could improve the effectiveness of P&T at this site.

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4. Correspondence with Mr. Jack Reich, Andco Environmental Processes, Inc., February 1998.

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6. Surfactant-Enhanced Remediation of a TCE-Contaminated Aquifer, Smith, James A., Sahoo, D., McLellan, H.M., and Imbrigiotta, T.E. Environmental Science and Technology, 1997, V.31, No-12, 3565-3572.

7. Design Guidelines for Conventional Pump-and-Treat Systems, Robert M. Cohen, James W. Mercer, Robert M. Greenwald, and Milovan S. Beljin. EPA Ground Water Issue, September 1997.

8. Comments on draft report provided by Frank Opet, PRP Representative, July 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. and Eastern Research Group, Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the LaSalle Electrical Superfund Site, LaSalle, Illinois

Pump and Treat of Contaminated Groundwater at the LaSalle Electrical Superfund Site, LaSalle, Illinois

Site Name: LaSalle Electrical Superfund Site	**Contaminants:** PCBs and chlorinated solvents - Maximum concentrations detected in 1980-1981 were PCBs (760,000 ug/L), TCE (13,341 ug/L), trans-1,2-DCE (7,152 ug/L), 1,1,1-TCA (3,123 ug/L), and vinyl chloride (500 ug/L)	**Period of Operation:** Status: Ongoing Report covers: 12/92 - 5/97
Location: LaSalle, Illinois		**Cleanup Type:** Full-scale cleanup (interim results)
Vendor: Ecology & Environment, Inc. ThermoCor Kimmons	**Technology:** Pump and Treat - Groundwater is extracted using 3 infiltration trenches, at an average total extraction rate of 17 gpm - Extracted groundwater is treated with oil/water separation, air stripping, and carbon adsorption, and discharged to a POTW	**Cleanup Authority:** CERCLA Remedial - ROD Date: 3/30/88
Additional Contacts: None		**State Point of Contact:** Rich Lange Illinois EPA (IEPA) 2200 Churchill Road P.O. Box 19276 Springfield, IL 62794-9276 (815) 223-1126
Waste Source: Spills from capacitor cleaning and spreading polychlorinated biphenyl (PCB)-laden waste oils as a dust suppressant	**Type/Quantity of Media Treated:** Groundwater - 23 million gallons treated as of May 1997 - DNAPL observed in groundwater on site - Groundwater is found at 3-5 ft bgs - Contaminants are primarily found in a shallow aquifer at the site - Hydraulic conductivity ranges from <0.01 to 0.22 ft/day	
Purpose/Significance of Application: Relatively high unit cost; system consists of collection trenches instead of extraction wells; relatively low groundwater flow.		

Regulatory Requirements/Cleanup Goals:
- The goal of this remedy is to restore the groundwater to primary drinking water standards; these are PCBs (0.5 ug/L), 1,2-DCE (5 ug/L), 1,1-DCA (5 ug/L), TCE (5 ug/L), PCE (100 ug/L), 1,1,1-TCA (200 ug/L), and vinyl chloride (2 ug/L).
- Containment was not a specific goal of this remediation.

Results:
- Groundwater monitoring results for the deep aquifer (through March 1996) and shallow aquifer (through May 1997) indicate that total contaminant concentrations have not been reduced below cleanup goals. At specific monitoring wells, contaminant concentrations fluctuate with precipitation rates.
- From 1993 to September 1997, the system removed approximately 127 pounds of contaminants from the groundwater; 1,1,1-TCA makes up the majority of the mass removed by the treatment system.

Pump and Treat of Contaminated Groundwater at the LaSalle Electrical Superfund Site, LaSalle, Illinois (continued)

Cost:

- Actual costs for pump and treat are approximately $6,138,576 ($5,314,576 in capital and $824,000 in O&M), which correspond to $266 per 1,000 gallons of groundwater extracted and $48,000 per pound of contaminant removed.

Description:

LaSalle Electrical Utilities operated this site as a manufacturing facility for electrical equipment from 1940 to 1978. PCBs and chlorinated solvents were used in the manufacturing process during this time. As a result of complaints, government agencies issued several orders in 1975 against the company for its manufacturing and waste handling practices. In 1980 and 1981, Illinois EPA performed sampling at the site which confirmed the presence of PCB and VOC contamination in soils and groundwater. The site was placed on the NPL in December 1982 and a ROD was signed in March 1988.

The groundwater collection system is a passive design that uses three infiltration trenches instead of wells. The three trenches form an H-pattern, and drain to a wet well, which in turn is pumped to the treatment unit. The trenches were installed horizontally at a depth of approximately 17 to 25 ft bgs. Approximately 127 pounds of contaminants (primarily 1,1,1-TCA) have been removed from the groundwater over 45 months, however the system has not achieved the cleanup goals. As of May 1997, no design modifications were being considered for this site.

SITE INFORMATION

Identifying Information:

LaSalle Electrical Superfund Site
LaSalle, Illinois

CERCLIS #: SCD980711394

ROD Date: March 30, 1988

Treatment Application:

Type of Action: Remedial

Period of operation: 12/92 - Ongoing
(Data collected through 1997)

Quantity of material treated during application: 23 million gallons of groundwater

Background

Historical Activity that Generated Contamination at the Site: Electrical equipment manufacturing

Corresponding SIC Code: 3612 (power, distribution, and specialty transformers)

Waste Management Practice That Contributed to Contamination: Spills from capacitor cleaning and spreading polychlorinated biphenyls (PCB)-laden waste oils as a dust suppressant

Location: LaSalle, Illinois

Facility Operations: [4,7]

- LaSalle Electrical Utilities (LEU) operated this 10-acre site as a manufacturing facility for electrical equipment from 1940 to 1978. PCB and chlorinated solvents were used in the manufacturing processes during this time.
- Site contamination resulted from operations, spills of dielectric fluids from capacitor cleaning, and PCB-laden waste oils that were applied as a dust suppressant to the ground surface.
- As a result of complaints, government agencies issued several orders in 1975 against LEU for its manufacturing and waste handling practices.
- In 1980 and 1981, Illinois EPA (IEPA) performed sampling at the site which confirmed the presence of PCB and volatile organic compound (VOC) contamination in soils and groundwater.
- In 1981, EPA ordered LEU to cease operations because of its waste management practices and existing health threats.
- The site was placed on the National Priorities List (NPL) in December 1982.
- Between 1982 and 1986, several emergency removal actions occurred at the site to package, stage, or cap highly contaminated soil.
- A remedial investigation (RI) and feasibility study were completed between 1983 and 1985.
- In March 1986, after review of the draft RI report, the U.S. EPA elected to split the site into two separate projects. The 1985 RI had adequately characterized the soil contamination in the area. However, it had failed to sufficiently determine the extent of groundwater contamination emanating from the LEU property. A second RI addressing groundwater conditions was completed in 1988.
- Under a separate Record of Decision (ROD), (issued in September 1986), highly contaminated soils were excavated and incinerated. The incinerated soils were replaced and regraded across the site.

Regulatory Context:

- A ROD was signed for groundwater remediation on March 30, 1988.

SITE INFORMATION (CONT.)

Background (Cont.)

- Site activities were conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection:
The selected remedy for groundwater at this site was extraction and treatment of groundwater via air stripping and carbon adsorption.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

State Contact:
Rich Lange*
Illinois EPA (IEPA)
2200 Churchill Road
P.O. Box 19276
Springfield, Illinois 62794-9276
(815) 223-1126

Treatment System Vendor:
Ecology & Environment, Inc.
ThermoCor Kimmons

*Indicates primary contact

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [6, 7]

Primary Contaminant Groups: PCBs and halogenated VOCs

- The primary contaminants of concern at this site are the PCBs: Arochlor-1242, -1248, and -1254; and VOCs: tetrachloroethylene (PCE), trichloroethylene (TCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethane (1,1-DCA), and vinyl chloride (VC).
- Maximum groundwater contaminant concentrations detected by EPA during initial investigations in 1980-1981 were PCB (760,000 µg/L), TCE (13,341 µg/L), trans-1,2-DCE (7,152 µg/L), 1,1,1-TCA (3,123 µg/L), and VC (500 µg/L).
- The plume of groundwater contaminants initially detected in 1980 was estimated by the IEPA to cover over 700,000 square feet [7].
- Figure 1 illustrates PCB concentration contours at the LaSalle Electrical site in 1982. The plume of VOCs is not shown in Figure 1; however, the VOC plume is approximately the same size and in the same location.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- Concentrations of PCBs in soils up to 17,000 ppm were detected at several locations on site. These soils were excavated and incinerated in 1991 and 1992.
- Site engineers observed a dense non-aqueous phase liquid (DNAPL) in the bottom three to five feet of a 10 foot well casing up to 300,000 µg/L PCB. The amount of DNAPL present in the subsurface was unknown; however, significant quantities of oily liquids were removed with excavated soils.

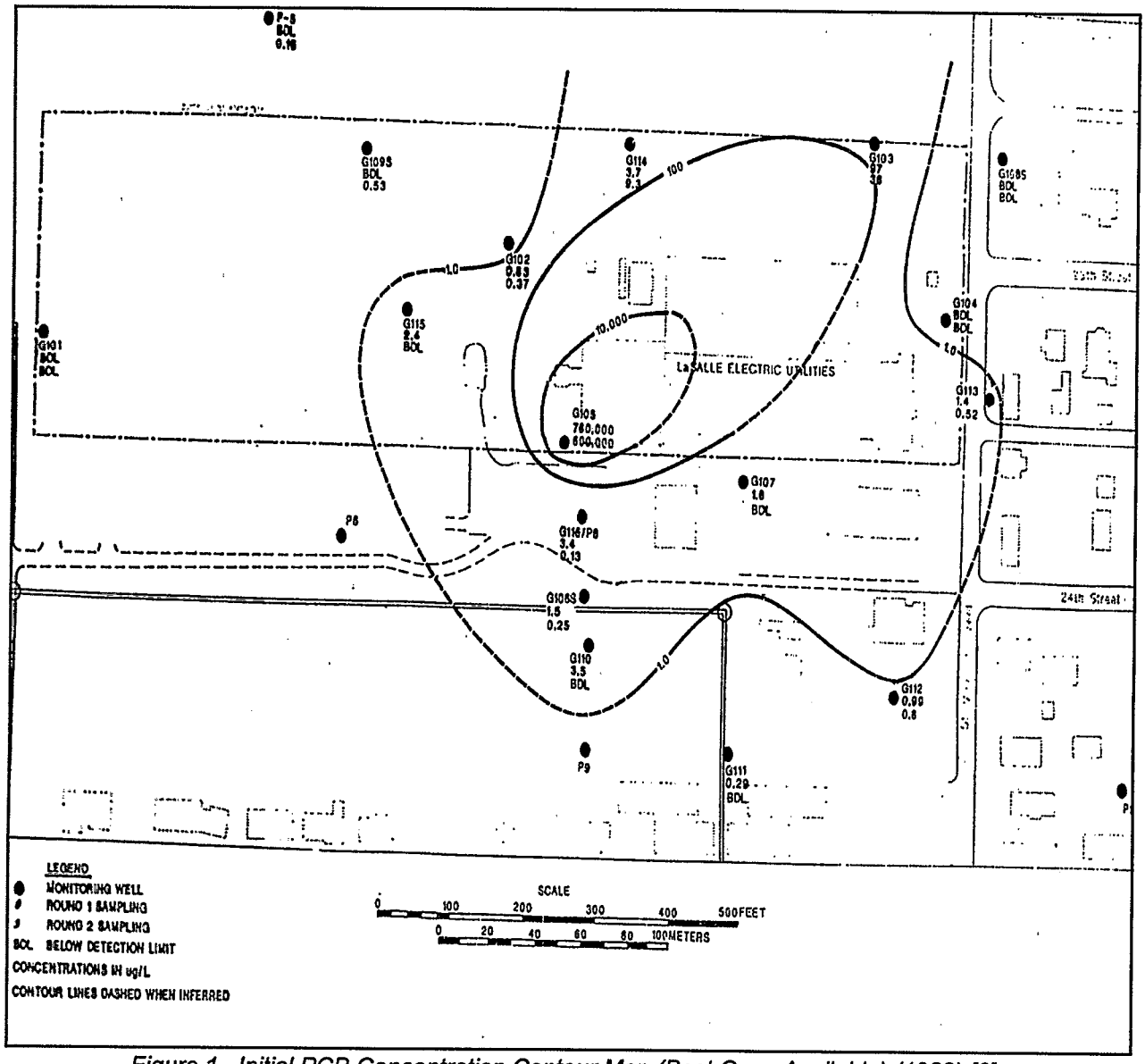

Figure 1. Initial PCB Concentration Contour Map (Best Copy Available) (1982) [6]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance [6]

Hydrogeology:

Three primary units have been identified within the upper 100 feet of the soils at this site. Two of these units function as aquifers (Units 1 and 3), and the third functions as an aquitard (Unit 2). Upward vertical gradients are observed across the site which limit the downward migration of contaminants into the lower water bearing unit (Unit 3). The water table is encountered at three to five feet below ground surface. Contaminants are primarily found in the shallow aquifer (Unit 1) and are migrating in a southeast direction with the natural groundwater flow.

Unit 1	Malden Till	Interbedded unit of sand, silt, and clay, which is an unconfined water-bearing unit.
Unit 2	Tiskilwa Till	Silty clay and clay with occasional silt and sand lenses, which acts as an aquitard. This unit is discontinuous across the site.
Unit 3	Bond Formation	Bedrock unit composed of clay, shale, and coal seams at depth.

Table 1 presents the technical aquifer characteristics. This information comes from the Phase II Remedial Investigation performed in 1988.

Table 1. Technical Aquifer Information [6]

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Malden Till	15-25	0.22 (K_h)	.016	Southeast
Tiskilwa Till	10-12	0.000005 (K_v)	NC	NC
Bond Formation	>60	0.0005 (K_h)	NC	Southeast

K_h - Horizontal conductivity, K_v - Vertical conductivity, NC - Not characterized

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping and carbon adsorption.

Supplemental Treatment Technology

Vapor-phase carbon adsorption, oil/water separation.

System Description and Operation

System Description [5,6]

- The groundwater collection system is a passive design that uses three infiltration trenches instead of wells. It was designed to capture the on-site groundwater directly beneath the original plant site, and extends 200 feet south of the original plant site. The one main east-west collection trench and the north-south collection trenches form an H-pattern. The north-south collection trenches drain to the east-west trench, which in turn flows to a wet well. Collected groundwater is pumped from the wet well to the groundwater treatment unit. The average extraction rate is 10-15 gpm. Figure 2 shows the groundwater collection and monitoring system at the LEU site.

TREATMENT SYSTEM DESCRIPTION (CONT.)

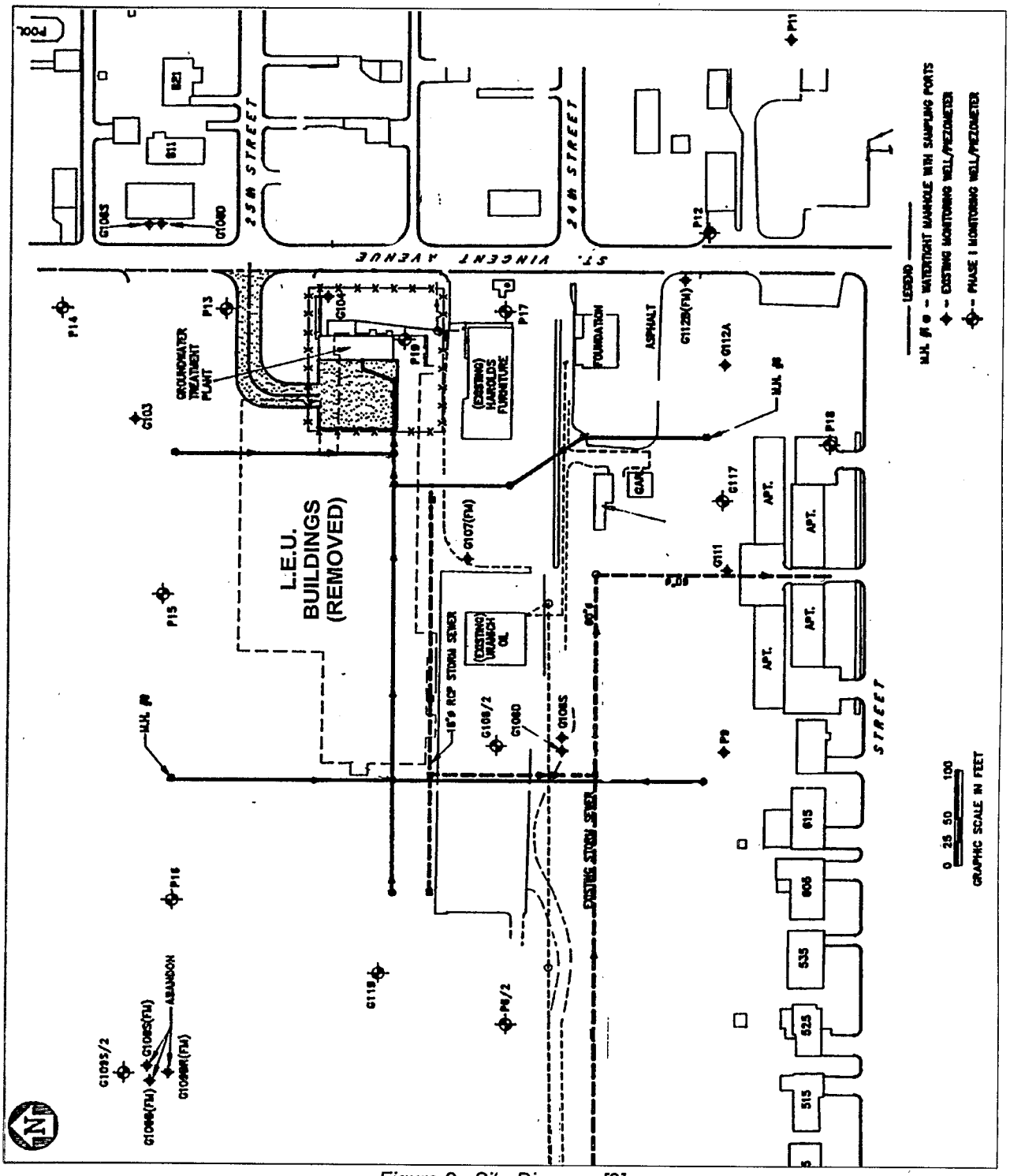

Figure 2. Site Diagram [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The collection system consists of trenches with six-inch perforated polyvinyl chloride (PVC) pipe installed horizontally approximately 17 to 25 feet deep. The perforated pipe was installed in a 4-foot deep by 4-foot wide gravel bed. The gravel bed is surrounded by filter fabric to retard infiltration of fines. The on-site trenches were backfilled with incinerated soil to within one foot of final grade. The backfilled soils were then capped with six inches of clay and six inches of topsoil to limit infiltration. Parts of the collection system which extended off-site were backfilled to within five feet of final grade and capped with clean fill and one foot of top soil.

- The groundwater treatment unit consists of an oil/water separator and twin air strippers for the chlorinated solvents. A vapor-phase carbon adsorption unit is used to treat gas vapors from the strippers. Two 10,000-pound liquid phase carbon adsorption systems are used to remove the suspended and dissolved PCBs. An acid injection system was added to the original design to control pH of the effluent.

- The air strippers are operated in series. Each is two feet in diameter and has 11 feet of packing material. The stripping columns are 23 feet tall. The design ratio of air to water is 50:1.

- Effluent from the treatment system is discharged to a local Publicly Owned Treatment Works (POTW) under an industrial pretreatment permit.

- The groundwater monitoring system includes monitoring wells for the deep aquifer and manhole sampling points in collection trenches for the shallow aquifer.

System Operation [5,7]
This report covers operation of the collection and treatment systems during construction and through September 1997.

- Quantity of groundwater pumped from aquifer in gallons:

Year	Volume Pumped (gal)
1992	3,015,000
1993	5,700,000
1994	2,620,000
1995	3,895,000
1996	4,800,000
1997 (9 months)	3,200,000

- The treatment unit was completed in April 1992 and began to operate by treating the groundwater and precipitation that accumulated in open excavations during construction activities.

- In December 1992, part of the collection system was installed. The remainder of the collection network was installed between March 1993 and June 1993. The collection system was installed in phases to minimize the number of open trenches at one time.

- Approximately eight million gallons were treated through the system between April 1992 and September 1993. The average extraction rate is approximately 18,000 gallons per day based on the volume of water treated to date.

- The full collection system went online in September 1993. The remedial system is operated in a batch mode. Groundwater is extracted for approximately 8-10 hours, then the aquifer is allowed to recover for 12-16 hours. The treatment system is designed for an optimum capacity of 20 gpm. It has been operating between 10-15 gpm to handle the volume of water extracted. According to the site contact, the treatment system has operated for approximately 15,530 hours and treated 14.6 million gallons since September 1993.

- The extraction system is operational five days a week 24 hours a day. An operator is on-site daily 4-8 hours.

- The pH of effluent is controlled to maintain compliance with the discharge permit. Caustic conditions also have caused a

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

mineral deposit to build up in the first carbon unit. Control of pH levels has minimized this problem.

- The oil/water separator has been used primarily as a settling tank for entrained solids. No oil component has been noted in the influent stream during the operation of the system.
- Air stripping media have not been changed; however, the polypropylene media has required acid washing to remove deposits every two years.
- Since start-up in 1993, the site has been operational approximately 75% of the time. The system was shut down from July 1994 through January 1995 during a period of negotiation with the construction contractor over cost and scope of work for operations and maintenance [7].
- Spent carbon was changed once in 1993. Influent concentrations to the carbon units have generally been below detection limits since that time and have not exceeded the capacity of the carbon.

Operating Parameters Affecting Treatment Cost or Performance

The groundwater extraction rate is a major operating parameter affecting cost or performance for this technology. Table 2 presents the average extraction rate between 1993 and 1997 and the performance parameters required to restore the groundwater to primary drinking water standards.

Table 2: Performance Parameters

Parameter	Value	
Average Extraction Rate (1993-1997)	15 - 18 gpm	
Performance Standard (effluent)	1,2-DCE	7 µg/L
	1,1-DCA	20 µg/L
	TCE	5 µg/L
	PCE	100 µg/L
	1,1,1-TCA	200 µg/L
	VC	2 µg/L
	PCBs	1 µg/L
Remedial Goals (aquifer)	1,2-DCE	5 µg/L
	1,1-DCA	5 µg/L
	TCE	5 µg/L
	PCE	100 µg/L
	1,1,1-TCA	200 µg/L
	VC	2 µg/L
	PCBs	.5 µg/L

Source: [4], [7]

Timeline

Table 3 shows a timeline for this remedial project.

Table 3: Project Timeline

Start Date	End Date	Activity
3/88	---	Record of Decision signed for this site
1/89	10/90	Remedial system designed
10/91	4/92	Treatment unit constructed
4/92	8/93	Treatment system operated while full system construction completed
12/92	6/93	Collection system constructed
9/93	---	Operations and quarterly monitoring began
6/94	12/94	Remedial system shutdown while contractor was replaced

Source: [5]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [4]

The goal of this remedy is to restore the groundwater to the primary drinking water standards as listed in Table 2. These standards are applied throughout the aquifer as measured in all on-site wells.

Treatment Performance Goals [4]

- The treatment system must reduce contaminant levels in the treated water to meet discharge requirements imposed by the local POTW. These requirements are stipulated in an industrial pretreatment permit which reflects the treatment standards included in the ROD and also are presented in Table 2.

Performance Data Assessment [5,8,9]

For this discussion and Figures 3 through 6, total contaminants consist of PCBs and VOCs.

- Figures 3 and 4 present groundwater monitoring results for the deep and shallow aquifers. Available data (through March 1996 for the deep aquifer and through May 1997 for the shallow aquifer) indicate that total contaminant concentrations have not been reduced below cleanup goals.

- Figure 3 illustrates changes in average total contaminant concentrations in the deep aquifer over time. This figure is generated from a geometric mean of data from four wells in the deep aquifer. The concentration of total contaminants was 6 µg/L in March 1996 [5,8].

- The maximum concentration of contaminants detected in the groundwater after 45 months of system operation were, PCB (BQL), TCE (530 µg/L), 1,1,1-TCA (1,700 µg/L), 1,1-DCE (1,800 µg/L), and VC (180 µg/L).

- The average groundwater concentration of total contaminants in the deep aquifer peaked at 125 µg/L in April 1993 and dropped to less than 40 µg/L by June 1993, as shown in Figure 3. The early peak appears to be due to high concentrations within one well.

- The majority of contaminants at this site are found in the shallow aquifer. Figure 4 shows an average of total contaminant concentrations detected at five manhole sampling points in the shallow aquifer. These sampling points are located in the collection trenches which intercept the shallow aquifer. MH1E located near the old LEU buildings shows the highest peak concentrations of total contaminants 1993-1997 with concentrations up to 11,800 µg/L. MH3S, located adjacent to MH1E, consistently showed the lowest measured total contaminant concentration with no discernable spiking.

- No contaminants have been detected in downgradient monitoring wells since the beginning of remedial operations. On the basis of this information, plume containment appears to have been achieved; however, containment was not a specific goal of the remedial system.

- Water level measurements indicate that the southern capture zone boundary, in the vicinity of monitoring well G111, is uncertain. A 60-inch leaking storm sewer pipe runs through the site at this point and creates an artificial recharge zone to the shallow aquifer. As a result a groundwater mound has been created which varies in size depending on precipitation and recharge rates [5].

- At wells G103, G107, and G112A, contaminant concentrations increase during wet seasons and decrease during dry seasons. This variance is likely due to

TREATMENT SYSTEM PERFORMANCE (CONT.)

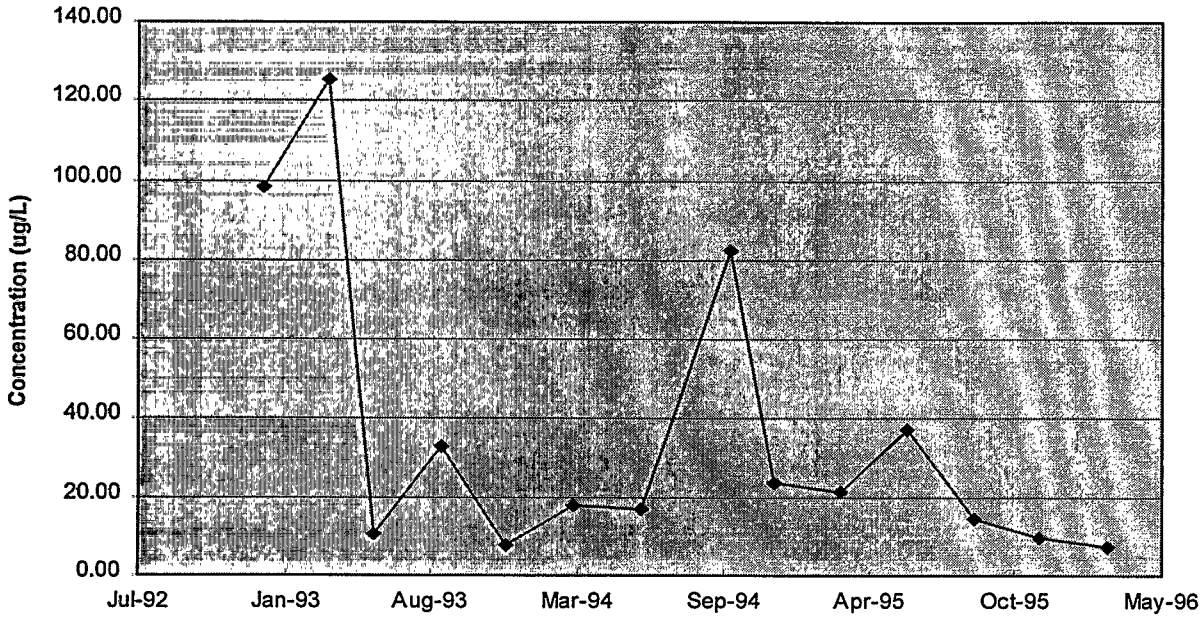

Figure 3. Average Deep Groundwater Concentrations for Total Contaminants (PCBs and VOCs) (Dec. 1992 - Mar. 1996) [6,8]

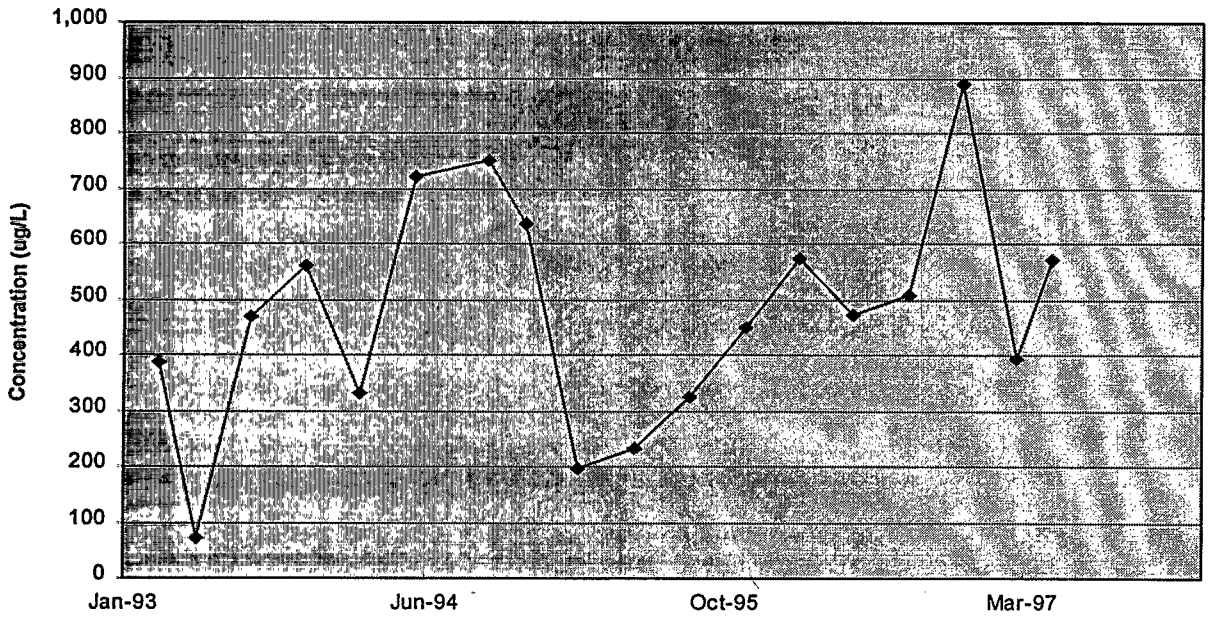

Figure 4. Total Contaminant Concentration in Shallow Aquifer Manholes (1993-1997) [6,8]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

precipitation infiltrating through residual contaminated soils [5]. The concentrations detected in the collection trenches do not coincide with this pattern.

- A total of 23 million gallons of groundwater have been treated through the remedial system. Taking into account the hours of system operation, a daily average treatment rate of 15-18 gpm has been achieved.
- As shown in Figure 5, the system has removed approximately 127 pounds of contaminant mass from 1993 to September 1997.
- The mass flux rate, as shown in Figure 5, varies between 0.07 and 0.29 lbs/day from start up through July 1994 when the system was temporarily shutdown. During the later operating period from 1995 to September 1997, the mass flux rate starts at 0.02 and increases to 0.19 lbs/day.
- Based on available data, 1,1,1-TCA is the primary contaminant detected in the influent samples and makes up the majority of the mass removed by the treatment system. Figure 6 illustrates the relationship between 1,1,1-TCA and the total contaminants removed from 1993 to September 1997.

Performance Data Completeness

- Contaminant mass removal was determined using analytical results from system influent measurements, along with treatment rate data. Wells were sampled quarterly for contaminant concentrations. Influent data were available through September 1997.
- Groundwater data are available from before treatment and during quarterly sampling events. Groundwater data from January 1993 through May 1997 were used in this report. Figure 3 includes only data through March 1996 because different wells were sampled after that date.
- Figures 3 and 4 are generated by calculating a geometric mean of data from specific monitoring points. The mean is used to represent a trend across the site.
- Data are available for water level measurements from before treatment and during quarterly sampling events.
- Effluent samples are collected on a weekly basis and analyzed for PCBs and VOCs. Effluent data are available from October 1993 through September 1997.
- Monthly influent and effluent samples for total PCB and VOC contaminants were used for mass flux determinations presented in Figure 5. Cumulative mass removal was generated from these data and monthly flow rates.
- Monthly influent and effluent samples were used for TCA data presented in Figure 6.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Illinois requirements. All monitoring was performed using EPA-approved methods, and the site contact did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

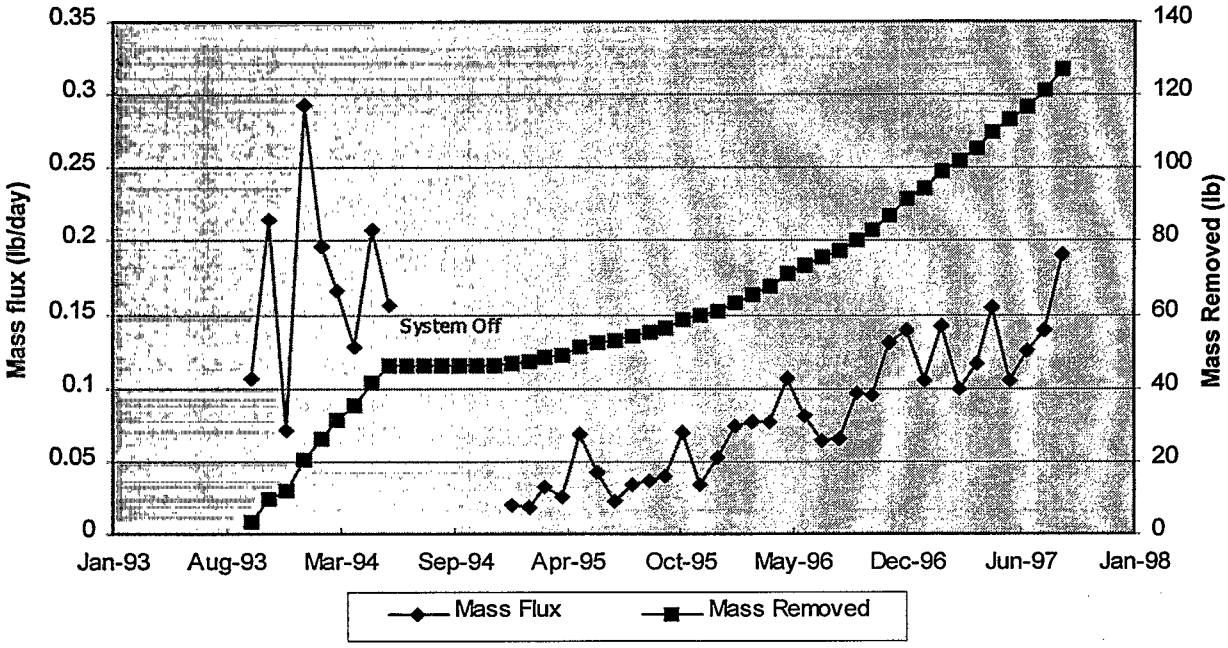

Figure 5. Mass Flux and Cumulative Removal (Oct. 1993 - Sept. 1997)

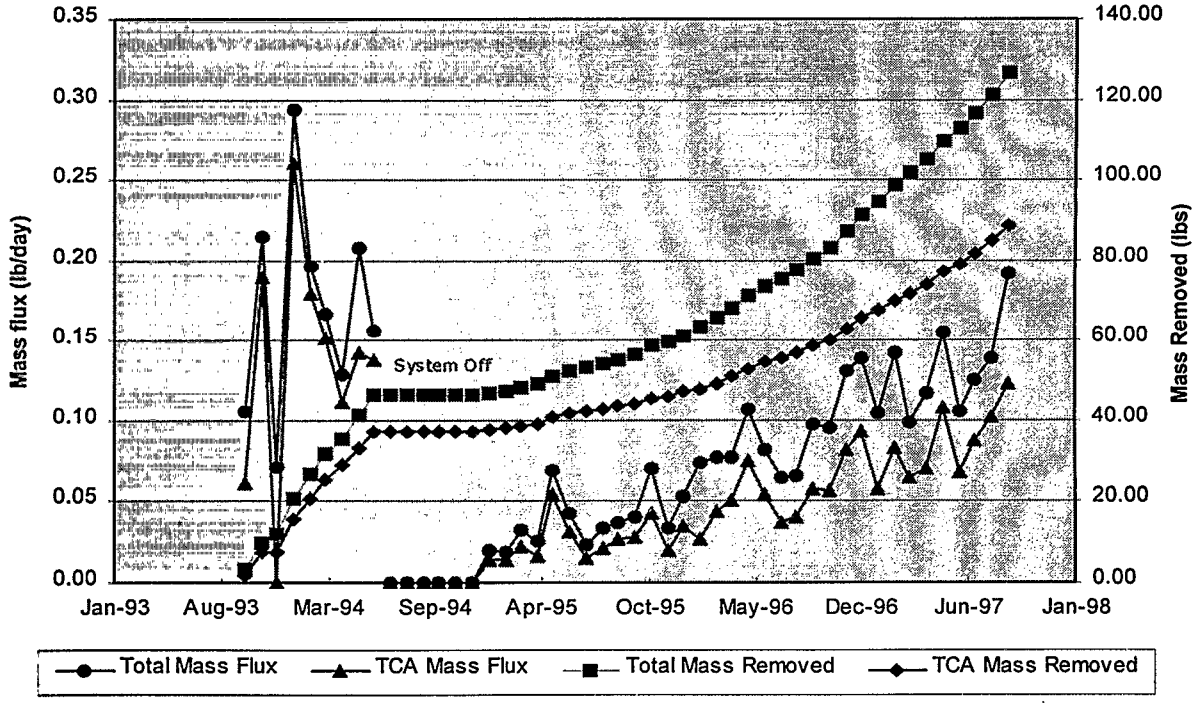

Figure 6. Comparison of TCA and Total Contaminant Mass Flux and Cumulative Removal (Oct. 1993 - Sept. 1997)

TREATMENT SYSTEM COST

Procurement Process

The IEPA is the lead agency for this site; however, U.S. EPA is providing operations and maintenance funding for the first 10 years. Ecology & Environment, Inc. has been contracted to provide site management activities. ThermoCor Kimmins was contracted to provide treatment system construction. Carmichael, Inc. has been contracted to provide long-term O&M.

Cost Analysis

- The majority of costs for design, construction, and operation of the treatment system at this site were provided by U.S. EPA.

Capital Costs [7]

Remedial Action	
Engineering and Site Management	$2,780,312
Analytical Services	$1,053,496
Parking Lot, Fence, etc.	$86,022
Treatment System	$1,186,423
Treatment Plant Structure	$208,323
Total Remedial Construction	**$5,314,576**

Operating Costs [7]

Plant Operations and Maintenance	$593,700
Analytical Services	$115,700
Carbon Treatment	$114,600
Total Cumulative Operating Expenses (1992-1997)	**$824,000**

Other Costs [7]

Remedial Design	$310,431
State Technical Assistance	$15,487
Total Remedial Design[1]	$325,918
EPA Personnel Costs	$95,895

[1]Includes the management of soils-related activities.

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the IEPA for this project.

OBSERVATIONS AND LESSONS LEARNED

- Total costs for the collection and treatment system were approximately $6,138,576 ($5,314,576 in capital and $824,000 in operations and maintenance) which corresponds to $48,000 per pound of contaminants removed and $266 per 1,000 gallons of groundwater.
- The collection system was installed in phases over a six-month period. On-site excavation was only to meet the remedial action objectives for PCBs in soil as stated in the ROD. The collection underdrain system was installed post-excavation for PCB thermal treatment and prior to backfilling. This sequential installation significantly reduced re-excavation and resulting costs.
- The treatment system performance data indicate that approximately 127 pounds of contaminants were removed from the groundwater over 45 months; however, the collection and treatment system has not achieved the cleanup goal.
- The leaking storm sewer drain has caused an artificial recharge zone in the vicinity of the collection system. The storm sewer

OBSERVATIONS AND LESSONS LEARNED (CONT.)

trench may also act as a conduit for plume migration off site [5].

- At specific monitoring wells, contaminant concentrations fluctuate with precipitation rates. During wet seasons contaminant concentrations are observed to increase, which is an indicator that contaminant materials are trapped in pore spaces or sorbed to unsaturated soils. When precipitation infiltrates, the contaminants are transported into the groundwater [5].

- PCBs were initially expected to be the primary contaminant at this site. According to the site contact and as shown in Figure 6, TCA accounts for the majority of the total contaminants in groundwater at the site [7].

- According to the site contact, the original design has been adequate in addressing the site cleanup efforts to date. No design alterations are currently being considered [7].

- The visual observation of an oily DNAPL material in a well casing confirms the presence of subsurface source zones. Additional subsurface source zones are likely present at this site. Persistent and highly variable concentrations in the groundwater may indicate the presence of additional DNAPLs, which may act as sources for persistent groundwater contamination.

REFERENCES

1. Phase II Construction Oversight, Ecology and Environment Engineering, April 1989.

2. Phase II Remedial Design, Ecology and Environment Engineering, June 1988.

3. Remedial Project Manager, U.S. Environmental Protection Agency.

4. Record of Decision, U.S. Environmental Protection Agency, March 1988.

5. Review and Assessment of Performance Report, LaSalle Electric Utilities Company Site, Groundwater Treatment Unit Inception Through December 1995, Ecology and Environment, Inc. 1996.

6. Phase II Remedial Investigation, Groundwater Hydrogeological Report, Ecology and Environment, Inc. 1988.

7. Conversations with IEPA Representative, May 29, 1997.

8. Quarterly monitoring data from Ecology and Environment, Inc. (1996-1997).

9. Monthly treatment unit data from LEU. (January 1996 - September 1997) Data supplied by Rich Lange, IEPA.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Pump and Treat of Contaminated Groundwater at the Mid-South Wood Products Superfund Site, Mena, Arkansas

Pump and Treat of Contaminated Groundwater at the Mid-South Wood Products Superfund Site, Mena, Arkansas

<table>
<tr><td>Site Name:
Mid-South Wood Products Superfund Site</td><td rowspan="2">Contaminants:
Semivolatiles - halogenated: pentachlorophenol (PCP); PAHs; heavy metals (chromium); and nonmetallic elements (arsenic)
- Maximum concentrations detected during RI include PCP (10,230 ug/L), fluoranthene (263 ug/L), chrysene (37 ug/L), benzo(a)anthracene (35 ug/L), Cr (183 ug/L), and As (18 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: 9/89 - 12/97</td></tr>
<tr><td>Location:
Mena, Arkansas</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Bill Fletcher
B&F Engineering, Inc.
928 Airport Road
Hot Springs National Park, AR 71913
(501) 767-2366</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 15 wells, at an average total pumping rate of 24 gpm
- Extracted groundwater is treated with oil/water separation, filtration, and carbon adsorption, and discharged to a surface water under a NPDES permit</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 11/14/86</td></tr>
<tr><td>State Point of Contact:
Mike Arjmandi
Arkansas Department of Pollution Control & Ecology
P.O. Box 8913
8001 National Drive
Little Rock, AR 72219-8913
(501) 682-0852</td><td>EPA Point of Contact:
Shawn Ghose, RPM
U.S. EPA Region 6
(6SF-AP)
1445 Ross Avenue
Dallas, TX 75202-2733
(214) 665-6782</td></tr>
<tr><td>Waste Source:
Improper disposal, on-site spills</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 100.6 million gallons treated as of December 1997
- DNAPL and LNAPL observed in groundwater at the site
- Extraction wells are located in 2 aquifers
- Hydraulic conductivities were not provided for this site</td></tr>
<tr><td>Purpose/Significance of Application:
Groundwater contaminated with wood treating chemicals; system optimization performed after eight years of operation; groundwater contamination had been reduced to one localized area of concern.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The cleanup goal stated in the ROD was to treat the groundwater contamination to levels that posed no health or environmental risk. Remedial goals were specified for PCP (0.20 mg/L), benzo(a)anthracene (0.01 mg/L), benzo(a)pyrene (0.01 mg/L), benzo(b+k)fluoranthene (0.01 mg/L), chrysene (0.01 mg/L), arsenic (0.05 mg/L), and chromium (0.05 mg/L).
- The performance goal for the recovery system was to provide containment of the plume on site.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Mid-South Wood Products Superfund Site, Mena, Arkansas (continued)

Results:

- Groundwater contamination has been reduced to one localized area of concern. Between April 1989 and May 1996, average concentrations of total contaminants in the groundwater were reduced 32%, from 0.14 to 0.09 mg/L, with concentrations of contaminants reduced to below cleanup goals in 29 of 35 wells monitored in May 1996. It is estimated that the pump and treat system will operate for a minimum of five more years to reach the specified goals.
- Monitoring data indicate that the plume has been contained. Because contamination was found along rock fractures and not in a continuous plume, plume size reduction could not be measured. During the first seven years of operation, 363 kg of PCP were removed by the system; data were not provided to estimate mass removal for other contaminants.

Cost:

- Estimated costs for pump and treat were $1,212,600 ($465,300 in capital and $747,300 in O&M), which correspond to $13 per 1,000 gallons of groundwater extracted and $1,500 per pound of PCP contaminant removed.

Description:

The Mid-South Wood Products site was originally developed in the late 1930s to produce untreated wood posts. In 1955, the facility added pressure treating to its process, and from 1967 to 1977, the site was operated as a PCP and creosote wood treatment facility. In 1977, the PCP plant was abandoned and a new plant was built to treat the lumber with a chromated copper arsenate (CCA) wood treating process. From 1978 to 1981, the Arkansas Department of Pollution Control & Environment sampled drinking wells near the site, investigating the source of a fish kill that occurred in November 1976. The source was ultimately determined to be an unauthorized release of wastewater from a waste pond at the site. Further contamination of the site resulted when liquids and sludge from the pond were sprayed on and around land farm areas at the site. The site was placed on the NPL in 1983 and a ROD was signed in November 1986.

An interim extraction system was built in late 1984 and operated from early 1985 until 1989. The system consisted of three pairs of extraction wells and French drains, and was designed to collect contaminated groundwater from shallow depths where flow and contamination were expected to be the greatest. An expanded extraction system, which began operating in the summer of 1989, consisted of nine shallow extraction wells and six deep extraction wells (drilled into bedrock formations at depths up to 170 ft bgs). In February 1997, three major changes were made to optimize system operations. Five recovery wells were removed from operation, five other wells began a period of on-off operation (three months on, three months off), and the sampling frequency for 12 monitoring wells was decreased. Groundwater contamination at the site has been reduced but has not yet met all remedial goals. It is estimated that the pump and treat system will operate for a minimum of five more years to reach the specified goals.

SITE INFORMATION

Identifying Information:

Mid-South Wood Products Superfund Site
Mena, Arkansas

CERCLIS #: ARD092916188

ROD Date: November 14, 1986

Treatment Application:

Type of Action: Remedial

Period of operation: September 1989 - Ongoing
(Performance data collected through December 1996; pumping data collected through December 1997)

Quantity of groundwater treated during application: 100.6 million gallons through December 1997

Background

Historical Activity that Generated Contamination at the Site: Wood treatment facility

Corresponding SIC Code: 2491 (Wood Preserving)

Waste Management Practice That Contributed to Contamination: Improper disposal, on-site spills

Location: Mena, Arkansas

Facility Operations: [2 3]

- The Mid-South Wood Products site is located on 57 acres in western Arkansas. Several streams flow through the site, feeding either the Ouachita or the Little Rivers. Previously, there were 14 private drinking wells nearby, serving the 18 properties adjacent to the site. Currently public water serves the site.
- The site was originally developed in the late 1930s to produce untreated wood posts. In 1955, the facility added pressure treating to its process. From 1967 to 1977, the site was operated as a pentachlorophenol (PCP) and creosote wood treatment facility. In 1977, the PCP plant was abandoned and a new plant was built to treat the lumber with a chromated copper arsenate (CCA) wood-treating process.
- The site includes the old wood treatment plant, an unlined waste pond, and two land farms. The waste pond was a collection basin for the waste from the PCP and creosote treatment processes.
- From 1978 to 1981, the Arkansas Department of Pollution Control & Environment (ADPC&E) sampled drinking wells near the site, investigating the source of a fish kill that occurred in November 1976. The source was ultimately determined to be an unauthorized release of wastewater from the waste pond.
- In 1978, an unsuccessful attempt was made to close the waste pond. Further contamination of the site resulted when liquids and sludge from the pond were sprayed on and around the land farm areas. A portion of the contaminated land farm soils were placed back into the waste pond as fill [2].
- An Administrative Order (AO) was issued by ADPC&E in March 1983 that directed the PRPs to perform short-term remedial actions and conduct a full site investigation.
- The site was placed on the NPL in 1983.
- EPA conducted a Remedial Investigation/ Feasibility Study (RI/FS) and a supplemental remedial investigation (SRI) of the CCA plant area in 1984 and 1986, respectively. The results of the investigations showed that the area around the CCA treatment plant was contaminated by spills of the wood treatment products

SITE INFORMATION (CONT.)

Background (Cont.)

and the unlined waste pond was contaminated by the disposal of wood treatment wastes.

- Groundwater samples collected during the RI/FS and the SRI from wells located around the waste pond, land farms, and CCA plant showed high concentrations of PCP. Lower concentrations of arsenic and chromium also were found in the groundwater.

- As specified in the Record of Decision (ROD), the contaminated soils from the waste pond and the old plant area were excavated for source control, stabilized, and consolidated in the waste pond. All other contaminated soil from the site was consolidated in one of the land farms. The waste pond and land farm were then capped with clay, sand, and topsoil to prevent further contamination of the groundwater.

Regulatory Context:

- EPA signed the final ROD for this site in September 1986. The ROD addressed both soil and groundwater actions.

- A Consent Decree was signed by the two identified Potentially Responsible Parties (PRPs) and entered in the Arkansas District Court on May 16, 1987.

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 §121, and the National Contingency Plan (NCP), 40 CFR 300.

- National Pollutant Discharge Elimination System (NPDES) permits were required to discharge treated groundwater to surface drains.

Groundwater Remedy Selection:
Groundwater extraction and treatment via carbon adsorption was selected as the remedy for this site.

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA

Remedial Project Manager:
Shawn Ghose*
U.S. EPA Region VI (6SF-AP)
First Interstate Bank Tower at Fountain Place
1445 Ross Avenue 12th Floor Suite 1200
Dallas , TX 75202-2733
(214) 665-6782

State Contact:
Mike Arjmandi
Arkansas Department of Pollution Control & Ecology
P.O. Box 8913
8001 National Drive
Little Rock, AR 72219-8913
(501) 682-0852

Treatment System Consultant:
Bill Fletcher*
B&F Engineering, Inc.
928 Airport Road
Hot Springs National Park, AR 71913
(501) 767-2366

*Indicates primary contacts

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1, 2, 6]

Primary Contaminant Groups: Semivolatile organic compounds and inorganics

- The contaminants of concern at the site are PCP, chromium, arsenic, and polynuclear aromatic hydrocarbons (PAHs), including benzo(b+k)fluoranthene, chrysene, and benzo(a)anthracene [1].
- The maximum concentrations detected in shallow groundwater during the RI include PCP (10,230 µg/L), chromium (183 µg/L), arsenic (18 µg/L), fluoranthene (263 µg/L), chrysene (37 µg/L), and benzo(a)anthracene (35 µg/L) [1].
- No samples were taken of the groundwater in the underlying bedrock unit during the RI, as additional study of the deep contamination was considered to be too costly, given the complexity of the hydrogeology. However, a sampling event in 1990 (after remedial operations began) revealed significant contamination in a well drilled to 172 feet below ground surface.
- The presence of light nonaqueous phase liquid (LNAPL) contamination by carrier oils has been observed directly [2]. In addition, fluoranthene and PCP were detected at concentrations at or greater than 60% of their aqueous solubility, suggesting the presence of dense nonaqueous phase liquids (DNAPLs). As noted above, while confined to the upper portion of the bedrock, DNAPLs were subsequently found at depths of 172 feet during deep drilling [2]. Figure 1 illustrates site layout and the location of monitoring wells. The monitoring wells are located primarily around the land farm and the old pond.
- Contaminants have been found only along fractures in rock along the fault line; therefore no continuous contaminant plume was defined. Thus, no plume map or volume estimate was generated.

MATRIX DESCRIPTION (CONT.)

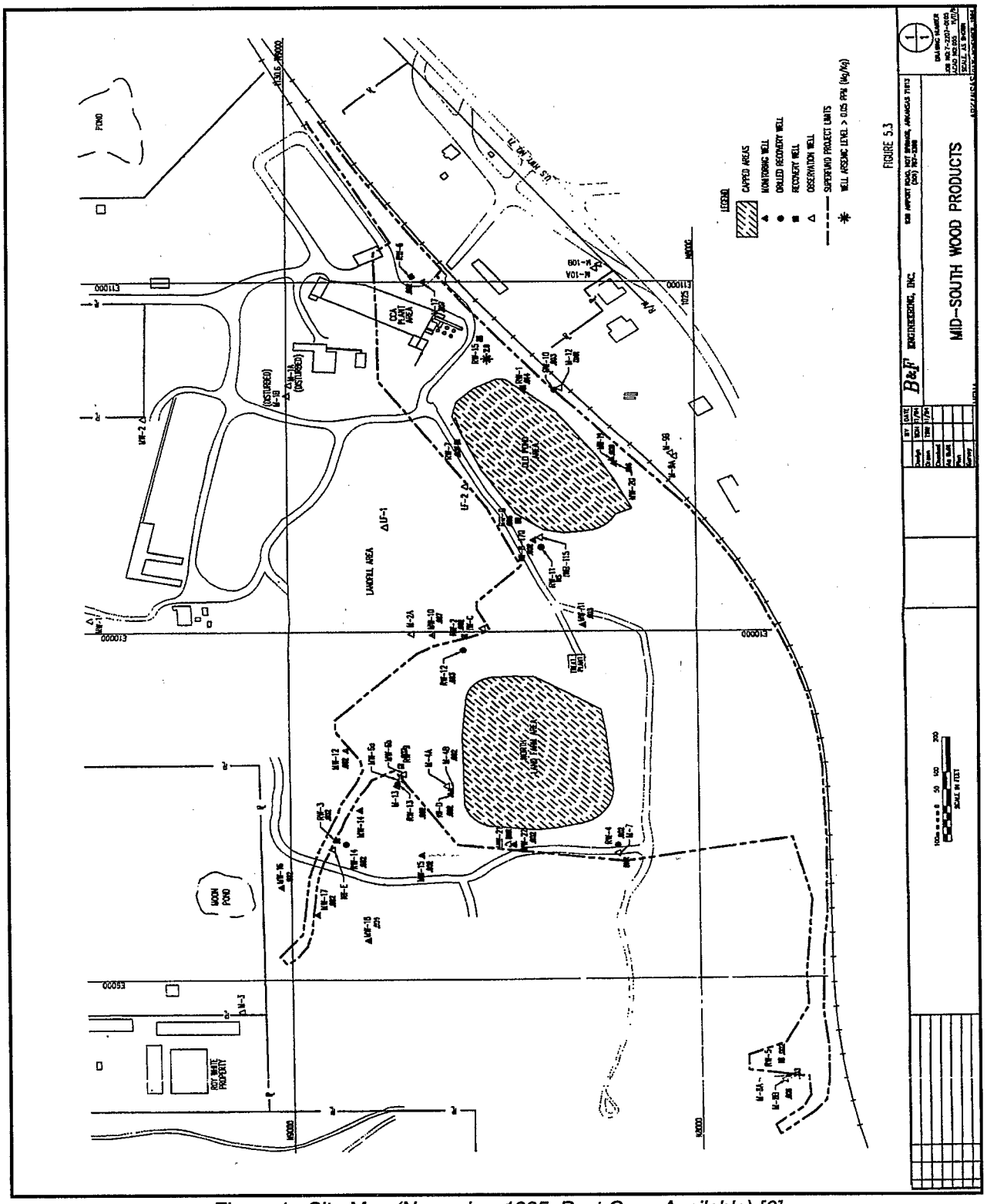

Figure 1. Site Map (November 1995, Best Copy Available) [6]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [1,2]:

One distinct hydrogeologic unit has been identified beneath this site. This unit has two separate geologic features: a thin layer of sandy, gravelly material overlying the sandstone bedrock of the Mississipian Age formation. A fault zone in the bedrock runs west to east and passes under the old waste pond. The fault zone is characterized by highly fractured shales and influences groundwater flow patterns by creating a highly permeable zone within the bedrock. Groundwater flows primarily to the west-northwest, except in the eastern two-thirds of the site, where it flows westerly to southwesterly. Groundwater flow velocity along the fault is approximately 20 ft/yr, or 0.055 ft/day. Higher velocities of 30 to 60 ft/yr have been observed along the slopes of the site.

Unit 1	Overburden Aquifer	Consists of 1 to 10 feet of silt, sand, and clay with gravel. The gravel consists primarily of angular rock fragments. The saturated zone in soil exists 1 to 9 feet above the lower bedrock formation.
Unit 2	Bedrock Aquifer	Consists of consolidated sandstone and shale bedrock. Groundwater mainly occurs in the joints, fractures, and bedding planes. Depth of water within the bedrock unit is generally 30 feet, with infiltration into deeper zones to depths of 172 feet.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1: Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Overburden Aquifer	1 - 10	**NA**	0.055	West-Northwest
Bedrock Aquifer	>10	**NA**	0.082	West-Northwest

Source: [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with liquid-phase carbon treatment

Supplemental Treatment Technology

Oil/water separator

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation

Table 2: Extraction Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/day)
RW-1, RW-2, RW-3, RW-5, RW-6, RW-7, RW-8, RW-9, RW-15	Overburden Aquifer*	12.8 - 23.4	8.7 - 3,216
RW-4, RW-10, RW-11, RW-12, RW-13, RW-14	Bedrock Aquifer	21 - 170	4,167 - 8,487

*Overburden wells are screened within a French drain.

Source: [2]

System Description

- In response to the 1983 AO, an interim extraction system was built in late 1984 and operated from early 1985 until 1989. The system consisted of three pairs of extraction wells and French drains. Each well was screened in a drain. The system was designed to collect contaminated groundwater from shallow depths where flow and contamination were expected to be the greatest [2]. Table 2 presents extraction well data.

- The 1986 ROD specified an expansion of the existing system as the final groundwater remedy. This expanded extraction system, which began operating in the summer of 1989, consisted of nine extraction wells (including the original three sets of drains), screened in eight French drains, and six deep extraction wells drilled into the bedrock formation to depths up to 170 feet [2].

- The original three French drains, installed in 1984, are located on a NW/SE axis across the site along the fault zone. Three of the five drains installed in 1989 are located along the same fault line, and two were installed downgradient of the old pond area [2].

- The French drain trenches were excavated to the depth of backhoe refusal at the top of the bedrock, which was approximately 15 feet. The bottom of the drains is filled with 4-inch pea gravel to a depth of one foot. The pea gravel is covered with approximately two feet of ½- to 1½-inch gravel, and the ditch is backfilled with clay [10].

- Five of the six drilled wells are located along the same axis as the original drains, and are installed close to, or in between, the three original French drains. The remaining drilled well was installed on the southwest corner of the land farm area [6].

- Recovery wells RW-2, 4, 6, 12, and 13 were closed February 1, 1997 as recommended in the 1995 Annual Report with approval from EPA. Recovery wells RW-3,5,9,10, and 14 began the on/off period [12].

- Extracted water is pumped through force mains to an oil/water separator and then to a storage tank. The water is then pumped through fabric filters to remove suspended solids and treated by carbon adsorption to remove organics. Treated groundwater is discharged to storm drains through two outfalls under an NPDES permit [2].

- The carbon treatment system consists of two parallel lines, each with two 2,000-pound canisters in series, to treat organics [2].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- An additional carbon treatment system was added in October 1996 to treat metals-contaminated groundwater from RW-15, located near the CCA plant. Originally, the contaminated groundwater from RW-15 was used as make-up water in the CCA plant. As plant operations declined in 1996, so did the demand for make-up water. Therefore, the new carbon treatment system was added to treat this water prior to discharge. The new system consists of two parallel lines, each with two 180-pound canisters set in series. The carbon system was used for less than one year. Plant operations resumed in 1997, and the water extracted from RW-15 was returned to use in plant operations [9].

- A network of six monitoring wells, along with the remaining recovery wells, is used to monitor changes in groundwater quality and water levels annually [7].

- The remaining 12 monitoring wells went from annual sampling to 5-year sampling as recommended in the 1995 Annual Report with approval from EPA [6].

System Operation

- Under the provisions of the 1983 AO, the interim treatment system operated from 1985 until 1989, when it was expanded. The final remedy began operation in September 1989. This report addresses the final remedy [2].

- Quantity of groundwater pumped from the bedrock and overburden aquifers in gallons is shown below [4,5,6,7].

Year	Volume Pumped (gallons)
1989	4,752,300
1990	12,691,050
1991	10,165,250
1992	14,676,650
1993	11,607,000
1994	19,958,200
1995	11,430,140
1996	12,557,350

- Approximately 40,000 pounds of carbon were used from September 1989 until December 1996. The canisters have been changed nine times since the start of the operation. The average volume of water treated by each canister was approximately 10 million gallons. [5,6,7]

- In June 1995, a Five Year Evaluation of the site was performed.

- The oil/water separator extracts small quantities of oil. From September 1992 to December 1995, two 55-gallon drums of oil were extracted from the groundwater [6].

- In late 1996, the site engineer reported that free oils had been detected in piezometer IWE, located near the two farthest downgradient recovery wells, RW-3 and RW-14. No concentrations of contaminants above detection limits have been detected in the recovery wells since 1990. The piezometer IWE was drilled prior to recovery well installation. Once IWE was in place, the casing may have trapped DNAPL, blocking the recovery wells' subsequent zones of influence. [7,9]

- In February 1997, three major changes were made to optimize system operations. First, five recovery wells in which no contaminants had been found above remedial goals for the past four years were removed from operation. Second, five other recovery wells meeting the same criteria for a period of the last three years began a period of on-off operation (three months on, three months off). Finally, the sampling frequency for 12 monitoring wells was decreased to once every five years. These wells have either a history of contaminant levels below detection limits or are in close proximity to wells that will continue to be sampled annually [9].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- An additional recovery well is planned near the waste pond. Monitoring well data have shown that contaminants in the groundwater in this area were not being remediated as quickly as other areas of the site [7].
- Monitoring wells M-17 (near CCA Plant) and MW-19 (near Old Pond) are scheduled to be over drilled in June 1998 and replaced with recovery wells. IWE will be over drilled and plugged.

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents the major operating parameters affecting cost or performance for this technology.

Table 3: Performance Parameters

Parameter	Value	
Average Pump Rate	24 gpm	
Performance Standard (effluent) (in mg/L)	NPDES effluent limitations	
	Arsenic	0.050
	Chromium	0.050
	Naphthalene	2.30
	Fluoranthene	3.98
Remedial Goal (aquifer) (in mg/L)	PCP	0.20
	Benzo(a)anthracene	0.01
	Benzo(a)pyrene	0.01
	Benzo(b+k)fluoranthene	0.01
	Chrysene	0.01
	Arsenic	0.05
	Chromium	0.05

Source: [2]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
1984	1989	Interim extraction system built and operated
11/86	---	Record of Decision signed
12/86	7/89	Remedial design and construction performed
1989	ongoing	Final extraction system operational
6/95	---	Five Year evaluation
10/96	---	RW-15 brought into treatment network, and two additional carbon filters to treat metals added to treatment system
2/97	---	System optimization performed

Source: [2]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1, 5]

- The cleanup goal stated in the ROD was to treat the groundwater contamination to levels that posed no health or environmental risk. This goal is to be achieved throughout the on-site aquifer.
- The cleanup goal for PCP was equal to the EPA reference dose. Goals for benzo(a)pyrene, benzo(a)anthracene, benzo(b+k) fluoranthene, and chrysene were set at the respective detection limits. Goals for arsenic and chromium were set at the maximum contaminant level (MCL) stipulated in 40 CFR 264.94, as listed in Table 3.

Treatment Performance Goals [1]

- The goal of the treatment system is to reduce effluent contaminant concentrations to meet NPDES permit requirements.
- The goal of the recovery system is to contain the plume on site.

Performance Data Assessment [4, 5, 6, 7]

For the purpose of this report, total contaminants includes arsenic, PCP, chromium, and total PAHs.

- Groundwater contamination has been reduced to one localized area of concern. The wells on the western portion have recorded contaminant levels below detection limits. RW-15 and other wells located around the CCA plant and pond area still show contaminant levels above the remedial goals.
- Between April 1989 and May 1996, average concentrations of total contaminants in the groundwater were reduced 32%, from 0.14 mg/L to 0.09 mg/L. Over this same period, average arsenic concentrations increased 20%, from 0.0030 mg/L to 0.0036 mg/L. Average PCP levels decreased 50%, from 0.022 mg/L to 0.011 mg/L. Average chromium concentrations decreased 83%, from 0.030 mg/L to 0.005 mg/L. Total PAHs decreased 34%, from 0.035 mg/L to 0.023 mg/L. Contaminant concentrations in some individual wells remain above remedial goals.
- PCP concentrations detected during the May 1996 monitoring were above the cleanup goal of 0.10 mg/L in five wells (RW-1, RW-7, RW-8, RW-15, and M-17). The maximum concentration of PCP detected in May 1996 was 6.6 mg/L (in RW-15, near the former CCA plant). Elevated levels of PCP also showed in the wells near the former pond area (RW-1, RW-7, RW-8, and M-17). Figure 2 illustrates that the PCP concentrations in the monitoring wells near the pond area have declined, but remain above the cleanup goal of 0.10 mg/L.
- Concentrations of contaminants detected in the May 1996 monitoring were below remedial goals in all but six of the 35 wells monitored. Arsenic concentrations were above the remedial goal of 0.05 mg/L in only one well (RW-15) at 0.69 mg/L. Chromium concentrations were above the remedial goal of 0.05 mg/L in only one well (RW-15) at 0.13 mg/L. Total PAHs concentrations were above the combined remedial goal of 0.40 mg/L in only one well (IWB-170) at 1.18 mg/L. The plume of total contaminants is concentrated in the former CCA plant area, in RW-15 and IWB-170. Figure 3 illustrates that the concentrations of PCP, chromium, and arsenic in RW-15 have declined since January 1991, but remain above the respective remedial goals.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- RW-15 remains the well with the highest levels of contaminants, specifically arsenic, chromium, and PCP. This well is located 100 feet downgradient of the CCA plant and upgradient of the pond area. The contamination found in this well reflects its proximity to both the CCA plant and the location of the old PCP plant. Overall, contaminant concentrations in this well have decreased during remedial operations (see Figure 3). Reasons for the sharp spikes in concentrations seen in both the first quarter of 1990 and the third quarter of 1991 are not known [9]. By the second quarter in 1996, concentrations of all three of the contaminants remained above remedial goals [7].

- The monitoring data for the wells downgradient of the land farm show that the concentrations of all contaminants remained below detection levels, indicating successful plume containment. Moreover, monitoring results from wells placed downgradient of the pond area but upgradient of the land farm show no evidence that contamination is moving between the two areas.

- Monitoring data have indicated that the area of contamination has decreased in size. The site operators have recommended that wells in the western portion of the site be either removed from service or operated on an on-off basis. The remaining wells around the waste pond still show contaminant levels higher than cleanup goals. It is estimated that the P&T system will operate for a minimum of five more years to reach the specified goals.

- Because contamination was found along rock fractures and not in a continuous plume, plume size reduction cannot be measured.

- NPDES limits have been exceeded six times for hazardous pollutants (arsenic or chromium) from July 1989 through December 1996. Only one out of the six exceedances was from Outfall 001, the treated groundwater. The other exceedances were at a stormwater outfall. Over the same period, effluent samples failed once for Seven-Day Renewal Chronic Toxicity to Certiodaphia and 10 times for reproduction criteria. Exceedances were reported to the Arkansas Department of Pollution Control and Ecology. No process changes were made.

- Figure 4 presents the removal of contaminants through the treatment system from 1990 to 1996. Over this period, a total of 93 million gallons of groundwater were treated, at a daily average treatment rate of 24 gpm.

- During the first seven years of operation, the carbon filter system removed a total of 363 kg of PCP. Other contaminants were removed as well, but sufficient data were not available to be able to estimate their mass. Therefore, removal of total contaminants is likely to be higher.

- PCP removal rates, reported in annual performance reports, declined from 0.39 kg/day in 1990 to 0.03 kg/day in 1995.

Performance Data Completeness

- The 18 monitoring wells and the 15 recovery wells located at the site were monitored on an annual basis and reported in the annual report.

- The data used in Figures 3 and 4 were taken from the summary table in the 1996 Annual Report [7].

- Data for contaminant removal through the carbon filter system were reported in the 1994 Annual Report and Five Year Evaluation, the 1995 Annual Report, and the 1996 Annual Report [4,6,7].

TREATMENT SYSTEM PERFORMANCE (CONT.)

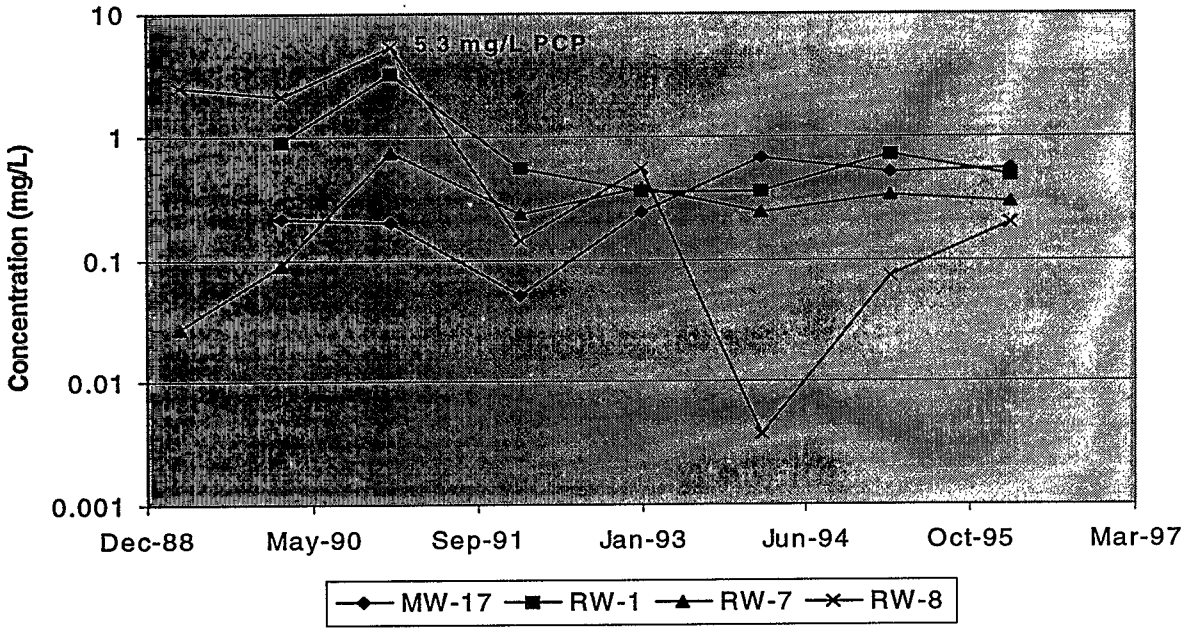

Figure 2. PCP Concentrations in Wells Near Pond Area (April 1989 to May 1996) [4,5,6,7]

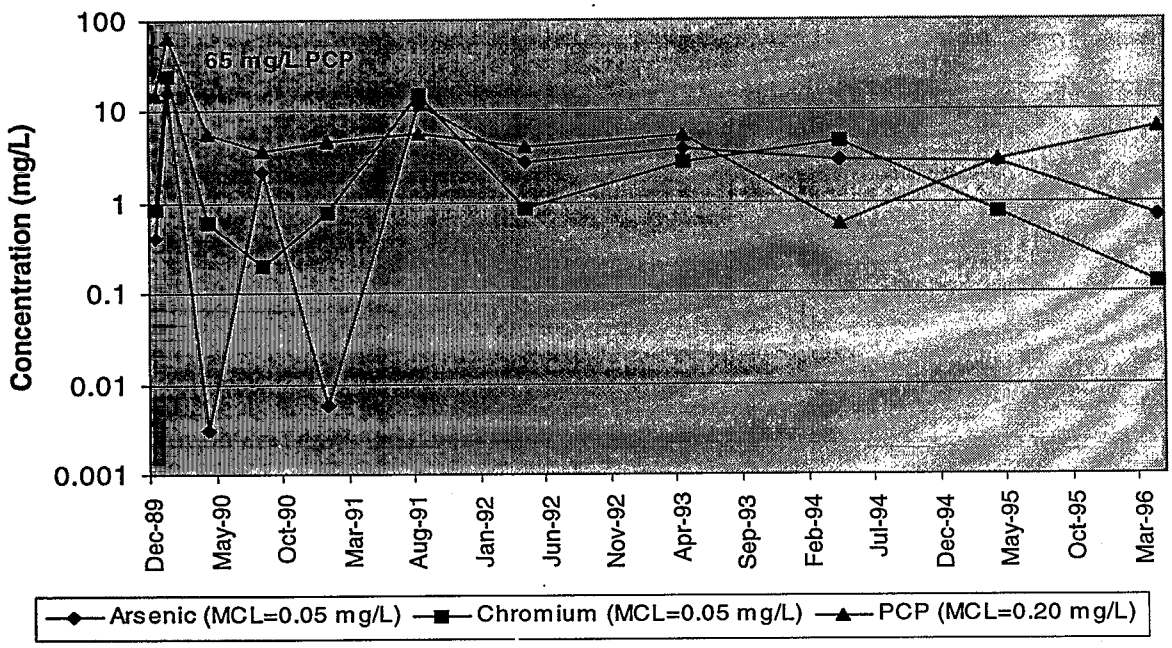

Figure 3. Contaminant Concentrations in RW-15, Near CCA Plant (April 1989 to May 1996) [4,5,6,7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

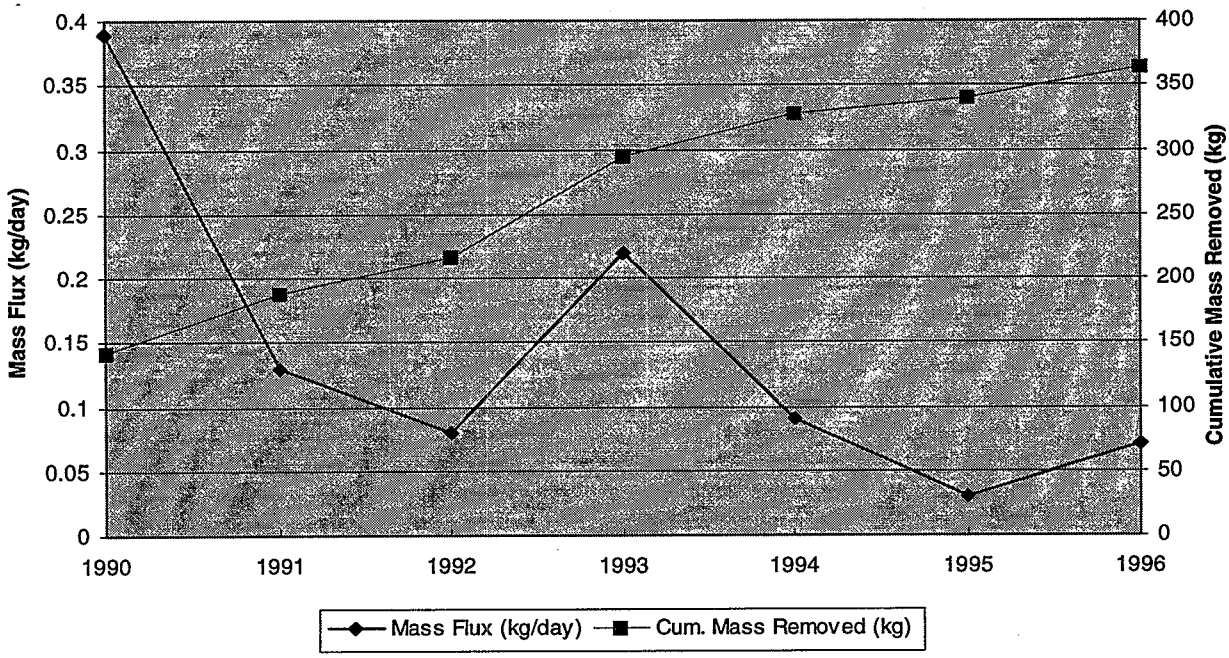

Figure 4. Mass Flux Rate and Cumulative PCP Removal (1990 to 1994) [5]

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Arkansas requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

B&F Engineering provided remedial design services and has provided monitoring and reporting services during the P&T operation period. Rollins provided construction services and Mid-South Wood Products (one of the two PRP's) has operated the P&T system.

Cost Analysis

All costs for design and construction and operation of the treatment system at this site were borne by the PRPs.

Capital Costs [6]

Remedial Construction and Design	
Mobilization, Bond & Insurance	$25,560
Health and Safety	$7,875
French Drain Construction	$95,100
Recovery Well Casings	$45,470
Recovery Well Pumps	$28,900
Rock Excavation	$11,393
Cable	$26,818
Treatment Plant	$141,990
RW-15 Well and Treatment Unit	$24,700
Miscellaneous	$57,470
Total Site Cost	**$465,276***

*Does not include stabilization, consolidation, and capping costs for remediation of contaminated soils.

Operating Costs [6]

Carbon Regeneration	$100,100
Sludge, Oil, Filter, etc. Disposal	$8,400
Miscellaneous Pipe, Filters, etc.	$10,500
Operating Labor Cost	$54,600
Contract Labor Cost	$8,400
Electrical Power Cost	$33,600
Analysis, Reporting, and Monitoring	$395,800
Annual Report	$24,500
Five Year Evaluation	$14,000
Carbon Canister Replacement	$45,000
Pump Replacement	$17,200
Meter Replacement	$2,600
Electrical Controls Replacement	$6,600
Filter Replacement	$4,000
Operator Training Cost	$4,000
Contingency Fund	$18,000
Estimated Total Operating Expenses Through 1996	**$747,300**

Note: Operating costs are based on annual cost estimates provided by B&F Engineering.

Annual Costs [8]	
1990	$136,350
1991	$103,350
1992	$88,350
1993	$90,350
1994	$88,750
1995	$152,000
1996	$88,150

Cost Data Quality

Estimated capital and operating and maintenance cost data are available from the system operator for this application.

OBSERVATIONS AND LESSONS LEARNED

- The site engineer identified one change order for the original groundwater treatment system construction contract, totaling $9,966.

- Estimated costs for the P&T treatment application at Mid-South were approximately $1,212,600, consisting of $465,300 in capital costs and $747,300 in cumulative operating and maintenance costs through 1996 [8]. This corresponds to unit costs of $13 per 1,000 gallons treated and $3,330 per kg PCP removed ($4,510 per pound PCP removed).

- The use of fabric filters to remove suspended solids has increased the operating life of the carbon filters. The high rate of changeout for the fabric filters has not added a significant level of effort to routine operations [8].

- The increase in mass flux seen in 1993 may be attributed to an increase in precipitation during the year. The increased precipitation could have accelerated groundwater flows, which would then cause a contaminant level increase in the recovery wells.

- DNAPLs have been visually observed from a drilled well at 172 feet of depth. The presence of DNAPL at the site also is suggested by fluoromethane, benzo(a)anthracene, and chrysene being detected at concentrations 60%, 63%, and 30% of their aqueous solubility, respectively. Similarly, PCP was detected at concentrations greater than its aqueous solubility. Further, a monitoring well near the waste pond has shown persistent elevated contaminant concentrations when compared to the other wells at the site [2,4].

- Initially, French drains were chosen to recover groundwater because engineers believed that the fractured nature of the bedrock would result in low yields from a system composed only of drilled extraction wells. Actual experience at this site has shown that the extraction rates from the French drains are much lower than those from the drilled extraction wells, and that pumping from the drilled wells has significantly changed groundwater flow patterns at the site [6].

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3. Superfund Site Status Summaries, U.S. EPA, "Mid-South Wood Products," http://www.epa.gov/earth1r6/6sf/midsouth, April 30, 1997.

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6. 1995 Annual Report, B&F Engineering, Inc., October 1996.

7. 1996 Annual Report, B&F Engineering, Inc., February 1997.

8. Cost estimates provided by Linda McCormick, B&F Engineering, Inc., June 1997.

9. Telephone conversation with Linda McCormick, B&F Engineering, Inc., October 6, 1997.

10. Personal Communication with Linda McCormick, B&F Engineering, Inc., October 16, 1997.

11. Comments on Draft Report, provided by Linda McCormick, B&F Engineering, Inc., June 1998.

12. Operations and Maintenance Manual, B&F Engineering, Inc., January 1997.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Pump and Treat of Contaminated Groundwater at the Odessa Chromium I Superfund Site, OU 2 Odessa, Texas

Pump and Treat of Contaminated Groundwater at the Odessa Chromium I Superfund Site, OU 2 Odessa, Texas

Site Name:
Odessa Chromium I Superfund Site, Operable Unit 2 (OU 2)

Location:
Odessa, Texas

Contaminants:
Heavy Metals (Chromium)
- Maximum concentration of Cr detected during 1985 sampling event was 72 mg/L

Period of Operation:
Status: Ongoing
Report covers: 11/93 - 1/98

Cleanup Type:
Full-scale cleanup (interim results)

Vendor:
Design and Management: IT Corporation (ITC)
Construction and Oversight: WATEC

Technology:
Pump and Treat
- Groundwater is extracted using 6 wells at an average total pumping rate of 60 gpm
- Extracted groundwater is treated for Cr removal with chemical treatment (ferrous ion, produced on site), pH adjustment, flocculation, precipitation, and multimedia filtration
- Treated groundwater is reinjected through 6 injection wells

Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/8/86

State Point of Contact:
Lel Medford
Texas Natural Resources Conservation Commission
P.O. Box 13087
Austin, TX 78711
(512) 239-2440

EPA Point of Contact:
Ernest Franke, RPM
U.S. EPA Region 6
First Interstate Bank Tower at Fountain Place
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733
(214) 655-8521

Waste Source:
Improper disposal practices

Purpose/Significance of Application:
Includes on-site treatment for chromium; relatively low groundwater flow; contamination in one aquifer

Type/Quantity of Media Treated:
Groundwater
- 125 million gallons treated as of January 1998
- Groundwater is found at 30-45 ft bgs
- Extraction wells are located in 1 aquifer, which is influenced by production wells in the area
- Hydraulic conductivity ranges from 1.7 to 5.1 ft/day

Regulatory Requirements/Cleanup Goals:
- Remediate groundwater so that chromium levels are less than the maximum contaminant level (MCL) or primary drinking water standard.
- Prior to 1990, the drinking water standard for chromium was 0.05 mg/L; in 1990, EPA revised the drinking water standard to 0.10 mg/L.
- Treated effluent that is reinjected into the aquifer must have a chromium level of less than 0.05 mg/L.
- The remedial system was required to create an inward gradient toward the site to contain the plume.

Results:
- Groundwater monitoring results indicate that chromium concentrations have been reduced compared to initial levels, but not to levels below the cleanup goal of 0.10 mg/L.
- Average chromium concentrations were reduced by 48% from January 1992 to January 1997.
- From December 1993 to 1996, 1,143 pounds of chromium have been removed from the groundwater.
- Treated effluent has met the required performance standard throughout treatment.
- Plume containment has been achieved since 1995; this was achieved after two monitoring wells were converted to recovery wells, and two other recovery wells were taken off line.

Pump and Treat of Contaminated Groundwater at the Odessa Chromium I Superfund Site, OU 2 Odessa, Texas (continued)

Cost:

- Actual costs for the P&T application were approximately $2,742,000 ($1,954,000 in capital and $728,000 in O&M), which correspond to $30 per 1,000 gallons of groundwater extracted and $2,400 per pound of contaminant removed.
- The ROD specified that the ferrous iron used in the treatment system be produced electrochemically, which limited the number of vendors to two and potentially increased the cost of the treatment system.
- The costs for design, construction, and operation of the P&T system were split 90:10 by EPA and TNRCC, respectively.

Description:

Metal plating and chrome plating facilities operated at this site from 1954 to 1977, producing chromium- and other metals-containing wastewater. In 1977, the TNRCC investigated citizen complaints of poor drinking water quality in private wells and discovered elevated levels of chromium in the groundwater. The chromium contamination was attributed to the discharge of chromium-containing wastewater into unlined dirt ponds, directly to the soils, and into a septic tank drain field; contaminants also are suspected to have migrated to the aquifer through an abandoned open well bore on the site. The Odessa I site was added to the NPL in September 1984, and a ROD for OU 2 was signed in September 1986. OU 1, not addressed by this case study, concerned providing for an alternate water supply to replace water previously supplied by contaminated wells.

The extraction system used at this site consisted of six extraction wells constructed in the Trinity Sand Aquifer to a depth of 138 ft bgs, each with a design yield of 14,400 gpd. Extracted groundwater was treated with ferrous iron (produced on site in an electrochemical cell), pH adjustment and aeration, clarification, and multi-media filtration. While chromium concentrations have been reduced to below the MCL in three wells, as of December 1996, groundwater cleanup goals have not been achieved throughout the site.

There were several startup problems that delayed full-scale operation at this site, including clogging of injection wells and filters by iron and calcium. These problems were solved through system modification and no longer interfere with operations.

SITE INFORMATION

Identifying Information:

Odessa Chromium I Superfund Site
Operable Unit 2 (OU 2)
Odessa, Texas

CERCLIS #: TXD980867279

ROD Date for OU2: September 8, 1986

Treatment Application:

Type of Action: Remedial

Period of operation: 11/93 - Ongoing
(Monitoring and mass removal data collected through December 1996)
(Data on volume treated collected through January 1998)

Quantity of material treated during application: 125 million through January 1998

Background [1, 2, 3]

Historical Activity that Generated Contamination at the Site: Metals plating

Corresponding SIC Code: 3471, Plating of Metals

Waste Management Practice That Contributed to Contamination: Improper disposal practices

Location: Odessa, Texas

Facility Operations:

- In 1977, the Texas Natural Resources Conservation Commission (TNRCC) investigated citizen complaints of poor drinking water quality in private wells and discovered elevated levels of chromium in the groundwater. The 0.4-acre facility at 4318 Brazos Avenue was identified by EPA as the source of chromium contamination.
- Metals plating and chrome plating facilities operated at the site from 1954 to 1977, producing chromium and other metals-containing wastewater. Operations at the site ceased in 1977.
- High levels of chromium were detected in the soil and groundwater. The chromium contamination was caused by discharge of chromium-containing wastewater into unlined dirt ponds, directly to the soils, and into a septic tank drain field. Contaminants are also suspected to have migrated into the aquifer through an abandoned open well bore on the site.
- In 1984, the building, foundation, and soils contaminated with chromium were excavated and disposed. Shallow soils, down to approximately two feet, were removed. The remaining soils at the site were found to contain other heavy metals at detectable levels, but at levels that posed no apparent risk to human health and the environment.
- From 1977 until 1985, the TNRCC conducted drinking water well surveys to determine the extent of the chromium contamination.
- The Odessa I site was added to the National Priority List (NPL) in September 1984.
- The Remedial Investigation and Feasibility Study (RI/FS) was completed in 1986.

Regulatory Context:

- For the Odessa I site, EPA issued two Records of Decision (ROD): Operable Unit 1 (OU1) to address the need for an alternative drinking water supply and Operable Unit 2 (OU2) to address groundwater cleanup.
- In 1986, through the ROD for OU1, an alternate drinking water source was made available to replace water previously supplied by the contaminated wells.
- On March 18, 1988, the ROD for OU2 was approved for groundwater remediation. Further soil removal was not required by the ROD.

SITE INFORMATION (CONT.)

Background (Cont.)

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), § 121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: Extraction of the groundwater and treatment of chromium through ferrous ion reduction, followed by reinjection of treated water to the aquifer, was determined to be the most appropriate remedy for groundwater based on treatability studies.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Ernest Franke
U.S. EPA Region 6
First Interstate Bank Tower
at Fountain Place
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75202-2733
(214) 655-8521

*Indicates primary contact

State Contact:
Lel Medford*
Texas Natural Resources Conservation Commission
P.O. Box 13087
Austin, Texas 78711
(512) 239-2440

Treatment System Vendor:
Design and Management: IT Corporation (ITC)
Construction and Operation: WATEC

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,4,9]

Primary Contaminant Group: Chromium

- The contaminant of concern is chromium. The groundwater is contaminated with the hexavalent chromium species. However, cleanup standards are set for total chromium. Likewise, laboratory analyses test for total chromium. For these reasons, chromium levels tested and regulated at the Odessa I site are for total chromium. No organic contaminants were detected in the soil or groundwater.
- During a 1985 sampling event, chromium was detected in the groundwater at levels up to 72 mg/L. During sampling events in 1993, prior to pump and treat application, chromium was detected at levels up to 4.3 mg/L.
- The chromium plume directly beneath the former on-site building was heavily concentrated in the Trinity Sands, which is the major aquifer in the region. The remnants of the Ogallala Aquifer found at

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

the site contain a few feet of saturated thickness at the most. The northern plume migration concurs with the north-northeasterly groundwater flow direction observed during the RI/FS.

- The initial volume of the chromium plume was estimated in the 1986 RI/FS to be 15 million gallons between 44th and 48th streets. The areal extent of the initial plume was estimated to be approximately 283,000 square feet, based on a chromium contour of 0.05 mg/L.
- The ROD required the chromium levels in the groundwater to meet the maximum contaminant level (MCL) for chromium. EPA changed the MCL from 0.05 to 0.10 mg/L in 1990.
- Figure 1 illustrates the boundaries for the chromium plume for 1994, 1995 and 1996. From 1994 and 1996, the surface area of the chromium plume has decreased from 440,000 ft^2 to 247,000 ft^2, a reduction in plume size of 44%. The areal plumes are based on a total chromium concentration contour of 0.1 mg/L.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [4,9]

Two distinct hydrogeologic units have been identified beneath this site. Soil and sandy caliche overlie the water-bearing formations. The first water-bearing unit is encountered at approximately 30 to 45 feet below ground surface.

Unit 1	Ogallala Formation (Perched Zone)	This unit is formed of fluvial plastics consisting of fan deposits of fine to coarse grained sands, silt, clay, and occasional strings of gravel. There are only erosional remnants of this formation present in the site area, with a saturated thickness of less than 10 feet in the lower most portion. The erosional remnants of the Ogallala are hydraulically connected to the underlying Trinity Sand Aquifer, and water from the Ogallala flows into the Trinity. The Ogallalla does not exist as a continuous aquifer and thus flow direction could not be measured.
Unit 2	Trinity Sand Aquifer	This unit consists of sands and ferragiorous calcite cemented sandstones. Settled lenses of gravel, clay, and siltstone occur at irregular intervals. This unit is the primary groundwater water supply for municipal and private residences in the area. It is underlain by the Chinle Formation, which acts as an effective aquitard. Groundwater in this unit in the area of the site was observed to flow north to northeast, which concurs with the spread of the plume from the source. However, changes in water levels have altered groundwater flow direction.

The water level in the Trinity Sand Aquifer has risen over 25 feet from 1986 to 1993. The rise in the water table is attributed to the decrease of public and private wells using the aquifer and to increased precipitation during this period.

MATRIX DESCRIPTION (CONT.)

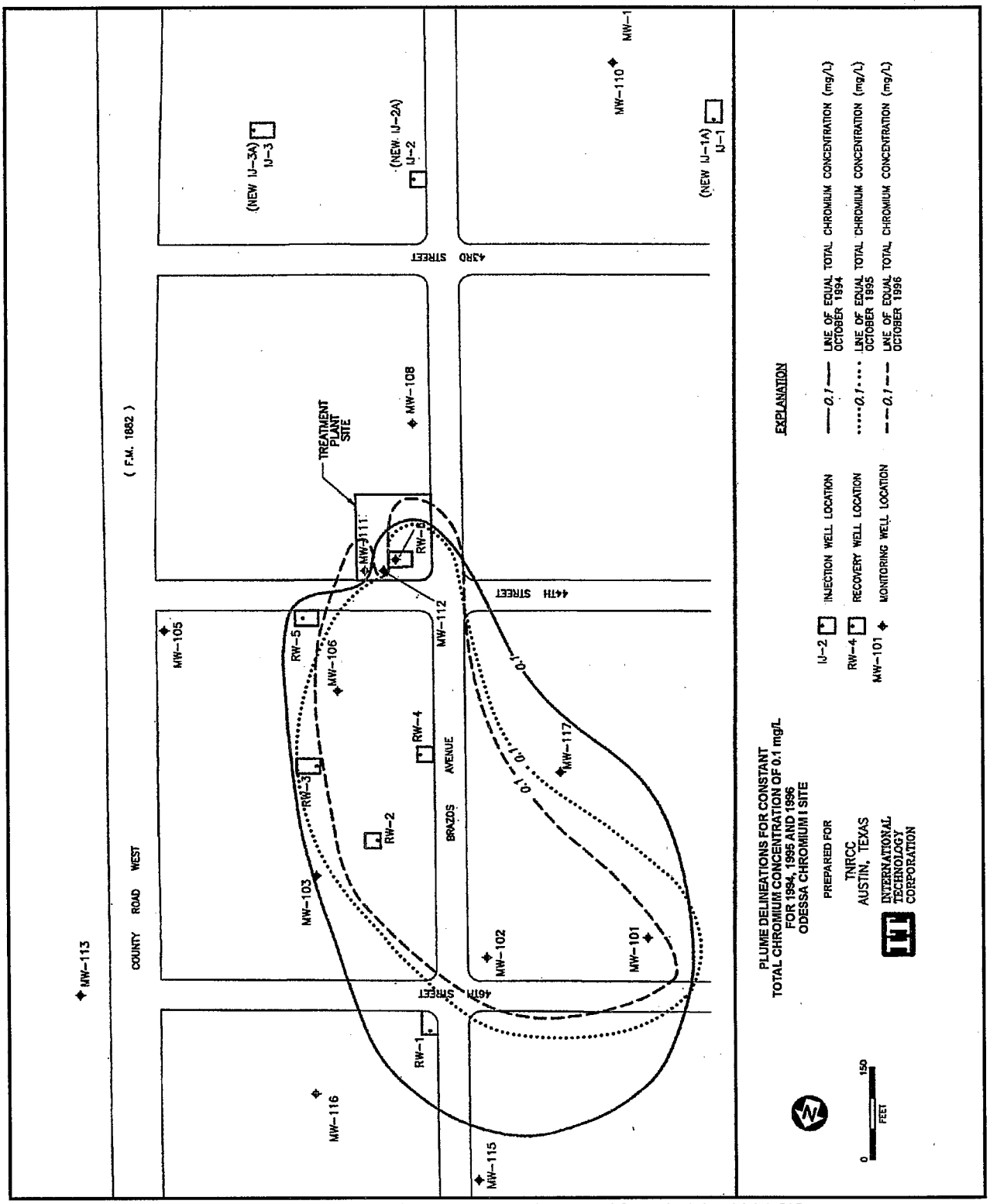


Figure 1. Chromium Concentration Contour Map, 1994 - 1996 [9]

MATRIX DESCRIPTION (CONT.)

Tables 1 and 2 include technical aquifer information and technical well data, respectively. Extraction wells are discussed in the following section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Flow Velocity (ft/day)	Flow Direction
Unit 1 (Ogallala)	0 - 10	1.6	0.02	Not Characterized[1]
Unit 2 (Trinity Sand)	70	1.7 - 5.1	0.03 - 0.00	North-Northeast[2]

[1]Water flows from the Ogallala to the Trinity, but the direction of flow has not been characterized.
[2]Flow observed during the 1986 remedial investigation was towards the north-northeast. However, the water table rose from 1986 to 1993 by 25 feet. Flow observed during a 1993 investigation was towards the southeast. Groundwater investigations since 1993 have shown groundwater flow direction to be northerly.

Source: [4]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with electrochemical precipitation of chromium using ferrous ion

Supplemental Treatment Technology

None

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/day)
RW-1/102	Trinity Sand	138	14,400
RW-2	Trinity Sand	138	14,400
RW-3	Trinity Sand	138	14,400
RW-4	Trinity Sand	138	14,400
RW-5/106	Trinity Sand	138	14,400
RW-6	Trinity Sand	138	14,400

Source: [4]

System Description [4, 5]

- The extraction system consists of six recovery wells, located in the Trinity Aquifer (Unit 2). No recovery wells were placed in the Ogallalla Formation, directly beneath the site because only erosional remnants of the Ogallalla remain in the vicinity of the Odessa I site. In addition, the groundwater in this zone flows directly into the Trinity Aquifer. A computer model was used to determine well placement and design extraction rates in the Trinity Aquifer. The modelling determined capture zone for the plume that exceeded 0.1 mg/L chromium.
- ITC used Randomwalk to model solute transport (an in-house model by Reed and Associates) and Geoflow to model groundwater flow (an in-house model by ITC).

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The metals treatment system is designed to treat the collected groundwater at a rate of 60 gpm. Influent tanks regulate flow through the treatment system.

- Water from the extraction wells is sent to a dual-chamber reaction tank. Ferrous ion is fed into the first chamber and mixed with the contaminated well water. Ferrous ion is produced on site in an electrochemical cell. The ion reduces the hexavalent chromium to trivalent chromium, to facilitate subsequent hydroxide precipitation. In the second chamber of the reaction tank, pH is adjusted to the range of 8.5 to 8.8 to achieve minimum solubility for chromium hydroxide. Also in the second chamber, ferrous ion is oxidized by aeration to insoluble ferric ion and converted to ferric hydroxide. Both the ferric and the chromium hydroxide are mixed with a poly-electrolyte in the second chamber.

- The treated water is clarified through a flocculation and precipitation tank, where insoluble hydroxides are precipitated out. From here, the treated water is polished through a multimedia filter for reinjection. A backwash unit stores a portion of the treated water, which is used to flush the filter at least once every 24 hours. The sludge from the clarifier is disposed off site.

- Chromium concentrations in the influent and the effluent from the treatment system are monitored continuously. If the level of chromium exceeds 0.05 mg/L in the effluent, it is pumped back through the treatment system. Treated water with chromium concentrations less than 0.05 mg/L is injected through a network of six injection wells.

- A network of 14 monitoring wells placed in the Trinity Aquifer is used to monitor plume containment quarterly. The six recovery wells are monitored on a monthly basis for water quality parameters as well.

System Operation [4,5,6,7]

- Quantity of groundwater pumped from the aquifer by year is:

Year	Volume Pumped (gal)
1992	361,000*
1993	5,339,885*
1994	28,400,155
1995	30,692,836
1996	30,598,566

*The volume pumped during 1992 was during a 30-day unsuccessful trial run. The extraction system operated only for the months of November and December in 1993.

- Initial startup began in July 1992. The injection wells and the filter began to clog with iron and calcium in the first 30 days of system operation. The extraction and treatment systems were shut down for the following alterations.

  -- The reactive tank was altered from a single-chamber to a two-chamber tank, separated by a baffle. The second chamber allowed for further precipitation of iron, the cause of clogging.

  -- A backwash unit was added after the multi-media polishing filter to unclog the filter of iron and other precipitates. The pH of the water after the clarifier was reduced to less than 7.5.

  -- Original injection wells continued to be used, but infiltration rates had slowed because of clogging. Three additional injection wells were constructed to increase the injection rate.

  -- After modifications were made from May 1993 to August 1993, the system resumed operation in November 1993.

  -- Backwash water is stored in the modified backwash unit and is added slowly to the influent tank. The slow addition avoids upsetting the pH balance in the influent tank.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Based on sampling events from 1993 to 1995, the higher chromium concentrations appeared to be migrating to the northwest. Recovery wells RW-1 and RW-5 were shut down and monitoring wells MW-102 and MW-106 were converted to recovery wells to continue pumping from areas in the plume with high chromium concentrations.
- One injection well was found to continually plug because of a local formation of silty fines. It was taken off line in May 1995. The rate of injection of treated water remained the same.
- The site has been operational 95% of the time since 1993. Downtime is primarily due to shutdowns for local brown outs and system maintenance.

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is extraction rate. Table 3 presents the values measured for this and other performance parameters.

Table 3. Performance Parameters

Parameter	Value
Average Pump Rate	86,500 gpd*
Performance Standard (effluent)	0.05 mg/L total chromium
Remedial Goal (aquifer)	0.10 mg/L total chromium

Source: [2, 6]

*The average system extraction rate from January 1998 until December 1996 was estimated for this report to be 86,500 gpd or approximately 14,400 gpd per well, based on the actual 125 million gallons pumped and 95% operating rate.

Timeline

Table 4 presents a timeline for this remedial action.

Table 4. Timeline

Start Date	End Date	Activity
January 1992	July 1992	Remediation system constructed
July 1992	August 1992	System started; injection wells clogged with iron and calcium
May 1993	August 1993	Alterations made to remedial system
November 1993	---	Continuous operation of remediation system begun. Monthly monitoring of groundwater begun.
April 1995	---	Shift in plume detected. Monitoring wells MW-102 and MW-106 converted to recovery wells RW-102 and RW-106. RW-1 and RW-5 shut down
May 1995	---	Injection Well IJ-2 taken off line because of plugging

Source: [2, 4, 6, 7]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [2]

- The cleanup goals as established by TNRCC and EPA are to remediate groundwater so that chromium levels are less than the maximum contaminant level (MCL), or the Primary Drinking Water Standard, of 0.10 mg/L. This goal is applied throughout the aquifer, as measured in all on-site monitoring wells.

Additional Information on Goals

- The original drinking water standard for chromium set by EPA was 0.05 mg/L. In 1990, EPA revised the standard to the Primary Drinking Water Standard of 0.10 mg/L.

Treatment Performance Goals [4]

- Effluent injected into the aquifer from the treatment system must have levels of chromium below 0.05 mg/L.
- As a secondary goal, the remedial system is required to create an inward gradient toward the site to contain the plume.

Performance Data Assessment [1, 3, 4, 5, 6, 7]

- Three wells have met the cleanup goal for chromium of 0.10 mg/L: RW-1, RW-3, and RW-5. The maximum concentration of chromium detected in the groundwater in January 1997 was 2.9 mg/L. Groundwater monitoring results indicate that chromium concentrations have been reduced compared to initial levels, but not to levels below the treatment goal.
- Figure 2 illustrates the changes in average chromium concentrations in the groundwater from January 1992 to January 1997 [6]. Average chromium levels were reduced by 48% during that time, from 0.98 mg/L in March 1992 to 0.54 mg/L in January 1997.
- The individual wells provided wide variations in month to month chromium concentrations for the first two years. The variation became less pronounced in 1996 with a noticeable downward trend [9].
- Concentrations of chromium in the groundwater have fluctuated in different wells. Figure 3 illustrates that chromium levels in RW-1 and RW-5 increased from 1992 to 1995. Figure 4 illustrates well-specific chromium levels that decreased from 1991 to 1997, then fluctuated during 1994. Figure 5 illustrates well-specific chromium levels that decreased from 1986 until 1997 [4,6].
- The September 1994 sampling event revealed spikes in concentrations of chromium in many wells [7]. The site contact has indicated that while no QA/QC problems were identified, the validity of the September 1994 sampling event is questionable [6].
- Other spikes in concentrations of chromium may be a result of incomplete source removal. According to the site contact, source control measures were applied only to shallow soils. Because the ROD did not specify complete removal of soil contamination, additional soil removal was not performed.
- Figure 6 presents the removal of chromium through the treatment system from December 1993 to 1996 [1,5]. During this time, a total of 1,143 pounds of chromium were removed from the groundwater [1]. Chromium mass removal was determined based on the chromium concentrations in the sludge. Data on the amount of chromium removed by the treatment system during the 30-day period in 1992 were not available.
- Figure 6 illustrates that mass flux decreased after the first year of system operation, from 1.2 pounds per day to less than 0.8 pounds per day [1].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- Effluent chromium levels have met the required performance standard of 0.05 mg/L throughout treatment [6].
- Based on sampling events, plume containment has been achieved since 1995 [3,6]. The site operators determined there was a failure in plume containment during 1993 and 1995, based on a rise in chromium concentrations in some monitoring wells during this period [4]. Two monitoring wells within the area of concern were converted to recovery wells, and two recovery wells from a less contaminated area were taken off line.

Performance Data Completeness

- Data on mass flux and mass removed are reported on a monthly basis and are available for this site from the TNRCC. Annual data were used for the analyses in Figure 6.
- For the chromium concentration analyses in Figures 2 through 5, annual monitoring data were used for 1993 and 1995 through 1997. Quarterly data were used for 1994. These data were supplied in monthly reports and in the Project Status Draft Report prepared by ITC in 1995. Monitoring data are available on a quarterly basis for this site from the TNRCC.
- A geometric mean was used for average chromium concentrations detected in the groundwater, as presented in Figure 4, to represent the overall trend of chromium contamination in the groundwater at the site.
- When concentrations below detection limits were encountered, half of the detection limit was used for evaluation purposes.

Performance Data Quality

The QA/QC program used throughout the remedial action met EPA and TNRCC requirements. All monitoring was performed using EPA Method 218.1 and EPA-approved methods for pH, total suspended solids, and other water quality parameters. Except for the September 1994 data (discussed above) the vendor did not note any exceptions to the QA/QC protocols [6].

TREATMENT SYSTEM PERFORMANCE (CONT.)

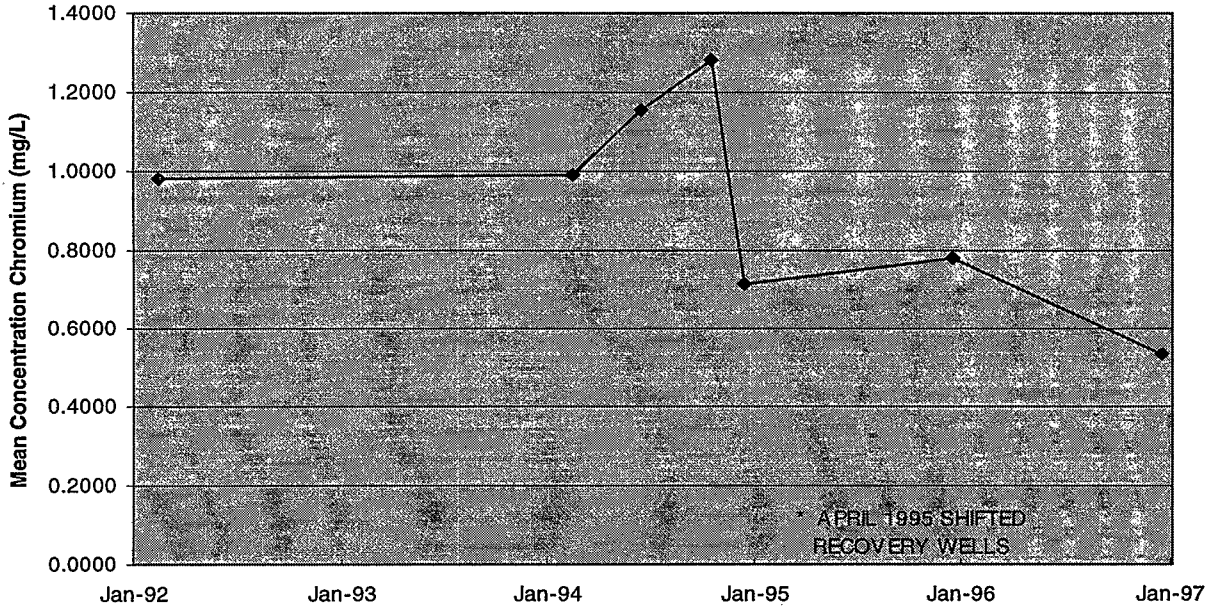


Figure 2. Average Chromium Concentrations in the Groundwater (1992 - January 1997) [4,6]

* Two monitoring wells converted to extraction wells; two other extraction wells shut down.

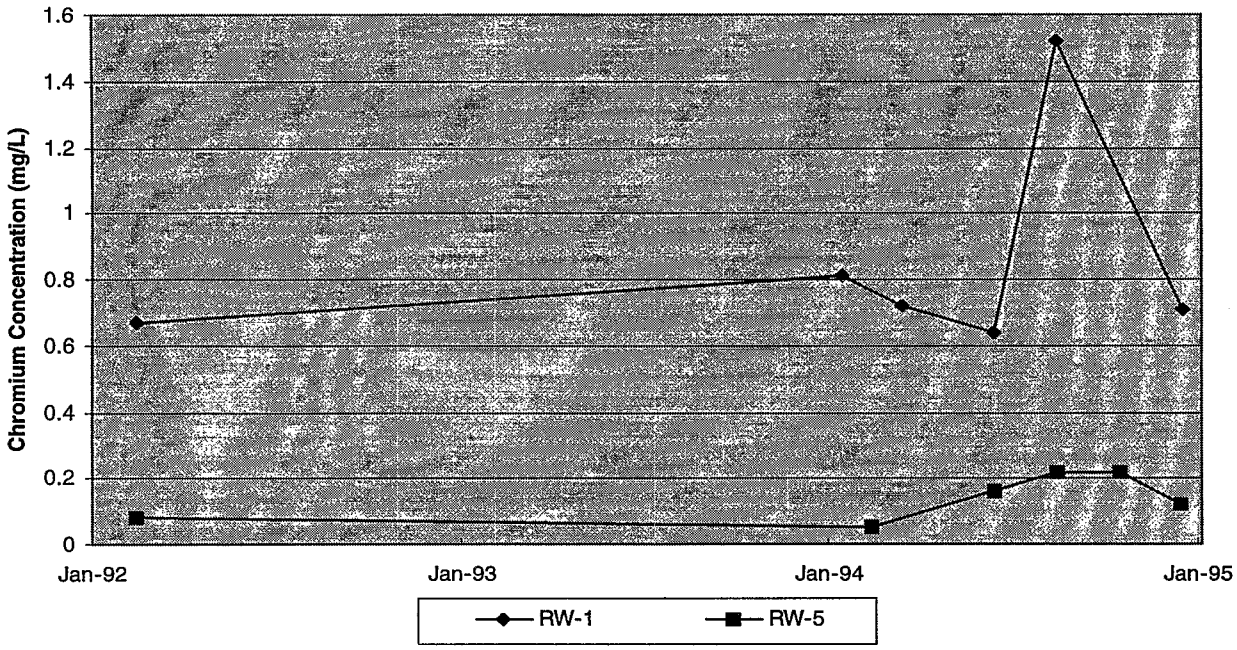
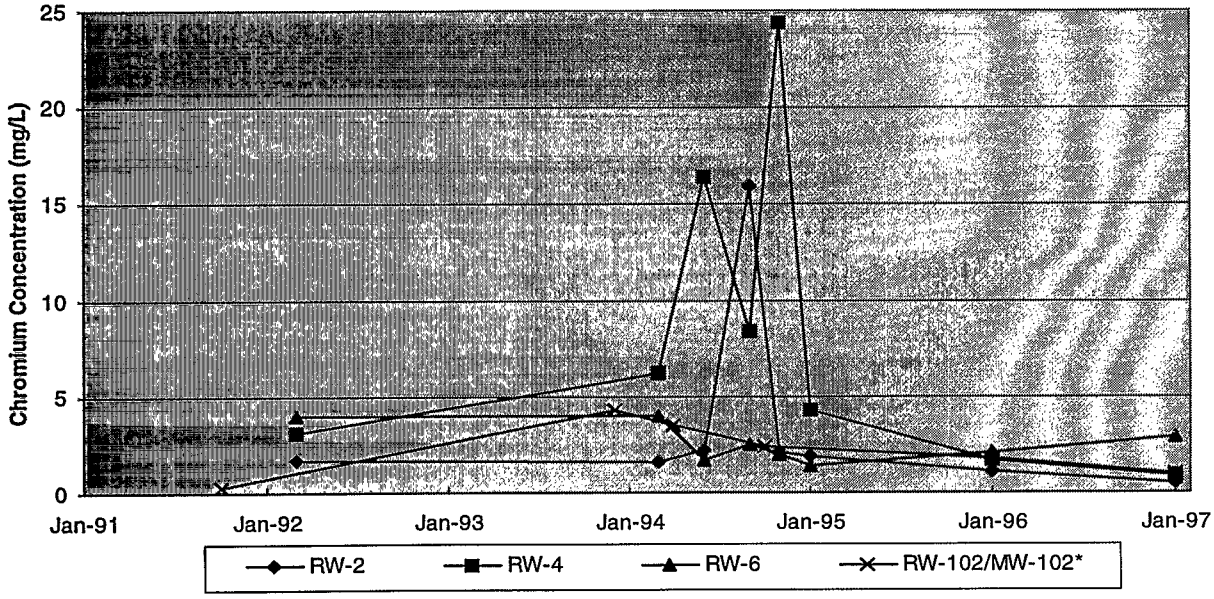


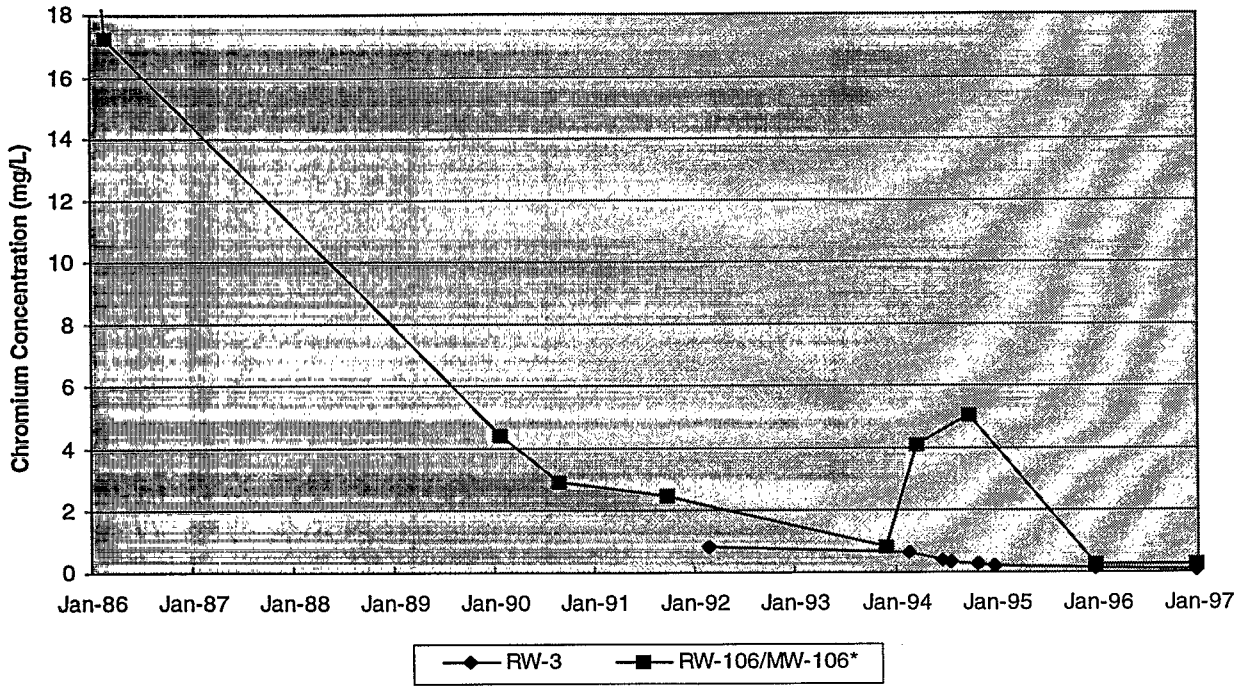
Figure 3. Chromium Concentrations in Wells RW-1 and RW-5 (1992 - 1997) [4,6]

TREATMENT SYSTEM PERFORMANCE (CONT.)



*RW-102 was MW-102 until 4/95

Figure 4. Chromium Concentrations in Wells RW-2, RW-4, RW-6, and RW-102 (1991 - 1997) [4,6]



*RW-106 was MW-106 until 4/95

Figure 5. Chromium Concentrations in Wells RW-3 and RW-106 (1986 - 1997) [4,6]

TREATMENT SYSTEM PERFORMANCE (CONT.)

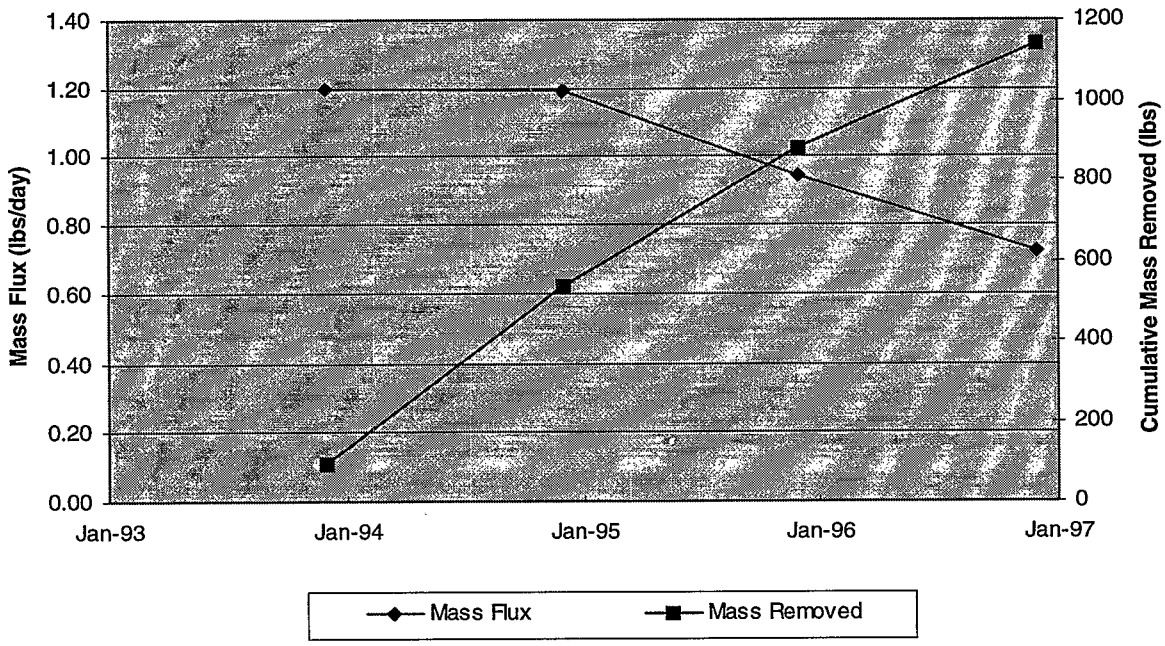


Figure 6. Mass Flux Rate and Cumulative Chromium Removal (1993 - 1996) [6]

TREATMENT SYSTEM COST

Procurement Process

TNRCC is the lead authority on this site. WATEC was awarded the construction and operations contract for the site. ITC was awarded the oversight contract for the site.

Cost Analysis

- The costs for design, construction, and operation of the P&T system at this site were split 90:10 by EPA and TNRCC, respectively.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [6]

Remedial Construction	
Mobilization Work	$334,723
Monitoring Wells - Sampling/Testing Analysis	$52,761
Groundwater Collection & Control	$287,947
Installation of Treatment Plant	$944,800
Site Restoration	$13,542
Site Security	$3,298
Construction Management	$316,533
Total Remedial Construction	**$1,953,604**

Operating Costs [6]

Operation and Maintenance	$774,418
Monitoring Costs	$13,841
Total Cumulative Operating Expenses (1993-1996)	**$788,259**
1993 Operating Costs (11/93 - 12/93)	$25,772
1994 Operating Costs (1/94 - 12/94)	$202,817
1995 Operating Costs (1/95 - 12/95)	$228,705
1996 Operating Costs (1/96 - 12/96)	$330,965

Other Costs [6]

Remedial Design	
Original Bid Design	$132,180
Final Amount (redesign in 1993) (total for design)	$230,438

Cost Data Quality

Actual capital and operation and maintenance cost data are available from TNRCC for this application.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the pump and treat application at Odessa I were approximately $2,742,000 ($1,954,000 in capital costs and $788,000 in operation and maintenance costs), which corresponds to $30 per 1,000 gallons of groundwater treated and $2,400 per pound of chromium removed. The $30 per 1,000 gallons is based on volume treated through December 1996, because cost data through 1998 were not available at the time of this report.
- The ROD specified that the ferrous ion used to reduce the chromium would be electrochemically produced, which limited the number of the on-site system vendors to two and potentially increased the cost of the treatment unit.
- The costs listed above include the system modifications performed in 1993 and in 1995. There have been no further changes to the cost for the remedial system at the site [3].
- Operating costs have increased from 1993 to 1996. The operations contract has a fixed annual cost for disposal of up to 500 lbs of chromium. Any amount of chromium beyond 500 lbs is paid on a cost plus fixed fee basis, resulting in additional annual disposal costs each year since 1993.
- While chromium levels have been reduced below the MCL in three wells, the groundwater cleanup goals have not been achieved as of December 1996. Extraction and treatment will continue until goals are achieved [3,4,6].
- Overall, average chromium concentrations decreased, but concentrations of chromium have fluctuated in some wells [4]. These variations in chromium levels are most likely a result of the increased groundwater level and further desorption of chromium from aquifer materials [3,7]. According to the site contact, because complete removal of all contaminated soils was not specified in the ROD, source control measures (i.e., soil removal) were applied to only shallow soils [4]. Deeper aquifer material may still contain high levels of chromium that can act as a source for continuing contamination [3,7]. The site contact also noted that complete source removal would have eliminated the source for a persistent plume [3].

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- The plume has been contained since 1995, after containment failure from 1993 to 1995 [1]. The shift in groundwater flow observed in 1993 may have caused the containment failure [6]. By adjusting the extraction system, plume containment was achieved. This illustrates the importance of flexibility in system operation.

- There were several startup problems, including clogging of injection wells and filter by iron and calcium, that delayed full-scale operations [4]. These problems were solved through system modification, and no longer interfere with operations. The site contractor has suggested that one potential approach to identifying the problems earlier would be to increase the length of pilot operations. At this site, pilot operations were conducted in hourly increments, and the results were used to simulate full-cycle operations. Had the pilot operations been conducted for a full 24-hour cycle, it is likely that the iron and calcium fouling problems that led to clogging would have been identified [4].

- Full-scale operations were delayed by iron encrustation in the injection wells and in the filter. Setting effluent standards for iron in the future could prevent such delays.

- ITC also has concluded that the continuous chromium monitors on the influent were not useful because they could not detect chromium levels above 1.0 mg/L. They did not operate until wells were well on the way to being clean. Monthly tracking was found to be helpful for monitoring site cleanup, but continuous data were not useful [4].

- During system operation, system operators determined that backwash from the filter system should be equalized and added slowly to the influent tank to avoid large changes in the influent chemistry [4]. During early system operations, backwash water was introduced directly into the influent tank. The differences between the pH levels in the backwash and the influent reduced the effectiveness of the reaction tank. The backwash storage unit allows gradual addition of backwash to the influent. This has alleviated the earlier problems in the reaction tank [4].

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7. Lessons Learned, ITC, January 1997.
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9. TNRCC comment on draft report, dated 3/11/98.

Analysis Preparation

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Pump and Treat of Contaminated Groundwater at the Odessa Chromium IIS Superfund Site, OU 2 Odessa, Texas

Pump and Treat of Contaminated Groundwater at the Odessa Chromium IIS Superfund Site, OU 2 Odessa, Texas

<table>
<tr><td>Site Name:
Odessa Chromium IIS Superfund Site, Operable Unit 2 (OU 2)</td><td rowspan="2">Contaminants:
Heavy Metals (Chromium)
- Maximum concentration of Cr detected during 1986 sampling event was 50 mg/L (perched zone aquifer)</td><td>Period of Operation:
Status: Ongoing
Report covers: 11/93 - 12/97</td></tr>
<tr><td>Location:
Odessa, Texas</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Design and Management: IT Corporation (ITC)
Construction and Oversight: WATEC</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 10 wells at an average total pumping rate of 58.5 gpm
- Extracted groundwater is treated for Cr removal with chemical treatment (ferrous ion, produced on site), pH adjustment, flocculation, precipitation, and multimedia and cartridge filtration
- Treated groundwater is reinjected through 9 injection wells</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 3/18/88</td></tr>
<tr><td>State Point of Contact:
Lel Medford
Texas Natural Resources Conservation Commission
P.O. Box 13087
Austin, TX 78711
(512) 239-2440</td><td>EPA Point of Contact:
Ernest Franke, RPM
U.S. EPA Region 6
First Interstate Bank Tower at Fountain Place
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733
(214) 655-8521</td></tr>
<tr><td>Waste Source:
Unlined wastewater-holding ponds and waste drum burial</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 121 million gallons treated as of December 1997
- Groundwater is found at 30-45 ft bgs
- Extraction wells are located in 2 aquifers, which are influenced by production wells in the area
- Hydraulic conductivity ranges from 1.6 to 5.1 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Includes on-site treatment for chromium; relatively low groundwater flow; contamination in two aquifers.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Remediate groundwater so that chromium levels are less than the maximum contaminant level (MCL) or primary drinking water standard.
- Prior to 1990, the drinking water standard for chromium was 0.05 mg/L; in 1990, EPA revised the drinking water standard to 0.10 mg/L.
- Treated effluent that is injected into the aquifer must have a chromium level of less than 0.10 mg/L.
- The remedial system was required to create an inward gradient toward the site to contain the plume.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Odessa Chromium IIS Superfund Site, OU 2 Odessa, Texas (continued)

Results:
- Groundwater sampling results show that chromium levels have been reduced to less than 0.10 mg/L in the Trinity Aquifer but not in the Ogallala Aquifer. Results from January 1997 show that concentrations have been reduced in the Ogallala Aquifer (since startup), but not to levels below 0.10 mg/L.
- The P&T system removed 131 pounds of chromium from the groundwater from 1993 to December 1996.
- Effluent chromium levels have met the required performance standard of 0.10 mg/L throughout system operation.
- The plume has been contained in both aquifers.

Cost:
- Actual costs for the P&T system were approximately $2,487,700 ($1,927,500 in capital and $560,200 in O&M), which correspond to $26 per 1,000 gallons of groundwater extracted and $19,000 per pound of contaminant removed.
- The ROD specified that the ferrous iron used in the treatment system be produced electrochemically, which limited the number of vendors to two and potentially increased the cost of the treatment system.
- The costs for design, construction, and operation of the P&T system were split 90:10 by EPA and TNRCC, respectively.

Description:
Basin Radiator & Supply operated a radiator repair facility at this site from 1960 to the early 1970s. Wastewater containing chromium was discharged to unlined ponds, and waste radiator sludge containing chromium corrosion inhibitors was buried on the site. In 1977, the TNRCC discovered elevated levels of chromium in the groundwater during investigations conducted in response to citizen complaints of contaminated well water. This site later became known as the Odessa II South (S) site. The Odessa IIS site was placed on the NPL in June 1986, and a ROD was signed for the site in March 1988.

The extraction system used at this site consisted of six extraction wells constructed in the Trinity Sand Aquifer and four extraction wells in the Ogallala Formation. Extracted groundwater was treated with ferrous iron (produced on site in an electrochemical cell), pH adjustment and aeration, clarification, and multi-media and cartridge filtration. While chromium concentrations have been reduced to below the MCL in the Trinity Aquifer, groundwater cleanup goals have not been achieved in the Ogallala Formation.

There were several startup problems that delayed full-scale operation at this site, including clogging of injection wells and encrustation of the multimedia filter by iron and calcium. These problems were solved through system modification and no longer interfere with operations.

SITE INFORMATION

Identifying Information:

Odessa Chromium IIS Superfund Site
Operable Unit 2 (OU 2)
Odessa, Texas

CERCLIS #: TXD980697114

ROD Date: March 18, 1988

Treatment Application:

Type of Action: Remedial

Period of Operation: 11/93 - Ongoing
(Performance data collected through December 1996)
(Data on volume treated collected through December 1997)

Quantity of Material Treated During Application: 121 million gallons

Background

Historical Activity that Generated Contamination at the Site: Radiator repair

Corresponding SIC Code: 7538

Waste Management Practice That Contributed to Contamination: Unlined wastewater-holding ponds and waste drum burial

Location: Odessa, Ector County, Texas

Facility Operations: [1, 2, 3]

- The site is located in a mixed residential, commercial, industrial area. The Basin Radiator & Supply formerly located in the 5300 block of Andrews Highway operated from 1960 to the early 1970s. Wastewater containing chromium was discharged to unlined ponds, and waste radiator sludge containing chromium corrosion inhibitors was buried on the site. Also located in the 5300 block of Andrews Highway was Wooley Tool and Manufacturing which had a chromium plating operation.

- In 1977, the Texas Natural Resource Conservation Commission (TNRCC) discovered elevated levels of chromium in the groundwater during investigations in response to citizen complaints of contaminated well water.

- The TNRCC concluded that the two facilities were the source of chromium in the groundwater: Wooley Tool and Manufacturing and Basin Radiator & Supply. The former became known as the Odessa II North site and the latter as the Odessa II South(S) site. The Odessa IIS site is the subject of this report.

- In 1978, the TNRCC removed drums, on-site buildings, and contaminated soils from the site.

- In 1986, the Remedial Investigation/ Feasibility Study (RI/FS) was completed. On June 10, 1986, Odessa IIS was placed on the National Priorities List (NPL).

Regulatory Context:

- For the Odessa IIS site, the EPA issued two Records of Decision (ROD). In 1986, the ROD for Operable Unit 1 (OU1) was signed to provide an alternative drinking water supply.

- On March 18, 1988, the ROD for OU2 was approved for groundwater remediation at Odessa IIS. Source control was not required by the ROD.

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

SITE INFORMATION (CONT.)

Background (Cont.)

Groundwater Remedy Selection:
Groundwater extraction followed by treatment to remove chromium contamination and injection of the treated water back to the aquifer was determined by the FS to be the most appropriate methodology for site remediation. The results of a pilot study confirmed the basic approach.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Ernest Franke
U.S. EPA Region 6
First Interstate Bank Tower at Fountain Place
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75202-2733
(214) 655-8521

State Contact:
Lel Medford*
Texas Natural Resources Conservation Commission (TNRCC)
P.O. Box 13087
Austin, Texas 78711
(512) 239-2440

Treatment System Vendor:
Design and Management: IT Corporation (ITC)
Construction and Operation: WATEC

*Indicates primary site contact

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1, 3]

Primary Contaminant Groups: Chromium

- The contaminant of concern is chromium. Hexavalent chromium is the species of concern in the groundwater because under the aquifer conditions it is the only species that is soluble and can affect the drinking water. The ROD stipulates a clean-up standard based on total chromium since the Maximum Contaminant Limit (MCL) was set for total chromium, instead of an individual species.
- Two hydraulically connected chromium plumes have been identified and are referred to as the Perched Zone plume and the Trinity Aquifer plume.
- The maximum concentration of chromium in the groundwater in the Trinity Aquifer, detected during a 1985 sampling event, was 2.8 mg/L. The maximum chromium concentration in the Perched Zone groundwater, detected in 1986, was greater than 50 mg/L.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization [1, 3] (Cont.)

- The initial volume of the chromium plume in the Perched Zone was estimated in the 1986 RI/FS at 980,000 gallons. The areal extent of the initial plume was estimated to be approximately 105,000 square feet.
- The initial volume of the chromium plume in the Trinity Aquifer was estimated in the 1986 RI/FS at 79,000,000 gallons. The areal extent of the initial plume was estimated to be approximately 585,000 square feet.
- The ROD required the site to be cleaned to meet the MCL for chromium. In 1990, EPA changed the MCL from 0.05 mg/L to 0.10 mg/L in 1990 by EPA. The plume size estimates were originally calculated based on the 0.05 mg/L contour.
- Figures 1 and 2 delineate the 0.1 mg/L chromium contours in the Perched Zone and Trinity Aquifer, respectively, as observed during a September 1994 (nine months after beginning treatment) sampling event.
- In the Project Status Draft Report, the plume volumes in the Perched Zone and Trinity Aquifer were calculated based on the revised 0.1 mg/L clean-up goal and data that were nine years more current than the original RI data. A significant change in the aquifer water level and the chromium concentration had occurred between 1985 and 1994 because of lower water withdrawal rates in the area.
- The Perched Zone plume was found to be 61,270 square feet in area and 690,000 gallons in volume, compared to the 1986 plume estimate of 105,000 square feet in area and 980,000 gallons in volume. The Trinity Aquifer plume was found to be 210,385 square feet in area and 44,000,000 gallons in volume, compared to the 1986 estimate of 585,000 square feet and 79,000,000 gallons. The plume reductions are in part because of lowered levels of chromium but also because of the less stringent standard.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [1, 3]

Two distinct hydrogeologic units have been identified beneath this site. Soil and sandy caliche overlie the water-bearing formations. The first water-bearing unit is encountered at approximately 30 to 45 feet below ground surface.

Unit 1	Ogallala Formation (Perched Zone)	This unit is formed of fluvial plastics consisting of fan deposits of fine to coarse grained sands, silt, clay, and occasional strings of gravel. A few miles to the south, the Ogallala has been removed by erosion. It is present in some parts of the site with a saturated thickness of approximately 5 to 15 feet, and is referred to as the Perched Zone. It is hydraulically connected and discharges to the underlying Trinity Sand Formation under natural conditions. The Ogallalla does not exist as a continuous aquifer and thus flow direction could not be measured.
Unit 2	Trinity Sand Aquifer	This unit consists of sands and ferragiorous calcite cemented sandstones. Settled lenses of gravel, clay, and siltstone occur at irregular intervals. This unit is the primary groundwater supply for municipal and private residences in the area. It is underlain by the Chinle Formation, which acts as an aquitard. Groundwater flow in this unit has been observed to flow north to northeast; however, changes in water levels have altered groundwater flow direction.

MATRIX DESCRIPTION (CONT.)

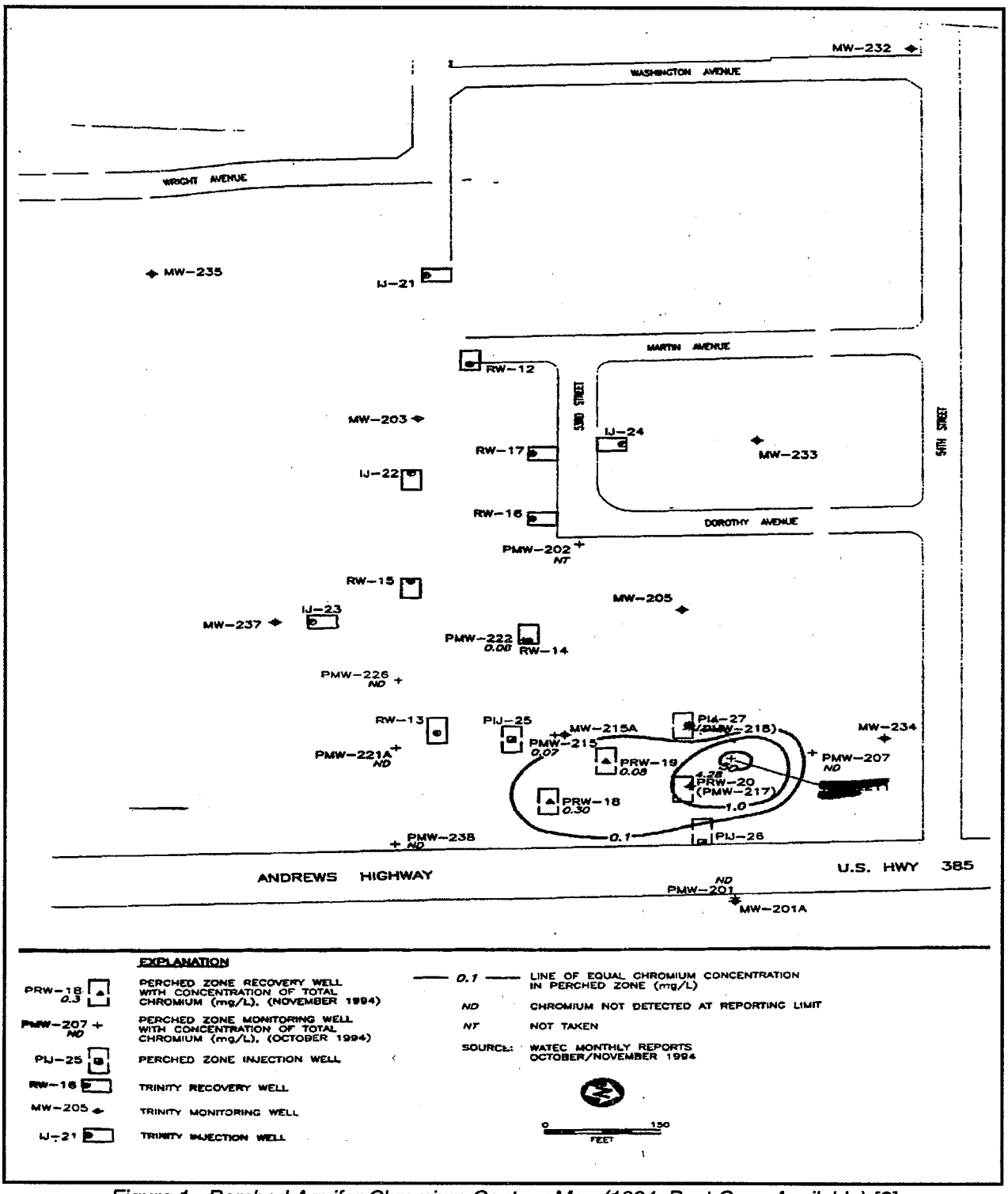

Figure 1. Perched Aquifer Chromium Contour Map (1994, Best Copy Available) [3]

MATRIX DESCRIPTION (CONT.)

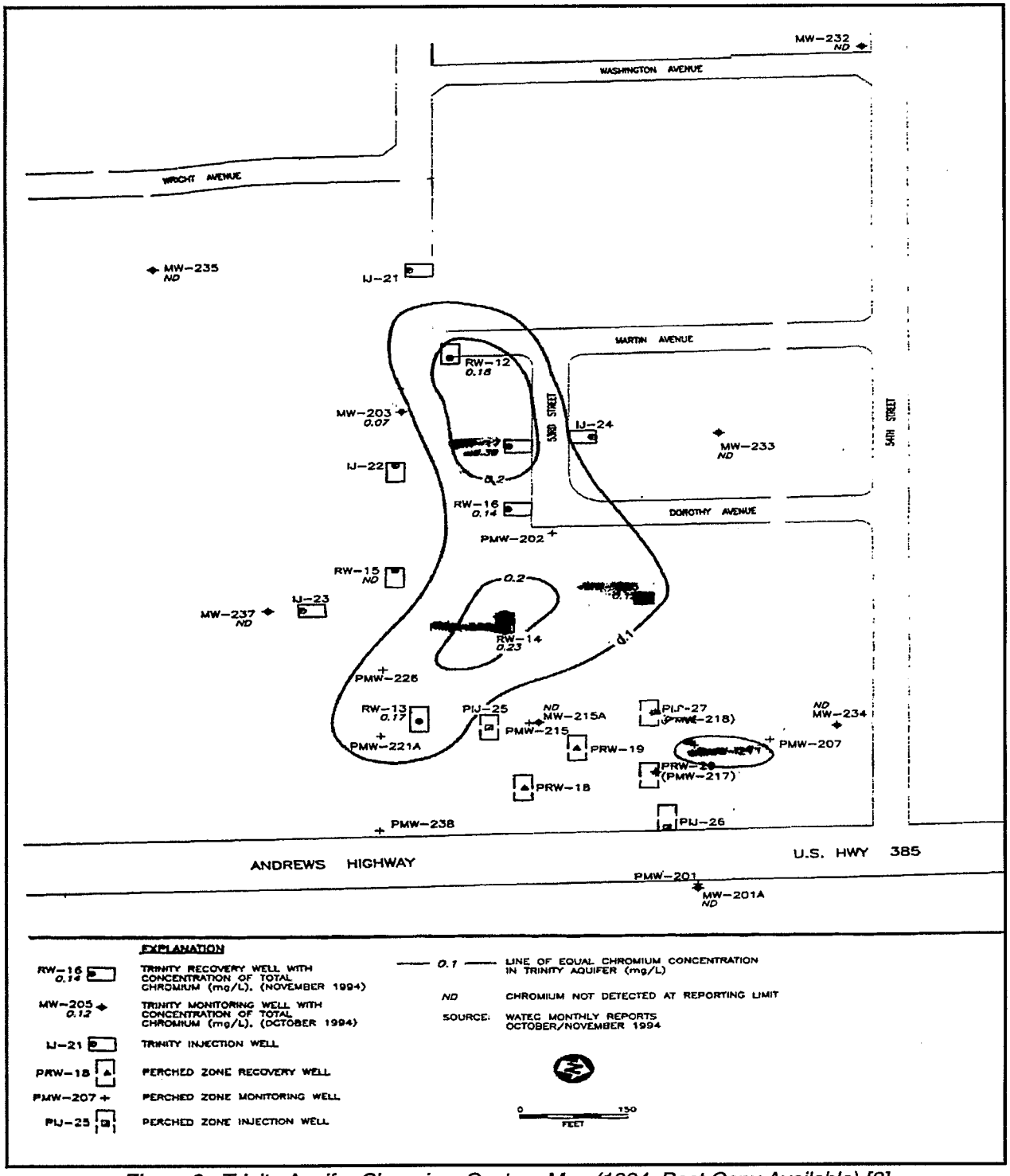

Figure 2. Trinity Aquifer Chromium Contour Map (1994, Best Copy Available) [3]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

The water level in the Trinity Aquifer has risen over 25 feet from 1986 to 1993. The rise in the water table is attributed to the decrease of public and private wells in the aquifer and to increased precipitation during this period.

Tables 1 and 2 present technical aquifer information and extraction well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Flow Velocity (ft/day)	Flow Direction
Unit 1	5 - 15	1.6	0.0190	Not Characterized
Unit 2	70	1.7 - 5.1	0.0262 - 0.0782	North-Northeast[1]

[1]Flow observed during the 1986 remedial investigation was towards the north-northeast. However, the water table rose from 1986 to 1993 by 25 feet and could have resulted in a change in groundwater flow direction.

Source: [1, 3]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with electrochemical precipitation of chromium using ferrous ion

Supplemental Treatment Technology

Solids removed by flocculation and filtration

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/day)
PRW18	Ogallala Formation	70	4,070
PRW19	Ogallala Formation	70	4,070
PRW20	Ogallala Formation	70	4,070
PRW28	Ogallala Formation	70	4,070
RW12	Trinity Aquifer	165	21,600
RW13	Trinity Aquifer	165	21,600
RW14	Trinity Aquifer	165	21,600
RW15	Trinity Aquifer	165	21,600
RW16	Trinity Aquifer	165	21,600
RW17	Trinity Aquifer	165	21,600

Source: [1,3,4]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

System Description [3, 5, 8]

- The extraction system consists of six recovery wells in the Trinity Aquifer and four recovery wells in the Ogallala Formation. ITC used Random Walk to model solute transport (an in-house model by Reed & Associates) and Geoflow to model groundwater flow (an in-house model by IT). Model results were used to determine well placement based on projected pumping rates.

- The metals treatment system is designed to treat the collected groundwater at a rate of 60 to 90 gpm. An influent tank regulates flow through the treatment system.

- Water from the extraction wells is sent to a dual chamber reaction tank (initially single chamber), into which ferrous ion is fed and mixed with the contaminated well water. Ferrous ion is produced on site in an electrochemical cell. The ion reduces the hexavalent chromium to trivalent chromium to facilitate subsequent hydroxide precipitation. In the second chamber of the reaction tank, pH is adjusted in the range of 8.5 to 8.8 to achieve minimum solubility for chromium hydroxide. Also, in the second chamber, excess ferrous ion is oxidized by aeration to insoluble ferric ion and converted to ferric hydroxide. The ferric and chromium hydroxide precipitate is mixed with a polyelectrolyte in the second chamber to aid settling.

- The treated water is clarified through a flocculation and precipitation tank. From here, the treated water is polished through a multimedia and cartridge filter for reinjection. The multimedia filters are backwashed with treated water based on pressure drop and the cartridge filters are replaced when a specified pressure differential is exceeded. The sludge from the clarifier and the cartridge filters are disposed off site as nonhazardous waste.

- Chromium concentrations in the influent to and the effluent from the system are monitored continuously. If the level of chromium exceeds 0.05 mg/L in the effluent, the effluent is recycled through the treatment system. Treated water with chromium concentrations less than 0.05 mg/L is injected through a network of six injection wells in the Trinity Aquifer and three injection wells in the Ogallala Formation.

- The recovery wells are monitored on a monthly basis for water quality parameters. A network of wells is used to monitor plume containment on a semiannual basis: 10 monitoring wells and the recovery wells in the Trinity Aquifer, and two monitoring wells and the recovery wells in the Ogallala Formation.

System Operation [3, 4, 5, 8]

- Quantity of groundwater pumped from aquifer by year:

Year	Volume Pumped (gal)
11/93-12/93	4,269,133
1994	29,660,519
1995	29,118,867
1996	31,257,749
1997	26,320,000

- Initial startup began in July 1992; however, the multimedia polishing filter and injection wells began to clog with iron and calcium in the first 30 days and treated water could not be reinjected. The extraction and treatment systems were shut down and the following alterations were made:

  -- The reaction tank was altered from a single-chamber to a two-chamber tank, separated by a baffle. The second chamber allowed for precipitation of the excess iron, the main clogging problem.

  -- A tank was added to receive backwash from the multimedia filters. The backwash tank acted as an equalization tank to prevent shock change to the system influent tank when the filters

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

were backwashed. The pH of the treated water was set to between 7.0 and 7.5 pH beyond the clarifier to prevent precipitation of calcium carbonate.

- -- Two additional injection wells were constructed to allow for higher reinjection rates.
- -- Backwash water is stored in the modified backwash unit and is slowly added to the influent tank. The slow addition avoids upsetting the pH balance in the influent.
- -- Modifications were completed in August 1993, and the extraction and treatment systems became operational in November 1993.

- In September 1996, a low-flow test was performed in case future extraction would be from the Ogallala Formation only, because the Ogallala Formation was being remediated more slowly than the Trinity Aquifer. The treatment system was tested for ability to operate at 20 gpm, and was successful at low flow rates.
- In March 1997, an additional recovery well was installed in the Ogallala Formation to expedite cleanup of the suspected source area. The additional well expanded the extraction network to a total of four recovery wells in the Ogallala Formation.
- Since November 1993, the site has been operational 95% of the time. Downtime is primarily due to shutdowns for local brown-outs and routine system maintenance.
- On December 12, 1997 the Odessa IIS plant was shut down for major modification. All of the Trinity Aquifer wells had met the clean-up criterion set by the ROD as did all but two of the Ogallala Formation wells. Since the remaining two perched zone wells produced less than two gpm total flow, it became inefficient to operate a 60 gpm plant for such a small flow. Modifications were made to collect the water from the two remaining Ogallala Formation wells in the influent and effluent tanks at the plant. These tanks are periodically discharged to a tank truck for transport to an off-site treatment plant.
- The equipment that was not needed in the modified plant was either disposed off site or disconnected and stored on site for future use. All of the Trinity Aquifer recovery wells with the exception of RW14 were plugged, as were Ogallala Formation wells PRW18 and PRW19. RW14 supplies injection water to two Ogallala Formation injection wells to aid in pushing contaminated water toward the Ogallala Formation recovery wells.

Operating Parameters Affecting Treatment Cost or Performance

The operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the average pump rate and other performance parameters.

Table 3. Performance Parameters

Parameter	Value
Average Pump Rate	84,200 gpd*
Performance Standard (effluent)	0.05 mg/L total chromium
Remedial Goal (aquifer)	0.10 mg/L total chromium

*The average system extraction rate from November 1993 until December 1996 was approximately 84,200 gpd, based on a total volume of 94 million gallons extracted and a 95% operation rate.
Source: [3, 4]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this application.

Table 4. Timeline

Start Date	End Date	Activity
January 1992	July 1992	Remediation system constructed
July 1992	August 1992	Trial run conducted and injection wells clogged with iron and calcium
August 1992	May 1993	Redesign and pilot studies performed
May 1993	August 1993	Alterations made to remedial system
November 1993	---	Continuous operation of remediation system begun. Monthly monitoring of groundwater began
September 1996	---	Treatment system tested for effectiveness during low flow
March 1997	---	Recovery Well PRW-28 constructed in Perched Zone
December 1997	---	Plant shut down and modified for collection of Perched Zone water only.

Source: [1-4]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

The cleanup goals as established by the EPA and TNRCC are to lower the chromium levels in the groundwater to less than the maximum contaminant level (MCL), or Primary Drinking Water Standard, of 0.10 mg/L. This goal is applied throughout the aquifer, as measured in all on-site monitoring wells.

Additional Information on Goals

The original drinking water standard for chromium set by EPA was 0.05 mg/L. In 1990, EPA revised the standard to the primary drinking water standard of 0.10 mg/L.

Treatment Performance Goals [3]

- Effluent injected into the aquifer from the treatment system must have levels of chromium below 0.10 mg/L.
- As a secondary goal, the remedial system is designed to create an inward hydraulic gradient toward the site to contain the plumes.

Performance Data Assessment [3, 4, 6]

- Based on monthly sampling events, cleanup goals have been achieved in the Trinity Aquifer but not in the Ogallala Formation [1,5]. Groundwater monitoring results from the January 1997 sampling event indicate that chromium concentrations in the Ogallala Formation have been reduced, but not to levels below treatment goals. However, in the Trinity Aquifer, chromium levels detected in the 1997 sampling event were all found to be below the MCL [6].
- Based on sampling results, the site operators have concluded that the plume has been contained in both aquifers [4,6].
- Figure 3 illustrates the decline in average chromium concentrations in the groundwater over time for the Trinity Aquifer. The average chromium levels in the groundwater have decreased in this unit.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- Figure 3 also shows a spiking of the average chromium concentrations in the Ogallala Formation in 1995. ITC has attributed this spike to desorption of chromium from the previously unsaturated zone that was affected by increased precipitation from 1986 to 1996[5]. Since then, concentrations have again dropped.

- The average concentration of chromium detected in the groundwater in the Ogallala Formation in January 1997 was 0.18 mg/L, while the maximum concentration found during the same sampling event was 0.88 mg/L, a level exceeding the MCL [4].

- Effluent chromium levels have met the required performance standard of 0.10 mg/L; thus, reinjection of effluent has been possible throughout system operation [4].

- From 1993 to December 1996, the P&T system removed a total of 131 pounds of chromium from the groundwater, as shown in Figure 4. Figure 4 illustrates the decline in contaminant removal rate for the P&T system during the first three years of full-scale system operation (1993-1996). The chromium removal rate decreased from 0.18 pounds per day in December 1993 to 0.05 pounds per day in 1996 [4].

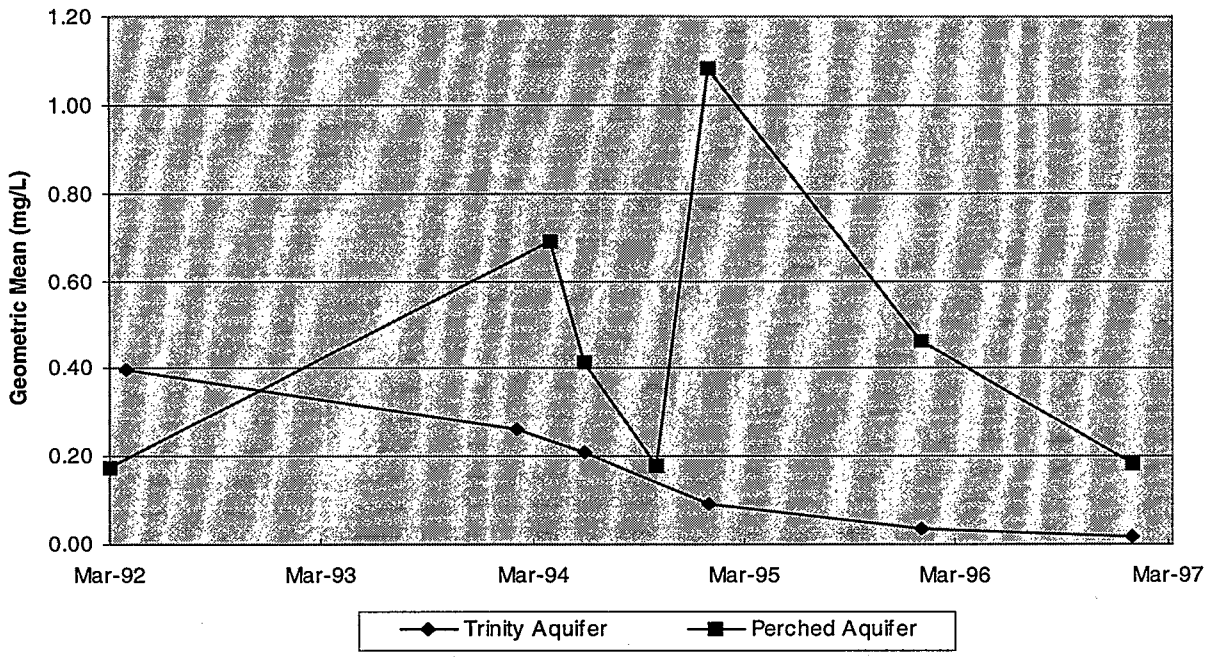

Figure 3. Average Chromium Concentrations from March 1992 - January 1997 [3,4]

TREATMENT SYSTEM PERFORMANCE (CONT.)

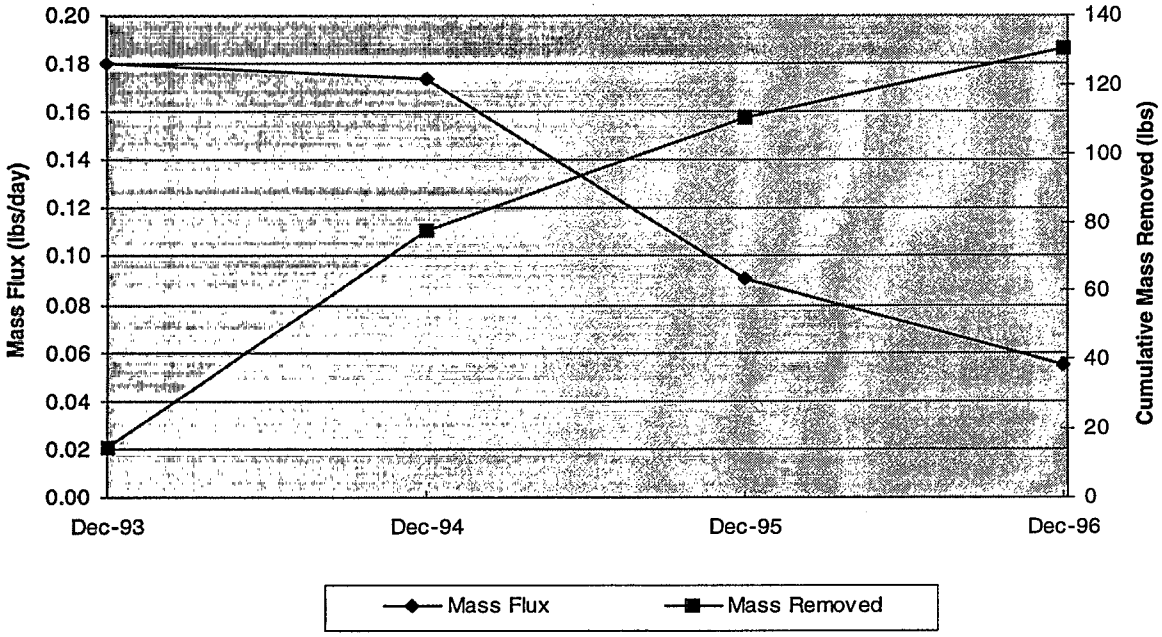

Figure 4. Mass Flux Rate and Cumulative Chromium Removal (1993 - 1996) [3,4]

Performance Data Completeness

- Data on mass flux and mass removed are reported on a monthly basis, and are available from the TNRCC. Annual monitoring data were used for Figure 3.
- Annual data on chromium mass removed were provided by the TNRCC and were used for Figure 4 analyses.
- A geometric mean was used for average chromium concentrations detected in the groundwater in Figure 4 to show the overall trend of chromium levels in the groundwater on an annual basis.
- When concentrations below detection limits were encountered, half of the detection limit was used for evaluation purposes.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the TNRCC requirements. All monitoring was performed using EPA Method 218.1 and EPA-approved methods for pH, total suspended solids, and other water quality parameters. The vendor did not note any exceptions to the QA/QC protocols [4].

TREATMENT SYSTEM COST

Procurement Process

The TNRCC is the lead authority on this site. WATEC was awarded the construction and operations contract for the site. ITC was awarded the oversight contract for the site.

Cost Analysis

- The costs for design, construction, and operation of the treatment system at this site were split 90:10 by the EPA and the TNRCC, respectively.

Capital Costs [6]

Remedial Construction	
Mobilization Work	$334,723
Monitoring Wells - Sampling/Testing Analysis	$43,500
Groundwater Collection & Control	$330,944
Installation of Treatment Plant	$884,962
Site Restoration	$13,542
Site Security	$3,298
Construction Management	$316,533
Total Remedial Construction	**$1,927,502**

Operating Costs [6]

Operation and Maintenance 1993-1996	$524,766
Monitoring: Sampling and Analysis 1993-1996	$35,466
Total 1993-1996 Operating Costs	**$560,232**
1993 Operating Costs (11/93-12/93)	$ 13,060
1994 Operating Costs (1/94-12/94)	$146,260
1995 Operating Costs (1/95-12/95)	$232,416
1996 Operating Costs (1/96-12/96)	$168,506

Other Costs [6]

Engineering Design	$417,452
Oversight	$48,154
EPA Oversight	$113,978

Cost Data Quality

- The costs listed above include the system modifications performed in 1993 and in 1995. There were no other changes to the cost of the remedial system for this site greater than 10% of the total cost [6].
- Actual capital and operations and maintenance cost data are available from the TNRCC for this application.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the P&T application at Odessa IIS were approximately $2,487,700 ($1,927,500 in capital costs and $560,200 in operations and maintenance costs), which corresponds to $26 per 1,000 gallons of groundwater treated and $19,000 per pound of chromium removed.
- The ROD specified that the ferrous ion used to reduce the chromium would be electrochemically produced. This requirement limited the on-site system to two vendors and potentially increased the cost of the treatment unit.
- Average concentrations of chromium in the Ogallala Formation spiked between 1993 and 1995. The increase may be a result of aquifer recharge through chromium-containing soil. ITC has determined the chromium in the Ogallala Formation is the source for chromium in the Trinity Aquifer. Because the Ogallala Formation is hydraulically connected to the Trinity Aquifer, water within the Ogallala Formation

OBSERVATIONS AND LESSONS LEARNED (CONT.)

is expected to continue to move downward over time, adding additional contaminated water to the Trinity Aquifer [3]. Continued extraction from the Ogallala Formation will help prevent downward migration of the plume to the Trinity Aquifer.

- Chromium levels in the Trinity Aquifer have been reduced to below the MCL. Extraction and monitoring of groundwater in the Trinity Aquifer will continue to ensure that concentrations remain stable. If levels of chromium remain below the MCL, extraction from this unit will be discontinued and increased pumping from the Ogallala Formation will begin [6].

- There were several startup problems, including clogging of injection wells and encrustation of the multimedia polishing filter by iron and calcium carbonate that delayed full-scale operations. These problems were accommodated through system modification, and no longer interfere with operations. ITC has suggested that one potential approach to identifying problems earlier would be to increase the length of pilot operations. At this site, pilot tests were conducted in hourly increments, and the results were used to simulate full-cycle operations. Had the pilot operations been conducted for a full 24-hour cycle, it is likely that the iron fouling problems that led to clogging could have been identified [2].

- Full-scale operations were delayed by iron and calcium encrustation in injection wells and the filter. Future effluent standards set for iron could prevent such delays.

- ITC found monthly monitoring of chromium levels in influent wells helpful. However, this was not the case for continuous monitoring. The continuous chromium monitors installed at this site could not detect levels above 1.0 mg/L [2].

- During system operation, ITC determined that backwash from the filter system should be equalized and added slowly to the influent tank to avoid large changes in the influent chemistry. During early system operations, backwash water was introduced directly into the influent tank. The differences between the pH levels in the backwash and the influent reduced the effectiveness of the reaction tank. The backwash storage unit allowed gradual addition of backwash to the influent. Addition of an equalization tank alleviated the earlier problems in the reaction tank [2].

REFERENCES

1. Record of Decision. USEPA, Odessa Chromium IIS, March 18, 1988.

2. Lessons Learned. IT Corporation, January 1997.

3. Project Status Draft Report. ITC, January 1995.

4. Odessa Chromium IIS Monthly Reports. ITC, December 1993/January 1994, January 1995, January 1996, January 1997.

5. Odessa Chromium I & IIS Superfund Sites Treatment System. Waste Abatement Technology, Inc. No date listed.

6. Correspondence with Mr. Lel Medford, TNRCC. February 12, March 5, March 11, March 14, June 4, July 29, and December 5, 1997.

7. Groundwater Regions of the United States. Heath, Ralph. U.S. Geological Survey Supply Paper 2242. 1984.

8. TNRCC comment on draft report, dated May 8, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Groundwater Containment at Site FT-01, Pope AFB, North Carolina

Groundwater Containment at Site FT-01, Pope AFB, North Carolina

<table>
<tr><td>Site Name:
Site FT-01, Pope AFB</td><td rowspan="2">Contaminants:
Total Petroleum Hydrocarbon (TPH), free product (JP-4 fuel):
- TPH concentrations in soil reported as high as 44,000 ppm
- 24,000 gallons of free product in groundwater</td><td>Period of Operation:
11/93 - ongoing (as of 4/98); projected completion in 2001
Data reported through November 1996</td></tr>
<tr><td>Location:
North Carolina</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor/Consultant:
Parsons Engineering Science</td><td rowspan="2">Technology:
Free product recovery system consisting of four recovery wells and one trench. JP-4 is recovered using a pneumatic skimmer pump and stored in a product recovery tank.</td><td>Cleanup Authority:
Installation Restoration Program</td></tr>
<tr><td>Additional Contacts:
U.S. Air Force Air Combat Command</td><td>Regulatory Point of Contact:
Information not provided</td></tr>
<tr><td>Waste Source: Fuel Spill</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater and free product - the areal extent of the plume was estimated at 1.5 acres. Groundwater is encountered between 2 and 5 feet below ground surface. The total amount of free product removed as of November 1996 was 5,163 gallons of JP-4.</td></tr>
<tr><td>Purpose/Significance of Application: Recovery of free product from groundwater</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
The operational objective of the free product recovery was to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater.</td></tr>
<tr><td colspan="3">Results:
Data on system performance were available for the first three years of operation (through November 1996). The total amount of JP-4 product recovered during this time was 5,163 gallons. Monthly removal rates ranged from 1 to 650 gallons.</td></tr>
<tr><td colspan="3">Cost:
The capital cost for the system was $289,000. The total cumulative O&M costs from November 1993 through November 1996 was $66,600. According to the report, accurate month-to-month O&M data were not available; however, the average monthly O&M costs were reported as $1,800. After three years of operation, the average O&M costs per unit of contaminant removed was $12.90/gallon of JP-4.</td></tr>
</table>

Groundwater Containment at Site FT-01, Pope AFB, North Carolina (continued)

Description:
Site FT-01 is located at the Pope AFB in North Carolina. Soil and groundwater at the site were contaminated with JP-4 fuel. TPH concentrations as high as 44,000 ppm were detected in soil at the site. The areal extent of groundwater contamination was estimated to be 1.5 acres with an estimated 24,000 gallons of free product floating on the groundwater. In September 1993, 3,175 tons of contaminated soil were removed from the site. In November 1993, a free product recovery system were installed at the site to recover JP-4 fuel.

The free product recovery system included four recovery wells and one trench. A pneumatic skimmer pump was used to recover the JP-4, which was then stored in a product recovery tank. The system was operational at the time of this report (April 1998) and is expected to operate through 2001. Data on cost and performance are available for the first three years of operation (through November 1996). During this time, 5,163 gallons of JP-4 fuel was recovered, with the monthly removal rates ranging from 1 to 650 gallons. The report includes a graph of JP-4 recovered versus time. As of November 1996, the curve had not flattened, indicating that the operational objectives of the system were still being met.

The total capital cost for this system was $289,000. The total O&M costs through November 1996 were $66,600. Although accurate monthly O&M costs were not available, the average monthly O&M cost was $1,800. The average O&M cost per unit of JP-4 fuel recovered was $12.90 per gallon.

Groundwater Containment at Site FT-01, Pope AFB

Site Background

This section focuses on the groundwater containment system located at FT-01, Pope AFB. A site map for FT-01 is included as Figure 37.

Contaminants in Soil

- TPH concentrations detected up to 44,000 ppm.
- In September 1993, 3,175 tons of contaminated soil were removed from the site.

Contaminants in Groundwater

- The areal extent of JP-4 fuel contamination was estimated at 1.5 acres.
- As much as 24,000 gallons of free product are floating on top of the groundwater.

Lithology

- Fine- to medium-grained sands to 25 feet bgs; hard silty clay from a depth of 26 feet bgs to 70 feet bgs.
- Groundwater is encountered between 2 and 5 feet bgs.

Groundwater Containment System Details

- Free floating product recovery system.
- The system consists of four recovery wells (RW-1, RW-2, RW-3, and MW-2) and one trench.
- JP-4 is recovered by a pneumatic skimmer pump and stored in a product recovery tank.

Operation Period

- The system began operation in November 1993 and may operate until 2001.

Total Capital Costs

- $289,000 for initial capital investment.

Total O&M Costs

- Total cumulative O&M costs from November 1993 through November 1996 were $66,600.

Cost and Performance of Groundwater Containment at Site FT-01

Groundwater Containment with Free Product Source Removal Operational Objectives

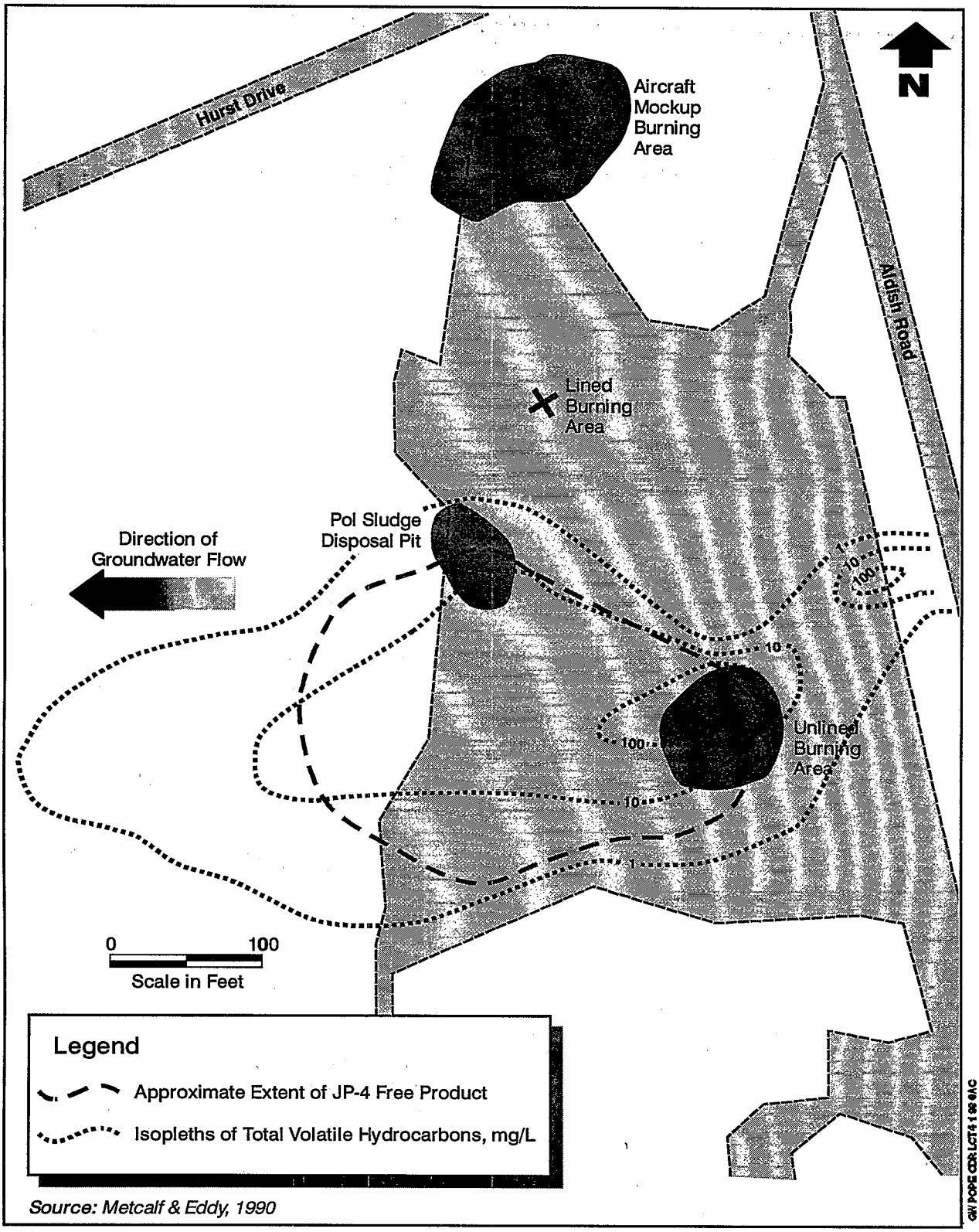
The objective of free product source removal is typically to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater. The emphasis for free product removal is that the mass of contaminants is cost effectively removed.

Cost for Operation

Figure 38 illustrates curves of the O&M costs for the groundwater containment system at Site FT-01. Accurate month to month data were not available. The monthly O&M costs average $1,800. Total O&M costs after three years of operation were $66,600.

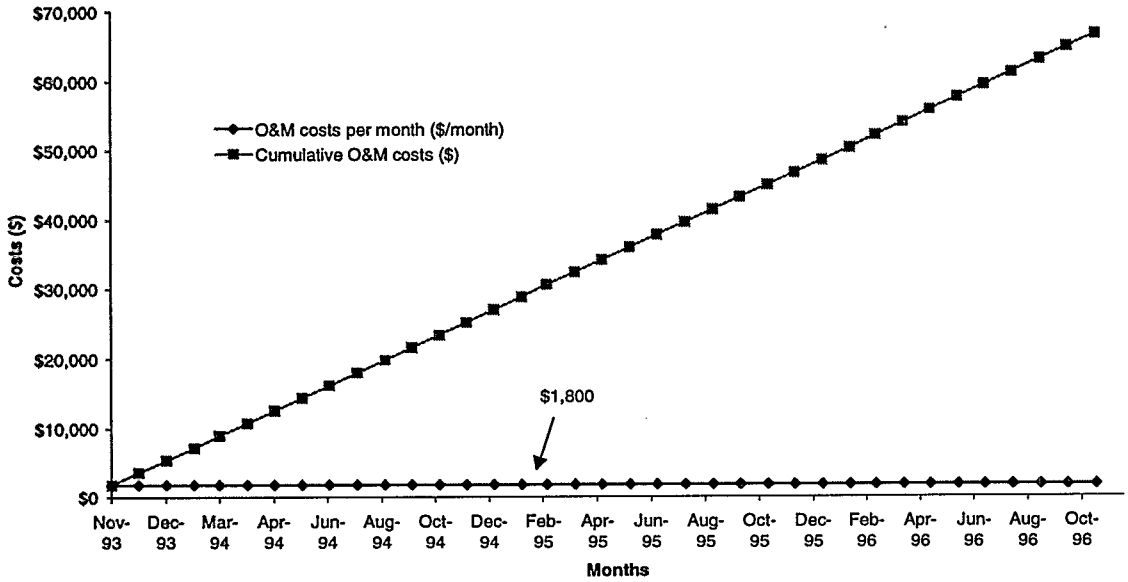
Contaminant Removal

Figure 39 illustrates curves of the removal rates of JP-4 product at the groundwater containment system at Site FT-01. Monthly removal rates of JP-4 product ranged from 1 to 650 gallons. Total contaminant removal after three years of operation was 5,163 gallons of JP-4 product. In November 1996, the curve representing the cumulative removal rate had not flattened, indicating that the removal rate was still adequate for this system's performance and it was meeting its operational objectives.



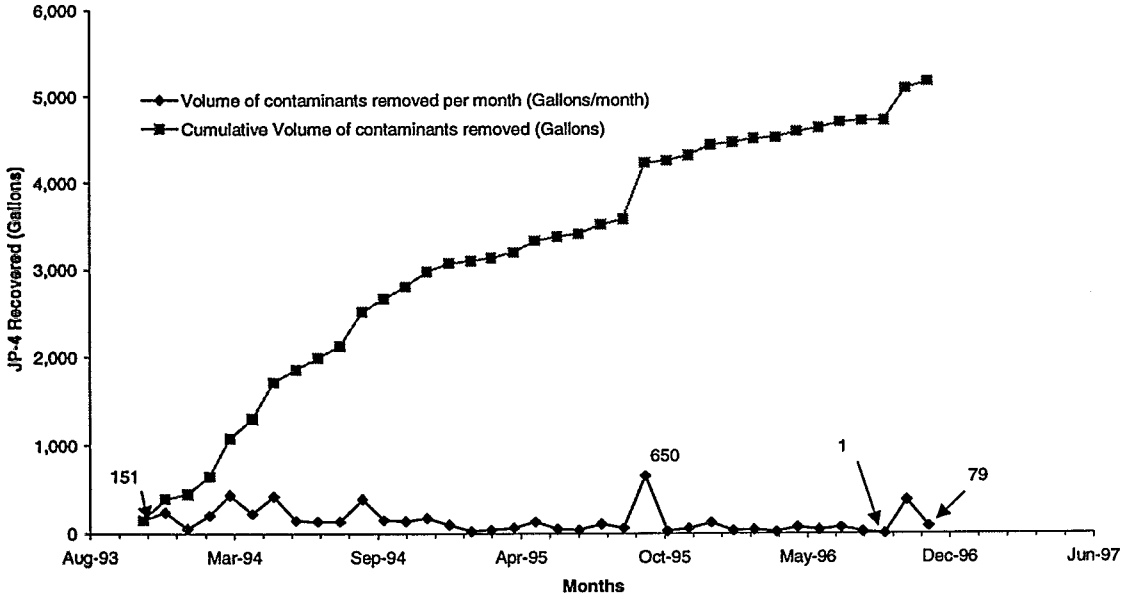
Source: Metcalf & Eddy, 1990

Figure 38
Monthly and Cumulative O&M Costs vs. Time
JP-4 Free Product
Site FT-01, Pope AFB



Rawft01.xls; O&M costs

Figure 39
Monthly & Cumulative JP-4 Product Recovery vs. Time
Site FT-01, Pope AFB



Rawft01.xls; Volume

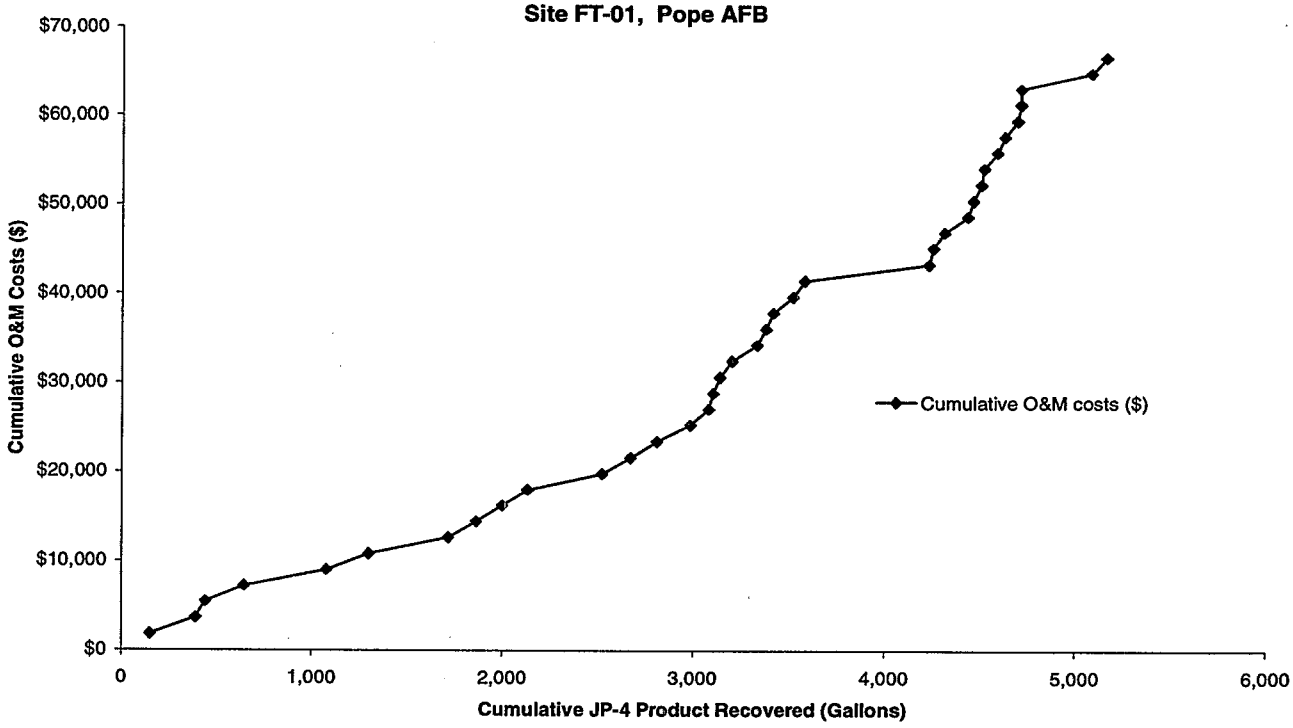
Correlation of Costs and Contaminant Removal

Figures 40 and 41 illustrate the relationship between the O&M costs and the removal rates for the groundwater containment system at Site FT-01.

Figure 40 illustrates the cumulative O&M cost over the cumulative contaminant removal. As of November 1996, this curve had not steepened. In November 1996, this groundwater containment system was operating efficiently for this system's performance and was meeting its operational objectives.

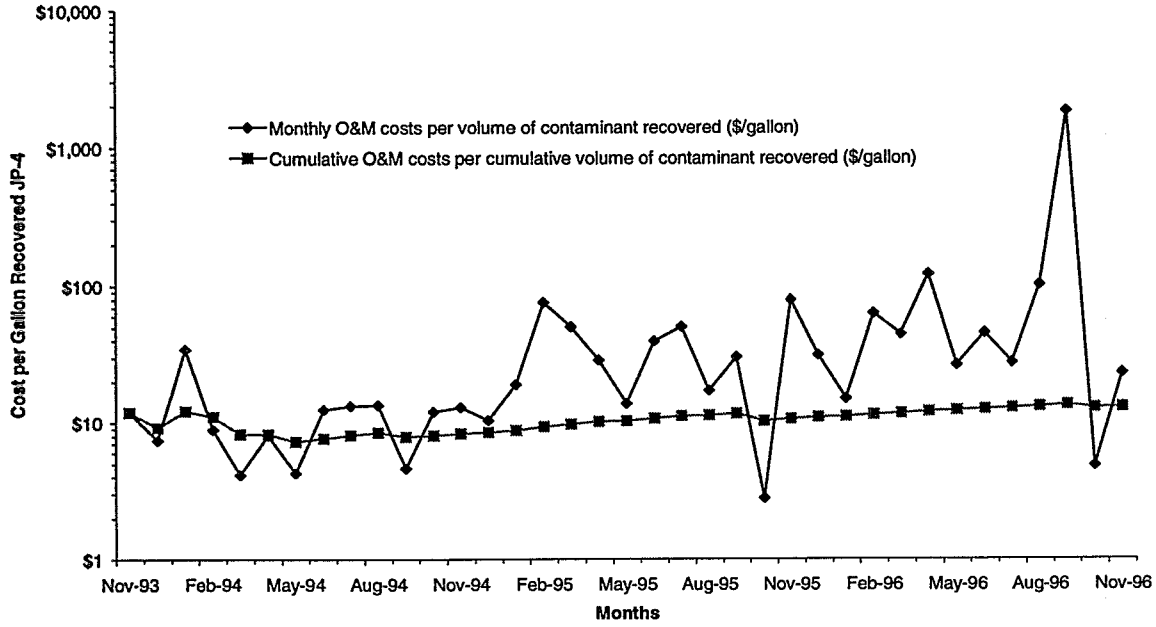
Figure 41 illustrates curves of the monthly and cumulative cost per unit of contaminant removal over the operation time of the technology. The monthly curve illustrates the cost per gallon of JP-4 product removal in each month. The cumulative curve illustrates that the average cost per unit of contaminant removal was $12.90/gallon of JP-4 product after three years of operation time.

Figure 40
Cumulative O&M Costs vs. Cumulative JP-4 Recovered
Site FT-01, Pope AFB



Rawft01.xls; $ vs. vol

Figure 41
Monthly and Cumulative Costs per Gallon of JP-4 Recovery vs. Time
Site FT-01, Pope AFB



Rawft01.xls; monthly$pergalovert

APPENDIX A

Detailed Cost and Performance Data Table

JP-4 Free-Product Recovery Pumping
Fire Protection Training Area No. 4 (FT-01)
Pope AFB

Date of contamination removal	Volume of contaminants removed per month (Gallons/month)	Cumulative Volume of contaminants removed (Gallons)	O&M costs per month ($/month)	Cumulative O&M costs ($)	Monthly O&M costs per volume of contaminant recovered ($/gallon)	Cumulative O&M costs per cumulative volume of contaminant recovered ($/gallon)
Nov-93	151	151	$1,800.00	$1,800.00	$11.92	$11.92
Dec-93	240	391	$1,800.00	$3,600.00	$7.50	$9.21
Jan-94	52	443	$1,800.00	$5,400.00	$34.62	$12.19
Feb-94	202	645	$1,800.00	$7,200.00	$8.91	$11.16
Mar-94	433	1,078	$1,800.00	$9,000.00	$4.16	$8.35
Apr-94	221	1,299	$1,800.00	$10,800.00	$8.14	$8.31
May-94	417	1,716	$1,800.00	$12,600.00	$4.32	$7.34
Jun-94	145	1,861	$1,800.00	$14,400.00	$12.41	$7.74
Jul-94	136	1,997	$1,800.00	$16,200.00	$13.24	$8.11
Aug-94	134	2,131	$1,800.00	$18,000.00	$13.43	$8.45
Sep-94	389	2,520	$1,800.00	$19,800.00	$4.63	$7.86
Oct-94	150	2,670	$1,800.00	$21,600.00	$12.00	$8.09
Nov-94	140	2,810	$1,800.00	$23,400.00	$12.86	$8.33
Dec-94	175	2,985	$1,800.00	$25,200.00	$10.29	$8.44
Jan-95	95	3,080	$1,800.00	$27,000.00	$18.95	$8.77
Feb-95	24	3,104	$1,800.00	$28,800.00	$75.00	$9.28
Mar-95	36	3,140	$1,800.00	$30,600.00	$50.00	$9.75
Apr-95	63	3,203	$1,800.00	$32,400.00	$28.57	$10.12
May-95	131	3,334	$1,800.00	$34,200.00	$13.74	$10.26
Jun-95	46	3,380	$1,800.00	$36,000.00	$39.13	$10.65
Jul-95	36	3,416	$1,800.00	$37,800.00	$50.00	$11.07
Aug-95	105	3,521	$1,800.00	$39,600.00	$17.14	$11.25
Sep-95	60	3,581	$1,800.00	$41,400.00	$30.00	$11.56
Oct-95	650	4,231	$1,800.00	$43,200.00	$2.77	$10.21
Nov-95	23	4,254	$1,800.00	$45,000.00	$78.26	$10.58
Dec-95	58	4,312	$1,800.00	$46,800.00	$31.03	$10.85
Jan-96	121	4,433	$1,800.00	$48,600.00	$14.88	$10.96
Feb-96	29	4,462	$1,800.00	$50,400.00	$62.07	$11.30
Mar-96	41	4,503	$1,800.00	$52,200.00	$43.90	$11.59
Apr-96	15	4,518	$1,800.00	$54,000.00	$120.00	$11.95
May-96	69	4,587	$1,800.00	$55,800.00	$26.09	$12.16
Jun-96	40	4,627	$1,800.00	$57,600.00	$45.00	$12.45
Jul-96	66	4,693	$1,800.00	$59,400.00	$27.27	$12.66
Aug-96	18	4,711	$1,800.00	$61,200.00	$100.00	$12.99
Sep-96	1	4,712	$1,800.00	$63,000.00	$1,800.00	$13.37
Oct-96	372	5,084	$1,800.00	$64,800.00	$4.84	$12.75
Nov-96	79	5,163	$1,800.00	$66,600.00	$22.78	$12.90

Groundwater Containment at Site SS-07, Pope AFB, North Carolina

Groundwater Containment at Site SS-07, Pope AFB, North Carolina

Site Name: Site SS-07, Blue Ramp Spill Site, Pope AFB	**Contaminants:** Volatile Organic Compounds (VOCs), free product (JP-4 fuel) - VOCs in soil detected as high as 1,000 ppm - 75,000 gallons of JP-4 fuel estimated to be floating on groundwater	**Period of Operation:** 11/93 - ongoing (as of 4/98) Data reported through November 1996
Location: North Carolina		**Cleanup Type:** Full-scale cleanup
Vendor/Consultant: Parsons Engineering Science	**Technology:** Free product recovery system consisting of a dual pump recovery system with one free product cut-off trench. JP-4 was recovered using pneumatic skimmer pumps and stored in a product recovery tank. The system operates at an average flow rate of 1 gallon per minute (gpm).	**Cleanup Authority:** Installation Restoration Program
Additional Contacts: U.S. Air Force Air Combat Command		**Regulatory Point of Contact:** Information not provided
Waste Source: Fuel Spill	**Type/Quantity of Media Treated:** Groundwater - Groundwater is encountered between 22.5 and 27 feet below ground surface.	
Purpose/Significance of Application: Recovery of free product using active pumping		

Regulatory Requirements/Cleanup Goals:
The operational objective of the free product recovery was to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater.

Results:
Data on system performance were available for the first three years of operation (through November 1996). The total amount of JP-4 product recovered during this time was 3,516 gallons. Monthly removal rates ranged from one to 340 gallons.

Cost:
The capital cost for the system was $394,000. The total cumulative O&M costs from November 1993 through November 1996 was $96,200. According to the report, accurate month-to-month O&M data were not available; however, the average monthly O&M costs were reported as $2,600. After three years of operation, the average O&M costs per unit of contaminant removed was $27.36/gallon of JP-4.

Groundwater Containment at Site SS-07, Pope AFB, North Carolina (continued)

Description:
Site SS-07, the Blue Ramp Spill Site, is located at the Pope AFB in North Carolina. Soil and groundwater at the site were contaminated with JP-4 fuel and VOCs. VOC concentrations as high as 1,000 ppm were detected in the vadose zone at the site, and the areal extent of the soil vapor plume was estimated to be 25 acres. Dissolved VOCs were detected in the groundwater and an estimated 75,000 gallons of free product was floating on the groundwater. In November 1993, a free product recovery system were installed at the site to recover JP-4 fuel.

The groundwater free product recovery system was a dual pump recovery system with one free product cut-off trench. JP-4 is recovered with pneumatic pumps and stored in a product recovery tank. The trench was extended in 1993 and again in 1995. The system was operational at the time of this report (April 1998) and is expected to operate for 40 years. Data on cost and performance are available for the first three years of operation (through November 1996). During this time, 3,516 gallons of JP-4 fuel was recovered, with the monthly removal rates ranging from 1 to 340 gallons. The report includes a graph of JP-4 recovered versus time. After April 1995, the curve began to flatten, indicating that the removal rate for the system is slowing. According to the report, it is recommended that the system be evaluated to determine how to increase product removal.

The total capital cost for this system was $394,000. The total O&M costs through November 1996 were $96,200. Although accurate monthly O&M costs were not available, the average monthly O&M cost was $2,600. The average O&M cost per unit of JP-4 fuel recovered was $27.36 per gallon.

Groundwater Containment at Site SS-07, Pope AFB

Site Background

This section focuses on the groundwater containment system located at the Blue Ramp Spill Site, SS-07, Pope AFB. A site map for SS-07 is included as Figure 42.

Contaminants in Soil

- Soil vapor investigations indicate concentrations of greater than 1,000 ppm of VOCs exist in the vadose zone.
- The soil vapor plume is estimated at 25 acres in areal extent.

Contaminants in Groundwater

- As much as 75,000 gallons of JP-4 free product are floating on top of the groundwater.
- Dissolved VOCs have also been detected within the groundwater.

Lithology

- Subsurface soils are silty to clayey fine-grained sands.
- Clay lenses ranging from 1 to 5 feet in thickness.
- Groundwater is encountered between 22.5 and 27 feet bgs.

Groundwater Containment System Details

- Dual pump recovery system with one free product cut-off trench (Radian Corporation, 1996).
- In 1993 and 1995, the free product cut-off trench was extended.
- The system operates at an average groundwater flow rate of 1 gpm.
- JP-4 is recovered by pneumatic skimmer pumps and is stored in a product recovery tank.

Operation Period

- The system began operation in November 1993 and may operate approximately 40 years.

Total Capital Costs

- $394,000 for initial capital investment.

Total O&M Costs

- Total cumulative O&M costs from November 1993 through November 1996 were $96,200.

Cost and Performance of Groundwater Containment at Site SS-07

Groundwater Containment with Free Product Source Removal Operational Objectives

The objective of free product source removal is typically to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater. The emphasis for free product removal is that the mass of contaminants is cost effectively removed.

Cost for Operation

Figure 43 illustrates curves of the O&M costs for the groundwater containment system at Site SS-07. Accurate month to month data were not available. The monthly O&M costs average $2,600. Total O&M costs after three years of operation were $96,200.

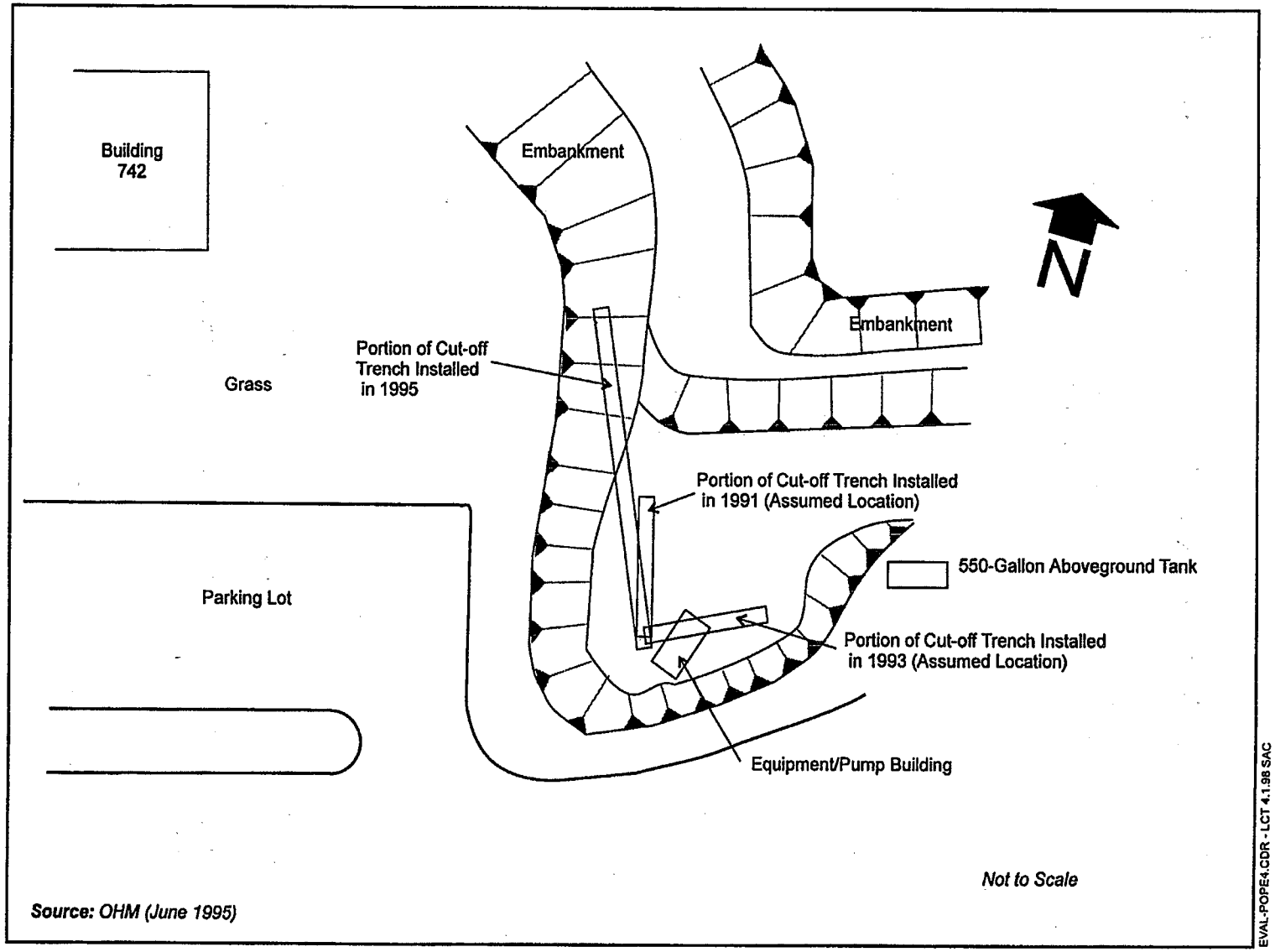
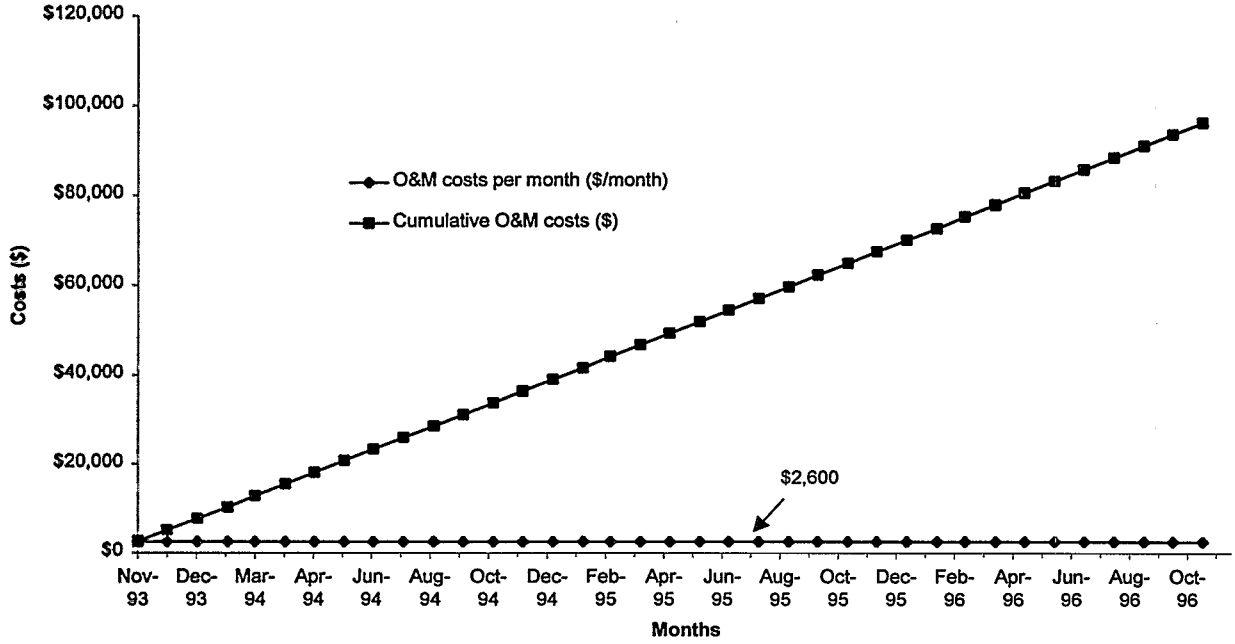


Figure 42. Free Product Recovery System at Site SS-07, Pope AFB

Figure 43
Monthly and Cumulative O&M Costs vs. Time
JP-4 Free Product Recovery
Site SS-07, Pope AFB



Raws07.xls; O&M costs

Contaminant Removal

Figure 44 illustrates curves of the removal rates of JP-4 product at the groundwater containment system at Site SS-07. Monthly removal rates of JP-4 product ranged from 1 to 340 gallons. Total contaminant removal after three years of operation was 3,516 gallons of JP-4 product. After April 1995 the curve representing the cumulative removal rate had begun to flatten, indicating that the removal rate for this system is slowing. It is recommended that the system be evaluated for increasing product removal.

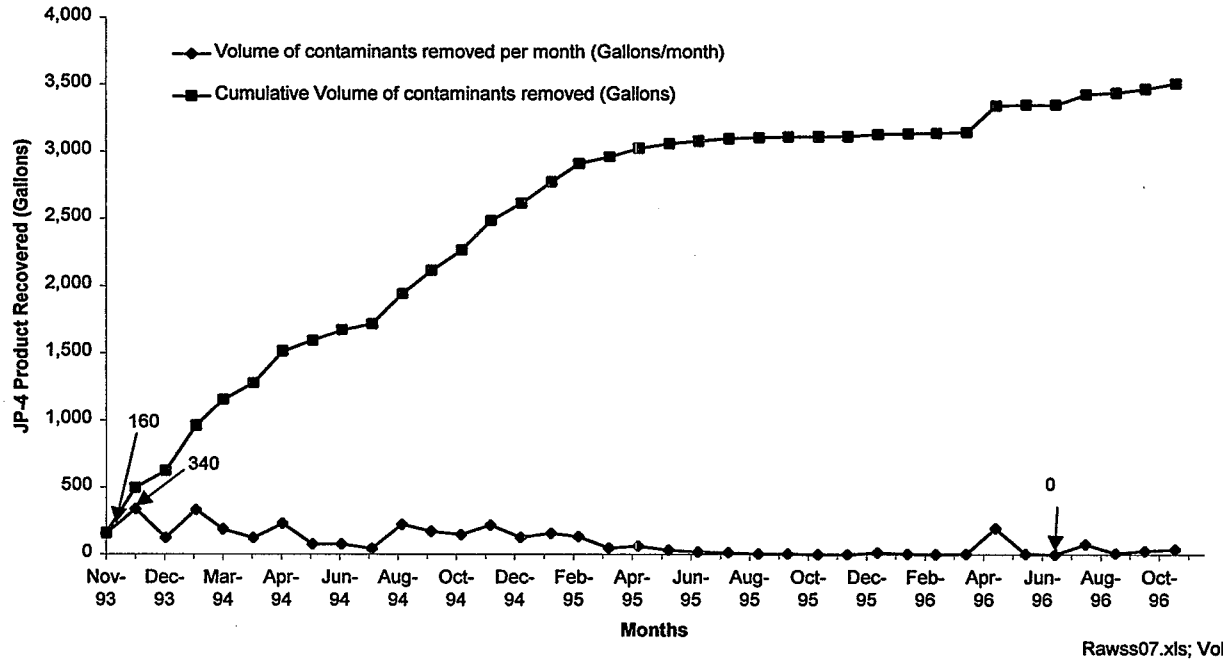
Correlation of Costs and Contaminant Removal

Figures 45 and 46 illustrate the relationship between the O&M costs and the removal rates for the groundwater containment system at Site SS-07.

Figure 45 illustrates the cumulative O&M cost relative to the cumulative contaminant removal. In November 1996, this curve was no longer vertical. In November 1996, this groundwater containment system was operating adequately for this system's performance and meeting its operational objectives of cost-effectively removing contaminants.

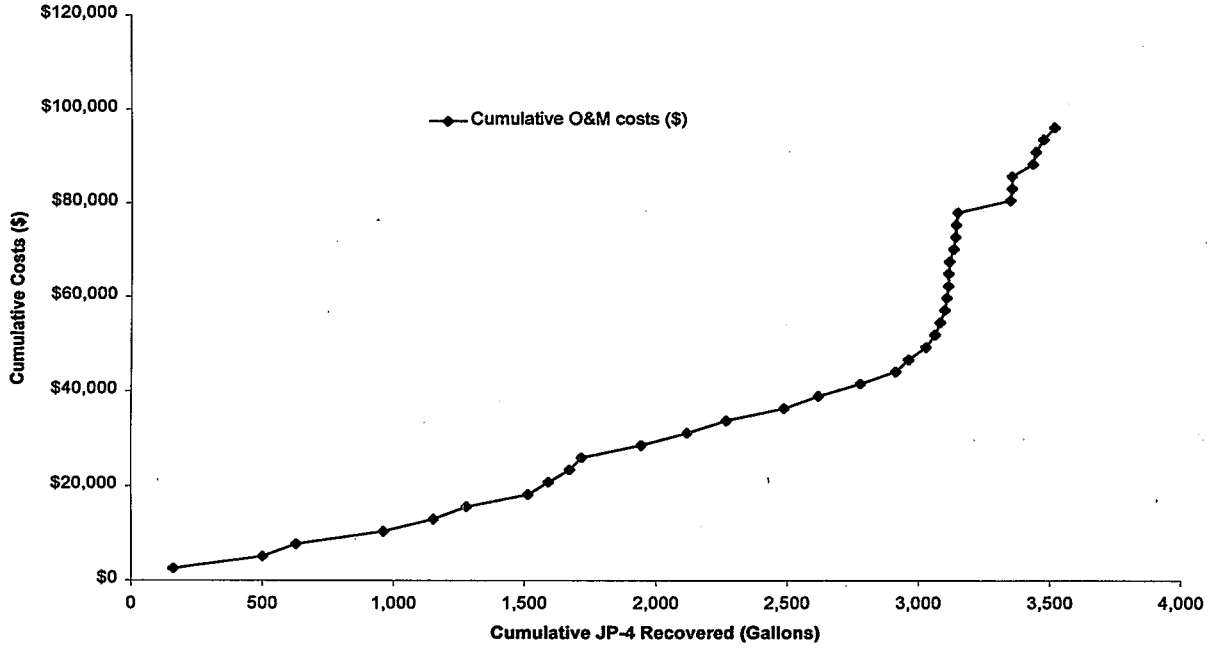
Figure 46 illustrates curves of the monthly as well as the cumulative cost per unit of contaminant removal over the operation time of the technology. The first curve illustrates the cost per gallon of JP-4 product removal in each month. The cumulative curve illustrates that the average cost per unit of contaminant removal was $27.36/gallon of JP-4 product after three years of operation time.

Figure 44
Monthly & Cumulative JP-4 Product Recovery vs. Time
Site SS-07, Pope AFB



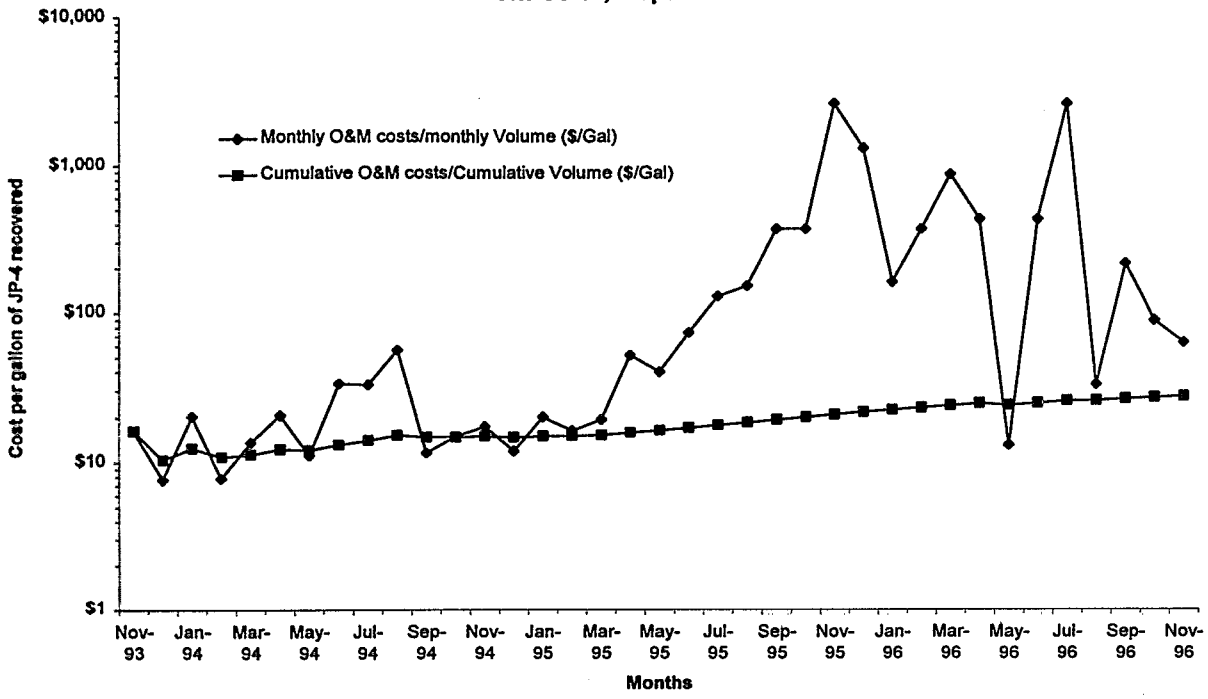
Rawss07.xls; Volume

Figure 45
Cumulative O&M Costs vs. JP-4 Product Volume Recovered
Site SS-07, Pope AFB



Rawss07.xls; O&M vs. vol

Figure 46
Monthly and Cumulative Costs per Gallon of JP-4 Recovered vs. Time
Site SS-07, Pope AFB



Rawss07.xls; mon$pergalovert

APPENDIX A

Detailed Cost and Performance Data Tables

JP-4 Free Product Recovery Pumping
Blue Ramp Spill Site (SS-07)
Pope AFB

Date of contamination removal	Volume of contaminants removed per month (Gallons/month)	Cumulative Volume of contaminants removed (Gallons)	O&M costs per month ($/month)	Cumulative O&M costs ($)	Monthly O&M costs/monthly Volume ($/Gal)	Cumulative O&M costs/Cumulative Volume ($/Gal)
Nov-93	160	160	$2,600	$2,600	$16.25	$16.25
Dec-93	340	500	$2,600	$5,200	$7.65	$10.40
Jan-94	128	628	$2,600	$7,800	$20.31	$12.42
Feb-94	334	962	$2,600	$10,400	$7.78	$10.81
Mar-94	192	1,154	$2,600	$13,000	$13.54	$11.27
Apr-94	126	1,280	$2,600	$15,600	$20.63	$12.19
May-94	234	1,514	$2,600	$18,200	$11.11	$12.02
Jun-94	78	1,592	$2,600	$20,800	$33.33	$13.07
Jul-94	79	1,671	$2,600	$23,400	$32.91	$14.00
Aug-94	46	1,717	$2,600	$26,000	$56.52	$15.14
Sep-94	226	1,943	$2,600	$28,600	$11.50	$14.72
Oct-94	175	2,118	$2,600	$31,200	$14.86	$14.73
Nov-94	150	2,268	$2,600	$33,800	$17.33	$14.90
Dec-94	220	2,488	$2,600	$36,400	$11.82	$14.63
Jan-95	130	2,618	$2,600	$39,000	$20.00	$14.90
Feb-95	160	2,778	$2,600	$41,600	$16.25	$14.97
Mar-95	135	2,913	$2,600	$44,200	$19.26	$15.17
Apr-95	50	2,963	$2,600	$46,800	$52.00	$15.79
May-95	65	3,028	$2,600	$49,400	$40.00	$16.31
Jun-95	35	3,063	$2,600	$52,000	$74.29	$16.98
Jul-95	20	3,083	$2,600	$54,600	$130.00	$17.71
Aug-95	17	3,100	$2,600	$57,200	$152.94	$18.45
Sep-95	7	3,107	$2,600	$59,800	$371.43	$19.25
Oct-95	7	3,114	$2,600	$62,400	$371.43	$20.04
Nov-95	1	3,115	$2,600	$65,000	$2,600.00	$20.87
Dec-95	2	3,117	$2,600	$67,600	$1,300.00	$21.69
Jan-96	16	3,133	$2,600	$70,200	$162.50	$22.41
Feb-96	7	3,140	$2,600	$72,800	$371.43	$23.18
Mar-96	3	3,143	$2,600	$75,400	$866.67	$23.99
Apr-96	6	3,149	$2,600	$78,000	$433.33	$24.77
May-96	200	3,349	$2,600	$80,600	$13.00	$24.07
Jun-96	6	3,355	$2,600	$83,200	$433.33	$24.80
Jul-96	0	3,355	$2,600	$85,800	$2,600.00	$25.57
Aug-96	79	3,434	$2,600	$88,400	$32.91	$25.74
Sep-96	12	3,446	$2,600	$91,000	$216.67	$26.41
Oct-96	29	3,475	$2,600	$93,600	$89.66	$26.94
Nov-96	41	3,516	$2,600	$96,200	$63.41	$27.36

Pump and Treat and Containment of Contaminated Groundwater at the Sylvester/Gilson Road Superfund Site Nashua, New Hampshire

Pump and Treat and Containment of Contaminated Groundwater at the Sylvester/Gilson Road Superfund Site Nashua, New Hampshire

<table>
<tr><td>Site Name:
Sylvester/Gilson Road Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents; volatiles - nonhalogenated; and heavy metals (selenium)
- Maximum concentrations detected in 1980 included methylene chloride (122,500 ug/L), chloroform (81,000 ug/L), tetrahydrofuran (1,000,000 ug/L), methyl ethyl ketone (80,000 ug/L), and toluene (140,000 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: 1982 through December 1995</td></tr>
<tr><td>Location:
Nashua, New Hampshire</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Construction:
Weston
O&M:
Joe Fritsch
Metcalf & Eddy
57 Gilson Road
Nashua, NH 03062</td><td rowspan="2">Technology:
Pump and Treat; Vertical Barrier Wall; Cap; and Soil Vapor Extraction
- Groundwater was extracted using 14 wells, located on site, at an average total pumping rate of 265 gpm
- Extracted groundwater was treated with addition of chemicals (lime slurry), flocculation, clarification, mixed-media pressure filtration, air stripping (at elevated temperature (175 °F), and biological treatment (biological treatment was used for only 50 of the 265 gpm extracted)
- Treated groundwater was reinjected on- and off-site through recharge trenches
- A slurry wall, 4 ft wide, 4,000 ft long, and as much as 100 ft deep, encloses the 20-acre site
- A 40-mil HDPE synthetic cap covers the area inside the slurry wall
- The SVE system included 66 wells and a boiler/incinerator for destruction of VOCs</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Dates: 7/29/82 and 9/22/83</td></tr>
<tr><td>State Point of Contact:
Tom Andrews
NHDES
6 Hazen Drive
Concord, MA 03301
(603) 271-2910</td><td>EPA Point of Contact:
Darryl Luce, RPM
U.S. EPA Region 1
JFK Federal Building
1 Congress Street
Boston, MA 02203
(617) 573-5767</td></tr>
<tr><td>Waste Source:
Waste disposal, drum burial, waste storage</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 1,200 million gallons treated as of December 1995
- LNAPL (toluene) observed in several monitoring wells on site
- Depth to groundwater was not provided for this site
- Extraction wells are located in 3 hydrogeologic units which are influenced by a nearby surface water
- Hydraulic conductivity in the upper unit ranges from 30 to 50 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
ACLs have been met for all contaminants, with one exception. The exception has an ACL which is less than the state standard and below the analytical detection limit for that constituent.</td></tr>
</table>

Pump and Treat and Containment of Contaminated Groundwater at the Sylvester/Gilson Road Superfund Site Nashua, New Hampshire (continued)

Regulatory Requirements/Cleanup Goals:

- The remedial goal for this site were set as alternate concentration limits (ACLs) within the containment structure. ACLs were set at 10% of the maximum concentration detected, and consisted of the following: vinyl chloride (95 ug/L), benzene (340 ug/L), chloroform (1,505 ug/L), 1,1,2-TCA (1.7 ug/L), MEK (8,000 ug/L), chlorobenzene (110 ug/L), methylene chloride (12,250 ug/L), toluene (2,900 ug/L), 1,1-DCA (1.5 ug/L), trans-1,2-DCA (1,800 ug/L), 1,1,1-TCA (200 ug/L), methyl methacrylate (350 ug/L), selenium (2.6 ug/L), and phenols (400 ug/L).
- Risk-based concentration levels were set for groundwater outside of the containment structure.
- A performance goal for the remedial system was to prevent the contaminant plume from further migration.

Results:

- As of December 1995, the remedial action appears to have attained ACLs for all contaminants except 1,1-DCA. The levels of 1,1-DCA are less than the state standard of 81 ug/L and below the analytical detection limit; EPA is reportedly considering adjusting the ACL set for this contaminant. From 1986 through 1995, the system removed 427,000 pounds of contaminants from the groundwater.
- A net inward flow into the containment structure has been maintained, thus reducing downward migration of contaminants.

Cost:

- Actual costs for the remedial application at this site were $27,600,000 ($9,100,000 in capital and $18,500,000 in O&M), which correspond to $23 per 1,000 gallons of groundwater extracted and $64 per pound of contaminant removed.
- The high O&M costs for this site were attributed to the 300 gpm treatment system and the number of staff required to operate it. For many years, the site was staffed with 15 full-time personnel who operated the site 24 hours/day.

Description:

The Sylvester/Gilson Road site is a 2-acre site. Approximately six acres of the site was used as a sand borrow pit for an undetermined number of years. Illegal dumping was first discovered in 1970. Although the total amount of hazardous waste disposed at the site had not been determined, documents show that approximately 900,000 gallons of hazardous waste were discarded at the site during a 10-month period in 1979. It was estimated that the site was used for hazardous waste disposal for five years. In 1981, initial remedial investigations by the state showed high concentrations of heavy metals and organic compounds in the groundwater under the site. A ROD for this site was signed in July 1982 and a supplemental ROD in September 1983. In July 1990, EPA issued a ESD for this application.

The remedial application at this site consisted of a pump-and-treat system, vertical barrier wall, cap, and soil vapor extraction system. Groundwater was extracted using 14 wells, located on site, and treated with addition of chemicals, flocculation, clarification, mixed-media pressure filtration, air stripping, and biological treatment. A slurry wall encloses the 20-acre site, and a HDPE synthetic cap covers the area inside the slurry wall. To address an area with LNAPL (toluene) that was identified part-way through the application, a SVE system was installed that included 66 extraction wells. As of December 1995, the remedial action appears to have attained ACLs for all contaminants except 1,1-DCA.

SITE INFORMATION

Identifying Information:

Sylvester/Gilson Road Superfund Site
Nashua, New Hampshire

CERCLIS #: NHD099363541

ROD Dates: July 29, 1982 and September 22, 1983.

ESD Date: July 10, 1990

Treatment Application:

Type of Action: Remedial

Period of operation: 1982 through 1995 (Performance Data Collected Through December 1995)

Quantity of groundwater treated during application: 1.2 billion gallons [1]

Background

Historical Activity that Generated Contamination at the Site: Illegal waste disposal

Corresponding SIC Code: NA

Waste Management Practice That Contributed to Contamination: Waste disposal, drum burial, waste storage

Location: Nashua, New Hampshire

Facility Operations:

- The Sylvester/Gilson Road Superfund Site is a 20-acre site. Approximately six acres of the site was used as a sand borrow pit for an undetermined number of years. Illegal dumping was first discovered in 1970. A court injunction was issued in 1976, which required removal of all materials from the site. The operator of the site failed to comply with the injunction. In 1978, New Hampshire state personnel observed drums being stored at the site. A second court order was issued in 1979 prohibiting further disposal of hazardous wastes on the site.

- Although the total amount of hazardous waste disposed of at the site had not been determined, documents show that approximately 900,000 gallons of hazardous waste were discarded at the site during a 10-month period in 1979 [5]. It was estimated that the site was used for hazardous waste disposal for five years [2, 10].

- During 1980, the state removed 1,314 drums of waste from the site and disposed of them off site.

- In 1981, initial remedial investigations by the State of New Hampshire showed high concentrations of heavy metals and organic compounds in the groundwater under the site. The contamination formed a plume in the groundwater, which was moving from the site toward Lyle Reed Brook. As the plume discharged to Lyle Reed Brook, hazardous compounds volatilized into the air at levels above acceptable public health limits [5].

- In December 1981, the EPA initiated an emergency containment action at the site that entailed installing a groundwater recirculation system. Four extraction wells were installed and pumped for containment only; no treatment was provided at this time. Contaminated groundwater was extracted and discharged to recharge trenches upgradient of the disposal area.

- A feasibility study was completed in May 1982 and a Record of Decision (ROD) was issued in July 1982. The ROD required a slurry wall to be installed around the 20-acre site and a synthetic cap to be placed over the area. The slurry wall and cap were designed to isolate the source area and provide containment of the groundwater plume. The containment system was installed by December 1982. The 1982 ROD also required groundwater extraction and treatment, but did not specify a treatment method for groundwater. However, pilot studies were underway to determine the appropriate treatment method. A groundwater recirculation system operated from 1981 until 1986.

SITE INFORMATION (CONT.)

Background (Cont.)

- A Supplemental ROD (SROD) concerning groundwater extraction and treatment was issued in September 1983. The SROD established cleanup goals within the slurry wall containment area. The groundwater treatment plant began operation in April 1986 to remove metals and organic compounds.

- In July 1990, EPA issued an Explanation of Significant Differences (ESD), which concluded that certain adjustments to the treatment remedy described in the SROD were necessary. These changes included an extension of operation by five years, additional extraction wells, and measures to control a toluene contamination source. The source control measures included a soil vapor extraction (SVE) system and an additional source-area groundwater well.

Regulatory Context:

- The ROD was signed on July 29, 1982, and the SROD was signed on September 22, 1983. An ESD was signed on July 10, 1990.

- The State of New Hampshire and the U.S. EPA have entered into a cooperative agreement for remediating this site.

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: In the original ROD, the selected remedy included construction of a slurry wall and cap with treatment of groundwater within the slurry wall. The treatment method was not included in the original ROD language. The SROD specified groundwater extraction, treatment via chemical and biological processes, and discharge to the on-site aquifer.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Darryl Luce
U.S. EPA Region I
John F. Kennedy Fed Bldg.
1 Congress Street
Boston, MA 02203
(617) 573-5767

* Indicates Primary Contact

State Contact:
Tom Andrews*
New Hampshire Department of Environmental Services (NHDES)
6 Hazen Drive
Concord, NH 03301
603-271-2910

Contractors:
Weston (construction oversight)

Metcalf & Eddy (O&M)
Contact: Joe Fritsch
57 Gilson Road
Nashua, NH 03062

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,5,6]

Primary Contaminant Groups: Heavy metals and volatile organic compounds (VOCs)

- The reported initial maximum concentrations of organic contaminants found in the groundwater included: tetrahydrofuran (THF) at 1,000,000 µg/L, methylene chloride at 122,500 µg/L, methyl ethyl ketone (MEK) at 80,000 µg/L, toluene at 140,000 µg/L, and chloroform at 81,000 µg/L. Selenium was the primary heavy metal compound detected in the groundwater.

- Because toluene and 1,1-DCA concentrations in the groundwater remained high after several years of treatment, toluene was thought to be floating on the water table as a non-aqueous phase liquid (NAPL) at the southern end of the site. In 1988, the toluene concentration in this area was 140,000 µg/L, approximately 26 percent of the aqueous solubility of toluene. 1,1-DCA concentrations also remained persistently high. Based on similar concentration contours for toluene and 1,1-DCA and the low water solubility for both contaminants, 1,1-DCA appeared to be in solution with the toluene NAPL.

- Figure 1 illustrates the total VOC concentration contours of the plume as detected during a December 1980 sampling event. The outermost concentration contour marks the 1,000 µg/L levels; the innermost contour marks the 1,000,000 µg/L levels.

- The size of the plume in Figure 1 was estimated to be 669,000 square feet at the 1,000 µg/L contour. The plume volume was estimated at 59.9 million gallons based the areal extent, 40 feet of plume thickness, and a porosity of 30%.

MATRIX DESCRIPTION (CONT.)

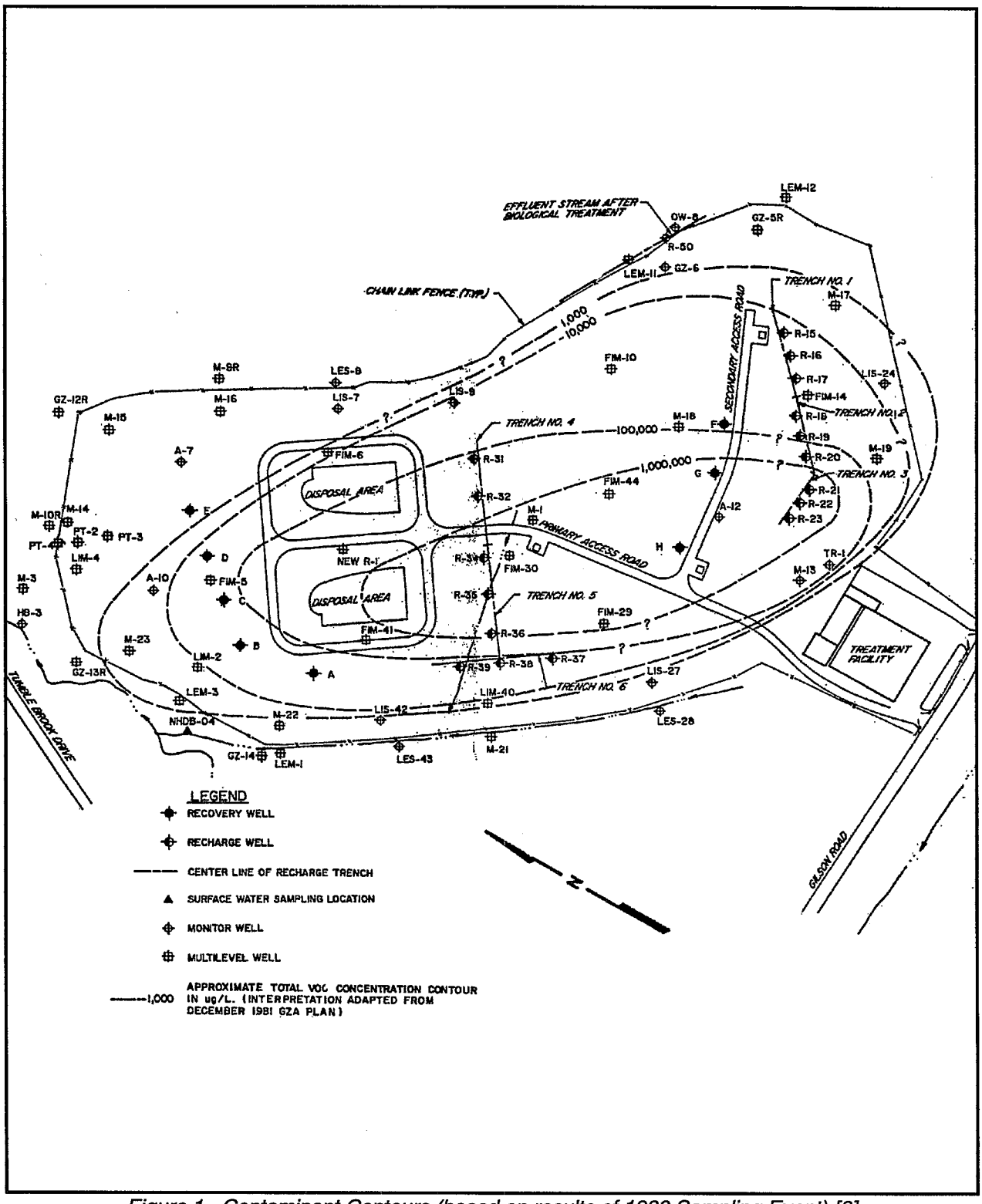


Figure 1. Contaminant Contours (based on results of 1980 Sampling Event) [9]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [4, 6]:

The site is underlain by fractured bedrock mantled with 20 to 100 feet of unconsolidated sediments. These sediments consist of a thin low-permeability glacial till covered by a high-permeability sand and gravel outwash deposit.

Unit 1	Stratified Drift	High permeability sand and gravel deposit. Groundwater encountered is under water table conditions.
Unit 2	Glacial Till	A discontinuous silt, sand, and gravel till layer with low permeability. This unit may act as a confining layer in some places.
Unit 3	Bedrock	A biotite schist of the Merrimack Group and igneous rocks. It is differentially weathered and fractured. The top of the bedrock surface is irregular, with variation in relief of more than 70 feet.

The site is located in the Lyle Reed Brook watershed. Lyle Reed Brook flows from the east to within 50 feet of the northern property boundary. Two major aquifers within this watershed underlie the site. One is a sand and gravel stratified drift aquifer, and the other is a fractured bedrock aquifer. A discontinuous till layer separates the two aquifers. In general, the till has a lower hydraulic conductivity than the overlying stratified drift, and may act as a confining layer in some places.

Groundwater in the stratified drift is under water table conditions, while groundwater within the fractured bedrock is under semiconfined conditions. Groundwater flows northwest through both aquifers and is encountered 10 to 20 feet below ground surface. The high-concentration area of the plume extended in a northwestern direction in an elliptical shape from the area of historical liquid waste disposal near the current location of Trench 3. Contamination has been detected in both aquifers.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Stratified Drift	20-80	30-50	0.15-0.25	Northwest
Glacial Till	0-20	5 (vertical)	NA	NA
Bedrock	>100	6,500 ft^2/day (transmissivity)	NA	Northwest

NA - not available

Source: [6]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with precipitation and high temperature air stripping.

Supplemental Treatment Technology

Biological treatment for polishing effluent from the groundwater treatment system prior to discharge to off-site recharge trenches.

System Description and Operation [1]

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/min)
A	Stratified Drift	51	45
B	Stratified Drift	56	45
C	Stratified Drift	50	53
D	Stratified Drift	52	90
E	Stratified Drift	50	61
F	Stratified Drift	46	49
G	Stratified Drift	35	48
H	Stratified Drift	46	90
I	Stratified Drift	55	23
J	Stratified Drift	56	22
K	Stratified Drift	34	17
Ka	Bedrock	68	25
L	Stratified Drift	50	40
La	Bedrock	85	25

Note: The average extraction rate for the extraction system is 265 gpm.

Source: [1]

System Description [1, 4]

- A 40-mil high-density polyethylene (HDPE) synthetic cap and containment wall were constructed to minimize infiltration and limit contaminant migration. The containment wall was constructed of bentonite slurry with a design hydraulic conductivity of 10^{-7} cm/sec. The slurry wall is approximately four feet wide, 4,000 feet in perimeter length, and 100 feet deep in some places. The bottom of the slurry wall is keyed into fractured bedrock. Approximately 20 acres is enclosed by the wall and covered by the cap.
- The remedial system includes 14 groundwater extraction wells (listed in Table 2) and seven recharge trenches. Groundwater is extracted, treated, then recharged through the trenches. The remedial system has been designed to isolate contaminated groundwater, recover and treat groundwater from within the slurry wall, and induce uniform flushing of the upper saturated zone.
- Four extraction wells (B, C, D, E) were installed in 1981 and 1982 as part of an emergency groundwater interception and recirculation system to halt the migration of

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

contaminated groundwater. Wells A, F, and G were installed in 1986 as part of the construction of the site groundwater remedial system. Wells H, I, J, K, Ka, L, and La were installed in 1991 as part of the modification to the groundwater remedial system. Wells A, B, C, D, E, I, and J are located in the downgradient portion of the site. Wells F, G, and H are located in the area of original dumping and contamination. Wells K, Ka, L, and La are located in areas that EPA and NHDES determined to be areas of persistent contamination. All extraction wells are located inside the slurry wall.

- Pumping rates for each well were initially set by the design engineer. Wells A, B, C, D, E, I, and J were pumped at a rate to minimize leakage of groundwater from the containment area. Wells F, G, and H were pumped at a rate to maximize recovery of contaminated groundwater. Well L was pumped at a rate to depress the water table in the vicinity of the SVE system and recover contaminated groundwater. Well K was pumped to reduce a persistent "hot spot". Bedrock wells Ka and La were pumped at very low rates and only as long as bedrock contamination was present.

- The treatment system consisted of physical, chemical, biological, and thermal unit processes (Figure 2). Approximately 265 gpm of groundwater passed through a pH adjustment tank where pH was adjusted to approximately pH 11 using a lime slurry. Water then flowed to a flocculation tank where polymer was added and mixed using a variable speed mixer. After flocculation, groundwater passed through an inclined plate settler where metals in the form of suspended solids were removed. The groundwater was then neutralized to pH 7. Neutralized groundwater was pumped through four (series) mixed-media pressure filters to remove small particulate matter. Following filtration, the groundwater temperature was raised to 175° F. Heated groundwater then passed through a stripping column for removal of VOCs. Stripped vapors were introduced into a boiler/incinerator where No. 2 fuel oil was burned to create sufficient heat to destroy organic vapors.

- Stripped groundwater was pumped through a heat exchanger to transfer heat from treated groundwater to incoming groundwater. Stripped groundwater was then divided into two streams: one stream (215 gpm) was discharged to on-site recharge trenches while the other stream (50 gpm) flowed to biological treatment. Biological treatment consisted of extended aeration with an activated sludge and removed the remaining volatile organic compounds before discharge to off-site recharge trenches.

- The biological treatment effluent was discharged off site to remove water from the containment area, thereby inducing water to flow into the containment area through the fractured bedrock below and reducing leakage downward from the site.

- The stripping column used at this site was a 4-foot diameter, 40-foot tall stainless steel stripper with demister at the top and stripped water sump at the bottom. The effective stripping depth was about 20 feet. The packing used was Type 3Y Flexipack elements stacked to approximately 16 feet.

- Well L and the SVE system were installed to recover and remove toluene from the source area identified by a toluene NAPL floating on the groundwater surface. The SVE system, which operated for approximately three years, consisted of six headers with eleven extraction/injection wells on each header. A variable speed pump extracted soil gas, and pumped the vapors into the boiler/incinerator for destruction of VOCs.

- The groundwater monitoring system consisted of 73 monitoring wells. All wells were sampled quarterly. Because there were many contaminants in the groundwater, three indicator compounds were selected to monitor water quality: toluene, THF, and 1,1-DCA.

TREATMENT SYSTEM DESCRIPTION (CONT.)

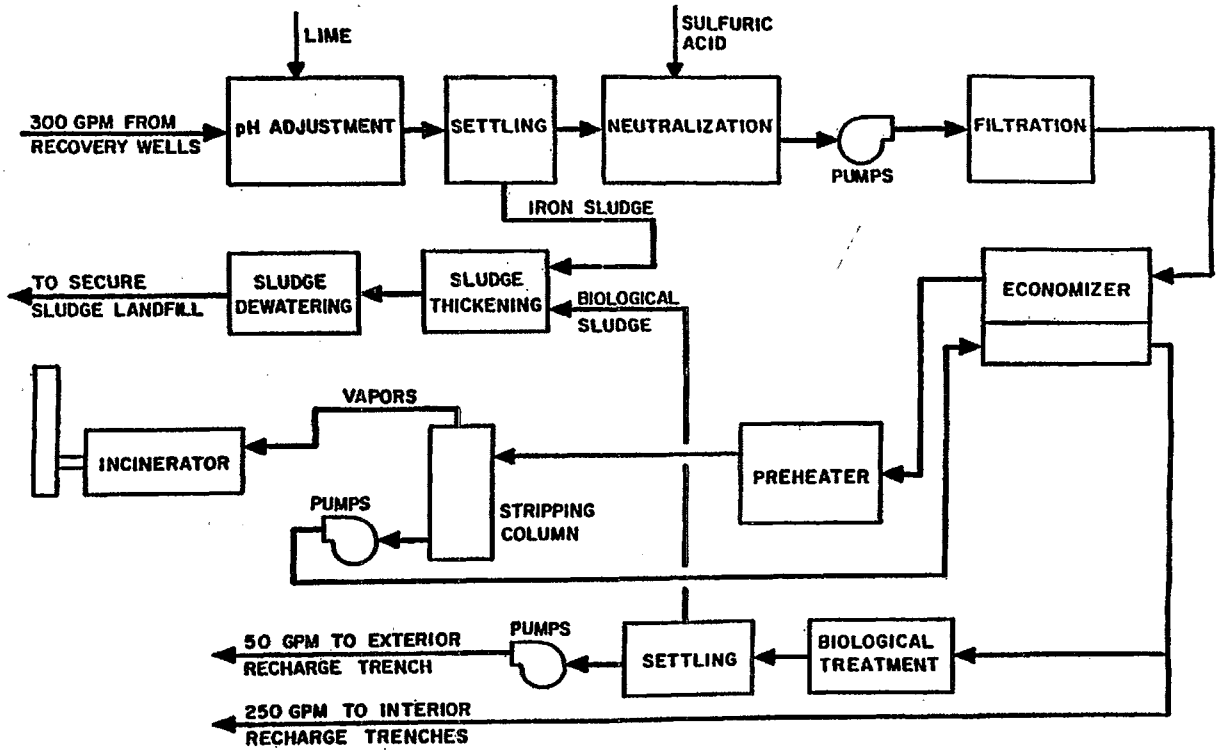


Figure 2. Process Flow Diagram of the Sylvester Groundwater Extraction and Treatment System [4]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

System Operation [1, 4]

- Quantity of groundwater pumped from aquifer by year:

Year	Total Volume Pumped (gallons)	Unit Name
1986	80,666,000	1,3
1987	138,029,000	1,3
1988	130,086,000	1,3
1989	112,587,000	1,3
1990	125,437,000	1,3
1991	107,285,000	1,3
1992	125,040,000	1,3
1993	125,476,000	1,3
1994	124,395,000	1,3
1995	126,889,000	1,3

- The remedial system operated from mid-1986 through 1995, with the following exceptions. Incinerator repair in 1989 reduced operation for approximately one month. The treatment facility was off line for a portion of 1991 and 1992 to make modifications. According to the site contact, the system has operated an average of 88% of the time between 1986 and 1995. The treatment facility was designed to operate 24 hours per day, 365 days per year.

- The groundwater treatment facility started up in April 1986, and full-scale operation commenced in June 1986. The SROD estimated that cleanup levels inside the 20-acre containment area would be met within two years of treatment system initiation. After two years, the SROD required EPA and NHDES to evaluate the site to determine the degree to which treatment goals had been met. In March 1988, the evaluation was performed and EPA and the NHDES concluded that several "hot spots," or areas of elevated groundwater contamination, persisted. An ESD was issued in July 1990, which included adjustments to the remedy as a result of the 1988 evaluation.

- As required by the ESD, the groundwater treatment plant operated for an additional four years, six additional recovery wells were installed in areas of greatest residual contamination, and the location of an apparent toluene contamination source was investigated.

- The total pump rate to the treatment facility did not increase substantially after the addition of six new extraction wells in 1991. The groundwater treatment facility was designed with a capacity of approximately 330 gpm, which could not be increased without decreasing contaminant removal efficiency. When new extraction wells were placed on line, the pumping rate from less contaminated existing wells was decreased.

- The original remedial design sought to optimize capture and treatment of contaminated groundwater while reducing leakage of groundwater from the site. Later optimization included increasing pumping rates at extraction wells with demonstrated greater groundwater contamination and using a MODFLOW model to maximize mass removal.

- The air stripper media and heat exchangers were acid washed quarterly to prevent clogging from iron fouling.

- High temperature air stripping was selected over conventional cold stripping because of the solubility of the organic compounds present and the desire to remove 90% of the VOCs on each pass through the stripper. While the removal efficiency was above expectations, the higher concentration of VOCs and greater total mass of pollutants resulted in a longer-than-expected treatment period to reduce groundwater concentrations to cleanup goals.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- In 1994 to 1995, a Remedial Action Evaluation Study was conducted to determine whether the remedy was protective of human health and the environment. The study concluded that the remedy used at the Sylvester/Gilson Road site was effective and that cleanup goals had been met. Groundwater extraction and treatment ceased on December 31, 1995 and access to the site was limited. On January 1, 1996, a three-year standby period was begun at the site. During this period, groundwater treatment equipment at the site will be maintained and kept in a ready state in the event that treatment must resume.

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents parameters affecting performance for this technology.

Table 3. Performance Parameters

Parameter	Value	
Average Pump Rate	265 gpm	
Performance Standard (Effluent)	1. Same as remedial goals for effluent discharged to recharge trenches. 2. MCLs for effluent discharged outside the slurry wall.	
Remedial Goal (within the containment structure)	Vinyl Chloride	95 µg/L
	Benzene	340 µg/L
	Chloroform	1,505 µg/L
	1,1,2-Trichloroethane	1.7 µg/L
	Methyl Ethyl Ketone	8,000 µg/L
	Chlorobenzene	110 µg/L
	Methylene Chloride	12,250 µg/L
	Toluene	2,900 µg/L
	1,1-Dichloroethane	1.5 µg/L
	Trans-1,2-Dichloroethane	1,800 µg/L
	1,1,1-Trichloroethane	200 µg/L
	Methyl Methacrylate	350 µg/L
	Selenium	2.6 µg/L
	Phenols	400 µg/L

Source: [5]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
7/29/82	---	Original ROD issued
9/22/83	---	SROD issued
10/83	3/84	Treatment facility designed
7/82	12/82	Slurry wall installed and synthetic cap placed over 20-acre area
4/84	4/86	Groundwater treatment facility constructed
6/86	---	Full-scale operations of groundwater treatment facility begin
7/90	---	ESD extending the operation of the treatment system, adding six new wells, and initiating toluene source removal actions issued
9/91	3/92	Six additional extraction wells installed to enhance plume recovery
3/92	---	Soil vapor extraction system added to remove toluene NAPL on groundwater surface
---	12/95	Remedial goals achieved and groundwater extraction and treatment system shut down
1/96	---	Three year standby period begun

Source: [2, 3, 7]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [8]

The remedial goal for this site was to clean up groundwater to meet the recommended Alternate Concentration Levels (ACLs) within the containment structure. ACLs were set for 14 groundwater contaminants, as shown in Table 3, at 10% of the maximum concentration detected. These limits were established to be protective of the bentonite slurry containment wall and the surrounding groundwater outside the containment system.

Additional Information on Goals [8]

- Risk-based concentration levels were set for groundwater outside of the containment structure. Treated water discharged to infiltration trenches outside the slurry wall must meet maximum contaminant levels.
- Volatization from Lyle Reed Creek must be reduced to acceptable exposure levels.

Treatment Performance Goals [8]

- One performance goal of the remedial system was to prevent the contaminant plume from further migrating. The slurry wall was designed to eliminate horizontal flow of contaminants; the extraction/infiltration system was designed to hydraulically minimize downward leakage of contaminants to the bedrock aquifer below.
- Another goal of the treatment system was to reduce contaminant concentrations by 90% with each pass through the treatment train. It was envisioned that treating two pore volumes would reduce groundwater concentrations by 99%.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment [1, 4, 5, 7]

For the purpose of this analysis, total contaminants includes all those contaminants listed in Table 3.

- According to the site contact, as of December 1995, the remedial action appears to have attained ACLs for all contaminants except 1,1-DCA. The levels of 1,1-DCA are below the New Hampshire groundwater quality standards of 81 µg/L and below the detection limit of analytical equipment feasible at this time. EPA is reportedly considering adjusting the ACL set for this contaminant.

- A slurry wall and cap were installed to contain the contaminant plume and minimize groundwater flow into and through the site, which would have carried contaminants further downgradient. Eliminating infiltration reduced the downward migration of groundwater into the bedrock. The extraction system further reduced downward migration by extracting more groundwater than was injected thus maintaining a net inward flow into the containment structure.

- Figure 3 presents the removal of contaminants through the treatment system from 1986 through 1995. The treatment system was shut down in December 1995. The mass flux data show that the mass of contaminant removed per day increased from 1986 to 1988 and reached a maximum of 512 pounds per day on average. The mass removed per day decreased in 1989 to 72 pounds and continued to decrease to less than 10 pounds per day in 1995. The total mass removed curve demonstrates that the mass of contaminants removed between 1986 and 1988 was 368,000 pounds, and between 1988 and 1995 was only 59,000 pounds.

- From 1986 through 1995, the P&T system removed approximately 427,000 pounds of contaminant mass from 1.2 billion gallons of groundwater treated.

- Most contaminant concentrations decreased after the treatment remedy was installed. However, two contaminants, toluene and 1,1-DCA, showed persistently high concentrations until a source control measure (SVE) aimed at removing a toluene NAPL was implemented.

- Figure 4 illustrates changes in total VOC concentrations in the groundwater since the remedial system was shut down. The total VOC measurement is the cumulative concentrations of contaminants detected in all monitoring wells. These data show that total concentrations are not rebounding.

Performance Data Completeness

- For the purpose of the analyses shown in Figure 3, annual flow rates, influent concentrations, mass removed data, and percent operational data were provided by the site contact.

- Quarterly data are available; however, an annual average was used in this report to present the data.

- The total VOCs data were taken from a common set of monitoring wells to demonstrate how contaminant concentrations are changing over the entire site.

- Contaminant mass removal was determined using analytical results from influent samples, along with flow rate data. Annual averages were used to calculate total mass removed and daily mass flux.

- Mass flux data was calculated with the following equation:

  mass flux = (Q x C_i) / %operational,
  where:

  mass flux = pounds per day
  Q = total yearly flow in gallons per year
  C_i = average annual influent concentration in pounds per gallon
  % operational = days of operation per year

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of New Hampshire requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

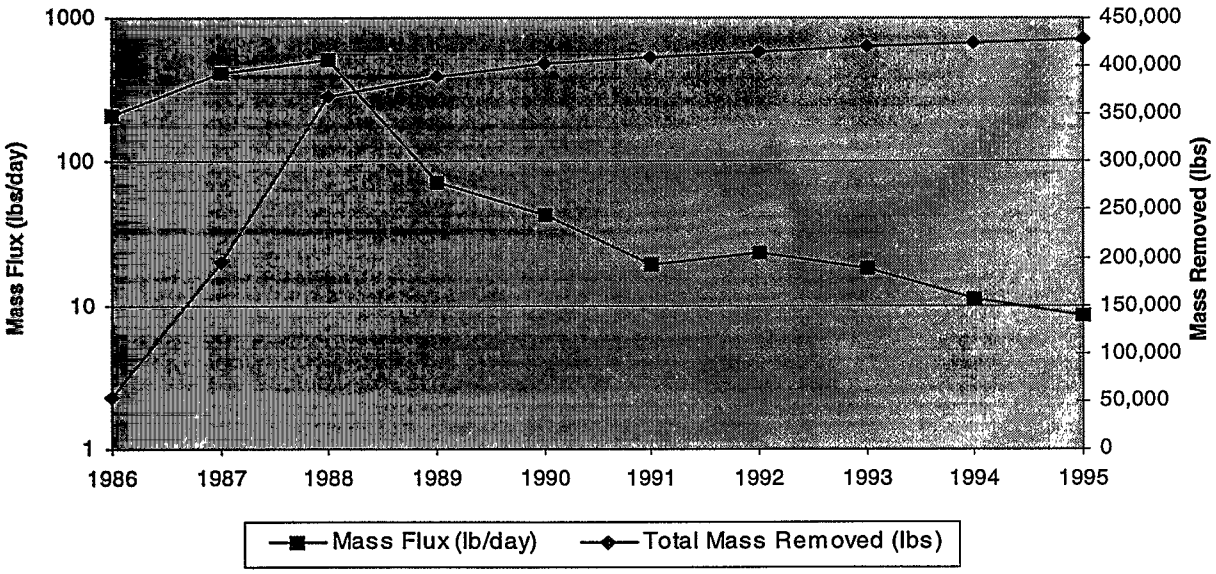


Figure 3. Mass Flux Rate and Cumulative Contaminant Removal (June 1986 - December 1995) [1]

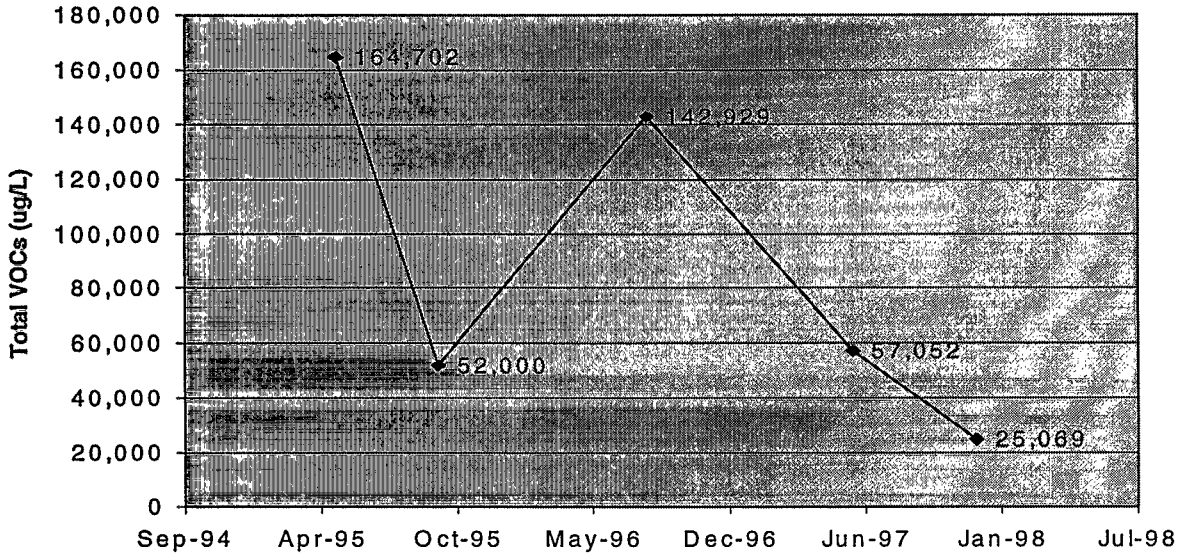


Figure 4. Total VOC vs. Time (1995 - 1997) Data Represents the Sum of All VOCs Detected [1]

TREATMENT SYSTEM COST

Procurement Process [1]

The NHDES is the lead for this site. Weston was the Remedial Action Contractor.

Cost Analysis [1]

- All costs through 1995 for design, construction and operation of the treatment system at this site were shared by the U.S. EPA (90%) and the State of New Hampshire (10%). As of 1996, all costs for the site have been borne by the State of New Hampshire.

Capital Costs [1]

Remedial Construction	
Slurry Wall & Cap	$2,200,000
Groundwater Extraction and Treatment Facility	$5,375,000
Change Order #1	$14,844
Change Order #2	$118,863
Change Order #3	$124,947
Groundwater Treatment Facility Modifications	$1,385,000
Change Order #1	Period of Performance Extension
Change Order #2	$39,179
Change Order #3	$31,329
Groundwater Treatment Facility Landfill Closure	$109,465
Total Site Construction	**$9,069,465**

Operating Costs [1]

Operating and Maintenance Cost

Year	Cost
1986	$1,142,411
1987	$1,615,500
1988	$1,590,169
1989	$1,574,255
1990	$1,908,630
1991	$1,896,018
1992	$1,981,405
1993	$1,961,017
1994	$1,940,022
1995	$2,116,624
1996	$375,385
1997	$366,170 (estimated)
Total Annual Operating Expenses	**$18,467,606**

Other Costs [1]

Remedial Design Cost	
Slurry Wall & Cap	$180,741
Groundwater Treatment Facility	$291,200
Groundwater Treatment Facility Modifications	$183,800
Remedial Action Evaluation and Closure Studies	
Remedial Action Investigation (1988)	$350,000
Remedial Action Evaluation and Closure Study (1994)	$810,000

Cost Data Quality

Actual cost data were provided by the NHDES site contact.

OBSERVATIONS AND LESSONS LEARNED

- The total construction and operating and maintenance (O&M) costs for the Sylvester/Gilson Road site were approximately $27.6 million (9.1 million in capital costs and $18.5 million in O&M costs) which corresponds to $64 per pound of contaminant removed and $23 per 1,000 gallons treated.

- Modifications were made to the system in 1991 to reflect changes required by the ESD and the site evaluation performed in 1988. These modifications resulted in a 15% increase in capital expenditures. The modifications included six new extraction wells and the installation of an SVE system for toluene source removal. (Listed as Groundwater Treatment Facility Modifications under Capital Costs.)

- O&M costs varied between approximately $1 and $2 million per year. The system was initially planned to operate for two years. As a result of higher than expected concentrations and overall mass of contaminants, the remedial system was required to operate for almost ten years.

- The high O&M costs at this site are attributed to the 300 gpm treatment system and number of staff required to operate it. For many years, the site was staffed with 15 full-time personnel who operated the site 24 hours per day.

- The slurry wall and cap contained the plume at the Sylvester/Gilson Road site. According to the site contact, this remedial action reduced the concentration of contaminants in Lyle Reed Brook while most groundwater contamination was being isolated and treated within the containment structure.

- Mass flux data from the Sylvester/Gilson Road site generally shows the typical asymptotic decline for mass removed using a P&T system. The mass flux slightly increased in 1992 to 23 lbs/day from 19 lbs/day in 1991. This increase was due to the addition of seven extraction wells installed in 1991.

- Based on persistent high toluene concentrations, additional investigations were performed and identified a toluene NAPL floating on the groundwater surface. As a result, a source removal action was initiated to remove the toluene NAPL after almost six years of P&T operation. After a SVE system was installed and removed the source area, groundwater concentrations were eventually reduced below cleanup goals.

REFERENCES

1. Data provided by site contact, Tom Andrews. August, 1997.
2. U.S. Environmental Protection Agency, Record of Decision, July 1982.
3. U.S. Environmental Protection Agency, Explanation of Significant Differences, July 1990.
4. U.S. Environmental Protection Agency, Evaluation of Groundwater Extraction Remedies Phase II, February 1992.
5. U.S. Environmental Protection Agency, Five Year Review, Sylvester/Gilson Road Superfund Site, September 1994.
6. U.S. Environmental Protection Agency, Innovative Operational Treatment Technologies for Application to Superfund Sites, April 1990.
7. New Hampshire Department of Environmental Services, Annual Report (1996-1997) The Gilson Road Superfund Site, June 1997.
8. U.S. Environmental Protection Agency, Supplemental Record of Decision, September 1983.
9. Plume map from: Remedial Program Evaluation Gilson Road Site, Nashua, NH, Weston, July 1989.
10. Correspondence with John Fritsch, Metcalf & Eddy, July 9, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM, Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the United Chrome Superfund Site Corvallis, Oregon

Pump and Treat of Contaminated Groundwater at the United Chrome Superfund Site Corvallis, Oregon

<table>
<tr><td>Site Name:
United Chrome Superfund Site</td><td rowspan="2">Contaminants:
Heavy Metals (Chromium)
- Testing in 1983-1984 showed concentrations of chromium up to 3,619 mg/L in the shallow aquifer and up to 30 mg/L in the deep aquifer</td><td>Period of Operation:
Status: Ongoing
Report covers: August 1988 through March 1997</td></tr>
<tr><td>Location:
Corvallis, Oregon</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Operations:
CH2M Hill, Inc.</td><td rowspan="2">Technology:
Pump and Treat
- Currently, groundwater is extracted using 9 wells in the upper aquifer and one well in the deep aquifer
- Pumping rates ranged from 4-11.5 gpm for the upper aquifer and 1.5-15.8 gpm for the deep aquifer
- Extracted groundwater was treated with a reduction and precipitation system until November 1994; since that time, extracted groundwater has been discharged to a POTW without on-site treatment</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/12/86</td></tr>
<tr><td>State Point of Contact:
Tom Penpraze
Utilities Division Manager
Public Works Dept.
City of Corvallis
P.O. Box 1083
Corvallis, OR 97339-1083</td><td>EPA Point of Contact:
Al Goodman, RPM
U.S. EPA Region 10
811 Southwest Sixth Ave.
Portland, OR 97204
(503) 326-3685</td></tr>
<tr><td>Waste Source:
Discharge to unlined disposal pit</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 62 million gallons treated as of March 1997
- Groundwater is found at 0-10 ft bgs
- Extraction wells are located in two aquifers, with flow from the upper to lower aquifer and lower to upper at times during the year
- Hydraulic conductivity ranges from 0.5 to 60 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Extracted groundwater was treated on-site at the beginning of this application; however, because concentrations dropped over time, on-site treatment was discontinued.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Cleanup goals require a concentration for chromium of 10 mg/L in the upper aquifer and 0.10 mg/L in the deep aquifer.
- The system is also required to hydraulically contain the contaminant plume.</td></tr>
<tr><td colspan="3">Results:
- Chromium concentrations in both aquifers have been reduced. In the upper aquifer, average chromium concentrations have been reduced from 1,923 mg/L in August 1988 to 18 mg/L in March 1997. In the deep aquifer, average chromium concentrations have been reduced from 1.4 mg/L in August 1991 to 0.11 mg/L in March 1997. Cleanup goals for chromium have been met in 11 or 23 wells in the upper aquifer and six of seven wells in the deep aquifer.
- Approximately 31,363 pounds of chromium have been removed from the upper aquifer and 96 pounds from the deep aquifer, for a total of 31,459 pounds as of March 1997.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the United Chrome Superfund Site Corvallis, Oregon (continued)

Cost:
- Actual costs for pump and treat were $4,637,160 ($3,329,840 in capital and $1,307,320 in O&M), which correspond to $75 per 1,000 gallons of groundwater extracted and $140 per pound of contaminant removed.
- Annual operating costs dropped by an order of magnitude when use of the treatment system was discontinued in 1992.

Description:
United Chrome products is a former industrial hard chrome plating facility that manufactured and repaired hard chrome plated parts from 1956 until early 1985. In 1956, a disposal pit for liquid waste was dug in the area west of the former on-site building, and chromium-laden wastewater was discharged to the pit from 1956 to 1982. In June 1983, EPA conducted a field investigation at the site, discovering chromium contamination in on-site surface water and soils. The site was placed on the NPL in September 1984 and a ROD was signed in September 1986.

Groundwater contamination was addressed in two phases. Phase 1 was directed at remediation of the upper aquifer and began in August 1988. Phase 2 was directed at remediation of the deep aquifer and began in September 1991. Currently, groundwater is extracted using nine wells in the upper aquifer and one well in the deep aquifer. Until November 1994, extracted groundwater was treated on site; since that time, extracted groundwater has been discharged to a POTW without on-site treatment. Chromium concentrations in both aquifers have been reduced, but have not yet met cleanup goals. Future operations of the groundwater extraction systems will be determined following a 1998 investigation of the remaining soil in the area of the former plating tanks and the disposal pit.

SITE INFORMATION

Identifying Information:

United Chrome Superfund Site
Corvallis, Oregon

CERCLIS #: ORD009043001

ROD Date: September 12, 1986

ESD Date: December 12, 1991

Treatment Application:

Type of Action: Remedial

Period of operation: 8/1/88 - Ongoing
(Mass Removal Data Collected From 8/88 through 3/97)
(Monitoring Well Data Collected from 8/88 through 12/96)

Quantity of groundwater treated during application [1]: 62 million gallons

Background

Historical Activity that Generated Contamination at the Site: Chrome plating

Corresponding SIC Code: 3471 (Plating of Metals)

Waste Management Practice That Contributed to Contamination: Discharge to unlined disposal pit

Facility Operations [1-4]:

- United Chrome Products is a former industrial hard chrome plating facility that manufactured and repaired hard chrome plated parts from 1956 until early 1985.
- In 1956, a disposal pit for liquid waste was dug in the area west of the former on-site building. Plating tanks were located just northeast of the disposal pit. Chromium-laden wastewater was discharged to the pit from 1956 to 1982. Sludges were removed from the pit and disposed of under the guidance of the Oregon Department of Environmental Quality (DEQ) in 1982 and 1983.
- In June 1983, EPA conducted a field investigation at the site, discovering chromium contamination in on-site surface water and soils. United Chrome Products was placed on the National Priorities List (NPL) on September 21, 1984.
- EPA performed contaminated soil removal activities at the site from July 2, 1985 until November 6, 1985. An on-site surface drainage ditch was dammed and rerouted as part of remedial activities in 1988.
- Groundwater contamination was addressed in two phases. Phase I was directed at remediation of the upper aquifer and containment of the plume. Phase II focused on remediation of the lower aquifer. Phase I began in August 1988 and Phase II began in September 1991.

Regulatory Context:

- The Record of Decision (ROD) for the site was signed on September 12, 1986.
- An Explanation of Significant Differences (ESD) was signed on December 12, 1991.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: The selected remedy was for extraction, treatment, and surface discharge of groundwater from the unconfined and confined aquifers and limited excavation of contaminated soil and removal of plating tanks and residual sludge. The remedy was modified by the ESD that allowed for discharge to the City of Corvallis Publicly Owned Treatment Works (POTW) in accordance with the Pretreatment Requirements.

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA

Site Contact:
Tom Penpraze
Utilities Division Manager
Public Works Department
City of Corvallis
P.O. Box 1083
Corvallis, OR 97339-1083

*Indicates primary contact

Remedial Project Manager:
Al Goodman*
U.S. EPA Region 10
811 Southwest Sixth Avenue
Portland, Oregon 97204
(503) 326-3685

Treatment System Vendor:
Operations Contractor: CH2M Hill, Inc.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization

Primary Contaminant Groups: Chromium

- The contaminant of concern in the groundwater is chromium. The groundwater is contaminated with the hexavalent chromium species. However, cleanup standards are set for total chromium. Likewise, laboratory analyses test for total chromium. For these reasons, chromium levels tested and regulated at the United Chrome site are for total chromium [3].

- Initial testing for chromium in the groundwater in 1983 revealed levels of up to 3,619 mg/L in the shallow aquifer and 3.0 mg/L in the deep aquifer. Later sampling in 1984 revealed levels of chromium of up to 30 mg/L in the deep aquifer [3].

- The contaminant plume in the upper unconfined aquifer as estimated by the 1985 remedial investigation (RI) was approximately 1 acre in size and 17 feet thick, with a plume volume of over 2 million gallons. The RI revealed that the contaminant plume in the deep aquifer was approximately 1.4 acres in size and 15 feet thick, with a plume volume of 2.4 million gallons [5].

- In 1988, a plume map was drawn to show the extent of contamination. Figure 1 shows the approximate boundary of the chromium contamination plumes in the upper and deep aquifers prior to treatment in August 1988. At that time, chromium concentrations in the upper aquifer as high as 19,000 mg/L were measured near the location of the plating tanks.

- Based on the plumes shown in Figure 1, the surface areas of the upper and deep plumes were 1.5 and 1.7 acres, respectively. The upper plume had migrated to the northeast concurrent with on-site flow direction. The chromium contamination plume in the deep aquifer migrated northeast of the former plating tanks, concurrent with groundwater flow in the deep aquifer.

MATRIX DESCRIPTION (CONT.)

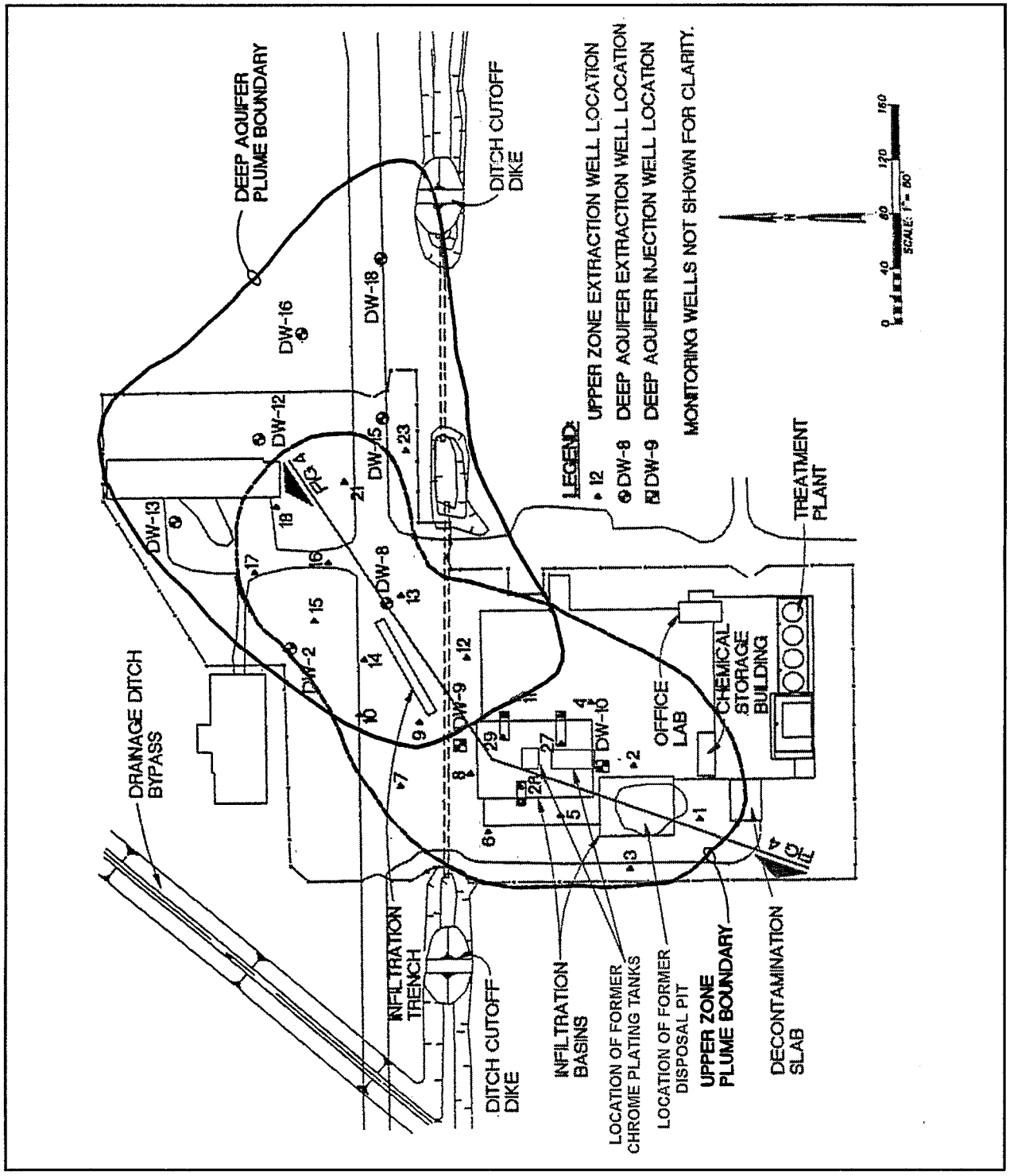

Figure 1. Chromium Contaminant Plumes in the Upper and Deep Aquifers Prior to August 1988 [2]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [2,5]:

The site hydrogeology consists of four hydrogeologic units, beginning with an upper aquifer (also called the upper zone) underlain by an upper aquitard and ending with a deep aquifer underlain by a lower aquitard.

Unit 1	Upper Aquifer	Approximately 18 feet thick and consisting of fine silt overlying the upper aquitard. Recharge to the upper aquifer is limited.
Unit 2	Upper Aquitard	Stiff dark gray clay, ranging from 2 to 10 feet thick, that grades into deep aquifer soils at about 23 feet below the ground surface.
Unit 3	Deep Aquifer	Interbedded silty sand and sandy gravel, ranging from 15 to 25 feet thick. It is semiconfined above by the upper aquitard and confined below by the lower aquitard. Recharge is supplied from the overlying silts. Water in this aquifer is used for drinking purposes. The nearest drinking water well is approximately 3,000 feet northeast of the site. Recharge to the lower aquifer is not limited.
Unit 2	Lower Aquitard	Plastic clay at least 40 feet thick.

Groundwater in the upper and deep aquifers regionally flows northeast. The unconfined water table in the upper zone fluctuates seasonally between 0 and 10 feet below the ground surface. Based on water level comparison between aquifers, groundwater flow through the upper aquitard is estimated as high as 0.4 foot per year from the upper aquifer to the deep aquifer. For about one month a year during dry summer conditions, the groundwater flows from the deep aquifer to the upper aquifer.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Upper Aquifer	15 - 18	0.5 - 2.5	0.008 - 0.04	North to Northeast*
Deep Aquifer	15 - 25	50 - 60	0.04 - 0.16	North to Northeast

*Previously, local groundwater flow in the upper aquifer was affected by a former drainage ditch and flowed south to southeast. The ditch has since been dammed and rerouted.

Source: [5]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) (original system)
Pump and discharge to POTW (current system)

Supplemental Treatment Technology

None

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation [1,2,6,7,9]

Table 2. Extraction Well Data

Wells	Unit Name	Depth (ft)	Design Pumping Rate (gpm)*
23 Wells	Upper Aquifer	9 - 19	7.5
7 Wells	Deep Aquifer	35 - 40	10.0

*Pumping rate for all wells in each unit

Source: [1,7]

System Description

- Since 1988, groundwater has been extracted from both aquifers. The initial extraction system used 23 wells in the upper aquifer and seven in the deep, as listed in Table 2. The current extraction system consists of 10 recovery wells, nine for the upper aquifer and one for the deep aquifer. Extracted water is discharged to the City of Corvallis POTW.

- Two infiltration basins and one infiltration trench (discontinued in 1993) were constructed to inject water from the City of Corvallis into the upper aquifer.

- Extracted water from the upper aquifer was formerly treated through a reduction and precipitation system with a 50 gpm capacity; however, since November 1994, chromium levels have been sufficiently reduced to allow discharge to the POTW in accordance with Pretreatment Standards. Extracted water from the deep aquifer has always been discharged to the POTW.

- Recovery wells were placed throughout the plume, with higher extraction rates from recovery wells with higher chromium contamination levels. No computer model was used, and upper zone extraction well spacing was determined from a pump test and plume geometry. Pumping rates are adjusted with orifice plates. Originally, 23 extraction wells were placed in the upper aquifer and seven extraction wells were placed in the deep aquifer. As chromium concentrations in extraction wells decreased below remedial goals, pumping from these wells was stopped, as discussed in the System Operation section.

- Groundwater quality is monitored semi-annually through a network of seven monitoring wells in the upper aquifer and five monitoring wells in the deep aquifer. Active extraction wells (nine in the upper aquifer and one in the deep aquifer) are monitored quarterly.

System Operation

- Average groundwater pumping rate from aquifer in gallons per minute (gpm):

Dates	Unit	Average Pumping Rate (gpm)
8/1/88 - 12/31/88	Upper	10.4
	Deep	None
1/1/89 - 12/31/89	Upper	9.3
	Deep	None
1/1/90 - 12/31/90	Upper	11.5
6/1/90 - 12/31/90	Deep	1.6
1/1/91 - 12/31/91	Upper	11.2
	Deep	6.6
1/1/92 - 12/31/92	Upper	8.8
	Deep	5.5
1/1/93 - 12/31/93	Upper	6.4
	Deep	15.8
1/1/94 - 12/31/94	Upper	4.5
	Deep	4.0
1/1/95 - 12/31/95	Upper	4.4
	Deep	10.1
1/1/96 - 12/31/96	Upper	4.0
	Deep	1.5
1/1/97 - 3/31/97	Upper	7.0
	Deep	3.2

TREATMENT SYSTEM DESCRIPTION (CONT.)

- The volume of water in the upper aquifer available for extraction is limited, and the upper aquifer becomes dewatered with too much pumping. Clean potable water was reinjected to recharge the aquifer and flush any sorbed chromium. By 1992, chromium levels had decreased more quickly than originally anticipated. Some wells that had chromium levels below the 10 mg/L cleanup goal were no longer pumped. In addition, by 1995, chromium levels had decreased sufficiently so that treatment of the water extracted from upper aquifer was no longer necessary.

- In 1991, because of the drop in chromium levels in the upper aquifer, an ESD was approved for the site to discharge extracted water which met pretreatment standards to the POTW. In November 1995, with permission from EPA, the treatment system was discontinued.

- Adjustments have been made to the upper aquifer extraction system since 1988 to optimize contaminant capture. Higher pumping rates were used at wells with greater levels of chromium contamination. Pumping has continued from nine of the original 23 extraction wells in the upper aquifer, because those nine had elevated levels of chromium. The remaining extraction wells in the upper aquifer were not used because levels of chromium were either below or slightly above the cleanup level of 10 mg/L (less than 15 mg/L).

- In the deep aquifer extraction system, only one of the seven original extraction wells was still operating during 1997. The cleanup goal of 0.10 mg/L of Cr in the lower aquifer was met in the other six extraction wells.

- Future operations of the groundwater extraction systems will be determined following a 1998 investigation of the remaining soil in the area of the former plating tanks and the disposal pit.

Operating Parameters Affecting Treatment Cost or Performance

One operating parameter affecting cost or performance for pump and treat is the extraction rate. Table 3 presents values for this and other performance parameters.

Table 3. Performance Parameters

Parameter	Value
Pump Rate Range (August 1988 - March 1997)	4.0 - 11.5 gpm, upper aquifer 1.5 - 15.8 gpm, deep aquifer
Remedial Goals	Upper Aquifer 10 mg/L, Cr Deep Aquifer 0.10 mg/L Cr
Treatment Performance Goals: Pretreatment Requirement	Cr 7 lbs/day maximum average discharge to POTW

Source: [1,3,4]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this application.

Table 4. Timeline

Start Date	End Date	Activity
9/12/86	—	ROD signed
2/4/87	9/11/87	Remedial design completed
8/88	—	Phase I of the remediation system begun. Pumping and treating from upper aquifer and monitoring begun.
9/91	—	Phase II of the remediation system begun. Pumping and treating from deep aquifer begun.
7/91	—	EW-77, EW-18, and EW-23 shut down
3/92	—	EW-21 shut down
5/92	—	EW-43 shut down
9/92	—	EW-3 shut down
1/94	—	EW-1 shut down
2/94	—	EW-11 shut down
9/94	—	EW-13 and EW-27 shut down
6/95	—	EW-16 shut down
1995	—	EW-9, DW-13, DW-17, and DW-18 shut down
1996	—	DW-16, DW-12, and DW-15 shut down
12/97	—	EW-2, EW-7, EW-12, and EW-15 shut down
11/1/92	—	ESD signed.
11/28/94	—	EPA approval to pump groundwater and discharge to POTW without pretreatment received

Source: [2,3]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [3]

The cleanup goals require a level of 10 mg/L for chromium in the upper aquifer and 0.10 mg/L (the current maximum contaminant limit, or MCL) for chromium in the deep aquifer.

Additional Information on Goals [3]

The cleanup goal of 10 mg/L for chromium in the upper aquifer was determined to be the maximum allowable concentration in the upper aquifer that was still protective of the deep aquifer, and that met the risk requirement for the upper aquifer. In addition, the MCL established by EPA for total chromium was originally 0.05 mg/L but was revised to 0.10 mg/L in 1992.

Treatment Performance Goals [3]

- The primary treatment performance goal is to hydraulically contain the contaminant plume.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment [1,6]

- Chromium concentrations in both aquifers have been reduced. Figure 2 illustrates the decrease in average chromium concentrations in both the upper and the deep aquifers over time. Performance data indicate that the average chromium concentrations in the upper aquifer have been reduced 99%, from 1,923 mg/L in August 1988 to 18 mg/L in March 1997. Average chromium concentrations in the deep aquifer have been reduced 92%, from 1.4 mg/L in August 1991 to 0.11 mg/L in March 1997.

- Cleanup goals for chromium have been met in 11 of 23 wells in the upper aquifer and in six of seven wells in the deep aquifer. Cleanup goals have been met in all perimeter wells. In the upper aquifer, chromium concentrations in 12 wells remain above the 10 mg/L cleanup goal, with a maximum concentration of 64 mg/L. In the deep aquifer, chromium concentrations in one well remain slightly above the 0.10 mg/L cleanup goal, with a maximum concentration of 0.11 mg/L.

- Approximately 31,363 lbs of chromium have been removed from the upper aquifer and approximately 96 lbs of chromium have been removed from the deep aquifer, for a total of 31,459 lbs removed. Figures 3 and 4 show mass removal over time from August 1988 through March 1997 for the shallow and deep aquifers, respectively. The mass removal rate has decreased since August 1988. The upper aquifer continues to yield approximately 0.8 lbs/day of chromium; however, the deep aquifer yields less than 0.01 lbs/day of chromium.

Performance Data Completeness

Average chromium concentrations and mass removal data used in Figures 2, 3, and 4 were provided in the 1997 First Quarterly Report. Chromium concentrations in individual wells are available in various quarterly reports. Monthly data from August 1988 through December 1996, the most recent data available, were used for Figure 2. Monthly data from August 1988 through March 1997 were used to depict mass removal in Figures 3 and 4.

Performance Data Quality

The QA/QC program used throughout the remedial action met EPA and State of Oregon requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

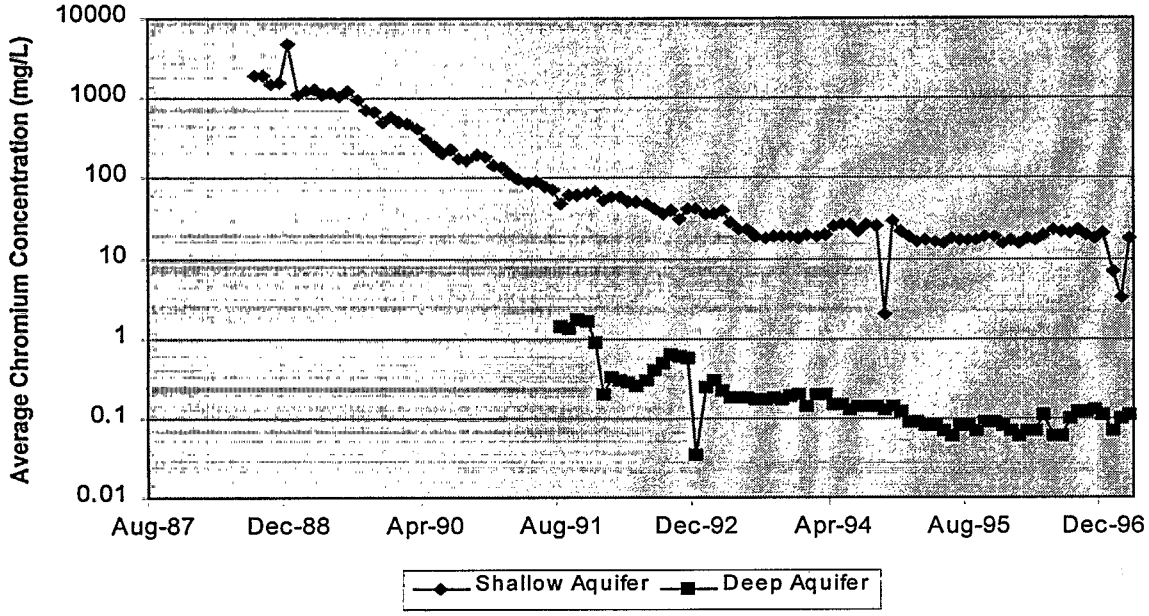

Figure 2. Chromium Levels in the Groundwater as a Function of Time [1]

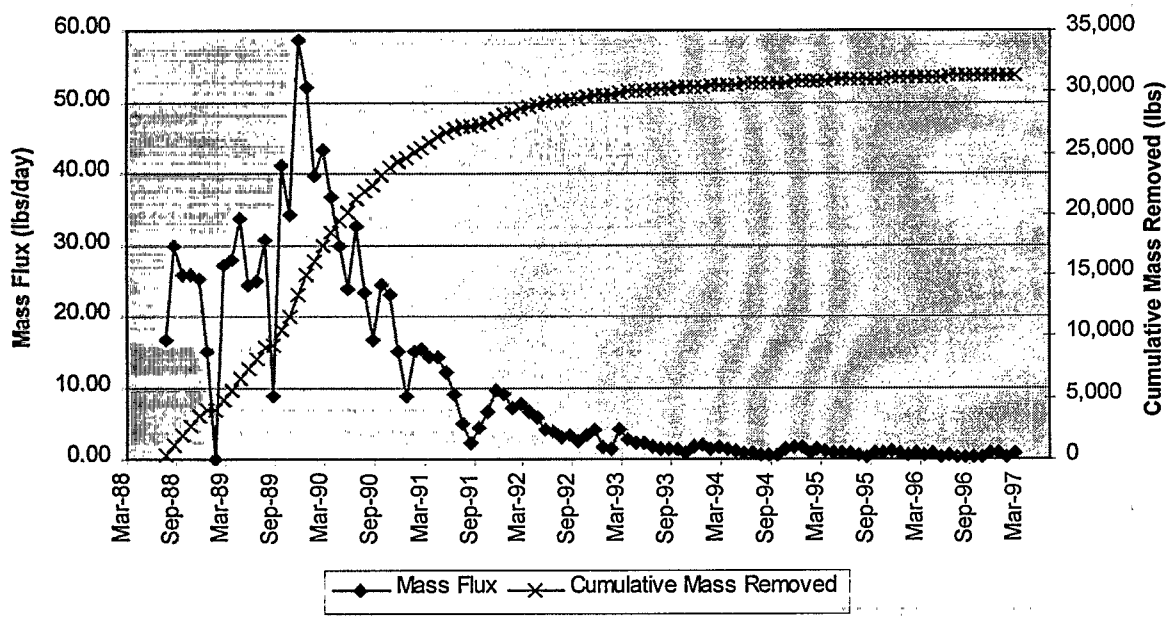

Figure 3. Chromium Mass Removed from the Upper Aquifer as a Function of Time [1]

TREATMENT SYSTEM COST

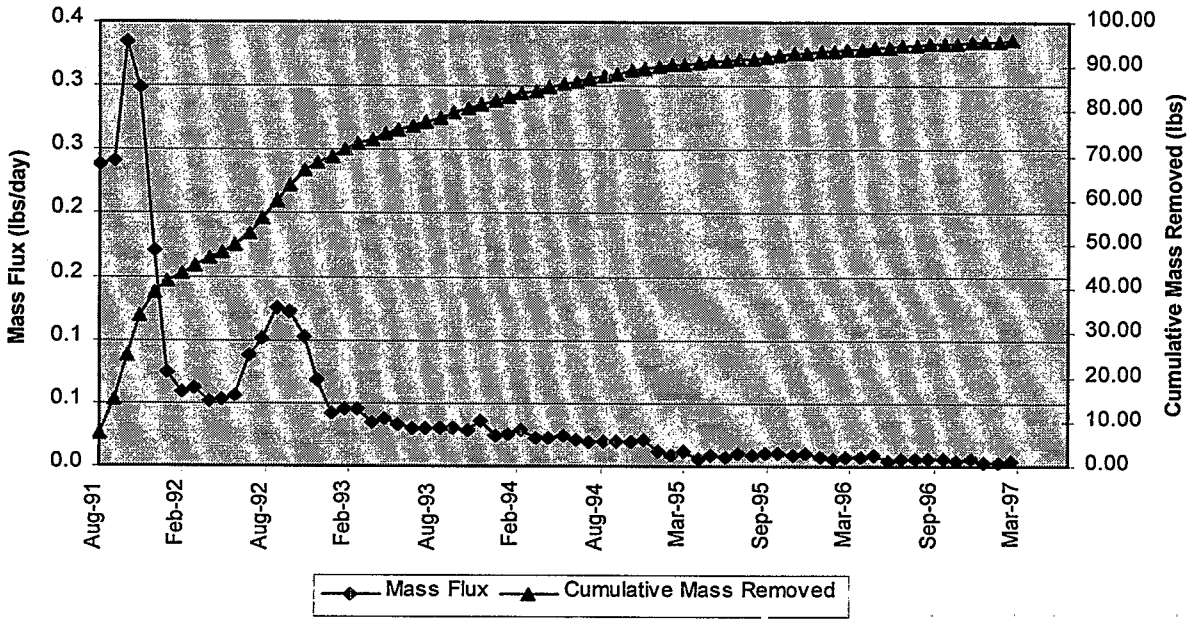

Figure 4. Chromium Mass Removed from the Deep Aquifer as a Function of Time [1]

Procurement Process

The City of Corvallis operates the remediation systems. EPA has contracted with CH2M Hill, Inc. to oversee and evaluate the remediation system.

Cost Analysis

All costs for investigation, design, and construction of the treatment system at this site were borne by EPA. The City of Corvallis has borne the costs of operation and made payment to EPA under terms of a Consent Decree.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [8]

Administration and Mobilization	$745,035
Monitoring Wells and Sampling	$131,903
Site Work	$300,195
Groundwater Extraction	$611,669
Treatment System	$1,374,625
Construction Management and Other Engineering Services	$130,235
State Oversight	$13,656
Other Costs	$22,522
Total Remedial Construction	**$3,329,840**

Operating Costs [9]

1987-1998 (fiscal year)	$11,722
1988-1989	$177,405
1989-1990	$97,838
1990-1991	$531,626
1991-1992	$251,573
1992-1993	$90,523
1993-1994	$53,428
1994-1995	$36,748
1995-1996	$25,374
1996-1997	$31,081
Cumulative 1987-1997	**$1,307,318**

Other Costs [8]

Remedial Investigation/Feasibility Study	$263,832
Corps Oversight	$4,759
Total RI/FS	**$268,590**
Remedial Design	$348,810
State Oversight	$15,059
Total Remedial Design	**$363,869**
EPA Oversight (Contractor included)	$250,000

Cost Data Quality

Actual capital and operating cost data were provided by the EPA Remedial Project Manager (RPM) and the City of Corvallis for this site.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the P&T application at United Chrome were approximately $4,637,160 ($3,329,840 in capital costs and $1,307,320 in operating costs. This cost corresponds to $75 per 1,000 gallons of water treated and $140 per pound of contaminant removed.
- Operations costs dropped by an order of magnitude when the treatment system was discontinued in 1992.
- The City of Corvallis realized the chromium level in the treatment system influent would drop below pretreatment standards prior to complete remediation, and planned accordingly. They used a modular shorter-term treatment system at a cost of $1.3 million, compared to a more expensive permanent remedy.
- Normal groundwater recharge to the upper aquifer is limited and reinjection of water into the aquifer was necessary to continue flushing the contaminated aquifer. Therefore, it was necessary to remove as little water as possible from the upper aquifer and to optimize the contaminant removal per gallon of water pumped. The flexible pumping and injecting system enabled the remediation system to operate in these conditions.

REFERENCES

1. United Chrome Quarterly Report/First Quarter 1997, Tom Penpraze, City of Corvallis, April 4, 1997.

2. Case History: Effective Groundwater Remediation at the United Chrome Superfund Site, U.S. EPA Region 10, CH2M Hill, undated.

3. Record of Decision, U.S. EPA Region 10, September 12, 1986.

4. Explanation of Significant Differences, U.S. EPA Region 10, November 1, 1992.

5. Final Remedial Investigation Report, Ecology and Environment, Inc., July 26, 1985.

6. Process Modification Request, Correspondence U.S. EPA Region 10, November 28, 1994.

7. United Chrome 1996 Annual Report, Tom Penpraze, City of Corvallis, March 11, 1997.

8. Ground-water Remedial Cost Analysis, Pump and Treat of Contaminated Groundwater at the United Chrome Products Site, Corvallis, OR, unpublished document prepared under the U.S. EPA Hazardous Site Control Division Remedial Operations Guidance Branch.

9. Draft comments provided by the City of Corvallis, August 1998.

10. Draft comments provided by Allan Goodman, EPA Region 10.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the U.S. Aviex Superfund Site, Niles, Michigan

Pump and Treat of Contaminated Groundwater at the U.S. Aviex Superfund Site, Niles, Michigan

Site Name: U.S. Aviex Superfund Site	**Contaminants:** Chlorinated solvents and volatiles - nonhalogenated - Maximum concentrations detected in 1985 sampling event were 1,1,1-TCA (200,000 ug/L), 1,2-DCA (1,600 ug/L), and diethyl ether (DEE, at 5,700 ug/L)	**Period of Operation:** Status: Ongoing Report covers: 7/93 - 12/96
Location: Niles, Michigan		**Cleanup Type:** Full-scale cleanup (interim results)
Vendor: EPA Contractor: Jack Brunner Tetra Tech EM Inc. 200 East Randolph Dr, Suite 4700 Chicago, IL 60601 (312) 856-8700 Air Stripping Tower: LANTAC Construction Subcontractor: ATEC Associates Inc. 2777 Finley Road, Unit 4 Downers Grove, IL 60515	**Technology:** Pump and Treat - Groundwater is extracted using 5 wells, located on site, at an average total pumping rate of 232 gpm - Extracted groundwater is treated with air stripping and discharged to a surface water under a NPDES permit	**Cleanup Authority:** CERCLA Remedial - ROD Date: 9/7/88
State Point of Contact: Carl Chavez MDEQ P.O. Box 30426 Lansing, MI 48909-7926 (517) 373-8174		**EPA Point of Contact:** Ken Glatz, RPM U.S. EPA Region 5 77 West Jackson Blvd. Chicago, IL 60604-3507 (312) 886-1434
Waste Source: Ruptured drums, leaking underground pipe	**Type/Quantity of Media Treated:** Groundwater - 329 million gallons treated as of December 1996 - DNAPL suspected in groundwater at this site - Groundwater is found at 20 ft bgs - Extraction wells are located in 1 aquifer - Hydraulic conductivity ranges from 9.1 to 45.4 ft/day	
Purpose/Significance of Application: Performed modeling for system optimization (MODFLOW and Randomwalk).		

Regulatory Requirements/Cleanup Goals:
- Remediate the groundwater to levels established by MDEQ and the maximum contaminant levels (MCLs) established by the SDWA.
- Cleanup goals include DEE (43 ug/L), 1,1,1-TCA (200 ug/L), 1,2-DCA (5 ug/L), 1,1-DCE (7 ug/L), TCE (5 ug/L), PCE (0.88 ug/L), benzene (5 ug/L), toluene (2,000 ug/L), ethylbenzene (680 ugL), and xylene (440 ug/L).
- A secondary goal of the system is to create an inward hydraulic gradient to contain the contaminant plume.

Pump and Treat of Contaminated Groundwater at the U.S. Aviex Superfund Site, Niles, Michigan (continued)

Results:
- The average concentration of total contaminants has decreased from 158 to 67 ug/L over 3 1/2 years of operation; however, contaminant concentrations have declined but remain above cleanup goals.
- Approximately 664 pounds of contaminants have been removed from the groundwater from September 1993 to December 1996.
- Plume containment has been maintained in this application; however, additional contamination has been identified outside of the original plume. This has been attributed to historically elevated levels not discovered during the RI/FS.

Cost:
- Actual costs for the P&T system from 1993-1996 were approximately $1,942,000 ($1,332,000 in capital and $610,000 in O&M), which correspond to $5 per 1,000 gallons of groundwater extracted and $2,925 per pound of contaminant removed.

Description:
The site was operated as a non-lubricating automotive fluids manufacturer from the early 1960s until 1978. Fluid manufacturing included repackaging of bulk products and formulation of new products from bulk ingredients. In July 1972, an underground pipe carrying diethyl ether (DEE) broke during excavation activities, releasing an unknown quantity to the soil and groundwater. In November 1978, a fire ruptured chemical-storing drums. The water used to extinguish the fire washed unknown amounts of chlorinated hydrocarbons onto unpaved areas. After the 1978 release, U.S. Aviex performed a groundwater investigation. The site was placed on the NPL in 1983 and a ROD was signed in 1988.

The pump and treat system currently in use at U.S. Aviex consists of five extraction wells installed to 100 ft bgs, and an air stripper 56 ft tall, 4 ft in diameter, and packed with plastic media. Groundwater monitoring data indicate that while maximum contaminant concentrations have dropped (up to 99% for 1,1,1-TCA), they remain above cleanup goals. In addition, contamination has been detected in wells down-gradient of the plume identified in the RI/FS, and EPA is in the process of further characterizing the plume.

SITE INFORMATION

Identifying Information:

U.S. Aviex Superfund Site
Niles, Michigan

CERCLIS #: MID980794556

ROD Date: September 7, 1988

Treatment Application:

Type of Action: Remedial

Period of operation: 7/93 - Ongoing (Performance Data Collected Through December 1996)

Quantity of material treated during application: 329 million gallons of groundwater treated

Background

Historical Activity that Generated Contamination at the Site: Production of industrial organic chemicals

Corresponding SIC Code: 2869, (manufacture of industrial organic chemicals)

Waste Management Practices That Contributed to Contamination: Ruptured drums, leaking underground pipe

Location: Niles, Michigan

Facility Operations: [1, 2]

- The site, a six-acre parcel of land, operated as a non-lubricating automotive fluids manufacturer, from the early 1960s until 1978. Fluid manufacturing included the repackaging of bulk products and the formulation of new products from bulk ingredients.
- In July 1972, an underground pipe carrying diethyl ether (DEE) broke during excavation activities, releasing an unknown quantity to the soil and groundwater.
- In response to the 1972 pipeline break, U.S. Aviex installed five on-site monitoring wells and supplied affected residences with bottled water. No remedial work was documented from 1972 to 1978.
- In November 1978, a fire ruptured chemical-storing drums. The water used to extinguish the fire washed unknown amounts of chlorinated hydrocarbons onto unpaved areas [1]. Operations at the site ceased in 1978.
- After the 1978 release, U.S. Aviex performed a groundwater investigation. In 1982, U.S. Aviex entered into an agreement with the Michigan Department of Environmental Quality (MDEQ) to construct an on-site pump and treat (P&T) system to contain the identified contamination.
- In November 1983, U.S. Aviex began extraction and treatment of groundwater from two extraction wells as an interim remedy during the remedial investigation. Contaminated soils were left in place.
- In 1983, the site was placed on the National Priorities List (NPL). In 1987, the MDEQ installed an alternate water supply system to affected residences.
- The Remedial Investigation/Feasibility Study (RI/FS) began in 1985, funded by U.S. Aviex. In 1988, U.S. Aviex was declared bankrupt and the RI/FS was completed by the EPA.
- Currently, EPA is further characterizing the site to determine the full extent of the contaminant plume.

Regulatory Context:

- The 1987 interim remedy was constructed under a 1982 agreement with the MDEQ. The performance data presented in this report do not address the performance of the 1983 interim remedy, but does address performance of the current system from July 1993 to December 1996.

SITE INFORMATION (CONT.)

Background (Cont.)

- The Record of Decision (ROD) for the U.S. Aviex site was signed on September 7, 1988, and addressed both on-site and off-site contamination in the soil and groundwater. The selected remedy for soil remediation was soil flushing; however, it was determined after the ROD during pre-design investigations that the soil was clean. No soil flushing was performed.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Remedy Selection: The selected remedy for groundwater treatment is extraction of groundwater, followed by treatment through air stripping, with discharge of treated water to nearby surface water.

Site Logistics/Contacts

Site Lead: EPA-Lead 1988-1996
Michigan Department of Environmental Quality (MDEQ)-Lead 1996-Ongoing

Oversight: EPA

Remedial Project Manager:
Ken Glatz
U.S. EPA Region 5
77 West Jackson Boulevard
Chicago, Illinois 60604-3507
(312) 886-1434

State Contact:
Carl Chavez*
MDEQ
PO Box 30426
Lansing, Michigan 48909-7926
(517) 373-8174

* Indicates Primary Contacts

Treatment System Vendors:
EPA Contractor: Jack Brunner*
Tetra Tech EM Inc. (Formerly PRC Environmental Management, Inc.)
200 East Randolph Drive, Suite 4700
Chicago, Illinois 60601
(312) 856-8700
Air Stripping Tower: LANTAC
Construction Subcontractor: ATEC Associates, Inc.
2777 Finley Road, Unit 4
Downers Grove, Illinois 60515

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1, 3, 4, 5, 6]

Primary Contaminant Groups: Volatile organic compounds (VOCs)

- The groundwater contaminants of concern detected at the site are the following VOCs:

MATRIX DESCRIPTION (CONT.)

benzene, 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE),*trans*-1,2-dichloroethene (*trans*-1,2-DCE), DEE, dichlorofluoromethane (DCFM), tetrachloroethene (PCE), 1,1,1-TCA, trichloroethene (TCE), and trichlorofluoromethane (TCFM). Contamination only has been detected in the upper water table aquifer.

- The index contaminants of the site are DEE, 1,1,1-TCA, and 1,2-DCA.
- The maximum concentrations of the index contaminants detected in on-site wells during a 1985 sampling event (data provided by U.S. Aviex) were 1,1,1-TCA (200,000 µg/L), DEE (5,700 µg/L), and 1,2-DCA (1,600 µg/L). The concentration of 1,1,1-TCA was greater than 60% of its solubility. The maximum concentrations detected in off-site wells during the 1984 sampling event were 1,1,1-TCA (3,000 µg/L), DEE (4,800 µg/L), and 1,2-DCA (1,700 µg/L).
- The concentration of 1,1,1-TCA detected during the 1985 remedial investigation, 200,000 µg/L, is greater than 20% of its solubility limit.
- Figure 1 illustrates contaminant concentrations detected during a 1988 RI/FS sampling episode performed by EPA. The plume extends southwest of the U.S. Aviex property, in the direction of observed groundwater flow.
- Based on the map shown in Figure 1, the initial contaminant plume was estimated to be approximately 18 acres in size. Based on an average depth of 30 feet as measured during the RI/FS and a standard porosity of 0.30, the plume volume in 1988 was calculated for this report to be approximately 53,664,000 gallons.
- From 1996-1997 EPA reexamined the plume. Figure 2 illustrates the plume delineated by data from a December 1996 quarterly sampling event.
- The additional assessment performed in 1997 detected DCA and DEE at concentrations greater than cleanup levels, in wells outside the initially identified plume (see later discussion under performance data assessment).
- DCA has been detected at concentrations above the cleanup level of 90 µg/L up to approximately 2,400 feet northwest of the initial plume boundary.
- DEE has a ROD-specified maximum contaminant level (MCL) of 43 µg/L based on the 1988 MDEQ standard; however, the health-based drinking water (HBDW) standard is currently 3,700 µg/L. No elevated levels of DEE above the current HBDW standard have been detected outside the initial plume. DEE has been detected above the 43 µg/L limit given in the ROD up to approximately 3,900 feet northwest of the initial plume boundary.

Matrix Characteristics Affecting Treatment Costs or Performance [1, 3, 5, 7]

Hydrogeology:

Two distinct hydrogeologic units have been identified beneath this site. The upper water table aquifer is a sand and gravel aquifer which extends from the water table, at approximately 20 feet below ground surface, to approximately 110 feet below ground surface. A discontinuous sandy clay layer divides the upper aquifer from the lower aquifer. Limited data are available on the lower aquifer, but it is known to be an artesian non-flowing aquifer confined by the sandy clay layer in the area of the site. The groundwater flow patterns observed in the confined aquifer are similar to those patterns of the upper aquifer. Replacement residential wells were installed in this aquifer. No contamination has been detected in the lower aquifer in the site vicinity.

MATRIX DESCRIPTION (CONT.)

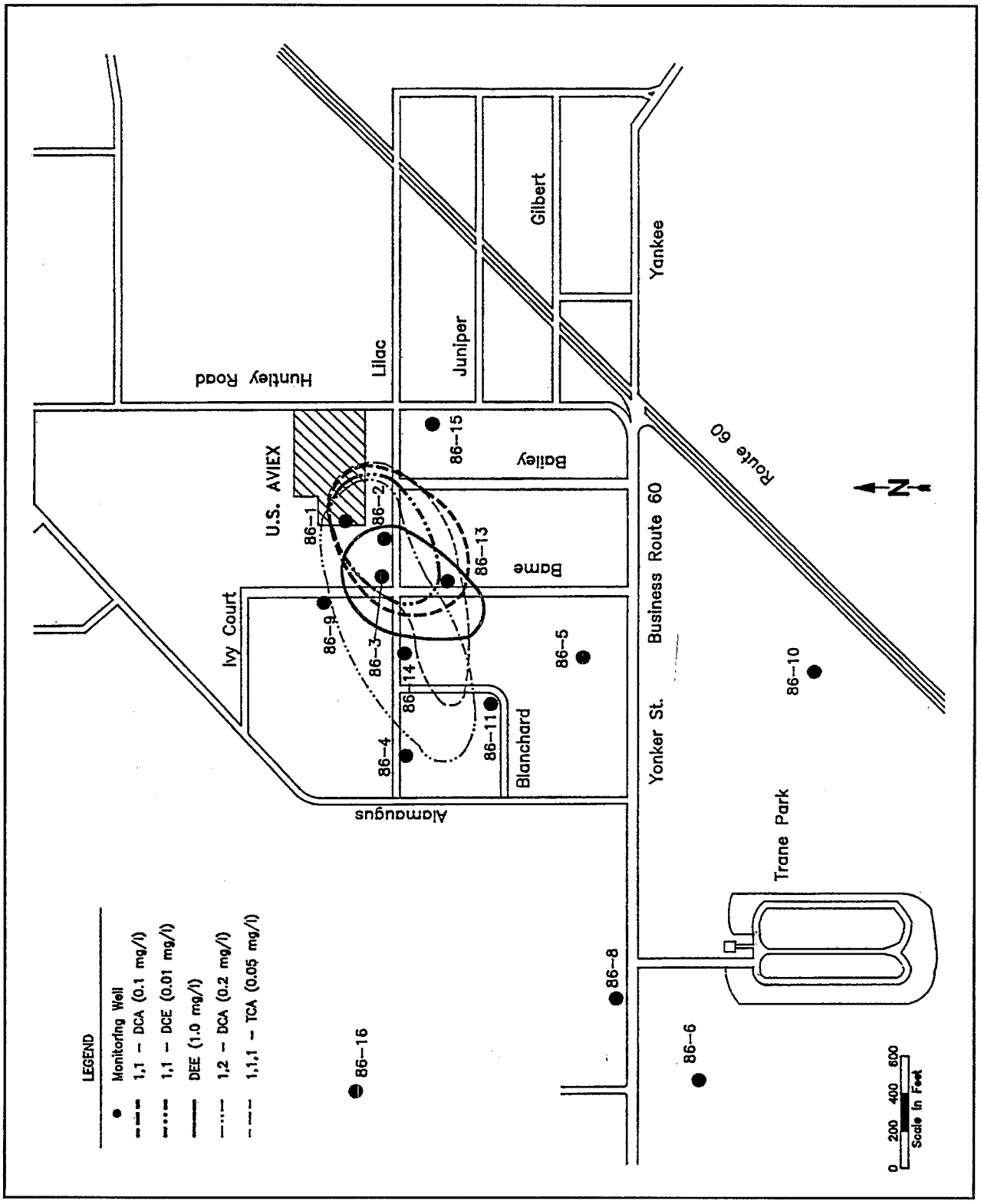

Figure 1. Distribution of Contamination (1988) [7]

MATRIX DESCRIPTION (CONT.)

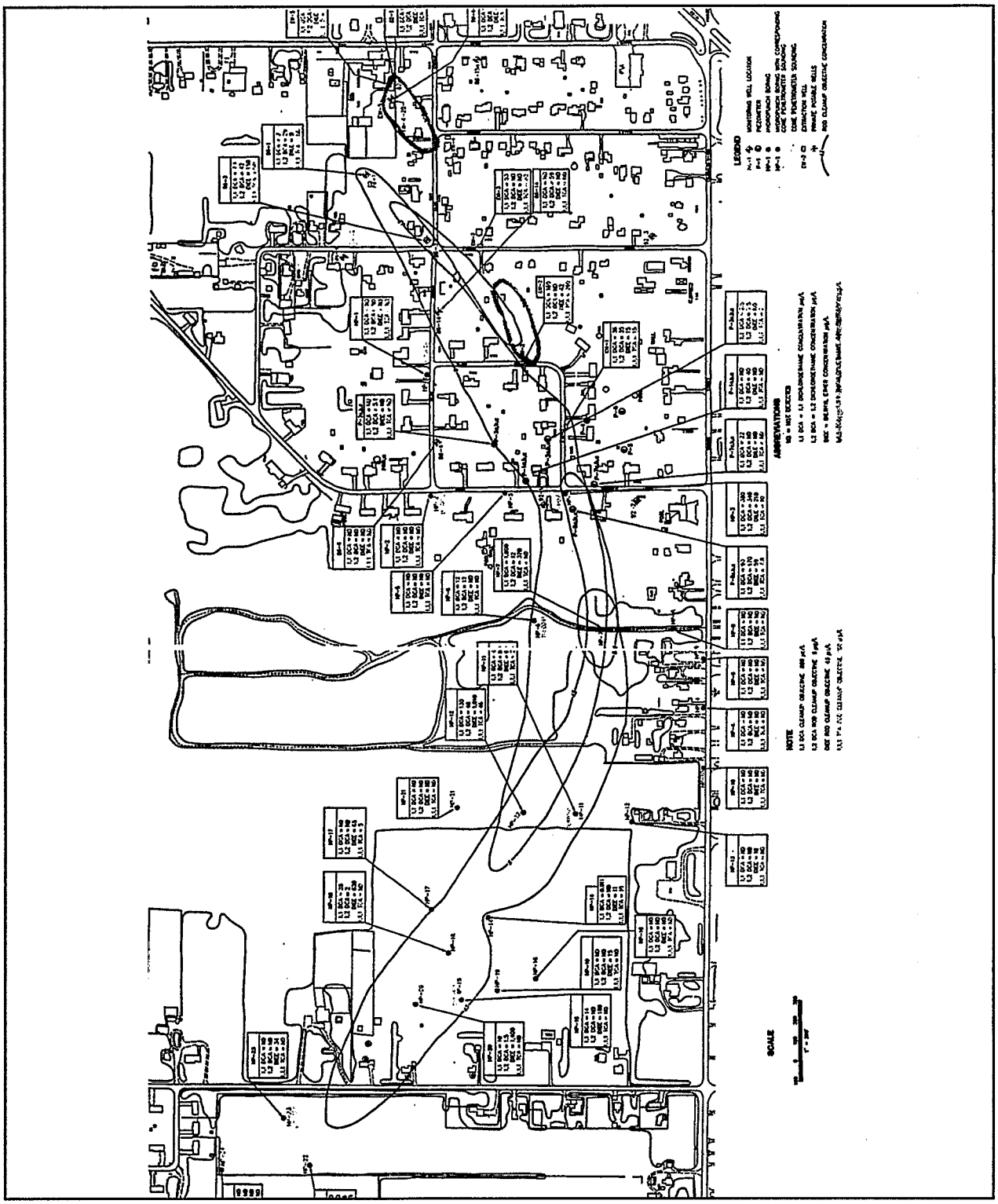

Figure 2. Distribution of Contamination (December 1996) [9]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

Groundwater in the site vicinity flows southwest, which concurs with the plume distribution southwest of the source. Prior to startup of remediation in 1993, the contaminant plume migrated further southwest than the previous sampling events indicated. Further characterization has been completed by Tetra Tech EM Inc. for the EPA and MDEQ to determine the extent of the plume, and is reported in their Additional Groundwater Assessment Summary Report.

The additional assessment determined that groundwater in the site vicinity of U.S. Aviex flows southwest, but regionally returns to northwest flow. Further discussion of the assessment is given in the Performance Data Assessment section.

Table 1 includes technical aquifer information.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Upper Aquifer	70-100	9.1 - 45.4	0.5	Southwest*
Lower Aquifer	Not Characterized	Not Characterized	Not Characterized	Not Characterized

* Groundwater flows southwest in the site vicinity, but flows northwest regionally.

Source: [1]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

System Description and Operation [2, 3, 5, 8, 10]

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/min)
EW-1	Upper Aquifer	100	100
EW-2	Upper Aquifer	100	50
EW-3	Upper Aquifer	100	50
EW-4	Upper Aquifer	100	50
EW-5	Upper Aquifer	100	50

Source: [1]

System Description

- In 1982, U.S. Aviex entered into an agreement with the MDEQ to construct a P&T system in an effort to prevent further migration of the groundwater contaminant plume detected both on and off site. The P&T system consisted of two extraction wells, an air stripper, and a force main.
- The extraction wells were placed on site in the area of the 1978 release to hydraulically contain the source. Groundwater was extracted, passed through the air stripper, and pumped to the force main outfall.
- This P&T system was an interim remedy that operated from 1982 until its shutdown in

TREATMENT SYSTEM DESCRIPTION (CONT.)

1988. No monitoring data were available from MDEQ or EPA records for operation from 1982 until 1988. Therefore, this report does not address the cost or performance of this interim remedy.

- After the RI/FS was conducted in 1985 to characterize contamination in the area and the ROD was signed in 1988, the existing P&T system was modified to meet requirements specified by the EPA in the ROD.

- The two extraction wells constructed as part of the 1982 P&T system were replaced in 1993 by a network of five extraction wells at a depth of 100 feet. Table 2 presents a summary of extraction well data and the specific design extraction rates. The total system design extraction rate is 300 gallons per minute (gpm). Assuming the system is operational 95% of the time and total extraction is 329 million gallons, the actual average volume of water treated is estimated to be approximately 190 gpm.

- The air stripper from the 1982 P&T system was retrofitted to meet the new remedial design requirements. The operating air stripper is 56 feet tall and 4 feet in diameter. Influent wastewater is distributed over a bed of plastic media, 46 feet high, packed in the air stripper. Air introduced at the bottom of the tower passes countercurrent to the groundwater, stripping the contaminants from the groundwater. The effluent vapor from the air stripper is discharged directly to the atmosphere. Treated water from the air stripper is ultimately discharged to the St. Joseph River via an effluent force main to the Bame-Huntley drain in accordance with National Pollutant Discharge Elimination System (NPDES) permit requirements.

- Groundwater quality is monitored through the five extraction wells and surrounding network of 18 monitoring wells. Groundwater flow is monitored through a network of 10 piezometers.

System Operation

- Quantity of groundwater pumped from aquifer in gallons (gal):

Year	Average Volume Pumped (Gal)
1993	58,850,000
1994	104,650,000
1995	79,720,000
1996	86,120,000
1997	67,290,000

- The site is operational 95% of the time. The treatment system is shut down four times per year or as needed for cleaning of the wells and system maintenance.

- The present extraction system was designed to contain the contaminant plume defined in the 1988 RI/FS and to allow for optimization of groundwater extraction rates from wells in source zone areas and off-property.

- EW-1 is located at the downgradient edge of the plume. Modflow and Randomwalk computer models determined that an extraction rate of 100 gpm from EW-1 would contain the plume. The other extraction wells, also analyzed by computer model, were designed to remove groundwater from areas closer to the source areas.

- The average groundwater extraction rates from 1993 until 1996 for each extraction well are listed below:

Well	Average Pumping Rate (gal/min)
EW-1	133
EW-2	24
EW-3	12
EW-4	16
EW-5	47

- Pumping from EW-1 was increased from 123 gpm in 1994 to 159 gpm in 1996, in an effort to contain the contaminant plume. At system operation startup in 1993, contaminant concentrations were detected

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

above clean-up levels in wells installed outside the remedial system capture zone to monitor collection system performance. To increase the system capture zone, pumping from EW-1 was increased. This approach has not been completely successful and the extent of the plume was re-investigated. The investigation by the EPA and state concluded that historical contamination existed outside the original plume, as discussed in the Performance Data Assessment section of this report.

- Because low levels of contamination were detected in extraction wells EW-3 and EW-4, these wells were shut down from 1994 through December 1996.
- Pumping from EW-2 was adjusted according to fluctuations in contaminant concentrations from this well. When contaminant concentrations decreased in 1995, pumping was decreased. When contaminant concentrations increased in 1996, pumping increased.
- Well EW-5 is located at the source area of the plume. It has pumped at about 50 gallons per minute from 1994 through December 1996.
- New plastic packing material was put in the air stripper in 1993 because of fouling. The packing media has not been changed since that time.
- Based on additional assessment, several options were identified by the treatment vendor for possible expansion of the treatment system [9].

Operating Parameters Affecting Treatment Cost or Performance

The groundwater extraction rate is a major operating parameter affecting cost or performance for this technology. Table 3 presents the average extraction rate between system start up in July 1993 through December 1996 and the required performance parameters.

Table 3: Operating Parameters

Parameter	Value
Average Extraction Rate	190-280 gpm
Remedial Goal (aquifer)	DEE 43 µg/L 1,1,1-TCA 200 µg/L 1,2-DCA 5 µg/L Benzene 5 µg/L Ethylbenzene 680 µg/L Toluene 2,000 µg/L Xylene 440 µg/L Chloroform 2 µg/L 1,1-DCE 7 µg/L TCE 5 µg/L PCE 0.88 µg/L trans-1,2-DCE 700 µg/L trichlorofluoromethene (TCFM) 32,000 µg/L dichlorofluoromethane (DCFM) 3,000 µg/L
Performance Standard (effluent) NPDES Requirements	DEE 275 µg/L 1,1,1-TCA 120 µg/L 1,2-DCA 560 µg/L Benzene 51 µg/L Ethylbenzene 62 µg/L Toluene 100 µg/L Xylene 40 µg/L Chloroform 43 µg/L 1,1-DCE 3 µg/L TCE 94 µg/L PCE 20 µg/L trans-1,2-DCE 90 µg/L TCFM 20 µg/L DCFM 20 µg/L

Source: [1, 8]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

A timeline for this remedial project is shown in Table 4.

Table 4: Project Timeline

Start Date	End Date	Activity
1982	---	Interim P&T system installed
1986	---	Interim P&T system shut down and RI/FS completed
9/7/88	---	Record of Decision signed
09/88	09/91	Remedial design
4/92	6/93	Remedial construction, including replacement of interim extraction wells
7/93	---	Remedial system begins operations; quarterly monitoring of groundwater begins
1993	---	Contamination detected in downstream monitoring wells; pumping from EW-1 and EW-5 increased
1997	---	Extent of plume examined

Source: [2, 3, 5]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

- The cleanup goals for the site are to remediate the groundwater to levels established by the MDEQ and the maximum contaminant levels (MCL) established by the Safe Drinking Water Act (SDWA); these levels are applied throughout the aquifer. The cleanup goals for DEE, 1,1,1-TCA, and 1,2-DCA are listed in Table 3.

Additional Information on Goals [1]

- The MDEQ health-based cleanup concentration for DEE is now 3,700 µg/L, not 43 µg/L as given in the ROD. EPA and MDEQ are deciding on future action regarding the cleanup standard for DEE.
- Emissions during operation of the air stripper will not be monitored because influent groundwater contaminant levels are not significant and vapor emissions comply with Clean Air Act and permitting requirements.

Treatment Performance Goals [1]

- The primary goal for the treatment system is to reduce index contaminant concentrations to levels which meet the NPDES requirements listed in Table 3.
- The secondary goal for the treatment system is to create an inward hydraulic gradient to contain the contaminant plume.

Performance Data Assessment [4, 5, 6, 8, 9]

For this discussion and Figures 2 and 3, total contaminant concentration includes concentrations of benzene, 1,2-DCA, 1,1-DCE, trans-1,2-DCE, DEE, DCFM, PCE, 1,1,1-TCA, TCE, and TCFM. In addition, this discussion addresses system performance only for the current P&T system; the interim system (1982-1986) is not included in this assessment.

- Contaminant concentrations have declined but remain above cleanup goals. The maximum concentration of 1,1,1-TCA has dropped from 200,000 µg/L to 400 µg/L, a 99.8% reduction. The maximum concentration of DEE dropped from 5,700 µg/L to 100 µg/L, a 98% reduction. The maximum concentration of 1,2-DCA dropped from 4,800 µg/L to 33 µg/L, a 99% reduction.
- As illustrated in Figure 3, average total contaminant concentrations have also declined, indicating contaminant reduction across the entire plume. The average

TREATMENT SYSTEM DESCRIPTION (CONT.)

Performance Data Assessment (Cont.)

concentration of total contaminants has decreased from 158 to 67 µg/L over 3 ½ years of operation, a 58% reduction. The average concentration of 1,1,1-TCA has decreased from 107 to 40 µg/L over 3 ½ years of operation, a 63% reduction.

- NPDES permit requirements have been met consistently over the 42 months of operation.
- In 1993, contaminants were detected at concentrations above cleanup goals in downgradient monitoring wells beyond the limits of the plume initially identified. The increased pumping rate in EW-1 was not sufficient to recapture the plume.
- The additional assessment, as discussed in the Matrix Description section, found contamination outside of the initial plume. However, the assessment determined the elevated DCA and DEE levels were not due to loss of plume containment. Wells along the perimeter and just outside the extraction well capture zone were not found to contain elevated levels of contaminants, which indicates that plume containment had been maintained. The discovery of contamination outside the originally estimated plume has been attributed to historically elevated levels not discovered during the RI/FS.
- To address the additional contamination, the number of extraction wells may be expanded or innovative remediation may be applied.
- Figure 4 presents the removal of total contaminants through the treatment system from September 1993 to December 1996. Over this period the P&T system removed approximately 664 pounds of total contaminant mass from the groundwater.
- During system startup in the first two months of operation, the contaminant mass removal was low, at 0.064 lb/day. The removal rate increased to 0.65 lb/day in November 1993, as shown in Figure 3. However, as contaminant levels in the groundwater dropped from 1993 to 1995, the removal rate also dropped from 0.65 lbs/day in November 1993 to 0.22 lb/day in December 1995.

Performance Data Completeness

- Data are available for contaminant concentrations in the groundwater in the extraction wells during quarterly sampling events from May 1993 to December 1996. Data are available for contaminant concentrations in the influent to the treatment system from September 1993 to September 1996. Data regarding the additional contamination outside the plume is available in Reference 9.
- Contaminant mass removal, depicted in Figure 4, was determined using analytical results of samples from the influent stream to the treatment plant from each well and the extraction well flow data, along with treatment effluent data, from September 1993 to September 1996.
- The geometric mean of total contaminant concentrations, depicted in Figure 3, was determined using analytical results from annual sampling of extraction wells and monitoring wells. The geometric mean represents the trend of contaminant concentrations across the entire plume.
- All extraction wells within the original plume were used for calculation of the mean concentration. When concentrations below detection limits were encountered, half of the detection limit was used for evaluation purposes.
- No data were available for the interim P&T system (1982-1986); therefore, the system performance was not evaluated as part of this report.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the MDEQ requirements. All monitoring was performed using EPA-approved methods: SW-846 Methods 601, 602, 624, 625, Hardness, and TDS. The vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM DESCRIPTION (CONT.)

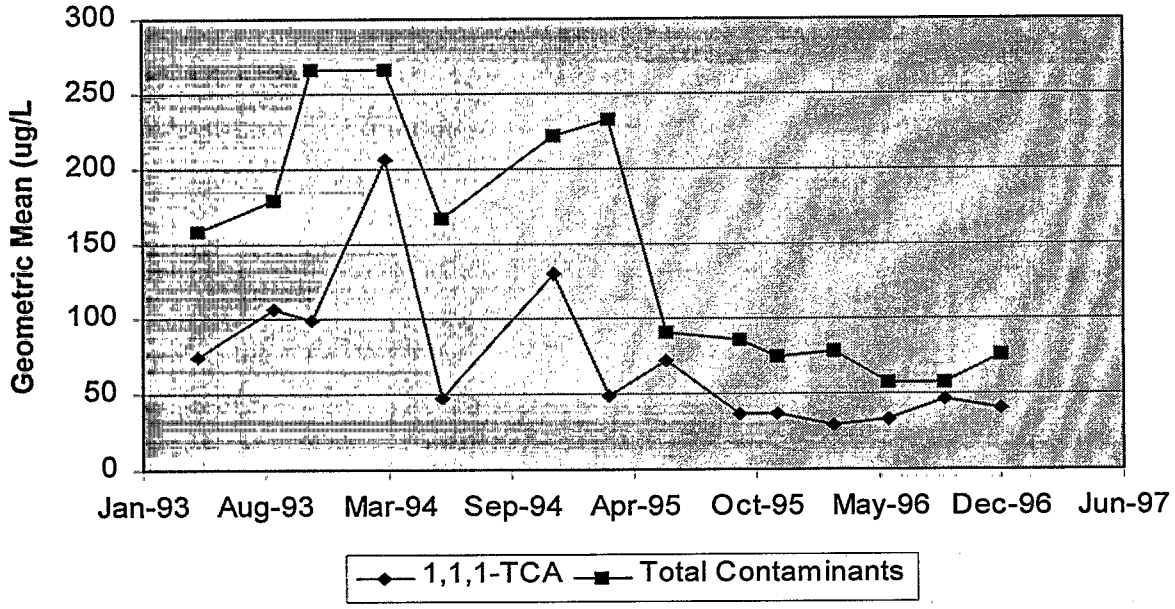

Figure 3. *Average Contaminant Concentrations from May 1993 until December 1996 [8]*

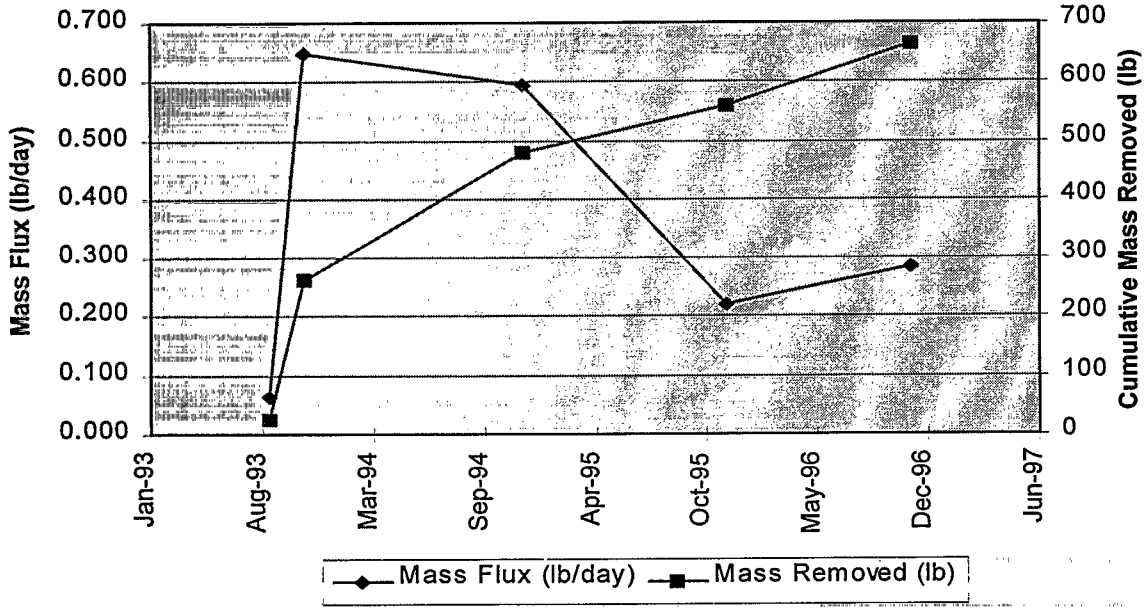

Figure 4. *Mass Flux Rate and Cumulative Total Contaminant Removal from September 1993 to December 1996 [8].*

TREATMENT SYSTEM COST

Procurement Process

EPA contracted with Tetra Tech EM Inc. (formerly PRC Environmental Management, Inc.) for design and construction oversight. ATEC Associates, Inc. constructed and operated the remedial system.

Cost Analysis

The costs incurred during initial remedial actions and during the beginning of the RI/FS through 1986 were paid for by U.S. Aviex. MDEQ and EPA provided the remainder of the remedial costs.

Capital Costs [4]

Remedial Construction of 1993 P&T System	
Mobilization and Preparatory Work	$223,833
Monitoring and Analysis	$45,511
Site Work	$354,241
Extraction Wells	$130,731
Vapor Phase Carbon Filter	$8,550
System Construction	$559,954
Decontamination of Equipment and Area	$8,855
Total Remedial Construction	**$1,331,675**

Other Costs [4,5]

Operating Costs from July 1993 until December 1996	
Utilities	$29,110
Sampling and Analytical Services	$238,887
Other Operations and Maintenance	$342,327
Total Operating Expenses	**$610,324**

Other Costs [4,5]

Total Remedial Design	$586,775
EPA Oversight Costs	$170,000
1987 Air Stripper	$25,000
1987 Effluent Force Main Outfall	$50,000

Cost Data Quality

Actual cost data are available from the site manager for this application.

OBSERVATIONS AND LESSONS LEARNED

- The actual cost for groundwater treatment at U.S. Aviex from 1993-1996 was approximately $1,942,000 ($1,332,000 in capital and $610,000 in operations and maintenance), which corresponds to $2,925 per pound of total contaminants removed and $5.00 per 1,000 gallons of groundwater treated.
- The impact of remediation on the plume size is inconclusive because of the new data regarding historically elevated contaminant levels.
- Contamination has been detected in wells downgradient of the plume identified in the RI/FS. As a result, further characterization and expansion of the remedial system is necessary. The further action will increase the cost.
- No performance data are available on the interim P&T system; however, operation of this system before the 1993 P&T system went on line may have impacted the total cost of the remediation. The interim system began remediation and contained part of the source area prior to full-scale remediation.

OBSERVATIONS AND LESSONS LEARNED (CONT.)

Observations and Lessons Learned (Cont.)

- Monitoring data from extraction wells indicate that while maximum contaminant concentrations in the groundwater have dropped significantly (up to 99% for 1,1,1-TCA), they remain above cleanup goals. After four years of P&T operation the rate of contaminant removal has slowed [4]. While no dense non-aqueous phase liquid (DNAPL) has been directly observed during sampling, high initial concentrations of 1,1,1-TCA (greater than 60% of its solubility) indicated the potential presence of DNAPL. DNAPLs act as a constant source of contamination and can replenish groundwater plumes as they slowly desorb and dissolve from saturated sediments into the aqueous phase. If DNAPLs are present, locating and eliminating them would improve the effectiveness of this remedy [6].
- The treatment system achieved a maximum rate of total contaminant removal of 0.65 lb/day during the first year of operation. The total contaminant removal rate has continuously declined since the beginning of operations. By December, 1995, the total contaminant removal rate had declined to 0.29 lb/day. The decline in contaminant removal rate is typical of P&T systems, in that they remove contaminants most efficiently at the beginning of operations, when contaminant levels are highest.

REFERENCES

1. Record of Decision, U.S. Environmental Protection Agency, September 7, 1988.
2. Correspondence with Mr. Carl Chavez, SMU #3 Project Manager, Michigan Department of Environmental Quality. May 5, May 13, and May 22, 1997.
3. Remedial Action Report Completion (RACR), PRC Environmental Management, Inc., January 26, 1994.
4. Ground-Water Cost Analysis, U.S. Environmental Protection Agency, unpublished.
5. Correspondence with Mr. Ron Riesing and Mr. Rick Hersemann, PRC Environmental Management, Inc. (Now Tetra Tech EM Inc.). April 21, May 9, May 15, and November 12 1997; March 24 and April 3, 1998.
6. Dense Nonaqueous Phase Liquids, Halin, Scott G. And J.W. Weaver, U.S. Environmental Protection Agency, March 1991.
7. Remedial Investigation/Feasibility Study, EDI Engineering and Science, 1988.
8. Annual Summary Monitoring Reports, PRC Environmental Management, Inc., 1993-1997.
9. Additional Groundwater Assessment Summary Report, U.S. Aviex Site, prepared by Tetra Tech EM Inc. for EPA Region 5 February 27, 1998.
10. Comments on draft report provided by Ron Riesing, Tetra Tech EM, Inc. May 20, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office in consultation with the MDEQ. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Pump and Treat of Contaminated Groundwater at the Western Processing Superfund Site, Kent, Washington

Pump and Treat of Contaminated Groundwater at the Western Processing Superfund Site, Kent, Washington

<table>
<tr><td>Site Name:
Western Processing Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents; volatiles - nonhalogenated (toluene); PAHs; and metals
- Maximum initial concentrations of chlorinated solvents and metals were trans-1,2-DCE (390 mg/L), TCE (250 mg/L), cadmium (2.5 mg/L), nickel (280 mg/L), and zinc (510 mg/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: 10/88 - 12/96</td></tr>
<tr><td>Location:
Kent, Washington</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Contractors:
OHM Remediation Services, Corp. (Formerly CWM)
Landau Associates, Inc.</td><td rowspan="2">Technology:
Pump and Treat and Vertical Barrier Wall
- Groundwater is extracted on-site using 15 wells at an average total pumping rate of 190 gpm; this water is treated with air stripping and reinjected through an infiltration system
- Prior to 1996, groundwater was extracted using 210 shallow, vacuum-operated recovery well points
- A slurry wall (vertical barrier wall), 40 ft deep, encloses the 13-acre site
- Groundwater is extracted off-site using 3 wells at an average total pumping rate of 40 gpm; this water is treated with filtration and air stripping prior to reinjection or discharge to a POTW</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/85</td></tr>
<tr><td>PRP Contact:
Paul Johansen
Western Processing
20015 72nd Avenue South
Kent, Washington 98032
(425) 393-2565

State Point of Contact:
Christopher Maurer, P.E.
Washington Department of Ecology</td><td>EPA Point of Contact:
Lee Marshall, RPM
U.S. EPA Region 10
1200 Sixth Avenue(ECL-116)
Seattle, WA 98010
(206) 553-2723</td></tr>
<tr><td>Waste Source:
Unauthorized dumping, spills, and leaks from surface impoundments</td><td colspan="3" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 974 million gallons treated as of December 1996
- LNAPL observed and DNAPL suspected in groundwater at this site
- Groundwater is found at 5-10 ft bgs
- Extraction wells are located in 2 aquifers; the aquifers are influenced by a nearby surface water
- Hydraulic conductivity ranges from 1 to 100 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Met goals for off-site plume within eight years of operation; shallow well points replaced recently with deeper wells to provide for containment; relatively large and expensive system.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Western Processing Superfund Site, Kent, Washington (continued)

Regulatory Requirements/Cleanup Goals:

- Groundwater cleanup goals were established in terms of surface water quality goals for Mill Creek (adjacent to the site), based on federal ambient water quality criteria. These goals were required to be met within three years. Surface water goals were established for cadmium (1.1 ug/L), chromium (207 ug/L), copper (11.8 ug/L), lead (3.2 ug/L), mercury (0.012 ug/L), nickel (158 ug/L), silver (0.12 ug/L), zinc (120 ug/L), cyanide (5.2 ug/L), and hardness (100 ug/L).
- Remedial goals for the off-site aquifer were established for cis-1,2-DCE (70 ug/L) and trans-1,2-DCE (70 ug/L).
- An ESD, issued in 1995, changed the focus of the remediation from site restoration to containment.

Results:

- Monthly monitoring data indicated that the surface water quality in Mill Creek met the established criteria by mid-1990. Further, concentrations for TCE, vinyl chloride, and zinc decreased in on-site wells by two orders of magnitude from 1988 to 1995. However, elevated concentrations of contaminants remain in on-site wells. As of June 1995, concentrations were reported as high as TCE (55,200 ug/L), DCE (14,600 ug/L), vinyl chloride (5,490 ug/L), cadmium (1,360 ug/L), and zinc (117,000 ug/L).
- The system achieved the cleanup goal for DCE in all three of the extraction wells located in the off-site plume. Concentrations of DCE have decreased in the off-site plume from above 2,000 ug/L in 1988 to less than 70 ug/L in January 1996. In addition, containment for the off-site plume has been achieved.
- A total of 102,000 pounds of contaminants have been removed from the groundwater during eight years of operation.

Cost:

- Actual costs for pump and treat were $48,730,000 ($16,032,629 in capital, including the slurry wall, and $32,697,483 in O&M), which correspond to $50 per 1,000 gallons of groundwater extracted and $478 per pound of contaminant removed.

Description:

This site operated as a waste processing facility from 1961 to 1983. Over 400 businesses transported industrial wastes to the site to be stored, reclaimed, or buried. Processes used at the site included recovery of metals from sludges and liquid wastes, spent solvent recovery, reprocessing of pickle liquor, and waste oil reclamation. In March 1981, during a RCRA audit, EPA first discovered violations of regulations governing waste storage, drum management, surface impoundments, and waste piles. Remedial investigations were conducted between 1983 and 1985. An initial ROD was issued in September 1985, and an amended ROD in September 1986.

Groundwater is extracted on-site using 15 well; this water is treated with air stripping and reinjected through an infiltration system. Prior to 1996, groundwater was extracted using 210 shallow, vacuum-operated recovery well points. Groundwater is extracted off-site using 3 wells; this water is treated with filtration and air stripping prior to reinjection or discharge to a POTW. The original approach to this site was an aggressive effort to fully restore the site to original conditions within seven years. Restoration was a priority and high costs were incurred to achieve this goal, including high operating costs. After eight years of pump and treat, the goal of restoration was changed to containment based on the technical impracticability of achieving full restoration.

SITE INFORMATION

Identifying Information:

Western Processing Superfund Site
Kent, Washington

CERCLIS #: WAD009487514

ROD Date: September 1985
Amended September 1986
Explanation of Significant Differences (ESD)
December 1995

Treatment Application:

Type of Action: Remedial

Period of operation: 10/88 - Ongoing (Performance data collected through December 1996)

Quantity of groundwater treated during application: 974 million gallons

Background

Historical Activity that Generated Contamination at the Site: Waste processing

Corresponding SIC Code: 4953W (Miscellaneous waste processing)

Waste Management Practice That Contributed to Contamination: Unauthorized dumping, spills, and leaks from surface impoundments

Location: Kent, Washington

Facility Operations: [3, 7]

- The 13-acre site operated as a waste processing facility from 1961 to 1983. Over 400 businesses transported industrial wastes to the site to be stored, reclaimed, or buried. Processes at the site included the recovery of metals from sludges and liquid wastes; spent solvent recovery; reclamation of caustics, flue ash, and ferrous sulfide; reprocessing pickle liquor; electrolytic destruction of cyanides; chemical recombination to produce zinc chloride and lead chromate; and waste oil reclamation. Operations ceased in 1983 by order of the EPA.
- In March 1981, during a RCRA audit, EPA first discovered violations of regulations governing waste storage, drum management, surface impoundments, and waste piles.
- In 1983, EPA performed an emergency waste removal operation to stabilize the site. Over 460,000 gallons and 127 drums of waste liquids were removed.
- Remedial investigations were conducted between 1983 and 1985.
- Site cleanup activities were divided into two phases. Phase I involved removing tanks, buildings, impoundments, and waste piles from the site. Phase II involved subsurface cleanup.
- The initial ROD was issued in September 1985. It was amended in 1986 to reflect the requirements to be included in the Consent Decree.
- In April 1987, a Consent Decree was entered to begin Phase II cleanup activities. In the summer of 1987, construction activities began, which included installing two extraction and treatment systems and a slurry wall, enclosing the site. Extraction and treatment began in October 1988.
- After eight years of remediation that focused on groundwater and soil restoration, the objective was changed to contain the contamination on site and prevent further off-site migration. An ESD was issued in December 1995 to reflect a Technical Impracticability (TI) Waiver.
- A new extraction system was installed in 1996 to provide more automated operation during the period of containment. A new treatment system was constructed for all groundwater extracted during containment operations and became operational in June 1997.

SITE INFORMATION (CONT.)

Background (Cont.)

Regulatory Context:

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, and the National Contingency Plan (NCP), 40 CFR 300.
- The ROD for the site was signed in September 1985 and amended in September 1986. A Consent Decree was issued in 1987. An ESD was issued in December 1995.

Groundwater Remedy Selection:

- Originally, the selected remedy was extraction and treatment of groundwater in conjunction with a passive containment system (slurry wall) and an aggressive effort to restore groundwater quality to acceptable levels within five to seven years. In the ESD, the remedy was changed to containment of the on-site and off-site plumes.

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA/State of Washington (Joint Oversight)

Remedial Project Manager:
Lee Marshall
U.S. EPA Region 10
1200 Sixth Avenue (ECL-116)
Seattle, WA 98010
(206) 553-2723

State Contact:
Christopher Maurer, P.E.
Washington Department of Ecology

Contractors:
OHM Remediation Services, Corp. (Formerly CWM)
Landau Associates, Inc.

PRP - Lead:
Paul Johansen*
Western Processing
20015 72nd Avenue South
Kent, Washington 98032
(425) 393-2565

*Indicates primary contact

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization [1, 2, 13, 17]

Primary Contaminant Groups: Halogenated volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), phenolic compounds, and metals

- The primary organic contaminants of concern are trichloroethene (TCE), *cis*- and *trans*-1,2-dichloroethene (DCE), methylene chloride, toluene, and vinyl chloride.
- The metal contaminants of concern are cadmium, zinc, chromium, nickel, copper, and lead.
- Figures 1 and 2 show plume maps from 1988, 1991, and 1995 for TCE and vinyl chloride.
- Investigations conducted during the remedial investigation identified more than 90 of EPA's priority pollutants at the site, mostly volatile and semivolatile organic compounds and metals.
- The maximum initial concentrations of contaminants detected were 390 mg/L (*trans*-1,2-DCE), 250 mg/L (TCE), 510 mg/L (zinc), 280 mg/L (nickel), and 2.5 mg/L (cadmium).
- In 1989, an EPA toxicologist suggested that the organic compound oxazolidinone present in the site groundwater might be genotoxic. As a result, an activated carbon system was added to remove this compound from the treated groundwater. The compound was later found to be non-hazardous and the carbon treatment system was removed [13].
- An immiscible liquid has been visually observed floating in samples taken from several on-site wells, confirming the presence of light nonaqueous phase liquid (LNAPL). The levels of DCE found in groundwater samples were also greater than 6% of solubility. Although this concentration indicates the likely presence of a dense nonaqueous phase liquid (DNAPL), DNAPLs were never found.
- The volume of the plume was estimated for this report to be approximately 500 million gallons, based on monitoring data collected in 1987 [17].
- The majority of contaminants are found on site within the upper unconfined aquifer. The on-site plume contains many contaminants and primarily impacts Mill Creek to the west of the site.
- A separate, deeper plume containing primarily *cis*-1,2-DCE is also present off site. This plume originates on site in the southern portion of the site.

MATRIX DESCRIPTION (CONT.)

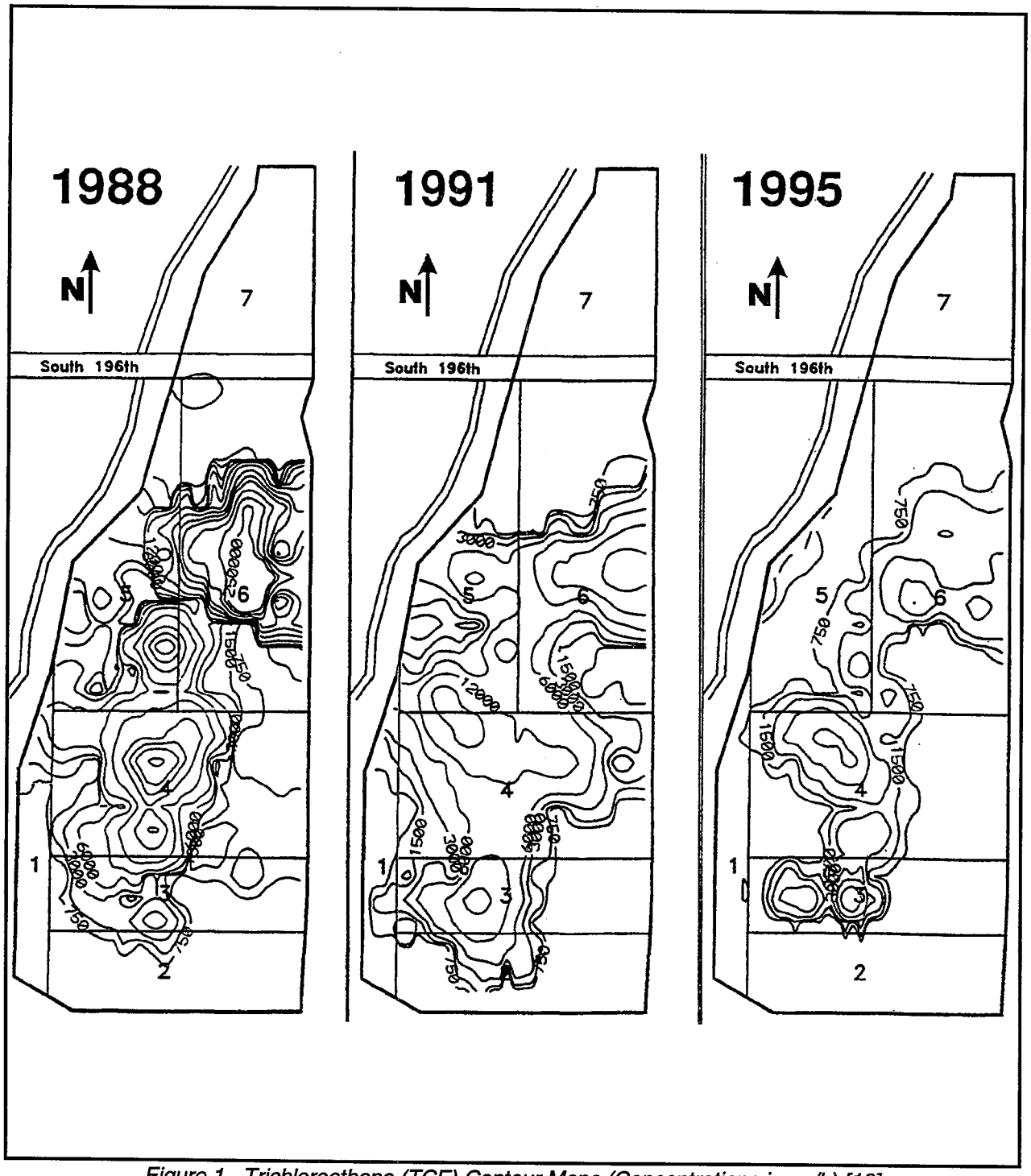

Figure 1. Trichloroethene (TCE) Contour Maps (Concentrations in µg/L) [10]

MATRIX DESCRIPTION (CONT.)

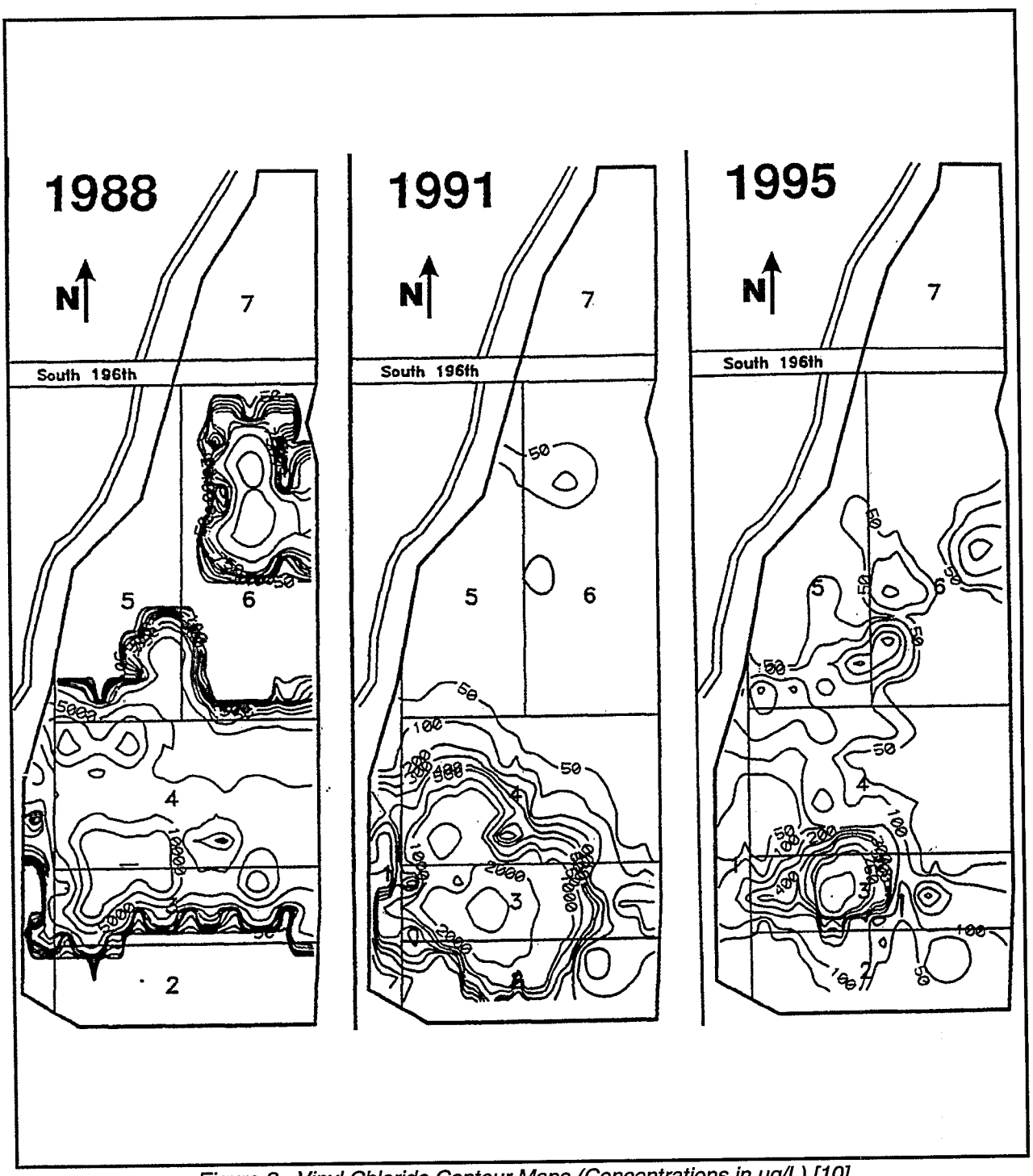

Figure 2. Vinyl Chloride Contour Maps (Concentrations in µg/L) [10]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [1]:

Three major geologic units comprise the hydrogeologic system in the vicinity of the site. These units comprise the White River Alluvium, the valley fill deposits that occur throughout the Kent Valley and beneath the Western Processing site. The alluvial fill consists primarily of sand, silt, and clay with occasional layers of sandy gravel. The White River Alluvium is not considered to be a major drinking water source due to naturally occurring poor water quality. Groundwater is encountered at 5 to 10 feet below ground surface. Shallow groundwater (Unit 1) flows northwest from the site and discharges into Mill Creek. The deeper aquifer (Unit 2) begins approximately 40 feet below ground surface. Groundwater in this unit flows northwest also, but passes below Mill Creek. Contaminants in Unit 2 were transported downgradient of the site and Mill Creek; contaminants in Unit 1 migrated to Mill Creek prior to the installation of a slurry wall around the site.

Unit 1 (Shallow Aquifer)	A complex sequence of discontinuous interbedded silt, sand, and clay lenses to a depth of 40 feet below ground surface.
Unit 2 (Deep Aquifer)	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.

Tables 1 and 2 present technical aquifer information and technical well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Velocity (ft/day)	Flow Direction
1	35 - 40	1 - 10	.27	Northwest
2	75 - 100	10 - 100	0.02 - 0.2	Northwest

Source: [1]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with air stripping and metals precipitation
In situ soil flushing (1988 - 1996)

Supplemental Treatment Technology

Passive containment system (slurry wall)
Carbon polishing (1990-1991)
Peroxide oxidation (1988 - 1989)
Chromium reduction (1988 - 1989)

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/min)
Wellpoints 1 - 210	Unit 1	30	100 - 200[1]
U-wells 1 - 6	Unit 1	40	15 each
T2 - T4	Unit 2	70	15 each

[1]Cumulative extraction yield

Source: [2]

System Description [2, 4, 14]

- Remedial systems at the site originally included an on-site extraction and treatment system, an off-site extraction and treatment system, and a slurry wall that enclosed the 13-acre site.

- The on-site extraction system, which operated from 1988 until 1997, consisted of 210 vacuum-operated recovery well points. These were divided into seven well-point groups, all of which were connected to three 30-horsepower centrifugal-vacuum pumps. Each of the well point installations was sand packed continuously from 5 to 30 feet below ground surface. Well points were installed over the entire site, with a greater density of well points in the areas known to have higher concentrations of contaminants.

- The objective of the on-site extraction system was to create and sustain a net inward flow of groundwater at the site perimeter and a net upward flow of groundwater within the area surrounded by the slurry wall. An infiltration system (soil flushing) was placed in the shallow on-site soils within the slurry wall to flush contaminants out. The soil-flushing system was designed to expedite leaching of contaminants from the shallow soils.

- The well-point system was designed to offer flexibility and "variable" pumped volume. Header pipes and valves at the top of each well could be used to select specific flow rates from each section of the system.

- The extraction system was modified in late 1996 and early 1997. Use of the shallow vacuum-operated well points (on site) was discontinued and a set of 15 deeper recovery wells were installed in 1996 to replace the vacuum-operated well point system.

- The original treatment system for groundwater extracted included stripping of VOCs, followed by oxidation of phenolic compounds with hydrogen peroxide, reduction of hexavalent chromium to the trivalent form, pH adjustment, metals precipitation, and carbon polishing. The carbon polishing step was removed in 1991. Treated water was reinjected into the ground through the infiltration system or discharged to the POTW.

- Because of severe fouling of the on-site stripping tower by inorganic precipitates, the treatment sequence was modified in September 1989 to provide metals precipitation before stripping of VOCs [10.]

- After 1989, the treatment system was modified to provide metals removal before air stripping, and phenol oxidation and hexavalent chromium reduction were discontinued. The treatment system was replaced in 1997 with a new automated system for VOCs only.

- Liquid-phase carbon filters were used to remove oxazolidinone from treated water before discharge to the POTW. EPA eventually determined that this compound

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

had no detrimental health effects and the carbon polishing was discontinued.

- The slurry wall, which is 40 feet deep and laterally confines the on-site contaminants to the site boundaries, enhances the recovery process. The soil/bentonite wall was installed using a backhoe and bucket excavator.

- The off-site extraction system consisted of three deep wells (trans wells) screened between 40 and 70 feet below ground surface. The purpose of the trans wells was to extract groundwater from an off-site plume of *cis*-1,2-DCE. The Consent Decree required overlapping zones of influence for these extraction wells. Each well was fitted with a submersible electric pump and designed to produce up to 15 gpm which was determined to provide sufficient overlapping zones.

- Water extracted from the off-site trans wells was directed to a separate treatment system consisting of a sand filter bed and an air stripper. Effluent from this system was reinjected to the infiltration gallery or discharged to the POTW.

- Contaminant concentrations in groundwater and water levels are monitored using a system of 51 monitoring wells and 28 piezometers located on and off the site in both Units 1 and 2.

System Operation [2, 4, 6, 7, 10, 13, 14]

- Construction and installation of the on-site and off-site extraction and treatment systems was completed in 1988. The slurry wall installation was completed in 1989 [2].

- Six new extraction wells (U-wells) were installed in the spring of 1993. Four of these were placed within the slurry wall and two were placed off site adjacent to the slurry wall, where high concentrations of organic contaminants were detected. These wells were equipped with dedicated down-well pumps and were connected directly to the existing treatment system. Well depths were approximately 40 feet [7].

- The average extraction rate for the site has been approximately 230 gpm based on annual averages from 1988 to 1997. The annual rate was reduced to 140 gpm in 1996 and 40 gpm in 1997 [10]. The extraction rate was reduced in conjunction with the change to a containment focus from a restoration focus, and because the infiltration of about 100 gpm of treated water was discontinued at the end of 1996.

Groundwater Pumped From Aquifer in gallons per minute (gpm):

	Average GPM Pumped	
Year	**On-Site System**	**Off-Site System**
1989	225	40
1990	225	40
1991	225	40
1992	225	40
1993	225	40
1994	225	40
1995	200	40
1996	100	40
1997	40	40

- The original on-site treatment system included a phenol oxidation and a chromium reduction process, which were discontinued by December 1988 because it was found that the concentrations of phenol and chromium in the influent were below effluent permit limits [14].

- Effluent from both treatment systems continue to be combined and discharged to the local POTW under a Waste Discharge Permit. The limitations in the permit have not been exceeded since operations began [10].

- The Western Processing facility also has a permit from the Puget Sound Air Pollution Control Agency for the emissions from the air stripper [6].

- The site is operational seven days per week, 24 hours per day. From 1988 until 1996, the system has operated 97% of the time for

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

a total of approximately 70,000 hours [13]. The new extraction and treatment systems that became operational in 1997 have experienced similar operational efficiency.

- Air stripping media for the off-site treatment system was changed once in the first year of operation because of fouling caused by scale buildup. Acid washing of the stripping tower was conducted once every three weeks to minimize scale buildup. This procedure required four hours of down time [13].
- The carbon system used to remove oxazolidinone from the treated groundwater required carbon changeouts approximately once per month in 1990 and early 1991. The air phase carbon system associated with the air stripping process required carbon changeouts approximately once per month at first, but has averaged about once every eight months due to declining contaminant concentrations and the use of more efficient activated carbon.

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents operating parameters affecting cost and performance at this site.

Table 3. Performance Parameters

Parameter	Value	
Average Extraction Rate (for both on- and off-site systems)	230 gpm	
Air Discharge Requirements	Hydrochloric gas	100 mg/l
	Methylene Chloride	100 mg/l
Treated Groundwater Discharge Permit Requirements (daily averages)	Arsenic	1.0 mg/l
	Cadmium	0.5 mg/l
	Chromium	2.75 mg/l
	Copper	3.0 mg/l
	Lead	2.0 mg/l
	Mercury	0.1 mg/l
	Nickel	2.5 mg/l
	Silver	1.0 mg/l
	Zinc	5.0 mg/l
	Cyanide	2.0 mg/l
	Organics[1]	Monitoring only
Remedial Goal (Surface Water Requirements)[2]	Cadmium	1.1 µg/L
	Chromium	207 µg/L
	Copper	11.8 µg/L
	Nickel	158 µg/L
	Lead	3.2 µg/L
	Zinc	120 µg/L
	Mercury	.012 µg/L
	Silver	.12 µg/L
	Cyanide	5.2 µg/L
	For Hardness	100 µg/L
Remedial Goal (Off-site Aquifer)	*trans*-1,2-DCE	70 µg/L
	cis-1,2-DCE	70 µg/L
Note: Average system yield over eight years of operation was 230 gpm for both systems based on annual data.		

Source: [3, 10]

[1]Organics include: Acrolein, Acrylonitrile, Benzene, Carbon Tetrachloride, Chlorinated Benzene, Chloroform, Dichlorobenzene, 1,2-Dichloroethane, Dichloroethylenes, Dichloropropane, Dichloropropene, Ethylbenzene, 1,1,2,2-Tetrachloroethane, Toluene, 1,1,2-Trichloroethane, Trichloroethene

[2]At the time of the Consent Decree, the organic compounds detected in Mill Creek did not have associated Ambient Water Quality Criteria values.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Timeline

Table 4 presents a timeline for major events performed during this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
9/85	---	Record of Decision issued
9/86	---	Amended Record of Decision issued
4/87	---	Consent Decree issued
4/87	---	Subsurface remediation begun
10/88	---	Operations for both P&T systems begun
5/88	10/89	Slurry wall constructed around the site
3/90	---	Three-year performance standards achieved for Mill Creek (surface water goals)
12/92	5/93	Five deep wells added to the collection system
10/86	8/93	Mill Creek restoration goals achieved
9/95	---	TI Waiver Petition submitted
6/96	---	Containment wells installed
12/95	---	ESD issued in response to TI Waiver (restoration goal changed to containment goal)
1/97	---	Containment pumping phased into operation
6/97	---	New treatment system started

Source: [3, 7, 10]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [11, 14]

As determined by the Consent Decree and the amended ROD, the following cleanup goals were established:

- Surface water quality goals for Mill Creek (adjacent to site) are Federal Ambient Water Quality Criteria (AWQC). The Consent Decree required that these goals be met within three years. Attachment A includes the Consent Decree text which pertains to surface water goals.
- Off-site groundwater goals were established by the Consent Decree for *cis*- and *trans*-1,2-DCE.

Additional Information on Goals [11]

- Shallow groundwater from the site discharges to Mill Creek. The surface water requirements were a means of measuring cleanup within shallow groundwater beneath the site. There were no other on-site cleanup goals set for the shallow groundwater.
- The ESD, issued in 1995, did not change the surface water or off-site groundwater cleanup or treatment performance goals from the amended ROD. The focus of remediation was changed from site restoration to containment.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Goals [11]

As determined by the Consent Decree and the amended ROD, the following treatment performance goals have been established:

- Achievement of an inward flow of shallow groundwater (<40 ft bgs) within a specified area of the site. This area is approximately defined by the property boundaries (see Figure 1 of this report).
- Achievement of either: 1) a reversal of groundwater flow for Unit 2 at a depth of 40 to 70 feet at the western boundary of the site; or 2) establishment of a hydraulic barrier to regional groundwater flow at the 40- to 70-foot depth at the western boundary of the site.
- Combined wastewater effluent from the treatment systems must meet discharge criteria included in the POTW discharge permit. Specific criteria are included in Table 3.
- All air emissions must comply with a discharge permit issued from the Puget Sound Air Pollution Control Agency. Specific criteria are included in Table 3.

Performance Data Assessment [10, 14, 15]

For this report, total metals includes zinc, nickel, chromium, copper, and cadmium. Total VOCs includes TCE, DCE, vinyl chloride, methylene chloride, and chloroform.

- According to monthly surface water monitoring data, surface water criteria in Mill Creek were achieved by mid-1990. Figure 3 shows concentrations of zinc in the downstream monitoring point of Mill Creek. Zinc concentrations were the highest of any metal contaminant. By mid-1990, concentrations were below 100 µg/L.
- The P&T system achieved the cleanup goal of 70 µg/L of DCE in all three of the extraction wells in the off-site trans plume.
- Concentrations of DCE in the off-site plume have decreased since operations began in 1988. As shown in Figure 4, concentrations of DCE have decreased in all three trans wells from above 2,000 µg/L in 1988 to less than 100 µg/L in January 1996, a 95% reduction.
- Contaminants have not increased in downgradient monitoring wells as noted in the 1996 Quarterly Report. On the basis of this information, plume containment for the off-site plume has been achieved [17].
- Monitoring well data from on-site wells (N-wells, U-wells, and monitoring wells) show contaminant concentrations for TCE, vinyl chloride, and zinc decreased by two orders of magnitude from 1988 to 1995.
- The maximum concentrations of contaminants detected in on-site well points (extraction wells) during the June 1995 sampling event were zinc (117,000 µg/L), cadmium (1,360 µg/L), DCE (14,600 µg/L), vinyl chloride (5,490 µg/L), and TCE (55,200 µg/L).
- Figure 5 shows the contaminant removal rate in pounds per day for the P&T systems from 1988 through 1996. This figure includes combined removal rates for total metals and total VOCs from both treatment systems. The extraction rate decreased to less than 20 lbs/day within 3 years. It has remained below 20 lbs/day since then. A total of 102,000 lbs of contaminants was removed during eight years of operation.

TREATMENT SYSTEM PERFORMANCE (CONT.)

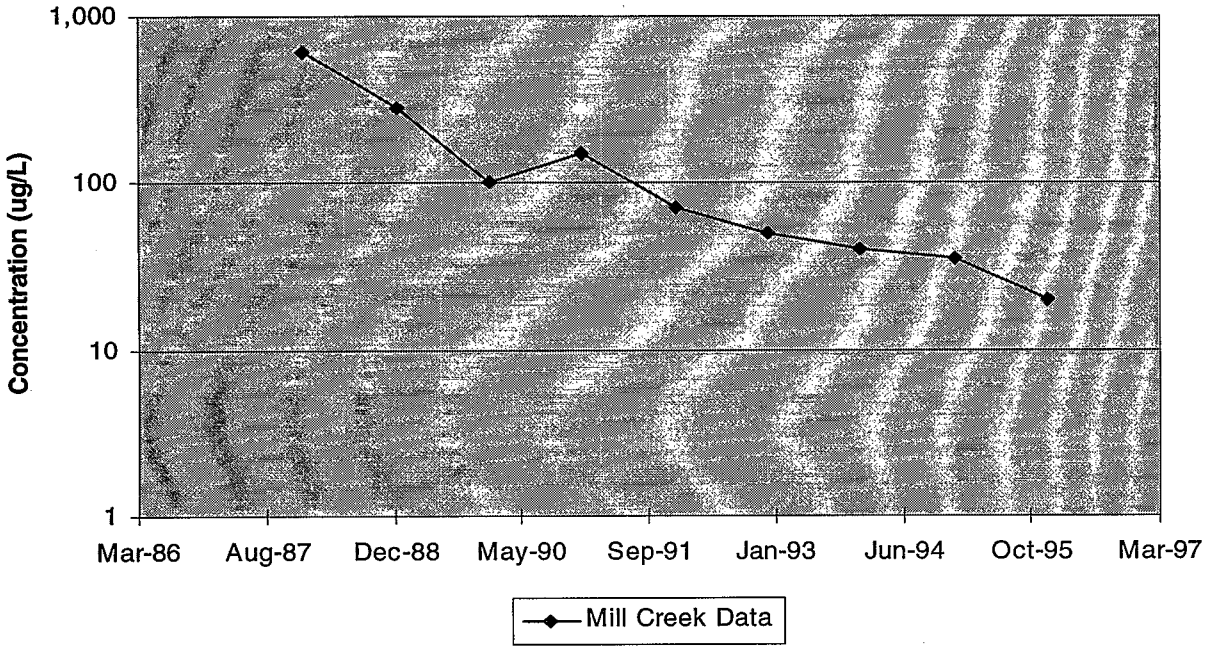

Figure 3. Zinc Concentration at Downstream Monitoring Point of Mill Creek (1988-1996) [10]

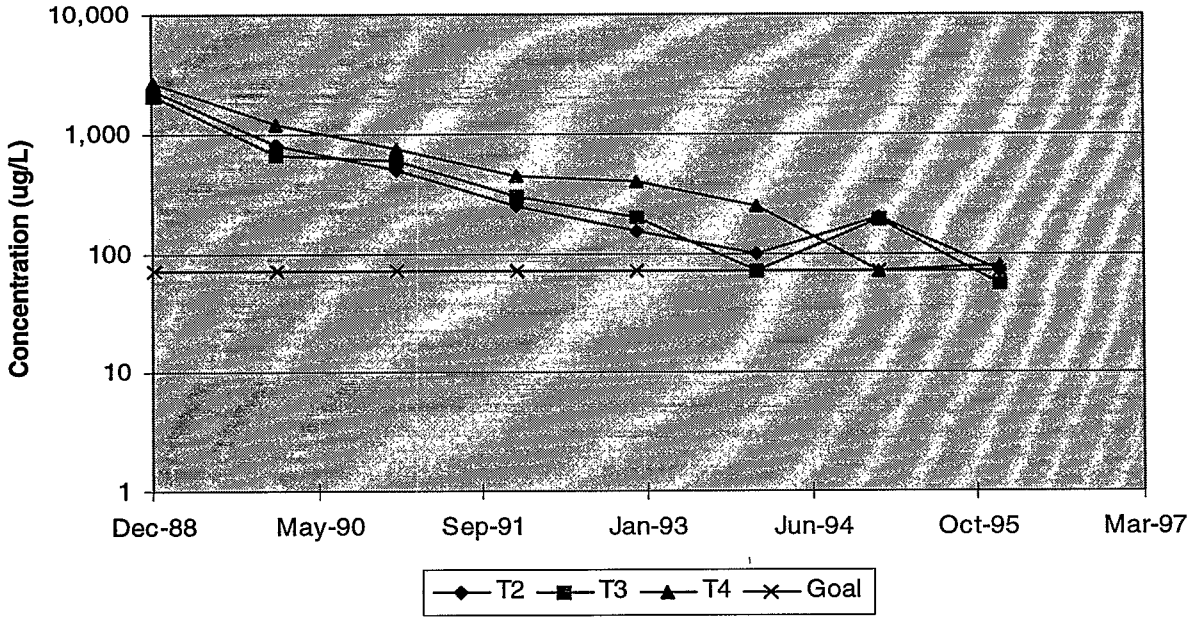

Figure 4. Total DCE Concentrations in 3 Trans Wells (1988-1996) [10,15]

TREATMENT SYSTEM PERFORMANCE (CONT.)

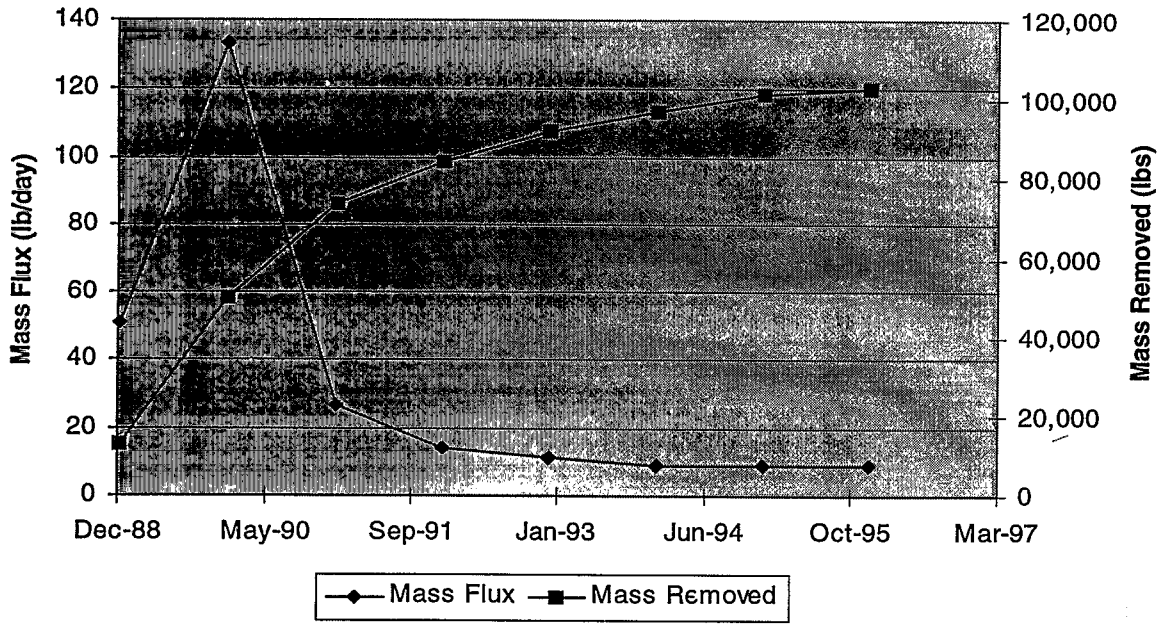

Figure 5. Mass Flux and Cumulative Contaminant Removal (1988-1996) [10,15]

Performance Data Assessment (Cont.)

- Data from annual reports indicate that inward flow gradients have been achieved in all but two deep (45 ft) piezometer pairs, which are both located in the northwest portion of the site. These two piezometer pairs, each composed of one piezometer located inside and one outside of the slurry wall, have historically displayed neutral or outward gradients [10].
- Discharge requirements established by the wastewater discharge and air emission permits have been met consistently by treatments systems on site [10].

Performance Data Completeness

- Data are available in annual reports for concentrations of contaminants in the groundwater and surface water according to the following schedule [10]:

Monitoring wells	Quarterly
N-Wells	Bimonthly
Trans Wells	Monthly
U-Wells	Bimonthly
Well Points	Annually
Stream Sampling Points	Quarterly

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness (Cont.)

- Data are available for influent and effluent concentrations to both treatment plants on a monthly basis.
- Contaminant mass removal data for the on-site system was provided by the site engineer.
- Contaminant mass removal for the off-site system was calculated from annual well concentration data and pumping rates from each well.
- Figures 2 and 3 were generated from data provided in annual reports. Figure 4 was generated from data provided by the primary contact for this site. Annual data were used to generate the graph.
- Data are available from 1988 through 1996 for this report. The 1995 Annual Report includes data from 1988 through 1995. Quarterly reports were used for data through the first quarter of 1996.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Washington requirements. All monitoring was performed using EPA-approved SW-846 methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

The Western Processing Trust Fund contracted with Chemical Waste Management (now OHM) to construct and operate the initial P&T system at the site. Landau Associates is the primary technical consultant to Western Processing Trust Fund. Tacoma Pump and Drilling Company has been contracted to provide parts of the installation.

Cost Analysis

- All costs for investigation, design, construction and operation of the treatment system at this site were borne by the PRPs. The following costs are for the remediation systems operating at this site through 1995 and exclude excavation and disposal [17].

Capital Costs [13, 16, 17]

Remedial Construction	
Administration and Mobilization	$2,827,998
On-Site Laboratory and Monitoring Wells	$1,051,610
Site Work	$3,282,631
Slurry Wall	$1,382,744
Extraction/Reinjection Wells and Infiltration System	$2,977,339
Original Treatment System	$1,895,740
Original Air Stripping System	$2,311,988
Oversight	$302,579
Total Construction	**$16,032,629**

Operating Costs [13, 16]

Operations and Maintenance	$18,866,923
Administration and Taxes	$4,057,576
Operational and Environmental Monitoring	$7,657,272
Wastewater Treatment Discharge Fees	$2,115,712
Total Operating Expenses (1988 - 1995)	**$32,697,483**

TREATMENT SYSTEM COST (CONT.)

Other Costs

Remedial Investigation	
Remedial Investigation/ Feasibility Study	$2,366,654
Oversight	$13,191
Total Investigation	**$2,379,845**
Remedial Design	
Remedial Design	$1,382,919
Oversight	$22,644
Total Design	**$1,405,563**

Cost Data Quality

Actual capital and operations and maintenance cost data are available from Landau Associates, Inc..

OBSERVATIONS AND LESSONS LEARNED

- The cost for groundwater remediation between 1988 and 1995 was approximately $48,730,000 ($16,032,629 in capital costs, including the slurry wall, and $32,697,483 in operating costs), corresponding to a unit cost of $50 per 1,000 gallons of groundwater treated and $478 per pound of contaminant removed.
- The average annual operating expenses estimated using the above information are about $4,500,000.
- The original approach to this site was an aggressive effort to fully restore the site to original conditions within seven years. Restoration was a priority and high costs were incurred to achieve this goal. For example, the on-site extraction system consisted of over 200 thirty-foot well points each connected to a vacuum extraction system. This system was very costly to install and operate, but was expected to restore the site. After eight years of P&T, the goal of restoration was changed to containment based on technical impracticability of achieving full restoration.
- Goals set for surface water (Mill Creek) were time-specific. Mill Creek goals were set to be achieved within three years of the Consent Decree. The PRPs made the decision to install a slurry wall around the site at a cost of approximately $1.4 million to achieve this goal.
- More detailed study of the interactions of the broad range of contaminants found at the site was started in 1990. This effort included studies relating to contaminant transport and partitioning coefficients, as well as additional testing on the LNAPL layer and recovery system. These studies added an additional $600,000 in overall costs.
- The use of a slurry wall and a groundwater extraction system was successful at meeting the surface water criteria for Mill Creek. The surface water goals were achieved within the three-year window granted by the Consent Decree.
- Cleanup efforts at this site were very complicated from an engineering perspective. Organic and inorganic compounds were located in the saturated zone to depths of 40 feet and below. Many source areas were spread over the 13-acre site and subsurface source zones were likely present in several areas. The chemical and hydrogeologic complexity of this site led to increased costs and ultimately a change in approach from restoration to containment.

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- The most rapid reductions in contaminant concentrations occurred between 1988 and 1991 (see Figure 3). Contaminant concentrations level out from 1991 through 1996. This trend has been observed at several other P&T sites.

REFERENCES

1. Final Report Hydrogeological Assessment, Hart Crowser and Associates, Inc., October 1984.
2. Remedial Action Plan Phase II: Subsurface Cleanup, Landau Associates, Inc., September 1984.
3. Record of Decision, U.S. Environmental Protection Agency, September 1985.
4. Schedule Work Plan, Chemical Waste Management, Inc., December 1987.
5. Quarterly Interpretive Report 4th Quarter 1993, Landau Associates, Inc., April 1994.
6. Remedial Action Report, Landau Associates, Inc., May 1994.
7. Remedial Action Report. Installation of Extraction Wells 5U1A, 5U2A, 1U3A, 1U4A, 1U5A, 1U6A and Well Points 207-210, Landau Associates Inc., May 24, 1994.
8. Technical Impracticably Waiver Petition, Western Processing, Landau Associates, Inc., September 12, 1995. (Referenced as T.I. Petition.)
9. Technical Impracticably Waiver Petition, Western Processing (Appendices), Landau Associates, Inc., September 12, 1995. (Referenced as T.I. Petition.)
10. 1995 Annual Evaluation, Western Processing, Landau Associates, Inc., May 14, 1997. (Referenced as 1995 Annual Evaluation.)
11. Copy of Western Processing Consent Decree. Filed April 10, 1987.
12. Explanation of Significant Differences, Western Processing Superfund Site, U.S. Environmental Protection Agency, December 11, 1995.
13. Correspondence with Paul Johansen and Bill Enkeboll, July 8, 1997.
14. 1991 Annual Evaluation, Landau Associates, Inc., August 5, 1992.
15. Quarterly Interpretive Report, 3rd Quarter 1996, Landau Associates, Inc., April 2, 1997.
16. Groundwater Remedial Cost Analysis, U.S. Environmental Protection Agency Unpublished.
17. Comments on draft report provided by Lee Marshall, Region 10 Project Manager, and Bill Enkeboll, Landau Associates.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Attachment A

Consent Decree Text Pertaining to Mill Creek Standards

Allowable Concentrations in Mill Creek.

a. If the concentration of a Mill Creek indicator chemical (as listed in Table 1) or other priority pollutant at the upstream (background) monitoring point in Mill Creek is less than two-thirds of the applicable upstream Federal Ambient Water Quality Criterion for Aquatic Organisms (Water Quality Criterion)[1], the maximum allowable concentration at the downstream compliance point[2] shall be the downstream Water Quality Criterion[3].

b. If a Water Quality Criterion is not achievable because the upstream (background) concentration of a chemical is near or above the Water Quality Criterion, the maximum allowable concentration at the downstream compliance point shall be the level described below:

   i. If the concentration of a Mill creek indicator chemical or other priority pollutant at the upstream (background) monitoring point in Mill Creek is at or above two-thirds of the upstream Water Quality Criterion but less than the upstream Water Quality Criterion, the maximum allowable concentration at the downstream compliance point shall be no more than the background concentration plus fifty (50) percent of the background concentration; or

   ii. If the concentration of a Mill Creek indicator chemical or other priority pollutant at the upstream (background) monitoring point in Mill Creek is at or above the upstream Water Quality Criterion, the maximum allowable concentration at the downstream compliance point shall be no greater than background plus eighty (80) percent of the upstream Water Quality Criterion.

c. Meeting the above performance standards shall not require responsibility for any contaminated water entering Mill Creek between the upstream monitoring and downstream compliance points that is contaminated by a source other than the Site or Western Processing activities. Upon demonstration by the Consenting Defendants that water contaminated by a source other than the Site or Western Processing activities is entering Mill Creek between the upstream monitoring and downstream compliance points and quantification of such contamination by the Consenting Defendants, an appropriate adjustment will be made by the Governments for the Contaminants attributable to such other source.

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[1]The applicable Water Quality Criteria shall be those final criteria published in the Federal Register as of the date of entry of this Consent Decree.

[2]The upstream monitoring point and the downstream compliance point are those described in subparagraph IV.D.7.b. below.

[3]Designation of upstream and downstream is necessary because the applicable Water Quality Criterion varies depending on the hardness of the water.