Superfund Record of Decision

Sprague Road Ground Water Plume Site
Ector County Texas

September 2000

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6

TABLE OF CONTENTS

Record of Decision
Table of Contents

LIST OF FIGURES

LIST OF TABLES

APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
COC	Chemical of Concern
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
LM	Leigh Metal Plating, Inc.
M&C	Machine and Casting, Inc.
MCL	Maximum Contaminant Level
NCC	National Chromium Corporation
NCP	National Contingency Plan
O&M	Operation and Maintenance
PRP	Potentially Responsible Party
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
Site	Sprague Road Ground Water Plume Superfund Site
TNRCC	Texas Natural Resource Conservation Commission
TWC	Texas Water Commission
TWDB	Texas Water Development Board

SPRAGUE ROAD GROUND WATER PLUME
ECTOR COUNTY, TEXAS
RECORD OF DECISION

DECLARATION

SITE NAME AND LOCATION

Sprague Road Ground Water Plume
Ector County, Texas
CERCLIS ID # TX0001407444

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Sprague Road Ground Water Plume Site (Site), in Ector County, Texas, which was chosen in accordance with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), 42 USC § 9601 et seq., as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300 et seq., as amended.

This decision was based on the Administrative Record, which has been developed in accordance with Section 113(k) of CERCLA, and which is available for review at the Ector County Public Library, 321 West 5th Street, Odessa, Texas, at the Texas Natural Resource Conservation Commission offices (TNRCC) in Austin, Texas, and at the United States Environmental Protection Agency (EPA) Region 6 offices in Dallas, Texas. The Administrative Record Index (Appendix C to the ROD) identifies each of the items comprising the Administrative Record upon which the selection of the remedial action is based.

The State of Texas concurs with the Selected Remedy.

ASSESSMENT OF THE SITE

The response action selected in this Record of Decision (ROD) is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

DESCRIPTION OF THE SELECTED REMEDY

This ROD sets forth the selected remedy for the Site, which involves the extraction and treatment of chromium contaminated ground water from a drinking water aquifer and the treatment of residual chromium in the section of unsaturated soils above the water table (vadose zone) that has the potential to act as a future source of contamination. The selected remedy is a comprehensive approach for this Site that addresses all current and potential future risks caused by ground water contamination. This remedy, by addressing the release of chromium to the ground water, completes the emergency response actions conducted by EPA and the State to remove the principal and low-level threat wastes from each of the abandoned chrome plating facilities. Specifically, this remedial action includes the ground water contaminant plumes originating from three abandoned chrome plating facilities: the Leigh Metal Plating, Inc. facility, the National Chromium Corporation facility, and the Machine and Casting, Inc. facility; and the residual contamination remaining in the vadose zone soils beneath the source areas at two of the three facilities: National Chromium Corporation facility and the Machine and Casting facility. The remedial measures will allow for restoration of the Site ground water to an unrestricted drinking water supply, and reduce the residual chromium concentrations in the vadose zone soils which has the potential to contribute to long-term contamination and prevent restoration of the ground water quality. Remediation of surface soils is not required because the risk assessment performed during the Remedial Investigation/Feasibility Study did not identify the surface soils as a risk to human health and the environment. In addition, the chromium in the vadose zone beneath the Leigh Metal Plating facility was insufficient to act as a potential source of ground water contamination. The major components of this remedy are:

- Installation of ground water extraction wells at each contaminant plume to maximize contaminant reduction and prevent further migration of the plume.
- Treatment of the contaminated ground water utilizing one of the presumptive remedies described in the Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites (OSWER Directive 9283.1-12, October 1996). Wastes generated during the treatment process would be transported to an off-site location for disposal in accordance with RCRA and CERCLA requirements.
- The re-injection of the treated water into the aquifer utilizing one or a combination of the following: injection wells, dry wells, and/or infiltration galleries.
- The use of infiltration galleries or other means to flush the hexavalent chromium from the vadose zone to levels that will ensure the area does not act as a potential source of contamination or prevent the restoration of the ground water under future land-use scenarios.
- Long-term ground water monitoring to evaluate the effectiveness of the ground water extraction and disposal system and ensure there is no further exposure to contaminated ground water above the applicable drinking standards.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective, and utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable. This remedy also satisfies the statutory preference for treatment as a principal element of the remedy (i.e., reduce the toxicity, mobility, or volume of materials comprising principal threats through treatment). Upon completion of the remedy, no hazardous substances will remain within the Site above levels that prevent unlimited use and unrestricted exposure. Because this remedy will require greater than five years to achieve these levels, a policy review will be conducted within five years after initiation of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

ROD DATA CERTIFICATION CHECKLIST

The following information is included in the Decision Summary section of this Record of Decision. Additional information can be found in the Administrative Record file for this site.

- Chemicals of concern (COCs) and their respective concentrations.
- Cleanup levels established for COCs and the basis for the levels are the Maximum Contaminant Levels under the Safe Drinking Water Act instead of a baseline risk assessment.
- Current and anticipated future land and ground water use assumptions used in the ROD.
- Potential land and groundwater use that will be available at the Site as a result of the Selected Remedy.
- Estimated capital, operation and maintenance (O&M), and total present worth costs; discount rate; and the number of years over which the remedy cost estimates are projected.
- Decisive factor(s) that led to selecting the remedy.

AUTHORIZING SIGNATURE

By: Myron O. Knudson Date: 9-29-00

Gregg A. Cooke
Regional Administrator
U.S. EPA Region 6

RECORD OF DECISION
SPRAGUE ROAD GROUND WATER PLUME SUPERFUND SITE
CONCURRENCE LIST

By: Vincent Malott Date: 9-21-00
Vincent E. Malott
Remedial Project Manager

By: Chris Villarreal for Date: 9/25/00
Gustavo T. Chavarria, Chief
AR/OK/TX Project Management Section

By: WK Honker Date: 9/25/00
William K. Honker, Chief
AR/OK/TX Branch

By: Anne Date: 9-21-00
Anne Foster
Site Attorney

By: Date: 09/25/00
Mark A. Peycke, Chief
Superfund Branch, Office of Regional Counsel

By: Myron O. Knudson Date: 9/26/00
Myron O. Knudson, P.E., Director
Superfund Division

9/26

By: Date: 9/29/00
Lawrence E. Starfield
Regional Counsel

THE DECISION SUMMARY

SITE NAME, LOCATION, AND BRIEF DESCRIPTION

The Sprague Road Ground Water Plume Superfund Site (Site), CERCLIS ID # TX0001407444, is just outside the northwest Odessa city limits in Ector County, Texas (Figure 1). The U.S. Environmental Protection Agency (EPA) is the lead agency for Site activities and is issuing this Record of Decision (ROD). The Texas Natural Resource Conservation Commission (TNRCC) provided technical assistance to EPA. The source of monies for the Remedial Investigation (RI) and Feasibility Study (FS) and the future remedial action is the Superfund trust fund.

The Site consists of three abandoned metal plating facilities located within 1 mile of each other (Figure 2): Leigh Metal Plating, Inc., which is also referred to in various reports and records as Leigh Metal Coating and Machining, Inc. (LM); National Chromium Corporation (NCC); and Machine and Casting, Inc. (M&C). Electroplating activities at these facilities, which included the repairing and reconditioning of oil field equipment, generated chromic acid rinsewater and sludge. The past operations and waste disposal practices at each of the three facilities have resulted in the release of chromium to the ground water.

SITE HISTORY AND ENFORCEMENT ACTIVITIES

Leigh Metal Plating, Inc.

History of Site Activities

The LM facility is approximately 3.6 acres in size and consists of an abandoned main office/machine shop building and a second building containing a chrome plating shop located at 2725 West 81st street (Figure 3). The facility was constructed on undeveloped lots in the Odessa Industrial Park and operated from 1976 to 1992. Facility operations included an electroplating system that used chromium solutions. An above-ground storage tank was utilized for the storage of chromic acid and alkali rinsewaters prior to off-site disposal. The open-top tank is constructed of fiberglass and has a maximum capacity of 4,200 gallons. The tank is contained in a 20-foot by 20-foot area enclosed by a concrete masonry wall.

History of Federal and State Investigations and Removal and Remedial Actions

In March 1984, an unknown volume of chromic acid from two chromic acid plating tanks was released inside the chrome plating shop. The rinsewater entered the soil beneath the chrome-plating shop through cracks in the concrete floor. Prior to a Texas Water Commission (TWC) inspection in February 1985, LM had approximately 211 cubic yards of contaminated soil beneath the plating shop excavated and disposed of at an off-site landfill. The excavation area underneath the building is approximately 5 to 6 feet deep and is protected by a metal awning erected on the west side of the chrome plating shop.

The TWC issued an Agreed Enforcement Order in May 1991 requiring LM to investigate contaminated soils from both active and inactive solid waste management units at the facility. On August 1, 1991, a citizen complaint reported green, discolored ice cubes at a nearby residence. TWC responded in August 1991 with a ground water quality survey in the vicinity of the LM facility and identified chromium contamination above drinking water standards in six wells east of the LM facility with concentrations ranging from 0.080 to 5.24 mg/L. The LM facility failed to meet the requirements of a subsequent Emergency Order issued by TWC in August 1991 for the ground water contamination. On October 6, 1992, the LM facility was abandoned following an Order for Relief entered by the United State Bankruptcy Court in the bankruptcy proceedings of Leigh Metal Coatings and Machining, Inc.

TWC installed eight monitoring wells in December 1992 to investigate the ground water contamination. Chromium concentrations from the two on-site and six off-site wells ranged from 0.050 mg/L to 4.30 mg/L. In September 1993, the TNRCC installed a water supply line from the City of Odessa to provide drinking water to the affected residences.

In June 1996, EPA proceeded with a removal assessment of the LM facility. A total of 53 soil samples were collected for X-ray fluorescence (XRF) analysis with six samples sent for laboratory verification. Due to interferences from the soil composition, the XRF results were only capable of delineating areas of chromium contamination greater than 150 mg/kg and the results appear to be biased high; however, laboratory analysis more accurately determined concentrations of chromium in the soil.

EPA proceeded with an emergency removal action between September and October 1996. During the removal, liquid and sludge wastes were removed from 13 vats, 85 drums, 83 pails, and numerous small containers. The emptied drums and pails were crushed and placed in the empty vats in the plating shop. A total of 4,070 gallons of liquid waste, and 2,550 gallons of solid waste were removed for off-site disposal.

A second EPA emergency response action in 1998 addressed the current risk to human health caused by exposure to the chromium contaminated ground water present in private drinking water wells by supplying bottled water to three residences. EPA is proceeding with a third emergency removal action for the LM facility following the signing of an Action Memorandum in August 2000. The planned removal action will provide for the installation of water lines to those residences with contaminated wells above the drinking water limits, and the removal of the abandoned plating room structure present at the facility.

History of CERCLA Enforcement Activities

EPA issued a General Notice letter on May 28, 1998, to the LM facility as a Potentially Responsible Party (PRP). EPA decided not to use special notice procedures pursuant to Section 122(e) of CERCLA for the RI/FS at the Site. EPA decided that it was inappropriate to invoke the Section 122(e) procedures because past dealings with the PRPs strongly indicated they would be unable to implement the RI/FS in a timely manner.

National Chromium Corporation

History of Site Activities

The NCC facility is approximately 2.5 acres in size and consists of an abandoned main office/machine shop building located at 2626 Stevens Road, approximately 850 feet south of the LM facility (Figure 4). The facility was constructed on undeveloped lots in the Odessa Industrial Park and operated from 1979 to 1993. Facility operations included chrome electroplating of compressor engines. The original waste disposal system was a hexavalent chrome destruction system. Liquid waste arising from process spills was gathered in a common sump and transferred to a 1000 gallon holding tank for treatment. The pH was reduced to 2.5 with the addition of sulfuric acid, and hexavalent chromium was reduced to the trivalent state with sodium bisulfite. Trivalent chromium was reduced with the addition of sodium hydroxide to a pH of 8.0. The sludge was then chemically fixed and filtered and consisted of primarily metal hydroxides of chromium and iron. The effluent water was discharged to an unauthorized drainfield on NCC property and the sludge was stored in metal drums. NCC experienced various problems with this treatment system and in 1980 supplemented the system with a 20,000 gallon evaporation pond.

History of Federal and State Investigations and Removal and Remedial Actions

Numerous compliance inspections were conducted from 1980 to 1991 by the TNRCC and its predecessor agencies, the TWC and the Texas Department of Water Resources (TDWR).

TDWR issued two non-compliance notices to NCC in 1982, and a 1983 inspection noted that waste chrome solution was discharged into a 20,000 gallon surface impoundment without treatment. The waste stream contained 50.4 mg/L total chromium and soil contamination contained 378 mg/L total chromium. A May 1983 TDWR enforcement report cited several violations, including improper storage of hazardous waste, unauthorized discharge of industrial wastewater, and failure to implement a ground water monitoring program.

TDWR and TWC compliance inspections referenced closure activities for the surface impoundment between 1984 and 1988, as well as continued chromic acid seepage from the building onto the soil. A TWC enforcement action in 1987 required NCC to close the impoundment and remove the wastes and soil. While NCC proceeded with closure of the surface impoundment between 1988 and 1989, all of the requirements had not been met prior to the facility closing in 1993. Closure of the surface impoundment included the excavation of the liquids, sludges, and liner along with the excavation of other nearby spill areas.

A 1995 TWC inspection identified the following wastes at the facility: chromium contaminated soil and caliche from the closure activities which was stored in eleven 10,000 gallon above ground storage tanks (ASTs); a partially excavated surface impoundment; wastes piles of chromium contaminated soil; two steel vats (300 and 500 gallon capacity) containing sludge and chrome plating solids; and numerous vats and containers of plating wastes inside the plating shop. Chromium continued to leach out of the open topped ASTs from rainfall, and chromium contamination was visible along the walls of the excavation of the former surface impoundment.

In 1995, EPA conducted a site assessment of the facility and determined the history and current enforcement status of the facility. Prior to the initiation of the sampling activities for the removal assessment in 1996, EPA obtained an Administrative Search Warrant from the U.S. District Court after access was denied by the current property owner. Sampling and analyses activities conducted in May 1996 focused on the on-site soils and nearby ground water wells which might be affected by the facility operations.

EPA proceeded with an emergency removal action in June and August 1996. A total of 115,700 pounds of vat and tank sludge, 40,620 pounds of tank liquid waste, and 5,187,340 pounds of soil waste were removed for off-site disposal. An action level for chromium of 390 mg/kg was established for the soil excavation with a maximum depth of 2 feet for removal. Due to interferences from the soil composition, the XRF results were only capable of delineating areas of chromium contamination greater than 150 mg/kg and the results appear to be biased high; laboratory analysis was necessary to accurately determine concentrations of chromium in the soil. The remaining excavated soil from the waste pile was consolidated into the former surface impoundment and covered with backfill dirt. Staged backfill dirt was leveled across the rest of the site.

The 1998 EPA emergency response action addressed the current risk to human health caused by exposure to the chromium contaminated ground water present in private drinking water wells by supplying bottled water to one residence. EPA is proceeding with a second emergency removal action for this facility following the signing of an Action Memorandum in August 2000. The planned removal action will provide for the installation of water lines to those residences with contaminated wells above the drinking water limits and the removal of the abandoned plating room present at the facility.

History of CERCLA Enforcement Activities

EPA issued a General Notice letter on May 21, 1998, to the LM facility as a PRP. EPA decided not to use special notice procedures pursuant to Section 122(e) of CERCLA for the RI/FS at the Site. EPA decided that it was inappropriate to invoke the Section 122(e) procedures because past dealings with the PRPs strongly indicated they would be unable to implement the RI/FS in a timely manner.

Machine and Casting, Inc.

History of Site Activities

The M&C facility is approximately 2 acres in size and consists of an abandoned office/machine shop building with an attached chrome plating room located at 8410 Sprague Road, approximately 1500 feet north of the LM facility (Figure 5). The facility was constructed on undeveloped lots in the Odessa Industrial Park and operated from 1978 to 1988. Facility operations included a cast iron welding and cylinder repair shop and a small electroplating system that used chromium solutions.

History of Federal and State Investigations and Removal and Remedial Actions

A TDWR compliance inspection in 1980 found an abandoned plating room which contained a full chrome plating vat, and staining on the floors and walls of the room. A TWC compliance inspection in 1988 identified a chrome waste spill in the northeast portion of the facility property; also, the full plating vat was still present and a large hole was discovered in the concrete floor of the plating room. Under the direction of the TWC, 48 drums of chromium-contaminated soil, 18 over-packed drums of chromium-contaminated debris, the plating vat, and

220 gallons of spent chrome plating solution were removed from the site. The facility was abandoned in 1988.

TWC sampled the ground water from nearby wells between 1989 and 1992 and identified chromium contamination in a private well 150 feet north of the M&C building at concentrations ranging from 0.825 to 3.84 mg/L. A Preliminary Assessment was prepared by the TWC for the EPA in 1992, and a Screening Site Inspection was prepared for the EPA in 1993.

EPA conducted a removal assessment of the facility in 1996. A total of 54 soil samples were collected for X-ray fluorescence (XRF) analysis with six samples sent for laboratory verification like the other two facilities. Due to interferences from the soil composition, the XRF results were only capable of delineating areas of chromium contamination greater than 150 mg/kg and the results appear to be biased high, and laboratory analysis was necessary to accurately determine concentrations of chromium in the soil.

EPA is proceeding with an emergency removal action for this facility following the signing of an Action Memorandum in August 2000. The planned removal action will remove the abandoned plating room present at the facility.

History of CERCLA Enforcement Activities

EPA has been unable to locate the PRP(s) for this facility.

Odessa Super Site

EPA conducted a ground water investigation between July and August 1996 as part of a removal assessment to delineate the chromium contaminant plumes originating from the LM, NCC, and M&C facilities. The combined facilities at that time were referred to as the Odessa Super Site. The purpose of the expanded site investigation was to collect sufficient information to design and install a ground pump and treat system that would realize potential cost savings from having a centralized treatment plant to address the three separate contaminant plumes. EPA proceeded with the installation of twelve monitoring wells and two piezometers and collected samples from 40 monitoring and private wells. Further plans for the design and construction of the pump and treat system were discontinued. The sampling results identified three separate chromium contaminant plumes originating from the LM, NCC, and M&C facilities.

National Priorities List

On April 1, 1997, EPA proposed the Site to the National Priorities List (NPL) of Superfund sites. The Site was placed on the NPL on October 27, 1997 (62 Fed. Reg. 186, September 25, 1997).

COMMUNITY PARTICIPATION

The RI/FS Reports and Proposed Plan for the Site were made available to the public on July 27, 2000. The documents are in the Administrative Record file and the information repository maintained at the EPA Docket Room in Region 6, at the TNRCC offices in Austin, Texas, and at the Ector County Public Library in Odessa, Texas. The notice of the availability of these documents was published in the Odessa American newspaper on July 26, 2000. A public comment period was held from July 27, 2000, to August 25, 2000. A formal public meeting was held on August 3, 2000, at the University Park Baptist Chruch to present the Proposed Plan and answer questions on the remedial alternatives. EPA's response to the comments received during this period is included in the Responsiveness Summary, which is part of this ROD. The EPA has kept the community and other interested parties apprised of Site activities through Open Houses, fact sheets, press releases and public meetings. Below is a brief chronology of public outreach efforts.

- In October 1997, EPA issued a fact sheet describing the Site background, the Superfund process, the availability of Technical Assistance Grants, EPA and State contact information, and the location of the information repositories.

- In January 1998, the EPA released a community relations plan that outlined a program to address community concerns and keep citizens informed about and involved in remedial activities.

- On March 5, 1998, EPA held an Open House at the University Park Baptist Church to describe the plans for the Remedial Investigation and Feasibility Study.

- On July 20, 1998, EPA issued a fact sheet describing the Phase I activities of the Remedial Investigation.

- On July 30, 1998, EPA held an Open House at the University Park Baptist Church to discuss the initial ground water sampling results during Phase I of the Remedial Investigation.

- On July 26, 2000, EPA published a notice and brief analysis of the Proposed Plan in the Odessa American and made the plan available to the public at the Ector County Public Library in Odessa, Texas.

- On July 27, 2000, EPA made the administrative record available for public review at EPA's offices in Dallas, Texas and at the Ector County Public Library in Odessa, Texas. This will be the primary information repository for local residents and will be kept up to date by EPA.

- From July 27, 2000, to August 25, 2000, the Agency held a 30 day public comment period to accept public comment on the alternatives presented in the Feasibility Study and the Proposed Plan and on any other documents previously released to the public.

- On August 3, 2000, the Agency held a public meeting to discuss the Proposed Plan and to accept any oral comments. A transcript of this meeting is contained in the Administrative Record. The Agency's response to comments received during the public comment period and at the public meeting are included in the Responsiveness Summary, which is part of this Record of Decision.

SCOPE AND ROLE OF RESPONSE ACTION

This response action is the final Site remedy and is intended to address fully the threats to human health and the environment posed by the conditions at this Site. The purpose of this response action is to clean up the ground water contamination originating from each of the three facilities to drinking water standards, and reduce contaminant concentrations in the soil which may contribute to long-term contamination of the ground water.

The previous removal actions conducted by TNRCC at the M&C facility in 1988, and by EPA at the LM and NCC facilities in 1996 addressed the source materials, which included spent chromium plating solution and chromium contaminated sludge, soil and debris. These source materials constituted the principal threat wastes at each of the facilities. The 1998 EPA emergency response action addressed the current risk to human health caused by exposure to the chromium contaminated ground water present in private drinking water wells by supplying bottled water. The EPA removal action initiated in 2000 will connect those residences to the City of Odessa water supply to replace the current bottled water service and will also address the risks posed by the abandoned plating room shops.

SITE CHARACTERISTICS

This section summarizes information obtained as part of the RI/FS activities at the Site. The following conceptual site model is presented for the entire Site, with the sampling strategy and predictive modeling used to simulate ground water flow and contaminant transport. The nature and extent of contamination and the affected media are presented for each of the three facilities.

Conceptual Site Model

The primary source of contamination at each of the facilities resulted from the daily operation of the chrome plating operations including spills, leaks, and waste disposal. The primary waste stream generated by the facility operations included chromic acid plating solution and spent chromic acid plating solution rinsate. The chromium detected at the Site consists of both a trivalent form which is less toxic and generally immobile in the subsurface; and a hexavalent form that is a known carcinogen and mobile in the subsurface soil and ground water.

While the nature of the chromic acid release was different in both quantity and duration at each of the three facilities, the migration route, exposure pathway, and potential human receptors are the same. After the release of the chromic acid solution, the liquid spread across the surface of the caliche layer and then moved downward through the various fractures in the caliche. The chromic acid solution proceeded vertically through the unsaturated soils (vadose zone) until reaching the water table. The residual chromium left in the vadose zone consists of both trivalent and hexavalent forms.

Upon entering the ground water, the chromium bearing solution easily mixed with the ground water and was transported along the preferential pathways in the aquifer and in the general direction of ground water flow. The shape and concentration profiles within the contaminant plumes reflect the nature and concentration of the contaminant release as well as the varying aquifer characteristics and ground water usage in each area.

Surface Soil

Soil samples were collected at each of the three facilities at a depth of 0 - 2 feet to determine the presence of contamination that may affect future industrial workers at a redeveloped facility on the property. A grid was used to locate the sample locations with additional biased samples collected at visually stained areas or suspected spill locations. Based on the arid conditions of the Site, the presence of sandy soils, and the source characteristics at the individual facilities, the soil samples were analyzed only for target analyte list (TAL) metals.

Vadose Zone

The section of unsaturated soils (vadose zone) above the water table was also sampled at each of the three facilities to determine if the residual quantity of hexavalent chromium was sufficient to act as a long-term source of contamination to the ground water. The vadose zone consists of a caliche horizon that extends from near the ground surface to an average depth of 15 feet with occurrences to 30 feet. The caliche is underlain by fine grained sandstone of the Pliocene Ogallala Formation which overlies the Antlers Formation (or Antlers Sand) in the Trinity Group of Lower Cretaceous Age. The Antlers Formation is also generally referred to as the "Trinity Sand" in the High Plains. There were no continuous low permeability layers noted in the field logs that would impede the vertical flow or cause lateral spreading of contaminants or water to the water table. There were also no perched water zones encountered during drilling at the sites.

Migration of hexavalent chromium through the vadose zone to ground water was modeled using the VS2DTI model developed by the U.S. Geological Survey. Infiltration via precipitation occurs at a low rate of, on average, 0.0035 centimeters per day as determined by the Hydrologic Evaluation of Landfill Performance (HELP) model. To evaluate future land use at the facilities, a septic drain field was also simulated as a potential contributor of water to act as a transport mechanism for chromium to enter the ground water.

Ground Water

Within the immediate Site area, the Trinity aquifer yields water for domestic, industrial, agricultural, and municipal supply wells. Ground water occurs at an approximate depth of 85 feet in the Trinity aquifer. Ground water flow is generally west to east across the M&C and LM facilities switching to a southeast direction near the NCC facility. The Trinity aquifer is underlain by an eroded surface of the Triassic Chinle Formation between 140 - 150 feet below ground surface. Within the Site area, the red clays of the Chinle Formation forms the lower aquitard for the Trinity aquifer.

Aquifer parameters were collected to support ground water modeling and development of remedial alternatives. An electromagnetic borehole flowmeter survey was used to evaluate the direction of ambient vertical gradients and to assess the relative hydraulic conductivity at discrete depths within the screened portion of ten monitoring wells. The tested wells showed a downward vertical gradient and a relatively higher hydraulic conductivity in the upper sands of the aquifer. The results of the survey indicated that the upper portion of the aquifer was the most likely preferential pathway for contaminant transport. The downward vertical gradient would also likely result in the entire thickness of the aquifer becoming contaminated.

Hydraulic measurements were collected from both slug tests and a pump test. The slug tests were performed on 13 monitoring wells using both falling-head and rising-head tests. Hydraulic conductivity measurements varied from 0.4 feet/day to 11.0 feet/day. The pump test was conducted for 55 hours and the calculated hydraulic conductivity was 13.8 feet/day. The average hydraulic gradients are 0.0071 for the LM contaminant plume; 0.0088 for the NCC contaminant plume; and 0.0128 for the M&C contaminant plume. The calculated average total porosity for the Trinity aquifer is 24 percent and the average effective porosity is 16 percent.

The average linear ground water velocity for the Site is 315 feet/year. To assess the transport of chromium in the ground water, the partitioning coefficient (Kd) value was calculated to determine the retardation rate of hexavalent chromium in the aquifer material. Due to sorption, the chromium is retarded by 2.875 or 0.35 times the rate of ground water flow. The resulting chromium contaminant plume is migrating at an approximate rate of 110 feet/year.

The ground water investigation included the installation of 21 monitoring wells and two piezometers. Monitoring wells were installed throughout the LM contaminant plume (8 wells and 2 piezometers); NCC plume (7 wells); and the M&C plume (6 wells). Monitoring wells generally included 20 foot screens with depths ranging from 100 to 133 feet. Ground water samples were collected from both monitoring wells and private water supply wells during three rounds of sampling in 1998 and 1999.

Ground water modeling was performed to simulate ground water flow and contaminant transport at the Site. The ground water modeling program DYNFLOW (finite element modeling code) was used for ground water flow and DYNTRACK was used to simulate contaminant transport at the Site. The significant uncertainty associated with the modeling effort is the lack of historic and current pumping rates from the numerous private wells throughout and surrounding the Site. Ground water usage varies from use as a drinking water supply to heavier demands as a water source for agricultural uses (e.g., horses, grass, fish ponds). Ground water usage also varies as a seasonal function with the heaviest demands during the summer months.

Leigh Metal Plating, Inc.

The LM facility is approximately 3.6 acres in size and consists of an abandoned main office/machine shop building and a second building containing a chrome plating shop. The site coordinates are 31° 55' 05" North latitude and 102° 25' 46" West longitude taken at the driveway of the office building.

Surface Soil Contamination

The surface soil is a silty fine sand with a thickness of 1 to 5 feet above the underlying caliche. A total of 46 soil samples were collected from 30 locations at a depth of 0 - 2 feet.

Chromium was detected at the highest concentrations along the western property boundary at 3,290 mg/kg, and near the main office/shop building at 555 - 1,930 mg/kg. Hexavalent chromium was detected at only one location at a maximum concentration of 346 mg/kg, with a corresponding total chromium concentration of 1,930 mg/kg.

Vadose Zone Contamination

The subsurface soil in the vadose zone was sampled to a depth of 60 feet at 3 locations in proximity to the former plating room. Twenty-two samples were collected and chromium was detected at concentrations ranging from 1.6 - 27.5 mg/kg. Hexavalent chromium was detected in one sample at 0.76 mg/kg.

Ground Water Contamination

Ground water samples were collected from 38 wells (both private and monitoring) surrounding the LM facility (Figure 6). The maximum detected chromium concentration was 3.78 mg/L in monitoring well LMW-14 located at the general mid-point of the contaminant plume. The estimated size of the chromium plume is 60 acres with an approximate length of 1,750 feet and width of 650 feet. Sample analysis did not detect either volatile or semi-volatile organic contaminants above their respective screening levels.

National Chromium Corporation

The NCC facility is approximately 2.5 acres in size and consists of a main office/machine shop building containing a chrome plating shop. The site coordinates are 31° 54' 59" North latitude and 102° 25' 11" West longitude taken at the southeast corner of the on-site building.

Soil Contamination

The surface soil is a silty fine sand with a thickness of 3 to 5 feet above the underlying caliche. Fifty soil samples were collected from 25 locations at a depth of 0 - 2 feet. Chromium was detected at the highest concentrations adjacent to the northern and western sides of the NCC building and within the footprint of the former impoundment. The five highest chromium concentrations across the property were between 151 - 8,040 mg/kg. Hexavalent chromium was also detected in concentrations as high as 86.9 mg/kg adjacent to the building and 261 mg/kg at the former impoundment.

Vadose Zone Contamination

The subsurface soil in the vadose zone was sampled to a depth of 65 feet at five locations in proximity to the former impoundment on the north side of the main building. Sixty-five samples were collected and chromium was detected at concentrations ranging from 1.6 - 1,170 mg/kg. Hexavalent chromium was detected at concentrations ranging from 0.26 - 38.7 mg/kg. The presence of hexavalent chromium concentrations above 1.0 mg/kg may represent a potential source of ground water contamination based on predictive modeling of the vadose zone. Water leaching downward from rainfall and any future septic system may contribute additional chromium contamination to the ground water. Because of the inconsistent distribution of hexavalent chromium in the vadose zone soils, this site waste is not readily classifiable as either a principal or low level threat waste.

Ground Water Contamination

Ground water samples were collected from 20 wells (both private and monitoring) surrounding the NCC facility (Figure 7). The maximum detected chromium concentration was 11.2 mg/L in monitoring well NMW-3 located on the facility property. The estimated size of the chromium plume is 15 acres with an approximate length of 950 feet and width 500 feet. Sample analysis detected 1,1-dichloroethylene, a volatile organic contaminant, at 0.007 mg/L and 0.009 mg/L in two on-site monitoring wells during separate sampling events.

Machine and Casting, Inc.

The M&C facility is approximately 2.5 acres in size and consists of a main office/machine shop building containing a chrome plating shop. The site coordinates are 31° 55' 18" North latitude and 102° 25' 59" West longitude taken at the southwest entrance gate into the M&C site.

Soil Contamination

The surface soil is a silty fine sand that is typically less than 2 feet in thickness and in some places absent above the underlying caliche. Thirty soil samples were collected from 15 locations at a depth of 0 - 2 feet . The highest chromium concentrations were detected along the southern property boundary at 97.3 mg/kg, and in a drainage area near the plating room at 340 mg/kg. Hexavalent chromium was not detected in the upper 2 feet of soil.

Vadose Zone Contamination

The vadose zone was sampled to a depth of 61 feet at four locations in proximity to the former plating room on the north side of the main building. Forty-eight samples were collected and chromium was detected at concentrations ranging from 1.7 - 4.1 mg/kg. Hexavalent chromium was detected at concentrations ranging from 0.16 - 1.5 mg/kg. The small plating room is the apparent source of the chromium detected in the ground water. The presence of hexavalent chromium concentrations above 1.0 mg/kg may represent a potential source of ground water contamination based on predictive modeling of the vadose zone. Water leaching downward from rainfall and any future septic system may contribute additional chromium contamination to the ground water. Because of the low concentration and inconsistent distribution of hexavalent chromium in the vadose zone soils, this site waste is not readily classifiable as either a principal or low level threat waste.

Ground Water Contamination

Ground water samples were collected from 22 wells (both private and monitoring) surrounding the M&C facility (Figure 8). The maximum detected chromium concentration was 0.270 mg/L in a private well M-1 adjacent to the M&C facility. The estimated size of the chromium plume is 6 acres with an approximate length of 1,100 feet and width of 150 feet. Sample analysis did not detect either volatile or semi-volatile organic contaminants above their respective screening levels.

CURRENT AND POTENTIAL FUTURE SITE AND RESOURCE USES

Leigh Metal Plating, Inc.

Land Use

The LM facility was built and operated at the site from 1976 until the facility closed in 1992. The facility has been abandoned since 1992 and the interior of the buildings have been subjected to vandalism. A perimeter security fence with locked gates is still in place around the site. The land uses adjacent to the LM facility consist primarily of active and abandoned industrial facilities with scattered abandoned and inhabited residential properties within the area (Figure 9). The adjacent Gulf Nuclear property has been abandoned and the building contains radioactive source material. EPA has conducted a site assessment of the Gulf Nuclear site and a separate emergency removal action will be conducted at that facility.

The reasonably anticipated future use of the LM facility remains as an industrial facility. This future use is based on the presence of the main building on the property and the surrounding industrial properties. The main building will also be evaluated by EPA as a possible location for the ground water treatment plant. Based on discussions with an Ector County elected official, an alternate use of the property may be for equipment storage by County departments or for recreational use (e.g., baseball fields). Future recreational use of this property and the surrounding abandoned properties may require the placement of additional soil since the current soil cover is thin or non-existent.

Ground Water Use

The adjacent industrial facilities and residential properties are connected to the City of Odessa water supply. As a result, the ground water use is for non-potable uses such as industrial operations or lawn irrigation. Prior to the area being connected to the City of Odessa water supply, the adjacent residences were dependent on private wells for their drinking water supply and many of the residences still maintain wells for use in lawn and garden irrigation. However, ground water is utilized as a drinking water source at residences east of the LM facility (Figure 9). The ground water flows in a west to east direction and the residences dependent on ground water for their drinking water supply are located downgradient of the LM facility. Because the area is in an arid environment, the potential beneficial use of the ground water remains as a drinking water supply.

National Chromium Corporation

Land Use

The NCC facility was built and operated at the site from 1979 until the facility closed in 1993. The facility has been abandoned since 1993 and the interior of the building has been subjected to vandalism. However, there is recent interest in reusing the property for industrial purposes. Land use adjacent to the NCC facility consists primarily of active and inactive industrial facilities north of Steven Road, and residential properties south of Steven Road (Figure 10).

The reasonably anticipated future use of the NCC facility remains as an industrial facility. This future use is based on the presence of the main building on the property and the surrounding industrial properties. The reasonably anticipated future use(s) of adjacent land north of Steven Road remains primarily industrial with continued residential land use south of Steven Road. The main building will also be evaluated by EPA as a possible location for the ground water treatment plant.

Ground Water Use

The adjacent industrial facilities are connected to the City of Odessa water supply and do not utilize private wells. The residences south of Steven Road are dependent on ground water for their drinking water supply (Figure 10). The ground water flows in a northwest to southeast direction and the residences dependent on ground water for their drinking water supply are located downgradient of the NCC facility. Because the area is an arid environment, the potential beneficial use of the ground water remains as a drinking water supply.

Machine and Casting, Inc.

Land Use

The M&C facility was built and operated at the site from 1978 until the facility closed in 1988. The facility has been abandoned since 1988 and the interior of the building also has been subjected to vandalism. The land uses adjacent to the M&C facility consist primarily of active and inactive industrial facilities to the north and south of the property, and inhabited residential properties immediately east of the property (Figure 11).

The reasonably anticipated future use of the M&C facility remains as an industrial facility. This future use is based on the presence of the main building on the property and the surrounding industrial properties. Also, the property fronts onto Sprague Road and Loop 338 which provides easy access for an industrial use. The main building will also be evaluated by EPA as a possible location for the ground water treatment plant. The reasonably anticipated future use(s) of adjacent land to the north and south remains primarily industrial with continued occupation of residential properties east of the site. Based on discussions with an Ector County elected official, an alternative use of the property may be for equipment storage by County departments or for recreational use. Future recreational use of this property and the surrounding abandoned properties would likely require the placement of additional soil since the current soil cover is thin or non-existent.

Ground Water Use

Based on interviews with the owner/operators of the adjacent facilities, private wells are used to supply water for their industrial operations and sanitary systems and bottled water is used for their drinking water. The residences east of the M&C facility utilize ground water for their drinking water supply (Figure 11). The ground water flows in a west to east direction and the residences dependent on ground water for their drinking water supply are located downgradient of the M&C facility. Because the area is an arid environment, the potential beneficial use of the ground water remains as a drinking water supply.

SUMMARY OF SITE RISKS

A baseline risk assessment was performed to estimate the probability and magnitude of potential adverse human health and environmental effects from exposure to contaminants associated with the Site assuming no remedial action was taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. The public health risk assessment followed a four step process: 1) hazard identification, which identified those hazardous substances which, given the specifics of the site were of significant concern; 2) exposure assessment, which identified actual or potential exposure pathways, characterized the potentially exposed populations, and determined the extent of possible exposure; 3) toxicity assessment, which considered the types and magnitude of adverse health effects associated with exposure to hazardous substances; and 4) risk characterization and uncertainty analysis, which integrated the three earlier steps to summarize the potential and actual risks posed by hazardous substances at the site, including carcinogenic and non-carcinogenic risks and a discussion of the uncertainty in the risk estimates. A summary of those aspects of the human health risk assessment which support the need for remedial action is discussed below followed by a summary of the environmental risk assessment.

Human Health Risks

Since ground water currently supplies drinking water to nearby residents, the contaminant concentrations in ground water were compared with Maximum Contaminant Levels (MCLs) under the Safe Drinking Water Act. Contaminant concentrations exceeding their respective MCLs were identified as a chemical of concern (COC). Chromium is the primary COC at the Site. Table 1 presents the COCs and exposure point concentration for each of the COCs detected in ground water (*i.e.*, the concentration that will be used to compare with the corresponding Federal MCL). The table includes the range of maximum concentration detected for each COC, and the number and type of wells with a detection of the COC above the corresponding MCL, and the relative location of the well (off-site or on-site) to the facility. The maximum concentration was used as the default exposure point concentration for comparison with the following MCLs: 0.1 mg/L for chromium; and 0.007 mg/L for 1,1-dichloroethene.

Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations in Ground Water

Exposure Point	Chemical of Concern	Maximum Concentration Detected in Private Well (mg/L)	Maximum Concentration Detected in Monitoring Well (mg/L)	Number of Private Wells Above MCL	Number of Monitoring Wells Above MCL
Leigh Metal Plating (On-site)	Chromium	---	0.015	—	0
Leigh Metal Plating (Off-Site)	Chromium	3.92	4.20	10	7
National Chromium Corp. (On-Site)	Chromium	---	12.8	---	2
	1,1-DCE	---	0.008	---	1
National Chromium Corp. (Off-Site)	Chromium	0.371	0.762	3	2
Machine & Casting, Inc. (On-Site)	Chromium	---	0.178	---	2

Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations in Ground Water

Exposure Point	Chemical of Concern	Maximum Concentration Detected in Private Well (mg/L)	Maximum Concentration Detected in Monitoring Well (mg/L)	Number of Private Wells Above MCL	Number of Monitoring Wells Above MCL
Machine & Casting Inc. (Off-Site)	Chromium	0.27	0.102	2	1

The past land use at the three facilities has been for commercial/industrial purposes and is a reasonably anticipated future land use at each facility. The baseline risk assessment focused on the likelihood of health effects for industrial workers that could result from current and future direct contact with contaminated soil. If one or more of the facility properties is instead utilized for recreational purposes, the duration of exposure to contaminants in the soil would be less than for an industrial worker and the corresponding risk would also be less than for an industrial worker. EPA considers two types of risk: cancer risk and non-cancer risk. EPA's statistical analysis of soil sampling data indicates that the probable exposure to chromium in the soil at the LM and NCC facilities would result in an excess lifetime cancer risk of 1×10^{-6} and 4×10^{-7}, respectively, for commercial/industrial workers. These cancer risks are below the acceptable risk range of 10^{-4} to 10^{-6}. The cumulative non-cancer adverse health effects for exposure to chromium in soil at the LM and NCC facilities would result in a hazard index of 0.2 and 0.005, respectively, for the same workers. These values do not exceed the "threshold level" (measured usually as a hazard index of less than 1) below which non-cancer health effects are no longer predicted. The contaminants of potential concern at the M&C facility did not exceed the EPA Region 6 screening toxicity values and thus no further calculations were made regarding potential cancer risks or adverse health effects to workers. The EPA Region 6 screening values for industrial workers are based on an exposure to a contaminant at a concentration representing a cancer risk of 1×10^{-6} or a hazard index less than 1.

Ecological Risks

A screening ecological risk assessment indicated that the potential for significant ecological impacts to occur was small. Due to the depth below ground surface of the water table, the ground water does not discharge to any nearby surface water body. Based upon the relatively small size of the facilities, low contaminant concentrations in the surface soils, the lack of any current natural habitat within the commercial/industrial areas, and the absence of nearby surface water bodies, there was little potential for significant exposure of wildlife to the contaminants.

Summary

It is the lead agency's current judgment that the Selected Remedy identified in this ROD is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

REMEDIAL ACTION OBJECTIVES

The Remedial Action Objectives (RAOs) for the Site are to:

- Prevent exposure to contaminated ground water, above acceptable risk levels;
- Prevent or minimize further migration of the ground water contaminant plume;
- Prevent or minimize further migration of contaminants from source materials to ground water; and
- Return ground waters to their expected beneficial uses wherever practicable.

The Remedial Goals for the following COCs in ground water are based on the corresponding MCLs: chromium - 0.1 mg/L; and 1,1-dichloroethene - 0.007 mg/L.

Based upon data developed in the RI and the Baseline Risk Assessment, remedial measures to address health risk associated with possible exposure to chromium source soils are not warranted because present and future risks for exposure to soils are within or below EPA's acceptable carcinogenic risk range or below a Hazard Index of one for compounds with non-carcinogenic effects.

The VS2DTI model was used to estimate residual hexavalent chromium concentrations in the vadose zone soils that are not expected to impair future ground water quality. The VS2DTI leaching model was arranged such that the model output was consistent with the ground water cleanup levels identified above. The presence of hexavalent chromium concentrations above 1.0 mg/kg may represent a potential source of ground water contamination based on predictive modeling of the vadose zone. Water leaching downward from rainfall and an anticipated future septic system may contribute sufficient chromium concentrations to exceed the ground water cleanup levels.

This interim cleanup level of 1.0 mg/kg in the vadose zone soil is consistent with the ARAR for ground water, attains EPA's risk management goal for remedial actions, and has been determined by EPA to be protective. This interim soil cleanup level must be met at the completion of the remedial action at the points of compliance. The area of the Site where these levels apply is 850 square yards at the M&C facility and 2,733 square yards at the NCC facility. There was insufficient hexavalent chromium at the LM facility to exceed the ground water cleanup levels. Chromium concentrations in the vadose zone leachate will be monitored to evaluate when concentrations have either achieved the interim cleanup goal or have achieved levels protective of the ground water based on updated predictive modeling.

DESCRIPTION OF ALTERNATIVES

Statutory Requirements/Response Objectives

Under its legal authorities, EPA's primary responsibility at Superfund sites is to undertake remedial actions that are protective of human health and the environment. In addition, Section 121 of CERCLA establishes several other statutory requirements and preferences, including: a requirement that EPA's remedial action, when complete, must comply with all federal and more stringent state environmental and facility siting standards, requirements, criteria or limitations, unless a waiver is invoked; a requirement that EPA select a remedial action that is cost-effective and that utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and a preference for remedies in which treatment which permanently and significantly reduces the volume, toxicity or mobility of the hazardous substances is a principal element over remedies not involving such treatment. Response alternatives were developed to be consistent with these Congressional mandates.

Technology and Alternative Development and Screening

CERCLA and the National Contingency Plan (NCP) set forth the process by which remedial actions are evaluated and selected. In accordance with these requirements, a range of alternatives were developed for the Site.

With respect to ground water response action, the alternatives developed to address the ground water contamination are based in part on the lessons learned from the Odessa I and II Superfund Sites located in Odessa, Texas; and a no action alternative. The two Odessa Superfund Sites are also contaminated with chromium from similar facility operations. However, the characteristics of the aquifer and ground water usage between the Sprague Road Site and the Odessa Sites requires separate evaluation and determination of the appropriate response action. At the Odessa I and II sites, the use of natural physical and chemical processes (i.e., natural attenuation) to restore ground water to drinking water use was considered as an alternative to attain site specific remediation levels within a similar time frame. However, natural attenuation was not considered at this Site because of the continued migration of the contaminant plume and the close proximity of additional private drinking water wells down gradient of the plume boundary. The use of other engineering systems (e.g., slurry wall, permeable reactive walls) also were not considered due to the depth of the water table and base of the aquifer.

With respect to residual contamination in the vadose zone, a range of alternatives was developed in which treatment that reduces the toxicity, mobility, or volume of the hazardous substances is a principal element. This range included an alternative that removes hazardous substances to the maximum extent feasible, eliminating or minimizing to the degree possible the need for long term management. This range also included an alternative that involves little or no treatment but provides protection through engineering or institutional controls, and a no action alternative.

In summary, of the 11 ground water and 9 vadose zone remedial technologies screened in the FS, 13 were retained as possible options for the cleanup of the Site. From this initial screening, remedial options were combined, and 2 ground water and 4 vadose zone options were selected for detailed analysis.

Summary of Remedial Alterantives for Ground Water

Alternative 1: No Further Action
Estimated Capital Cost: $0
Estimated Annual O&M Costs: $0
Estimated Present Worth: $0

Regulations governing the Superfund program require that the "no action" alternative be evaluated at every Site to establish a baseline for comparison. Under this alternative, EPA would take no action at the Site to prevent exposure to the ground water contamination.

Alternative 2: Ground Water Extraction and Treatment
Estimated Capital Cost: $6,128,000
    Testing/Mobilization: $400,000
    Extraction/Injection Well System: $1,792,000
    Treatment System: $1,787,000
    Indirect Costs: $1,353,000
    Contingency (20%): $796,000
Estimated Annual O&M Costs: $1,119,000 - 1,254,000
Estimated Present Worth (7%): $20,102,000
Implementation Time Frame: 1 - 2 Years

The remedy components for Alternative 2 include the use of treatment to remove chromium from the ground water above a concentration of 0.1 mg/kg. The components include:

- Ground water extraction wells would be installed at each of the three facilities. The proposed number and location of extraction wells is based on ground water modeling of the Site and includes 4 wells at the M&C facility, 8 wells at the LM facility, and 10 wells at the NCC facility. The final number and location of extraction wells would be determined during the remedial design.

- Once extracted, the ground water would be conveyed through underground, double-walled piping to a treatment plant(s) located at one or more of the three facilities.
- The treatment component of this ground water alternative would utilize presumptive technologies identified in EPA's ground water presumptive strategy, "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites," October 1996, OSWER Directive Number 9283.1-12. Since the primary contaminants of concern are chromium and potentially other metals, one or more of the presumptive technologies - chemical precipitation, ion exchange/adsorption, or electrochemical methods - would be used for treating the contaminants in the extracted ground water. The actual technologies and sequence of technologies used for the treatment system would be determined during remedial design.
- The precipitate or sludge wastes generated during the treatment process would be transported to an off-site location for disposal in accordance with the Resource Conservation and Recovery Act (RCRA) requirements.
- The treated water would be conveyed through underground, single-walled piping to injection wells or infiltration galleries. The treated water would be injected back into the aquifer using either injection wells screened in the aquifer, dry wells screened in the vadose zone, or infiltration galleries installed within a few feet of the surface. The current cost estimate is based on the use of a total of 8 injection wells located at the M&C facility (2 wells), LM facility (3 wells), and NCC facility (3 wells). The use of one or more of these options and the number and location of injection wells/infiltration galleries would be determined during the remedial design.
- Ground water monitoring will be performed to evaluate both the effectiveness of the system as well as ensure that there is no exposure to contaminants above the drinking water limits.

Ground water will be extracted throughout the plume to both maximize contaminant removal and prevent further migration of the individual contaminant plumes. The ground water would be restored to drinking water quality through extraction and treatment to meet the final cleanup levels throughout the entire plume.

Based on predictive ground water modeling, the expected cleanup time frame may extend from 20 to 25 years. However, the cleanup time frames for the Odessa I and II Sites has generally been less than 10 years. Remedy refinements may be needed during the life of the remedy. Such adjustments may include adjusting the number and location of extraction wells, adjusting the pumping rate, etc. A contingency included in this component is the use of certain chemicals, such as ferrous sulfate, to reduce the mobile hexavalent chromium to the immobile trivalent chromium. The use of such chemicals would be limited to areas of high chromium concentrations near the original source areas within the existing facility boundaries. The ground water extraction system would be used to prevent off-site migration and the use of the ground water monitored until conditions return to drinking water quality.

Summary of Remedial Alternatives for the Vadose Zone

Remedial alternatives were developed to address the potential for chromium leachate in the vadose zone to act as an ongoing source of chromium contamination in the ground water. The presence of hexavalent chromium concentrations above 1.0 mg/kg in the vadose zone soil may represent a potential source of ground water contamination based on predictive modeling. Water leaching downward from rainfall and an anticipated future septic system may contribute additional chromium contamination to the ground water.

VZ Alternative 1: No Further Action

Estimated Capital Cost: $0
Estimated Annual O&M Costs: $0
Estimated Present Worth: $0

Regulations governing the Superfund program require that the "no action" alternative be evaluated at every Site to establish a baseline for comparison. Under this alternative, EPA would take no action at the Site to prevent exposure to the ground water contamination.

VZ Alternative 2: Cap

Estimated Capital Cost: $129,000
- *Site Work: $21,460*
- *Cap Construction: $77,895*
- *Institutional Controls: $30,000*
- *Indirect Capital Costs: $43,860*
- *Contingency (20%): $25,800*

Estimated Annual O&M Costs: $12,500 - 35,000
Estimated Present Worth: $329,000
Implementation Time Frame: Less Than 1 Year

The remedy components for Alternative 2 include engineering controls and institutional controls to address hexavalent chromium concentrations in the vadose zone above a concentration of 1.0 mg/kg at the M&C and NCC facilities. The components include:

- A 3-foot thick multilayered cap constructed of a 1 foot thick soil layer over a compacted clay layer. The cap size is estimated to be 850 square yards at the M&C facility and 2,733 square yards at the NCC facility.
- Annual site monitoring and maintenance to ensure the integrity of the cap construction and 5-year site reviews.

- Institutional controls on the future use of the property to eliminate the possible installation of a nearby septic leach field or other construction activity on the cap area that would reduce the effectiveness of the cap. The entity responsible for implementing the property easement is uncertain at each of the facilities; since the M&C facility is abandoned with no identified owner, either a future purchaser of the property or Ector County would be required to the file the property easement; at the NCC facility, EPA has required the issuance of a warrant to gain access to the property to perform the CERCLA emergency removal action and future cooperation is uncertain.
- Ground water monitoring would be conducted under the ground water remedy.

The purpose of the cap is to reduce rain water infiltration that has the potential to further leach hexavalent chromium from the vadose zone to the underlying ground water. Operation and maintenance activities would consist of repairs to the cap resulting from vandalism or unauthorized trenching activities. The long-term reliability of the constructed cap is uncertain since the area is located at a potential industrial facility with no current mechanism to implement an institutional control to maintain the integrity of the alternative. While the cap would be effective in reducing any potential leaching in the vadose zone, the inability to either implement or enforce an institutional control raises the uncertainty as to long-term effectiveness and reliability of the alternative. Failure to maintain the cap effectiveness would jeopardize the restoration of the ground water.

The available land use at each facility would continue to be for industrial/light commercial operations. Site use above and surrounding the cap would be limited to protect the integrity of the cap as described by the institutional control. Since there is no cleanup level to be achieved with the installation of the alternative, the facility would be available for reuse following installation of the cap.

VZ Alternative 3: Vadose Zone Flushing

Estimated Capital Cost: $624,000
- *Site Work: $239,400*
- *Infiltration Galleries: $165,725*
- *Indirect Capital Costs: $137,700*
- *Contingency (20%): $81,000*

Estimated Annual O&M Costs: $35,000 - 56,000
Estimated Present Worth (7%): $1,072,000
Estimated Time for Implementation: Less Than 1 Year
Estimated Time to Reach Remedial Goals: 25 Years

The remedy components for Alternative 3 include treatment to remove hexavalent chromium in those areas of the vadose zone above a concentration of 1.0 mg/kg at the M&C and NCC facilities. The components include:

- Installation of an infiltration gallery to flush water downward through the soils to leach the hexavalent chromium from the soils. Infiltration galleries consist of slotted pipes installed below the ground surface similar to a septic system drain field.
- This alternative would be coupled with a ground water extraction system to capture and remove the chromium.
- Ground water monitoring would be conducted under the ground water remedy.

Key ARARs applicable to this alternative include any contaminated soil that may be excavated during installation of the infiltrations galleries and subsequently disposed at an off-site location. The potential ARARs include the Federal Resource Conservation and Recovery Act (RCRA) for the identification and listing of hazardous waste (40 CFR Part 261), the RCRA Land Disposal Restrictions (40 CFR Part 268) for disposal of the hazardous waste, and the RCRA standards applicable to generators of hazardous waste (40 CFR Part 262) for reporting and manifesting when transporting hazardous waste.

This alternative would provide long-term effectiveness and permanence since the contaminants flushed from the vadose zone would be treated by removal along with the extracted ground water. The system would make use of the steady supply of treated water from a ground water extraction system to accelerate the flushing of the hexavalent chromium. The vadose zone would continue to be flushed until ground water monitoring indicated that there was a reduction in chromium below the drinking water standard. Operation and maintenance activities would focus on potential scaling problems inside the piping.

The available land use at each facility would continue to be for industrial/light commercial operations. Future site use could also include septic leach fields. Since there is no surface cleanup level that has to be achieved, the facility would be available for reuse following installation of the infiltration gallery

VZ Alternative 4: Vadose Zone Flushing with Excavation of Hot Spots and Off-Site Disposal

Estimated Capital Cost: $930,000
  Site Work: $425,400
  Infiltration Galleries: $178,140
  Indirect Capital Costs: $205,360
  Contingency (20%): $102,800
Estimated Annual O&M Costs: $35,000 - 56,000
Estimated Present Worth (7%): $1,378,000
Estimated Time for Implementation: Less Than 1 Year
Estimated Time to Reach Remedial Goals: Less Than 25 Years

This alternative is the same as Alternative 3 except that soils to a depth of 10 feet below the ground surface would be excavated to remove local hot spots containing high chromium concentrations prior to the installation of an infiltration gallery. Removing the most contaminated soil would reduce the time frame required for remediation by both eliminating the need to flush these contaminants to the ground water table, and reducing the volume of the vadose zone for cleanup. For the purposes of developing the cost estimate, 10 percent of the soils were assumed to be contaminated and would be disposed of off-site at a RCRA hazardous waste Subtitle C facility. The CERCLA Off-Site Disposal Policy directs that CERCLA wastes may only be disposed in a regulated landfill that is in compliance with all environmental laws. The policy is applicable to the selected remedy because the wastes generated from the treatment of the contaminated ground water will be disposed at an off-Site facility.

COMPARATIVE ANALYSIS OF ALTERNATIVES

CERCLA § 121(b) presents several factors that at a minimum EPA is required to consider in its assessment of alternatives. Building upon these specific statutory mandates, the NCP articulates nine evaluation criteria to be used in assessing the individual remedial alternatives.

A detailed analysis was performed on the alternatives using the nine evaluation criteria in order to select a site remedy. The nine criteria are divided into two threshold criteria: (1) overall protection of human health and the environment, and (2) compliance with applicable or relevant and appropriate requirements (ARARs); five balancing criteria: (3) long-term effectiveness and permanence, 4) reduction of toxicity, mobility, or volume of contaminants through treatment, (5) short-term effectiveness, (6) implementability, and (7) cost; and two modifying criteria: (8) State acceptance and (9) community acceptance.

1. Overall Protection of Human Health and the Environment

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls.

All of the alternatives, except the no-action alternatives, are protective of human health and the environment by eliminating, reducing, or controlling risks posed by the Site through treatment of the contaminated ground water, flushing of the soils, engineering controls, and/or institutional controls. Ground water alternative 2 is protective of human health by controlling the contaminant plume migration and reducing contaminant concentrations through pumping and treating the ground water, and providing an alternative water supply to those residences affected by the current contaminant plume. Alternative 2 provides protection to current users of the ground water and protects against exposure to residences outside the limits of the contaminant plume.

Vadose zone alternatives 3 and 4 would provide long-term protection by flushing the chromium contamination into the active ground water extraction system to ensure the ground water restoration efforts are successful. The protection against future ground water contamination increases with vadose alternatives 3 and 4 as the treatment processes decrease the potential for future leachate generation. Vadose zone alternative 2 would provide adequate protection by reducing potential infiltration through the soils. However, perpetual cap maintenance and enforcement of institutional controls would be required to ensure total protectiveness. Any breach in the cap would potentially allow infiltration to mobilize chromium from the vadose zone, potentially after the ground water restoration efforts were successful.

2. Compliance with Applicable, Relevant, and Appropriate Requirements (ARARs)

CERCLA § 121(d) and NCP § 300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs", unless such ARARs are waived under CERCLA § 121(d)(4).

Applicable requirements are those substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address hazardous substances, the remedial action to be implemented at the site, the location of the site, or other circumstances present at the site. Only those State standards that are more stringent than Federal requirements may be relevant and appropriate. Relevant and appropriate requirements are those substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law which, while not applicable to the hazardous materials found at the site, the remedial action itself, the site location or other circumstances at the site, nevertheless address problems or situations sufficiently similar to those encountered at the site that their use is well-suited to the site.

Compliance with ARARs addresses whether a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for a invoking waiver.

The Selected Remedy will attain the respective Federal and State ARARs associated with the drinking water standards for ground water. Acquisition of permits will not be necessary for on-site treatment operations or the use of injection wells or infiltration galleries for the disposal of treated ground water. The use of injection wells or infiltration galleries are granted an exemption under RCRA Section 3020(b) and the Underground Injection Control Regulations (40 CFR § 141.13). Management of hazardous wastes generated during the remedial action will achieve the RCRA requirements for waste characterization (40 CFR Part 261), reporting and manifesting hazardous waste for off-site disposal (40 CFR Part 262), and the disposal of hazardous waste subject to the Land Disposal Restrictions (40 CFR Part 268).

3. Long-term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk and the adequacy and reliability of controls.

The ground water alternative 2 would remove the threat of direct exposure by achieving the long-term goal of restoring the ground water to drinking water standards. The long-term effectiveness of the ground water extraction system in removing chromium contaminated ground water from the Trinity aquifer has been demonstrated at the Odessa I and II Superfund Sites. Restoring ground water quality by attaining drinking water standards in a reasonable time frame is expected at the Sprague Road Ground Water Plume Site based on the similar site characteristics and contaminants. Areas of high chromium concentration beneath the NCC facility may require a longer time frame to achieve the drinking water standard.

The vadose zone alternatives 3 and 4 provide the greatest degree of long-term effectiveness and permanence with the removal of contaminants from the vadose zone ensuring that the ground water restoration efforts are successful. Alternative 2 provides a lesser degree of effectiveness and permanence since chromium contamination in the vadose zone remains unaddressed without treatment. The long-term effectiveness of alternative 2 is questionable because of the uncertainties associated with the long-term integrity of the cap and the enforcement of the institutional controls.

Reviews at least every five years, as required, would be necessary to evaluate the effectiveness of any of these alternatives until hazardous substances are reduced to levels that prevent unlimited use and unrestricted exposure.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Ground water alternative 2 utilizes treatment to remove the contaminants of concern from the ground water to achieve drinking water standards throughout each of the contaminant plumes. The alternative would also contain further plume migration until the drinking water standards are achieved.

Vadose zone alternatives 3 and 4 would reduce the volume of the contaminants in the vadose zone by flushing the contaminants to the ground water. Implementation of either alternative 3 or 4 concurrently with a ground water extraction system, would allow the flushed contaminants to be extracted and treated at the treatment plant, thus reducing the contaminants' toxicity and mobility. Alternative 3 also includes the off-site disposal of an increased volume of contaminated soil. Off-site disposal of the soil is less preferable than treatment at the site. Alternative 2 would only reduce mobility of the contaminants beneath the cap by controlling infiltration to the vadose zone.

5. **Short-term Effectiveness**

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers and the community during construction and operation of the remedy until cleanup goals are achieved.

The length of time needed for construction of the extraction and injection well system, associated piping, and the treatment plant(s) for ground water alternative 2 is approximately one year. The length of time necessary to reach the ground water remedial goals has been estimated at 20 -25 years, though a shorter time frame was achieved at the Odessa I and II sites. After the water is treated to remove the chromium, the water is either injected back into the aquifer or allowed to infiltrate downward through the soil to the aquifer. These reinjection systems will be located on or adjacent to the facility property. While some water will be lost during the treatment process, the majority of the water will be returned to the aquifer to generally maintain the water table within the immediate area. Residences are not expected to have any loss in utility of their wells. Nearby residences would not be exposed to the hazardous substances recovered by the ground water treatment plant(s). During the remedial design phase of alternative 2, the installation of the water supply lines would proceed within the area.

All of the vadose zone alternatives, except for the no action alternative, pose a potential risk to construction workers during the excavation of soil and the installation of the cap or the infiltration galleries. Potential risks to workers are from exposure to chromium contaminated soil and dust. However, air monitoring and dust suppression would control the potential for exposure and prevent off-site movement to nearby residences. Workers would be required to wear appropriate levels of protection to avoid exposure during excavation. The transport of contaminated soil to an off-site disposal facility would pose some degree of risk to nearby residences. The use of properly sealed trailers would prevent dust from blowing off of the excavated soil. The length of time needed for construction of the vadose alternatives is estimated at less than 6 months.

6. Implementability

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

All of the alternatives are equally implementable without construction difficulties. The presumptive treatment technologies for contaminated ground water are proven treatment methods that can be installed at the site with minimal impacts. Operation and maintenance of the treatment system would include the collection and off-site disposal of the chromium sludge from the chemical precipitation or electrochemical system or the off-site regeneration of the ion exchange cells. The selection of a treatment system will be addressed during the remedial design. The installation of injection and extraction wells can be performed with locally available labor and materials. Installation of the water supply lines and water lines to and from the wells within existing right-of-ways would require coordination with the City of Odessa and Ector County. Some administrative issues requiring resolution involve access to adjacent property surrounding the three facilities for the installation of wells or pipelines.

Construction of the cap for vadose zone alternative 2 is relatively straightforward and the materials for construction are readily available. The ability to impose institutional controls to restrict land use is uncertain because of the absence of a land owner for the M&C and LM facilites, and an uncooperative land owner for the NCC facility. Installation of the infiltration gallery for alternatives 3 and 4 is also relatively straightforward and the materials for construction are readily available. Operation and maintenance would include cleaning or replacing any clogged or damaged lines.

7. Cost

Cost includes estimated capital and operation and maintenance costs as well as present worth costs. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent.

The present worth cost for ground water alternative 2 is \$20,102,000. The present worth costs for vadose zone alternatives 3and 4 are more than double the cost for vadose zone alternative 2 at \$1,072,000 and \$1,378,000 versus \$329,000, respectively. Integration of the vadose zone alternative 3 or 4 with the preferred ground water alternative may offer some cost savings by providing a disposal method for the treated ground water.

8. State/Support Agency Acceptance

The State of Texas concurs on the Selected Remedy (Appendix A).

9. **Community Acceptance**

EPA did not receive comments from the community in support of, or in opposition to, the preferred alternative identified in the Proposed Plan. The main issues raised during the public comment period were directed toward the potential impacts to continued usage of the private wells in the area and how the preferred remedy would impact the ground water quality in the uncontaminated private wells. These issues were incorporated into the ground water modeling performed during the Feasibility Study and will continue to be a part of the objectives during the Remedial Design phase of the project.

PRINCIPAL THREAT WASTE

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (NCP § 300.430(a)(1)(iii)(A)). The "principal threat" concept is applied to the characterization of "source materials" at a Superfund site. A source material includes materials that contain high concentrations of hazardous substances, pollutants, or contaminants that are highly toxic or highly mobile that act as a reservoir for migration of contamination to ground water, surface water, or air or acts as a source for direct exposure. At this Site, the vadose zone soils do not contain a concentrated source of hexavalent chromium that would act as an ongoing source of ground water contamination due to infiltration from rainfall. As a result, the residual contamination in the vadose zone soils is not classifiable as either a principal or low level threat waste. Contaminated ground water generally is not considered to be a source material, unless there is a separate phase liquid present in the ground water. At this Site, the chromium contamination occurs as a dissolved phase in the ground water and is not classfiable as either a principal or low-level threat waste. As a result, there are no source materials that meet the definition of a principal threat waste. While the ground water and vadose zone contamination is not considered a principal threat waste, and there were no other principal threats identified at the Site following the emergency removal action, the selected remedy does utilize treatment as a principal element.

SELECTED REMEDY

Summary of the Rationale for the Selected Remedy

The selected remedy for the Sprague Road Ground Water Plume Site includes ground water alternative 2, Ground Water Extraction and Treatment, and vadose zone alternative 3, Vadose Zone Flushing. The selected remedy is a comprehensive remedial strategy which controls the ground water plume migration, reduces the contaminant concentrations to achieve the remedial action goals, and utilizes source reduction to ensure the long-term restoration of the ground water under future land-use scenarios. Ground water alternative 2 is preferred because of the demonstrated success of the strategy in achieving the remedial goals and objectives while preventing further exposure to the contaminants. Vadose zone alternative 3 was preferred over the other alternatives based on the removal of contaminants to allow for future site reuse without requiring the transportation of large volumes of soil to an off-site disposal facility. In addition, alternative 3 can be incorporated into the disposal system for the treated ground water.

Description of the Selected Remedy

The selected ground water remedy will achieve the remedial action objectives of: 1) preventing exposure to contaminated ground water, above acceptable risk levels; 2) preventing or minimizing further migration of the ground water contaminant plume; and 3) returning ground waters to their expected beneficial uses wherever practicable. The selected vadose zone remedy will achieve the remedial action objective of preventing or minimizing further migration of contaminants from source materials to ground water by flushing the chromium from the soils for capture and removal by the ground water extraction system. The selected remedy consists of the following components:

- Installation of ground water extraction wells at each of the three ground water contaminant plumes. The extraction wells will be installed throughout the contaminant plumes to establish hydraulic containment of the contaminant plumes to prevent further migration and maximize contaminant removal to achieve the remedial goals. The estimated number and location of extraction wells is based on ground water modeling of the Site and includes 4 wells at the M&C facility, 8 wells at the LM facility, and 10 wells at the NCC facility. The final number and location of extraction wells would be determined during the remedial design based on revised modeling to incorporate additional data on aquifer parameters and contaminant migration.
- Installation of underground, double-walled piping to convey the contaminated ground water to a treatment plant. A leak detection system will be installed to detect the accidental release of contaminated water from the piping due to breakage or other failure in the lines.
- Installation of one or more treatment plant(s) to be located at the facilities. The location and number of treatment plants will be determined during the remedial design phase based on the relative cost-effectiveness of combining plant operations, length of piping from various well locations, differences in estimated cleanup time frames for each plume, etc. The treatment component of this ground water alternative would utilize presumptive technologies identified in EPA's ground water presumptive strategy, "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites," October 1996, OSWER Directive Number 9283.1-12. Since the primary contaminants of concern are chromium and potentially other metals, one or more of the presumptive technologies - chemical precipitation, ion exchange/adsorption, or electrochemical methods - would be used for treating the contaminants in the extracted

ground water. The actual technologies and sequence of technologies used for the treatment system would be determined during remedial design.

- The precipitate or sludge wastes generated during the treatment process would be transported to an off-site location for disposal in accordance with the Resource Conservation and Recovery Act (RCRA) requirements.
- Installation of underground, single wall piping to convey the treated water from the treatment plant(s) to injection wells or infiltration galleries.
- The treated water would be injected back into the aquifer using one or a combination of injection wells screened in the aquifer, dry wells screened in the vadose zone, or infiltration galleries installed within a few feet of the surface. The injection system will maintain the general water table to ensure the conservation of the resource and enhance the flushing of the aquifer for contaminant removal. The current cost estimate is based on the use of a total of 8 injection wells located at the M&C facility (2 wells), LM facility (3 wells), and NCC facility (3 wells). The use of one or more of these options and the number and location of injection wells/infiltration galleries would be determined during the remedial design.
- Installation of infiltration galleries over the original source areas to flush the residual hexavalent chromium from the soils downward to the ground water. The treated water from the ground water extraction system will be used as the flushing agent. Leachate monitoring of the vadose zone will be performed to evaluate the quantity of chromium being removed and the overall effectiveness of the system in meeting the remedial action objective.
- Ground water monitoring will be performed to evaluate both the effectiveness of the system as well as ensure that there is no exposure to contaminants above the drinking water limits.

Based on predictive ground water modeling, the expected cleanup time frame may extend from 20 to 25 years. However, the cleanup time frames for the Odessa I and II Sites has generally been less than 10 years. Remedy refinements may be needed during the life of the remedy. Such adjustments may include adjusting the number and location of extraction wells, adjusting the pumping rate, etc. A contingency included in the selected remedy is the use of certain chemicals, such as ferrous sulfate, to chemically alter the mobile hexavalent chromium to the immobile trivalent chromium in either the ground water or vadose zone soils. The effectiveness of such reagants would be limited to areas on the facility with higher chromium concentrations. The ground water extraction system would be used to prevent off-site migration and the use of the ground water monitored until conditions return to drinking water quality.

The ex-situ treatment component of the ground-water remedy will utilize presumptive technologies identified in *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (EPA 540-R-96-023, October 1996), included as Appendix B of the ROD. Since the primary contaminant of concern is chromium, one or more of the presumptive technologies - chemical precipitation, ion exchange/adsorption, or electrochemical methods - will be used for treating aqueous contaminants in the extracted ground water. Chemical precipitation chemically converts dissolved metals in water such as chromium into an insoluble precipitate or sludge. Ion exchange replaces dissolved metals in water with non-toxic ions as the water passes over an impregnated resin. Electrochemical processes use electrical current applied between two electrodes to attract the dissolved metals in water forming a precipitate or sludge. The actual technologies and sequence of technologies used for the treatment system would be determined during the remedial design. Final selection of these technologies will be based on additional site information to be collected during the remedial design. Additional information concerning presumptive technologies for the ex-situ treatment component of the remedy is provided in Appendices D5 through D8, and advantages and limitations of each of these technologies are listed in Appendix C4. (See Section 3.4 and Appendix C3 of EPA 540-R-96-023 for a discussion of site information needed for selection and design of the ex-situ treatment system.).

Based on this additional information and sound engineering practice the treatment system shall be designed to reduce the chromium concentration in the extracted water to 0.1 mg/L or less. In addition, since the predicted time frames for restoration of the separate ground water plumes is different, the treatment plant should be able to be easily modified to treat the expected flow decrease as individual extraction wells are shut down. Other design factors shall include the following:

- Maximizing long-term effectiveness.
- Maximizing long-term reliability (*i.e.*, minimize the likelihood of process upsets).
- Minimizing long-term operating costs.

For the purpose of estimating the approximate cost of the treatment component of the selected remedy, the use of ion exchange units is assumed for removing chromium from the ground water.

Summary of the Estimated Remedy Costs

The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the selected remedy. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the Administrative Record file, an Explanation of Significant Differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost. The present worth costs for the selected remedies using a 7% discount factor is $20,102,000 for the ground water remedy and $1,072,000 for the vadose zone remedy.

CAPITAL COST ESTIMATE FOR THE GROUND WATER REMEDY

Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Mobilization	lump sum	$400,000	1	$400,000
Extraction/Injection Well Network				
• Extraction Wells (6" diameter, 140' depth)	each	$14,000	22	$308,000
• Pumps and Controls	each	$6,00	22	$132,000
• Extraction Pipeline (double wall)	linear feet	$30	12,000	$360,000
• Extraction Pipeline (installation)	linear feet	$30	12,000	$360,000
• Leak Detection System	lump sum	$20,000	1	$20,000
• Injection Wells (48" diameter, 30' depth)	each	$35,000	9	$315,000
• Injection Pipeline (single wall)	linear feet	$5.50	6,000	$33,000
• Injection Pipeline (installation)	linear feet	$30	6,000	$180,000
• Manholes	each	$2,500	24	$60,000
• Lift Stations	each	$2,00	12	$24,000
Treatment Facility				
• Site Preparation	acres	$1,000	2	$2,000
• Building (50' x 100')	lump sum	$250,000	1	$250,000
• Utilities	lump sum	$30,000	1	$30,000
• Tanks	lump sum	$215,000	1	$215,000
• Pumps	lump sum	$370,000	1	$370,000
• Ion Exchange Resin Beds	each	$210,000	2	$420,000
• Instruments and Controls	lump sum	$100,000	1	$100,000
• Equipment Installation	lump sum	$300,000	1	$300,000
• Equipment Shipping	lump sum	$100,000	1	$100,000
Subtotal				$3,979,000
Indirect Costs				
• Field Indirect	lump sum	2%	1	$79,580
• Supervision, Inspection, Overhead	lump sum	4%	1	$159,160
• Contractor Profit	lump sum	10%	1	$397,900
• Contractor Bonds	lump sum	5%	1	$198,950
• Design	lump sum	10%	1	$397,900
• Resident Engineering	lump sum	3%	1	$119,370
• Contingency	lump sum	20%	1	$795,800
Total Capital Costs				$6,128,000

ANNUAL O&M COST ESTIMATE FOR THE GROUND WATER REMEDY
YEARS 1 -20

Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Extraction/Injection Well Network				
• Well Maintenance (22 extraction wells, 9 injection wells)	each	$1,000	31	$31,000

ANNUAL O&M COST ESTIMATE FOR THE GROUND WATER REMEDY
YEARS 1 -20

Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Treatment Facility				
• System Performance Monitoring (influent and effluent)	each	$500	52	$26,000
• Chemicals for Resin Regeneration	lump sum	$100,000	1	$100,000
• Carbon Change Out	lump sum	$10,000	1	$10,000
• Filter Replacement	lump sum	$2,000	1	$2,000
• Resin Replacement	lump sum	$100,000	1	$100,000
• Sludge Disposal	lump sum	$54,00	1	$54,000
• Labor	lump sum	$275,000	1	$275,000
• Electricity	lump sum	$90,000	1	$90,000
Extraction Well Monitoring	each	22	$400	$8,800
Monitoring Wells (quarterly sampling)	each	200	$400	$80,000
Subtotal				$867,000
Indirect Costs	lump sum	19%	1	$164,730
Contingency	lump sum	20%	1	$173,400
Total O&M Costs				$1,205,100
Five Year Review Costs	lump sum	$21,000	4	$48,400

ANNUAL O&M COST ESTIMATE FOR THE GROUND WATER REMEDY
YEARS 21 -25

Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Extraction/Injection Well Network				
• Well Maintenance (15 extraction wells, 7 injection wells)	each	$1,000	22	$22,000
Treatment Facility				
• System Performance Monitoring (influent and effluent)	each	$500	52	$26,000
• Chemicals for Resin Regeneration	lump sum	$80,000	1	$80,000
• Carbon Change Out	lump sum	$10,000	1	$10,000
• Filter Replacement	lump sum	$2,000	1	$2,000
• Resin Replacement	lump sum	$80,000	1	$80,000
• Sludge Disposal	cubic yard	$44,000	1	$44,000
• Labor	lump sum	$275,000	1	$278,000
• Electricity	lump sum	$90,000	1	$80,000
Extraction Well Monitoring	each	22	$400	$8,800

ANNUAL O&M COST ESTIMATE FOR THE GROUND WATER REMEDY YEARS 21 -25				
Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Monitoring Wells (quarterly sampling)	each	200	$400	$80,000
Subtotal				$867,000
Indirect Costs	lump sum	19%	1	$150,000
Contingency	lump sum	20%	1	$158,000
Total O&M Costs				$1,098,000
Five Year Review Costs	lump sum	$21,000	1	$21,000

CAPITAL COST ESTIMATE FOR THE VADOSE ZONE REMEDY				
Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Mobilization	lump sum	$35,000	1	$35,000
Site Work				
• Excavate Soil	cubic yard	$5.00	5400	$27,000
• Stabilize Building Foundations	lump sum	$2,500	2	$5,000
• Off-Site Soil Disposal	cubic yard	$200	540	$108,000
• Soil Transportation	cubic yard	$60	540	$32,400
• Waste Characterization	each	$250	108	$27,000
• Air Monitoring	lump sum	$2,500	2	$5,000
Construct Infiltration Gallery				
• Sand Layer	cubic yard	$25	1800	$45,000
• Gravel Layer	cubic yard	$23	610	$14,000
• Slotted PVC Pipe	linear foot	$6.50	14,000	$91,000
• Geotextile Filter Fabric	square foot	$1.25	3,950	$5,000
• Backfill	cubic yard	$2.50	3,010	$7,525
• Piezometers	each	$200	6	$1,200
• Manholes	each	$2,000	2	$2,000
Subtotal				$405,000
Indirect Costs				
• Field Indirect	lump sum	2%	1	$8,100
• Supervision, Inspection, Overhead	lump sum	4%	1	$16,200
• Contractor Profit	lump sum	10%	1	$40,500
• Contractor Bonds	lump sum	5%	1	$20,250
• Design	lump sum	10%	1	$40,500
• Resident Engineering	lump sum	3%	1	$12,150
• Contingency	lump sum	20%	1	$81,000
Total Capital Costs				$624,000

ANNUAL O&M COST ESTIMATE FOR THE VADOSE ZONE REMEDY
YEARS 1 -25

Description of Direct Costs	Units	Unit Cost	Quantity	Cost
Maintenance	lump sum	$25,000	1	$25,000
Indirect Costs	lump sum	19%	1	$4,750
Contingency	lump sum	20%	1	$5,000
Total O&M Costs				$35,000
Five Year Review Costs	lump sum	$21,000	4	$21,000

Expected Outcomes of the Selected Remedy

The expected outcome of the selected remedy is for the contaminated ground water to return as a suitable supply of drinking water and no longer pose a threat to the surrounding uncontaminated areas. Because the aquifer under the Site currently supplies drinking water and is classified as a Class IB aquifer, a current source of drinking water, MCLs established under the Safe Drinking Water Act are ARARs. The following remedial goals for the chemicals of concern in the ground water are based on the corresponding MCLs: 0.1 mg/L for chromium; and 0.007 mg/L for 1,1-dichloroethene. Periodic assessments of the protection afforded by remedial actions will be made as the remedy is being implemented and at the completion of the remedial action. Approximately 20 to 25 years are estimated as the amount of time necessary to achieve the goals consistent with the use of the ground water as a drinking water supply.

The remedial goals identified in the ROD must be met at the completion of the remedial action throughout the three separate groundwater contaminant plumes. The current plume boundaries originating from the LM, NCC, and M&C facilities are illustrated in Figures 6, 7, and 8. Compliance will be demonstrated by applying statistical evaluations to the contaminant concentrations in individual wells that have previously exceeded the remedial goals.

It is anticipated that the selected remedy will also provide socio-economic and community revitalization impacts such as the availability of the abandoned properties will be made available for reuse upon completion of the treatment system and soil flushing system. Installation of the treatment systems is expected to be completed within two to three years.

STATUTORY DETERMINATIONS

The remedial action selected for implementation at the Sprague Road Ground Water Plume Superfund Site is consistent with CERCLA and, to the extent practicable, the NCP. The selected remedy is protective of human health and the environment, will comply with ARARs and is cost effective. In addition, the selected remedy utilizes permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable, and satisfies the statutory preference for treatment that permanently and significantly reduces the mobility, toxicity or volume of hazardous substances as a principal element.

Protection of Human Health and the Environment

The selected remedy at this Site will protect human health and the environment by eliminating, reducing or controlling exposures through treatment and engineering controls. To address the immediate risks to users of the ground water, water supply lines from the City of Odessa will be extended to those residences with wells containing chromium above the Federal drinking water standards. By pumping and treating the contaminated ground water, the selected remedy will prevent further migration of the contaminant plumes to unaffected users of the ground water. Long-term operation of the ground water extraction system will reduce the chromium concentrations in the ground water below the protective Federal drinking water standards (ARARs) and return the ground water to its full beneficial use. Integration of the soil flushing system with the ground water extraction system will remove the soil as a long-term threat to the restoration efforts of the ground water. Implementation of the selected remedy will not pose any unacceptable short-term risks or cause any cross-media impacts.

Compliance with Applicable or Relevant and Appropriate Requirements

The selected remedy complies with those Federal and State requirements that are applicable or relevant and appropriate for this remedial action.

Chemical-Specific ARARs

- Federal Safe Drinking Water Act (SDWA), Maximum Contaminant Levels, Maximum Contaminant Level Goals, and Action Levels (40 CFR Part 141): These regulations specify primary drinking water standards for public water supply systems. These requirements are relevant and appropriate to ground water used for drinking water by residences with private water supply wells.
- Federal Resource Conservation and Recovery Act (RCRA), Identification and Listing of Hazardous Waste (40 CFR Part 261): These regulations define those solid wastes that are subject to regulation as hazardous waste. The requirements are applicable to solid wastes generated during the treatment of contaminated ground water which may be classified as a hazardous waste, if they exhibit any RCRA characteristics.
- Federal Resource Conservation and Recovery Act (RCRA), Land Disposal Restrictions (40 CFR Part 268): These regulations identify hazardous wastes that are restricted from land disposal, the timetable and any exceptions for implementing these restrictions, and the treatment standards for hazardous waste

to meet the land disposal restrictions. The requirements are applicable to hazardous wastes generated from the treatment of the contaminated ground water. Hazardous wastes generated from the treatment process will disposed at an off-site location.

Action-Specific ARARs

- Federal Resource Conservation and Recovery Act (RCRA), Section 3020(b), exempts from the ban on underground injection of treated contaminated ground water into or above an underground source of drinking water if the following three conditions are met: 1) the injection is a CERCLA response action or a RCRA corrective action; 2) contaminated ground water must be treated to substantially reduce hazardous constituents prior to such injection; and 3) the response action or corrective action must be sufficient to protect human health and the environment upon completion. Injections wells will be utilized to return treated ground water to the aquifer as part of the ground water extraction and treatment system.
- Federal Safe Drinking Water Act (SDWA), Underground Injection Control Regulations (40 CFR § 141.13): These regulations provide exemptions to wells used to inject contaminated ground water that has been treated and is being reinjected in the same formation from which it was withdrawn. Injections wells will be utilized to return treated ground water to the aquifer as part of the ground water extraction and treatment system.
- Federal Resource Conservation and Recovery Act (RCRA), Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262): These regulations define the requirements for reporting and manifesting when transporting hazardous waste. The requirements are applicable to hazardous wastes generated from the treatment of the contaminated ground water. Hazardous wastes generated from the treatment process will disposed at an off-site location.

To Be Considered Criteria

- EPA Memorandum dated April 6, 1981, Procedures for Rounding-Off Analytical Data to Determine Compliance with Maximum Contaminant Levels Present in NIPDWR (National Interim Primary Drinking Water Regulations), from Joseph A. Cotruvo, Director, Criteria and Standards Divison, Office of Drinking Water, to Water Supply Representatives, Regions I - X, and holders of Water Supply Guidance Series: This memorandum states that data that contains digits beyond the significant digit contained in the National Interim Primary Drinking Water Regulations should be rounded-off by dropping the digits that are not significant. For this Site, the MCL for chromium is 0.1 mg/L, yet, the laboratory analysis for ground water samples is capable of providing results with two additional significant digits. For purposes of determining when the remedial goals have been achieved at the compliance point, laboratory data reported as 0.100 mg/L to 0.149 mg/L for chromium will rounded off to 0.1 mg/L. Chromium data reported as 0.150 mg/L to 0.199 mg/L will be rounded off to 0.2 mg/L.

- *Methods for Evaluating the Attainment of Cleanup Standards, Volume 2: Ground Water* (EPA 230-R-92-014, July 1992): In implementing the selected ground water remedy, the reference document provides a variety of standard statistical methods that may be useful in evaluating the uncertainty of whether the ground water cleanup remedial goals for a Site have been met.
- *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (OSWER Directive 9283.1-12, October 1996): The objective of a presumptive remedy guidance is to use the Superfund program's past experience to streamline site investigations and speed up selection of cleanup actions. The guidance document provides a presumptive response strategy applicable to the ground water contamination as well as the applicable treatment technologies for the contaminants of concern at this site.

Cost Effectiveness

The selected remedy is cost-effective and represents a reasonable value for the money to be spent. In making this determination, the following definition was used: "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." [NCP § 300.430 (f) (1) (ii) (D)]. This was accomplished by evaluating the "overall effectiveness" of those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment and ARAR-compliant). The overall effectiveness of the remedy is determined by evaluating three of the five balancing criteria used in the detailed analysis of the alternatives: (1) long-term effectiveness and permanence; (2) reduction in toxicity, mobility, and volume through treatment; and (3) short-term effectiveness. Overall effectiveness was then compared to costs to determine cost-effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs and hence this alternative represents a reasonable value for the money to be spent.

The estimated present worth costs of the selected remedies are $20,102,000 for the ground water component and $1,072,000 for the vadose zone component. The "no action" alternative for the ground water was not protective of human health and the environment or ARAR-compliant. Although alternative 2 (Cap) for the vadose zone is $743,000 less expensive, the chromium contamination in the vadose zone will remain a long-term threat to the ground water restoration efforts, and therefore the selected remedy is cost-effective. The additional cost for the vadose zone remedy provides a significant increase in protection of human health and the environment. The selected remedy for the vadose zone will provide an overall level of protection comparable to Alternative 4 (Flushing and Excavation) at a lower cost.

Utilization of Permanent Solutions and Alternative Treatment (or Resource Recovery) Technologies to the Maximum Extent Practicable

The selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the Site. Of those alternatives that are protective of human health and the environment and comply with ARARs, EPA has determined that the selected remedy provides the best balance in terms of the five balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against off-site treatment and disposal and considering State and community acceptance.

While there were no principal or low-level threats identified at the three facilities comprising the Site, the selected remedy satisfies the criteria for long-term effectiveness by removing chromium from the ground water and from the soil that poses a long-term threat to the restoration efforts for the ground water. The selected remedy does not present short-term risks different from the other treatment alternatives. There are no special implementability issues that sets the selected remedy apart from any of the other alternatives evaluated.

Preference for Treatment as a Principal Element

While the ground water and vadose zone contamination is not considered a principal threat waste, and there were no other principal threats identified at the Site following the emergency removal action, the selected remedy does utilize treatment as a principal element. By utilizing treatment technologies to remove the chromium from the ground water, the selected remedy addresses the risk posed by the Site. By utilizing treatment as a significant portion of the remedy, the statutory preference for remedies that employ treatment as a principal element is satisfied.

Five-Year Review Requirements

Upon completion of the remedy, no hazardous substances will remain within the Site above levels that prevent unlimited use and unrestricted exposure. However, because this remedy will require greater than five years to achieve these levels, pursuant to CERCLA § 121 (c) and as provided in the current guidance on Five Year Reviews [OSWER Directive 9355.7-02, *Structure and Components of Five-Year Reviews* (May 23, 1991), OSWER Directive 9355.7-02A, *Supplemental Five-Year Review Guidance* (July 26, 1994), OSWER Directive 9355.7-03A, the *Second Supplemental Five-Year Review Guidance* (December 21, 1995), OSWER Directive 9355.7-03B-P, the draft *Comprehensive Five-Year Review Guidance* (October 1999),] EPA will conduct a policy five-year review until the cleanup levels are achieved.

DOCUMENTATION OF SIGNIFICANT CHANGES

The Proposed Plan for the Site was released for public comment on July 27, 2000. The Proposed Plan identified Alternative 2, Ground Water Extraction and Treatment, and Alternative 3, Vadose Zone Flushing, as the preferred alternatives for the ground water remediation. EPA did not receive comments from the community in support of, or in opposition to, the preferred alternative identified in the Proposed Plan. EPA determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate. A component of the Preferred Alternative was the installation of water supply lines to those residences with drinking water wells with chromium concentrations above the MCL. This component is now being addressed by EPA's emergency removal authority and is no longer a component of the Selected Remedy. The estimated costs for the remedial alternative has been amended to reflect the change in components for the alternative.

RESPONSIVENESS SUMMARY

STAKEHOLDER ISSUES AND LEAD AGENCY RESPONSES

The main issues raised during the public comment period were directed toward the potential impacts to continued usage of the private wells in the area and how the preferred remedy would impact the ground water quality in the uncontaminated private wells. The initial phase of the ground water modeling conducted during the Feasibility Study included minimizing the potential lowering of the water table in nearby private wells as well as ensuring that treated water injected back into the aquifer would not impact the surrounding private wells. These issues will continue to be a part of the objectives during the Remedial Design phase of the project.

TECHNICAL AND LEGAL ISSUES

The public comment period for the Proposed Plan began July 27, 2000, and closed on August 25, 2000. EPA received one comment by email on the Proposed Plan during the public comment period. A Public Meeting held on August 3, 2000, at the University Park Baptist Chruch in Odessa, Texas was attended by 6 people. This responsiveness summary is prepared from the email and oral comments received during the comment period. The transcript of the public meeting is a part of the Administrative Record.

1. <u>Comment:</u> How will the proposed remedy affect the water supply from wells on Apollo Street. With the drought as bad as it is, what will be the impact on the water and will the proposed remedy cause our water supply to be depleted? There has never been a problem with a good supply of water or bad water quality on Apollo Street.

   <u>Response:</u> One of the concerns is the potential effect from the proposed pumping wells on nearby private wells and the potential for lowering the ground water table. Since the homes in this area are dependent on private wells for their drinking water supply, the conservation of the ground water is an important part of the proposed ground water cleanup operation. The nearest source of contamination to residences on Apollo Street is the Machine and Casting facility. EPA's simulation for the Machine and Casting area includes 4 extraction wells distributed within the chromium plume (south of Hillmont) and along the leading edge of the plume on Mary Francis Avenue. Each of these wells would pump at a rate of 12 gallons per minute for a total flow rate of 48 gallons per minute. After this water is treated to remove the chromium, the water is either injected back into the aquifer or allowed to infiltrate downward through the soil to the aquifer. These reinjection systems will be located on the Machine and Casting facility property or immediately west of the facility along Sprague Road. Some water will be lost during the

treatment process, but the majority of the water will be returned to the aquifer. The extraction and reinjection system will generally maintain the water table within the immediate area. Residences on Apollo street are not expected to have any loss in utility of their wells because of the distance between the proposed extraction well locations and Apollo street.

2. Comment: What is in the rear of the National Chromium Corporation property?

   Response: The facility property was cleared during the 1996 removal action and the impoundment has been filled in.

3. Comment: Are the proposed remedy costs for all three sites?

   Response: The costs for the selected remedy includes all three facilities.

4. Comment: Would there be any additional costs to the residents in this area on their water bills?

   Response: The selected remedy, including the connections for homes to the City of Odessa water supply, will be paid for through the Superfund trust fund. For homes which will be connected to the City of Odessa water supply, the monthly bills for water usage will then be the responsibility of the resident.

5. Comment: Will there be any restrictions on private water well use in the area?

   Response: No; the ground water extraction system will be designed to operate within the area and will accommodate the continued operation of private wells.

6. Comment: How often will the ground water be monitored?

   Response: The initial frequency of ground water monitoring will be at least on a quarterly basis. Once the system is performing within the design specifications, the frequency will likely be reduced.

7. Comment: How will the water injected back into the aquifer affect the private wells that are still clean and can this cause any spreading of the ground water contamination?

   Response: The extraction and injection well system was modeled to create a circulation cell in the aquifer so that the water taken out of the aquifer can be treated and then used to flush additional chromium toward the extraction wells. Ground water monitoring will continue during the operation of the pump and treat system to verify that contamination is not being spread to uncontaminated areas of the aquifer.

8. Comment: What will EPA do if a private well became contaminated in the future?

   Response: Should a private well be contaminated by further migration of the chromium contaminant plume, EPA may provide a connection to the City of Odessa water supply if contaminants from the Site exceeded the drinking water limits in the private well.

9. Comment: What is the risk to those private wells between the contaminant plumes from the Machine and Casting and Leigh Metal facilities?

   Response: The private wells between the two contaminant plumes should not be impacted from the contamination. The Machine and Casting and Leigh Metal contaminant plumes are moving in a general west to east direction and the contamination is not expected to spread north or south of the current flow direction. Ground water monitoring will be used to verify that conditions in the aquifer have not changed to cause an unexpected reversal of the flow direction.

10. Comment: Will the private wells tested during the Remedial Investigation be re-tested in the future?

    Response: Only those private wells that are near the contaminant plume or are likely to be impacted from continued contaminant migration will be a part of the future monitoring program. If data collected in the future suggests that contaminant migration has changed such that additional wells are threatened, then the monitoring program would be expanded to ensure that human health remains protected at the Site.

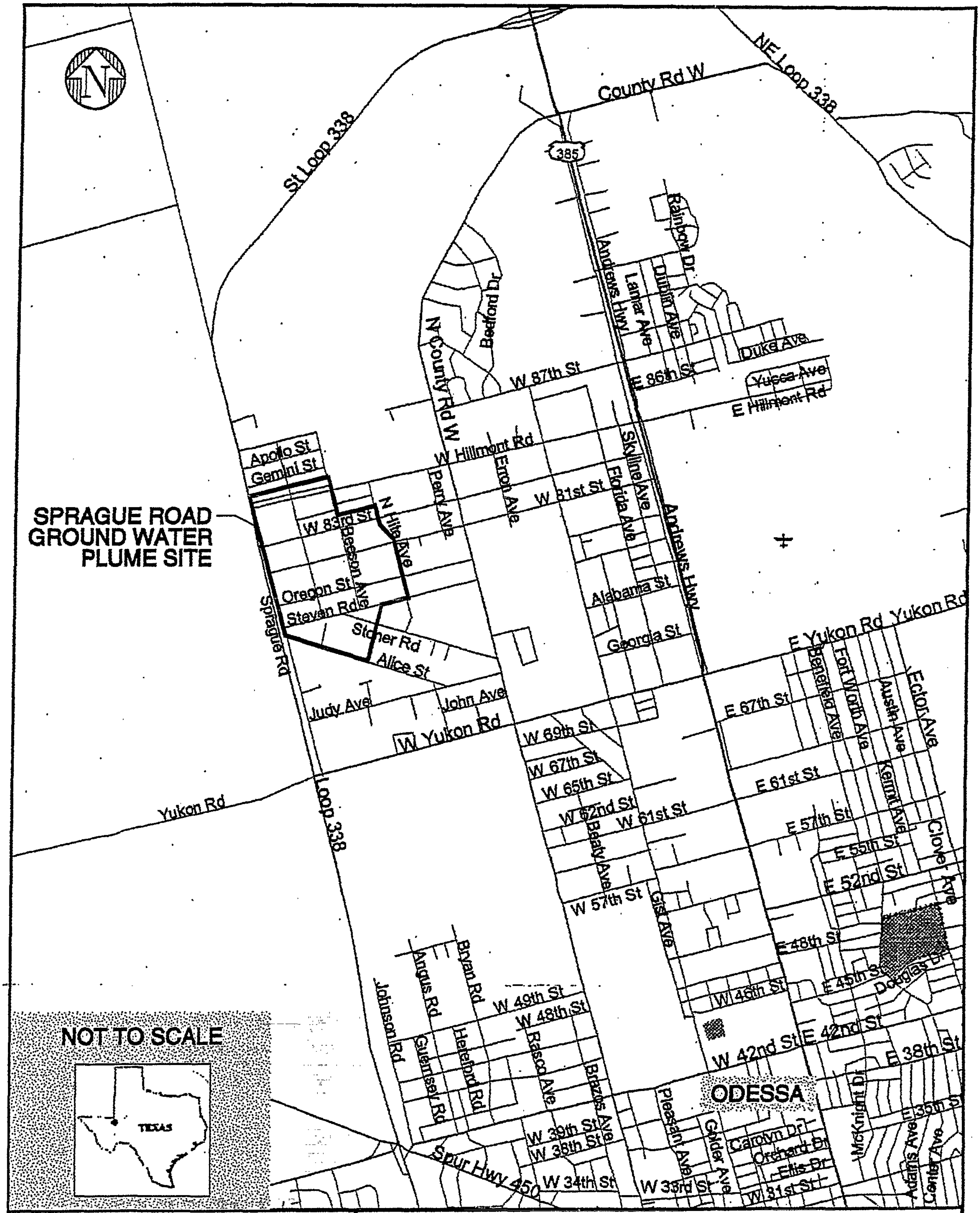
11. Comment: How will the residents stay updated on the progress of the cleanup?

    Response: EPA will continue to issue fact sheets describing the progress of the cleanup as well as host Open Houses to provide an opportunity to answer specific questions the residents may have on their well or the Site cleanup.

12. Comment: Is the rate for the City of Odessa water supply customers the same for residents inside the Odessa city limits as for those outside the city limits?

    Response: The City of Odessa rate for water usage outside the city limits is 1.5 times the rate charged for customers inside the city limits.

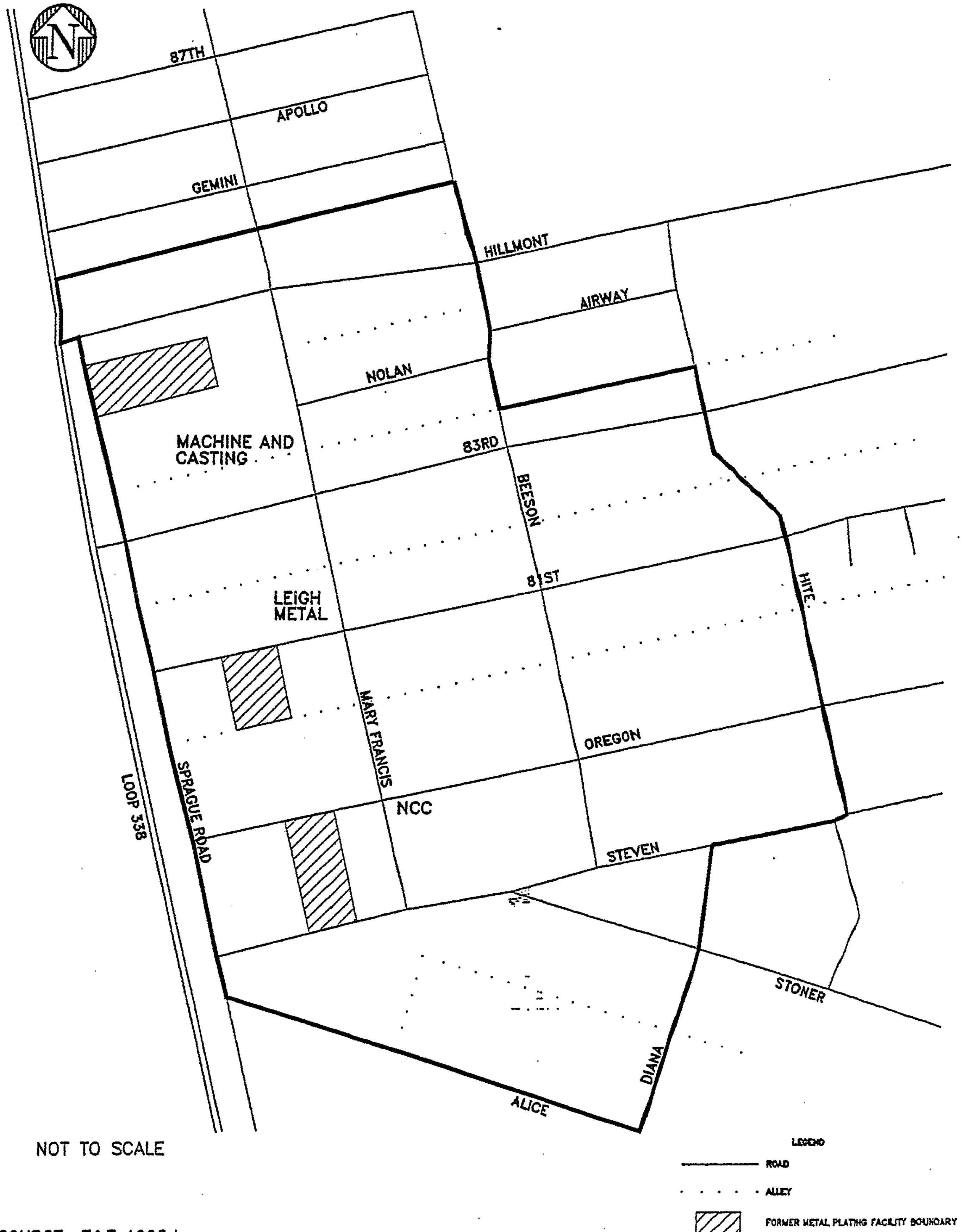
FIGURES



CDM FEDERAL PROGRAMS CORPORATION

Site Location Map
Sprague Road Ground Water Plume Site
Odessa, Texas

Figure 1

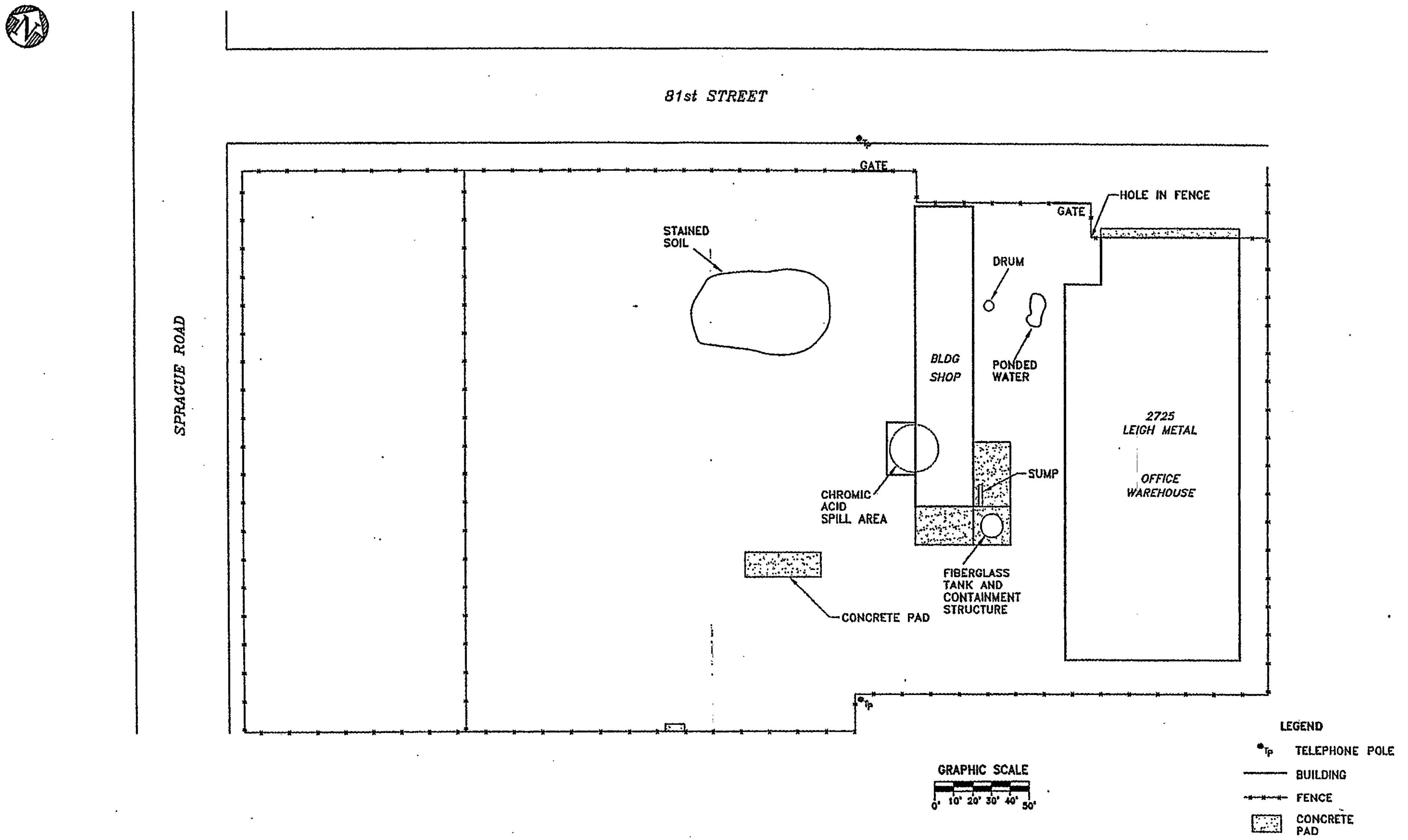


SOURCE: E&E 1996d.

CDM FEDERAL PROGRAMS CORPORATION

Locations of the Three Former Metal Plating Facilities
Sprague Road Ground Water Plume Site
Odessa, Texas

Figure 2

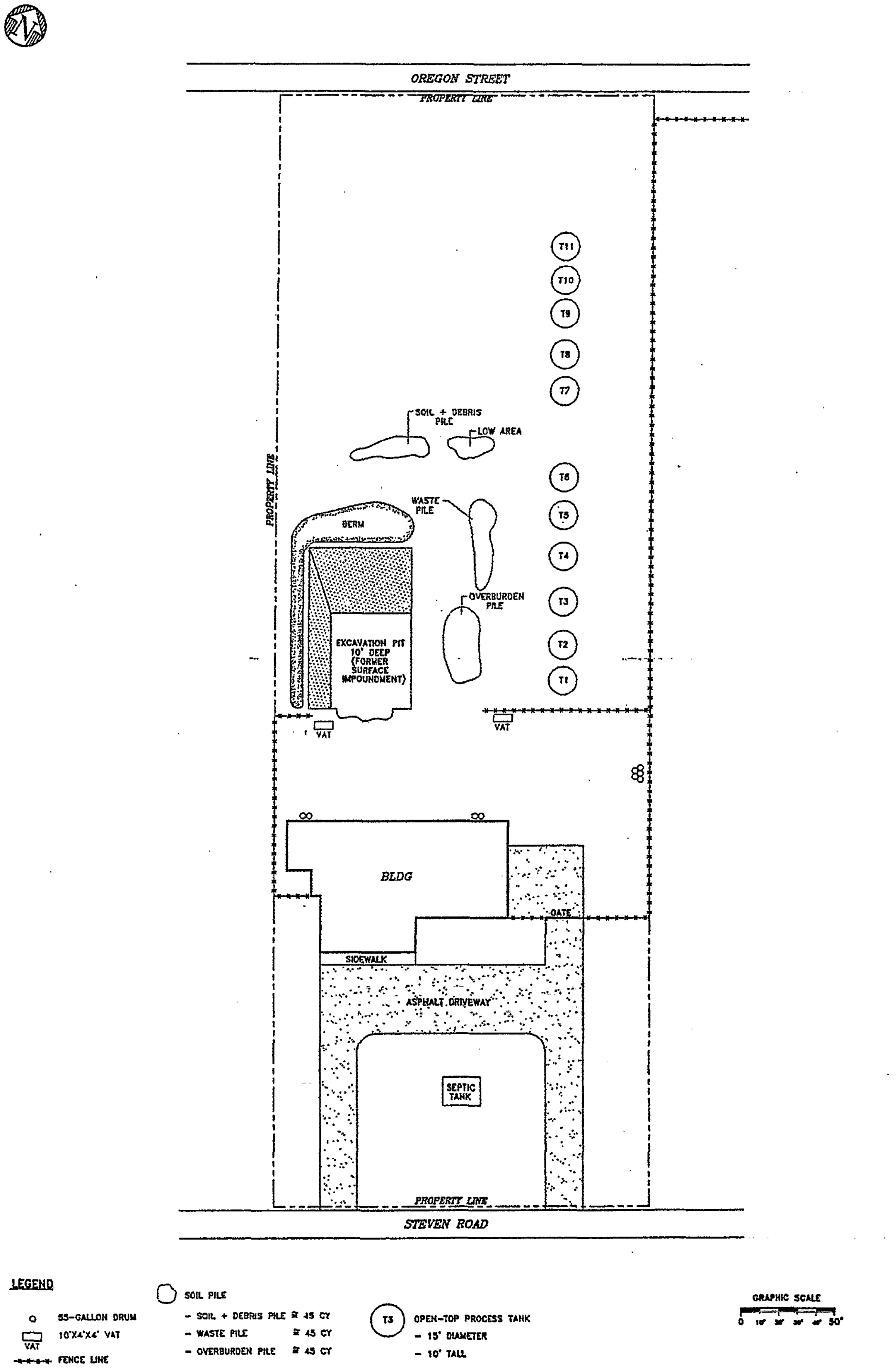


Source: E&E 1996c

CDM FEDERAL PROGRAMS CORPORATION

Figure 3

Pre-Removal Site Map
Leigh Metal Plating, Inc.
Sprague Road Ground Water Plume Site
Odessa, Texas

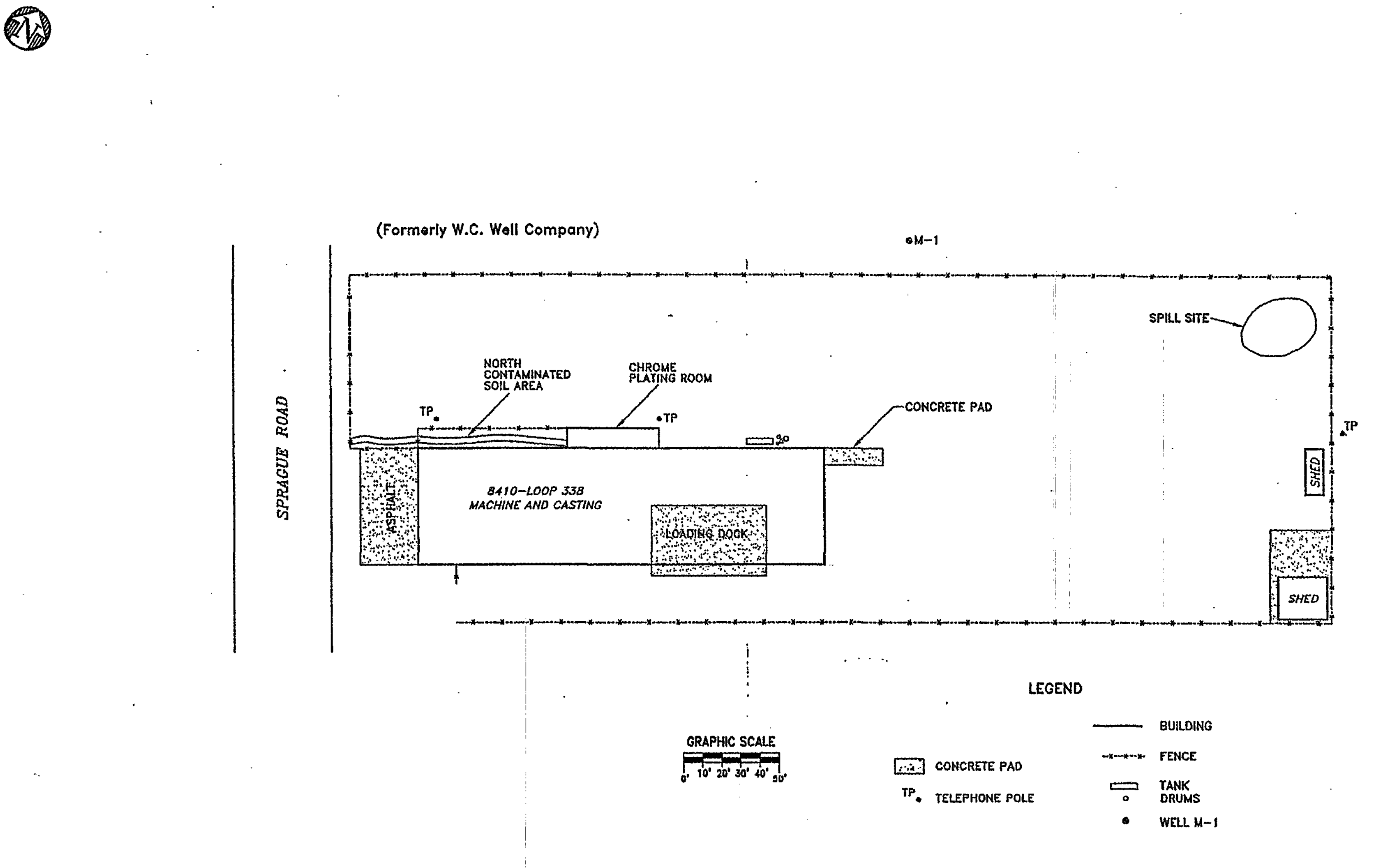


Source: E&E 1996a

CDM FEDERAL PROGRAMS CORPORATION

Figure 4

Pre-Removal Site Map
National Chromium Corporation
Sprague Road Ground Water Plume Site
Odessa, Texas



Source: E&E 1996b

CDM FEDERAL PROGRAMS CORPORATION

Figure 5

Pre-Removal Site Map
Machine and Casting, Inc.
Sprague Road Ground Water Plume Site
Odessa, Texas

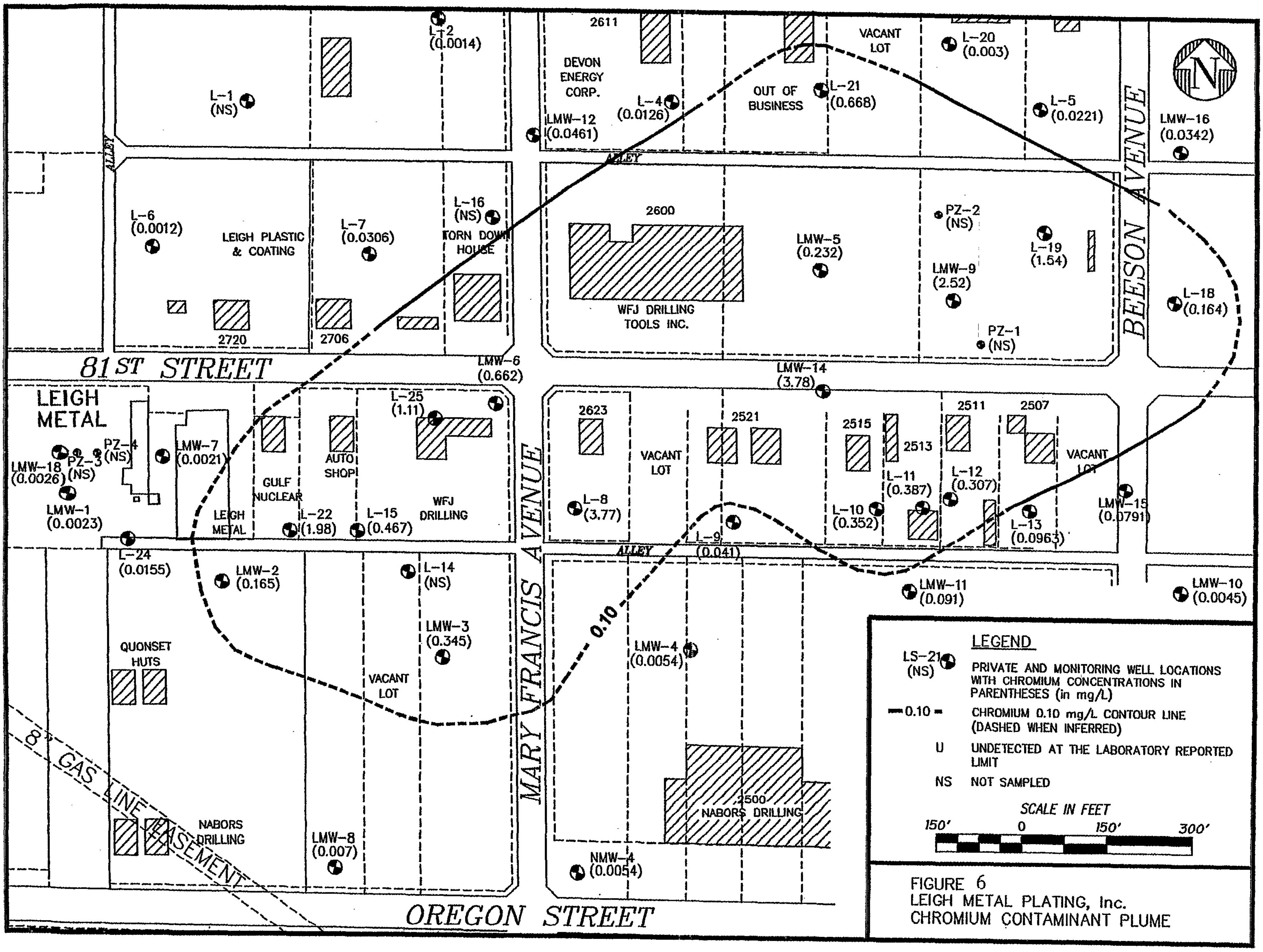


FIGURE 6
LEIGH METAL PLATING, Inc.
CHROMIUM CONTAMINANT PLUME

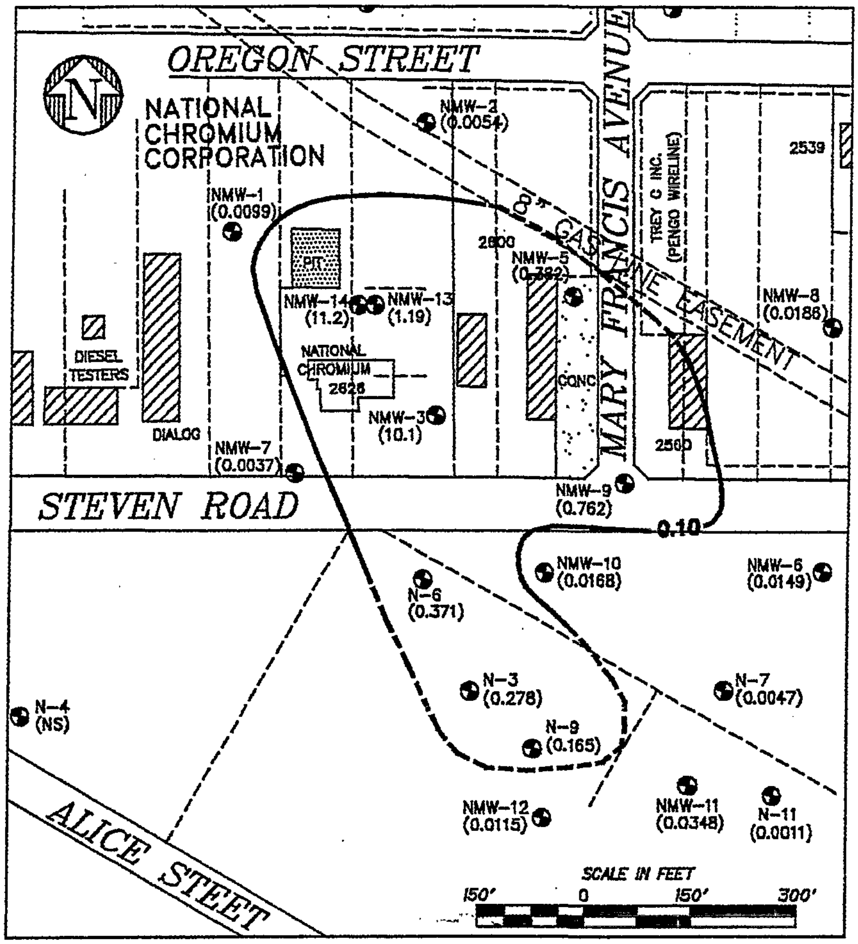
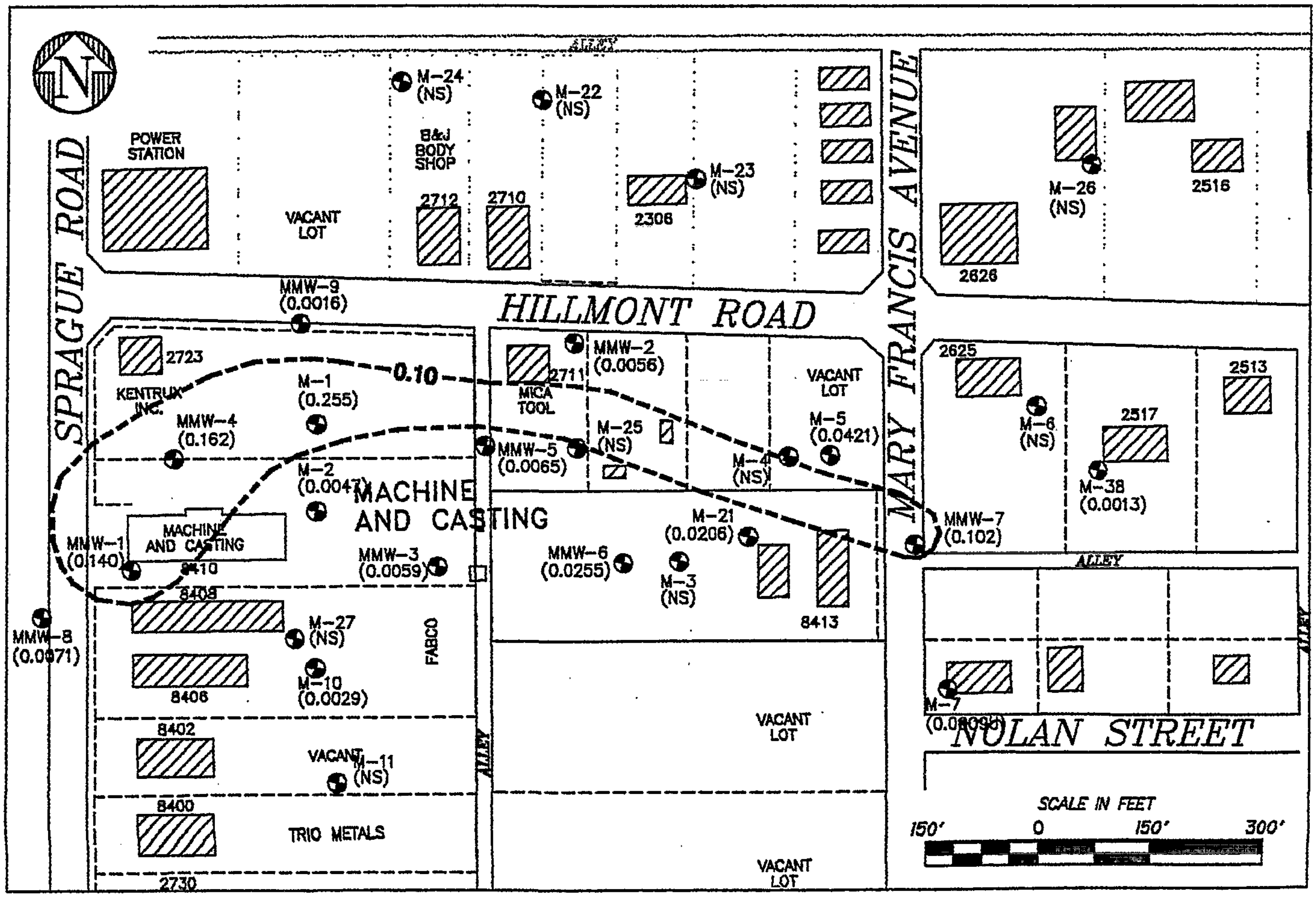


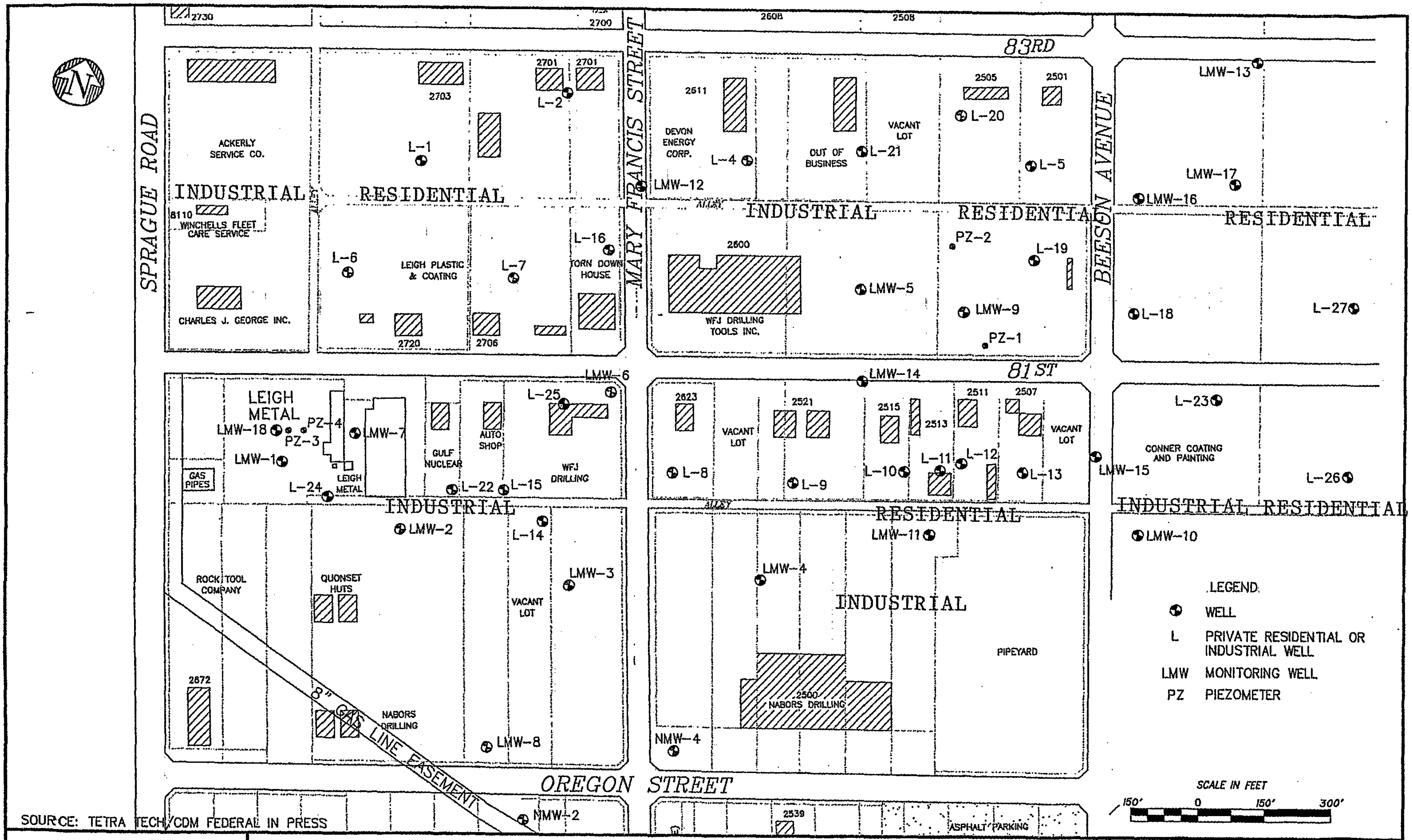
FIGURE 7 (LEFT)
NATIONAL CHROMIUM CORPORATION
CHROMIUM CONTAMINANT PLUME

LEGEND

LMW-4 (0.016) ●	PRIVATE AND MONITORING WELL LOCATIONS WITH CHROMIUM CONCENTRATIONS IN PARENTHESES (in mg/L)
— 0.10 —	CHROMIUM 0.10 mg/L CONTOUR LINE (DASHED WHEN INFERRED)
U	UNDETECTED AT THE LABORATORY REPORTED LIMIT
NS	NOT SAMPLED

FIGURE 8 (BELOW)
MACHINE AND CASTING INC.
CHROMIUM CONTAMINANT PLUME



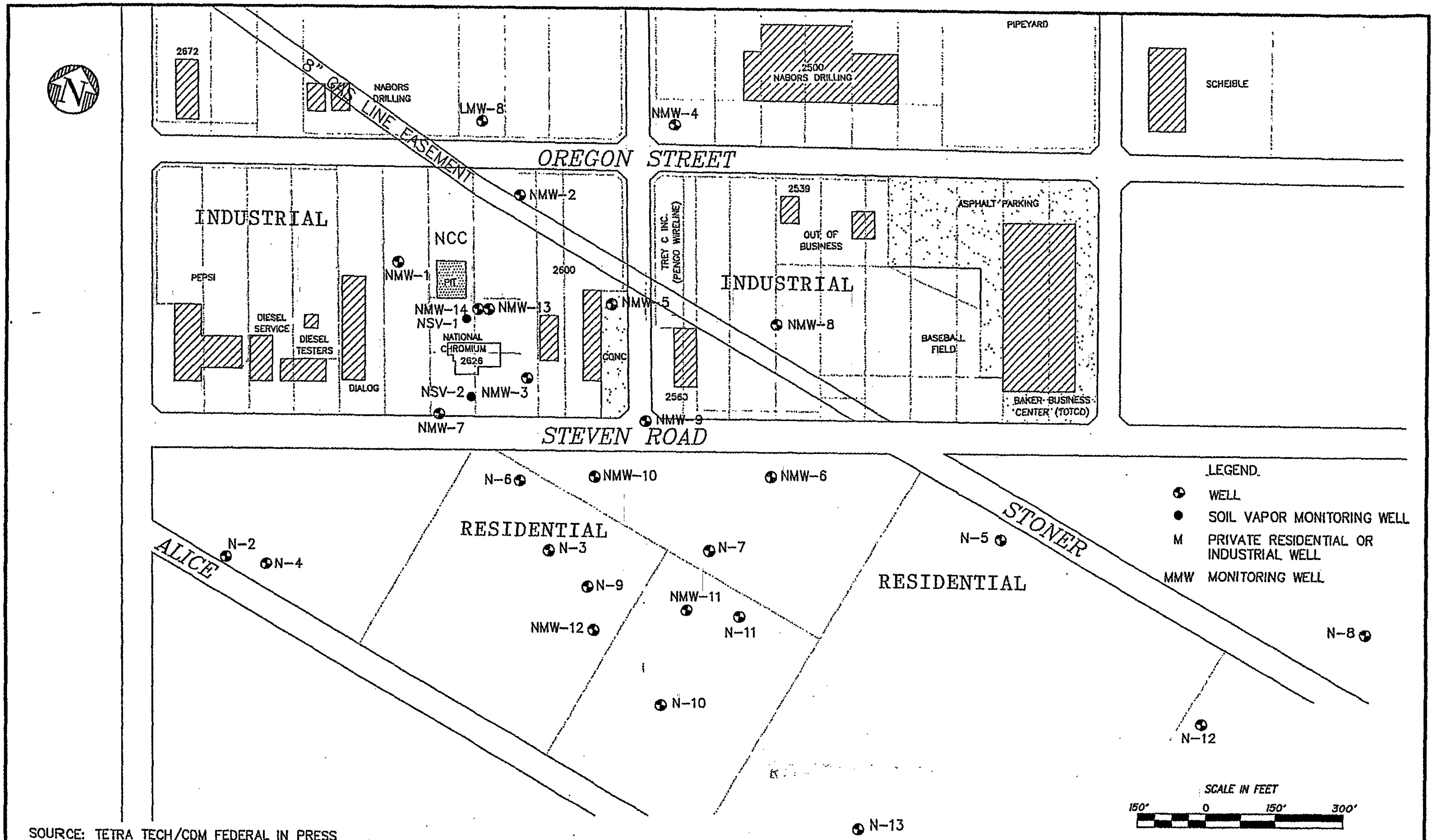


SOURCE: TETRA TECH/CDM FEDERAL IN PRESS

CDM FEDERAL PROGRAMS CORPORATION

Figure 9

Leigh Metal Plating, Inc.
Sprague Road Ground Water Plume Site
Odessa, Texas

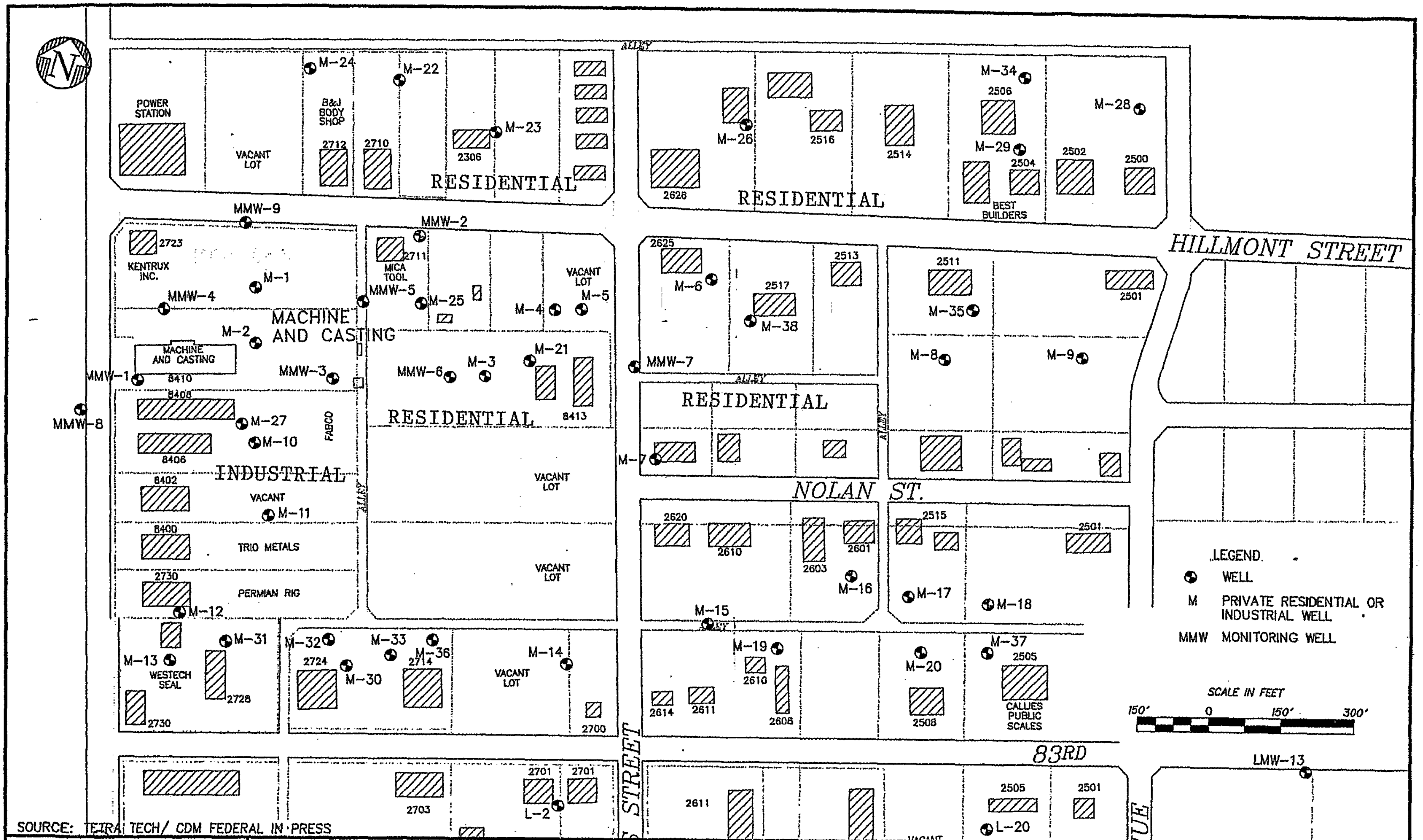


SOURCE: TETRA TECH/CDM FEDERAL IN PRESS

CDM FEDERAL PROGRAMS CORPORATION

Figure 10

National Chromium Corporation
Sprague Road Ground Water Plume Site
Odessa, Texas



SOURCE: TETRA TECH/ CDM FEDERAL IN PRESS

CDM FEDERAL PROGRAMS CORPORATION

Figure 11

Machine and Casting, Inc.
Sprague Road Ground Water Plume Site
Odessa, Texas

APPENDIX A

Robert J. Huston, *Chairman*
R. B. "Ralph" Marquez, *Commissioner*
John M. Baker, *Commissioner*
Jeffrey A. Saitas, *Executive Director*

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

Mr. Myron O. Knudson, P.E, Director
Superfund Division
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

Re: Record of Decision for Sprague Road Ground Water Plume, Federal Superfund Site
Odessa, Ector County, Texas, September 2000

Dear Mr. Knudson:

The Texas Natural Resource Conservation Commission (TNRCC) has completed its review of the above-referenced document. We concur that the response action for the Sprague Road Ground Water Plume Federal Superfund Site, Ector County, Texas, described in the September 2000 Record of Decision is the most appropriate for this site.

Sincerely,

Jeffrey A. Saitas, P.E.
Executive Director

JAS/DP/mmw

P.O. Box 13087 • Austin, Texas 78711-3087 • 512/239-1000 • Internet address: www.tnrcc.state.tx.us

APPENDIX B

Directive 9283.1-12
EPA 540/R-96/023
PB96-963508
October 1996

PRESUMPTIVE RESPONSE STRATEGY AND EX-SITU TREATMENT TECHNOLOGIES FOR CONTAMINATED GROUND WATER AT CERCLA SITES

FINAL GUIDANCE

Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

NOTICE

This document provides guidance to EPA staff. It also provides guidance to the public and to the regulated community on how EPA intends to exercise its discretion in implementing the National Contingency Plan. The guidance is designed to implement national policy on these issues. The document does not, however, substitute for EPA's statutes or regulations, nor is it a regulation itself. Thus, it cannot impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA may change this guidance in the future, as appropriate.

CONTENTS

APPENDICES

A. Additional Background Information

B. ROD Language Examples For Selected Remedy

C. Ex-Situ Treatment Technologies for Ground Water

D. Descriptions of Presumptive Treatment Technologies

FIGURES

HIGHLIGHTS

ACRONYMS USED IN THIS GUIDANCE

ACL	Alternate Concentration Limit
ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by SARA
CERI	Center for Environmental Research Information
CFR	Code of Federal Regulations
CSGWPP	Comprehensive State Ground Water Protection Program
DNAPL	Dense Nonaqueous Phase Liquids
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
FS	Feasibility Study
GAC	Granular Activated Carbon
LNAPL	Light Nonaqueous Phase Liquids
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NAPL	Nonaqueous Phase Liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated Biphenyl Compounds
POTW	Publicly Owned Treatment Works
RARA	Resource Conservation and Recovery Act
RD	Remedial Design
RD/RA	Remedial Design/Remedial Action
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SACM	Superfund Accelerated Cleanup Model
SARA	Superfund Amendments and Reauthorization Act of 1986
UV	Ultra Violet (light)
VOC	Volatile Organic Compound

PREFACE

Presumptive Remedies Initiative. The objective of the presumptive remedies initiative is to use the Superfund program's past experience to streamline site investigations and speed up selection of cleanup actions. Presumptive remedies are expected to increase consistency in remedy selection and implementation, and reduce the cost and time required to clean up similar types of sites. The presumptive remedies approach is one tool within the Superfund Accelerated Cleanup Model (SACM) (EPA, 1992d).

Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation. Refer to EPA Directive, *Presumptive Remedies: Policy and Procedures* (EPA, 1993d) for general information on the presumptive remedy process and issues common to all presumptive remedies. This directive should be reviewed before utilizing a presumptive remedy and for further information on EPA expectations concerning the use of presumptive remedies. **"Presumptive remedies are expected to be used at all appropriate sites,"** except under unusual site-specific circumstances (EPA, 1993d).

Other Presumptive Remedy Guidance. Previous fact sheets from EPA's Office of Solid Waste and Emergency Response (OSWER) have established presumptive remedies for municipal landfill sites (EPA, 1993f), for sites with volatile organic compounds in soils (EPA, 1993e) and for wood treater sites (EPA, 1995g). A presumptive response selection strategy for manufactured gas plant sites is under development. Additional fact sheets are in progress for sites contaminated with polychlorinated biphenyl compounds (PCBs), metals in soils and for grain storage sites.

Relation of this Guidance to Other Presumptive Remedies. The fact sheets mentioned above provide presumptive remedies (or a strategy for selecting remedies) for "source control" at specific types of sites. With respect to ground-water response, source control refers to containment or treatment of materials that may leach contaminants to ground water, or a combination of these approaches. In general, treatment is expected for materials comprising the principal threats posed by a site, while containment is preferred for low level threats (EPA, 1991c). Where contaminants have reached ground water and pose an unacceptable risk to human health or the environment, a ground-water remedy will generally be required in addition to the source control remedy and this guidance should be consulted.

Instead of establishing one or more presumptive remedies, this guidance defines a **presumptive response strategy**. EPA expects that some elements of this strategy will be appropriate for **all** sites with contaminated ground water and all elements of the strategy will be appropriate for many of these sites. In addition, this guidance identifies **presumptive technologies** for the ex-situ treatment component of a ground-water remedy, that are expected to be used for sites where extraction and treatment is part of the remedy. (The term presumptive technology is used in this guidance to denote only the ex-situ treatment component of a ground-water remedy.) Other remedy components could include methods for extracting ground water, enhancing contaminant recovery or degradation of contaminants in the subsurface, discharging treated water, preventing contaminant migration, and institutional or engineering controls to prevent exposure to contaminants.

Applicability to RCRA Corrective Action Program. EPA continues to seek consistency between cleanup programs, especially in the process of selecting response actions for sites regulated under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund program) and corrective measures for facilities regulated under the Resource Conservation and Recovery Act (RCRA). In general, even though the Agency's presumptive remedy guidances were developed for CERCLA sites, they should also be used at RCRA Corrective Action sites to focus RCRA Facility Investigations, simplify evaluation of remedial alternatives in the Corrective Measures Study, and influence remedy selection in the Statement of Basis. For more information refer to the RCRA Corrective Action Plan (EPA, 1994c), the proposed Subpart S regulations (Federal Register, 1990b), and the May 1, 1996 RCRA Corrective Action Advance Notice of Proposed Rulemaking (Federal Register, 1996).

Use of this Guidance. The **presumptive response strategy** , described in Section 2.1, integrates site characterization, early actions, remedy selection, performance monitoring, remedial design and remedy implementation activities into a comprehensive, overall response strategy for sites with contaminated ground water. By integrating these response activities, the presumptive strategy illustrates how the Superfund Accelerated Cleanup Model (SACM) can be applied to ground-water cleanup. Although this response strategy will not necessarily streamline the remedial investigation/feasibility study (RI/FS) phase, EPA expects that use of the presumptive strategy will result in significant time and cost savings for the overall response to contaminated ground water. By providing a mechanism for selecting achievable remediation objectives, the presumptive strategy will minimize the need for changing these objectives during remedy implementation. By optimizing the remedy for actual site conditions during implementation, the effectiveness of the selected remedy can be greatly increased, which will reduce the time and cost required to achieve remediation objectives.

The **presumptive technologies** for treating extracted ground water, identified in Section 3.1, are the technologies that should generally be retained for further consideration in the Detailed Analysis portion of the feasibility study (or in the remedial design as explained in Section 3.3.3). This guidance and its associated Administrative Record will generally constitute the Development and Screening of Alternatives portion of the feasibility study (FS) for the ex-situ treatment component of a ground-water remedy (see Section 3.3.2). In this respect, the presumptive technologies will streamline the FS for this component of a ground-water remedy in the same way that other "presumptive remedies" streamline the FS for the overall remedy for their respective site types (see EPA, 1993d).

1.0 INTRODUCTION

In implementing the Superfund and other remediation programs, cleanup of contaminated ground water has proven to be more difficult than anticipated. For many sites, the program expectation of returning ground waters to their beneficial uses (see Section 1.2.1) often requires very long time periods and may not be practicable for all or portions of the site. Thus, the ultimate cleanup goal for ground water may need to be different over different areas of the site (see Section 1.3.1). For sites where achieving the ultimate goal will require a long time period, interim remediation objectives will generally be appropriate, such as preventing further plume migration. **Therefore, a critical first step in the remedy selection process is to determine the full range of remedial objectives that are appropriate for a particular site.**

This guidance is intended to emphasize the importance of using site-specific remedial objectives as the focus of the remedy selection process for contaminated ground water. Those remedy components that influence attainment of remedial objectives should receive the greatest attention. For example if restoring the aquifer to beneficial use is the ultimate objective, remedy components that influence attainment of cleanup levels in the aquifer include: methods for extracting ground water, enhancing contaminant recovery, controlling subsurface contaminant sources (e.g., nonaqueous phase liquids or NAPLs, discussed in Appendix A1) or in-situ treatment of contaminants. **Some or all of these remedy components should be included in remedial alternatives that are developed and evaluated in detail in the feasibility study (FS) when aquifer restoration is a remedial objective.**

Although the technologies employed for treating extracted ground water and the types of discharge for the treated effluent are important aspects of a remedy, they have little influence on reducing contaminant levels or minimizing contaminant migration in the aquifer. In developing this guidance, historical patterns of remedy selection and available technical information were reviewed in order to identify presumptive technologies for ex-situ treatment of ground water. **By providing presumptive technologies, this guidance attempts to streamline selection of these technologies and shift the time and resources employed in remedy selection to other, more fundamental aspects of the ground-water remedy.**

Although extraction and treatment has been and will continue to be used as part of the remedy for many sites with contaminated ground water, it may **not** be the most appropriate remediation method for all sites or for all portions of a given contaminant plume. Also, remedial alternatives that combine extraction and treatment with other methods, such as natural attenuation (defined in Section 2.6.5) or in-situ treatment, may have several advantages over alternatives that utilize extraction and treatment alone (see Section 2.4.2). (Remedial alternatives are evaluated against remedy selection criteria defined in the National Contingency Plan at §300.430(e)(9)(iii) (Federal Register, 1990a).) In general, the remedy selection process should consider whether extraction and treatment can achieve remedial objectives appropriate for the site and how this approach can be most effectively utilized to achieve these objectives. **This guidance also describes a presumptive response strategy which facilitates selection of both short and long-term remediation objectives during remedy selection, and allows the effectiveness of the remedy to be improved during implementation.**

1.1 Purpose of Guidance

In summary, this guidance is intended to:

- **Describe a presumptive response strategy**, at least some elements of which are expected to be appropriate for **all** sites with contaminated ground water;

- **Identify presumptive technologies** for treatment of extracted ground water (ex-situ treatment) that are expected to be used (see EPA,1993d) for sites where extraction and treatment is part of the remedy;

- **Simplify the selection** of technologies for the ex-situ treatment component of a ground-water remedy, and improve the technical basis for these selections; and

- **Shift the time and resources** employed in remedy selection from ex-situ treatment to other, more fundamental aspects of the ground-water remedy, as discussed above.

1.2 Expectations and Objectives for Ground-Water Cleanup

Careful consideration should be given to national program expectations as well as site-specific conditions when determining cleanup objectives that are appropriate for a given site.

1.2.1 Program Expectations. Expectations for contaminated ground water are stated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), as follows:

> "EPA expects to return usable ground waters to their **beneficial uses** wherever practicable, within a **timeframe** that is reasonable given the particular circumstances of the site. When restoration of ground water to beneficial uses is **not practicable** , EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction." (Federal Register, 1990a; §300.430 (a)(1)(iii)(F), emphasis added.)

The Preamble to the NCP explains that the program expectations are not "binding requirements." "Rather, the expectations are intended to share collected experience to guide those developing cleanup options" (Federal Register, 1990a; at 8702).

1.2.2 Objectives for Site Response Actions. The program expectations can be used to define the following overall objectives for site response actions, which are generally applicable for **all** sites with contaminated ground water:

- Prevent exposure to contaminated ground water, above acceptable risk levels;

- Prevent or minimize further migration of the contaminant plume (plume containment);

- Prevent or minimize further migration of contaminants from source materials to ground water (source control); and

- Return ground waters to their expected beneficial uses wherever practicable (aquifer restoration).

In this guidance the term "response action" is used to indicate an action initiated under either CERCLA removal or remedial authority. "Response objective" is the general description of what a response action is intended to accomplish. Source control is included as an objective because the NCP expectation of aquifer restoration will not be possible unless further leaching of contaminants to ground water is controlled, from both surface and subsurface sources. **The objectives, given above, are listed in the sequence in which they should generally be addressed at sites.**

Monitoring of ground-water contamination is not a separate response objective, but is necessary to verify that one or more of the above objectives has been attained, or will likely be attained (see Section 2.1.3). Other response objectives may also be appropriate for some sites, depending on the type of action being considered and site conditions (e.g., maximizing the reuse of extracted ground water may be an appropriate objective for some sites). **Response objectives may be**

different over different portions of the contaminant plume , as discussed in Section 1.3.1.

1.3 Lessons Learned

The most important lesson learned during implementation of Superfund and other remediation programs is that complex site conditions are more common than previously anticipated, including those related to the source and type of contaminants as well as site hydrogeology. As a result of these site complexities, restoring all or portions of the contaminant plume to drinking water or similar standards may not be possible at many sites using currently available technologies.

1.3.1 Sources and Types of Contaminants. Approximately 85 percent of sites on the CERCLA National Priorities List (NPL sites) have some degree of ground-water contamination. Contaminants have been released to ground water at a wide variety of site types and can include a variety of contaminants and contaminant mixtures. **Sources** of contaminants to ground water not only include facilities from which the original release occurred (e.g., landfills, disposal wells or lagoons, storage tanks and others) but also include contaminated soils or other subsurface zones where contaminants have come to be located and can continue to leach into ground water (e.g., NAPLs, see Appendix A1). Thus, the plume of contaminated ground water may encompass NAPLs in the subsurface (sources of contamination) as well as dissolved contaminants. In this case, different response objectives may be appropriate for different portions of the plume. For example, source control (e.g., containment) may be the most appropriate response objective for portions of the plume where NAPLs are present and can not practicably be removed, while aquifer restoration may be appropriate only for the remaining portions of the plume (see Section 2.5.3).

Although originating from a variety of sources, contaminants which reach ground water tend to be those that are relatively mobile and chemically stable in the subsurface environment (e.g., less likely to sorb to soil particles or degrade above the water table). Organic and inorganic contaminants most frequently found in ground water at CERCLA sites are listed in Appendix A2. Sixteen of the 20 most common organic contaminants are volatile organic compounds (VOCs). Of the 16 VOCs, 12 are chlorinated solvents and four are chemicals found in petroleum fuels. Petroleum fuels are **light** nonaqueous phase liquids (LNAPLs, with a density lighter than water); while most chlorinated solvents are **dense** nonaqueous phase liquids (DNAPLs) in pure form (see Appendix A1).

1.3.2 Factors Limiting Restoration Potential. At many sites, restoration of ground water to cleanup levels defined by applicable or relevant and appropriate requirements (ARARs) or risk-based levels may not be possible over all or portions of the plume using currently available technologies. Two types of **site conditions** inhibit the ability to restore ground water:

- Hydrogeologic factors, and
- Contaminant-related factors.

Recent studies by EPA and others have concluded that complex site conditions related to these factors are more common at hazardous waste sites than originally expected (EPA, 1989a, 1992b, 1992g, and 1993b; and the National Research Council, 1994). Examples of hydrogeologic or contaminant-related factors affecting the difficulty of restoring ground water are given in Figure 1. These types of site conditions should be considered in the **site conceptual model** , which is an interpretive summary of the site information obtained to date (**not** a computer model). Refer to EPA, 1993b and 1988a for additional information concerning the site conceptual model. **For every site, data should be reviewed or new data should be collected to identify factors that could increase (or decrease) the difficulty of restoring ground water.**

Figure 1. Examples of Factors Affecting Ground-Water Restoration Potential

Certain site characteristics may limit the effectiveness of subsurface remediation. The examples listed below are highly generalized. The particular factor or combination of factors that may critically limit restoration potential will be site specific. (Figure 1 is taken from EPA, 1993b with minor modifications.)

	Site/Contaminant Characteristics	Generalized Remediation Difficulty Scale Increasing difficulty →
Site Use	Nature of Release	Small Volume Short Duration Slug Release → Large Volume Long Duration Continual Release
Chemical Properties	Biotic/Abiotic Decay Potential	High → Low
	Volatility	High → Low
	Contaminant Retardation (Sorption) Potential	Low → High
Contaminant Distribution	Contaminant Phase	Aqueous, Gaseous → Sorbed → LNAPLs → DNAPLs
	Volume of Contaminated Media	Small → Large
	Contaminant Depth	Shallow → Deep

	Hydrogeologic Characteristics	
Geology	Stratigraphy	Simple Geology, e.g., Planar Bedding Strata → Complex Geology, e.g., Interbedded and Discontinuous
	Texture of Unconsolidated Deposits	Sand → Clay
	Degree of Heterogeneity	Homogeneous e.g., well-sorted sand → Heterogeneous e.g., interbedded sand and silts, clays, fractured media, karst
Hydraulics/Flow	Hydraulic Conductivity of Aquifer	High (>10^{-2}cm/sec) → Low (< 10^{-4}cm/sec)
	Temporal Variation of Flow Regime	Little/None → High
	Vertical Flow	Little Component → Large Downward Flow

1.3.3 Assessing Restoration Potential. Characterizing **all** site conditions that could increase the difficulty of restoring ground water is often not possible. As a result, the likelihood that ARAR or risk-based cleanup levels can be achieved (**restoration potential**) is somewhat to highly uncertain for many sites, even after a relatively complete remedial investigation. This uncertainty can be reduced by using remedy performance in combination with site characterization data to assess the restoration potential. By implementing a ground-water remedy in more than one step or phase (as two separate actions or phasing of a single action as described in Section 2.2), performance data from an initial phase can be used to assess the restoration potential and may indicate that additional site characterization is needed. In addition to providing valuable data, the initial remedy phase can be used to attain short-term response objectives, such as preventing further plume migration. Phased implementation of response actions also allows realistic long-term remedial objectives to be determined prior to installation of the comprehensive or "final" remedy.

A detailed discussion of factors to consider for assessing restoration potential is provided in *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA, 1993b; Section 4.4.4). An especially important tool for this evaluation is the site conceptual model, which should integrate data from site history, characterization and response actions. This assessment could provide justification for waiving ARARs due to technical impracticability from an engineering perspective over all or portions of a site (EPA, 1993b). It is recommended that technical assistance be enlisted from regional technical support staff or the Technical Support Project (EPA, 1994d) when evaluating technical impracticability.

Data from remedy performance are not always necessary to justify an ARAR waiver due to technical impracticability (see Section 2.6.3). At the completion of the remedial investigation (RI), site conditions may have been characterized to the extent needed for EPA (or the lead agency) to determine that ground-water restoration is technically impracticable from an engineering perspective (EPA, 1993b; EPA 1995b). For this case, an ARAR waiver request can be submitted to EPA (or the lead agency), and if approved, included in the Record of Decision (ROD). It will often be appropriate to include an ARAR waiver in the ROD for portions of a site where DNAPLs have been confirmed in the aquifer (see Section 2.5.3).

2.0 PRESUMPTIVE RESPONSE STRATEGY

2.1 Definition and Basis for Strategy

Key elements of the presumptive strategy are summarized in Highlight 1. In the presumptive response strategy, site characterization and response actions are implemented in a several steps, or in a **phased approach** . In a phased response approach, site response activities are implemented in a sequence of steps, or phases, such that information gained from earlier phases is used to refine subsequent investigations, objectives or actions (EPA, 1989a, 1992b, 1993b).

In general for sites with contaminated ground water, site characterization should be coordinated with response actions and both should be implemented in a step-by-step or phased approach.

Performance data from an initial response action are also used to assess the likelihood that ARAR or risk-based cleanup levels can be attained by later, more comprehensive actions. Although it is recognized that phased implementation may not be appropriate for all ground-water remedies, EPA expects that some elements of this strategy will be appropriate for **all** sites with contaminated ground water and that all elements will be appropriate for many of these sites. **For this reason, the response approach given in**

Highlight 1. Presumptive Response Strategy

- For sites with contaminated ground water, **site characterization should be coordinated with response actions** and both should be implemented in a phased approach (Sections 1.3.3 and 2.1).
- **Early or interim actions** should be used to reduce site risks (by preventing exposure to and further migration of contaminants) and to provide additional site data (Section 2.1.2).
- Site characterization and performance data from early or interim ground-water actions should be used to **assess the likelihood of restoring ground water** to ARAR or risk-based cleanup levels (restoration potential). (Sections 1.3.3 and 2.1.2.)
- The restoration potential should be assessed **prior to establishing objectives for the long-term remedy** (Sections 1.3.3 and 2.1.2).
- All ground-water actions should include provisions for **monitoring and evaluating their performance** (Section 2.1.3).
- Ground-water response actions, especially those using extraction and treatment, should generally be **implemented in more than one phase** -- either as two separate actions or phasing of a single action (Sections 2.2.1 and 2.2.2).
- In addition to phasing, **post-construction refinements** will generally be needed for **long-term** remedies, especially those using extraction and treatment (Section 2.3.1).

Highlight 1 is a presumptive strategy for contaminated ground water.

Also, this response strategy is considered presumptive because the **basic elements were included in <u>all</u> previous policy directives** concerning ground-water remediation from EPA's Office of Solid Waste and Emergency recommended use of a phased approach for site characterization and response actions, and more frequent use of early actions to reduce site risks. Better integration of site activities and more frequent use of early actions are also essential components of the Superfund Accelerated Cleanup Model (SACM), defined in EPA, 1992d.

2.1.1 Benefits of Phased Approach. Implementing investigations and actions in phases provides the following major **benefits**:

- Data from earlier response actions are used to further characterize the site and assess restoration potential;
- Attainable objectives can be set for each response phase;
- Flexibility is provided to adjust the remedy in response to unexpected site conditions;
- Remedy performance is increased, decreasing remediation timeframe and cost; and
- Likely remedy refinements are built into the selected remedy, better defining the potential scope and minimizing the need for additional decision documents.

2.1.2 Early Actions. "Early" refers to the timing of the start of an action with respect to other response actions at a given site. For Superfund sites, early actions could include removal actions, interim remedial actions, or early final remedial actions (EPA, 1992b and EPA, 1991b). Although initiated prior to other actions, some early ground-water actions may need to operate over a long time period (e.g., hydraulic containment actions). In this guidance the later, more comprehensive ground-water action is called the "long-term remedy, " consistent with SACM terminology (EPA, 1992e). Early actions that should be considered in response to contaminated ground water are listed in Highlight 2, categorized by response objective. **Early or interim actions should be used to reduce site risks (by preventing exposure to contaminated ground water and further migration of contaminants) and to provide additional site data.**

Factors for determining which response components are suitable for early or interim actions include: the timeframe needed to attain specific objectives, the relative urgency posed by potential or actual exposure to contaminated ground water (e.g., likelihood that contaminants will reach drinking water wells), the degree to which an action will reduce site risks, usefulness of information to be gained from the action, site data needed to design the action, and compatibility with likely long-term actions (EPA, 1992e). Whether to implement early response actions and whether to use removal or remedial authority for such actions should be determined by the "Regional Decision Team" defined under SACM (EPA, 1992f) or similar decision-making body for the site.

Early or interim actions should be integrated as much as possible with site characterization and with subsequent actions in a phased approach. Once implemented, early actions will often provide additional site characterization information, which should be used to update the site conceptual model. Also, treatability studies (see Section 3.4.5) needed for selection or design of the long-term remedy should be combined with early actions whenever practical. Site characterization and performance data from early or interim ground-water actions should be used to assess the likelihood of restoring ground water to ARAR or risk-based cleanup levels (restoration potential). **The restoration**

Highlight 2. Early Actions That Should Be Considered

Prevent exposure to contaminated ground water:

- Plume containment
- Alternate water supply
- Well head treatment
- Use restrictions

Prevent further migration of **contaminant plume**:

- Plume containment
- Contain (and/or treat) plume "hot spots"

Prevent further migration of contaminants **from sources**:

- Source removal and/or treatment
    - Excavate wastes or soils and remove from site
    - Excavate soils and treat ex-situ
    - Treat soils in-situ
    - Extract **free-phase NAPLs** (see Appendix A1)
- Source containment
    - Contain wastes or soils
    - Contain subsurface **NAPLs**

Provide additional site data:

- Assess restoration potential
- Combine actions with treatability studies

potential should be assessed prior to establishing objectives for the long-term remedy (see Section 1.3.3). **2.1.3 Monitoring.** Monitoring is needed to evaluate whether the ground-water action is achieving, or will achieve, the intended response objectives for the site (see Section 1.3.1) and other performance objectives for the action (e.g., discharge requirements). **All ground-water actions should include provisions for monitoring and evaluating their performance.** A monitoring plan should be developed for both early and long-term actions. In general, the monitoring plan should include:

- Response objectives and performance requirements for the ground-water action;
- Specific monitoring data to be collected;
- Data quality objectives;
- Methods for collecting, evaluating and reporting the performance monitoring data; and
- Criteria for demonstrating that response objectives and performance requirements have been attained.

Flexibility for adjusting certain aspects of monitoring during the life of the remedy should be included in the monitoring plan, such as changes in the monitoring frequency as the remedy progresses or other changes in response to remedy refinements (see Section 2.3.1). A detailed discussion of the data quality objectives process is provided in EPA, 1993j. Methods for monitoring the performance of extraction and treatment actions are discussed in EPA, 1994e.

2.2 Phased Response Actions

In general, ground-water response actions, especially those using extraction and treatment, should be implemented in more than one phase. There are two options for phasing response actions - implementation of two separate actions, or implementation of a single action in more than one phase. It is recognized that phased implementation may not be appropriate for all ground-water remedies. In some cases, it may be more appropriate to install the entire remedy and then remove from service those components that later prove to be unneeded.

2.2.1 Two Separate Actions. In this approach an early or interim ground-water action is followed by a later, more comprehensive action (the long-term remedy). A flow chart of this approach is given in Figure 2. Earlier ground-water actions are used to mitigate more immediate threats, such as preventing further plume migration. Response objectives for the long-term remedy are not established until after performance of the earlier action is evaluated and used to assess the likelihood that ground-water restoration (or other appropriate objectives) can be attained. Two separate decision documents are used, in which response objectives are specified that are appropriate for each action. The earlier decision document could be an Action Memorandum or an Interim Record of Decision (Interim ROD), since the early action could be initiated under either CERCLA removal or remedial authority. **This approach should be used when site characterization data are not sufficient to determine the likelihood of attaining long-term objectives (e.g., restoring ground water) over all or portions of the plume, which will be the case for many sites.** In order to provide sufficient data for assessing the restoration potential, the early or interim action may need to operate for several years.

2.2.2 Phasing of a Single Action. In this approach the long-term remedy for ground water is implemented in more than one design and construction phase. A flow chart of this approach is given in Figure 3. Response objectives for the long-term remedy are specified in a single Record of Decision (ROD) prior to implementing the remedy. Provisions for assessing the attainability of these objectives using performance data from an initial remedy phase are also included in the ROD. Thus, phased remedy implementation and assessment of remedy performance are specified in one ROD. A second decision document could still be required if evaluation of the first phase

Figure 2. Phased Ground-Water Actions: Early Action Followed by Long-Term Remedy

This approach should be used when site characterization data are not sufficient to determine the likelihood of attaining long-term objectives (e.g., restoring ground-water) over all or portions of the plume.

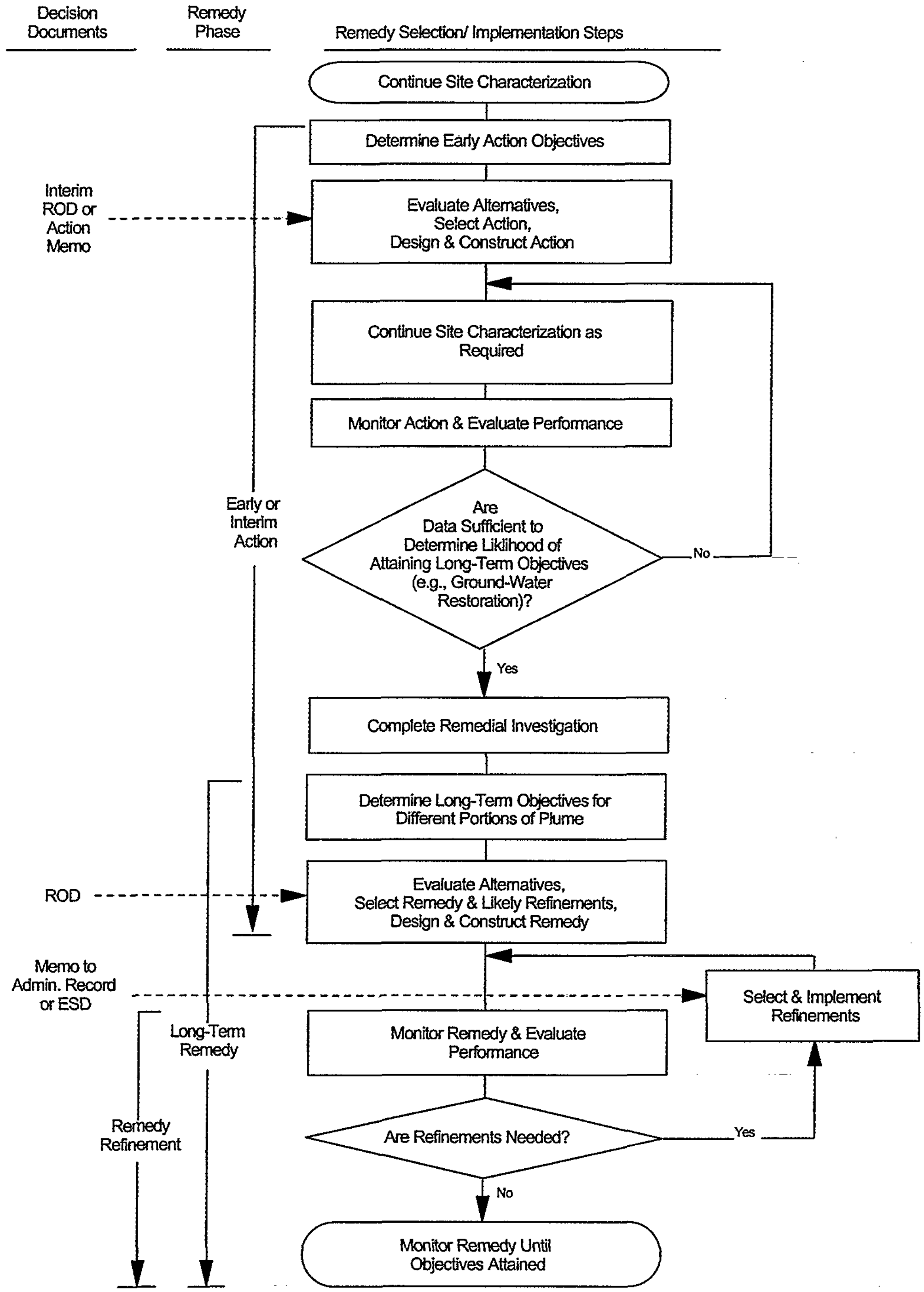
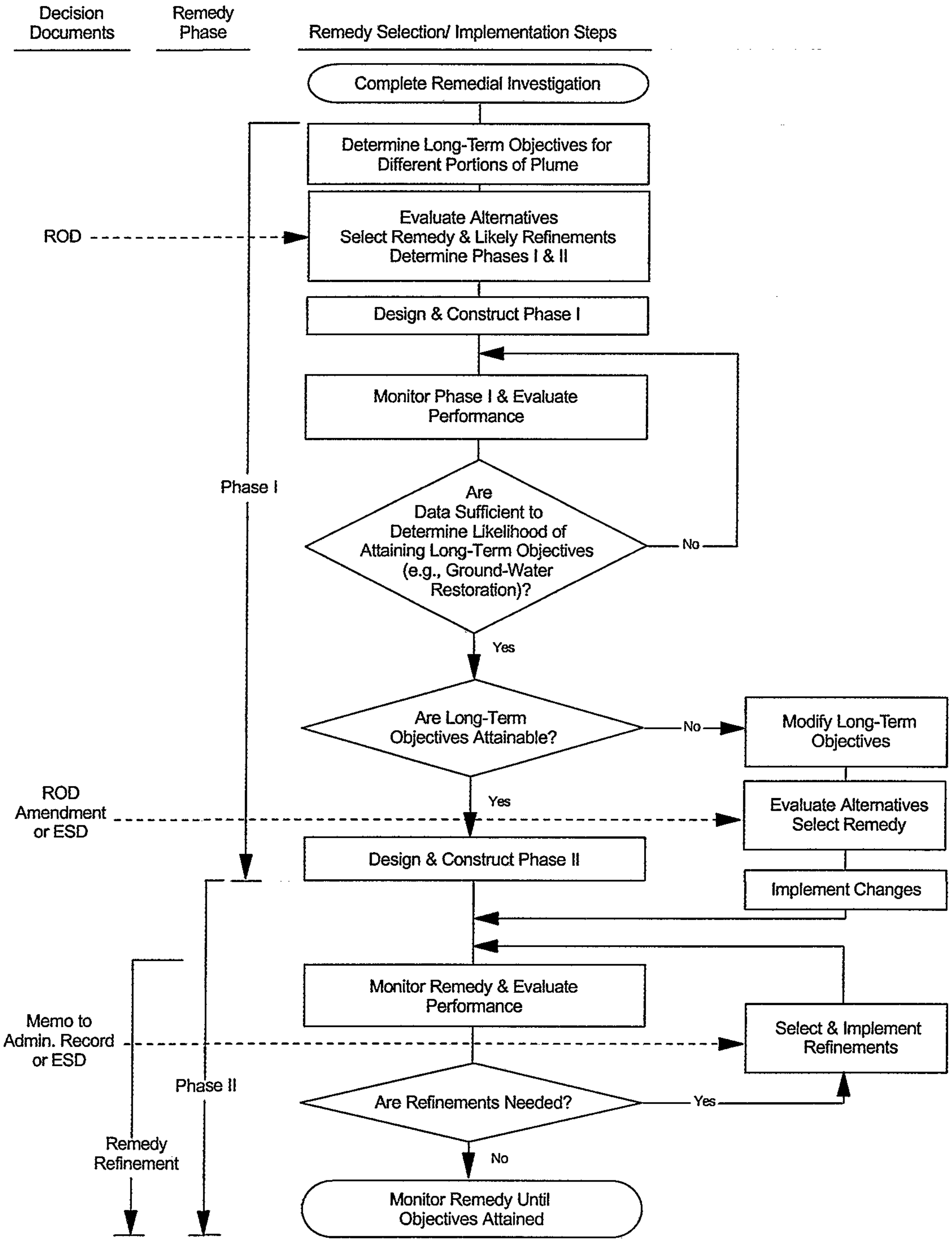


Figure 3. Phased Ground-Water Actions: Long-Term Remedy Implemented in Phases

This approach should be used when site characterization data <u>are sufficient</u> to determine that the likelihood of attaining long-term objectives is relatively high.



indicates that long-term objectives or other aspects of the remedy require modification, and the modified remedy differs significantly from the selected remedy in terms of scope, performance or cost (EPA, 1991a). **This approach should be used when site characterization data indicate that the likelihood of attaining long-term objectives is relatively high.**

When phased remedy implementation is specified in a ROD, the Agency should ensure that the proposed plan contains sufficient information regarding the nature, scope timing and basis of future decision points and alternatives that the public is able to evaluate and comment on the proposed remedy. Example language illustrating how such an approach can be specified in the selected remedy portion of the ROD is included in Appendices B1 and B2 for hypothetical sites. These examples follow the suggested ROD language given in EPA, 1990b, although the wording has been updated to reflect this and other recent guidance (EPA, 1993b). For comparison, suggested ROD language from the EPA, 1990b is included as Appendix B4.

Phased implementation of a remedy can often be beneficial even for relatively simple ground-water actions. For example, one extraction well could be installed as the initial phase and the performance of this well would be used to determine whether any additional wells are needed **and** whether long-term objectives need to be re-evaluated.

Phased implementation of an extraction and treatment remedy will require that the treatment system be designed to accommodate phased installation of the extraction system. Presumptive technologies for the treatment system and other design considerations are discussed in Section 3. Use of modular treatment components, which can be easily added or removed from the treatment system, may facilitate phased implementation or other changes in flow or contaminant concentration that may occur during the life of a remedy. Another approach is to design the treatment system for the higher flows expected from all phases of the extraction system. Some components of the remedy, such as buried portions of the piping distribution system, are difficult to install in phases and should be designed to carry the highest expected flows.

2.3 Post-Construction Refinements

Even after phased implementation of a ground-water remedy, post-construction refinements will generally be needed because of the long time period over which the remedy will operate, especially for extraction and treatment remedies. The refinement portion of the long-term remedy, after phased design and construction, is shown in both Figures 2 and 3.

2.3.1 Types of Refinements. Post-construction refinements that should be considered for extraction and treatment remedies are given in Highlight 3. These refinements are intended to be relatively minor changes to the remedy (i.e., for which an Explanation of Significant Differences (ESD) or ROD Amendment would generally **not** be required). For example, adding a new extraction or reinjection well, or a few additional monitoring wells should be considered a minor modification to a remedy that includes a relatively large number of such wells, because the overall scope, performance and cost of the remedy are not significantly changed (EPA, 1991a). One or more such refinements should generally be implemented when the results of a remedy evaluation indicate that they are needed to increase the performance of the remedy or to decrease the remediation timeframe.

2.3.2 Documenting Refinements. Potential post-construction refinements should be included in the ROD as part of the selected remedy. Listing specific remedy refinements in the ROD serves to communicate the anticipated full scope of the remedy to all concerned parties at an early date, and also minimizes the likelihood that a subsequent **ESD or ROD Amendment will be needed.** When remedy refinements are specified in a ROD, the Agency should ensure that the

Highlight 3. Remedy Refinements for Extraction/Treatment Remedies

- Change the extraction rate in some or all wells.
- Cease extraction from some wells.
- Initiate "pulsed pumping" (see Appendix A4).
- Add or remove extraction or reinjection wells, or drains.
- Add or remove monitoring wells.
- Refine source control components of remedy.
- Refine enhanced recovery or in-situ degradation components of remedy (see Note).
- Refine ex-situ treatment components

NOTE: A ground-water remedy could include both extraction and treatment and in-situ treatment methods.

proposed plan contains sufficient information regarding the nature, scope timing and basis of future decision points and alternatives that the public is able to evaluate and comment on the proposed remedy. Example ROD language specifying likely post-construction refinements for the extraction portion of the selected remedy is given in Appendices B1 and B2. Even if an ESD is not required, a letter or memorandum should be included in the post-ROD portion of the Administrative Record explaining the minor remedy modifications and the reasons for them. Additional information concerning documentation of remedy modifications can be found in the EPA fact sheet entitled *Guide to Addressing Pre-ROD and Post-ROD Changes* (EPA, 1991a).

2.4 Integrating Response Actions

In general, actions in response to contaminated ground water should be planned and implemented as part of an overall strategy. Earlier actions (see Highlight 2 for examples) should be compatible with and not preclude implementation of later actions. For example, permanent facilities should not be constructed which could interfere with possible later actions (e.g., structures that would interfere with later construction of extraction wells or of a cap).

2.4.1 Integrating Source Control and Ground-Water Actions. Restoration of contaminated ground water generally will not be possible unless contaminant sources have been controlled in some manner. Source control is a critical component for active restoration remedies (e.g., extraction and treatment and in-situ methods) as well as for natural attenuation (defined in Section 2.6.5). Selection of appropriate source control actions should consider whether other contaminant sources (i.e., NAPLs) are likely to be present in addition to contaminated soils. If NAPLs are present, the vast majority of contaminant mass will likely reside in the subsurface NAPLs rather than in the surficial soils. Therefore, for this case source control actions that are intended to minimize further contamination of ground water should focus on controlling migration of contaminants from the subsurface NAPLs. Also, capping or treatment of surficial soils may be needed to prevent exposure to contaminants from direct soil contact or inhalation, but these actions alone would be ineffective in preventing further contamination of ground water at sites where NAPLs are present.

2.4.2 Combining Ground-Water Restoration Methods. A remedy could include more than one method for restoring ground water to its beneficial uses, such as combining extraction and treatment with natural attenuation or in-situ-treatment with extraction and treatment. Extraction and treatment is especially useful for providing hydraulic containment of those portions of the plume where contaminant sources are present (e.g., subsurface NAPLs or contaminated soils), or for containing or restoring those plume areas with relatively high concentrations of dissolved contamination ("hot spots"). However, extraction and treatment may not be the best method for restoring large areas of the plume with low contaminant levels.

Once source areas are controlled, natural attenuation may be able to restore large portions of the plume to desired cleanup levels in a timeframe that is reasonable (see Section 2.6.2) when compared with the timeframe and cost of other restoration methods. Thus, natural attenuation of some plume areas combined with extraction and treatment to contain source areas and/or plume "hot spots" may be the most appropriate restoration approach for many sites with relatively large, dilute plumes. Whether or not natural attenuation is used alone or combined with other remediation methods, the Agency should have sufficient information to demonstrate that natural processes are capable of achieving the remediation objectives for the site. EPA is currently preparing a directive that will provide more detailed discussion of EPA policy regarding the use of natural attenuation for remediation of contaminated ground water (EPA, 1996c).

By combining in-situ treatment and extraction and treatment methods it may be possible to significantly increase the effectiveness with which contaminants are removed from the aquifer. In this guidance, in-situ treatment methods for ground water are divided into two types:

- Methods that can be used to **enhance contaminant recovery** during extraction and treatment (e.g., water, steam or chemical flooding; hydraulic or pneumatic fracturing); and

- Methods for **in-situ degradation of contaminants** generally involve adding agents to the subsurface (i.e., via wells or treatment walls) which facilitate chemical or biological destruction, and have the potential to be used as an alternative to extraction and treatment for long-term restoration of ground water.

Examples of both types of in-situ treatment methods are given in Appendix A3. Reinjection of treated ground water can be used as a method for enhancing contaminant recovery as well as a discharge method, if the reinjection is designed for this purpose as part of an extraction and treatment remedy. When considering enhanced recovery methods for sites with subsurface NAPLs, potential risks of increasing the mobility of NAPLs should be evaluated. Methods of in-situ degradation of contaminants most frequently used at Superfund sites include air sparging, various types of in-situ biological treatment and permeable treatment walls or gates (EPA, 1995e). Additional information concerning air sparging and permeable treatment walls is available in EPA, 1995f and EPA, 1995d, respectively. EPA encourages the consideration, testing and use of in-situ technologies for ground-water remediation when appropriate for the site.

2.5 Strategy for DNAPL Sites

Dense nonaqueous phase liquids (DNAPLs) pose special cleanup difficulties because they can sink to great depths in the subsurface, continue to release dissolved contaminants to the surrounding ground water for very long time periods, and can be difficult to locate. Due to the complex nature of DNAPL contamination, a phased approach to characterization and response actions is especially important for sites where DNAPLs are confirmed or suspected. A recent EPA study concluded that subsurface DNAPLs may be present at up to 60 percent of CERCLA National Priorities List sites (EPA, 1993c). Refer to Appendix A1 for additional background information on DNAPLs.

Two types of subsurface contamination can be defined at DNAPL sites, the:

- DNAPL zone, and the

- Aqueous contaminant plume.

The **DNAPL zone** is that portion of the subsurface where immiscible liquids (free-phase or residual DNAPL) are present either above or below the water table. Also in the DNAPL zone, vapor phase DNAPL contaminants are present above the water table and dissolved phase below the water table. The **aqueous contaminant plume** is that portion of the contaminated ground water surrounding the DNAPL zone where aqueous contaminants derived from DNAPLs are dissolved in ground water (or sorbed to aquifer solids) and immiscible liquids are not present.

2.5.1 Site Characterization. If DNAPLs are confirmed or suspected, the remedial investigation (RI) should be designed to delineate the:

- Extent of aqueous contaminant plumes, and the
- Potential extent of DNAPL zones.

Methods and strategies for characterizing DNAPL sites as well as suggested precautions are discussed in other guidance (EPA, 1992a and 1994b) and by Cohen and Mercer, 1993. The reason for delineating these areas of the site is that response objectives and actions should generally be different for the DNAPL zone than for the aqueous contaminant plume. It is recognized that for some sites complete delineation of the DNAPL-zone may not be possible.

2.5.2 Early Actions. The early actions listed in Highlight 2 should be considered. Also, the following early actions are specifically recommended for DNAPL sites (EPA 1992b, 1993b):

- Prevent further spread of the aqueous plume (plume containment);
- Prevent further spread of hot spots in the aqueous plume (hot spot containment);
- Control further migration of contaminants from subsurface DNAPLs to the surrounding ground water (source control); and
- Reduce the quantity of source material **(free-phase DNAPL**) present in the DNAPL zone, to the extent practicable (source removal and/or treatment).

At DNAPL sites, hot spots in the aqueous plume often are associated with subsurface DNAPLs. Therefore, the second and third actions listed above are essentially the same.

2.5.3 Long-Term Remedy. The long-term remedy should attain those objectives listed above for the **DNAPL zone** , by continuing early actions or by initiating additional actions. Although contaminated ground waters generally are not considered **principal threat** wastes, DNAPLs may be viewed as a principal threat because they are sources of toxic contaminants to ground water (EPA, 1991c). For this reason EPA expects to remove or treat DNAPLs to the extent practicable in accordance with the NCP expectation to "use treatment to address the principal threats posed by a site, wherever practicable" (Federal Register, 1990a; §300.430 (a)(1)(iii)(A)). However, program experience has shown that removal of DNAPLs from the subsurface is often not practicable, and no treatment technologies are currently available which can attain ARAR or risk-based cleanup levels where subsurface DNAPLs are present. **Therefore, EPA generally expects that the long-term remedy will control further migration of contaminants from subsurface DNAPLs to the surrounding ground water and reduce the quantity of DNAPL to the extent practicable.**

For the **aqueous plume** , the long-term remedy should:

- Prevent further spread of the aqueous plume (plume containment);

- Restore the maximum areal extent of the aquifer to those cleanup levels appropriate for its beneficial uses (aquifer restoration).

In general, restoration of the aquifer to ARAR or risk-based cleanup levels in a reasonable timeframe will not be attainable in the DNAPL zone unless the DNAPLs are removed. For this reason, it is expected that ARAR waivers due to technical impracticability will be appropriate for many DNAPL sites, over portions of sites where non-recoverable DNAPLs are present (EPA, 1995c). Also, EPA generally prefers to utilize ARAR waivers rather than ARAR compliance boundaries for such portions of DNAPL sites (see Section 2.6.4). A waiver determination can be made after construction and operation of the remedy or at the time of remedy selection (i.e., in the ROD), whenever a sufficient technical justification can be demonstrated (EPA, 1993b; EPA 1995b). For further information refer to Section 2.6.3 of this guidance and EPA's *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA, 1993b). Restoration of the aqueous plume may also be difficult due to hydrogeologic factors, such as sorption of dissolved contaminants to solids in finer grained strata. For some sites, ARAR waivers may also be appropriate for all or portions of the aqueous plume when supported by adequate justification.

2.6 Areas of Flexibility in Cleanup Approach

The current response approach to contaminated ground water, as defined in the NCP and other guidance, includes several areas of flexibility in which response objectives and the timeframe in which to meet them can be adjusted to meet site specific conditions. These are briefly discussed below.

2.6.1 Beneficial Uses and ARARs. Since EPA generally expects to return contaminated ground waters to their beneficial uses wherever practicable, the required cleanup levels for a given site should be determined from applicable or relevant and appropriate requirements (ARARs) based on the current and expected future beneficial uses of the ground water at that site. Depending on state requirements and water quantity or quality characteristics, some ground waters are not expected to provide a future source of drinking water (e.g., EPA Class III ground waters (EPA, 1986) or similar state designations). In general, drinking water standards are relevant and appropriate cleanup levels for ground waters that are a current or future source of drinking water, but are **not** relevant and appropriate for ground waters that are not expected to be a future source of drinking water (Federal Register, 1990a; Preamble at 8732). (Drinking water standards include federal maximum contaminant levels (MCLs) and/or non-zero maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act, or more stringent state drinking water standards.) Ground waters may have other beneficial uses, such as providing base flow to surface waters or recharging other aquifers. For contaminated ground waters that discharge to surface water, water quality criteria established under the Clean Water Act, or more stringent state surface water requirements, may also be cleanup level ARARs (Federal Register, 1990a; Preamble at 8754). Thus, the beneficial uses of contaminated ground water at a particular site will generally provide the basis for determining which federal or state environmental requirements are applicable or relevant and appropriate cleanup levels. For additional information on the determination of cleanup levels, refer to EPA, 1988b, Chapter 4.

Determination of current and expected future beneficial uses should consider state ground-water classifications or similar designations. Several states have developed ground-water use or priority designations as part of a Comprehensive State Ground Water Protection Program (CSGWPP), defined in EPA, 1992h. EPA is currently developing a directive (EPA, 1996a) which will recommend that EPA remediation programs **should generally defer** to state determinations of future ground-water use -- even when this determination differs from the use that would otherwise have been determined by EPA -- when such determinations are:

- Developed as part of an CSGWPP that is endorsed by EPA, and
- Based on CSGWPP provisions that can be applied at specific sites (EPA, 1996a).

This provision of the directive, when final, is intended to supersede previous guidance contained in the Preamble to the NCP (Federal Register, 1990a; at 8733). Refer to EPA, 1996a for additional information concerning the role of CSGWPPs in the selection of ground-water remedies. When information concerning beneficial uses is not available from a CSGWPP, ground-water classifications defined in EPA, 1986 (i.e., EPA Classes I, II or III) or "more stringent" state ground-water classifications (or similar state designations) should generally be used to determine the potential future use, in accordance with the NCP Preamble (Federal Register, 1990a; at 8732-8733). **Regardless of the ground-water use determination, remedies selected under CERCLA authority must protect human health and the environment and meet ARARs (or invoke an ARAR waiver).**

Many states have **antidegradation** or similar regulations or requirements that may be potential ARARs. Such requirements typically focus on 1) prohibiting certain discharges, 2) maintaining ground-water quality consistent with its beneficial uses, or 3) maintaining naturally occurring (background) ground-water quality. Regulations of the third type do not involve determination of future ground-water use, and often result in cleanup levels that are more stringent than the drinking water standard for a particular chemical. Such requirements are potential ARARs if they are directive in nature and intent and established through a promulgated statute or regulation that is legally enforceable (see Federal Register, 1990a; Preamble at 8746). For further information concerning issues related to state ground-water antidegradation requirements, refer to EPA, 1990a.

2.6.2 Remediation Timeframe. "Remediation timeframes will be developed based on the specific site conditions" (Federal Register, 1990a; Preamble at 8732). Even though restoration to beneficial uses generally is the ultimate objective, a relatively long time period to attain this objective may be appropriate for some sites. For example, an extended remediation timeframe generally is appropriate where contaminated ground waters are not expected to be used in the near term, and where alternative sources are available. In contrast, a more aggressive remedy with a correspondingly shorter remediation timeframe should generally be used for contaminated ground waters that are currently used as sources of drinking water or are expected to be utilized for this purpose in the near future (Federal Register, 1990a; at 8732). A state's CSGWPP may include information helpful in determining whether an extended remediation timeframe is appropriate for a given site, such as the expected timeframe of use, or the relative priority or value of ground-water resources in different geographic areas.

A **reasonable timeframe** for restoring ground waters to beneficial uses depends on the particular circumstances of the site and the restoration method employed. The most appropriate timeframe must be determined through an analysis of alternatives (Federal Register, 1990a; Preamble at 8732). The NCP also specifies that:

> "For ground-water response actions, the lead agency shall develop a limited number of remedial alternatives that attain site-specific remediation levels within different restoration time periods utilizing one or more different technologies." (Federal Register, 1990a; §300.430(e)(4).)

Thus, a comparison of restoration alternatives from most aggressive to passive (i.e., natural attenuation) will provide information concerning the approximate range of time periods needed to attain ground-water cleanup levels. An excessively long restoration timeframe, even with the most aggressive restoration methods, may indicate that ground-water restoration is technically impracticable from an engineering perspective (see Section 2.6.3). Where restoration is feasible using both aggressive and passive methods, the longer restoration timeframe required by a passive alternative may be reasonable in comparison with the timeframe needed for more aggressive restoration alternatives. The most appropriate remedial option should be determined based on the nine remedy selection factors defined in the NCP (Federal Register, 1990a; §300.430 (e)(9)(iii)). Although restoration timeframe is an important consideration in evaluating whether restoration of ground water is technically impracticable, no single time period can be specified which would be considered excessively long for all site conditions (EPA, 1993b). For example, a restoration timeframe of 100 years may be reasonable for some sites and excessively long for others.

2.6.3 Technical Impracticability. Where restoration of ground water to its beneficial uses is not practicable from an engineering perspective, one or more ARARs may be waived by EPA (or the lead agency) under the provisions defined in CERCLA §121(d)(4)(C)). The types of data used to make such a determination are discussed in *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA, 1993b). Alternative remedial strategies, to be considered when restoration ARARs are waived, are also discussed in EPA, 1993b. A finding of technical impracticability may be made in the Record of Decision (ROD) prior to remedy implementation, or in a subsequent decision document after implementation and monitoring of remedy performance.

2.6.4 Point of Compliance. The area over which ARAR or risk-based cleanup levels are to be attained is defined in the NCP as follows:

> "For ground water, remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when waste is left in place" (Federal Register, 1990a; Preamble at 8713).

Thus, the edge of the waste management area can be considered as the point of compliance, because ARAR or risk-based cleanup levels are not expected to be attained in ground water within the waste management area. In general, the term “waste left in place” is used in the NCP to refer to landfill wastes that, at the completion of the remedy, will be contained or otherwise controlled within a waste management area.

For the purposes of ARAR compliance, EPA generally does not consider DNAPLs as “waste left in place.” DNAPLs are typically not located in a waste management area, as envisioned in the NCP. This is because the full extent of DNAPL contamination is often not known, DNAPLs can continue to migrate in the subsurface, and measures for controlling their migration are either unavailable or have uncertain long-term reliability. Also, as discussed in Section 2.5.3, restoration of the aquifer to ARAR or risk-based cleanup levels generally will not be attainable in a reasonable timeframe unless the DNAPLs are removed. **For these reasons, EPA generally prefers to utilize ARAR waivers rather than an alternate point of compliance over portions of sites where non-recoverable DNAPLs are present in the subsurface** (EPA, 1995c).

The NCP Preamble also acknowledges that “an alternative point of compliance may also be protective of public health and the environment under site-specific circumstances” (Federal Register, 1990a; at 8753). For example, where the contamination plume is “caused by releases from several distinct sources that are in close geographical proximity...the most feasible and effective cleanup strategy may be to address the problem as a whole, rather than source by source, and to draw the point of compliance to encompass the sources of release” (Federal Register, 1990a; at 8753). The NCP Preamble goes on to say that "...where there would be little likelihood of exposure due to the remoteness of the site, alternate points of compliance may be considered, provided contamination in the aquifer is controlled from further migration" (Federal Register, 1990a; at 8734). The Agency has not developed additional guidance on the use of alternate points of compliance at Superfund sites.

2.6.5 Natural Attenuation. Natural attenuation is defined in the NCP as "biodegradation, dispersion, dilution, and adsorption" of contaminants in ground water (Federal Register, 1990a; Preamble at 8734). The NCP goes on to explain that natural attenuation may be a useful remedial approach if site-specific data indicate that these processes "will effectively reduce contaminants in the ground water to concentrations protective of human health [and the environment] in a timeframe comparable to that which could be achieved through active restoration." This approach differs from the "no action" alternative because natural attenuation is expected to attain cleanup levels in a reasonable timeframe (discussed in Section 2.6.2). The NCP recommends use of natural attenuation where it is "expected to reduce the concentration of contaminants in the ground water to the remediation goals [ARAR or risk-based cleanup levels] in a reasonable timeframe."

Natural attenuation may be an appropriate remedial approach for portions of the contaminant plume when **combined with other remedial measures** needed to control sources and/or remediate "hot spots" (also see Section 2.4.2). Whether or not natural attenuation is used alone or combined with other remediation methods, the Agency should have sufficient information to demonstrate that natural processes are capable of achieving the remediation objectives for the site. One caution is that natural attenuation may not be appropriate for sites where contaminants biodegrade to intermediate compounds that are more toxic and degrade more slowly.

Additional EPA policy considerations regarding the use of natural attenuation for remediation of contaminated ground water are provided in EPA, 1996c. Although currently in draft, this EPA directive recommends that remedies utilizing natural attenuation should generally include: 1) **detailed site characterization** to show that this approach will be effective; 2) **source control measures** to prevent further release of contaminants to ground water; 3) **performance monitoring** to assure that natural attenuation is occurring as expected; and 4) **institutional controls** and other methods to ensure that contaminated ground waters are not used before protective concentrations are reached. Also, **contingency measures** may be needed in the event that natural attenuation does not progress as expected.

2.6.6 Alternate Concentration Limits. Alternate concentration limits (ACLs) are intended to provide flexibility in establishing ground-water cleanup levels under certain circumstances. In the Superfund program, EPA may establish ACLs as cleanup levels in lieu of drinking water standards (e.g., MCLs) in certain cases where contaminated ground water discharges to surface water. The circumstances under which ACLs may be established at Superfund sites are specified in CERCLA §121(d)(2)(B)(ii), and can be summarized as follows:

- The contaminated ground water must have "known or projected" points of entry to a surface water body;
- There must be no "statistically significant increases" of contaminant concentrations in the surface water body at those points of entry, or at points downstream; and
- It must be possible to reliably prevent human exposure to the contaminated ground water through the use of institutional controls.

Each of these criteria must be met and must be supported by site-specific information. Such information also must be incorporated into the appropriate portions of the Administrative Record (e.g., the RI/FS and ROD).

The NCP Preamble also advises that ACLs not be used in every situation in which the above conditions are met, but only where active restoration of the ground water is "deemed not to be practicable" (Federal Register, 1990a; at 8754). This caveat in the Preamble signals that EPA is committed to the program goal of restoring contaminated ground water to its beneficial uses, except in limited cases. In the context of determining whether ACLs could or should be used for a given site, the term "practicability" refers to an overall finding of the appropriateness of ground-water restoration, based on an analysis of remedial alternatives using the Superfund remedy selection criteria, especially the "balancing" and "modifying" criteria (EPA, 1993b). (These criteria are defined in part §300.430(e)(9)(iii) of the NCP (Federal Register, 1990a.) This is distinct from a finding of "technical impracticability from an engineering perspective," which refers specifically to an ARAR waiver and is based on the narrower grounds of engineering feasibility and reliability with cost generally not a major factor, unless ARAR compliance would be inordinately costly (see Section 2.6.3 and EPA, 1993b). Where an ACL is established, such an ARAR waiver is not necessary. Conversely, where an ARAR is waived due to technical impracticability, there is no need to establish CERCLA ACLs, as defined above. When establishing an ACL, a detailed site-specific justification should be provided in the Administrative Record which documents that the above three conditions for use of ACLs are met, and that restoration to ARAR or risk-based levels is "not practicable" as discussed above.

Although alternate concentration limits are also defined in the RCRA program, users of this guidance should be aware of **several important differences in the use of ACLs by the RCRA and Superfund programs**. For "regulated units" (defined in 40 CFR 264.90) ACLs are one of the three possible approaches for establishing concentrations limits of hazardous constituents in ground water. Those options are described in 40 CFR 294.94(a). Factors considered when determining whether an ACL is appropriate for a particular facility are provided in 40 CFR 264.94(b). The use of RCRA ACLs is not strictly limited to cases where contaminated ground water discharges to surface water, or to cases where ground-water restoration is considered "not practicable" (as is the case in Superfund). However, the factors considered in the RCRA ACL decision are meant to ensure that establishment of ACLs will be protective of human health and the environment.

A specific reference to ACLs is not made in the existing framework for implementing RCRA Corrective Action at "non-regulated units" (Federal Register, 1990b and 1996). However, the Corrective Action framework recommends flexibility for the development and use of risk-based cleanup standards, based on considerations similar to those used for establishing ACLs under 40 CFR 264.94.

3.0 PRESUMPTIVE TECHNOLOGIES

3.1 Presumptive Technologies for Ex-Situ Treatment

Presumptive technologies for the treatment portion of an extraction and treatment remedy (ex-situ treatment) are identified in Highlight 4. Descriptions of each of the presumptive technologies are presented in Appendices D1 through D8. These technologies are presumptive for treatment of **contaminants dissolved** in ground water that has been extracted from the subsurface, and are expected to be used for this purpose at "all appropriate sites." (Refer to the Preface of this guidance and EPA, 1993d for further information concerning the Agency's expectations concerning the use of presumptive treatment technologies.)

Highlight 4. Presumptive Technologies For Treatment Of Extracted Ground Water

For treatment of dissolved **organic contaminants**, volatiles, semivolatiles and others (see Note):

- Air stripping
- Granular activated carbon (GAC)
- Chemical/UV oxidation (for cyanides also)
- Aerobic biological reactors

For treatment of dissolved **metals**:

- Chemical precipitation
- Ion exchange/adsorption
- Electrochemical methods (when only metals are present)
- Aeration of background metals

For treatment of **both organic and inorganic constituents**:

- A combination of the technologies listed above

NOTE: A given treatment train could include a combination of one or more of the presumptive technologies for treatment of **dissolved** contaminants as well as other technologies for other purposes (e.g., separation of solids) as indicated in Appendix C2.

3.1.1 Design Styles within Presumptive Technologies. The presumptive technologies identified in Highlight 4 refer to technology types rather than specific designs (design styles). Each presumptive technology represents a single process falls within one of these technology types (e.g., innovative air stripper designs, or innovative media for ion exchange/adsorption of metals). A listing of design styles of the presumptive technologies typically considered during Superfund remedy selection are listed in Appendix C1.

3.1.2 Benefits of Presumptive Technologies. Use of the presumptive technologies identified in this guidance will simplify and streamline the remedy selection process for the ex-situ treatment portion of a ground-water remedy by:

- Simplifying the overall selection process, since the large number and diverse assortment of these technologies have been reduced to relatively few technology types;
- Eliminating the need to perform the technology screening portion of the feasibility study (FS), beyond the analysis contained in this guidance and its associated Administrative Record. (See Section 3.3.2);
- Allowing, in some cases, further consideration and selection among the presumptive technologies to be deferred from the FS and ROD to the remedial design (RD), which prevents duplication of effort and allows selection to be based on additional data collected during the RD (see Section 3.3.3);
- Shifting the time and resources employed in remedy selection from ex-situ treatment to other, more fundamental aspects of the ground-water remedy (see Section 1.0); and
- Facilitating the use of extraction and treatment for early actions, where appropriate, since selection of the treatment component is simplified.

3.1.3 Consideration of Innovative Technologies. Use of presumptive technologies for treatment of extracted ground water is intended to simplify the remedy selection process, but does not preclude the consideration of innovative technologies for this purpose in the FS or RD. Refer to the EPA fact sheet, *Presumptive Remedies: Policy and Procedures* (EPA, 1993d), for additional information. Many innovative or emerging technologies for ex-situ treatment are actually design variations of one of the presumptive technology types, as discussed above, and others may be considered on a site-specific basis. In addition, EPA encourages consideration of in-situ treatment technologies for ground-water remedies, either when combined with extraction and treatment or as an alternative to such methods (see Section 2.4.2).

3.2 Basis for Presumptive Technologies

3.2.1 Sources of Information. Three sources of information were used to determine which technologies should be identified as presumptive for ex-situ treatment of ground water:

- Review of the technologies selected in **all RODs** signed from fiscal years 1982 through 1992;
- Review of capabilities and limitations of ex-situ treatment technologies from engineering and other technical literature; and
- Detailed evaluation of the technologies considered in the FS and selected in the ROD or RD for a sample of 25 sites for which at least one ex-situ treatment technology was selected.

The above information is summarized in a separate report entitled *Analysis of Remedy Selection Results for Ground-Water Treatment Technologies at CERCLA Sites* (EPA, 1996b). A total of 427 RODs selected at least one ex-situ technology for treatment of ground water, as of September 30, 1992. From these RODs, a sample of 25 sites were selected for detailed evaluation of the rationale used to select these technologies as part of the ground-water remedy.

3.2.2 Rationale for Indentifying Presumptive Technologies. At least one of the eight presumptive technologies, identified in Highlight 4, was selected as part of the ground-water remedy in 425 of 427 RODs, or **99.5 percent** of the time. In only five RODs were technologies other than the presumptive technologies selected as part of the treatment train. Therefore, presumptive technologies were the **only** technologies selected for ex-situ treatment of dissolved ground-water contaminants in 420 of the 427 RODs.

More importantly, all the presumptive technologies are well understood methods that have been used for many years in the treatment of drinking water and/or municipal or industrial wastewater. Engineering Bulletins or Technical Data Sheets have been developed by EPA and the Naval Energy and Environmental Support Activity, respectively, for five of the eight presumptive technologies. These publications generally include site specific performance examples, and are included as references, along with other publications, with the description of each technology in Appendix D.

In the 25 site sample, the presumptive technologies, identified in Highlight 4, were the **only** technologies selected in the ROD for **all** sites and the only technologies implemented in the RD for 24 sites. Other technologies were consistently eliminated from further consideration, usually in the technology screening step, based on technical limitations which were verified by the engineering literature. As part of this evaluation the large number and diverse assortment of technologies considered for ex-situ treatment of ground water were categorized according to the underlying treatment process. A complete listing of the technologies considered in the FS, ROD or RD for the 25 sites is given in Appendix C1, categorized by process type and with the presumptive technologies identified.

Some technologies are identified as presumptive even though they were selected in relatively few RODs. **Aeration of background metals** was identified as presumptive because this technology is often used for removal of iron and manganese, and was considered and selected for this purpose at two of the 25 sample sites. **Electrochemical methods** for metals removal were also identified as presumptive because these methods were considered at all three sample sites where metals were the only contaminants of concern, and were selected at two of these sites. **Chemical/UV oxidation** and **aerobic biological reactors** were identified as presumptive technologies for treating organic contaminants for the following technical reasons:

- A range of chemical, physical and biological treatment methods should be included in the presumptive technologies, because air stripping and granular activated carbon, alone or combined, may not provide cost effective treatment (see Section 3.4.5) for all organic contaminants.
- These methods destroy organic contaminants as part of the treatment process instead of transferring them to other media, which reduces the quantity of hazardous treatment residuals (e.g., spent carbon) that will require further treatment.
- Ongoing research and development efforts, by EPA and others, are expected to increase the cost effectiveness of these treatment methods.

3.3 Remedy Selection Using Presumptive Technologies

Selection of technologies for long-term treatment of extracted ground water requires an understanding of the types of technologies that will be needed, how they will be used in the treatment system and site-specific information for determining the most appropriate and cost-effective technologies. **The presumptive technologies for treating dissolved contaminants in extracted ground water, identified in Highlight 4, are the technologies that should be retained for further consideration in the Detailed Analysis portion of the feasibility study (FS).** This guidance and its associated Administrative Record will generally constitute the Development and Screening of Alternatives portion of the FS for the ex-situ treatment component of a ground-water remedy, as discussed in Section 3.3.2.

Site information needed to select cost-effective treatment technologies (see Section 3..4) is often not collected until the remedial design (RD) phase. **In such cases, it will generally be appropriate to specify performance requirements for the treatment system in the ROD, but defer selection of specific technologies until the RD**, as discussed in Section 3.3.3.

3.3.1 Use of Technologies in Treatment Systems. Complete treatment of extracted ground water generally requires that units of more than one technology, or multiple units of a single technology (unit processes), be linked together in a treatment train. A given treatment train could include some combination of treatment technologies for the following purposes:

1. Separation of mineral solids and/or immiscible liquids from the extracted ground water during initial treatment (pretreatment);
2. Treatment of **dissolved contaminants** ;
3. Treatment of vapor phase contaminants from the extracted ground water or those generated during treatment;
4. Separation of solids generated during treatment;
5. Final treatment of **dissolved contaminants** prior to discharge (polishing); and

6. Treatment of solids generated during treatment.

Presumptive technologies for treatment of **dissolved contaminants** in extracted ground water (No. 2 and 5, above) are identified in Highlight 4. Examples of the types of technologies used for other purposes are given in Appendix C2, along with a listing of the general sequence of unit processes used in a treatment train. Solid residuals (such as sludges from chemical or biological processes, or spent carbon media) will generally require additional treatment or disposal, either as part of the treatment train or at a separate facility. Presumptive technologies for purposes other than for treatment of dissolved contaminants have **not** been identified in this guidance.

Use of modular treatment components, which can be easily added or removed from the treatment system, may facilitate phased implementation or other changes that may occur during the life of a remedy. Phased implementation of the extraction portion of a remedy may require that some components of the treatment system also be installed in stages. Also, modification of the treatment system over time may be needed in response to changes in the inflow rate or contaminant loadings, or to increase the effectiveness or efficiency of the treatment system.

3.3.2 This Guidance Constitutes the FS Screening Step. This guidance and its associated Administrative Record will generally constitute the "development and screening of alternatives" portion of the feasibility study (FS), for the ex-situ treatment component of a ground-water remedy. When using presumptive technologies, the FS should contain a brief description of this approach (see fact sheet entitled *Presumptive Remedies: Policy and Procedures* (EPA, 1993d)), and refer to this guidance and its associated Administrative Record. Such a brief description should fulfill the need for the development and screening of technologies portion of the FS for the ex-situ treatment component of the remedy.

3.3.3 Deferral of Final Technology Selection to RD. Although EPA prefers to collect the site information needed for technology selection prior to the ROD, it is sometimes impracticable to collect some of the necessary information until the remedial design (RD) phase. (See Section 3.4 for a summary of site information generally needed for selection of these technologies.) In reviewing remedy selection experience for a sample of sites, EPA found that at seven of 25 sites (28 percent) the type of technology selected in the ROD for treatment of extracted ground water was later changed in the RD because of additional site information obtained during the design phase (EPA, 1996b). Where EPA lacks important information at the ROD stage, it may be appropriate to defer final selection among the presumptive ex-situ treatment technologies (as well as selection of specific design styles) to the RD phase.

In this approach, EPA would identify and evaluate the technologies and provide an analysis of alternative technologies in the FS (this guidance and its associated administrative record will generally constitute that discussion). The proposed plan would identify the technologies that may be finally selected and specify the timing of and criteria for the future technology selection in sufficient detail that the public can evaluate and comment on the proposal. The ROD would also identify all ARARs and other performance specifications and information associated with discharge and treatment of the extracted ground water, including the types of discharge, effluent requirements, and specifications developed in response to community preferences. Specifying the performance criteria and other requirements in the ROD (using a type of "performance based approach") ensures that the remedy will be protective and meet ARARs. Overall, the ROD should be drafted so that the final selection of technologies at the RD phase follows directly from the application of criteria and judgments included in the ROD to facts collected during the RD phase. If the ROD is drafted in this fashion, documenting the final technology selection can generally be accomplished by including a document in the post-ROD portion of the Administrative Record, which explains the basis of technology selection (e.g., Basis of Design Report, or memorandum to the RD file).

Advantages of deferring selection of ex-situ treatment technologies to the RD include:

- The remedy selection process is further streamlined, since final selection and the accompanying detailed analysis for these technologies is performed only in the RD not in both the FS and the RD, minimizing duplication of effort;
- Site information collected during the RD can be used to make final technology selections as well as to design the treatment train, which facilitates selection of the most cost effective technologies (see Section 3.4.5);
- The likelihood that changes in the treatment train will be made during the RD is explicitly recognized in the ROD; and
- The time and resources employed in the FS can focus on other components of the ground-water remedy that have more direct influence on attainment of **remedial objectives** for contaminated ground water (see Section 1.0).

Cost estimates for remedial alternatives, including the ex-situ treatment component, will need to be included in the FS regardless of whether or not technology selection is deferred to the RD. For cost estimating purposes when deferring technology selection to the RD, reasonable assumptions should be made concerning the treatment system, including assumptions concerning the presumptive technologies and likely design styles to be used. To assist in making such assumptions, advantages and limitations for the presumptive technologies are summarized in Appendix C4. Also, brief descriptions of the presumptive technologies and references for additional information are provided in Appendix D. Assumptions used for estimating treatment costs should be consistent across all remedial alternatives. All assumptions should be clearly stated as such in the FS and ROD.

Example ROD language for deferring technology selection to the RD is given in Appendix B3 for a hypothetical site. This language is only for the ex-situ treatment portion of an extraction and treatment remedy and should appear in the selected remedy portion of the ROD when following this approach.

3.4 Information Needed for Selecting Technologies

The site information listed in Highlight 5 is generally needed to determine the treatment components of a complete treatment train for extracted ground water and to select the most appropriate technology type and design style for each component. Further detail regarding site data needed and the purpose of this information is provided in Appendix C3. Much of this information is also needed for design of the extraction component of an extraction and treatment remedy.

3.4.1 When Should this Information be Collected? The information listed in Highlight 5 is needed for design of the treatment train. Therefore, it must be collected prior to or during the design phase, for either an early action or long-term remedy. Much of this information should also be available for selecting among the presumptive technologies, since it is generally needed to determine the technologies most appropriate for site conditions. The timing of information needed during remedy selection is different when deferring technology selection to the RD than when selecting technologies in the ROD, as discussed in Section 3.3.3. However, much of this information can be collected along with similar data gathered during the remedial investigation (RI). In general, it is recommended that as much of this information as possible be obtained prior to the RD in order to minimize the

Highlight 5. Summary of Site Information Needed For Treatment Train Design

- Total extraction flow rate
- Discharge options and requirements
  - Target effluent concentrations
    - Contaminants
    - Degradation products
    - Treatment additives
    - Natural constituents
  - Other requirements
    - Regulatory
    - Operational
  - Community concerns or preferences
- Water quality of treatment influent
  - Contaminant types and concentrations
  - Naturally occurring constituents
  - Other water quality parameters
- Treatability information

NOTE: Further detail is provided in Appendix C3.

need for additional site investigations during the RD and to accelerate the RD phase.

much of this information can be collected along with similar data gathered during the remedial investigation (RI). In general, it is recommended that as much of this information as possible be obtained prior to the RD in order to minimize the need for additional site investigations during the RD and to accelerate the RD phase.

3.4.2 Extraction Flow Rate . Inflow to the treatment system is the total flow from all extraction wells or drains. Estimates of total extraction flow rate often have a **high degree of uncertainty** (i.e., one or more orders of magnitude), depending on type of data and estimation method used. Expected flow rates from extraction wells are typically estimated from hydraulic properties of the aquifer. Aquifer hydraulic properties may have considerable natural variation over the site and accurate measurement of these properties is often difficult. In order to reduce uncertainty during design of the treatment system, **aquifer properties used in estimating the inflow should generally be obtained from pumping-type aquifer tests** and not from "slug tests," laboratory measurements on borehole samples or values estimated from the literature.

Pumping-type aquifer tests provide a much better estimate of average aquifer properties than other methods, because a much larger volume of aquifer is tested. For the same reason, ground water extracted during pumping tests is more representative of that which will enter the treatment system, and should generally be used for treatability studies of ex-situ treatment technologies instead of samples obtained from monitoring wells. Suggested procedures for conducting pumping-type aquifer tests are given in EPA, 1993i. Methods for treatment of contaminated ground water extracted during pumping-type aquifer tests are discussed in Section 3.5.

The likely variability in the total extraction rate during the life of the remedy should also be estimated. Variability in the extraction rate could result from addition or removal of extraction wells, short-term operational changes in the system (e.g., changing the pumping rates) or seasonal fluctuations in the water table. The number of extraction wells could change as a result of implementing the remedy in phases or from post-construction refinement of the remedy (see Section 2.3.1).

3.4.3 Discharge Options and ARARs. All options for discharge of ground water after extraction and treatment should be identified and considered in the FS, especially options that include re-use or recycling of the extracted ground water. Water quality requirements for the treated effluent (i.e., effluent ARARs) may be different for each discharge option. Examples of regulatory requirements include those promulgated under the federal Safe Drinking Water Act and Clean Water Act , which would apply to discharges to a drinking water system or to surface waters, respectively; and state requirements for these types of discharge. Effluent requirements could also include those for chemicals added during treatment, contaminant degradation products, and naturally occurring constituents (e.g., arsenic), in addition to those for contaminants of concern. **In general, one or more types of discharge for extraction and treatment remedies should be selected in the ROD, not deferred to the RD.** ARARs for the treated effluent will determine the overall level of treatment needed, which in turn determines the type of components needed in the treatment train (see Section 3.3.1) and is a critical factor in selecting appropriate treatment technologies.

In some cases it may be appropriate to select more than one type of discharge for the selected remedy. One type of discharge may be preferred, but may not be capable of accepting the entire flow of treated effluent. For example, it may be possible to re-use or recycle a portion but not all of the discharge. It may also be desirable to reinject a portion of the treated effluent for enhanced recovery of contaminants (aquifer flushing) but prohibitively costly to reinject the entire discharge.

In addition to the types of discharge, ARARs and other specifications related to technology selection or operating performance of the treatment system should be specified in the ROD. Regulatory requirements for all waste streams from the treatment system should be specified, including those for the treated effluent; releases to the air; and those for handling, treatment and disposal of solid and liquid treatment residuals. Other specifications could include those preferred by the affected community, such as requirements to capture and treat contaminant vapors (even though not required by ARARs) or limits on operating noise. Other specifications may also be needed to maintain continued operation of the system, such as water quality conditions necessary to minimize chemical and/or biological clogging of injection wells or drains.

3.4.4 Water Quality of Treatment Influent. In order to design the treatment system, contaminant types and concentrations and other water quality parameters must be estimated for the total flow entering the system. Since some technologies are more effective than others in removing certain contaminant types, this is an important technology selection factor. Concentrations of naturally occurring constituents as well as background and site-related contaminants in the extracted ground water should also be measured, as discussed in Appendix C3.

3.4.5 Treatability Studies. Treatability studies involve testing one or more technologies in the laboratory or field to assess their performance on the actual contaminated media to be treated from a specific site. These studies may be needed during the RI/FS to provide qualitative and/or quantitative information to aid in selection of the remedy, or during the RD to aid in design or implementation of the selected remedy. Three tiers of testing may be undertaken: 1) laboratory screening, 2) bench-scale testing, or 3) pilot-scale testing. Treatability studies may begin with any tier and may skip tiers that are not needed (EPA, 1989c).

For treatment of extracted ground water, treatability studies are generally needed to accurately predict the effectiveness and total cost of a technology for a given site, including construction and operating costs; and the costs of other components that may be needed in the treatment train (see Section 3.3.1). Optimizing the cost effectiveness of the treatment train is especially important for systems designed to operate over a long time period. (In this guidance, optimizing the cost effectiveness of the treatment system is defined as meeting all treatment and other performance requirements while minimizing total costs per unit volume of water treated.) Treatability studies may also indicate that some technologies provide cost effective treatment when all of the above factors are considered, even though these technologies were infrequently selected in past RODs (e.g., chemical/UV oxidation or aerobic biological reactors). For these reasons treatability studies will be helpful in selecting among the presumptive technologies. Similarly, a presumptive treatment technology should **not** be eliminated from further consideration in the FS or RD simply because a treatability study is required to determine its applicability for a given site. In general, some type of treatability study should be performed prior to or during the design of any system expected to provide **long-term treatment** of extracted ground water, including systems using presumptive technologies.

3.5 Treatment Technologies for Aquifer Tests

Although pumping-type aquifer tests are the preferred method of determining average aquifer properties (see Section 3.4.2) and this information is useful for remedy selection, such testing is often deferred to the RD phase because of the need to determine how to treat and/or dispose of the extracted ground water. To facilitate use of such tests earlier in the site response, ex-situ treatment technologies most suitable for this application are discussed below.

3.5.1 Treatment Needs during Aquifer Tests. In comparison to an extraction and treatment remedy, pumping-type aquifer tests (see Section 3.4.2) generate relatively small flows of contaminated ground water over a short period of time. At the time of such tests, the estimated pumping rates and contaminant loadings generally have a high degree of uncertainty. Often the total volume of ground water extracted during testing is held in storage tanks or lined ponds to prevent the discharge from affecting water levels in observation wells and interfering with the test. Storage of the extracted ground water also allows subsequent flow to a treatment system to be controlled and optimized. For example, if storage vessels are used for both the untreated and treated water, the extracted water can be routed through the treatment system as many times as necessary to meet discharge and/or disposal requirements. Therefore, the cost effectiveness of treatment technologies (see Section 3.4.5) is less important for aquifer testing than for the long-term remedy, because of the much smaller volume of ground water to be treated and the much shorter period of operation.

3.5.2 Treatment Technologies for Aquifer Tests. Technologies for treating ground water extracted during aquifer tests should be able to treat a wide range of contaminant types, be available in off-the-shelf versions (short lead time for procurement), have a short on-site startup time, be relatively simple to operate, and be available in easily transportable units. Of the presumptive technologies identified above, the three most suitable for this application are:

- Granular activated carbon,
- Air stripping, and
- Ion exchange/adsorption.

Granular activated carbon can effectively remove most dissolved organic contaminants and low concentrations of some inorganic compounds. Ion exchange/adsorption can remove most metals. Air stripping may be applicable for volatile organic contaminants (VOCs) and generally is more cost effective than granular activated carbon for treating VOCs when flow rates are greater than about three gallons per minute (Long, 1993). Granular activated carbon may still be needed in conjunction with air stripping, for treating dissolved semivolatile organic contaminants, or for reaching stringent effluent requirements for VOCs. Granular activated carbon may also be needed for treatment of vapor phase contaminants separated by an air stripper. Also, treatability studies generally are not required for the above three technologies, especially for **short-term** applications. Additional information regarding the availability and field installation of skid or trailer mounted treatment units (package plants) is available in EPA, 1995a.

Other presumptive ex-situ treatment technologies (chemical/UV oxidation, aerobic biological reactors, chemical precipitation, and electrochemical methods) generally are less suitable for aquifer testing purposes. In general, these other technologies require longer lead times for procurement and longer time on-site for startup; and have more complex operating requirements and higher capital costs.

4.0. REFERENCES

Cohen, R.M., and J.W. Mercer, 1993. DNAPL Site Evaluation , C.K. Smoley, Boca Raton, FL and ORD Publication EPA/600/R-93/022.

EPA, 1986. "Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Final Draft," November, 1986.

EPA, 1988a. "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final," OSWER Directive 9355.3-01, EPA/540/G-89/004, October 1988.

EPA, 1988b. "Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites," OSWER Directive 9283.1-2, EPA/540/G-88/003, December 1988.

EPA, 1989a. "Considerations in Ground Water Remediation at Superfund Sites," OSWER Directive 9355.4-03, October 18, 1989.

EPA, 1989b. "Interim Final Guidance on Preparing Superfund Decision Documents," OSWER Directive 9335.3-02, October 1989.

EPA, 1989c. "Guide for Conducting Treatability Studies Under CERCLA, Interim Final," OERR/ORD Publication EPA/540/2-89/058, December 1989.

EPA, 1990a. "ARARs Q's & A's: State Ground-Water Antidegradation Issues," OSWER Publication 9234.2-11/FS, July 1990.

EPA, 1990b. "Suggested ROD Language for Various Ground Water Remediation Options," OSWER Directive 9283.1-03, October 10, 1990.

EPA, 1991a. "Guide to Addressing Pre-ROD and Post-ROD Changes," OSWER Publication 9355.3-02FS-4, April 1991.

EPA, 1991b. "Guide to Developing Superfund No Action, Interim Action, and Contingency Remedy RODs," OSWER Publication 9355.3-02FS-3, April 1991.

EPA, 1991c. "Guide to Principal Threat and Low Level Threat Wastes," OSWER Publication 9380.3-06FS, November 1991.

EPA, 1992a. "Estimating Potential for Occurrence of DNAPL at Superfund Sites," OSWER Publication, 9355.4-07FS, January 1992.

EPA, 1992b. "Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities - Update," OSWER Directive 9283.1-06, May 27, 1992.

EPA, 1992c. "Guidance on Implementation of the Superfund Accelerated Cleanup Model (SACM) under CERCLA and the NCP," OSWER Directive 9203.1-03, July 7, 1992.

EPA, 1992d. "The Superfund Accelerated Cleanup Model (SACM)," OSWER Publication 9203.1-02I, November 1992.

EPA, 1992e. "Early Action and Long-Term Action Under SACM - Interim Guidance," OSWER Publication 9203.1-05I, December 1992.

EPA, 1992f. "SACM Regional Decision Teams - Interim Guidance," OSWER Publication 9203.1-05I, December 1992.

EPA, 1992g. "Evaluation of Ground-Water Extraction Remedies: Phase II, Volume 1 Summary Report," OSWER Publication 9355.4-05, February 1992.

EPA, 1992h. "Final Comprehensive State Ground Water Protection Program Guidance," Publication EPA 100-R-93-001, December 1992.

EPA, 1993a. "Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA," OSWER Publication 9360.0-32, EPA/540-R-93-057, August 1993.

EPA, 1993b. "Guidance for Evaluating Technical Impracticability of Ground-Water Restoration," OSWER Directive 9234.2-25, EPA/540-R-93-080, September 1993.

EPA, 1993c. "Evaluation of the Likelihood of DNAPL Presence at NPL Sites, National Results," OSWER Publication 9355.4-13, EPA/540-R-93-073, September 1993.

EPA, 1993d. "Presumptive Remedies: Policy and Procedures," OSWER Directive 9355.0-47FS, EPA/540-F-93-047, September 1993.

EPA, 1993e. "Presumptive Remedies: Site Characterization and Technology Selection For CERCLA Sites With Volatile Organic Compounds In Soils," OSWER Directive 9355.0-48FS, EPA/540-F-93-048, September 1993.

EPA, 1993f. "Presumptive Remedy for CERCLA Municipal Landfill Sites," OSWER Directive 9355.0-49FS, EPA/540-F-93-035, September 1993.

EPA, 1993g. "Innovative Treatment Technologies: Annual Status Report (Fifth Edition)", Publication EPA 542-R-93-003, September 1993.

EPA, 1993h. "In-situ Treatment of Contaminants: An Inventory of Research and Field Demonstrations and Strategies for Improving Ground Water Remediation," OSWER Publication EPA/500/K-93/001, January 1993.

EPA, 1993i. "Ground Water Issue, Suggested Operating Procedures for Aquifer Pumping Tests," OSWER Publication EPA/500/S-93/503, February 1993.

EPA, 1993j. "Data Quality Objectives Process for Superfund, Interim Final Guidance" OSWER Publication 9355.9-01, EPA/540/R-93/071, September 1993.

EPA, 1994a. "Alternative Methods for Fluid Delivery and Recovery," ORD/CERI Publication EPA/625/R-94/003, September 1994.

EPA, 1994b. "DNAPL Site Characterization," OSWER Publication 9355.4-16FS, EPA/540/F-94/049, September 1994.

EPA, 1994c. "RCRA Corrective Action Plan," OSWER Directive 9902.3-2A, EPA/520/R-94/004, May 1994.

EPA, 1994d. “Technical Support Project, Direct Technical Assistance for Site Remediation,” OSWER Publication EPA/542-F-94/004, October 1994.

EPA, 1994e. “Methods for Monitoring Pump-and-Treat Performance,” ORD Publication EPA/600/R-94-94/123, June 1994.

EPA, 1995a. "Manual: Ground Water and Leachate Treatment Systems," ORD/CERI Publication EPA/625 R-94/005, January 1995.

EPA, 1995b. “Consistent Implementation of the FY 1993 Guidance on Technical Impracticability of Ground-Water Restoration at Superfund Sites,” OSWER Directive 9200.4-14, January 19, 1995.

EPA, 1995c. “Superfund Groundwater RODs: Implementing Change This Fiscal Year,” OSWER Memorandum from Elliott P. Laws to Regional Administrators and others, July 31, 1995 (no publication number).

EPA, 1995d. “In-Situ Remediation Technology Status Report: Treatment Walls,” OSWER Publication EPA/542 K-94-004, April 1995.

EPA, 1995e. “Innovative Treatment Technologies: Annual Status Report (Seventh Edition),” OSWER Publication EPA-542-R-95-008 Number 7, Revised, September 1995.

EPA, 1995f. “Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide,” OSWER Publication EPA/542-B-95-003, October 1995.

EPA, 1995g. "Presumptive Remedies for Soils, Sediments and Sludges at Wood Treater Sites,", OSWER Directive 9200.5-162, EPA/540-R-95/128, December 1995.

EPA, 1996a. “Consideration of ‘Comprehensive State Ground Water Protection Programs’ by EPA Remediation Programs,” **Draft** OSWER Directive 9283.1-09 dated June 1996. Final Directive expected by November 1996.

EPA, 1996b. "Analysis of Remedy Selection Experience for Ground Water Treatment Technologies at CERCLA Sites," **Draft** Final Report dated July 1996. Final Report expected by November 1996.

EPA, 1996c. "Use of Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites," **Draft** OSWER Directive ___ dated September 1996. Final Directive expected by February 1997.

Federal Register, 1990a. Volume 55, No. 46, March 8, 1990; 40 CFR Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule" (NCP).

Federal Register, 1990b. Volume 55, No. 145, July 27, 1990; 40 CFR Parts 264, 265, 270 and 271, "Corrective Action for Solid Waste Management Units at Hazardous Waste Facilities; Proposed" (proposed Subpart S regulations).

Federal Register, 1996. Volume 61, No. 85, May 1, 1996; "Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities, Advance Notice of Proposed Rulemaking."

Long, G. M., 1993. "Clean up Hydrocarbon Contamination Effectively," *Chemical Engineering Progress* , Vol. 89, No. 5.

National Research Council, 1994. Alternatives for Ground Water Cleanup , National Academy Press, Washington, DC.

APPENDIX A

Additional Background Information

Appendix A1: Background on **DNAPL** Contamination

Appendix A2: **Contaminants** Most Frequently Reported in Ground Water at CERCLA NPL Sites

Appendix A3: Examples of **In-Situ** Treatment Technologies

Appendix A4: Definition and Discussion of **Pulsed Pumping**

Appendix A1: Background on DNAPL Contamination

DNAPL Background

A **nonaqueous phase liquid (NAPL)** is a chemical that is a liquid in its pure form, which does not readily mix with water but does slowly dissolve in water. **Dense NAPLs (DNAPLs)** sink while **light NAPLs (LNAPLs)** float in water. When present in the subsurface NAPLs slowly release vapor and dissolved phase contaminants, resulting in a zone of contaminant vapors above the water table and a plume of dissolved contaminants below the water table. The term NAPL refers to the undissolved liquid phase of a chemical or mixture of compounds and not to the vapor or dissolved phases. NAPLs may be present in the subsurface as either **"free-phase"** or as **"residual-phase."** The free-phase is that portion of NAPL that can continue to migrate and which can flow into a well. The residual-phase is that portion trapped in pore spaces by capillary forces, which can **not** generally flow into a well or migrate as a separate liquid. Both residual and free-phase NAPLs are sources of vapors and dissolved contaminants.

LNAPLs tend to pose less of a cleanup problem than DNAPLs. The most common LNAPLs are petroleum fuels, crude oils and related chemicals, which tend to be associated with facilities that refine, store or transport these liquids. Since LNAPLs tend to be shallower, are found at the water table and are associated with certain facilities, they are generally easier to locate and clean up from the subsurface than DNAPLs.

DNAPLs pose much more difficult cleanup problems. These contaminants include chemical compounds and mixtures with a wide range of chemical properties, including chlorinated solvents, creosote, coal tars, PCBs, and some pesticides. Some DNAPLs, such as coal tars, are viscous chemical mixtures that move very slowly in the subsurface. Other DNAPLs, such as some chlorinated solvents, can travel very rapidly in the subsurface because they are heavier and less viscous than water. A large DNAPL spill not only sinks vertically downward under gravity, but can spread laterally with increasing depth as it encounters finer grained layers. These chemicals can also contaminate more than one aquifer by penetrating fractures in the geologic layer which separates a shallower from a deeper aquifer. Thus, large releases of DNAPLs can penetrate to great depths and can be very difficult to locate and clean up.

The contamination problem at DNAPL sites has two different components, as shown in **Figures A1-1 and A1-2**, the:

- DNAPL zone, and the
- Aqueous contaminant plume.

The **DNAPL zone** is that portion of the subsurface where immiscible liquids (free-phase or residual DNAPL) are present either above or below the water table. Also in the DNAPL zone, vapor phase DNAPL contaminants are present above water table and dissolved phase below water table. The **aqueous contaminant plume** is that portion of the contaminated ground water surrounding the DNAPL zone where aqueous contaminants derived from DNAPLs are dissolved in ground water (or sorbed to aquifer solids) but immiscible liquids are **not** present. Depending on the volume of the release and subsurface geology, the DNAPL zone may extend to great depths and over large lateral distances from the entry location, as discussed above.

Appendix A1: Background on DNAPL Contamination (continued)

Planning of site investigation and remedial activities at sites with subsurface DNAPLs should include certain precautions, to minimize the potential for further DNAPL migration resulting from such activities. Further detail on characterization of DNAPL sites is provided in EPA, 1994 and in Cohen and Mercer, 1993 (see below).

DNAPL References

Additional information concerning DNAPL contamination can be obtained from the following references:

Cohen, R.M., and J.W. Mercer, 1993. DNAPL Site Evaluation, C.K. Smoley, Boca Raton, FL, 1993; and EPA/600/R-93/022, February 1993.

EPA, 1991. "Ground Water Issue: Dense Nonaqueous Phase Liquids," OSWER Publication EPA/540/4-91-002, March 1991.

EPA, 1992a. "Estimating Potential for Occurrence of DNAPL at Superfund Sites," OSWER Publication 9355.4-07FS, January 1992.

EPA, 1992b. "Dense Nonaqueous Phase Liquids -- A Workshop Summary, Dallas, Texas, April 16-18, 1991," Office of Research and Development Publication EPA/600/R-92/030, February 1992.

EPA, 1992c. "Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities - Update," OSWER Directive 9283.1-06, May 27, 1992.

EPA, 1993b. "Guidance for Evaluating Technical Impracticability of Ground-Water Restoration," OSWER Directive 9234.2-25, EPA/540-R-93-080, September 1993.

EPA, 1994. "DNAPL Site Characterization," OSWER Publication 9355.4-16FS, EPA/540/F-94/049, September 1994.

Appendix A2: Contaminants Most Frequently Reported in Ground Water at CERCLA NPL Sites [1]

Organic Contaminants:

Rank	Organic Contaminants (Other Names)	Chemical[2] Group	Halo-[2] genated?	DNAPL?[3]	No.[1] Sites
1	Trichloroethylene, 1,1,2- (TCE) [cs]	Volatile	Yes	Yes	336
2	Tetrachloroethene (perchloroethene; PCE) [cs]	Volatile	Yes	Yes	170
3	Chloroform (trichloromethane) [cs]	Volatile	Yes	Yes	167
4	Benzene [pf]	Volatile	No	No	164
5	Toluene [pf]	Volatile	No	No	159
6	Trichloroethane, 1,1,1- (methyl chloroform; 1,1,1-TCA) [cs]	Volatile	Yes	Yes	155
7	Polychlorinated biphenyls	PCB	Yes	Yes	139
8	Trans-Dichloroethylene, 1,2- (trans-1,2-DCE) [cs]	Volatile	Yes	Yes	107
9	Dichloroethane, 1,1- (1,1-DCA) [cs]	Volatile	Yes	Yes	105
10	Dichloroethene, 1,1- (vinylidene chloride; 1,1-DCE) [cs]	Volatile	Yes	Yes	95
11	Vinyl chloride (chloroethylene) [cs]	Volatile	Yes	No	82
12	Xylene [pf]	Volatile	No	No	76
13	Ethylbenzene [pf]	Volatile	No	No	68
14	Carbon tetrachloride (tetrachloromethane) [cs]	Volatile	Yes	Yes	68
15	Phenol	Semivol.	No	No	61
16	Methylene chloride (dichloromethane) [cs]	Volatile	Yes	Yes	58
17	Dichloroethane, 1,2- (ethylene dichloride; 1,2-DCA) [cs]	Volatile	Yes	Yes	57
18	Pentachlorophenol (PCP)	Semivol.	Yes	Yes	53
19	Chlorobenzene (benzene chloride) [cs]	Volatile	Yes	Yes	48
20	Benzo(A)Pyrene	Semivol.	No	Yes	37

Appendix A2: Contaminants Most Frequently Reported in Ground Water at CERCLA NPL Sites (continued)[1]

Inorganic Contaminants:

Rank	Inorganic Contaminants	No.[1] Sites
1	Lead	307
2	Chromium and compounds	215
3	Arsenic	147
4	Cadmium	127
5	Mercury[4]	81
6	Copper and compounds	79
7	Zinc and compounds	73
8	Nickel and compounds	44
9	Cyanides (soluble salts)	39
10	Barium	37

NOTES:

[1] Number of CERCLA National Priorities List (NPL) sites for which the chemical was reported in ground water as a contaminant of concern in the Superfund Site Assessment, for either proposed or final NPL sites. This data was obtained from the Superfund NPL Assessment Program (SNAP) data base, as of August 30, 1994. At that time total of 1294 sites were listed on the NPL (64 proposed and 1230 final).

[2] Classification of organic contaminants as volatile, semivolatile, PCB, or pesticide; and as halogenated or nonhalogenated is from EPA Publication, "Technology Screening Guide for Treatment of CERCLA Soils and Sludges," EPA/540/2-88/004, September 1988.

[3] Classification of whether or not a chemical is a dense nonaqueous phase liquid (DNAPL) in pure form is from Cohen and Mercer, 1993 (see References).

[4] In pure form mercury is also a DNAPL.

[cs] These organic contaminants are chlorinated solvents. A total of 12 are listed.

[pf] These organic contaminants are constituents of petroleum fuels. A total of four are listed.

Appendix A3: Examples of In-Situ Treatment Technologies [1]

I. Enhanced Recovery Methods	Treatment Agents (and process type)	Agent Delivery Methods
Recirculation/flooding:		
- Water flooding (physical)	- Water - Heated water	- Injection wells - Injection wells
- Steam flooding (physical)	- Steam	- Injection wells
- Chemical flooding [2] (chemical)	- Surfactants - Solvents - Redox agents	- Injection wells - Injection wells - Injection wells
- Nutrient flooding [2] (biological)	- Nitrate - Other	- Injection wells
Thermal enhanced recovery:		
- Radio frequency	- Heat	- Electrodes in wells
- Electrical resistance (AC or DC)	- Heat	- Electrodes in wells
Enhancement of secondary permeability:		
- Induced fracturing with water or or air pressure (physical)	Not applicable	Not applicable
Other methods:		
- Electromigration (electrical)	- Electric current	- Electrodes in wells

---

NOTES:

[1] List of technologies and technology status is from EPA, 1993h (see References section of guidance).

[2] Chemicals or nutrients for micro-organisms, respectively, are added to reinjection water.

Appendix A3: Examples of In-Situ Treatment Technologies (continued)[1]

II. In-situ Treatment Processes	Treatment Agents	Agent Delivery Methods
Physical/chemical treatment:		
- Volatilization and oxygen enhancement by **air sparging**	- Air	- Injection wells - **Permeable walls/gates** [3]
- Reductive dehalogenation by metal catalysts (abiotic)	- Iron filings - Other agents	- **Permeable walls/gates** [3]
Biological treatment:		
- Oxygen enhancement of aerobic organisms (also includes air sparging, above)	- Hydrogen peroxide - Oxygen/surfactant (microbubbles)	- Injection wells [4] - Injection wells [4]
- Nutrient enhancement of aerobic organisms	- Nitrate - Other	- Injection wells [3]
- Nutrient enhancement of anaerobic organisms to produce enzymes that degrade contaminants (cometabolism)	- Methane - Other	- Injection wells
- Sequential anaerobic-aerobic treatment	- Methane and/or Oxygen	- Injection wells

---

NOTES:

[3] In permeable treatment walls/gates, treatment agents are added with trench backfill materials or are injected via perforated pipes placed in the backfill. These walls are placed in the subsurface across the natural flow path of the contaminant plume. They can be combined with impermeable flow barriers in a "funnel and gate" arrangement, in which flow is directed through the treatment walls/gates.

[4] Use of permeable treatment walls/gates to deliver treatment agents for these methods may also be feasible.

Appendix A4: Definition and Discussion of Pulsed Pumping

Pulsed Pumping

In pulsed pumping, some or all extraction pumps are turned off and then back on for specified periods of time (e.g., one or more monitoring periods). The on and off cycles can be continued or the extraction and treatment remedy can be returned to continuous pumping. Although not widely used in remedies to date, this method may be effective in **enhancing the recovery of contaminants from the aquifer**. Pulsed pumping can recover contaminants located in the following portions of the aquifer that are relatively unaffected during pumping:

- Upper portions of the aquifer that have been dewatered by pumping, and
- Zones with minimal ground-water flow during pumping (flow stagnation zones).

Pulsed pumping **may** also enhance contaminant recovery for aqueous phase contaminants that are sorbed to the aquifer matrix. Therefore, pulsed pumping can be initiated as a **post-construction refinement** of an extraction and treatment remedy (see Section 2.4), when an evaluation of remedy performance indicates that this technique may increase the recovery of contaminants from the aquifer.

Pulsed pumping can also be used as a method of evaluating the effectiveness of an extraction and treatment remedy and/or the effectiveness of source control actions. For example, if contaminant levels increase substantially when pumping is stopped, it is an indication that contaminants continue to be derived from source materials, and that additional remedial measures (e.g., source control/removal) may be necessary. These source materials could include aqueous contaminants sorbed to aquifer solids in finer-grained aquifer layers, NAPLs (refer to Appendix A1), contaminated soils, or other sources.

Pulsed pumping should generally **not be initiated** until after sufficient monitoring data has been obtained from continuous pumping to establish a statistically valid performance trend. Also, the influence of pulsed pumping on plume containment should be considered; and extraction wells used primarily for containment (i.e, at plume leading edge) should generally not be pulsed.

APPENDIX B

ROD Language Examples For Selected Remedy

Appendix B1: Phased Implementation of Ground-Water Remedy

Appendix B2: Phased Implementation of **Extraction Component** of Remedy at a DNAPL Site

Appendix B3: **Deferring Selection** of Treatment Components to Remedial Design

Appendix B4: Suggested ROD Language from **1990 OSWER Directive**

Appendix B1: Phased Implementation of Ground-Water Remedy

Site Conditions:

At **hypothetical Site 1** (an LNAPL site) surficial soils and the underlying ground water in Aquifer C are contaminated with volatile organic compounds (VOCs). At this site, Aquifer C is currently used as a source of drinking water, with several wells located on-site and in the estimated path of the contaminant plume.

Early actions were used for exposure prevention and source control. Under Superfund **removal authority**, an alternate water supply was provided to several residences, and leaking drums and heavily contaminated soils were excavated and taken off-site for disposal. A soil vapor extraction system was installed as an **interim remedial action**. No further source control actions are planned. DNAPLs are not likely to be present in the subsurface because most of the contaminants are LNAPLs rather than DNAPLs in pure form. The selected ground-water remedy relies on extraction and treatment for preventing further migration of the contaminant plume and for restoration of Aquifer C. **The selected remedy will be implemented in two construction phases.**

ROD Language for Extraction Component of Remedy:

The following, or similar language, should appear in the **Selected Remedy** section of the ROD:

> *The **ultimate goal** for the ground-water portion of this remedial action is to restore Aquifer C to its beneficial uses. At this site, Aquifer C is currently used as a source of drinking water. Based on information obtained during the remedial investigation and on a careful analysis of all remedial alternatives, EPA and the State of ___ believe that the selected remedy will achieve this goal.*
>
> *The **extraction portion of the ground-water remedy** will be implemented in two phases. In **phase one**, a sufficient number of extraction wells will be installed with the **objective of minimizing further migration of the contaminant plume**. It is currently estimated that two to four extraction wells will be required for phase one.* [1] *After construction of phase one is completed, the extraction system will be carefully monitored on a regular basis and its performance evaluated. **Operation and monitoring of phase one for a period of up to one year may be needed to provide sufficient information to complete the design of phase two.***
>
> *In **phase two**, additional extraction wells will be installed with the **objective of restoring Aquifer C for use as a source of drinking water**, in addition to maintaining the remedial objectives for phase one. Restoration is defined as attainment of required cleanup levels in the aquifer, over the entire contaminant plume. Cleanup levels for each ground-water contaminant of concern are specified in Table __ of the ROD. Current estimates indicate that an additional two to four extraction wells may be required to attain these cleanup levels within a timeframe of approximately 20 years.* [1] *However, **monitoring and evaluation of the performance of phase one will be used to determine the actual number and placement of wells for phase two**.*

The selected remedy will include ground-water extraction for an estimated period of 20 years, during which the system's performance will be carefully monitored, in accordance with the monitoring plan defined in Section ___ of the ROD, and adjusted as warranted by the performance data collected during operation. ***Refinement*** *of the extraction system may be required, if EPA determines that such measures will be necessary in order to restore Aquifer C in a reasonable timeframe, or to significantly reduce the timeframe or long-term cost of attaining this objective.* ***Refinement of the extraction system may include any or all of the following:***

1) *Adjusting the rate of extraction from some or all wells;*

2) *Discontinuing pumping at individual wells where cleanup goals have been attained;*

3) *Pulsed pumping of some or all extraction wells to eliminate flow stagnation areas, allow sorbed contaminants to partition into ground water, or otherwise facilitate recovery of contaminants from the aquifer; and*

4) *Installing up to two additional ground-water extraction wells to facilitate or accelerate cleanup of the contaminant plume.* [1]

It is possible that performance evaluations of the ground-water extraction system - after completion of phase one, during implementation or operation of phase two, or after subsequent refinement measures - will indicate that restoration of Aquifer C is technically impracticable from an engineering perspective. ***If such a determination is made by EPA, the ultimate remediation goal and/or the selected remedy may be reevaluated.*** [2]

NOTES:

1. Although not required in a ROD, the **estimated number of wells** is included in this example for the following reasons, to:

   - Provide a **basis for estimating the cost** of the selected remedy, including upper and lower costs for phase one, phase two and the potential refinement measures;

   - Provide some **specificity regarding how the extraction component of the remedy will be used in the overall remediation strategy**, because changes in the extraction system directly influence the time period required to attain the remedial objectives for this site; and to

   - Provide some **bounds for the scope, performance and cost of the selected remedy**, which will assist in determining whether future, post-ROD remedy modifications require an Explanation of Significant Differences (see Section 2.4 of this guidance).

2. Reevaluation of the ultimate remediation goal and/or the selected remedy would generally require an ESD or ROD amendment.

Appendix B2: Phased Implementation of Extraction Component of Remedy at a DNAPL Site

Site Conditions :

At **hypothetical Site 2** (a DNAPL site), ground water in Aquifer A is contaminated with volatile and semivolatile organic contaminants (no metals as contaminants of concern). DNAPLs have also been observed in this aquifer. At this site, Aquifer A is not currently used as source of drinking water, but several wells are located off-site in the estimated path of the contaminant plume.

The selected remedy includes extraction and treatment for hydraulic containment of the likely **DNAPL-zone** (see Appendix A1 of this guidance) and for restoration of the aquifer outside the DNAPL-zone. Reinjection of a portion of the treated ground water will be used to enhance recovery of contaminants from the aquifer. It has been determined that aquifer restoration within the DNAPL-zone is technically impracticable from an engineering perspective, as explained in the **Statutory Determinations** section of the ROD. **The remedy will be implemented in two construction phases.**

ROD Language for Extraction Component of Remedy :

The following, or similar language, should appear in the **Selected Remedy** section of the ROD:

> *The* ***ultimate goal*** *for the ground-water portion of this remedial action is to restore the maximum areal extent of Aquifer A to its beneficial uses. At this site Aquifer A is potentially useable as a source of drinking water and is currently used off-site for this purpose. Based on information obtained during the remedial investigation and on a careful analysis of all remedial alternatives, EPA believes that the selected remedy will achieve this goal.*
>
> *The* ***extraction portion of the ground-water remedy*** *will be implemented in two phases. In* ***phase one****, a sufficient number of extraction wells will be installed to achieve* ***two remedial objectives for Aquifer A*** *: 1) minimizing further migration of contaminants from suspected subsurface DNAPL areas to the surrounding ground water; and 2) minimizing further migration of the leading edge of the contaminant plume. It is currently estimated that three to five extraction wells will be required for phase one.* [1] *After construction of phase one is completed, the extraction system will be carefully monitored on a regular basis and its performance evaluated. This evaluation may provide further information concerning the extent of the DNAPL-zone.* ***Operation and monitoring of phase one for a period of up to two years may be needed to provide sufficient information to complete the design of phase two.***
>
> *In* ***phase two****, additional extraction wells will be installed with the objective of* ***restoring the maximum areal extent of Aquifer A*** *for use as a source of drinking water, in addition to maintaining phase one objectives. Reinjection wells and related pumping equipment for flushing a portion of the treated ground water through the aquifer (water flooding) will also be installed in order to enhance the recovery of contaminants. Restoration is defined as attainment of required cleanup levels in the aquifer, over the portion of the contaminant plume outside the DNAPL-zone. Cleanup levels for each ground-water contaminant of concern are specified in Table __; although cleanup level ARARs within the DNAPL-zone have been waived by EPA due technical impracticability from an engineering perspective, as discussed in Section __ of the ROD. Current estimates indicate that these cleanup levels can be attained in the portion of Aquifer A outside the DNAPL-zone within a timeframe of approximately 25 years.*

Appendix B2: Phased Implementation of Extraction Component of Remedy at a DNAPL Site (continued)

Current estimates also indicate that an additional two to six extraction wells and two to four reinjection wells may be required for phase two. [1] ***However, monitoring and evaluation of the performance of phase one will be used to determine the actual number and placement of wells for phase two.***

The selected remedy will include ground-water extraction for an ***estimated period of 25 years****, during which the system's performance will be carefully monitored, in accordance with the monitoring plan defined in Section ___ of the ROD, and adjusted as warranted by the performance data collected during operation.* ***Refinement*** *of the extraction system may be required, if EPA determines that such measures will be necessary in order to restore the maximum areal extent of Aquifer A in a reasonable timeframe, or to significantly reduce the timeframe or long-term cost of attaining this objective.* ***Refinement of the extraction system may include any or all of the following:***

1) *Adjusting the rate of extraction from some or all wells;*
2) *Discontinuing pumping at individual wells where cleanup goals have been attained;*
3) *Pulsed pumping of some or all extraction wells to eliminate flow stagnation areas, allow sorbed contaminants to partition into ground water, or otherwise facilitate recovery of contaminants from the aquifer;*
4) *Installing up to two additional ground-water extraction wells to facilitate or accelerate cleanup of the contaminant plume; and* [1]
5) *Installing up to two additional reinjection wells.* [1]

It is possible that performance evaluations of the ground-water extraction system - after completion of phase one, during implementation or operation of phase two, or after subsequent refinement measures - will indicate that restoration of portions or all of Aquifer A is technically impracticable from an engineering perspective. ***If such a determination is made by EPA, the ultimate remediation goal and/or the selected remedy may be reevaluated.*** [2]

NOTES:

1. The reasons for including the **estimated number of wells** in this example are discussed in the Notes section of the previous example, Appendix B2.

2. Reevaluation of the ultimate remediation goal and/or the selected remedy would generally require an ESD or ROD amendment.

Appendix B3: Deferring Selection of Treatment Components to Remedial Design

Site Conditions :

Hypothetical Site 2 is the same site used in the previous example, Appendix B2. Most of the treated ground water will be discharged to the nearby Muddy River, although a portion (20 to 30 percent) will be reinjected to Aquifer A to enhance contaminant recovery. Contaminant-specific and other water quality requirements for discharge to the Muddy River were specified by the state and are listed in Table ___ of the ROD. Other specifications for the treatment system are also listed in the ROD, which include filtering of suspended mineral solids to minimize clogging of reinjection wells; and treatment of vapor phase organic contaminants from air stripping or other processes, as requested by the local community.

ROD Language for Treatment Component of Remedy :

*The **ex-situ treatment component of the ground-water** remedy will utilize presumptive technologies identified in Directive 9283.1-12 from EPA's Office of Solid Waste and Emergency Response (OSWER), included as Attachment __ of the ROD. Since contaminants of concern include volatile and semivolatile organic compounds, **one or more of the presumptive technologies** - air stripping, granular activated carbon (GAC), chemical/UV oxidation and aerobic biological reactors - will be used for treating aqueous contaminants in the extracted ground water. Other technologies will also be needed in the treatment system for removal of suspended mineral solids and treatment of vapor phase contaminants. **The actual technologies and sequence of technologies used for the treatment system will be determined during remedial design.** Final selection of these technologies will be based on additional site information to be collected during the remedial design. (See Section 3.4 and Appendix C3 of OSWER Directive 9283.1-12 for a discussion of site information needed for selection and design of the ex-situ treatment system.) Based on this additional information and sound engineering practice the treatment system shall be designed to:*

- *Attain the chemical-specific discharge requirements and other performance criteria specified in Table __ and Section __ of the ROD; and*
- *Treat, or be easily modified to treat, the expected flow increase from phase one to phase two of the extraction system.*

Other design factors shall include:

- *Maximizing long-term effectiveness,*
- *Maximizing long-term reliability (i.e., minimize the likelihood of process upsets), and*
- *Minimizing long-term operating costs.*

Additional information concerning presumptive technologies for the ex-situ treatment component of the remedy is provided in OSWER Directive 9283.1-12. Descriptions of each of the presumptive technologies are presented in Appendices D1 through D8, and advantages and limitations of each of these technologies are listed in Appendix C4 of this directive.

Appendix B3: Deferring Selection of Treatment Components to Remedial Design (continued)

__For the purpose of estimating the approximate cost of the treatment component__ of the selected remedy, the following treatment sequence is assumed for __aqueous contaminants__: flow equalization tanks, a gravity oil-water separator, an air stripper, followed by GAC units. GAC will also be used to treat __vapor phase contaminants__ from the air stripper. The GAC units will be thermally reactivated at an off-site facility. Separated DNAPL compounds will be recycled if possible, but since the actual composition of the recovered liquids is unknown, costs for incineration at an off-site facility were used for the cost estimate.

Appendix B4: Suggested ROD Language from 1990 OSWER Directive

Recommended language for the Selected Remedy section of the ROD was given in OSWER Directive 9283.1-03, entitled "Suggested ROD Language for Various Ground-Water Remediation Options," dated October 10, 1990. For the RODs in which the final remedy without a contingency is selected, this Directive recommended that "the following type of language should appear in the **Selected Remedy** section of the ROD:"

> *The goal of this remedial action is to restore ground water to its beneficial use, which is, at this site, (specify whether this is a potential or actual drinking water source, or is used for non-domestic purposes). Based on information obtained during the remedial investigation and on a careful analysis of all remedial alternatives, EPA < (optional) and the State/Commonwealth of _____ > believe that the selected remedy will achieve this goal. It may become apparent, during implementation or operation of the ground-water extraction system and its modifications, that contaminant levels have ceased to decline and are remaining constant at levels higher than the remediation goal over some portion of the contaminated plume. In such a case, the system performance standards and/or the remedy may be reevaluated.*
>
> *The selected remedy will include ground-water extraction for an estimated period of _____ years, during which the system's performance will be carefully monitored on a regular basis and adjusted as warranted by the performance data collected during operation. Modifications may include any or all of the following:*
>
> *a) at individual wells where cleanup goals have been attained, pumping may be discontinued;*
>
> *b) alternating pumping at wells to eliminate stagnation points;*
>
> *c) pulse pumping to allow aquifer equilibration and to allow adsorbed contaminants to partition into ground water; and*
>
> *d) installation of additional extraction wells to facilitate or accelerate cleanup of the contaminant plume.*
>
> *To ensure that cleanup goals continue to be maintained, the aquifer will be monitored at those wells where pumping has ceased on an occurrence of every _____ years following discontinuation of ground-water extraction.*

APPENDIX C

Ex-Situ Treatment Technologies for Ground Water

Appendix C1:	Ex-Situ **Technologies Considered** in Sample of 25 Sites
Appendix C2:	**Other Components** Needed for Treatment Trains
Appendix C3:	**Information Needed** for Selection of Technologies and Design of Treatment Train
Appendix C4:	**Advantages and Limitations** of Presumptive Treatment Technologies

Appendix C1: Ex-Situ Technologies Considered in Sample of 25 Sites

Technologies that were **considered** for treatment of extracted ground in the sample of 25 sites reviewed in detail (EPA, 1996b) are listed below. These technologies were either considered in the feasibility study (FS), or considered and/or selected in the record of decision (ROD) or remedial design. The technologies are listed according to overall process type, and by design style within each type. Those technologies identified as **presumptive technologies** are also indicated. For further information on how presumptive technologies were identified, refer to Section 3.2 of this guidance and EPA, 1996b.

For Treatment of **Organic** Contaminants:

Presumptive Technologies:

Air stripping:

- Packed tower
    - Ambient temperature
    - Higher temperature
- Aeration methods
    - Ambient temperature
    - Higher temperature
- Cascade falls

Granular activated carbon (GAC)

Chemical/UV oxidation:

- Chemical oxidation alone
    - Ozone
    - Hydrogen peroxide
    - Chlorine compounds
    - Potassium permanganate
- Chemical with UV oxidation
    - Ozone
    - Hydrogen peroxide
- UV oxidation alone (photolysis)
- Alkaline chlorination (**for cyanide**)
- Unspecified oxidation methods

Aerobic biological reactors:

- Attached growth
    - Trickling filter
    - Rotating biological contactors
    - Fixed bed
- Suspended growth
    - Activated sludge
    - Sequencing batch reactors
    - Aeration ponds/lagoons
    - Unspecified suspended growth
- Unspecified aerobic reactors

For Treatment of **Metals**:

Chemical precipitation:

- Hydroxide precipitants
    - Sodium hydroxide
    - Lime
    - With prior chemical reduction
- Sulfide precipitants
    - Sulfur dioxide
    - Sodium sulfide
    - Sodium bisulfide/bisulfites
    - With prior chemical reduction
    - Unspecified sulfide precipitant
- Other precipitation methods
    - Ferrous sulfate
    - Potassium permanganate
    - Activated consumable element
    - Unspecified chemical precipitation

Ion exchange/adsorption:

- Fixed bed
    - Impregnated/synthetic resin
    - Activated alumina
- Electrodialysis
- Unspecified ion exchange

Electrochemical methods:

- Electrochemical reduction
- Magnetically activated

Aeration of Background Metals:

- Aeration basin
- Cascade aeration
- Other aeration methods

Appendix C1: Ex-Situ Technologies Considered in Sample of 25 Sites (continued)

For Treatment of **Organic** Contaminants:

Other Technologies Considered:

Chemical treatment:
- Hydrolysis
- Catalytic dehydrochlorination
- Catalytic dechlorination
- Chlorinolysis

Thermal Destruction:
- Incineration
- Calcination
- Wet air oxidation
- Supercritical water oxidation
- Microwave discharge/plasma

High temperature separation:
- Steam stripping
- Distillation

Membrane filtration:
- Reverse osmosis
- Ultrafiltration

Anaerobic biological treatment:
- Anaerobic biological reactor
- Enzymatic degradation

Liquid-liquid extraction:
- Solvent extraction
- Liquid carbon dioxide extraction

Evaporation:
- Evaporation basin

Land treatment:
- Surface spreading
- Spray irrigation

For Treatment of **Metals**:

Granular activated carbon (for metals)

Reverse Osmosis

Biological treatment of metals

Appendix C2: Other Components Needed for Treatment Trains [1]

Solid or Liquid Separation Technologies

- Oil/grease separation [4]
- Filtration [5]
- Coagulation [5] (or flocculation)
- Clarification [5] (or sedimentation)

Effluent Polishing Technologies [2]

- Activated carbon
- Ion exchange
- Neutralization

Vapor Phase Treatment Technologies [3]

- Activated carbon
- Resin adsorption
- Catalytic oxidation
- Thermal incineration
- Acid gas scrubbing
- Condensation

General Sequence of Unit Processes Used in Aqueous Treatment Trains

Sequence	Unit Treatment Process	Treatment Stage
Begin	Equalize inflow	Pretreatment
	Separate solid particles	Pretreatment
	Separate oil/grease (NAPLs)	Pretreatment
	Remove metals	Treatment
	Remove volatile organics	Treatment
	Remove other organics	Treatment
	Polish organics [2]	Post-treatment
	Polish metals	Post-treatment
End	Adjust pH, if required	Post-treatment

NOTES:

[1] In addition to the presumptive technologies listed in the guidance, other treatment components are needed either prior to (pretreatment) or subsequent to (post-treatment) the presumptive technologies. This listing is not intended to be presumptive. Not listed are technologies that may be required for treatment residuals, such as spent carbon.

[2] Effluent polishing technologies are those used for the final stage of treatment prior to discharge, and can include pH adjustment (neutralization) as well as additional removal of aqueous constituents.

[3] Vapor phase contaminants released during water treatment may need to be contained and treated. This includes organic contaminants volatilized during air stripping, from biological treatment, or other gases released from chemical oxidation, reduction or biologic processes (e.g., hydrochloric acid, hydrogen sulfide, methane, etc.).

[4] Methods for separation of oil and/or grease from water include, but are not limited to, gravity separation and dissolved air floatation. These methods can be used to remove NAPLs from the extracted ground water.

[5] These technologies can be used to remove solid particles at the beginning of the treatment train or for removal of other solids resulting from chemical precipitation, chemical/UV oxidation or biological treatment.

Appendix C3: Information Needed for Selection of Technologies and Design of Treatment Train

Information Needed	Purpose of Information
1. Total extraction flow rate: ● Total extracted flow ● Flow variability ● Uncertainty of estimate	**Inflow** to the treatment system is the total flow from all extraction wells. Since this flow must also be discharged, large flows may determine the availability of some discharge options. Flow rate and concentration determines the mass loading (mass per unit water volume) of each contaminant entering the treatment system. The mass loading determines the dimensions and capacities of treatment vessels, and whether continuous flow or batch design are used for each treatment unit. Flow is also a factor for selecting among the presumptive treatment technologies because some are less cost effective for high or low flows. **Variable inflow** rates may require use of flow equalization tanks, batch instead of continuous flow operation or use of modular treatment units that can be added or subtracted from the treatment train. Some technologies can handle variable flow more easily than others. Variable extraction rates may result from short-term operational changes, seasonal changes or phased well installation. **Uncertainty** in the flow estimate can result from natural variability of aquifer properties over the site, and from the method used to measure these properties. Since flow is a critical design parameter, additional characterization may be needed to reduce the level of uncertainty. **Estimates of the total extraction rate should be based on pumping type aquifer tests, since this method provides a much better estimate of average aquifer properties than other methods.**

Appendix C3: Information Needed for Selection of Technologies and Design of Treatment Train (continued)

Information Needed	Purpose of Information
2. Discharge options and effluent requirements: ● Options available ● Target effluent concentrations, each option - Contaminants - Contaminant degradation products - Treatment additives - Natural constituents - Water quality parameters ● Other requirements, each option - Regulatory - Operational ● Community concerns or preferences	Options for discharge of treated ground water could include: discharge to surface waters; discharge to a drinking water system; reuse or recycling for other purposes (e.g., industrial processes); infiltration or reinjection to shallow subsurface or reinjection to the same aquifer; or discharge to POTW. Target effluent concentration levels for both contaminants and naturally occurring constituents may be markedly different for each discharge option. Effluent requirements could include those for chemicals added during treatment, contaminant degradation products, naturally occurring constituents (e.g., arsenic), and water quality parameters (e.g., suspended solids) in addition to maximum concentration levels for chemicals of concern. These requirements will determine the overall level of treatment needed, which in turn determines the type of components needed in the treatment train and is a critical factor in selecting appropriate treatment technologies. Each discharge option may have different water quality requirements for the treated effluent, from both a **regulatory** and **operational** standpoint. For example, reinjection to the subsurface must meet substantive federal and/or state requirements for underground injection (regulatory) as well as minimize chemical and biological clogging of injection wells or infiltration lines (operational). Use of the best available technology (BAT) could also be a regulatory requirement. The **affected community** may also have concerns or preferences regarding the type of discharge. **Target effluent concentrations** determine the overall removal efficiency the treatment train must attain for each constituent. For example, if the target effluent level is 10 mg/L and the inflow concentration is 1000 mg/L, then the treatment train must attain an overall removal efficiency of 99.0 percent (1000 - 0.99(1000) = 10). The treatment train may need to include more than one type of technology, or multiple units of a single technology, in order to attain the required overall removal efficiency.

Appendix C3: Information Needed for Selection of Technologies and Design of Treatment Train (continued)

Information Needed	Purpose of Information
3. Water quality of treatment influent: • Contaminant types and concentrations: - Inorganic chemicals - Organic chemicals - Concentration changes over time - Nonaqueous phase liquids (NAPLs)	**Contaminant types and concentrations** must be estimated for the total flow entering the treatment system. Since some technologies are more effective in removing certain contaminant types, this is an important technology selection factor. Inflow concentrations are needed to determine the removal efficiency of the treatment train, as discussed above. **The design should consider the potential for inflow concentrations to change over time.** Contaminant concentrations usually decrease as remediation progresses. Also, short term increases may occur if a "hot spot" of more highly contaminated ground water is captured by the extraction system. Samples obtained from **pumping type aquifer tests provide better estimates of average contaminant concentrations**, because such samples are obtained from a relatively large aquifer volume. If present, subsurface **NAPLs** (refer to Appendix A1) may become entrained in the extracted ground water. These immiscible liquids should be removed in a pretreatment step (process used prior to other treatment methods). Also, a specialized extraction system may be needed to remove free-phase NAPLs from the subsurface.
• Naturally occurring constituents: - Major cations (metals) and anions - Organic chemicals - Radionuclides	**Naturally occurring** or non-site related constituents may need to be removed to prevent interference with treatment processes and may be a factor in technology selection. **Metals** such as iron, manganese, and calcium can leave mineral deposits (scaling) on air stripper packing and on activated carbon or other treatment media. If not accounted for, these metals can also cause premature exhaustion of ion exchange capacity and increased consumption of reagents in chemical oxidation or precipitation processes. Iron also promotes biological fouling in air strippers. Heavy metals (e.g., lead, mercury) and cyanides can be toxic to microorganisms in biological reactors. Metals can also form deposits on well screens of extraction or reinjection wells (encrustation) or promote biological fouling (clogging) on well screens.

Appendix C3: Information Needed for Selection of Technologies and Design of Treatment Train (continued)

Information Needed	Purpose of Information
3. Water quality of influent (continued): ● Other water quality parameters: - Indicator parameters - Design parameters	Dissolved **organic constituents** (e.g., from decay of organic materials or from landfill leachate) can interfere with adsorption of targeted compounds and can cause premature exhaustion of activated carbon. Metal-organic complexes can interfere with chemical oxidation or precipitation processes. If present, naturally occurring **radionuclides** can accumulate in treatment media or residuals (e.g., activated carbon or chemical sludges) resulting in potential exposure hazards for personnel and additional transportation and disposal considerations. Other water quality parameters are used as effluent quality standards, indicator parameters, or design parameters for treatment processes. **Indicator parameters** are used to indicate the presence of other constituents. For example, total dissolved carbon (TDC) is a measure of the relative level of dissolved organic constituents. Gross alpha and gross beta particle activity are relatively simple measurements that indicate the relative abundance of **naturally occurring radionuclides** . Other indicator parameters include: total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD) and total suspended solids (TSS). Temperature and pH are **design parameters** for most treatment processes. Also, high levels of total suspended solids (TSS) in extracted ground water may indicate that extraction wells are not properly designed or developed. Most treatment technologies require that suspended solids in excess of certain level be removed during pretreatment, where acceptable levels may differ for each technology.

Appendix C3: Information Needed for Selection of Technologies and Design of Treatment Train (continued)

Information Needed	Purpose of Information
4. Treatability information: • From technical literature • Treatability studies - Laboratory screening - Bench-scale testing - Pilot-scale testing • Modeling predictions • Projections of effluent quality	Treatability information is needed to select technology types and design styles from among the presumptive technologies; and for selection and design of other components of the treatment train. The particular mix of contaminants and naturally occurring constituents can vary considerably for different sites. Treatability information is available in the **technical literature** for some technologies, including air stripping and granular activated carbon (GAC). **Treatability studies** include 1) laboratory screening, 2) bench-scale testing, or 3) pilot-scale testing. These studies may begin with any tier and skip tiers that are not needed (see Section 3.4 of guidance). **Computer models** for predicting treatment performance are available for some technologies. In general, treatability studies should be performed prior or during the design of any system expected to provide **long-term treatment** of extracted ground water, including systems using presumptive technologies. Treatability studies are needed to accurately predict the effectiveness and cost of a technology for a given site, including construction and operating costs; and the costs of other components of the treatment train. Optimizing the cost effectiveness of the treatment train (i.e., minimizing the total cost per unit volume of water treated) is especially important for systems designed to operate over a long time period. Treatability studies **may reveal unexpected site conditions**, such as the presence of naturally occurring compounds that interfere with the planned treatment process or that metal contaminants can be effectively removed by removing mineral solids. Such studies are also needed to determine pretreatment requirements, and requirements for treating aqueous, vapor and solid waste streams resulting from a particular treatment process. Treatability studies are needed to determine optimum chemical reagents and reagent quantities for pH adjustment; oxidation, reduction or precipitation of contaminants; and parameters for design of biological and other reactors. Treatability studies should be performed on samples obtained from **pumping type aquifer tests** instead of from monitoring wells, because such samples are more representative of contaminated ground water that will enter the treatment system. Samples obtained for treatability studies should be obtained after several hours of pumping.

Appendix C4: Advantages and Limitations of Presumptive Treatment Technologies

Technology	Advantages	Limitations
Treatment Technologies for the Removal of Organic Contaminants		
Air Stripping	• Successfully used in hundreds of groundwater applications • Low operating cost relative to other technologies (e.g., energy usage is relatively low). • Operationally simple system requiring a minimum of operator assistance. • Treatability studies often not required for selection or design, but are recommended. • Trained contractors available to implement the technology.	• Contaminants transferred to air, and treatment of air emissions may be required. • Pretreatment for metals removal and pH control may be needed to reduce fouling and corrosion. • Post-treatment (polishing) may be required. • Large surges in influent concentrations can reduce removal efficiency because the efficiency for an individual compound is fixed regardless of influent concentrations. • Air stripping is not as effective for compounds with low Henry's law constants or high solubilities.[b,c] • Cold weather can reduce efficiency.
Granular Activated Carbon	• Successfully used for contaminated ground water at many Superfund and underground storage tank sites. • Operationally simple system requiring a minimum of operator assistance. • Regularly used as a polishing step following other treatment technologies. • Treatability studies generally not required, but are recommended (information is available from carbon vendors). • Trained contractors available to implement the technology. • Generally a cost-effective alternative as single- step treatment for flows less than about 3 gpm.[d]	• Activated carbon is generally too costly for use as a single-step treatment if ground-water chemistry requires high carbon usage rates. • Contaminants are not destroyed but are transferred to another media (i.e., spent carbon must be regenerated or disposed of properly). • Pretreatment for suspended solids removal is often required. • Pretreatment for metals removal and pH control may be needed to reduce fouling and corrosion. • Organic compounds that have low molecular weight and high polarity are not recommended for activated carbon (e.g., acetone). • Naturally occurring organic compounds may exhaust carbon bed rapidly and may interfere with the adsorption of targeted chemicals.

Appendix C4: Advantages and Limitations of Presumptive Treatment Technologies (continued)

Technology	Advantages	Limitations
Chemical/ UV Oxidation	• Where oxidation is complete, organic contaminants are destroyed and not transferred to other media; minimal residuals generated. • Effective on a wide variety of volatile and semivolatile organics, including chlorinated organics, as well as cyanide and some metals. • Operating costs can be competitive with air stripping and activated carbon.	• Incomplete oxidation will leave original contaminants and possibly toxic oxidation products; activated carbon polishing may be required. • Capital costs may preclude small-scale applications, especially for ozone systems. • Metals may precipitate during oxidation, requiring filtration post-treatment and residuals disposal. • UV light sources are subject to fouling and scaling from solids, iron compounds, carbonates, etc. Pretreatment may be required to remove these substances. • Process must be closely monitored to ensure contaminant destruction and to prevent safety hazards. • Peroxide and other chemical oxidants must be properly stored and handled. • Site-specific treatability studies are necessary (process may require large quantities of oxidizer to destroy target compound(s) if reactive nontarget compounds are present).
Aerobic Biological Reactors	• Organic contaminants degraded, often with minimal cross-media environmental impacts. • Proven effective for many organic compounds. • Some systems (e.g., trickling filters and rotating biological contactors) have minimal energy requirements and generally low capital and operating costs. • Can be designed to require a minimum of operator attention. • Relatively simple, readily available equipment. • Trained contractors available to implement the technology.	• A residual organic sludge is generated that must be disposed of properly. • Some compounds are difficult or impossible to degrade (recalcitrant) or slow to degrade. • Difficulties acclimating microorganisms to contaminants are possible; requires longer startup time than other technologies to achieve effective steady-state performance • Volatile organics may require air emission controls or pretreatment to remove them. • Variations in flow or concentration may require significant operator attention to prevent microorganisms from being killed. • Cold weather can cause operational difficulties. • Treatability studies are needed for selection and design. • Pretreatment may be needed to remove contaminants toxic to the microorganisms, such as heavy metals. • Low organic loading and the potential for supplementary nutrients and food sources must be considered.

Appendix C4: Advantages and Limitations of Presumptive Treatment Technologies (continued)

Technology	Advantages	Limitations
Treatment Technologies for the Removal of Inorganic Contaminants		
Chemical Precipitation	• Most commonly used method for removing soluble heavy metal ions from contaminated water. • Pretreatment for solids and iron generally not required. Hydroxide Precipitation • Reliable method, chemicals relatively easy to handle, and not costly. Carbonate Precipitation • Reliable method, calcium carbonate easy to handle, and not costly. • Effectively removes a variety of soluble metals. Sulfide Precipitation • Reliable method. • High removal efficiency over a broader pH range. • Relatively insensitive to most chelating agents. • Can remove chromates and dichromates without reducing hexavalent chromium to trivalent form if ferrous ions are present or added.	• A residual sludge is generated that must be treated and/or disposed of properly; metals are not usually easy to recover from sludge. • Up to four times stoichiometric chemical additions may be required, especially for sulfide precipitation (see below). Hydroxide Precipitation • Organics or complexing ions may form chelates/complexes instead of insoluble metal hydroxides. • Optimum pH is different for each metal hydroxide, one pH may not effectively treat all soluble metal ions; successive treatments may be required. • pH must be controlled within a narrow range. • Naturally occurring sulfate in ground water may react with lime to form gypsum, which increases sludge, can clog filters, and can coat pipelines (caustic soda addition can reduce this problem but increases costs and dissolved solids [sodium salts] that must be removed from treated ground water). Carbonate Precipitation • Calcium carbonate is not effective for ground water with high alkaline content. • Pretreatment to remove organic, chelating, or oil and grease contaminants may be required. Sulfide Precipitation (Soluble Sulfide) • Excess sulfide ions that are not precipitated remain in solution. They may be removed by using aeration to convert them from ionic to oxide form (sulfate). • pH control between 8 and 9.5 is required to avoid release of hydrogen sulfide gas. • Cost is high compared to hydroxide and carbonate precipitation Sulfide Precipitation (Insoluble Sulfides) • Ferrous sulfide is used in amounts greater than that required by stoichiometric considerations. • Produces more sludge than soluble sulfide or hydroxide processes.

Appendix C4: Advantages and Limitations of Presumptive Treatment Technologies (continued)

Technology	Advantages	Limitations
Treatment Technologies for the Removal of Inorganic Contaminants (continued):		
Ion Exchange/ Adsorption	• High removal efficiencies for heavy metals. • Suitable for use as a polishing step after other technologies. • Technology is reasonably well understood. • On-site backflushing of exchange media allows immediate reuse.	• Resins are usually costly and may not be cost-effective for large treatment loadings. • Generates large volume of backflush solution (approximately 2.5 to 5% of the original ground-water flow rate) that is concentrated in the metals removed and requires treatment or disposal. • Requires bench-scale testing to determine operational requirements and suitability of prospective resins. • Beds can be fouled by particulate matter, oxidizing agents, oils, greases, biological growths, and intra-bed precipitates; therefore, pretreatment may be needed. • Resins may be irreversibly harmed by aromatics and certain other organic compounds; and by iron, manganese, and copper if enough dissolved oxygen is present. Pretreatment may be needed. • Spent resins require treatment before disposal.
Electro- chemical Methods	• High removal efficiencies for certain heavy metals. • Can treat both metals and cyanide simultaneously. • Technology is reasonably well understood. • Requires little floor space due to short residence time for hexavalent chromium reduction. • Requires minimal operator attention. • Low operating costs compared to chemical reduction or precipitation. • Requires no chemical addition.	• Particulate matter, oxidizing agents, oils, greases, biological growths may reduce process efficiency; therefore, pretreatment may be needed. • Hexavalent chromium reduction generates a heavy metal precipitate that must be removed from solution in a subsequent clarification or settling process. • A heavy metal sludge residual may be generated that may require treatment (dewatering and/or fixation) and that will require disposal. • A spent acid rinse solution may be generated that requires treatment or disposal. • Electrodes must be replaced occasionally.

NOTES:

[a] U.S. Environmental Protection Agency. 1991. Engineering Bulletin: *Air Stripping of Aqueous Solutions*. EPA/540/2-91/022. 8 pp.

[b] B. Lamarre. 1993. Selecting an air stripper (what to consider!) *The National Environmental Journal*: 26-29.

[c] G. M. Long. 1993. Clean up hydrocarbon contamination effectively. *Chemical Engineering Progress*: 58-66.

APPENDIX D

Descriptions of Presumptive Treatment Technologies

Appendix D1:	Air Stripping
Appendix D2:	Granular Activated Carbon
Appendix D3:	Chemical/UV Oxidation
Appendix D4:	Aerobic Biological Reactors
Appendix D5:	Chemical Precipitation
Appendix D6:	Ion Exchange/Adsorption
Appendix D7:	Electrochemical Methods
Appendix D8:	Aeration of Background Metals

Appendix D1: Air Stripping

Air stripping uses volatilization to transfer contaminants from ground water to air. In general, water is contacted with an air stream to volatilize dissolved contaminants into the air stream. Stripping of a specific chemical depends on the equilibrium vapor pressure of that chemical as expressed by its Henry's law constant.

Applicability

Air stripping is *applicable* to most of the volatile organic compounds (VOCs) as well as volatile inorganics such as ammonia and hydrogen sulfide. VOCs with high solubility in water (e.g., acetone) are more difficult to air strip. Air stripping is *potentially applicable* to certain halogenated semi-volatile organic compounds (SVOCs). It is *not applicable* to nonhalogenated SVOCs; heavy organics such as PCBs, dioxins/furans and pesticides; or inorganic metal compounds (U.S. EPA, 1991).

Air stripping is most effective for contaminants with a dimensionless (molar volume) Henry's law constant greater than 0.01 (or 2.4×10^{-4} atm-m^3/gmol at 25° C). (Henry's law constants are available in U.S. EPA [1990]). Removal efficiencies greater than 99 percent are difficult to achieve for certain compounds. In general, other treatment technologies will be required for such chemicals when ground-water concentrations are high (e.g., above 10,000 ppm or 1 percent).

Contaminant Fate

Contaminants are not destroyed by air stripping but are physically separated from contaminated ground water and transferred to air. Depending on the level of contaminants in the air discharge, the contaminated air stream may need further treatment. Additional polishing treatment of the aqueous effluent also may be necessary, depending on discharge requirements.

Design

Air strippers are designed for a specific target chemical (either the predominant contaminant or the most difficult-to-strip contaminant) with a desired target removal efficiency. The air stripping process is well understood and the technology is well developed. Air stripping has an extensive track record in a variety of applications.

The most frequently used configuration is a packed tower equipped with an air blower. The ground water is fed into the top of the stripper and the air is introduced at the bottom, creating a countercurrent gas-liquid contact. Random plastic packing is frequently used to improve gas-liquid contact. Structured packing and steel packing may also be used. Packed-tower air stripper design involves specification of stripper column diameter and packing height for a specified ground-water flow rate and air-to-water ratio. Shallow-tray aeration devices provide an alternative gas-liquid contacting system that provides a more compact, lower profile system that is less subject to fouling.

Alternative Techniques/Enhanced Methods

- For high flow rates (over 1,000 gpm), cooling towers (large structures with cascading water primarily used to cool water using countercurrent ambient air flow) may provide a cost-effective alternative to conventional packed towers.
- Shallow tray air strippers or diffused tank aeration units are less susceptible to fouling problems than packed towers and may be preferable where the water to be treated contains high concentrations of certain inorganics (e.g., iron).

Alternative Techniques/Enhanced Methods (continued)

- Because the efficiency of air stripping increases at higher temperatures, increasing the influent ground-water temperature (typically about 55° F) using a heat exchanger can increase the stripper's removal efficiency, especially for less volatile contaminants.
- Steam stripping methods, which use steam rather than air as the stripping medium, can be used to remove highly soluble contaminants and SVOCs not usually amenable to air stripping. However, operation costs for steam stripping can be two to three times greater than air stripping, depending on the cost of steam. In this guidance, these methods are not considered a type of air stripping and are not identified as a presumptive technology for ex-situ treatment of ground water.

Pre/Post-treatment

- Pretreatment to remove iron and other metals and to control hardness may be necessary to reduce fouling and mineral deposition in packed tower air strippers.
- Granular activated carbon is sometimes used to polish the treated water from an air stripper to further reduce organic contaminant levels and meet discharge requirements.
- Contaminants in the air discharge may be reduced by activated carbon adsorption, catalytic oxidation, or incineration to meet air emission requirements.

Selected References

Lamarre, B. 1993. Selecting an air stripper (what to consider!). The National Environmental Journal: 26-29.

Nyer, E.K. 1985. Groundwater Treatment Technologies. Van Nostrand Reinhold, New York, NY. 187 pp.

Nyer, E.K. 1993. Practical Techniques for Groundwater and Soil Remediation. CRC Press, Inc., Boca Raton, FL. 214 pp.

Okoniewski, B.A. 1992. Remove VOCs from wastewater by air stripping. Chemical Engineering Progress: 89-93.

U.S. EPA Environmental Protection Agency. 1990. Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF) - Air Emission Models. EPA/450/3-87-026. Office of Air Quality Planning and Standards, Research Triangle Park, NC. Appendix D.

U.S. Environmental Protection Agency. 1991. Engineering Bulletin: Air Stripping of Aqueous Solutions. EPA/540/2-91/022. Office of Research and Development, Cincinnati, OH. 9 pp.

Appendix D2: Granular Activated Carbon

Activated carbon removes contaminants from ground water by adsorption. The adsorption process takes place in three steps: (1) contaminant migration to the external sorbent surface; (2) diffusion into the sorbent pore structure; and (3) adsorption onto the sorbent surface. The principal form of activated carbon used for ground-water treatment is granular activated carbon (GAC). GAC is an excellent sorbent due to its large surface area, which generally ranges from 500 to 2,000 m^2/g.

Applicability

GAC is *applicable* to a wide variety of contaminants including: halogenated volatile and semivolatile organics, nonhalogenated volatile and semivolatile organics, PCBs, pesticides, dioxins/furans, most organic corrosives, metals, radioactive materials, inorganic cyanides, and certain oxidizers. GAC is *potentially applicable* to certain organic cyanides, and it is *not applicable* to asbestos, inorganic corrosives, and reducers (U.S. EPA, 1991). GAC is sometimes used alone for ground-water treatment. However, GAC is typically used for polishing aqueous effluents or controlling air emissions from other treatment technologies.

The adsorption capacity of activated carbon varies for specific organic compounds and for different types of GAC (based on the origin of coal and the percent binder used in the manufacture of the GAC). Contaminant-specific adsorption isotherms for a given type of GAC are generally available from the carbon manufacturer.

Contaminant Fate

Contaminants are not destroyed by carbon adsorption, but are physically separated from contaminated water and transferred to carbon. After exhaustion, the spent carbon may be reactivated, regenerated, incinerated, or disposed of. Thermal reactivation and incineration destroy most or all adsorbed organic contaminants. Steam or hot gas regeneration is not appropriate for spent GAC from treatment of contaminated ground water but can be used for spent GAC from air emission control devices. GAC used for metals sorption may require disposal. If disposed of, spent GAC may have to be managed as a hazardous waste.

Design

Activated carbon is a well-developed, widely used technology with many successful ground-water treatment applications, especially for secondary polishing of effluents from other treatment technologies. Contaminated ground water is contacted with a fixed GAC bed in a vessel. Flow direction is generally vertically downward, although an upward flow configuration is also possible. Fixed-bed configurations are also used for air emission control.

Adsorber design involves determining total carbon requirements and the number and dimensions of vessels needed to house the carbon. The amount of carbon required for a given application depends on the loading of adsorbable constituents in ground water (or contaminated air stream), the carbon's adsorption capacity for these constituents, and the carbon reactivation (or regeneration) frequency. Depending on the ground-water suspended solids content, it may be necessary to periodically backwash down flow carbon beds to relieve pressure drop associated with solids accumulation.

Alternative Techniques/Enhanced Methods

- Staged bed (multiple beds operated in series) and pulsed bed (carbon beds operated with nearly continuous "pulsed" addition of fresh carbon and withdrawal of spent carbon) designs can be used if higher removal efficiencies are required.

Alternative Techniques/Enhanced Methods (continued)

- Because the adsorption capacity of GAC is much higher for gas phase treatment than for liquid phase treatment, it is often more economical to use an air stripper followed by gas phase GAC to treat the air stripper exhaust than to use GAC alone for ground-water treatment.

- **GAC is not identified as a presumptive technology for removal of metals dissolved extracted ground water. Spent carbon used for metals removal can be difficult to regenerate and may require treatment and/or disposal as a hazardous waste.** Although GAC can remove low concentrations of certain metals, it has not been widely used for this purpose (U.S. EPA, 1991).

Pre/Post-treatment

- Pretreatment may be required to remove natural organic matter, such as fulvic and humic acids, that may interfere with the adsorption of the target contaminants or rapidly exhaust the GAC.
- Naturally occurring **radionuclides**, if present in ground water, can accumulate in the GAC during treatment, **which could result in potential exposure hazards for operating personnel and the spent carbon may require treatment and/or disposal as hazardous waste**.

- Thermal reactivation, using heat alone or steam, is typically used as a post-treatment method for the spent carbon. The carbon is reactivated in a high-temperature reactor under reducing conditions. Most organic contaminants are thermally degraded during the reactivation process.

Selected References

Long, G.M. 1993. Clean up hydrocarbon contamination effectively. *Chemical Engineering Progress*, 89(5):58-67.

Stover, E.L. 1988. Treatment of herbicides in ground water. *Ground Water Monitoring Review*: 54-59.

Stenzel, M.H. 1993. Remove organics by activated carbon adsorption. *Chemical Engineering Progress*: 36-43.

U.S. Environmental Protection Agency. 1991. *Engineering Bulletin: Granular Activated Carbon Treatment*. EPA/540/2-91/024. Office of Emergency and Remedial Response, Washington, D.C. 8 pp.

Appendix D3: Chemical/UV Oxidation

Chemical oxidation uses chemical oxidizing agents to destroy toxic organic chemicals and cyanide compounds (CN) in ground water. Commonly used oxidizing agents include: ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. Ozone and hydrogen peroxide are generally preferred for removing organics and CN from ground water because chlorine-based oxidants can produce toxic byproducts (e.g., HCl, chlorinated organics). Ultraviolet light (UV) is often used in conjunction with ozone and/or hydrogen peroxide to promote faster and more complete destruction of organic compounds (reaction rates may be increased by factors of 100 to 1,000).

Applicability

Chemical oxidation is *applicable* to both volatile and semivolatile organic compounds and cyanide compounds. Chemical oxidation is *potentially applicable* to PCBs, dioxins/furans, and metals (oxidation can be used to precipitate metals under certain conditions). Chemical oxidation is *not applicable* to asbestos and radioactive materials (U.S. EPA, 1991).

Chemical oxidation generally is effective for concentrations less than 500 µgL, but has been used for certain compounds at concentrations ranging up to several thousand mg/L. UV can enhance the oxidation of compounds that are resistant to chemical oxidation alone (e.g., PCBs). Iron or copper catalysts may be required for efficient destruction of certain organic compounds (e.g., phenols).

Contaminant Fate

Complete oxidation decomposes hydrocarbons into carbon dioxide and water, although chlorinated organic compounds also yield chloride ions. CN is oxidized to ammonia and bicarbonate by hydrogen peroxide in an alkaline environment. If oxidation is incomplete, toxic constituents may remain, or intermediate degradation products can be formed that may be toxic. These toxic substances may be removed using GAC as a secondary or polishing treatment step.

Design

Chemical oxidation is a proven and effective technology that is carried out in either batch or continuous reactors. Oxidants are generally added to contaminated ground water in a mixing tank prior to introduction into the reaction vessel (reactor). The use of ozone as the oxidizing agent requires an onsite ozone generator and an ozone decomposition unit or other ozone emission control device. The use of hydrogen peroxide as the oxidizing agent requires storage tanks and special handling protocols to ensure operator safety. The use of chlorine as the oxidizing agent may produce HCl gas. If HCl is produced, an acid gas removal system may be necessary.

UV lamps, if used, are typically enclosed in quartz tubes submerged inside the reaction vessel. The tubes are subject to fouling or scaling from compounds such as iron oxide or calcium carbonate and from biological flocs from microorganisms in ground water. If fouling occurs, oxidation rates are drastically reduced.

Site-specific treatability studies are generally recommended for chemical oxidation systems. Extensive pretreatment may be required to condition ground water for effective oxidation. If UV lamps are used, the studies must evaluate the potential for fouling or scaling of the quartz tubes at the ground-water composition, oxidant concentration, and UV intensity conditions anticipated for long-term system operation. If fouling or scaling is likely, pretreatment and/or physical methods for keeping the tubes clean (e.g., wipers) may be required. If metals are to be removed by oxidation, solids should be removed by clarification or filtration prior to UV oxidation. Provisions for removing precipitated metal sludges also may be necessary.

Appendix D3: Chemical/UV Oxidation (continued)

Alternative Techniques/Enhanced Methods

- UV radiation can be used in combination with a chemical oxidizing agent to increase the effectiveness of oxidation, especially for difficult-to-oxidize compounds.
- Metal catalysts, such as iron or copper, can be used in combination with a chemical oxidizing agent to increase the effectiveness of oxidation for certain types of compounds.
- Hydrodynamic cavitation is an innovative technology recently demonstrated under EPA's SITE program that uses forced cavitation of gas to enhance destruction of organics during UV oxidation processes.

Pre/Post-treatment

- Pretreatment may be necessary to remove solids, microorganisms, calcium carbonate, iron oxides, and/or other metals that can interfere with the oxidation process or UV transmission. A pretreatment sequence of precipitation, flocculation, clarification, and/or filtration steps may be necessary.
- Post-treatment of the aqueous effluent with GAC may be necessary if destruction is not complete or if toxic byproducts are formed during oxidation.
- If toxic metals precipitate during the oxidation process, treatment and/or proper disposal of the resulting sludge may be required.

Selected References

U.S. Environmental Protection Agency. 1990. *CERCLA Site Discharges to POTWs Treatability Manual.* EPA/540/2-90/008. Office of Emergency and Remedial Response. PB91-921269/CCE. NTIS. Springfield, VA. pp. 11-7 to 11-17.

U.S. Environmental Protection Agency. 1991. *Engineering Bulletin: Chemical Oxidation Treatment*. EPA/540/2-91/025. Office of Emergency and Remedial Response, Washington, D.C. 8 pp.

U.S. Environmental Protection Agency. 1993. *Superfund Innovative Technology Evaluation Program. Technology Profiles. Sixth Edition.* EPA/540/R-93/526. Office of Research and Development, Washington, DC.

U.S. Navy. 1993. *UV/Oxidation Treatment of Organics in Ground Water.* NEESA Document Number 20.2-051.7. Navy Energy and Environment Support Activity, Port Hueneme, CA. 11 pp.

Appendix D4: Aerobic Biological Reactors

Biological reactors use microorganisms to degrade organic contaminants in ground water in ex situ reactors. There are two basic types of ex situ biological treatment processes: aerobic reactors and anaerobic reactors. Aerobic reactors use oxygen to promote biodegradation and are widely used. Anaerobic reactors degrade organics in the absence of oxygen. This guidance focuses on aerobic biological treatment because anaerobic treatment processes are not widely used for ground-water treatment.

Applicability

Aerobic biological reactors are *applicable* to a wide variety of halogenated and nonhalogenated volatile and semivolatile organics. Aerobic biological reactors are *potentially applicable* to heavy organics, such as PCBs and certain pesticides, and organic and inorganic cyanides, but are generally not as effective for such recalcitrant compounds. Aerobic processes are *not applicable* to metals, asbestos, radioactive materials, or corrosive or reactive chemicals (U.S. EPA, 1992).

Contaminant Fate

Organic compounds are decomposed to carbon dioxide and water (aerobic processes) or to methane and carbon dioxide (anaerobic processes). Volatile organics are also removed by volatilization as a competing mechanism. Microbial growth produces an excess organic sludge (biomass) that must be disposed of properly. This sludge may concentrate metals and recalcitrant organic compounds that are resistant to degradation. Biodegradation may produce decomposition byproducts that are emitted to the air or dissolved in the effluent, and these decomposition byproducts may require additional treatment.

Design

Ex situ biological treatment of ground water is conducted in bioreactors. The primary factors influencing bioreactor design are the microbial organic utilization rates and the peak organic loading rate (i.e., flow rate times organic concentration). Treatability tests are necessary to determine these and other design parameters. Under most circumstances, bioreactors require a significant startup time to acclimate the microorganisms to the specific contaminants being treated before the bioreactor will operate at optimal degradation rates. There are two general types of bioreactor design:

- In **suspended growth** reactors, microbes are kept suspended in water using mechanical aerators or diffused air systems. These aeration systems also keep the solution well mixed, improving contact between microbes and dissolved contaminants and supplying oxygen to the system. Activated sludge systems are the most common suspended growth bioreactors. Other examples include aerated ponds or lagoons, stabilization ponds (using both algae and bacteria), and sequencing batch reactors.
- In **attached growth** reactors, biomass is attached to a solid substrate, such as sand, rock, plastic, activated carbon, or resin. Reactor design is dependent upon the surface area of substrate media available for biomass growth. Examples include trickling filter, rotating biological contactor, fluidized bed, fixed bed, and roughing filter designs.

Alternative Techniques/Enhanced Methods

- Direct addition of powdered activated carbon (PAC) into suspended growth bioreactors can both improve removal efficiency and reduce the likelihood of process upsets by buffering the concentrations of toxic compounds at levels amenable to biodegradation.

Alternative Techniques/Enhanced Methods (continued)

- Microbial augmentation (the addition of specially cultured microorganisms) may be used to increase the system's removal efficiency for certain difficult-to-degrade contaminants.
- Anaerobic reactors (digesters) may be preferred for the treatment of certain ground-water contaminants (e.g., certain chlorinated organics) that are difficult to degrade aerobically. **However, anaerobic reactors have not been identified as a presumptive technology for the following reasons**: 1) anaerobic processes have not been widely used for ground-water treatment; 2) reaction rates are slower than for aerobic processes, which result in longer startup times (for acclimation) and longer treatment times; and 3) such reactors have a greater sensitivity to process upsets, especially where flow and contaminant concentrations vary over time. These factors generally result in higher operation and maintenance requirements and costs, and lower performance efficiencies than for aerobic processes in ground-water applications.

Pre/Post-treatment

- Chemical precipitation (for metals) or other pretreatment (e.g., PAC addition for organics) may be required to reduce (or buffer) concentrations of compounds that are toxic to microorganisms.
- Carbon adsorption post-treatment may be used to reduce contaminant concentrations in the treated water to meet discharge requirements.
- Because certain aerated bioreactor designs (e.g., mechanically aerated activated sludge systems, aerated ponds and lagoons) present difficulties for direct capture and control of air emissions, an air stripper (with emission controls) may be a cost-effective treatment prior to biodegradation if volatile contaminant emissions need to be controlled. For other bioreactor designs, such as diffused-aeration activated sludge and trickling filter systems, air emissions are more easily captured and can be treated using carbon adsorption, catalytic oxidation, or incineration.

Selected References

Eckenfelder, W.W., J. Patoczka, and A.T. Watkins. 1985. Wastewater treatment. *Chemical Engineering*: 60-74.

Flatman, P.E., D.E. Jerger, and L.S. Bottomley. 1989. Remediation of contaminated groundwater using biological techniques. *Ground Water Monitoring Review*: 105-119.

U.S. Environmental Protection Agency. 1979. *Selected Biodegradation Techniques for Treatment and/or Ultimate Disposal of Organic Materials*. EPA-600/2-79-006. Office of Research and Development, Cincinnati, OH.

U.S. Environmental Protection Agency. 1981. *Literature Study of the Biodegradability of Chemicals in Water (Volume 1. Biodegradability Prediction, Advances in and Chemical Interferences with Wastewater Treatment)*. EPA/R806699-01. Office of Research and Development, Cincinnati, OH.

U.S. Environmental Protection Agency. 1992. *Engineering Bulletin: Rotating Biological Contactors*. EPA/540/S-92/007. Office of Research and Development, Cincinnati, OH. 8 pp.

Appendix D5: Chemical Precipitation

Chemical precipitation chemically converts dissolved metal and/or other inorganic ions in ground water into an insoluble form, or precipitate. Metal ions generally precipitate out as hydroxides, sulfides, or carbonates and are removed as solids through clarification and filtration. In this guidance, chemical precipitation is defined to include chemical precipitation of metals by oxidizing or reducing agents, as well as any pH adjustment (neutralization) and solids removal steps required.

Applicability

Chemical precipitation is *applicable* to dissolved metal and other inorganic ions (such as arsenate and phosphate). Chemical precipitation is *not applicable* to volatile or semivolatile organic compounds (U.S. Navy, 1993).

Contaminant Fate

Dissolved metals are converted to insoluble forms, which are subsequently removed by flocculation, clarification, and/or filtration. The solid residue (chemical sludge) containing the metal contaminant then must be treated and/or disposed of properly.

Design

The process generally takes place at ambient temperatures. Batch reactors are generally favored for lower flowrates (e.g., up to about 50,000 gpd), and usually use two tanks operating in parallel. Each tank can act as a flow equalizer, reactor, and settler, thus eliminating separate equipment for these steps. Continuous systems have a chemical feeder, flash mixer, flocculator, settling unit, filtration system (if used), and control system for feed regulation. Site-specific treatability tests are required to determine the optimum type and dosage of precipitation chemicals, necessary pretreatment steps, and post-treatment requirements for aqueous effluent and sludge residuals.

There are three types of precipitation chemicals:

- **Metal hydroxides** are formed by the addition of alkaline reagents (lime or sodium hydroxide). Precipitation is then initiated by adjusting pH to the optimum level for the particular metal ion. Maintaining pH levels within a relatively narrow optimum range is usually necessary to achieve adequate metal precipitation. Pretreatment with oxidizing or reducing chemicals (e.g., hydrogen peroxide, ferrous sulfate) may be necessary to precipitate some metals (e.g., iron, manganese, chromium) in their least soluble form. Natural organic matter can inhibit the formation of insoluble metal hydroxides by forming metal-organic complexes. Metal hydroxide precipitation is typically effective for arsenic, cadmium, chromium (+3), nickel, zinc, manganese, copper (+2), tin (+3), and iron (+3).
- **Metal sulfides** are formed by the addition of either soluble sulfides (e.g., hydrogen sulfide, sodium sulfide, or sodium bisulfide) insoluble sulfides (e.g., ferrous sulfide). Sodium sulfide and sodium bisulfide are most commonly used. Sulfur dioxide and sulfur metabisulfite have also been demonstrated for chromium reduction prior to precipitation. Metal sulfides have lower solubilities than metal hydroxides, and effective metal removal efficiencies can be achieved over a broader pH range. The method is mainly used to remove mercury and lead and may be used to remove arsenic, cadmium, chromium (+3,or +6), silver and others. Sulfide precipitation also can be used to treat filtered ground water after hydroxide precipitation.

Appendix D5: Chemical Precipitation (continued)

Alternative Techniques/Enhanced Methods

- **Metal carbonates** are formed by the addition of calcium carbonate or by adding carbon dioxide to metal hydroxides. Solubilities of metal carbonates are intermediate between the solubilities of metal hydroxides and metal sulfides. Insoluble metal carbonates are easily filtered from treated ground water. The method is particularly good for precipitating lead, cadmium, and antimony.
- Sodium xanthate has shown promise as a precipitation agent similar to sodium sulfide.

Pre/Post-treatment

- Pretreatment to adjust pH is normally required to obtain the lowest precipitate solubility.
- Pretreatment may be necessary to oxidize iron or manganese compounds or reduce hexavalent chromium compounds into forms that can be readily precipitated.
- Depending on discharge requirements, the aqueous effluent may need pH adjustment and/or further polishing. Activated alumina or ion exchange media are regenerable treatment options for effluent polishing for metals. Activated carbon also may be used but spent carbon may require treatment and disposal as a hazardous waste.
- The sludge may require stabilization treatment by addition of lime/fly ash or portland cement to reduce permeability and the leachability of metals prior to disposal. In some cases, metals may be recovered from the residue for reuse, but this is generally not economical.

Selected References

Monopoli, A.V. 1993. Removing dissolved inorganics from industrial wastewater. *The National Environmental Journal:* 52-56.

U.S. Environmental Protection Agency. 1987. *Handbook on Treatment of Hazardous Waste Leachate.* EPA/600/8-87/006. Office of Research and Development, Cincinnati, OH. pp. 44-45.

U.S. Environmental Protection Agency. 1990. *CERCLA Site Discharges to POTWs Treatability Manual.* EPA/540/2-90/008. Office of Emergency and Remedial Response. PB91-921269/CCE. NTIS, Springfield, VA. pp. 11-23 to 11-36.

U.S. Navy. 1993. *Precipitation of Metals from Ground Water.* NEESA Document Number 20.2-051.6. Navy Energy and Environment Support Activity. Port Hueneme, CA. 11 pp.

Appendix D6: Ion Exchange/Adsorption

Ion exchange removes metal contaminants from water by passing contaminated ground water through a granular solid or other porous material, usually an impregnated resin, that exchanges sorbed ions (e.g., H^+, OH^-, Na^+, Li^+, CO_3^{--}) for contaminants dissolved in ground water. The ion exchange media are selected to have sorptive affinity for the ionic forms (cation or anion) of the contaminants being removed. The ion exchange media can therefore be either cationic, anionic, or a mixture of the two. Because ion exchange is a reversible process, resins can be regenerated by backwashing with a regeneration solution (e.g., brine; strong or weak acids or bases). Conventional ion exchange resins are generally too costly for large-scale ground-water treatment and are predominantly used for polishing of aqueous effluents after other treatment processes.

Applicability

Ion exchange is *applicable* to ionic contaminants such as dissolved metals or nitrates. Ion exchange is *not applicable* to non-ionic contaminants such as most organic compounds.

Contaminant Fate

Contaminants are removed from ground water through sorption onto the exchange media. When most of the exchange sites of the media become filled, the exchange media are regenerated by backflushing with a suitable regeneration solution. The concentrated backflush solution must then be disposed of or stripped of its contaminants. Exchange resins can generally be regenerated many times and have a relatively long useful life.

Design

Various resin types are available to tailor systems to discrete ionic mixes. For example, acid exchangers replace cations in water with hydrogen ions and base exchangers replace anions with hydroxide ions. Weak acid and base exchangers are selective for more easily removed ions while strong acid and base exchangers are less selective, removing most ions in the ground water. Generally, ease of cation and anion removal follows an affinity sequence specific to the ions in question. Synthetic resins are available with unique selectivity sequences. The wide variety of resins and other ion exchange media (e.g., activated alumina, biological materials) that are available make the selection of an appropriate exchange media a critical design step. Information on the applicability of specific resins may be obtained from resin manufacturers. In addition, ion exchange resins generally have an optimum pH range for effective metals removal. pH control may be required to achieve maximum removal efficiency from ground water.

A typical ion exchange installation has two fixed beds of resin. While one is in operation, the other is regenerated. Batch, fixed column, and continuous column bed designs can be used. Downflow column designs are generally preferred. Continuous column systems eliminate the need for backwashing but are not commonly used because of the complexity of the resin removal mechanics.

Flow rates up to 7,000 gpm have been reported for ion exchange systems. However, conventional ion exchange is generally cost-effective for ground-water treatment only at low flow rates or low contaminant concentrations. It is therefore primarily used as a polishing step following chemical precipitation or other treatment.

Alternative Techniques/Enhanced Methods

- Activated alumina is an anionic exchange medium comprised of granulated, dehydrated aluminum hydroxide. Activated alumina is effective for removing fluoride, selenium, chromium (+6), and arsenic ions, which are exchanged for hydroxide ions. Adjustment of pH may be necessary to achieve optimal removal efficiency. The alumina is regenerated with a sodium hydroxide solution.
- Biological materials (e.g., algae, crop residues) have recently shown great promise as an innovative ion exchange media for metals. Biological media are significantly less costly than conventional resins (cents per pound vs. dollars per pound), and may become more commonly used for metals removal from ground water.
- Electrodialysis uses alternately placed cation and anion permeable membranes (made of ion exchange resin) and an electrical potential to separate or concentrate ionic species.
- Activated carbon adsorption can also be used to remove inorganics at low concentrations. **However, activated carbon is not identified as a presumptive technology for removal of metals dissolved extracted ground water.** Spent carbon used for metals removal can be difficult to regenerate and may require treatment and/or disposal as a hazardous waste.

Pre/Post-treatment

- Pretreatment may be required to remove suspended solids at concentrations greater than about 25 mg/L or oil at concentrations greater than about 20 mg/L. Large organic molecules also can clog resin pores and may need to be removed.
- pH adjustment may be necessary to achieve optimal metals removal.
- The backwash regeneration solution must be treated to remove contaminants.
- Post-treatment of spent ion exchange media may be required to recover concentrated contaminants or management as a hazardous waste may be required.

Selected References

Clifford, D., Subramonian, S., and Sorg, T.J., 1986. "Removing Dissolved Inorganic Contaminants from Water," *Environmental Science and Technology*, Vol. 20, No. 11.

Nyer, E.K. 1985. *Groundwater Treatment Technologies.* Van Nostrand Reinhold. New York, NY. 187 pp.

U.S. Environmental Protection Agency. 1990. *CERCLA Site Discharges to POTWs Treatability Manual.* EPA/540/2-90/008. Office of Emergency and Remedial Response. PB91-921269/CCE. NTIS. Springfield, VA. pp. 11-102 to 11-112.

Appendix D7: Electrochemical Methods

Electrochemical processes use direct electrical current applied between two immersed electrodes to drive chemical oxidation-reduction reactions in an aqueous solution. Historically, electrochemical processes have been used to purify crude metals or to recover precious metals from aqueous solutions. Positively charged metal ions are attracted to the negatively charged electrode (the cathode), where they are reduced. The reduced metals typically form a metallic deposit on the cathode. Negatively charged ions are attracted to the positively charged electrode (the anode), where they are oxidized.

For contaminated ground water treatment, electrochemical cells have been used for the reduction (and subsequent precipitation) of hexavalent chromium to trivalent chromium. In this process, consumable iron electrodes are used to produce ferrous ions (Fe^{2+}) at the anode and hydroxide ions (OH^-) at the cathode. An oxidation-reduction reaction then occurs between the ferrous, chromium, and hydroxide ions to produce ferric hydroxide $Fe(OH)_3$ and chromic hydroxide $Cr(OH)_3$, which subsequently precipitate from solution.

Applicability

Electrochemical processes are *applicable* to dissolved metals. It is most commonly used in ground water treatment for the reduction and precipitation of hexavalent chromium. The process also may be applicable to removing other heavy metals including arsenic, cadmium, molybdenum, aluminum, zinc, and copper ions. Electrochemical processes have also been used for the oxidation of cyanide wastes (at concentrations up to 10 percent). Electrochemical processes are *not applicable* to organic compounds or asbestos.

Contaminant Fate

Dissolved metals either deposit on the cathode or precipitate from solution. Precipitates form an inorganic sludge that must be treated and/or disposed of, typically in a landfill. Spent acid solution, which is used to periodically remove deposits formed on the electrodes, will also require proper treatment and disposal. Cyanide ions are hydrolyzed at the anode to produce ammonia, urea, and carbon dioxide.

Design

Electrochemical reactors generally operate at ambient temperatures and neutral pHs. Both batch reactors and continuous flow reactors are commercially available. A typical electrochemical cell for hexavalent chromium reduction consists of a tank, consumable iron electrodes, and a direct current electrical supply system. An acid solution is used to periodically clean the iron electrodes, which need to be replaced when they are significantly consumed. Reactor residence times required for treatment depend on the contaminants present as well as the degree of mixing and current density. Reduction of hexavalent chromium generally requires short residence times (approximately 10 seconds), whereas treatment of cyanide compounds requires longer process times.

Pre/Post-treatment

- Pretreatment may be necessary to remove suspended solids.
- Settling or clarification post-treatment may be necessary to remove the precipitated trivalent chromic and ferric hydroxides formed during hexavalent chromium electrochemical reduction.

Pre/Post-treatment (continued)

- The sludge may require stabilization prior to disposal by addition of lime/fly ash or portland cement to reduce permeability and metal leachability. In some cases, metals may be recovered from the plated electrode or precipitated residue, but this is generally not economical for typical ground-water applications.

Selected References

Englund, H.M. and L. F. Mafrica. 1987. *Treatment Technologies for Hazardous Waste.* APCA Reprint Series RS-13. Air Pollution Control Association, Pittsburgh, PA. pp. 43-44.

U.S. Environmental Protection Agency. 1990. *A Compendium of Technologies Used in the Treatment of Hazardous Wastes.* EPA/625/8-87/014. Office of Research and Development. PB91-90-274093. NTIS. Springfield, VA. p. 23.

Appendix D8: Aeration of Background Metals

Aeration (contact with air) removes some metals from water by promoting chemical oxidation and the formation of insoluble hydroxides that precipitate from the water. Aeration for metals removal differs from air stripping in that precipitation rather than volatilization is the desired effect of the technology.

Applicability

Aeration techniques are useful for the removal of limited number of dissolved cations and soluble metal compounds. This method is well suited for the removal of back ground metals such as iron and manganese which is necessary as part of a selected remedy such as pretreatment to air stripping. Methods of aeration for metals include aeration tanks, aeration basins, or cascade aeration. Aeration methods are usually not sufficient as an independent technology for iron and manganese, but are utilized as a step in the treatment process. Often, the air-water contact in tank and cascade aeration is not enough to obtain high removal efficiencies. Spray basins are limited by area, wind, and ice particle formation (Nyer, 1985).

Contaminant Fate

Dissolved metals are oxidized to insoluble hydroxides which precipitate from solution, and can then can be subsequently removed by flocculation, sedimentation, and/or filtration.

Design

The three types of aeration systems:

- Aeration tanks bubble compressed air through a tank of water.
- Cascade aeration occurs when air is made by turbulent flow and agitation.
- Spray or aeration basins use an earthen or concrete basin with a piping grid and spray nozzles that spray the water into the air in very fine droplets.

Related methods include aeration used to remove volatile organic contaminants from water are considered to be a type of air stripping, as discussed in Section 2.1.1. The use of aeration to promote aerobic biological treatment processes is considered to be an element of biological treatment as discussed in Section 2.1.4.

Pre/Post Treatment

- Aeration is often a pretreatment for other remediation technologies, such as air stripping, to remove certain metals.
- Aeration can be followed by other treatments such as flocculation, sedimentation, and/or filtration to remove oxidized metals.

Appendix D8: Aeration of Background Metals

Selected References

Betz. 1962. *Betz Handbook of Industrial Water Conditioning.* Trevose, PA. pp.19-22

Nyer, E.K. 1985. *Groundwater Treatment Technologies.* Van Nostrand Reinhold, New York, NY. 187 pp.

Nyer, E.K. 1993. *Practical Techniques for Groundwater and Soil Remediation* . CRC Press, Inc, Boca Raton, FL. 214 pp.

APPENDIX C