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Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites

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Interim Final

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Notice

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Executive Summary

This document provides guidance for making key decisions in developing, evaluating, and selecting ground-water remedial actions at Superfund sites. It provides information that can be used in the process of investigating and assessing remedial actions for contaminated ground water and may be considered a primer on pertinent aspects of ground-water contamination that are important to the development of sound remedies.

This guidance focuses on policy issues and the decision-making approach and highlights key considerations to be addressed during the remedy selection process. The statutory and policy framework presented here for ground-water remedial actions was drawn from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA)--henceforth referred to as CERCLA--and program policies to implement these acts.

The goal of Superfund ground-water remediation is to protect human health and the environment by restoring ground water to its beneficial uses within a reasonable time frame, given the particular site circumstances. CERCLA requires that remedial actions protect human health and the environment, meet applicable or relevant and appropriate requirements (ARARs) as established by Federal and State standards, and be cost-effective. CERCLA also requires the selection of remedies that use permanent solutions and treatment technologies or resource recovery technologies to the maximum extent practicable and expresses a preference for the selection of remedies that use treatment that permanently and significantly reduces the mobility, toxicity, or volume of hazardous substances as a principal element.

The *Ground-Water Protection Strategy* (U.S. EPA, 1984) plays an important role in the ground-water remedial action decision-making process because the Superfund program generally applies the basic framework outlined in the strategy for protecting ground water according to its current and future vulnerability, use, and value. The ground-water remedial action approach presented in this document is consistent with the *Ground-Water Protection Strategy* and with the development, evaluation, and selection of remedial alternatives linked to the characteristics of the ground water.

When remediating ground water, potential ARARs of other regulations must be met unless a waiver is used. For ground water, the main sources of these requirements are the Resource Conservation and Recovery Act, the Safe Drinking Water Act, and the Clean Water Act.

Before initiating remedial investigation/feasibility study (RI/FS) activities, site management planning should be conducted. This planning identifies potential removal actions and operable units and their optimal sequence and timing. Site management planning is a dynamic process in which refinements continue to be made throughout the RI/FS process as a better understanding of the site is obtained. At the same time that site management planning is conducted, scoping also occurs, during which data collection activities that will take place during the RI/FS are planned.

Cleanup levels for ground water are selected to maintain the ground water's beneficial uses. If the ground water is potentially drinkable, cleanup levels are determined according to health-based standards for drinking water. If the ground water discharges

into an aquatic habitat, cleanup levels may be based on those protective of aquatic life. Aggregate effects of multiple contaminants found in ground water should be assessed to ensure that risks do not exceed protective levels.

Remedial action objectives are developed after site characterization. Remedial action objectives specify the area of attainment, the restoration time frame, and cleanup levels. Cleanup levels should be achieved throughout the area of attainment as quickly as is practicable considering the particular site circumstances. Factors that affect the restoration time frame include technical feasibility, feasibility of providing an alternate water supply, the potential use and value of the ground water, institutional controls, and the ability to monitor and control the movement of ground water. The area of attainment includes the entire ground-water plume except for the area directly beneath any waste that is contained and managed onsite. (Though property ownership may increase the flexibility for extending the restoration time frame, it does not affect the specification of the area of attainment over which cleanup levels must be achieved.)

Several types of remedial action alternatives that span a range of technologies and restoration time frames should be developed early in the FS process. Potential response approaches include the following:

- An active restoration alternative that reduces contaminant levels to required cleanup levels in the minimal time feasible
- Additional active restoration alternatives that achieve cleanup levels over longer time frames
- A plume containment alternative that prevents expansion of the plume
- A natural attenuation alternative that includes institutional controls and monitoring
- An alternative involving wellhead treatment or provision of an alternate water supply and institutional controls when active restoration is not practicable

The remedial action alternatives should be developed and screened on the basis of general considerations of effectiveness, implementability, and cost. Best professional judgment should be used to identify those remedies that meet the remedial action objectives for the site and are not disproportionately costly. Preference should be given to alternatives that provide the most rapid restoration that can be achieved practicably.

A detailed analysis of alternatives should be conducted using the following criteria:

- Overall protection of human health and the environment
- Compliance with ARARs--waivers to ARARs are listed in CERCLA and may be warranted under specific conditions
- Long-term effectiveness and permanence
- Reduction of mobility, toxicity, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

Executive Summary (continued)

A remedy is selected from alternatives that undergo a detailed analysis and is determined to provide adequate protection of human health and the environment, to attain ARARs, or to provide grounds for invoking a waiver. Within these bounds, the remedy is to be cost-effective, providing overall effectiveness that is proportional to cost. The selected remedy will be the alternative found to provide the best balance of tradeoffs among alternatives in terms of the nine evaluation criteria listed above. This remedy represents the maximum extent to which permanent solutions and treatment technologies can be used practicably.

Often, the success of a ground-water remedial action is difficult to predict until the action has been initiated and operational data have been assessed. Because of the uncertainties in characterizing contaminated ground water, remedial actions often are selected on the basis of limited data. This guidance promotes a flexible decision-making process for ground-water remedial actions to accommodate these uncertainties and resolve the differences between design and actual performance. For sites at which actual performance lags behind design performance, as measured by contaminant mass removal, for example, a determination should be made to (1) continue the existing remedial action and revise the remedial action objectives for the site, (2) upgrade or replace the selected remedy to meet the remedial action objectives, or (3) terminate the remedial action if there is no longer a threat to human health or the environment. Fundamental changes in the remedial action require modification of the Record of Decision (ROD).

Appendix A to this guidance document presents a case study, or hypothetical scenario, to demonstrate key features of the ground-water remedial action decision process. The study focuses on the decisions that must be made during the RI/FS and the pertinent factors affecting evaluation of alternatives and selection of a ground-water remedy.

Appendix B presents the framework of EPA's policy for investigating and remediating multiple source plumes, i.e., plumes caused by multiple sites (some of which are not necessarily Superfund sites). The strategy identifies which actions might be accomplished by PRPs; it also includes schedules for enforcement functions necessary to support PRP action.

Appendix C describes the contents of a ROD that supports an interim action. Although RODs for interim actions need to adequately describe the rationale for the action and how the statutory criteria are met, such RODs will often be less detailed than the RODs prepared for final remedial actions.

Appendix D presents two basic ground-water equations that can be used to estimate the restoration time frame.

Appendix E lists standards and health-based criteria that may be pertinent in setting preliminary cleanup levels.

Contents

Contents (continued)

Contents (continued)

Page

Exhibits

Figures

Tables

List of Acronyms

ACLs	Alternate concentration limits
ARARs	Applicable or relevant and appropriate requirements
BAT	Best available technology
BCT	Best conventional technology
CAG	Carcinogen Assessment Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CWA	Clean Water Act
DCE	Dichloroethene
DEHP	Bis(2-ethylhexyl)phthalate
DNAPL	Dense nonaqueous phase liquid
DQOs	Data quality objectives
DWEL	Drinking water equivalent level
ERD	Emergency Response Division of OERR
HA	Health advisory
HI	Hazard index
IRIS	Integrated Risk Information System
ISV	In situ vitrification
K_{oc}	Organic carbon partition coefficient
K_p	Partition coefficient
LOAEL	Lowest observed adverse effects level
LOEL	Lowest observed effects level
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
NCP	National Contingency Plan
NOAEL	No observed adverse effects level
NOEL	No observed effects level
NPL	National Priorities List
NPDES	National Pollutant Discharge and Elimination System

List of Acronyms (continued)

OERR	Office of Emergency and Remedial Response
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
PA/SI	Preliminary assessment/site inspection
PCE	Perchloroethene,Tetrachloroethene
PHRED	Public Health Review Evaluation Database
PRP	Potentially responsible party
POTW	Publicly owned treatment works
QSAR	Quantitative structure-activity relationships
RPM	Remedial project manager
RCRA	Resource Conservation and Recovery Act
RfD	Reference dose
RI/FS	Remedial investigation/feasibility study
ROD	Record of Decision
RSD	Risk-specific dose
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SWMU	Solid-waste management unit
TBC	To-be-considered
TCA	Trichloroethane
TCE	Trichloroethene
TVO	Total volatile organic
UIC	Underground injection control
UPL	Unacceptable pollutant levels
VOC	Volatile organic compound
WQC	Water quality criteria

List of Definitions

Absorption	Transport of a substance through the outer boundary of a medium, frequently through biological membranes, through active transport, passive diffusion, etc.
Adsorption	Bonding, frequently ionic, of a substance to soil or other medium. A substance is said to be adsorbed if the concentration in the boundary region of a soil particle is greater than in the interior of the contiguous phase.
Applicable requirements	Requirements promulgated under Federal or State law that specifically address the circumstance at a Superfund site.
Area of attainment	The area of the plume outside the boundary of any waste to be managed in place as part of the final remedy and inside the boundaries of the contaminant plume.
Cleanup level	The contaminant concentration goal of the remedial action, i.e., the concentration of a ground-water contaminant to be achieved through remedial action.
Cost-effectiveness	One of the mandates for remedial action under CERCLA. It requires a close evaluation of the costs required to implement and maintain a remedy as well as the selection of protective remedies whose costs are proportional to their overall effectiveness.
Dense nonaqueous phase liquid	A liquid that is more dense than liquid water and is not appreciably soluble in water. Hence, the liquid forms a second phase below the ground water.
Hot spots	Term used to denote zones where contaminants are present at much higher concentrations than surrounding areas.
Implementability	Implementability includes the technical and administrative feasibility of an action as well as the availability of needed goods and services.
Institutional controls	Controls prohibiting or limiting access to contaminated media; may consist of deed restrictions, use restrictions, permitting requirements, etc.

List of Definitions (continued)

Interim action	An action that initiates remediation of a site but may not constitute the final remedy.
Operable unit	An overall response action that by itself eliminates or mitigates a release, a threat of a release, or an exposure pathway.
Performance evaluation	An evaluation undertaken after remediation has been implemented to determine the effectiveness of the remedial action.
Practicability	An action is practicable from an engineering perspective if it can be implemented within cost and time constraints, is not unreasonably difficult or complex, and is reliable.
Relevant and appropriate requirements	Requirements that, while not "applicable" to a Superfund site, address situations sufficiently similar to a site that their use is well suited.
Remedial action objectives	Cleanup objectives that specify the level of cleanup, area of cleanup (area of attainment), and time required to achieve cleanup (restoration time frame).
Removal action	An action that is implemented to address a direct threat to human health or the environment.
Restoration time frame	Time required to achieve cleanup levels.
Site management planning	A planning phase in which the types of response approaches to be taken to address site problems and their optimal sequence are identified.
Sorption	Adsorption and/or absorption.
Systemic effects	Effects that require absorption and distribution of the toxicant to a target organ at which point effects are produced. Most chemicals that produce systemic toxicity do not cause a similar degree of toxicity in all organs but usually demonstrate major toxicity to one or two organs.
To-be-considered	Guidelines and criteria that should be considered when evaluating remedial actions.
Technical feasibility	A determination that the technology can be implemented and maintained on the basis of engineering judgment.
Transmissivity	A measure of the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient of 1.

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Chapter 1
Introduction

1.1 Purpose and Objectives

This guidance document focuses on key issues in the development, evaluation, and selection of ground-water remedial actions at Superfund sites. Statutory mandates require that remedies be protective and utilize permanent solutions and treatment technologies to the maximum extent practicable. Consistent with these mandates, the goal of Superfund ground-water actions is to restore ground water to its beneficial uses within a reasonable time frame, given the particular site circumstances.

The principal objectives of this guidance are as follows:

- Present the analytical framework and statutory basis for formulating ground-water alternatives
- Outline factors that should be examined to evaluate and compare ground-water alternatives
- Highlight key considerations for selecting a ground-water remedy
- Illustrate with a case study the remedial investigation (RI) and feasibility study (FS) process for ground water

Technical aspects of ground-water investigation, evaluation, and remediation are not discussed in detail here. Throughout the text, however, the reader is referred to other sources that do address these technical concerns. In addition, *Geraghty & Miller's Groundwater Bibliography* (van der Leeden, 1987) lists numerous resources, organized by subject, related to ground water.

This document has been prepared as a resource for three groups: (1) EPA and State remedial project managers (RPMs) responsible for the overall scope, structure, quality, and completeness of RI/FSs involving ground-water contamination, (2) contractors or the Corps of Engineers that plan and execute RI/FSs at Superfund sites with ground-water contamination, and (3) others responsible for preparing remedial alternatives and recommending ground-water remedial actions at Superfund sites.

Although each Superfund site presents unique environmental conditions and human health problems, a consistent approach should be used when collecting and analyzing data and developing and evaluating ground-water remedial alternatives. The consideration of both the issues and the decision-making approach presented here should provide reasonable consistency in analyzing ground-water remedial action alternatives at sites that pose similar contamination problems and threats to human health and the environment.

1.2 Overview of the Remedial Process

The Superfund remedial process begins with the identification of site problems during the preliminary assessment/site inspection, which is conducted before a site is listed on the National Priorities List; continues through site characterization in the RI and development, screening, and detailed analysis of remedial alternatives in the FS; and culminates in the selection, implementation, and operation of a remedial action.

EPA describes each step of the RI/FS process and describes how the steps are integrated in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (RI/FS Guidance)* (U.S. EPA, 1989). With the framework provided by the *RI/FS Guidance* and the ground-water guidance given here, the reader should be able to evaluate ground-water contamination at specific sites, focusing on decisions that are pertinent to remedial actions for contaminated ground water. The first steps in the RI/FS process include planning how site activities will be managed and determining data needs. Data collection occurs throughout the RI/FS and remedy implementation process and generally focuses on making and refining the following decisions:

- Establishing remedial action objectives

  Establishing preliminary cleanup levels

- Determining the area of attainment
- Estimating the restoration time frame

- Developing remedial action alternatives
- Conducting a detailed analysis of the alternatives
- Selecting a remedy
- Designing and constructing the remedy
- Evaluating the remedial action performance

Figure 1-1 shows the steps comprising the Superfund RI/FS process. Arrows from the key decision points at the bottom of Figure 1-1 indicate where the decision points fit into the process. Figure 1-2 provides an overview of the alternative selection process that is specific to ground water.

1.3 Other EPA Guidance Documents Pertinent to Ground-Water Remedial Actions Under Superfund

Several other EPA documents provide guidance for Superfund decision-making and may be pertinent to ground water. Table 1-1 lists these publications, describes their contents, and notes the steps within the RI/FS process in which they will be particularly useful.

1.4 Organization of this Document

The remainder of this document is divided into six chapters and six appendixes, summarized below.

Chapter 2, "Statutory and Policy Framework for Ground-Water Remedial Alternatives," discusses specific elements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the written directives that have been used to implement CERCLA and establish the policy for ground-water remedial actions under Superfund.

Chapter 3, "Scoping Ground-Water Remedial Activities," describes the two planning activities conducted before data collection: (1) planning site management activities, which includes determining approaches for remediating ground-water contamination i.e., identifying appropriate removal actions and operable units; and (2) scoping data collection activities, which involves selecting the types of ground-water studies that will be conducted at a site.

Chapter 4, "Establishing Preliminary Cleanup Levels," describes how to determine preliminary cleanup levels from available standards and health-based criteria.

Chapter 5, "Developing Remedial Alternatives," focuses on issues specific to ground-water contamination that influence the development of remedial action alternatives.

Chapter 6, "Detailed Analysis of Alternatives and Selection of Remedy," discusses the alternative evaluation process and how this process guides the selection of the final remedy.

Chapter 7, "Evaluating Performance and Modifying Remedial Actions," addresses ground-water remedial action performance. This section provides guidance for deciding whether the remedial action should be continued without modification, continued but upgraded, replaced or discontinued because remedial action objectives have been met and the remedy is complete.

Appendix A, "Case Study with Site Variations," presents a hypothetical case study to demonstrate the application of the guidance provided in this manual.

Appendix B, "Strategy for Addressing Ground-Water Contamination From Multiple Sources Involving Superfund Sites," presents the EPA policy framework and provides guidance on RI/FS and remedial response activities for multiple-source ground-water contamination sites. At these sites, releases from sources other than the Superfund site contribute to ground-water contamination. Ground-water remedial actions that clean up or control releases from the Superfund site must be combined with corrective actions for other contaminant sources to be effective. Ground-water remediation at these multiple-source sites may involve coordination with agencies and authorities outside of Superfund.

Appendix C, "Documenting an Interim Action," describes the contents of the Record of Decision (ROD) needed to support operable units that are taken as interim actions.

Appendix D, "Basic Ground-Water Equations," provides some equations that can be used to estimate the restoration time frame.

Appendix E, "Tables of U.S. EPA Standards, Criteria, and Guidelines for Establishing Ground-Water Cleanup Levels," provides a reference, current at the time of this writing, for setting preliminary cleanup levels.

Appendix F, "Sample Letter to Obtain Property Access," provides a format for requesting access to adjacent properties under which a contaminant plume has migrated.

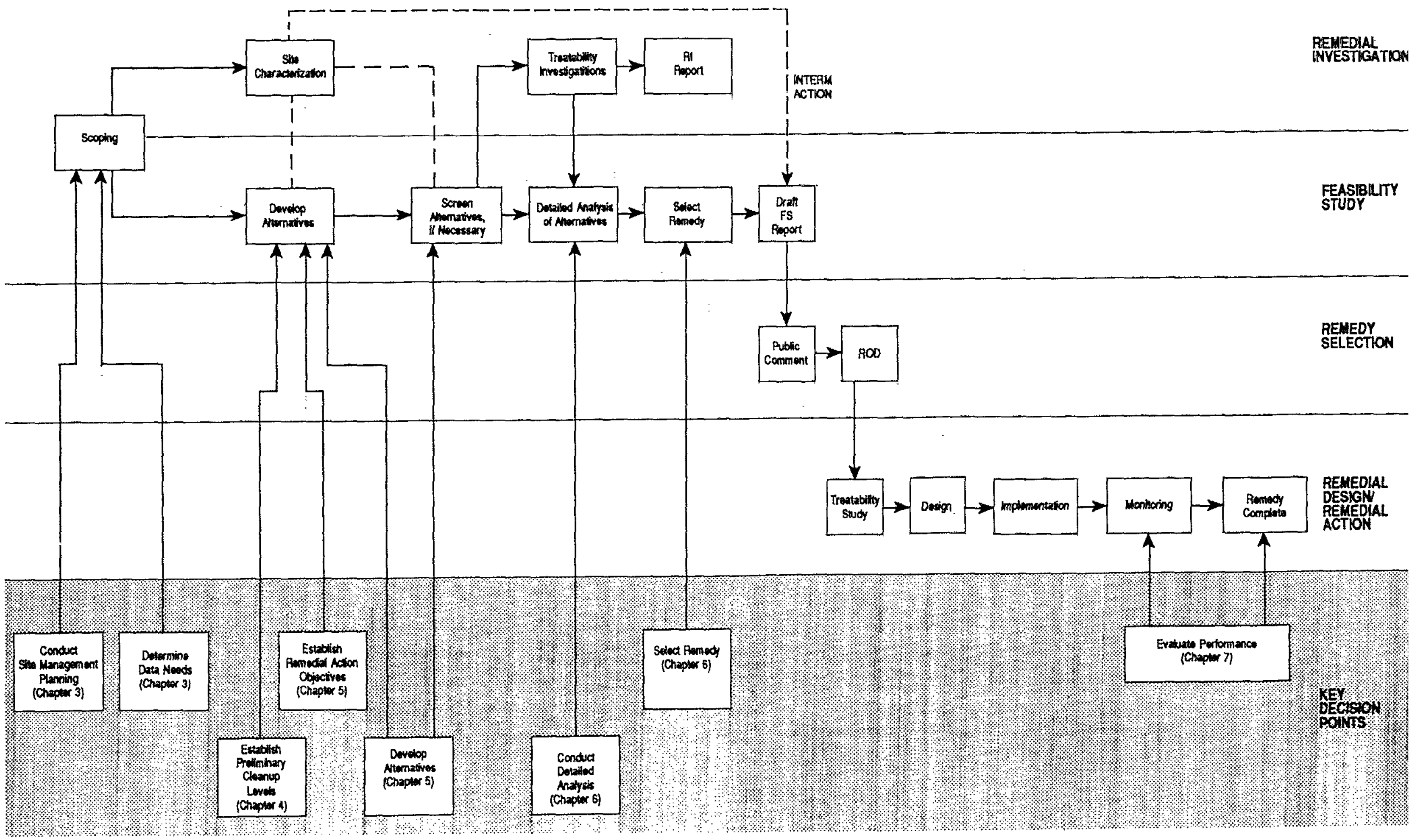


Figure 1.1 Decision Points in the Superfund Process.

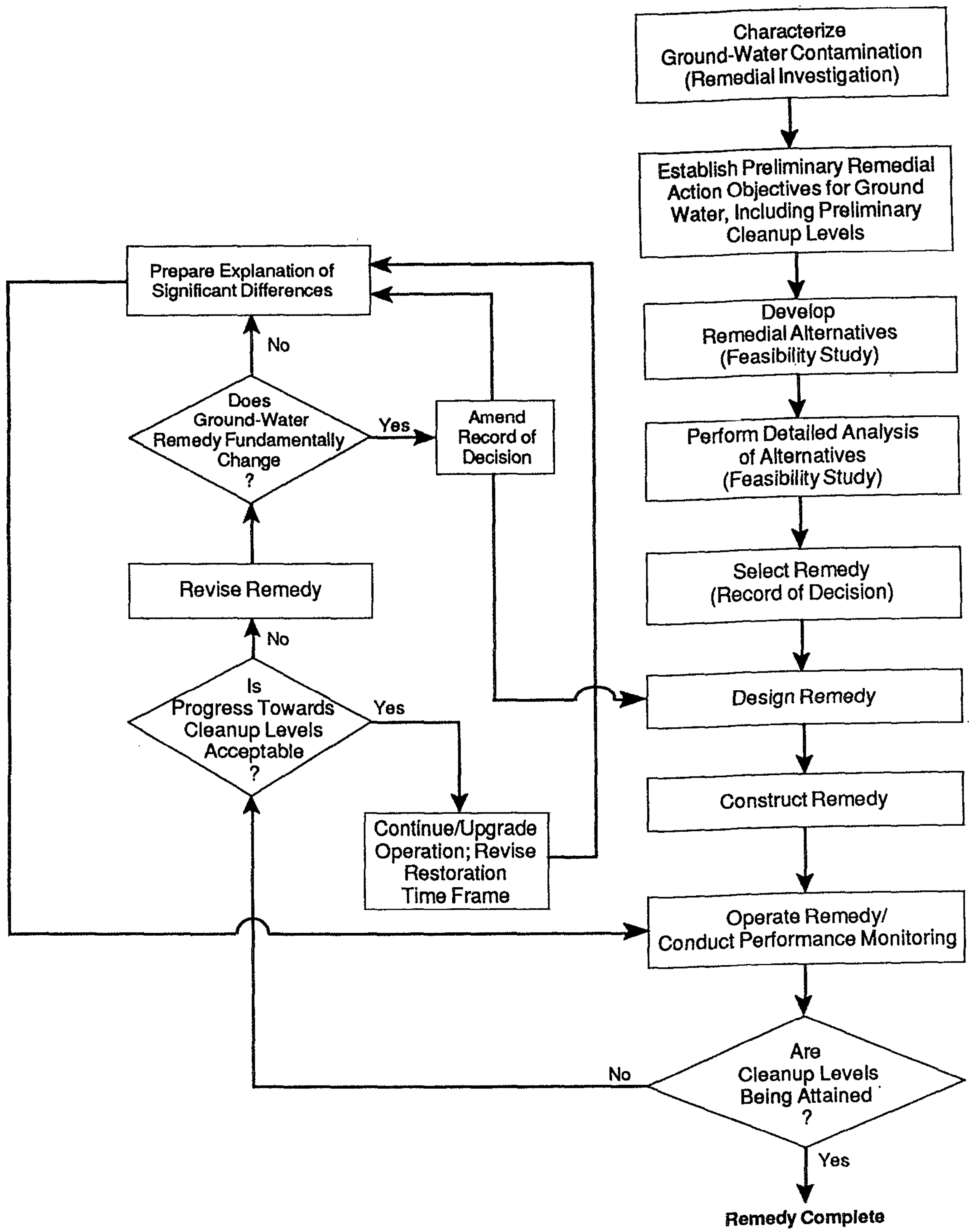


Figure 1-2 **Overview of the Ground-Water Remedy Selection Process.**

Table 1-1. EPA Guidance Documents Pertinent to Ground-Water Remedial Actions Under Superfund*

Title	Issuing Office	Citation	Status	Contents	Possible Resource for
Alternate Concentration Limit Guidance	OSWER	EPA/530-SW-87-107	Final	Describes how to develop alternate concentration limits under RCRA.	Setting cleanup levels for exposure-based scenarios for Class III ground water
Compendium of Superfund Field Operations Methods	OERR	EPA/540/P-87/001a & b August 1987	Final	Presents techniques used during the fieldwork phase of the RI.	Scoping and field investigation during the RI
Data Quality Objectives for Remedial Response Activities (DQO Guidance)	OERR/OWPE	EPA/540/G-87/003a	Final	Identifies the framework and process by which DQOs are developed. DQOs are qualitative and quantitative statements specifying the quality of data needed to support Agency decisions.	Scoping activities
Endangerment Assessment Handbook	OWPE	U.S. EPA August 1985	Draft	Provides guidance on conducting endangerment assessments.	RI
Exposure Factors Handbook	ORD	U.S. EPA September 1987	Draft	Guidance for assessing human exposure.	Selection of exposure assumptions and pathways for drinking water
Ground-Water Protection Strategy	OGWP	U.S. EPA August 1984	Final	Provides framework for protecting ground water.	Scoping
Guidance for Applicants for State Wellhead Protection Program Assistance Funds Under the Safe Drinking Water Act	OGWP	U.S. EPA June 1987	Final	Explains EPA's policies and procedures for implementing the wellhead protection assistance program.	Determining response objectives
Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA	OERR	U.S. EPA March 1989	Interim Final	Provides an understanding of the RI/FS process. Presents structure for conducting an RI/FS.	RI/FS process
Guidance Document for Providing Alternate Water Supplies	OERR	U.S. EPA October 1987	Final	Provides guidance or planning and implementing programs to provide alternate water supplies.	Taking removal actions, formulating remedial alternatives
Guidance on Preparing Superfund Decision Documents	OERR	U.S. EPA March 1988	Draft	Guidelines for documenting and amending Proposed Plans and RODs.	Documentation of the selected remedy

(continued)

*Contact the EPA Public Information Center, Washington, D.C. (202) 382-2080 for information on where to obtain documents.

Table 1-1. Continued

Title	Issuing Office	Citation	Status	Contents	Possible Resource for
Guidelines for Delineating Wellhead Protection Areas	OGWP	EPA/440/6-87-010	Final	Describes procedures and information needed to specify wellhead protection areas.	Determining response objectives
Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy	OGWP	U.S. EPA, April 1988	Draft	Presents methods used to classify aquifers.	Classifying ground water
Handbook for Remedial Actions at Waste Disposal Sites	OSW	U.S. EPA, October 1985	Final	Provides basic understanding of remedial actions, describes how to select remedial actions, and gives an example.	Alternative development, screening, and evaluation
Methods for Determining the Locations of Abandoned Wells	NWWA/EPA	NWWA, 1987	Final	Presents methods for locating abandoned wells.	Field investigation during the RI
Modeling Remedial Actions at Uncontrolled Hazardous Waste Sites	OERR/ORD	EPA/540/2-85-001 April 1985	Final	Presents model selection and use guidelines for assessing site conditions and remedial action performance.	FS
RCRA Ground-Water Monitoring Technical Enforcement Guidance Document	OWPE	U.S. EPA, OSWER Directive 9950.1, September 1986	Final	Describes the essential components of a RCRA ground-water monitoring system.	Technical considerations during scoping and performance evaluation
Superfund Exposure Assessment Manual	OERR	U.S. EPA, OSWER Directive 9285.5-1, March 22, 1988	Final	Provides overall understanding of the integrated exposure assessment process, references estimation procedures and computer modeling techniques.	RI (and modeling)
Superfund Public Health Evaluation Manual	OERR	EPA/540/1-86/060 (OSWER Directive 9285.1-1), October 1986	Final	Provides guidance on methods for evaluating effects to human health.	RI, selecting indicator chemicals, and determining aggregate effects
The CERCLA Compliance With Other Laws Manual	OERR	EPA, June 1987, OSWER Directive 9243.1-01	Interim Final	Identifies potential ARARs, procedures for identifying ARARs, waiver criteria, and hypothetical scenarios.	Scoping, FS
Water Quality Standards Handbook	OW/Regulations and Standards	U.S. EPA, December 1983	Final	Guidance and implementation of WQC.	Determination of preliminary cleanup levels

Chapter 2

Statutory and Policy Framework for Ground-Water Remedial Alternatives

2.1 Introduction

This chapter identifies important provisions and requirements of environmental statutes and policies that affect the decision-making process at Superfund sites that have ground-water contamination. CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), provides the statutory framework for cleaning up hazardous waste sites, and the National Contingency Plan (NCP) (U.S. EPA, 1985) codifies EPA's implementation policy written under CERCLA. This chapter integrates important requirements and provisions of both CERCLA and the policy directives that address its implementation. Other environmental statutes and policies that affect Superfund ground-water remediation include:

- The *Ground-Water Protection Strategy* (U.S. EPA, 1984) and its associated *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (U.S. EPA, 1986b) (also called *Classification Guidelines*) (U.S. EPA, 1986b)
- The Resource Conservation and Recovery Act (RCRA)
- The Safe Drinking Water Act (SDWA)
- The Clean Water Act (CWA)

Further discussion of Superfund's responsibility to meet the environmental statutes can be found in *The CERCLA Compliance with Other Laws Manual* (U.S. EPA, 1988a)

2.2 Requirements and Provisions of CERCLA and the NCP

The proposed NCP (U.S. EPA, 1988d) incorporates the requirements and provisions of SARA. This guidance has been prepared on the basis of CERCLA as amended by SARA and the existing NCP (1985) and is consistent with the proposed NCP and directives issued by the Office of Solid Waste and Emergency Response (OSWER) (U.S. EPA, 1986a, 1987a, and 1987k)

The following CERCLA requirements must be addressed specifically during remedy selection and must be discussed in the ROD. The discussion should demonstrate that the remedy does the following:

- Protects human health and the environment (CERCLA Section 121(b))
- Attains the applicable or relevant and appropriate requirements (ARARs) of Federal and State laws (CERCLA Section 121(d)(2)(A)) or warrants a waiver under CERCLA Section 121(d)(4)
- Reflects a cost-effective solution, taking into consideration short- and long-term costs (CERCLA Section 121(a))
- Uses permanent solutions and treatment technologies or resource recovery technologies to the maximum extent practicable (CERCLA Section 121(b))
- Satisfies the preference for remedies that employ treatment that permanently and significantly reduces the mobility, toxicity, or volume of hazardous substances as a principal element or explains why such a remedy was not selected (CERCLA Section 121(b))

In addition, the following provisions of CERCLA may or may not be pertinent to ground-water remediation depending on site-specific circumstances:

- Alternate concentration limits (ACLs) from those otherwise applicable or relevant and appropriate requirements can only be used for determining off site cleanup levels under special circumstances (CERCLA Section 121(d)(2)(B)(ii)).
- Ground-water remedial actions that restore ground water are to be federally funded until cleanup levels are achieved or up to 10 years,

whichever comes first (CERCLA Section 104(c)(6)).

- A performance evaluation must be conducted at least every 5 years if wastes are left onsite (CERCLA Section 121(c)). By policy this has been interpreted to apply where wastes are left above health-based levels.

The requirements for a remedy to be protective and cost-effective are discussed in detail in Chapter 6. The other requirements and provisions and the policy for implementing them are outlined below.

2.2.1 Applicable or Relevant and Appropriate Requirements

When setting cleanup levels under CERCLA, ARARs are considered in the following manner, as described in the *CERCLA Compliance With Other Laws Manual* (U.S. EPA, 1988a):

- Applicable requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Superfund site.

- Relevant and appropriate requirements, like applicable requirements, are cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law. While not technically applicable to a hazardous substance, pollutant or contaminant, remedial action, location, or other circumstance at a Superfund site, relevant and appropriate requirements address problems or situations sufficiently similar to those encountered at a Superfund site so that their use is well-suited.

Policies for determining which requirements at a site are ARARs have been described in guidance documents (U.S. EPA, 1988a and 1987k). Figure 2-1 presents several action-specific ARARs that may be required for various ground-water remedial actions. ARARs typically fall into three categories:

- Chemical-specific ARARs are health- or environmentally based numerical values limiting the amount of a contaminant that may be discharged to, or allowed to remain in, environmental media. These include, for example, maximum contaminant levels (MCLs) established under the SDWA. Generally, chemical-specific ARARs are used when setting preliminary cleanup levels.

- Location-specific ARARs restrict activities or limit concentrations of contaminants in effluent because a site is in a special location such as a floodplain, wetland, or historical area.

- Action-specific ARARs are technology- or activity- based limitations and may include, for example, limitations on discharges of treated water to streams.

ARARs most pertinent to ground-water remedies relate to setting cleanup levels, operating treatment processes, and managing treatment residuals. CERCLA specifies six conditions under which ARARs may be waived (CERCLA Section 121(d)(4)). These are discussed in Chapter 6.

2.2.2 Use of Permanent Solutions and Treatment Technologies to the Maximum Extent Practicable

CERCLA requires an assessment of permanent solutions and treatment technologies and mandates that they be used to the maximum extent practicable. Information on treatment technologies suitable to ground water is presented in Chapter 5.

The additional cost and time associated with treatability testing and uncertainties associated with implementing a technology that is not in common use should be considered when assessing treatment. The practicable extent to which permanent solutions and treatment technologies can be used is based on a site-specific analysis of alternatives against nine evaluation criteria.

2.2.3 Preference for Treatment as a Principal Element

CERCLA expresses a preference for remedies that employ treatment that permanently and significantly reduces the mobility, toxicity, or volume of hazardous substances as a principal element. Emphasis is placed on destruction or detoxification of hazardous materials rather than on protection strictly through prevention of exposure. Furthermore, the statute requires an explanation of why this preference is not met when the principal threats are not treated. This is discussed further in Chapter 6.

2.2.4 CERCLA Restrictions on Establishing ACLs

CERCLA specifies that ACLs, (i.e., levels of contamination that will remain in the ground water at the completion of the remedial action that are above levels safe to human health and the environment but to which exposure is prevented) cannot be

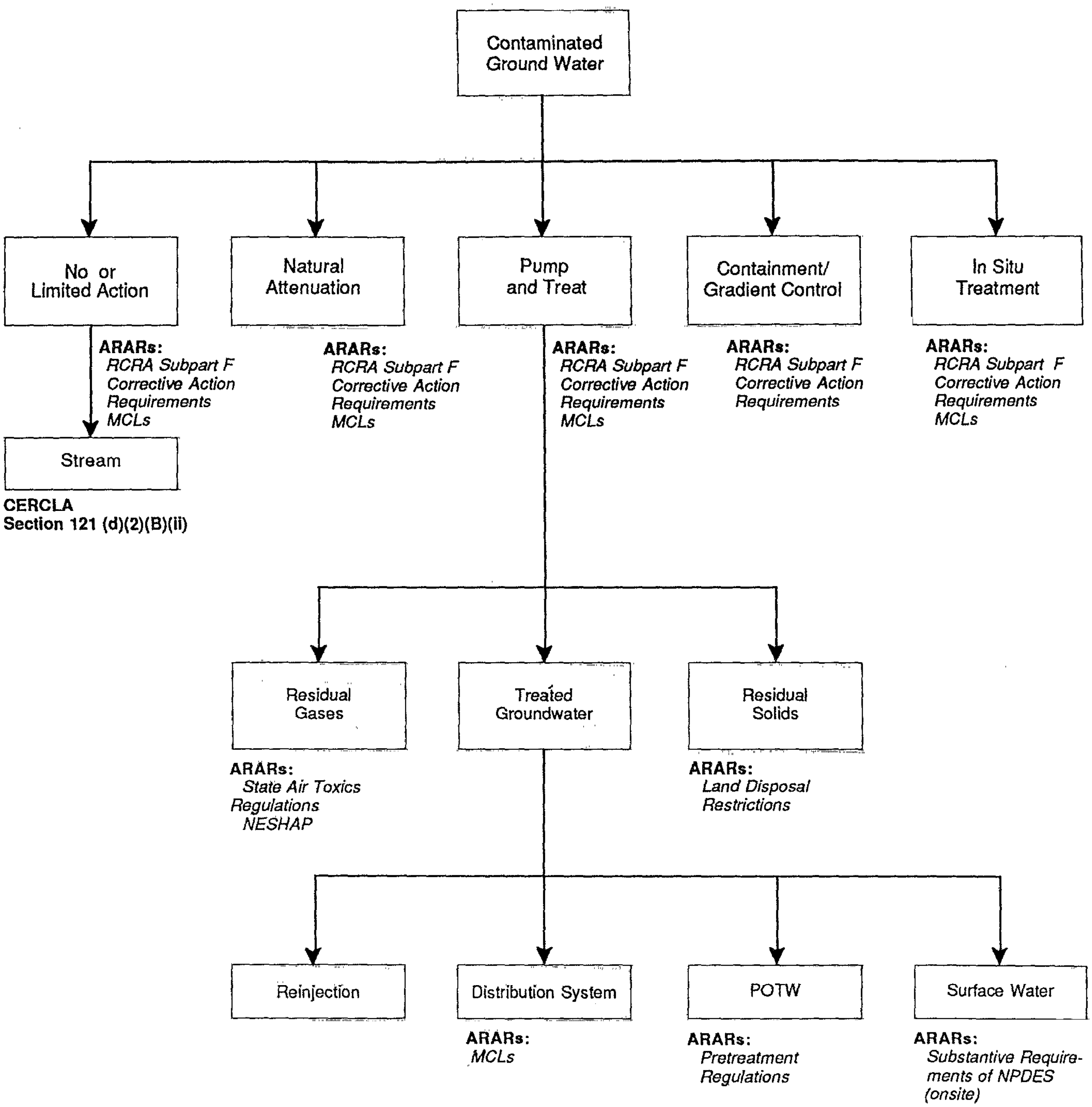


Figure 2.1 Possible Action-Specific ARARs for Ground-Water Remedial Actions.

established for ground water if the process for establishing the ACLs assumes that the first point of human exposure is beyond the boundary of the facility, except under the following scenario: The ground water has a known or projected point of entry to surface water and there are no statistically significant increases in contaminant concentration in the surface water or at any point at which contaminants are expected to accumulate. In addition, there must be reliable institutional controls preventing exposure to ground-water contaminants that are above cleanup levels. It is the policy of EPA that this provision be used only when cleanup to ARARs is not practicable. The method for establishing ACLs under CERCLA generally considers the factors specified for establishing ACLs under RCRA, but, for the most part, will be governed by the restrictions outlined above. This is discussed further in Chapter 4.

2.2.5 *Funding Remedial Actions*

Funds for remedial activities come from both Federal and State sources unless enforcement actions have provided for potentially responsible party (PRP)-led investigation or remediation (i.e., cases for which cost recovery is planned or there are viable PRPs). States are required to pay up to 10 percent of the costs of the remedial action. Federal funding of remedial actions that restore ground or surface water continues for up to 10 years. After 10 years or when cleanup levels are achieved, the State fully funds any necessary operation and maintenance. The 10-year funding provision should be applied only to actions to restore ground or surface waters and not to actions to reduce exposure to contaminants. For example, if ground water is pumped and treated to provide an alternate water supply and not to restore the ground water, this provision should not be applied, and Federal funding would only cover capital and startup costs. Also, Federal funding would not cover long-term leachate control actions, i.e., actions in which leachate is extracted and treated as part of the source control remedy. If the facility responsible for the contamination is operated by a state or a political subdivision of a state, the state is required to pay 50 percent of the cost of the remedial action (CERCLA Section 104(f)). Additional information on funding remedial actions is available from "Interim Guidance on Funding for Ground and Surface Water Restoration" (U.S. EPA, 1987e).

2.2.6 *Evaluating Remedial Action Performance*

CERCLA requires that remedial actions be reviewed periodically and at least every 5 years after initiation of the remedial action as long as contaminants remain at the site. For ground-water remediation, performance evaluations (or 5-year reviews) are required as long as contaminant concentrations exceed health-based levels. Performance evaluations are routinely conducted throughout a remedial action at a frequency that is site-specific and usually involve annual monitoring. Performance evaluations are discussed further in Chapter 7.

2.3 U.S. EPA's *Ground-Water Protection Strategy and Classification Guidelines*

It is the policy of EPA's Superfund program to use as a guide the framework provided by EPA's *Ground-Water Protection Strategy* (U.S. EPA, 1984) in determining the appropriate remediation for contaminated ground water. Three classes of ground water have been established on the basis of ground-water value and vulnerability to contamination. The *Classification Guidelines* (U.S. EPA, 1986b) provides guidance in determining the potential beneficial uses of the contaminated ground water, i.e., whether it is Class I, Class II, or Class III. The expected use of the *Ground-Water Protection Strategy and Classification Guidelines* is described in the forthcoming policy statement entitled "Implementation of Ground-Water Classification in the Environmental Protection Agency."

The various ground-water classes are described next.

Special ground water (Class I) is (1) highly vulnerable to contamination because of the hydrological characteristics of the areas in which it occurs, and (2) characterized by either of the following factors:

- The ground water is irreplaceable; no reasonable alternative source of drinking water is available to substantial populations.
- The ground water is ecologically vital; the aquifer provides the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat.

Current and potential sources of drinking water and water having other beneficial uses includes all other ground water that is currently used (IIA) or is potentially available (IIB) for drinking water, agriculture, or other beneficial use.

Ground water not considered a potential source of drinking water and of limited beneficial use (Class IIIA and Class IIIB) is saline, i.e., it has a total dissolved solids levels over 10,000 milligrams per liter (mg/l), or is otherwise contaminated by naturally occurring constituents or human activity that is not associated with a particular waste disposal activity or another site beyond levels that allow remediation using methods reasonably employed in public water treatment systems. Class III also includes ground water that is not available in sufficient quantity at any depth to meet the needs of an average household.

Class IIIA includes ground water that is interconnected to surface water or adjacent ground water that potentially could be used for drinking water. Class IIIB includes ground water that has no interconnection to surface water or adjacent aquifers. For Class IIIA ground water, establishing cleanup levels should take into consideration the degree of interconnection to Class I or Class II ground water or the rate of discharge to surface water so that levels of contaminants in higher class ground water do not increase as a result of the interconnection.

According to the *Classification Guidelines*, the Class III designation may apply to ground-water contamination that is caused by human activity and is widespread and not attributable to a specific site. For the Superfund process, however, remedial action objectives for Class III ground water that is contaminated as a result of human activity would typically be determined initially using the process described in this guidance for Class II ground water and may involve coordination with other parties, as described in Appendix B. This is further described in Chapter 4.

Using the *Classification Guidelines* as a guide, a determination is made as to whether ground water falls within Class I, Class II, or Class III. The specifications for the three classes are outlined in Figure 2-2. Such classifications are site-specific and limited in scope. Ground water is classified by EPA under the Superfund program to assist in determining the appropriate type of remediation for a Superfund site. Classifications performed by EPA under the Superfund program do not apply to the general geographic area in which they are performed, nor to any Federal, State, or private action other than Superfund remediation.

Some states have developed and promulgated their own ground-water classification systems. A State's classification system may be used to determine remediation goals. Furthermore, a promulgated State system may be an ARAR. In addition, State wellhead protection programs, especially those developed pursuant to the SDWA, may influence classification of ground water (U.S. EPA, 1987g). For example, if a Superfund site is within a wellhead protection area, Class IIA ground water may be treated as Class I. The *Guidance for Applicants for State Wellhead Protection Program Assistance Funds Under the Safe Drinking Water Act* (1987e) describes the criteria for establishing wellhead protection areas.

2.4 Application of RCRA to Ground-Water Remediation

Pertinent RCRA regulations are presented in this section to familiarize the reader with its provisions. Throughout this discussion, RCRA's relationship to Superfund remediation is discussed. RCRA requirements that potentially are applicable or relevant and appropriate to Superfund ground-water actions include the land disposal restrictions (40 CFR 268) and the ground-water monitoring and response program (40 CFR 264, Subpart F). Regulations for corrective action at solid waste management units (40 CFR 264, Subpart S), referred to here as the subpart S regulations, are being developed and may also be applicable or relevant and appropriate when promulgated. RCRA requirements regarding closure of units may also be ARARs at Superfund sites at the completion of remedial action. Because the closure requirements that address ground-water contamination refer simply to Subpart F, closure specifications will not be addressed as a separate section in this guidance.

2.4.1 *The Land Disposal Restrictions*

The RCRA land disposal restrictions require that hazardous waste be treated to established levels before being placed in a land-based unit. The schedule for implementation of the land disposal restrictions is presented in Table 2-1.

Ground-water treatment residuals from Superfund remedial actions, such as spent carbon or ion exchange resins that are contaminated with RCRA-listed waste for which treatment standards have been promulgated must either meet the land disposal restrictions or be delisted under RCRA before disposal. Ground-water treatment system residuals from Superfund remedial actions that exhibit the RCRA-hazardous waste toxicity characteristic will have to be treated until concentrations are below the characteristic levels established under RCRA before disposal once the land disposal restrictions for characteristic wastes become effective.

Treated ground water from Superfund remedial actions that is discharged to surface water must meet the substantive requirements of a National Pollutant Discharge and Elimination System (NPDES) permit but would not have to meet the RCRA land disposal restriction levels, because discharges to surface waters that meet the requirements of an NPDES permit are exempt from the RCRA land disposal restrictions.

Treated ground water that is discharged to a publicly owned treatment works (POTW) must meet the pretreatment requirements of the POTW, as specified by the CWA. If the discharge will go to a POTW that does not have established pretreatment standards, the remedial action should be evaluated to determine if the POTW's NPDES permit will be in violation as a result of the discharge. The land disposal restrictions are only triggered when the treated ground water is placed directly in a surface impoundment.

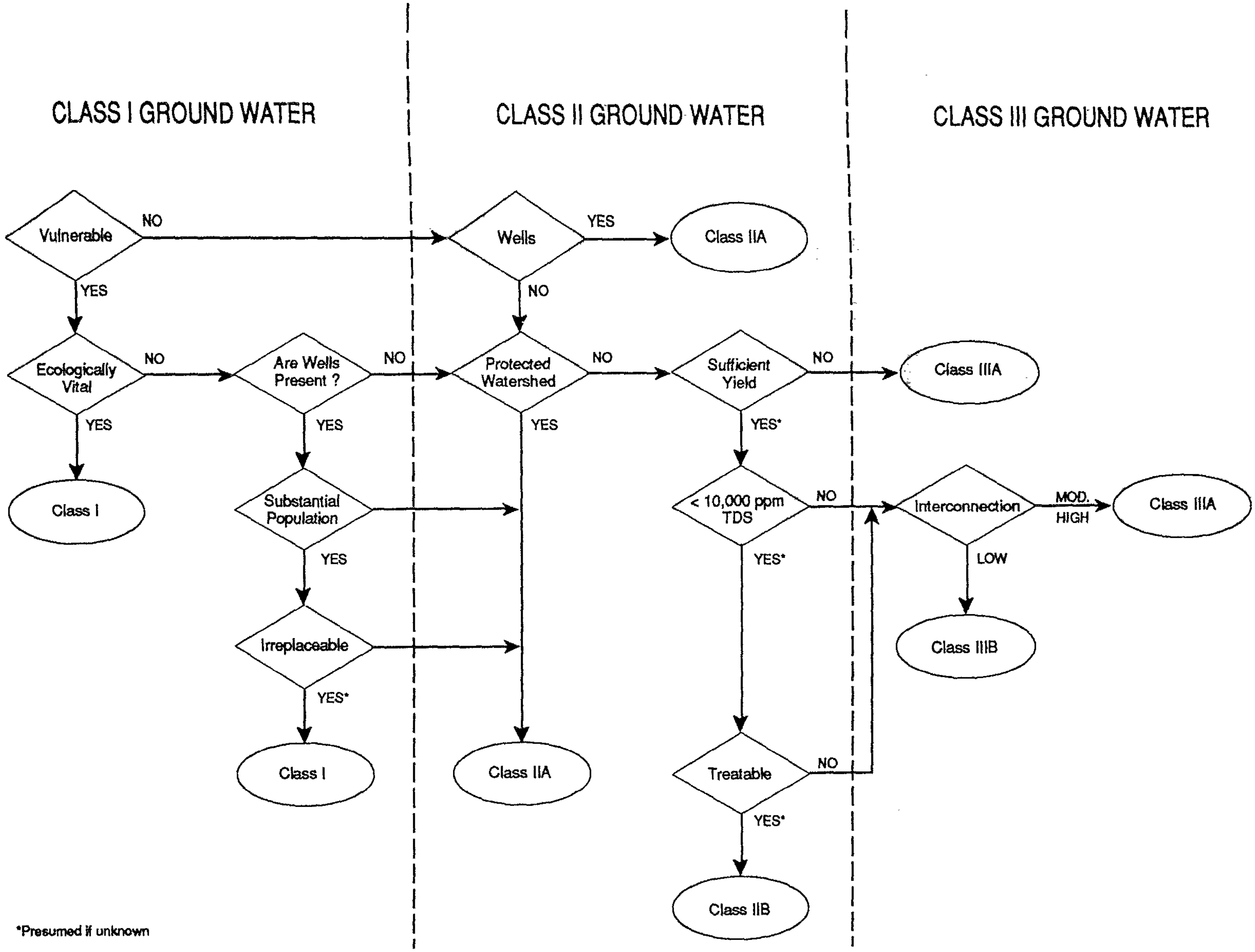


Figure 2-2 ***Ground-Water Classification Flow Chart.***

Table 2-1. **Schedule for Implementation of the Land Disposal Restrictions**

	Wastes	Effective Date of Ban
Solvents and Dioxin Wastes[a]	F001 to F005 (Spent solvents)	November 8, 1986
	F020 to F023, F026 to F028 (Dioxin-containing wastes)	November 8, 1988
	Soil and debris contaminated with certain solvents and dioxins from CERCLA/RCRA corrective actions	November 8, 1990
	Soil and debris contaminated with certain solvents and dioxins not from CERCLA/RCRA corrective actions	November 8, 1988
	Solvent wastes from small quantity generators	November 8, 1988
	Solvent wastes generated from CERCLA/RCRA corrective actions	November 8, 1988
	Solvent-water mixtures, solvent-containing sludges and solids, and non-CERCLA/RCRA corrective action soil with less than 1 percent total solvent constituents	November 8, 1988
California List Wastes[b]	California list (except HOCs)	July 8, 1987
	Dilute HOCs (Greater than or equal to 1,000 mg/l and less than 10,000 mg/l)	July 8, 1987
	Liquid and non-liquid HOCs	November 8, 1988
	Soil and debris contaminated with HOCs not from CERCLA/RCRA sites	July 8, 1989
	Soil and debris contaminated with HOCs from CERCLA/RCRA corrective actions	November 8, 1990
Remaining Wastes[c]	One-third of all ranked and listed hazardous waste ("First Third") except:	August 8, 1988
	Petroleum Refining Wastes (K048, K049, K050, K051, K052)	August 8, 1990
	Electric Arc Furnace Dust (K0621--high zinc)	August 8, 1990
	Brine Refining Muds/Mercury Cell Process (K071)	August 8, 1990
	Wastewater Treatment Sludge/Mercury Cell Process (K106)	August 8, 1990
	Soil and debris contaminated with First Third Wastes for which BDAT is *solids incineration*	August 8, 1990
	Two-thirds of all ranked and listed hazardous wastes ("Second Third")	June 8, 1989
	All remaining ranked and listed hazardous wastes and all hazardous wastes identified by characteristic under RCRA Section 3001 ("Third Third")	May 8, 1990
	Any hazardous waste listed or identified under RCRA Section 3001 after November 8, 1984	Within 6 months of the date of identification or listing

[a]The solvent and dioxin wastes are:

F001 Spent halogenated solvents used in degreasing (e.g., tetrachloroethylene, trichloroethylene, methylene chloride) and sludges from the recovery of these solvents in degreasing operations.

F002 Spent halogenated solvents (e.g., tetrachloroethylene, trichloroethylene, methylene chloride) and still bottoms from the recovery of these solvents.

F003 to F005 Spent non-halogentated solvents (e.g., xylene, acetone, cresols, toluene, methyl ethyl ketone) and still bottoms from the recovery of these solvents.

F020 to F023 and F026 to F028 Dioxin-containing wastes

[b]The California lists wastes are RCRA-listed hazardous wastes that are liquids except halogenated organic compounds (HOCs), and

- Contain free cyanides (greater than or equal to 1,000 mg/l)
- Contain PCBs (greater than or equal to 50 ppm)
- Contain HOCs (greater than or equal to 1,000 mg/kg)
- Have a pH less than 2
- Contain certain metals:
  - -Arsenic (greater than or equal to 500 mg/l)
  - -Cadium (greater than or equal to 100 mg/l)
  - -Chromium (greater than or equal to 500 mg/l)
  - -Lead (greater than or equal to 500 mg/l)
  - -Mercury (greater than or equal to 20 mg/l)
  - -Nickel (greater than or equal to 134 mg/l)
  - -Selenium (greater than or equal to 100 mg/l)
  - -Thallium (greater than or equal to 130 mg/l)

[c]See 40 CFR 268.10.

Discharges via the sewage system are exempt from the land disposal restrictions under the domestic sewage exemption.

2.4.2 *The RCRA Ground-Water Monitoring and Response Program*

The RCRA ground-water protection standards establish requirements for regulated units (surface impoundments, waste piles, land treatment units, and landfills) that received hazardous waste after July 26, 1982. Because most Superfund sites have not received hazardous waste since this date, the RCRA ground-water regulations generally are not applicable to Superfund sites unless the Superfund action involves active placement of RCRA wastes in such units. However, these requirements may be relevant and appropriate. RCRA requirements are generally met by standard procedures used for Superfund sites, and RODs should contain language to this effect. Feasibility studies and RODs need only note this consistency in the ARAR discussions. RCRA regulations specify monitoring requirements, concentration standards, and corrective action measures. These are described in the following paragraphs.

2.4.2.1 Monitoring Requirements

The RCRA monitoring requirements consist of three categories: detection monitoring, compliance monitoring, and corrective action monitoring.

- *Detection monitoring* is used to determine if a release to ground water has occurred.
- When a release has occurred, *compliance monitoring* is used to determine if any ground-water concentration standards have been exceeded.
- *Corrective action monitoring* is used when the ground-water protection standard has been exceeded and corrective action is implemented. Corrective action monitoring establishes the effectiveness of measures taken to remediate ground water.

At a Superfund site with contaminated ground water, it has already been determined that a ground-water remediation decision must be made. Therefore, RCRA's detection monitoring and compliance monitoring requirements are not generally relevant and appropriate. However, RCRA corrective action monitoring requirements may be applicable or relevant and appropriate. If a new hazardous waste treatment storage or disposal facility is created as a result of remedial actions taken at the site, detection and compliance monitoring may also be applicable.

2.4.2.2 Concentration Standards

Concentration standards under the RCRA ground-water protection standards (Subpart F) are the background level of the constituent, the MCL for the constituent (RCRA MCL), or an alternate concentration limit (RCRA ACL). (RCRA MCLs have been so noted because currently there are no automatic provisions for revising or supplementing the MCLs in RCRA as they are promulgated or revised under the SDWA.) As discussed in Chapter 4 of this guidance, Superfund ground-water remedies for existing or potential sources of drinking water should reduce concentrations to existing MCLs or to more stringent State standards. Contaminants for which MCLs have not been set must meet cleanup levels derived from other health-based or environmentally based standards, a process that is comparable to using RCRA ACLs derived from health-based considerations. Therefore, Superfund is generally consistent with the requirements of RCRA. This should be noted in the ROD.

For Class III ground water, it is expected that both RCRA and Superfund would require similar cleanup approaches considering the factors listed under the RCRA regulation's ACL provision (e.g., physical and chemical characteristics of the waste, including its potential for migration, current and future uses of the ground water, and the existing quality of ground water) since this is a determination based on exposure. Additional information on RCRA's ACL provision is available in the *Alternate Concentration Limit Guidance* (U.S. EPA, 1987b.)

2.4.2.3 Corrective Action Program

Under RCRA, a corrective action program is implemented if a release above the ground-water protection standard is confirmed. The corrective measures under RCRA include removal or treatment in place of any hazardous constituents that exceed RCRA's established concentration limits. These action-specific measures may be applicable or relevant and appropriate requirements for Superfund. They are summarized below and discussed in conjunction with Superfund requirements.

- RCRA requires a corrective action program that prevents hazardous constituents from exceeding concentration limits at the compliance point--the boundary of the waste management area--if any concentration level exceeds the ground-water protection standard. Consistent with statutory mandates, the Superfund cleanup goal, on the other hand, is to attain health-based standards within the area of attainment--the area that encompasses the entire contaminant plume beyond the boundaries of any waste managed in place as part of the final remedy. Therefore, the area of the plume to be remediated under Superfund is consistent with the area of the plume to be remediated under RCRA.

- In addition to requiring a corrective action program, RCRA requires that a ground-water monitoring program be implemented to demonstrate the effectiveness of the corrective action. RCRA corrective action measures may be terminated when ground-water monitoring data demonstrate that the contaminant levels are below the ground-water protection standard for a period of 3 years. (EPA is reevaluating this 3-year requirement and anticipates making the time period site specific.) Under Superfund, requirements for evaluating the effectiveness of a remedy are site-specific and must demonstrate that cleanup levels are achieved. This is generally consistent with the RCRA requirements.

2.4.3 The Subpart S Regulations

Under Subpart S of the RCRA regulations, requirements for corrective action at solid waste management units (SWMUs) are currently being drafted. The basic requirements for SWMU corrective action are currently in effect under the authority of the Hazardous and Solid Waste Amendments of 1984. SWMUs include both regulated and previously unregulated units at RCRA facilities without regard to the time the waste was received. Subpart F, discussed above, is also being revised to ensure consistency between Subpart F and Subpart S.

Subpart S will cover all releases to soil, air, and surface water and some releases to ground water from SWMUs. The releases to ground water that Subpart S will cover include (1) releases to ground water from regulated units if treatment, storage, or disposal occurred before July 26, 1982, and (2) releases from unregulated units (i.e., those not regulated under Subpart F) without regard to the time of activity. When these regulations are promulgated they may be applicable or relevant and appropriate to Superfund sites.

Remediation of ground-water releases from regulated units receiving waste after July 26, 1982, will still be covered under Subpart F.

2.5 The Safe Drinking Water Act

Three provisions of the SDWA may pertain to Superfund ground-water remediation: the drinking water standards, the underground injection control (UIC) program, and the State wellhead protection program.

MCLs developed under the SDWA generally are ARARs for current or potential drinking water sources within the area of attainment. Although MCLs are developed using cost and technical considerations, they are also protective of human health for exposure from drinking water. There are currently 38 promulgated primary MCLs for chemicals. Eighty-three MCLs will have been promulgated by 1989, 25 additional MCLs are to be proposed by 1991, and an additional 25 MCLs are to be proposed every 3 years thereafter. For Superfund, cleanup levels that are more stringent than MCLs may be required to achieve adequate protection in some cases; these are discussed in Chapter 4.

EPA has also developed MCL goals (MCLGs) that are entirely health based. MCLGs serve as guidance for establishing MCLs. Under Superfund, MCLGs may be considered when setting cleanup levels in situations where multiple pathways or multiple contaminants increase risks, as discussed in Chapter 4.

The UIC program developed under the SDWA provides standards and procedures for underground injection of fluids. Underground injection wells are divided into the following five general classes for permitting and regulatory purposes:

- Class I wells are those used to inject industrial, hazardous, and municipal wastes beneath the lower most formation containing an underground drinking water source within 1/4-mile of the well bore.
- Class II wells are those used to dispose of fluids that are brought to the surface in connection with oil and gas production, to inject fluids for the enhanced recovery of oil or gas, or to store liquid hydrocarbons.
- Class III wells are those used to inject fluids for the extraction of minerals.
- Class IV wells are used to inject hazardous or radioactive waste into or above a formation that contains an underground drinking water source that is within 1/4-mile of the well. Operation or construction of Class IV wells, though generally prohibited, is allowed as part of a Superfund remedial action if the wells are used to reinject treated ground water into the same formation from which it was withdrawn.
- Class V wells include all wells not incorporated in Classes I through IV, including, for example, recharge wells, septic system wells, and shallow industrial disposal wells.

Superfund ground-water actions would most likely involve Class IV wells. There are currently no substantive requirements in the regulations for the construction of these wells; closure of Class IV wells (40 CFR 144.23) requires only that the well be plugged or closed in a way that is acceptable to the Regional Administrator.

According to the SDWA's State wellhead protection program, states are required to develop programs to establish wellhead protection areas to protect public water supply systems from contamination. These programs may be location-specific ARARs for Superfund remedial actions and under certain circumstances may lead to a higher level of cleanup at sites within wellhead protection areas, according to the State wellhead protection program. Additional guidance on the wellhead protection programs can be found in *Guidelines for Delineation of Wellhead Protection Areas* (U.S. EPA, 1987g) and the *Guidance for Applicants for State Wellhead Protection Program Assistance Funds Under the Safe Drinking Water Act* (1987e).

2.6 The Clean Water Act

The CWA establishes permit requirements and discharge limits for remedial actions that involve the discharge of treated or untreated contaminated ground water into a navigable stream. Provisions of the CWA that may be ARARs include the following:

- Regulation of discharges to surface waters through the NPDES permitting process
- Best available technology (BAT) and best conventional technology (BCT) for treating wastewaters
- Water quality criteria (WQC) (U.S. EPA, 1986d), which are discussed further in Chapter 4
- Water quality standards that must be promulgated by states

NPDES Discharges to Surface Water. Both onsite and offsite discharges from CERCLA sites to surface water are required to meet the substantive NPDES requirements. In addition, offsite discharges are required to meet the administrative requirements.

Best Available Technology and Best Conventional Technology. All direct discharges to surface water must meet technology-based guidelines. For toxic and nonconventional pollutants, the BAT that is economically achievable must be used, while for conventional pollutants, the BCT must be used. At CERCLA sites, BAT and BCT are determined on a case- by-case basis using Best Professional Judgment. Once the technology is selected, the numerical effluent discharge limits are derived by applying the levels of performance of the treatment technology to the wastewater discharge. The numerical effluent limits must be consistent with the State's water quality standards.

Water Quality Criteria. WQC for protection of human health and aquatic life are established by EPA and serve as guidelines to states, which are required to set water quality standards for use in implementing their NPDES permitting programs.

Water Quality Standards. Water quality standards are numerical limitations that must be met in the receiving water body at all times. Thus, the dilution of the effluent in the receiving water body must be determined. Discharges of wastewater at CERCLA sites must be consistent with these promulgated standards.

Chapter 3
Scoping Ground-Water Remedial Activities

3.1 Introduction

Before collecting any data, it is useful to conduct two planning activities:

- Site management planning, which involves identification of the types of actions that are taken to address site problems and their optimal sequence
- Project planning, which includes such activities as scoping data collection activities and initiating identification of ARARs

Figure 3-1 illustrates the planning process for ground-water remedial alternatives. This chapter will concentrate on site management planning and scoping. These two tasks will be discussed in terms of implementing remedial actions at sites with ground-water contamination. Assistance and advice in conducting ground-water investigations can be obtained from EPA laboratory resources--specifically the Environmental Monitoring Systems Laboratory (Las Vegas, Nevada) for monitoring and site characterization assistance and the Robert S. Kerr Environmental Research Laboratory (Ada, Oklahoma) for fate and transport evaluations. In addition, other Federal agencies, including the U.S. Geological Survey, U.S. Army Corps of Engineers, Department of Interior, and the Agency for Toxic Substances and Disease Registry, can also provide assistance.

3.2 Site Management Planning

During site management planning, existing data are evaluated and a conceptual understanding of the site is developed. This conceptual understanding should incorporate all known and suspected sources of contamination, types of contaminants and affected media, routes of migration, and human and environmental receptors. Site management planning is refined as data are collected and the site characteristics and contaminant migration pathways are better understood.

Site management planning identifies the response approaches that will be taken to address the site problems. Two response approaches can be taken to remediate ground water at Superfund sites:

- Removal actions can be taken to prevent human exposure to contaminants that may cause health effects and to prevent further degradation of the ground water.
- Remedial actions can be taken as operable units. Operable units are (1) final actions that completely address a discrete area of a site or (2) interim actions taken to mitigate a threat or prevent further degradation of ground water.

3.2.1 Removal Actions

Removal actions are authorized for any release that presents a threat to public health, welfare, or the environment, as determined by the lead agency (U.S. EPA, 1987j). CERCLA limits Superfund-financed removal actions to $2 million and 12 months unless the criteria for granting an exemption to the statutory limits are satisfied.

In addressing ground-water contamination problems, removal actions may be used in several ways: (1) to provide alternate water supplies, (2) to prevent plume migration by implementing methods such as barrier wells and interceptor trenches, (3) to pump and treat contaminated ground water, or (4) to control the source of contamination (e.g., by excavating soil hot spots or buried drums). In determining whether to use removal authority, the lead agency considers the nature of the threat, the scope of the response, and the availability of other response mechanisms. Furthermore, if a removal action will be used for (1), (2), or (3) above, it must be shown that an existing drinking water supply is threatened and that the removal program action level policy is satisfied.

The Office of Emergency and Remedial Response (OERR) action level policy[1], discussed in greater detail in Section 3.2.1.1, states that removal actions

[1]The action level referred to here is not the same as the action level that triggers corrective action discussed in the RCRA regulations.

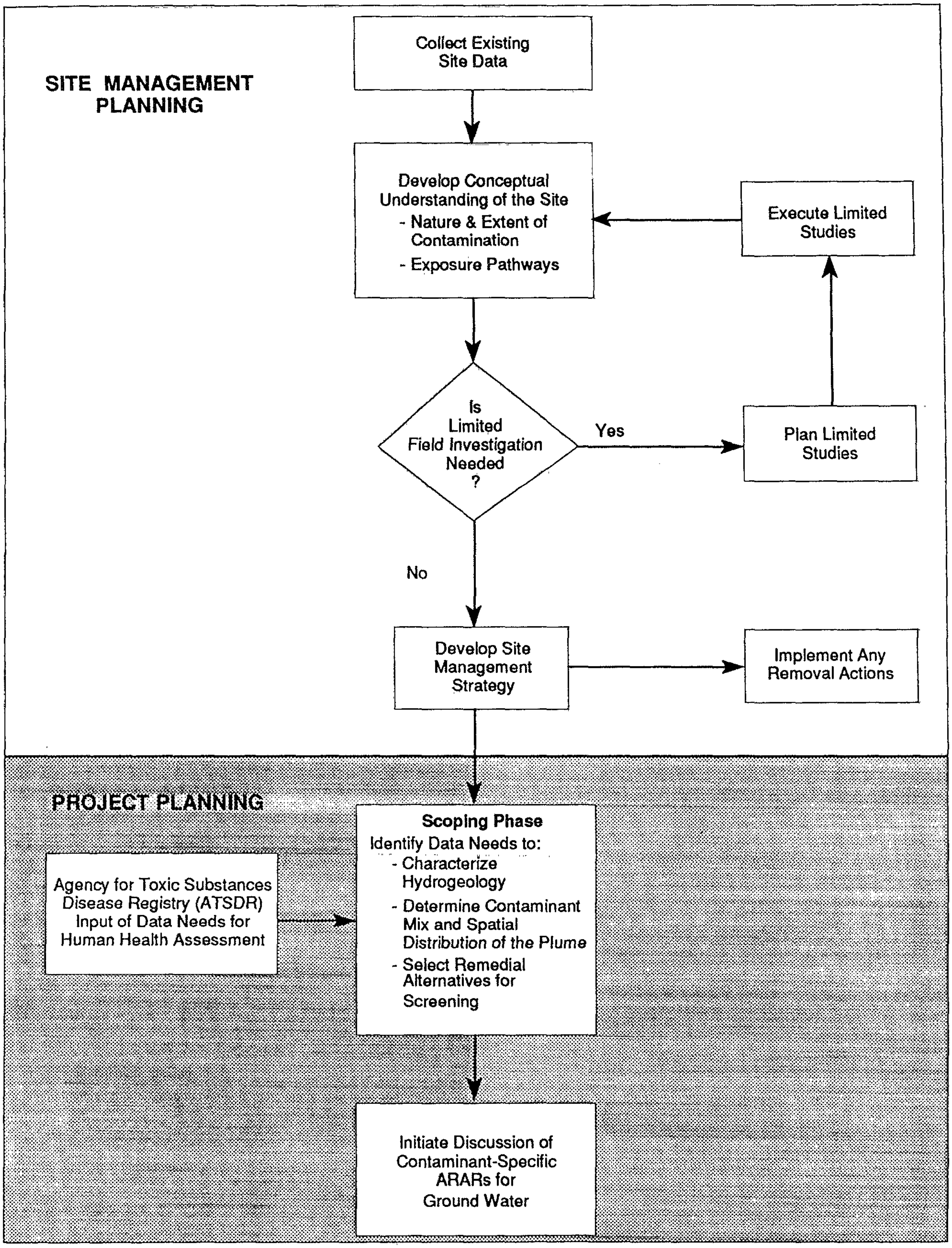


Figure 3-1 Planning and Scoping Ground-Water Remedial Activities.

may be implemented if (1) the numeric action levels established by OERR are exceeded at the drinking water tap, or (2) a site-specific health effects analysis is conducted, and the analysis indicates that the site poses a serious health threat. Figure 3-2 indicates the steps under the removal action level policy for determining if a removal action should be implemented in these cases.

In general, removal actions are most useful for providing alternate water supplies and source control actions. Ground-water plume control and treatment is outside the scope of removal authority for many sites because of the $2-million/12-month statutory limits on removal actions. However, there are two types of statutory exemptions available to these limits: (1) the emergency exemption, and (2) the consistency exemption. Under the OERR action level policy, to qualify for an emergency exemption, the exemption request must demonstrate that contaminant levels exceed the 10-day health advisory, significantly exceed the numeric action levels, or that an emergency exists based on site-specific factors. If contaminant levels exceed the numeric action level by only a minimal amount, a consistency exemption may be warranted. The *Superfund Removal Procedures* manual (U.S. EPA, 1988f) provides more information on preparing an exemption request. States and PRPs should be encouraged to pursue removal actions, particularly provision of alternate water supplies as described in the "Removal Program Priorities" memorandum (U.S. EPA, 1988e).

For any site at which a removal action is being considered, the remedial project manager (RPM) should consult the regional removal program office to ensure that removal authorities and procedures are correctly understood. Although an RI/FS and a Record of Decision (ROD) are not required for removal actions, an Action Memorandum must be prepared for all removals, and engineering evaluation/cost analysis is required for certain removal actions.

3.2.1.1 Action Levels for Undertaking Removal Actions

Action levels to determine whether a removal action should be implemented in response to ground-water contamination have been established by OERR (U.S. EPA, 1987j). Action levels may be either: (1) numeric values based on drinking water equivalent levels (DWELs) and, for potential human carcinogens, the 10^{-4} excess lifetime cancer risk level, or (2) site-specific factors (see Chapter 4 for a discussion of DWELs). Sites may qualify for removal action if the numeric trigger is exceeded at the drinking water tap, or an analysis of site-specific factors has been performed that indicates that a significant health threat exists. Exhibit 3-1 presents an example of a removal action taken because action levels were exceeded. Removal actions to prevent future health threats may also be undertaken if it can be demonstrated that a numeric action level will be exceeded within 6 months.

Action Levels Based on Numeric Values. Numeric action levels for providing removal actions at Superfund sites are summarized below:

	Volatiles	Non-volatiles
Carcinogens	Lower of (50% x DWEL) and 10^{-4} excess lifetime cancer risk	Lower of DWEL and 10^{-4} excess lifetime cancer risk
Noncarcinogens	50% x DWEL	DWEL

Exceptions to Numeric Action Levels. Numeric action levels should not be used for certain contaminants. The ERD of OERR will develop an action level on a site-specific basis for two situations:

- The calculated action level for a contaminant is lower than or equal to the MCL, e.g., vinyl chloride.
- The calculated action level is based on the DWEL, but the 10-day health advisory is lower than the DWEL, e.g., barium. Removal actions may be undertaken if the concentrations of these contaminants exceed the DWEL. If the concentration is between the DWEL and the 10-day health advisory, ERD will review individual site conditions.

Action Levels Based on Site-Specific Factors. Removal actions may be undertaken on the basis of site-specific factors if a significant health threat exists, even though the numeric action level has not been exceeded. Under these circumstances, the health risks posed at the site must be analyzed in detail, and the analysis must indicate that site-specific factors result in a serious health threat.

ERD approval must be obtained before initiating any removal action on the basis of site-specific factors unless an emergency exists, in which case ERD must be notified as soon as possible.

3.2.1.2 Source Control

Removal actions can also be used to excavate hot spots such as buried drums in soil and other contaminant sources. These actions prevent or reduce further ground-water degradation. Actions to remove surface and subsurface contamination do not have to satisfy the removal action level policy, although the Action Memorandum for the site must

Exhibit 3-1. Removal Action at the Cherokee Site

The ground water throughout a major portion of Cherokee County, Kansas, is contaminated with metals as a result of past mining practices. Because soil contamination is very extensive, a source control action is not feasible. Remedial actions at the site are being considered for the overall region.

Eight residences were found to have levels of cadmium in their drinking water above its action level of 17 µg/l, which is the DWEL.

Upon evaluation of these data, the regional office determined that a removal action should be implemented. In-line filtration/ion exchange systems were provided to reduce or eliminated toxic metal exposure to the eight families using the contaminated wells. Water samples were taken from the homes with the treatment systems to ensure that the families were being protected.

show that a threat to human health or the environment exists.

3.2.2 Operable Units

Operable units are portions of an overall response action that by itself eliminates or mitigates a release, a threat of a release, or an exposure pathway. An operable unit may reflect the final remediation of a defined portion of a site. Chapters 5 and 6 provide detailed discussions of the process for defining operable units and evaluating them to provide a basis for selecting a remedy. Examples of operable units related to ground water include:

- Providing an alternate water supply
- Remediating a contaminant plume
- Remediating hot spots
- Remediating contamination in a shallow aquifer
- Remediating contamination in a deep aquifer

Source control actions are sometimes also implemented as operable units. Ground-water remedial actions cannot be evaluated without considering source control actions, because source control actions generally contribute to ground-water restoration. Cleanup levels for soil should protect ground water if there is a potential for migration to ground water. A ground-water action implemented before a source control action is selected should be based on an analysis of a range of source control actions and their effects on ground-water remediation. Exhibit 3-2 is an example of a site with several operable units.

The following factors can help to identify potential operable units.

- *Presence and location of hot spots*--Can a remedial action be implemented to reduce or eliminate hot spots without adversely affecting the overall plume?
- *Site geology, including hydrogeology and stratigraphy*--Can one zone of contamination be remediated while investigation of other zones of contamination continues, or are the zones too closely interconnected?
- *Chemical and physical nature of contaminants as it affects their removal*--Are some contaminants amenable to air-stripping, for example, while others are amenable to gradient control?
- *Extent and location of threats to human health and the environment*--Is action needed to alleviate a potential threat while the investigation continues?

At many sites, it is appropriate to implement an operable unit as an interim action before completing the RI/FS. Operable units taken as interim actions should eliminate, reduce, or control human health risk; be consistent with the final remedy; and satisfy the statutory requirements described in Chapter 2. They are generally followed by subsequent remediation. Ground-water interim actions include source control actions that prevent further ground-water degradation, provision of alternate water supplies, and pump and treat actions. One important advantage of interim actions is that they facilitate the collection of valuable data that will reduce uncertainty at the site and lead to more effective final remedies. When appropriate, interim actions should be flexible and should provide for contingency measures that are consistent with information obtained during implementation. Documentation of interim actions is described in Appendix C.

Interim actions may be implemented to prevent exposure to contaminants or prevent further degradation of ground water (by remediating hot spots, for example). This is discussed in the following sections.

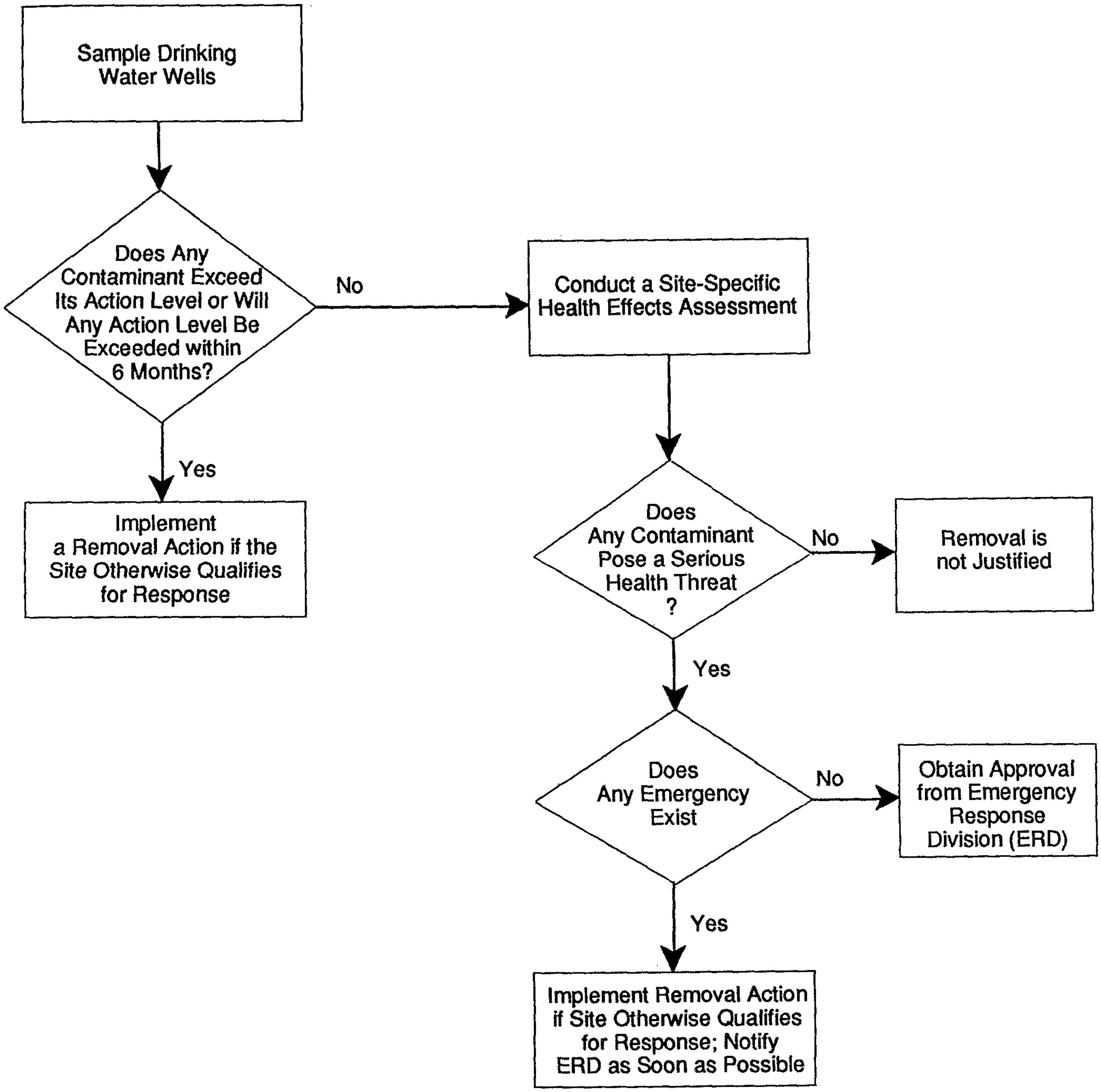


Figure 3-2 Removal Action Level Policy Flow Chart.

Exhibit 3-2. Identifying Operable Units

The Combe Fill South Landfill, New Jersey, is an inactive municipal landfill consisting of three separate fill areas covering about 65 acres. Because it is situated on a hill, surface water drains almost radially from the site. Leachate runoff, ground water, and surface-water runoff from the southern portion of the site constitute the headwaters of Trout Brook, which flows southeast toward a river.

Natural unconsolidated deposits of local soils and granitic saprolite overlie highly fractured granite bedrock. A shallow aquifer lies in the saprolite layer, saturating much of the waste, with a deeper aquifer in the fractured bedrock. The deep aquifer is the major source of potable water in the vicinity of the landfill. Numerous residential wells draw water from this aquifer, and a municipal well is about 1 mile from the site. In localized areas, the shallow aquifer is able to provide domestic water supplies.

The landfill was originally approved by the state for disposal of municipal and nonhazardous industrial wastes, sewage sludge, septic tank wastes, and waste oils. Approximately 5 million cubic yards of waste material are buried at the landfill.

The RI performed at the site revealed the presence of a wide range of contaminants, consistent with the known uses of the site and the variety of wastes accepted there. The RI produced three major findings:

- The ground water beneath the site has been contaminated by hazardous substances emanating from the landfill. Both the shallow and deep aquifers have been affected.
- Potable residential wells have been contaminated with various chemicals that have migrated offsite.
- Other wells farther downgradient of the site are at risk because of the continued offsite migration of the contaminated ground water.

The technical components of the recommended alternative were proposed in a single ROD and are as follows:

- Provision of an alternate water supply and, while the alternate water supply system is under construction, provision of bottled water for affected residents
- An active collection and treatment system for landfill gases
- Expanded environmental monitoring of water, air, soils, and leachate
- A cap that covers the landfill
- Pumping and onsite treatment of shallow ground water and leachate
- Surface water controls to accommodate runoff
- A second-phase feasibility study to evaluate the need for remediation of the deep aquifer

The main concern over pumping deep wells is the possibility of drawing contaminated water down from the shallow aquifer. Because of the fractured nature of the bedrock, patterns of vertical flow and recovery are difficult to predict. Consequently, a more reasonable approach was to remediate the shallow aquifer to achieve the desired reduction in contaminant levels and then evaluate the need for deep aquifer pumping in a second-phase feasibility study. If vertical connections exist, pumping would be initiated in the deeper zone, if necessary, when contaminant levels in the shallow zone no longer pose a threat.

3.2.2.1 Interim Actions to Prevent Exposure

If the removal action levels discussed in Section 3.2.1.1 are exceeded and the site otherwise qualifies for removal response (that is, the action can be accomplished within the $2-million/12-month limits or satisfies the criteria for exemption), a removal action would generally be considered. If exposure to contaminants does not meet the criteria for a removal action, but drinking water supplies are threatened or have been affected at levels below the removal action levels, however, an interim action can be considered. Interim actions for ground water are appropriate when there is enough information (e.g., contaminants of concern are identified) to determine which remedial technology or process option (e.g., well head treatment or an alternate water supply) will be selected. It may not be necessary to complete a detailed FS since there will probably be a limited number of alternatives to consider. Exhibit 3-3 presents an example of an interim action that was implemented to prevent exposure to contaminated ground water.

3.2.2.2 Interim Actions to Prevent Further Degradation of Ground Water

If contaminants are migrating away from the source or from a contaminant hot spot and action can be taken to prevent expansion of the ground-water plume, an

Exhibit 3-3. Interim Action: Alternate Source of Drinking Water

In Charlevoix, Michigan, an interim action was taken to supply the town with an alternate permanent source of drinking water. An RI/FS was subsequently completed to investigate the location of the source and the extent of contamination. A focused FS was conducted to evaluate alternatives for supplying water to Charlevoix, a town on Lake Michigan with a population of 5,000 during the summer months. The town well was contaminated with 50 parts per billion (ppb) of trichloroethene, and monitoring wells upgradient of the town well indicated that higher concentrations of both trichloroethene and tetrachloroethenes were moving toward the well.

Several alternatives were considered:

- Installation of new city wells
- Provision of bottled water
- Use of an adjacent community's water
- Installation of home treatment systems
- Treatment with granular-activated carbon or air-stripping
- Treatment of Lake Michigan water

The alternative selected was to design an intake and treatment plant for the use of Lake Michigan water. In conjunction, well use restrictions in the area were implemented; wells may only be installed if a permit is obtained. Installation of new wells was rejected, because a new wellfield would have to have been located a substantial distance away from the town, as contamination was extensive in the large sand aquifer underlying the town. Water supply was inadequate in adjacent communities. Treatment alternatives were substantially more expensive than most of the other options, and bottled water and home treatment systems did not provide reliable long-term protection. Bottled water was supplied, however, until the selected alternative was in place.

The interim action evaluation was completed in 6 months, and a ROD was signed in 1984. Design and construction of the treatment facility took place approximately 1 year later. The full RI/FS was completed at about the time plant startup began, at which time a second ROD was signed.

Two factors motivated the rapid selection and implementation of this alternative: the town's sole source of drinking water was contaminated; and an alternate source of drinking water with unlimited supply and limited treatment requirements was available.

interim action to prevent further degradation of ground water while the RI/FS is being completed can be taken. The benefits of an interim action must be balanced with the possibility that the plume will be drawn farther away from the source because of the early stage of the investigation and consequent lack of information about the site. Key factors to consider in determining whether to implement this type of interim action include:

- The estimated rate of plume expansion--this may be the primary factor for determining the cost-effectiveness of taking the action before the full RI/FS has been completed. If the contaminants potentially will migrate vertically or horizontally during the RI/FS, the cost of restoring this additional area of the plume should be considered in light of the cost-effectiveness of initiating the early action.

- The location of sources contributing to the ground-water contamination--if the sources of ground-water contamination have not been fully defined, the interim action could increase migration of contaminants from unidentified sources. Contingency measures should be outlined in the description of the remedy, and methods to evaluate whether or not they are necessary should be implemented. This may include placement of monitoring wells upgradient of the contaminated area so that unidentified plumes are detected before they reach the extraction wells.

- The stage of plume characterization--initiation of ground-water extraction could alter the plume such that concentration gradients are no longer continuous. If the horizontal and vertical extent of contamination at the site has not been completely defined, the resulting distortion may make full definition of the plume difficult.

Exhibit 3-4 presents an example of an interim action that was implemented to prevent further ground-water degradation.

3.3 Project Planning--Data Collection Activities

Data collection activities should be efficiently organized and focused on site-specific issues. Before identifying specific data collection activities, the following should be accomplished:

Exhibit 3-4. Interim Action: Preventing Further Ground-Water Degradation

An interim action was taken at Tacoma well 12A before completion of the RI/FS to prevent the contaminant plume from contaminating the entire well field.

Tacoma well 12A was one of 13 production wells serving the City of Tacoma, Washington, during peak summer water demand. Well 12A had been found to be contaminated with approximately 500 parts per billion of 1,1,2,2-tetrachloroethane as well as by smaller concentrations of a few other volatile organic compounds. Monitoring wells installed in 1981 and sampled from 1981 through 1983 had indicated the general extent of the plume. Well 12A was believed to be located at the leading edge of the plume, which was upgradient of the well field during the summer pumping season when the natural ground-water flow is reversed. There was concern that operation of the well field to meet peak water demand would draw contamination into the rest of the well field.

The interim action involved designing an air-stripping system for well 12A, which was then pumped continuously to act as an interceptor well. Low levels of contamination in an adjacent well disappeared following initiation of pumping at the interceptor well. The air-stripping design allowed treated water to enter the drinking water system. The system was still in operation in 1988.

The benefits of the interim action include:

- The interim action was implemented rapidly, in time for use during the peak demand period
- The well field was protected from contamination
- Only one air-stripping system had to be installed

The project took about 6 months to complete from the time a ROD was signed. The RI/FS for the project was completed in approximately 2 years, when another ROD was signed.

A ground-water treatment system at the source was subsequently installed.

The factors that made this interim action possible included:

- A general understanding of the relationship of the source to the well field
- Contaminants amenable to treatment
- Information on contaminant concentration such that the inlet design criteria of the air-stripping system could be specified
- Active cooperation by local, State, and Federal agencies

Without knowing plume concentration and extent, design of the system would have been less certain.

- Any existing or imminent exposures should be eliminated using removal authority as discussed in Section 3.2.1
- Potential exposure pathways should be identified
- Site-specific questions related to aquifer class and appropriate response should be considered
- A thorough examination of existing data should be completed before collecting additional data during the RI

The potential exposure pathways are generally identified before RI/FS activities have been initiated. Figure 3-3 illustrates potential exposure pathways at sites with contaminated ground water. If ground water at any depth below the site could be used for drinking water, any abandoned wells that could serve as conduits for contaminant movement to uncontaminated aquifers should be located. *Method for Determining the Locations of Abandoned Wells* (NWWA, 1987) provides guidance on this subject.

The evaluation of existing data includes evaluating logs of existing wells in the area to provide geologic information. Other sources of existing data that provide information for scoping are listed in Table 2-1 of the *RI/FS Guidance*. Information can also be obtained from the U.S. Geological Survey or State and local agencies that collect and inventory hydrogeologic and well-construction information.

A thorough site-specific data-collection strategy will be organized to address the investigation goals listed below. Questions to focus these data collection activities are presented in Table 3-1.

- Characterization of the hydrogeology (i.e., geology and ground-water hydrology, including aquifer properties)
- Characterization of contamination (i.e., plume size and composition)
- Evaluation of plume movement and response
- Assessment of design parameters for potential treatment technologies
- Consideration of technical uncertainty

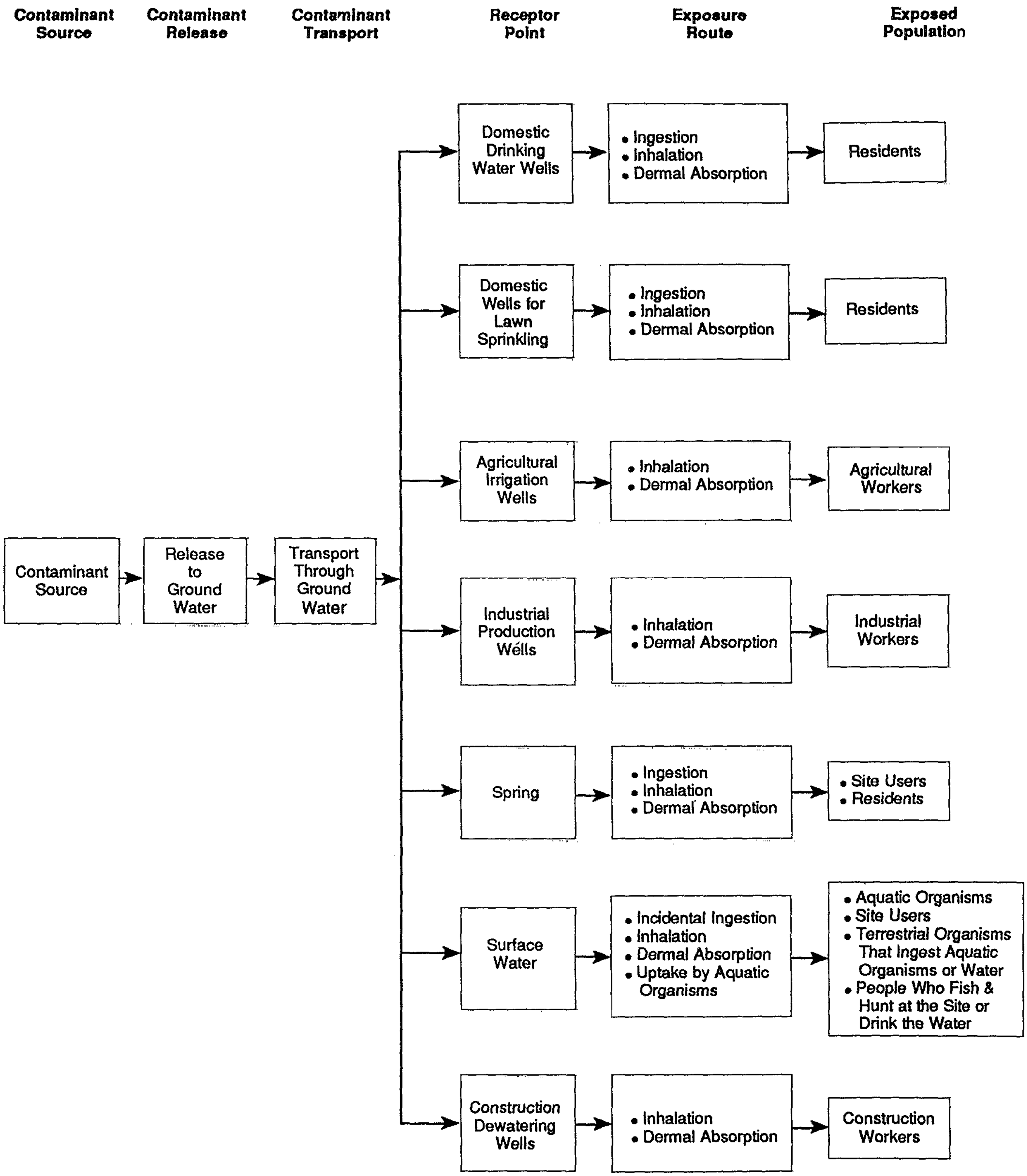


Figure 3-3 **Exposure Pathways Related to Ground Water.**

Table 3-1. Questions to Focus Data Collection Activities

Level of Contamination		-Will contaminants continue to migrate from the source to the ground water at levels that exceed health-based or environment-based standards? -Is current ground-water contamination above health-based or environment-based levels? -Is there a significant potential for contamination above health-based or environment-based levels? -Will natural attenuation result in contaminant levels below health-based or environment-based levels?
Exposure to Contamination on the Basis of Ground-Water Classification		-Which ground-water classification describes the ground water?
	Class I or IIA	-Is any domestic well water contaminated above health-based levels? -Is an alternative water supply in use? -Is the ground water ecologically vital?
	Class IIB	-Are unaffected downgradient wells that serve substantial populations irreplaceable? -Is there a reasonable potential for domestic, agricultural, or other beneficial uses of water from the area of the plume?
	Class III	-Could the contamination migrate and contaminate Classes I, IIA, or IIB ground water or surface water?
Contaminant Properties Affecting Treatment	Single Non-aqueous Phase	-Is the flashpoint of the non-aqueous phase below 80 degrees F? -Is metal removal required? -Can the non-aqueous liquid be recycled?
	Single Aqueous Phase	-Is metal removal required? -If all the metals in the waste concentrate in the sludge, will the sludge be a hazardous waste? -Will concentrations in the sludge be above the land disposal restrictions, or must sludge be treated to meet ARARs? -Is organic removal required and feasible? -Are the organics toxic to biomass?
	Mixed Phases	-Will pumping result in an emulsion?
Response Action	Natural Attenuation	-Will natural attenuation result in contaminant levels below health-based or environment-based levels at all wells? -Would natural attenuation of the plume result in significant spread of contaminants above health-based or environment-based levels beyond current boundaries? -Would the plume enter surface water where the resultant concentration of a contaminant would increase to a statistically significant level? -Is there confidence that institutional controls within the boundaries of the plume would be effective during natural attenuation, considering growth rate in the area and other potential increases in water demand?
	Containment	-Would a containment system be effective in limiting plume expansion during extraction? -Are contaminants amenable to containment by a slurry wall? -Would a slurry wall be technically feasible to construct? -Would construction of a slurry wall result in adverse environmental impacts? -Would a low-rate pumping system or French-drain system be technically feasible to construct and operate?

(continued)

Table 3-1. Continued

Response Action (continued)	Extraction & Discharge	-Is the aquifer amenable to extraction, considering transmissivity, interconnection, etc? -Can any surface water in the vicinity accept treated discharge? -Would a ground-water recharge option such as infiltration trenches or spray irrigation be feasible? -Is a publicly-owned treatment works (POTW) available for discharge? -Can permission be obtained to discharge to the POTW? -Will pretreatment be required before discharging to the POTW?
	Biodegradation	-Is the site environment compatible with biodegradation considering climate, soil, biota, surface water, and ground water? -Can the waste be treated biologically considering physical and chemical characteristics, toxicity, enhancement requirements, degradability of related compounds, and by-products of degradation? -Is on-site or off-site biodegradation prevented by regulation? -Will biodegradation increase the mobility of contaminants and possibly worsen the ground-water contamination threat? -Will safety or environmental considerations preclude biodegradation as an alternative considering site and waste characteristics? -Will public health and welfare considerations prevent the timely use of biodegradation?

Each of these goals is described in the sections that follow.

To ensure that the data generated to address these goals are adequate to support a decision, a clear definition of the objectives and the method by which decisions will be made must be established early in the project planning phase. These determinations are facilitated through the development of qualitative and quantitative data quality objectives (DQOs) specified to ensure that data of known and appropriate quality are obtained in support of remedial actions and Agency decisions. The process for determining DQOs is described in detail in *Data Quality Objectives for Remedial Activities (DQO Manual)* (U.S. EPA, 1987d).

Sources of technical information that describe the design of remedial alternatives are referenced throughout the following discussion. In addition, regional and EPA laboratory representatives have formed a ground-water forum that meets periodically to discuss technical issues that have arisen at sites; members of this forum may be contacted to discuss technical concerns. Also, the ground-water work station, an analytical ground-water computer system, is available at the Regions to assist in visualizing and modeling ground-water contamination (U.S. DOE, 1986 and 1988).

3.3.1 Characterization of the Hydrogeology

To analyze data relating to the distribution and movement of contaminants in the subsurface, it is necessary to understand the site hydrogeology. Pertinent information includes the physical properties and three-dimensional characteristics of the geologic formations; the ground-water hydrology including location of recharge and discharge zones, piezometric surface for each hydrogeologic unit, seasonal or long-term fluctuations in water levels for each unit; and the hydraulic properties (transmissivity, storage coefficient) of the aquifers and aquitards.

3.3.1.1 Geology

The majority of information regarding the geologic formations and related structures underlying the site will be obtained through the description of sediment samples collected during drilling of soil borings and monitoring wells. It is worthwhile to describe all strata underlying the site to at least the maximum depth of known or potential contamination and generate a reliable and complete description of the subsurface geology. Continuous core samples can be collected using auger or rotary drilling methods. In addition to laboratory analysis, in situ analysis can also be made of the geology through borehole and other geophysical methods. These methods can provide many of the same parameters determined through laboratory analysis, at a reduced cost. Other geophysical methods can provide information on the extent of certain plumes, areas of buried trenching operations, and abandoned well locations.

The information obtained during the geologic investigation can be presented in geologic cross sections and fence diagrams. Laboratory analysis of sediment or rock samples may include grain size analysis, plasticity, moisture content, dry density, clay mineralogy identification, partition coefficient for pertinent chemicals, and hydraulic conductivity.

3.3.1.2. Ground-Water Hydrology

Ground-water movement can be analyzed through the measurement of water levels in wells and piezometers. It is helpful to categorize wells according to the elevation and geologic formation of the screened interval so that the horizontal and vertical gradients of hydraulic potential can be analyzed separately. If there are enough measuring points, a contour map of the piezometric surface of each aquifer can be prepared. The contour map can be evaluated to determine possible areas of ground-water recharge and discharge and to identify the direction of ground-water movement. Water level data collected from all the wells on the same day provides the most representative information for producing a potentiometric surface map. In addition, to indicate the magnitude and period of fluctuations as well as any long-term change in water levels, it is generally recommended that data be collected from a subset of wells over a period of time and plotted as a hydrograph to determine short-term tidal fluctuations or long-term seasonal fluctuations.

3.3.1.3 Aquifer Properties

Aquifer tests can be used to determine the hydraulic properties of the aquifers and aquitards within the area of interest, and to evaluate the performance and effectiveness of an extraction system. These tests are conducted by artificially causing ground-water movement either through pumping or injecting water and then monitoring the fluctuations in ground-water levels.

Aquifer tests are conducted to measure aquifer parameters such as transmissivity, hydraulic conductivity, and the storage coefficient. These parameters are used to estimate the ground-water flow rate, the optimal pumping rate for ground-water extraction, proper well location, and plume migration behavior. Vertical hydraulic conductivities can be evaluated by monitoring the water levels in observation wells that are screened at different depths than the pumping well.

It is beneficial to conduct aquifer pumping tests during an RI/FS whenever ground-water extraction is expected to be part of the remedy. Because one of the objectives of an aquifer test during RI/FS activities may be to design an extraction well system, the most accurate information will be obtained when the pumping well is placed in the same formation and pumped at the same rate as the proposed extraction system.

When scoping an aquifer test, it is important to consider disposal of contaminated ground water (see Section 2.4.1 for potential requirements for this discharge). Temporary onsite storage of treated water may be required if the water cannot be discharged.

Additional information on aquifer tests can be found in *Applied Hydrogeology* (Fetter, 1988) and *Groundwater and Wells* (Driscoll, 1986).

3.3.2 Characterization of Contamination

This section presents technical information about methods used to characterize the hydrogeology and ground-water contamination of a site. Topics discussed include indicator chemicals, plume definition, and contaminant-soil interaction. Although not discussed in this guidance, source areas also should be defined to characterize contamination that might pose an ongoing threat to the ground water.

Information about the contaminant mix and spatial distribution of the plume is generally needed to select and analyze remedial alternatives during screening and detailed analysis phases. Physical and chemical properties of contaminants, such as density and solubility, should be assessed because they influence plume movement. It should be recognized that some contaminants may not be detectable using routine analytical services, though they are present at levels that would be above cleanup levels. In these cases, special analytical services may have to be used.

3.3.2.1 Indicator Chemicals

Indicator chemicals are those site contaminants that are generally the most mobile and toxic in relation to their concentration; consequently, they reflect the majority of the risk posed by the site. Generally indicator chemicals are selected on the basis of toxicity, mobility, persistence, treatability, and volume of contaminants at the site. By initially identifying these constituents and then limiting analysis to those constituents during the investigation, analytical costs can be reduced. During initial testing of the remedial action, however, samples should be analyzed for all contaminants present to ensure that indicator chemicals have been appropriately selected.

Indicator chemicals are used during modeling and during some monitoring activities to reduce cost and simplify characterization of the site and remedial alternatives. Samples are generally analyzed once for total metals, cyanide, semi-volatiles, volatiles, and major anions and cations; periodically for those contaminants found at the site; and more frequently (e.g., during aquifer tests) for indicator chemicals. Before completing the remedial action, samples should be analyzed for all contaminants originally detected.

All migration pathways should be considered when determining indicator chemicals, particularly when the proposed treatment results in transferring contaminants between media. For example, chemicals treated in an air stripper may cause inhalation threats but not ingestion threats. Consequently, those chemicals should be considered for selection as indicator chemicals. Chemical structure may also guide selection of indicator chemicals since chemicals with similar structure often have similar properties; this is the basis of quantitative structure-activity relationships (QSAR), which are discussed in the scientific literature. One method for selecting indicator chemicals can be found in the *Superfund Public Health Evaluation Manual* (U.S. EPA, 1986f).

3.3.2.2 Plume Definition

Determining both the horizontal and vertical extent of a contaminant plume is a complex problem. In addition to sampling ground-water monitoring wells, a wide variety of field techniques such as soil gas analysis and geophysical surveys (U.S. EPA, 1988g) can be used to obtain relevant data. The locations of the monitoring wells should be determined from ground-water flow directions estimated from existing site data. It is best to obtain the advice of someone with hydrogeology experience to determine where to place wells and at what depth they should be screened on a site-specific basis. It is usually most efficient to install wells in a phased approach, i.e., increasing the distances from the source area in three dimensions with each subsequent round of investigation. Sources and methods for obtaining the information needed to assess the extent and movement of a ground-water plume are listed in Table 3-7 of the *RI/FS Guidance*. Technical details of methods listed in the table can be found in the *Compendium of Superfund Field Operations Methods* (*Compendium*) (U.S. EPA, 1987c) and the *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (TEGD)* (U.S. EPA, 1986e). When it becomes clear that contaminants have migrated beyond property boundaries, an effort should be initiated to identify neighboring property owners and obtain access to the properties necessary to complete the investigation. The Superfund Enforcement Branch at EPA Region IX has prepared a sample letter requesting property access. A copy of this letter is provided in Appendix F.

3.3.2.3 Contaminant-Soil Interaction

Since ground-water extraction is frequently a component of ground-water remediation, it is important during site characterization to collect the data needed to estimate the effectiveness of pumping to remove contaminants to cleanup levels. The sorption characteristics of the particular soil and contaminants present at the site affect extraction and can substantially increase the restoration time frame for remedies that depend on extraction of ground water. Core sampling and the resultant analysis of the saturated zone can provide important sorption data.

While extensive sorption data may not be needed to extract dissolved product or pure organic phase liquids that are lighter than the aqueous phase, it is difficult to extract residual ground-water contamination that has saturated the soil such that levels remaining are predicted to continue to cause ground-water contamination above health-based levels.

The partition coefficient (K_p) can be used to indicate the tendency of a contaminant to sorb to the soil from the ground water and desorb from the soil to the ground water. The K_p is defined as the ratio of the concentration of contaminant in soil, µg/g, to the concentration of contaminant in ground water, µg/ml. For organic compounds, the K_p can be estimated using the fraction of a contaminant that is in the aqueous phase and from an analysis of total organic carbon. Thermodynamic and kinetic variables can be used to estimate K_p for metals.

More accurate values for K_p are obtained from direct measurements in bench scale sorption studies. Studies should be designed to measure desorption as opposed to adsorption or absorption because the mechanism for desorption is frequently different. While estimated values of K_p are of adequate precision in some cases, it may be desirable to reduce uncertainty. Estimated values of K_p often are only precise to three to five orders of magnitude while values determined in the laboratory are generally accurate to within one to two orders of magnitude.

3.3.3 *Analysis of Plume Movement and Response*

Ground-water modeling performed during the RI/FS process can be used as a tool to estimate plume movement and response to various remedies. However, caution should be used when applying models at Superfund sites because there is uncertainty whenever subsurface movement is modeled, particularly when the results of the model are based on estimated parameters.

The purposes of modeling ground-water flow include the following:

- Guide the placement of monitoring wells and hydrogeologic characterization when the RI is conducted in phases
- Predict concentrations of contaminants at exposure points
- Estimate the effect of source-control actions on ground-water remediation
- Evaluate expected remedy performance during the FS so that the rate of restoration can be predicted and the cost effectiveness comparisons can be made

Various models are available to predict contaminant concentrations and remedy performance. These vary in the number of simplifying assumptions that must be made, the cost of running the model, and the level of effort needed.

More complex models incorporate more information and require more data and expertise to run. Regardless of the complexity of the model, however, representative input data must be used to obtain reliable results, and the results of the models must be interpreted correctly. The determination of whether or not to use modeling and the level of effort that should be expended is made on the basis of the objectives of the modeling, the ease with which the subsurface can be conceptualized mathematically, and the availability of data. Figure 3-4 presents a flow chart of the decisions and the activities associated with formulating and implementing a ground-water model. A case study illustrating how models might be used at a Superfund site is presented in Exhibit 3-5.

Table 3-2 lists some of the processes evaluated and variables used when modeling ground water. Field data are collected to characterize some of the variables listed in the table. Estimates based on literature values or professional judgment are frequently used as well. The factors listed in the second column of Table 3-2 are not typically modeled but can significantly affect contaminant movement at some sites. These factors should be considered qualitatively when appropriate. Information on ground-water modeling can be obtained from the Center of Exposure Assessment Modeling, Athens, Georgia, (phone number 404/546-3546) and the International Ground-Water Modeling Center at Butler University, Indianapolis, Indiana. In addition, the Office of Solid Waste (OSW) is preparing guidance on the implications for modeling the factors in Table 3-2 in the forthcoming *Handbook of Assessment and Remediation of Contaminated Ground Water*. Finally, the Office of Health and Environmental Assessment has developed guidance on modeling for exposure assessments (U.S. EPA, Review Draft, June 1987).

3.3.4 Assessment of Design Parameters for Potential Treatment Technologies

A range of remedial alternatives is identified early in the RI/FS process to focus data collection activities on remedy selection. The design of many remedial technologies requires data that may not generally be collected during the RI. It is important to consider data needs for design during scoping to reduce the amount of time needed to select and implement the remedy. Table 3-3 lists some of the data needs for evaluation and design of various remedial technologies.

Frequently, the best way to develop meaningful and reliable design criteria is to conduct a treatability study to establish the effectiveness of a particular remedial alternative or remedial technology. The need for treatability studies should be identified during the scoping process when possible so they can be initiated early in the RI/FS to avoid affecting the overall project schedule. The advantages of treatability studies should be weighed against the increase in time and cost for conducting them.

Other site-specific information can affect remedial design. An example of site-specific information that may be important to evaluate is the presence of naturally occurring radionuclides at a site. Radionuclides extracted with the contaminated soil vapor or ground water may accumulate on the collection media designed to remove the site contaminants. If buildup of radionuclides on the collection media is found to occur there is the potential for personnel exposure problems and additional transportation and disposal requirements. A study assessing the potential for this type of buildup to occur is under way in a joint project being conducted by OERR and the Office of Radiation Programs.

3.3.5 Technical Uncertainty

This section describes situations in which technical uncertainty can arise and discusses how to address technical uncertainty so that cost-effective decisions can be made about data collection.

Data collected during the RI are used primarily to support a cleanup decision. It is important to recognize that some technical uncertainty is inherent in the RI/FS process. Reducing this uncertainty should be weighed against time and resource limitations, and often remedy selection should move ahead using best professional judgment even if the level of uncertainty is high. The value of collecting and analyzing additional data for remedy selection is related to how much the information helps distinguish remedial alternatives and what the technical uncertainty is of the performance of these alternatives.

Technical uncertainty arises from the following determinations:

- Predicting the nature, extent, and movement of contamination
  - Source volume, concentration, and timing of release
  - Physical, chemical, and biological characteristics of contaminants
  - Contaminant dispersion and diffusion
- Determining contaminant movement through the vadose zone

Exhibit 3-5. Ground-Water Modeling at a Superfund Site

An abandoned industrial facility was found to be contaminating ground water when solvents were detected at low levels at a nearby municipal well. The site was listed on the National Priorities List, and an RI/FS was initiated.

Background

Soil at the site was found to be contaminated with several volatile organic compounds including tetrachloroethene, trichloroethene, vinyl chloride, and trans-1,2- dichloroethene. To characterize the extent of the soil contamination, a soil sampling grid was set up at 50-foot centers in the suspected source areas, and samples were taken at 2.5-foot intervals in the saturated zone, which terminated in bedrock. Samples were also collected from the bedrock layer to determine contaminant migration at this depth. From analysis of the soil and bedrock samples, the total mass of contaminants was estimated.

A source control remedy to remove the most highly contaminated soils in the unsaturated zone was completed to prevent further degradation of the ground water. Also, ground-water wells were installed at several of the boring locations. Samples of ground water indicated that concentrations of volatile organic solvents had reached levels as high as 50 ppm. Because the municipal well was screened in the contaminated aquifer, pumping at this well was temporarily stopped to prevent further spreading of the plume.

On the basis of data taken from the municipal well, the aquifer was determined to be permeable enough to use extraction practicably. It was anticipated that a large mass of contaminants would be extracted with the ground water because the solubilities of many of the contaminants were high. Therefore, ground-water extraction and treatment was expected to be part of the ground-water remedy at this site. An aquifer test was performed to determine the optimal pumping rate.

To actively restore the ground water to health-based levels and remove remaining contaminants from the unsaturated zone, it was proposed to dig trenches and flush the aquifer by reinjecting treated ground water to the saturated zone. The low levels of contaminants found in the bedrock layer were predicted to be removed because pumping the upper zone would induce an upward vertical gradient in the bedrock formation.

The remedial action objectives were as follows:

- Cleanup levels for individual constituents were based on health-based levels for drinking water and result in a total volatile organics (TVO) concentration of 80 ppb
- The area of attainment includes the entire contaminant plume because, upon completion of the proposed remedial action, there will be no onsite containment or management of waste
- The restoration time frame was estimated using several modeling approaches as described in the next section

Modeling Restoration Time Frame

Three ground-water models were used to reflect the site situation and evaluate the sensitivity of the predicted restoration time frame to various parameter estimates and physical processes:

- Batch flushing model
- Continuous flushing model
- Simple advection/dispersion model

Batch Flushing Model. The batch flushing model was used to calculate the restoration time frame on the basis of equilibrium batch flushing. This model takes into account the porosity of the soil, the organic carbon partition coefficient of the contaminants, the organic content of the soils, and the ground-water pumping rate. The soil porosity and organic content were determined from field data while the organic carbon partition coefficient was estimated from the literature (Lyman, 1982). The soil/water partition coefficient was calculated from the product of the fraction of organic carbon in soils and the chemical-specific organic carbon partition coefficient:

$$K_d = K_{oc} \times f_{oc}$$

where

K_d = soil/water partition coefficient

K_{oc} = organic carbon partition coefficient

f_{oc} = fraction of the soil that is organic carbon

The number of pore volumes (aquifer flushes) per unit time could be calculated using estimates of the optimal ground-water pumping rate, the volume of contaminated area, the porosity of the soil, and the partition coefficients for the various contaminants. Using the batch flushing model, remedial action to 80 ppb of TVOs was estimated to take approximately 27 years. A more detailed description of this calculation can be found in Appendix D.

Exhibit 3-5. Continued

Continuous Flushing Model. The continuous flushing model uses a laboratory-derived leaching rate (partitioning) constant to determine the time it would take to flush the volatile organic compounds out of the saturated soils. A mass balance approach is used to calculate contaminant concentration changes with the number of control volumes of contaminated soils (the control volume is a unit volume of soil). This information is then used to determine the time required to reach cleanup levels throughout the entire plume. The application of this model requires contaminant concentration data for both the saturated soils and the ground water, in addition to the leaching rate constant. The fundamental mass balance relationship is as follows:

VOC mass in ground water at time t	=	VOC mass in ground water at time t-1	-	VOC mass removed through pumping	+	VOC mass leached into ground water from soil

The leaching rate constant was determined from bench-scale tests of three saturated soil cores of varying contaminant concentrations. This model predicted a restoration time frame of 9 years. A more detailed description of the model is found in Appendix D.

Advection/Dispersion Model. The simple advection/dispersion model assumes steady-state flow with an instantaneous release of contaminants into ground water. This model requires estimating the coefficient of molecular diffusion for the contaminants and takes into account the fact that diffusion is occurring in a porous medium. As the contaminant mass is transported through the flow system, the concentration distribution of the contaminant mass at time t is given by the following expression:

$$C_{x,y,z,t} = \frac{M}{8(\pi t)^{3/2}\, D_x D_y D_z^{\;1/2}}\, exp\; \frac{-X^2}{4D_x t} - \frac{Y^2}{4D_y t} - \frac{Z^2}{4D_z t}$$

where:

C	=	concentration
M	=	mass of contaminant introduced at the point source
t	=	time
$D_{x,y,z}$	=	coefficients of dispersion in the x, y, and z directions
X, Y, Z	=	distances in the x, y, and z directions

This model calculated a restoration time frame of 5 years. A more detailed description of this model can be found in *Groundwater* (Freeze and Cherry, 1979, page 395).

Summary

By using three different models, the effect of the model assumptions on the projected restoration time frame could be evaluated. The restoration time frames predicted by the three models are summarized below:

Model	Treatment Time
Batch flushing	27 years
Continuous flushing	9 years
Advection/dispersion	5 years

The batch flushing model predicted a longer restoration time frame than either of the other models because it used the concentration of VOC contaminants in ground water to calculate the theoretical concentrations in soil. Because the calculated soil contaminant concentrations were higher than the soil concentrations determined from sampling and analysis, it was determined that this model did not adequately predict actual site conditions. The higher soil concentrations caused the model to predict a longer restoration time frame, which appeared to be unrealistic.

The continuous flushing model is based on site soil and ground-water data as well as an experimentally-derived leaching constant. For these reasons, it was the preferred model. The model is very sensitive to the dynamic leaching constant; therefore, it was important to collect representative soil cores from the site. Extensive soil and ground-water data were also needed to accurately assess the extent of contamination.

The advection/dispersion model greatly oversimplified the site hydrogeology and chemical characteristics of adsorption and partitioning and for this reason underestimated the treatment time needed to restore the aquifer to the desired cleanup levels.

References:

Lyman, W. J., W.F. Reehl, and D.H. Rosenblatt, *Handbook of Chemical Property Estimation Methods*, McGraw-Hill, New York, 1982.

Freeze, R.A. and J.A. Cherry, *Groundwater*, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1979.

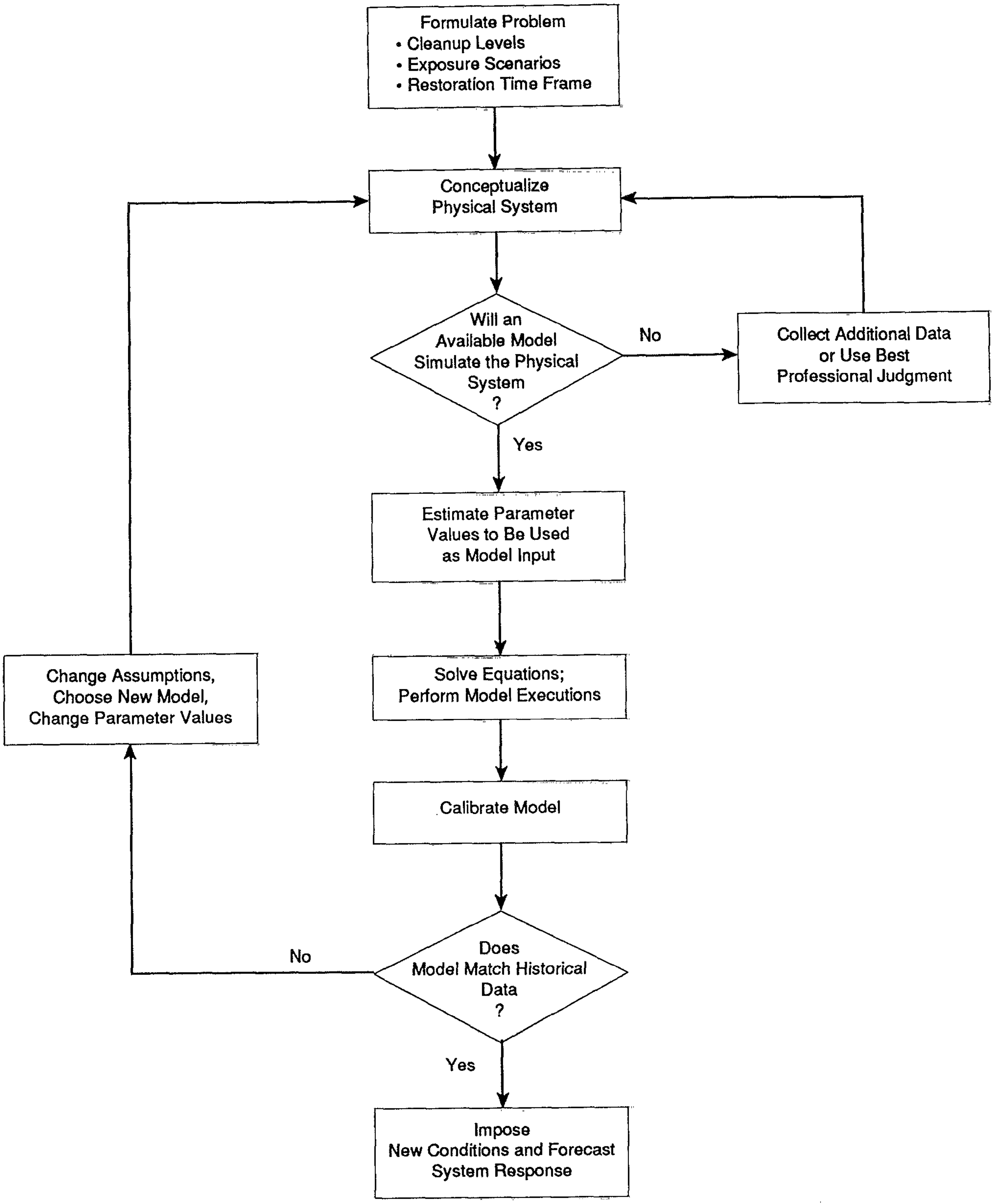


Figure 3-4 The Steps of Formulating and Implementing Ground-Water Model.

Table 3-2. Processes and Variables Applicable to Ground-Water Modeling

	Processes and Variables Frequently Incorporated in Models [1]	Processes and Variables That Should Be Considered Qualitatively [2]
Physical	Flow in saturated porous media - advection - hydrodynamic dispersion - molecular diffusion - density stratification - aquifer properties and heterogeneities - hydraulic head distribution - hydrogeologic boundaries - aquifer recharge - evapotranspiration	Flow in fractured media Particle transport in any medium Flow in unsaturated porous media Multiphase flow in any medium
Chemical	Radionuclide decay Sorption	Redox reactions Ion exchange Complexation Co-solvation Volatilization Precipitation
Biological		Microbial population dynamics Substrate utilization Biotransformation Adaptation Co-metabolism

(1)Site-specific conditions will determine which data are required to model desired processes or determine variables.

(2)These processes and variables can be modeled, but such models are state-of-the-art.

  - Hydraulic conductivity and soil water potential
  - Moisture content of soil
  - Chemical and biological characteristics of soil

- Estimating the rate and direction of the ground-water flow
  - Hydraulic conductivity (viscosity, density, permeability)
  - Anisotropy and heterogeneity of hydrogeology
  - Aquifer characteristics (porosity and organic carbon content)
  - Aquifer stresses arising, for example, from ground-water pumping at other wells and infiltration (naturally and artificial recharge)
  - Seasonal variation in ground-water levels
  - Tidal/pressure effects
  - Storage characteristics of the aquifer
  - Aquifer thickness and areal extent

- Estimating the cost of remedial alternatives

When deciding how much information to collect, one should examine the extent to which the additional information will reduce the uncertainty of remedy selection and predicted performance of remedial alternatives (e.g., see the discussion on contaminant-soil interactions in Section 3.3.2.3). For example, in deciding how much uncertainty is acceptable for hydraulic conductivity, one should consider how much the uncertainty in hydraulic conductivity affects uncertainty in remedy selection. If the additional information allows one to distinguish between two alternatives, it is probably worthwhile to collect the information. Frequently, however, it is not possible to significantly reduce the uncertainty in the variables that contribute most to the overall uncertainty of the decision.

To assess the effect of uncertainty in some variables a sensitivity analysis can be performed. A sensitivity analysis evaluates how the uncertainty in particular variables affects the predicted cost and effectiveness of the remedial alternatives. To conduct a sensitivity analysis, values of variables are systematically changed, and estimates of cost and effectiveness are recalculated to determine the importance of each assumption. Alternatively, a different but equally plausible ground-water flow model could be used. Uncertainty in variables that have the greatest effect on the prediction of the uncertainty of remedy performance should be closely examined.

Instead of conducting a formal sensitivity analysis, an informal approach can be used to decide whether to collect additional data to characterize a variable such as cost. In this case, the two or three largest sources of uncertainty related to characterizing cost should be identified. If the additional data would reduce the uncertainty inexpensively and in a reasonable period

Table 3-3. Typical Technology Selection and Design Parameters

Technology	Typical Screening Parameters	Typical Design Parameters[a]
Extraction	Aquifer storage coefficient Soil type/porosity Hydraulic conductivity Aquifer saturated thickness Contaminant sorption Contaminant solubility	Aquifer parameters Depth to the aquifer Number of wells Well extraction rate Contaminant distribution Presence of non-aqueous phase
Air-stripping	Contaminant volatility Disposal of treated water	Ground-water temperature Influent flow rate Contaminant concentrations
Carbon adsorption	Contaminant adsorptability Total organic carbon Disposal of treated water Metals separation	Influent flow rate Carbon adsorptive capacity Contaminant concentrations
Chemical destruction (e.g., KPEG, peroxide treatment)	Susceptibility to reaction Total organic carbon	Influent flow rate Dose of reactant Contaminant concentrations
Metals precipitation	Metals solubility pH Metals concentration Management of residuals Disposal of treated water	Influent flow rate Alkalinity/acidity Coagulant dosage Contaminant concentrations
Nonaqueous phase separation	Contaminant solubility Contamination concentrations Specific gravity	Influent flow rate Total suspended solids
In situ biodegradation	Soil type/porosity, permeability--primary and secondary Contaminant biodegradability Aquifer properties Distribution of microorganisms Dissolved oxygen Contaminant concentration	Nutrient requirements Contaminant distribution Injection/extraction well flow rates Aquifer parameters Biodegradation rate
In situ solvent wash and extraction	Soil type/porosity, permeability--primary and secondary Contaminant solubility Sorption properties Organic moisture content	Aquifer parameters Depth to the aquifer Contaminant distribution Contaminant concentrations
In situ vapor extraction	Soil type/porosity, permeability--primary and secondary Contaminant volatility Contaminant concentration	Contaminant distribution Well radius of influence Extraction well flow rates Hydraulic conductivity
In situ vitrification	Contaminant concentration Depth of contamination Area of contamination Soil type/moisture content Presence of reactive compounds Electrical conductivity	Contaminant distribution Underlying geology Rate of carbon usage for off-gas treatment

[a]When possible, data for design can be collected during implementation of an interim remedy. Design parameters also include considerations such as standards to be attained for all emissions to air and water and any generation of solid waste.

of time, then they should be collected. Exhibit 3-6 presents an example of a sensitivity analysis.

If there is sufficient confidence that a particular remedy will be effective for a site, a detailed evaluation, which is discussed in Chapter 6, should be made. Data to reduce the uncertainty of important variables should be collected throughout the remedial selection, design, and construction phases to refine and modify the remedy.

Exhibit 3-6. Using A Sensitivity Analysis

To address the adequacy of the hydrogeologic data collected at the San Gabriel basin, and to improve the performance of a ground-water model by further refining the estimates of model parameters, a sensitivity analysis was performed. The sensitivity analysis evaluated the following model parameters:

- Hydraulic conductivity
- Specific yield
- Recharge from precipitation
- Artificial recharge
- Boundary conditions
- Ground-water pumping

The analysis consisted of the following:

- Varying a particular model parameter
- Rerunning the model for the first 5 years of the simulation period
- Observing the effect of the parameter variation on both the simulated water levels and the calculated ground-water velocity

From this analysis, it was found that the calculated velocity was highly variable within the basin. Velocity provided a useful measure of the relative importance of the different parameters in predicting ground-water flow. The greatest degree of uncertainty was associated with the vertical distribution of hydraulic conductivity. On the basis of the analysis, the ground-water velocities calculated from the model were found to vary between 50 and 200 ft/yr. The original analysis of the hydraulic properties of the basin led to estimates of hydraulic conductivity that were estimated to vary from 10 to 1,000 ft/yr. Because the horizontal and vertical distribution of hydraulic conductivity, the areal distribution and magnitude of specific yield, and recharge at spreading basins and from precipitation lead to the most uncertainty, additional data acquisition and analysis would be most useful for these variables.

Because the San Gabriel site is very large (165 square miles) decisions about scoping may be very costly. Thus, an extensive modeling effort was undertaken to provide initial information to develop data quality objectives. In summary, the sensitivity analysis defined which parameters were critical, and the variance in ground-water velocity was reduced from 10 to 1,000 ft/yr to 50 to 200 ft/yr. This approach led to a better understanding of the accuracy and precision of the results. On the basis of the sensitivity analysis, areas of further data collection were identified and priorities were set.

Chapter 4
Establishing Preliminary Cleanup Levels

4.1 Introduction

CERCLA requires that remedial actions be protective of human health and the environment. In addition, remedial actions must attain ARARs (unless a waiver is used). For ground water that is a current or potential source of drinking water, i.e., Class I or Class II, cleanup levels generally will be based on chemical-specific ARARs or health-based levels. This chapter presents information needed to establish preliminary cleanup levels in the aquifer. The information presented here is generally presented in the risk assessment chapter of the RI report. Preliminary cleanup levels should be developed early in the RI/FS process and modified as more information is collected. Final cleanup levels should be presented in the FS and the ROD.

This chapter is organized into the following sections:

- Determination of cleanup levels
- Derivation of chemical-specific ARARs and consideration of other pertinent materials (to-be-considereds (TBCs))
- Assessment of aggregate effects
- Alternate concentration limits
- Summary

Ground water that is not a potential drinking water source because of natural conditions (i.e., Class III ground water) is not explicitly addressed in this chapter because health-based cleanup levels for Class III ground water are usually not appropriate. Environmental considerations (i.e., effects on biological receptors) and prevention of plume expansion determine cleanup levels for Class III ground water. Also, if the Class III ground water is connected to ground water that is Class I or Class II, it may be appropriate to set cleanup levels at the point of interconnection, as described in the following section. Further discussion of Class III ground water is presented in Section 5.4.2.

Health-based cleanup levels for soil are usually based in part on a soil ingestion exposure pathway. In addition, it is generally appropriate to consider the potential for contaminants to leach from soil to ground water. By modeling the leaching rate of contaminants and determining health-based levels in ground water, soil cleanup levels can be calculated. Depending on the site soil, consideration of leaching may tend to produce lower cleanup levels than consideration of soil ingestion. A project to compile a compendium of methods that have been used to determine soil cleanup levels on the basis of the potential for the contaminants to migrate to ground water is currently under way at OERR. This compendium will be distributed to the Regions as a resource.

4.2 Determination of Cleanup Levels

4.2.1 Process

Cleanup levels will generally be set at health-based levels, reflecting current and potential use and exposure. For systemic (noncarcinogenic) toxicants, cleanup levels should be set at levels to which humans could be exposed on a daily basis without appreciable adverse effects during their lifetime. For carcinogens, cleanup levels should reflect an individual excess lifetime cancer risk that falls in the range commonly expressed as the 10^{-4} to 10^{-7} unit risk range. The Agency believes that remedial actions reducing risks to within this range are generally protective of human health.

Often, ARARs, such as MCLs, will be used to determine cleanup levels. However, ARARs may not be available or they may not be adequate if multiple contaminants, multiple pathways, or other factors present an aggregate risk that is not sufficiently protective given the specific site circumstances. In these circumstances, the appropriate level of protection should be determined during the risk assessment using Agency guidelines and other Federal criteria, advisories, or guidances.

For ground water that is a current or potential source of drinking water, MCLs set under the SDWA or more stringent State standards devised to protect drinking water will generally be ARARs. If MCLs are not available, proposed MCLs should be considered. However, it is still necessary to perform a risk assessment; aggregate risk should be calculated for all contaminants in the ground water, including those with MCLs. Aggregate risk is calculated using the risk-specific dose (RSD) or the reference dose (RfD), as discussed in Section 4.4.

If an ARAR does not exist for a contaminant, then TBCs should be identified. RSDs, RfDs, health advisories (HAs), and State or Federal criteria developed for waters other than ground water are TBCs for ground water. MCLGs should be consulted and may be relevant and appropriate if multiple contaminants or multiple pathways warrant levels that are more stringent than MCLs. Also, WQC should be considered and may be relevant and appropriate at some sites, particularly those sites where ground water discharges to surface water that is used for fishing. WQCs may also be relevant and appropriate when they are the most recent health-based level that has been developed.

Generally, if cleanup levels for carcinogens are not determined by ARARs, the 10^{-6} risk level should be the starting point for the analysis of alternatives and the appropriate level of protection. The use of 10^{-6} as an analytical starting point expresses the Agency's preference for being at the protective end of the risk range but is not a strict presumption that the final remedial action should attain that risk level. The final cleanup level and resulting risk level will be achieved by balancing a number of factors relating to exposure, uncertainty, and technical limitations.

Environmental effects must also be considered. WQC for protection of aquatic organisms should be used when Superfund sites pose potential environmental effects. Also, some information on environmental effects may be available in the scientific literature; see Verscheuren (1983), for example. Additional information on environmental effects is available from the *User's Manual for Ecological Risk Assessment* (Barnhouse, 1986) and the eco-risk document currently being developed by OSWER, entitled, "Superfund Environmental Evaluation Manual."

The most common ARARs and TBCs are summarized in Table 4-1, and Appendix E lists the values of these ARARs and TBCs at the time of this writing. Figure 4-1 is a flow diagram showing the decision path for identifying ARARs and TBCs.

Figure 4-2 shows the process for developing ARARs and TBCs from basic scientific information. This is discussed in the following sections.

4.2.2 One Source of Common Health-Based Criteria: The Integrated Risk Information System

The Integrated Risk Information System (IRIS) is a computer-based catalog of Agency risk assessment information for chemical substances. Values for some of the TBCs are listed in IRIS. This system is designed for Federal, State, and local environmental health agencies as a source of the latest information about EPA's regulatory decisions for specific chemicals. IRIS was developed by an intra-agency review group in response to repeated requests for Agency risk assessment information.

Chemicals found in IRIS are categorized on the basis of the type of effect they cause. Chemicals that cause growth of tumors are considered to be carcinogenic, while chemicals that induce effects other than carcinogenicity or mutagenicity are considered to be systemic toxicants.

EPA has developed a system for classifying the weight of evidence of carcinogenicity in chemicals. The EPA carcinogen classification system contains the following designations:

- Group A--Human Carcinogen
- Group B--Probable Human Carcinogen
- *Group C--Possible Human Carcinogen*

Evidence for the carcinogenicity of chemicals in humans stems primarily from long-term animal tests and epidemiological studies (studies of disease in human populations). Short-term animal tests, pharmacokinetic studies, structure-activity relationships, and other toxicological information are also considered in developing a framework for evaluating the weight of evidence of a chemical's potential to be a human carcinogen.

Systemic toxicants are those believed to be toxic only at concentrations above a threshold dose; doses below this threshold are not expected to result in a significant adverse effect. The mechanism for the toxicity of noncarcinogens differs from that for carcinogens for which it is believed that there is no threshold; any dose presents some incremental risk (hence, the MCLG for carcinogens is set at zero). Some chemicals can cause both systemic toxic and carcinogenic effects.

The risk assessment information contained in IRIS, except as specifically noted, has been reviewed and agreed upon by two intra-agency review groups--the RfD work group and the Carcinogen Risk Assessment Verification Endeavor (CRAVE) work group. As these groups continue to review and verify risk assessment-related information, additional chemicals and new information will be added to IRIS. IRIS is available through Dialcom's electronic mail, the computer-based electronic communications system to which the EPA subscribes. Further information on IRIS can be obtained by contacting the Office of Information Resources Management, or IRIS user-support, at (513) 569-7254, FTS-684-7254. Specific details on the derivation of the chemical

Table 4-1. Potential ARARs and TBCs

Primary potentially applicable or relevant and appropriate requirements (ARARs)

- Promulgated State standards
- Maximum contaminant levels (MCLs)

Other potential ARARs and to-be-considereds (TBCs)

- Proposed MCLs generally should be given first priority among TBCs.
- Risk-specific doses (RSDs)--To be considered when evaluating human health threats from carcinogens in drinking water when MCLs, proposed MCLs, or State standards are not available, and for determining the risk level associated with an ARAR.
- Reference doses (RfDs)--To be considered when evaluating human health threats from systemic toxicants in drinking water. Use when MCLs, proposed MCLs, or State standards are not available, or when determining aggregate risks associated with ARARs.
- Lifetime health advisories (HAs)--To be considered when evaluating human health threats from systemic toxicants in drinking water when MCLs, proposed MCLs, State standards, or RfDs are not available.
- Maximum contaminant level goals (MCLGs) and proposed MCLGs--If technically feasible, to be considered when other human health threats at the site justify setting lower cleanup levels. (MCLGs may be relevant and appropriate if multiple contaminants or multiple exposure pathways require levels that are more stringent than MCLs.)
- Water quality criteria (WQC)--To be considered for protection of aquatic organisms and for evaluating health threats from fish ingestion and ingestion of drinking water. (May be relevant and appropriate, particularly if the beneficial uses of the ground water includes any association with a surface water body or when there are not more recently adopted health-based criteria or guidelines.)

information in IRIS can be found in the *Integrated Risk Information System* (U.S. EPA, 1987i). Information needed for selecting indicator chemicals and other agency standards and guidelines is described in the *Superfund Public Health Evaluation Manual* (U.S. EPA, 1986f), which has a data base format called the Public Health Review and Evaluation Database (PHRED). PHRED is available from the Toxics Integration Branch, OERR.

4.3 Derivation of Chemical-Specific ARARS and TBCs

Two kinds of standards are considered ARARs for remediation of ground water that is current or potential drinking water when they are available: MCLs and promulgated State standards. RSDs, RfDs, and HAs may be TBCs. As discussed previously, in some cases WQC and MCLGs may be relevant and appropriate. Unlike ARARs, which are established through the rulemaking process, TBCs must be defended on their merits if they are challenged during public comment; therefore, they should be supported with thorough documentation.

4.3.1 *Maximum Contaminant Levels*

MCLs are enforceable standards set for public water supply systems promulgated under the SDWA. Generally, they are relevant and appropriate for ground water that is a current or potential source of drinking water, but are applicable at the drinking water tap if there are at least 25 users or 15 service connections to a public water supply system.

MCLs are set at levels that are determined to be protective and are as close as practicable to the MCLGs; but, in addition, the MCL must account for the use of the best available technology, cost, and other considerations. Currently, MCLs have been established for eight organic compounds, six pesticides, and eight inorganics. MCLs that have been proposed in the *Federal Register* but are not yet promulgated will become potential ARARs when they are promulgated; therefore, they should be considered carefully. Approximately 40 MCLs were proposed in the *Federal Register* in 1988; these are noted in Appendix E.

4.3.2 *Promulgated State Standards*

Promulgated State standards are laws and regulations that are of general applicability and are legally enforceable. State advisories, guidances, or other nonbinding guidelines, as well as standards that are not of general applicability, are not considered ARARs. That is, State requirements that are promulgated specifically for one or more Superfund sites are not of general applicability and are not ARARs.

General State goals that are promulgated may be ARARs. For example, a State antidegradation statute that prohibits degradation of surface waters below specific levels of quality or in ways that preclude certain uses of that water may be an ARAR. A

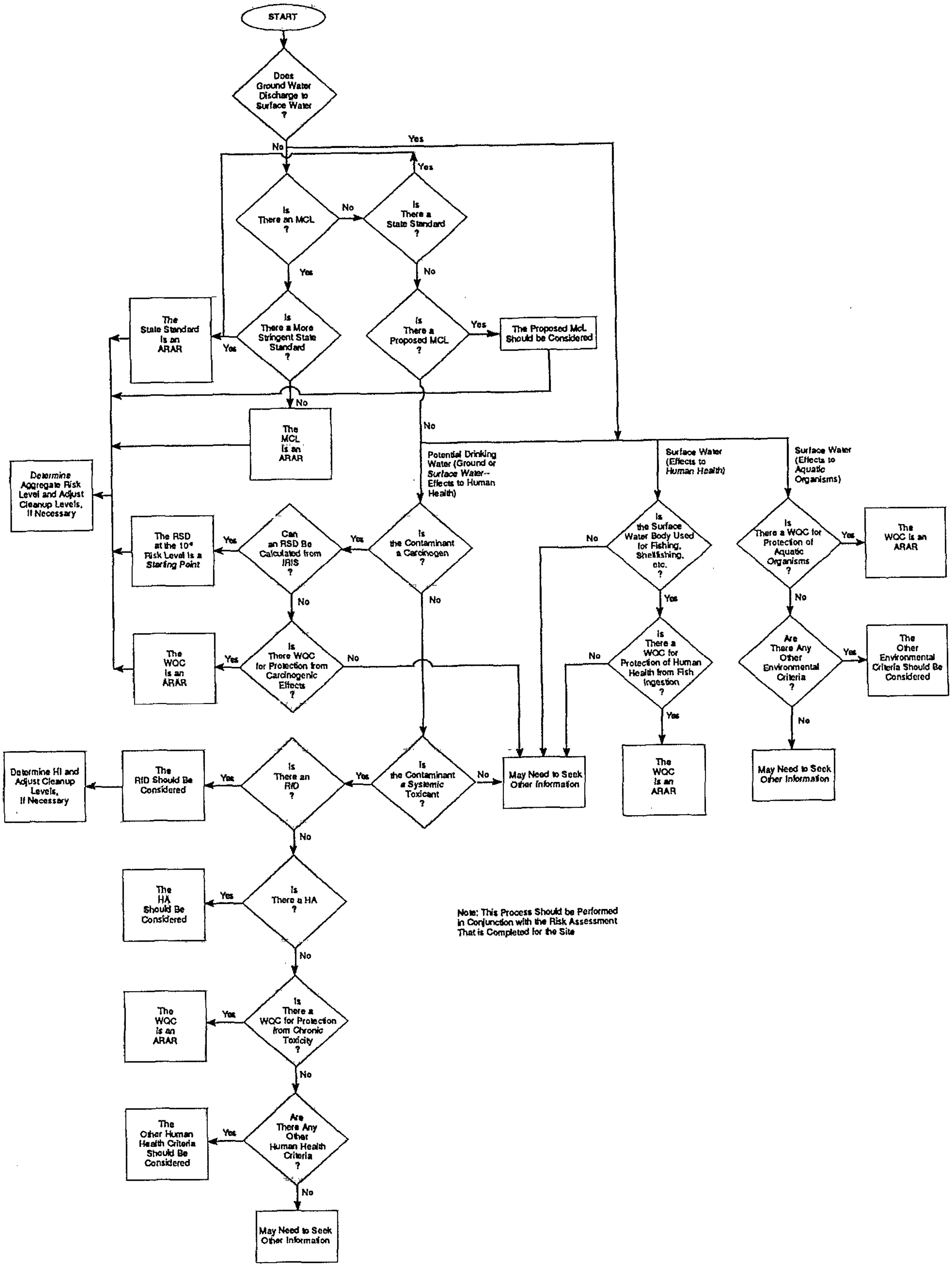
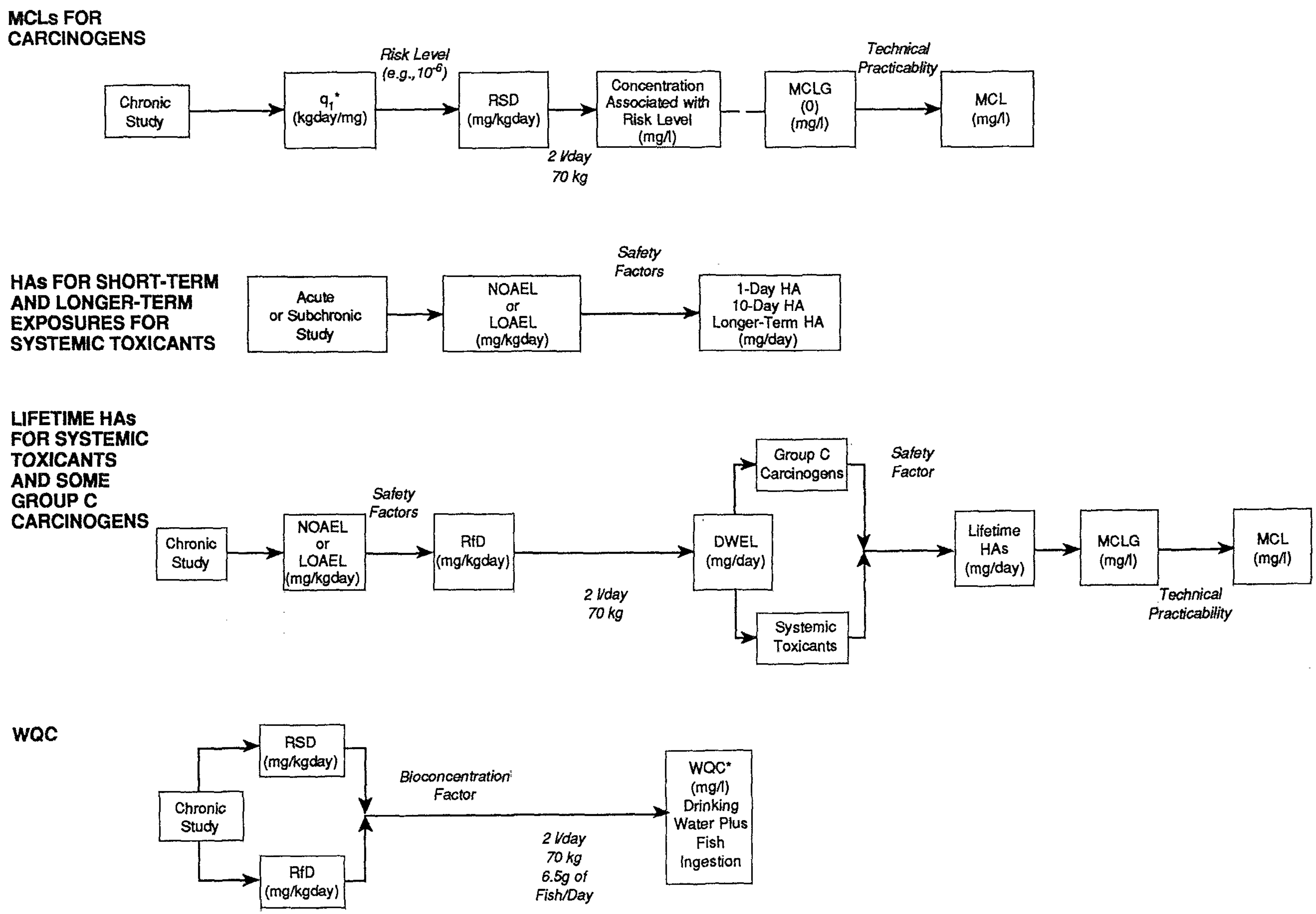


Figure 4-1 Flow Chart for Determing Site-Specific Cleanup Levels on the Basis of Existing Standards and Criteria.



*WQC are also developed to reflect fish ingestion alone and have been calculated to reflect drinking water alone in the *Superfund Public Health Evaluation Manual* (U.S. EPA, 1986). WQC are also developed for effects to aquatic organisms.

Figure 4-2 Derivation of Some Standards and Health-Based Criteria.

general prohibition against discharges to surface waters of toxic materials in toxic amounts also may be an ARAR. Because the scope of these goals is general, compliance must be interpreted within the context of specific regulations designed to implement them, the specific circumstances at the site, and the remedial alternatives being considered.

A waiver from complying with State standards that are inconsistently applied can be invoked (see Chapter 6).

4.3.3 *Risk-Specific Doses for Carcinogens*

Cancer potency factors are developed by the EPA Carcinogen Assessment Group (CAG) and the EPA Environmental Criteria and Assessment Office in a series of health effects assessment documents. Cancer potency factors are also referred to as slope factors or q_1^*, and can be found in the IRIS data base. RSDs are determined by dividing the selected risk level (e.g., 10^{-6}) by the cancer potency factors. They represent the dose of chemical in mg per kg of body weight per day associated with the specific risk level used. To calculate the concentration of a carcinogen in ground water associated with a selected cancer risk level, the following equation is used:

$$Conc.\,(mg/l) = \frac{RSD\,(mg/kgday)\,x\,body\,weight\,(kg)}{drinking\,water\,injestion\,rate\,(l/day)}$$

Body weight for the average adult is generally assumed to be 70 kg, and the drinking water ingestion rate is generally assumed to be 2 liters per day.

As stated, for carcinogens, cleanup levels should reduce aggregate risks to within the 10^{-4} to 10^{-7} range, and the 10^{-6} risk level should be used as a starting point.

4.3.4 *Reference Doses*

RfDs are derived from extensive analysis of toxicological data by an Agency review group headed by representatives from the Office of Research and Development. RfDs can be found in the IRIS data base, along with discussions on the strengths and limitations of each chemical's information base.

The RfD is an estimate of the daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of adverse effects during a lifetime. It is expressed in units of mg per kg body weight per day. RfDs are derived from toxicological no-observed-effects levels (NOELs), no-observed-adverse-effects levels (NOAELs), lowest-observed-effects level (LOELs), or lowest-observed-adverse-effects levels (LOAELs), using uncertainty factors that account for interspecies and intraspecies diversity and the quality of the experimental data. The NOAEL is the highest concentration of chemical that, when administered to a test animal, does not cause an adverse health effect, while the LOAEL is the lowest concentration that, when administered to a test animal, does cause an adverse health effect. NOEL and LOEL are analogous to NOAEL and LOAEL, respectively, but take into consideration any health effect, not just adverse effects.

DWELs are calculated from RfDs and are determined on the basis of medium-specific lifetime exposure levels, assuming 100 percent exposure from that medium. At the level of the DWEL, noncarcinogenic health effects would not be expected to occur. To obtain a ground-water DWEL, the following equation should be used:

$$DWEL\,(mg/l) = \frac{RfD\,(mg/kgday)\,body\,weight\,(kg)}{drinking\,water\,ingestion\,rate\,(l/day)}$$

Body weight for the average adult is assumed to be 70 kg, and the drinking water ingestion rate is assumed to be 2 liters per day.

4.3.5 *Health Advisories*

HAs are nonenforceable contaminant limits published by the Office of Drinking Water for 1-day, 10-day, longer-term (usually 7 years), and lifetime exposures to chemicals. HAs are generally published for noncarcinogenic endpoints of toxicity. Lifetime HAs are not recommended for Group A and Group B carcinogens, because carcinogenic effects are expected to result in more stringent health standards. For Group C carcinogens, lifetime HAs are based on noncarcinogenic endpoints of toxicity. An additional uncertainty factor of 10 is used when determining the lifetime HA to reflect possible carcinogenic effects. When determining cleanup levels for Group C carcinogens, the more stringent of the HA and the level corresponding to the 10^{-6} cancer risk should be used, if available.

Lifetime HAs are derived from DWELs by incorporating known exposure to contaminants from sources other than drinking water, such as diet. (However, exposure from inhalation of contaminants from showering, for example, is not incorporated into HAs.) HAs have been published for pesticides, inorganic chemicals, and organic compounds (U.S. EPA, 1987f).

4.3.6 *Maximum Contaminant Level Goals*

MCLGs, established under the SDWA (40 CFR 141), are set, with a margin of safety, at levels that would result in no known or anticipated adverse effects to health over a lifetime. MCLGs for Group A and Group B carcinogens are set at zero. MCLGs for Group C carcinogens are either set at zero or at the lifetime HA, depending on available information. For noncarcinogens, the MCLG generally corresponds to the lifetime HA. Proposed MCLGs may also be considered when establishing cleanup levels. In cases where multiple contaminants or multiple exposure pathways lead to very high risks, MCLGs may be relevant and appropriate.

4.3.7 Water Quality Criteria

WQC are established for evaluating toxic effects on human health and aquatic organisms. Values reflecting risk levels of 10^{-5}, 10^{-6}, and 10^{-7} are published for carcinogens. WQC are also published for noncarcinogenic (chronic toxic) effects. WQC are determined for the following exposure settings:

- Human exposure from ingestion of contaminated drinking water and contaminated fish
- Human exposure from ingestion of contaminated fish alone

In addition, WQC are used to derive criteria for human exposure from ingestion of contaminated drinking water alone in the *Superfund Public Health Evaluation Manual* (U.S. EPA, 1986e).

The final values of WQC that protect human health may differ from MCLs because WQC take into consideration a bioconcentration factor and fish ingestion factor, while MCLs take into consideration economic and treatability factors. Also, many WQC have not recently been updated.

If the contaminated water is a drinking water source, MCLs are generally an ARAR. However, if there is no MCL or if the ground water discharges to surface water and contaminants are affecting aquatic organisms, or if other health-based standards are not available, WQC should be consulted and may be relevant and appropriate. Because WQC do not incorporate such factors as detection limits, technical feasibility of achieving standards, or cost, the cleanup levels for a site may have to be adjusted from the WQC value. The *WQC Standards Handbook* (U.S. EPA, 1983) describes factors to consider when using WQC and when determining cleanup levels that are based on WQC.

4.4 Assessment of Aggregate Effects

The aggregate effects from contaminants at a site for a particular medium, in this case ground water, generally should be determined, using methods described in the "Guidance for Health Risk Assessment of Chemical Mixtures," (U.S. EPA, 1986a).

Generally, both carcinogenic risks and risks from systemic toxicants are assumed to be additive. For example, the aggregate risk posed by all of the carcinogens in an exposure pathway is assumed to be the sum of the risks from the individual carcinogens.

For carcinogens (including Class C carcinogens), aggregate risk levels calculated from cleanup levels should fall within the 10^{-4} to 10^{-7} risk range. The 10^{-6} aggregate excess lifetime cancer risk level is considered the starting point for analysis, but other risk levels between 10^{-4} and 10^{-7} may be supported on the basis of other factors such as exposure, technical limitations, and uncertainties. If cleanup levels based on ARARs and TBCs result in an aggregate risk level that falls outside the protective risk range, then cleanup levels should be more stringent than the ARARs or TBCs. Setting cleanup levels within the risk range and ensuring that these levels at least meet ARARs will assure that adequately protective cleanup levels are set.

Effect levels from systemic toxicants may be added when they act by the same mechanisms or would otherwise magnify the toxic effect. To add effect levels from systemic toxicants, the hazard index (HI) is used. The HI is calculated using the equation:

$$HI = \sum_{i=1}^{n} DI_i / RfD_i$$

where i = chemical i in the mixture, and DI_i = daily intake of the chemical in mg/kg-day.

Initially, the HI should be determined from daily intakes on the basis of cleanup levels for all systemic toxicants as a screening approach as described in the *Superfund Public Health Evaluation Manual* (U.S. EPA, 1986f). If the HI exceeds or is close to 1.0, chemicals should be segregated by mechanism of action and separate HIs should be calculated for each group of chemicals. Cleanup levels may need to be lowered if segregating chemicals does not reduce the HI to below 1.0, however.

Exhibit 4-1 is an example of setting cleanup levels.

Table 4-2 describes factors that should be analyzed to determine the most appropriate aggregate risk level. The analysis of these factors is not quantitative but is merely a qualitative indication of the appropriate level within the protective risk range at which a remedy should be designed to perform. The factors that are presented in this table highlight considerations that may be pertinent to particular sites and need not be addressed in every case. Although listed as a separate factor in Table 4-2, detection limits should not be the sole factor for deviating from the starting point, such as the 10^{-6} cancer risk level, unless special analytical services have been investigated and it is technically infeasible to detect the chemical at the desired concentration.

Exhibit 4-1. Setting Cleanup Levels at Seymour Recycling

The Seymour Recycling site, located in Seymour, Indiana, is situated on 14 acres in an agricultural area 1/2 mile south of a subdivision. Waste management activities at the site began in the 1970s and included processing, storing, and incinerating chemical wastes. Surface contamination from 50,000 drums and 100 storage tanks has resulted. Ground-water contamination of the shallow aquifer is extensive, and a contaminant plume extends 1,100 feet from the site boundary. The deeper aquifer, which is separated from the shallow aquifer by a silty clay aquitard, has very limited contamination.

More than 35 hazardous organic chemicals have been detected in ground water, including 1,2-dichloroethene, benzene, vinyl chloride, and 1,1,1-trichloroethane. Ten carcinogens and 12 noncarcinogens with critical toxicity values have been identified in ground water at the site.

Establishment of Cleanup Levels

For carcinogens with MCLs, the cleanup levels were stricter than the MCLs because of the aggregate effects of the contaminants. The aggregate risk of the six organic carcinogens detected at the site which have MCLs is 4×10^{-4} at the MCL levels. An aggregate excess cancer risk of 1×10^{-5} was selected as the ground-water cleanup level for carcinogens. This risk level was selected because there are a large number of ground-water contaminants, because there is limited understanding of the contaminants' aggregate effect, because low levels of contaminants will continue to migrate when the extraction system is terminated, and because the aquifer is a potential source of drinking water. A 1×10^{-6} risk level must be met at the site's nearest receptor. In addition to meeting the 1×10^{-5} aggregate risk level, the individual MCLs must be met throughout the aquifer. The compounds used for setting the aggregate excess cancer risk for the site were:

Benzene	1,1,2-Trichloroethane
Methylene chloride	1,1-Dichloroethene
Chloroform	Trichloroethene
Tetrachloroethane	1,4-Dioxane
1,2-Dichloroethane	Vinyl chloride

This list will be revised if other chemicals that are carcinogenic by the oral route of exposure are identified or if other compounds are identified as possible, probable, or known human carcinogens.

For noncarcinogens, the total hazard index (HI) for all compounds for which there is a reference dose (RfD) will not exceed 1.0. These compounds include the following:

Barium	Manganese
2-Butanone	Methylene chloride
Copper	Nickel
2-Methylphenol	Phenol
4-Methylphenol	Toluene
1,1-Dichloroethane	Zinc

In addition, for those compounds for which there is an MCL, the MCL will not be exceeded. The list shall be updated as additional RfDs or other information becomes available and as MCLs are established for additional compounds.

The information needed to evaluate many of these factors is often included in the risk assessment for a site. In addition, information gained during implementation of an interim action may be useful for evaluating these factors.

4.5 Alternate Concentration Limits

Section (121)(d)(2)(B)(ii) of CERCLA restricts the use of ACLs for offsite exposure in the selection of a remedial action in lieu of otherwise applicable limitations. ACLs can only be used as cleanup levels at the end of the remedial action and only if the following conditions are met:

- The ground water has known or projected points of entry into surface water, which is a reasonable distance from the facility boundary.
- There will be no statistically significant increase at the 95 percent confidence level of constituent concentrations occurring in the surface water in

Table 4-2. Factors Considered When Determining Preliminary Cleanup Levels

Factors Related to Exposure	**Timing of exposure**	If data demonstrate that exposures are occurring continuously, more stringent cleanup levels may be warranted than if exposures were projected or the probability of exposure is low.
	The potential for human exposure from other pathways	If a site presents a threat from contaminants from two or more media or pathways (e.g., soil and ground-water exposure) and there is a potential for exposure from multiple media, more stringent cleanup levels may be warranted because of the potential for higher exposure.
	Population sensitivities	The current risk borne by the population may be substantial enough to warrant a more stringent cleanup level for a contaminant in ground water. If the site is near a school where the potential for children to be exposed is higher than normal, then more stringent cleanup levels may be appropriate, though this is accounted for to some extent during development of standards and health-based criteria, which takes into account sensitive individuals.
	Potential effects on environmental receptors	The presence of a particular plant or animal species near the site may warrant a more stringent cleanup level.
	Cross-media effects of alternatives	A remedy that achieves an acceptable risk level in one medium may not be preferred if it only achieves this level by transferring contaminants to another medium at an unacceptable risk level.
Factors Related to Uncertainty	**Effectiveness and reliability of alternatives**	A remedy that has been demonstrated to be effective and reliable at sites that are similar may be chosen over a remedy that might reach a more protective level under ideal conditions but is undemonstrated for the conditions of a particular site. If a remedy with a low degree of certainty of attaining cleanup levels is chosen, the system could be designed to meet more stringent cleanup levels to increase the probability that that the remedy will fall within the protective risk range; thus providing an additional measure of safety. Also, the reliability of any institutional controls that are part of the alternative should be considered.
	Reliability of exposure data	If exposures are actually occurring, more stringent cleanup levels may be warranted than if exposures are only predicted to occur using transport modeling. Less stringent cleanup levels may be warranted when exposure is expected to be intermittent.
	Reliability of scientific evidence	A contaminant that is a known human carcinogen may require a more stringent cleanup level than a contaminant for which there is weak evidence of carcinogenicity. The weight of evidence with respect to severity of effect should also be considered.
Factors Related to Technical Limitations	**Detection/quantification limits for contaminants**	If standard laboratory procedures can only detect contaminants at concentrations reflecting the 10^{-4} risk level, for example, then that level may be appropriate. However, in some situations, such as when the quantification limit is higher than the cleanup level, it may be appropriate to use special analytical methods to achieve lower quantification limits. (This should not be the sole criterion for deviating from cleanup levels.)
	Technical limitations to restoration	If remediation is technically limited because of site hydrogeological characteristics, the nature of the soil matrix, or difficulties associated with treatment of a particular contaminant, more stringent cleanup levels may not be feasible. In addition, if the ability to monitor and control the movement of contaminants is technically limited, such as in karst aquifers, highly varied alluvial deposits, or with dense nonaqueous phase liquids, it may be difficult to monitor the actual reduction achieved.
	Background levels	Cleanup levels lower than background levels are not, in general, practicable; e.g., if the background level of a particular contaminant is at the 10^{-4} risk level, a more stringent cleanup level is not practicable. However, if background levels are above ARARs and the ground water is a drinking water source, it may be appropriate to initiate a coordinated response with other agencies. If background levels are high because of natural sources, well-head treatment may be the most effective solution, although such ground water is probably not a drinking water supply.

the discharge zone or at any point where constituents are expected to accumulate.

- Institutional controls will be implemented that will preclude human exposure to ground-water contaminants between the facility boundary and the point of entry into the surface water.

In addition, ACLs should only be developed under this provision when remediating to drinking water levels is not practicable. Furthermore, ACLs should be used only if there is no significant degradation of uncontaminated ground water before discharge to surface water occurs. Exhibit 4-2 presents an example of using ACLs.

Determining statistically significant increases of constituent concentrations in surface water should include the following steps as appropriate:

- Samples of surface water should be taken during a period in which the flow (for rivers and streams) or standing volume (for ponds and lakes) is near base flow conditions for the specific season. Stream width and depth should also be considered.
- Surface water samples should be collected within the discharge zone of the ground-water contaminant plume. Because ground-water movement near surface water bodies can be complex, initial samples may have to be collected adjacent to the facility as well as some distance downstream to identify the discharge zone.
- Sediment and biota samples should be collected when surface water samples are collected to determine if contaminants are accumulating in the sediments or biota.
- Contaminant degradation should be considered, and analysis for potential degradation products should be conducted.
- If concentrations of contaminants in shallow and deep ground water adjacent to the surface-water body are not detectable, this statistical determination need not be performed. If the levels are detectable, then concentrations in the discharge zone should be compared to concentrations in a background area of the surface-water body.
- If concentrations of contaminants are found in the deeper aquifer, then samples should be taken downstream.
- If ACLs are established for a site, periodic surface water sampling should be conducted.

4.6 Summary

When establishing preliminary cleanup levels, the following steps should be taken:

- Identify ARARs and associated risk levels for carcinogen and daily intake values for systemic toxicants
- Identify TBCs for contaminants for which ARARs are not available (it may also be important to identify TBCs for contaminants with ARARs in order to calculate aggregate risks or evaluate impacts, such as environmental effects, not addressed by ARARs)
- Assess aggregate risk in the ground water and determine the appropriate risk level (carcinogens) or HI (systemic toxicants)
- If it is not practicable to attain applicable requirements and site condition permits, consider establishing ACLs and using institutional controls, if necessary, to restrict site access

Exhibit 4-2. Ground Water Discharging to Surface Water

The Newport Dump site is a 39-acre former municipal landfill in Wilder, Kentucky, that lies on the Licking River, a tributary of the Ohio River. Approximately 250 feet downstream of the site is the main water intake for a water treatment plant. The plant withdraws up to 18 mgd from the Licking River and serves about 75,000 people. The site was used by the city for the disposal of residential and commercial wastes from the 1940s until its closure in 1979.

The major concern at the site is leachate migration to a nearby unnamed stream forming the southern border of the site and to the Licking River. The surface water contaminant migration pathway was examined by collecting surface water and sediment samples at six locations in the stream and five nearshore locations in the Licking River. Many of these sampling points were also paired with shallow ground-water sampling points to evaluate the potential ground-water distribution to surface water.

Shallow ground water, which discharges to the Licking River, was sampled and contained metals, solvents, and polycyclic aromatic hydrocarbons. Samples of the deeper ground water were clean.

Surface water and sediment samples were collected from the stream and the river, and two samples were taken at the surface-water intake. The results of the chemical analyses demonstrated that the levels of contaminants in the stream were below all detectable levels except for toluene, which was detected in upstream samples as well as downstream samples. Ground-water dilution by the Licking River was calculated to be over 40,000 to 1 under low flow conditions. Thus, it was concluded that site contaminants did not have any effect on the quality of the Licking River.

The main receptors for contaminant releases from the site are the 75,000 residents served by the water intake. Approximately, 1,200 individuals live within a 1-mile radius of the site, but no private or public drinking water wells were found within this area. The potential receptors include those people who eat fish caught from the Licking River. Currently, there is no recreational use of the site, though the site has uncontrolled access. The risk assessment found no evidence of any current public health or environmental concerns associated with the site. It was therefore concluded that the principal human exposure point associated with the site is the withdrawal of surface water from the intake on the Licking River.

Currently, no data exist that demonstrate that contaminants detected onsite are increasing contaminant levels in the Licking River. Of the seven indicator chemicals used, only toluene was detected in a raw water sample collected at the intake. However, toluene was also detected in higher concentration in a background sample; therefore, there was no increase in concentration as a result of the site. Ground-water remediation between the landfill and the Licking River is not practicable because (1) concentrations of contaminants are low, (2) ground-water flow to the river is relatively low, and (3) the cost of remediation is high. Consequently, ACLs, as defined in Section 121 (d)(2)(B)(ii) of CERCLA, were developed. They are presented below:

Actual and Projected Concentration Levels

Indicator Chemicals	Ground-Water Concentration, mg/l	Proposed ACL, mg/l[1]	Standard or Health-Based Criteria, mg/l	Projected Concentration in the Licking River, mg/l
Arsenic	0.064	0.64	0.05 (MCL)	1.6×10^{-6}
Barium	7.4	74	1 (MCL)	1.9×10^{-4}
Chromium	1.5	15	0.05 (MCL)	3.8×10^{-3}
Nickel	2.4	24	0.13 (WQC)	6.0×10^{-5}
Toluene	0.017	0.17	0.14 (WQC)	4.2×10^{-3}

[1]These concentrations are ten times the level of ground-water contamination.

The proposed ACLs are based on actual ground-water contamination levels. At the ACL levels, concentrations projected in the Licking River will be below all existing health and environmental standards and criteria. Therefore, they represent a protective baseline limit for deciding if any future remedial action will be necessary.

Chapter 5
Developing Remedial Alternatives

5.1 Introduction

This chapter describes how remedial alternatives are developed. Developing remedial alternatives occurs when enough site information has been obtained to identify appropriate operable units or final remedies. If necessary, alternatives are screened on the basis of general considerations of effectiveness, implementability, and cost to reduce the number of remedial alternatives considered in the detailed analysis.

Detailed guidance on the development of alternatives is provided in Chapter 4 of the *RI/FS Guidance* (U.S. EPA, 1988c). This chapter presents additional information for developing a reasonable range of remedial action alternatives for sites with contaminated ground water.

Developing remedial action alternatives encompasses the following steps:

- Determining remedial action objectives
  - Establishing preliminary cleanup levels (see Chapter 4)
  - Determining the area of attainment
  - Estimating the restoration time frame
- Developing alternatives
  - Determining response actions
  - Determining process options
  - Formulating alternatives

In actual project applications, these steps may be repeated at various stages of the Superfund process including:

- During the RI to assist in planning cost-effective RI activities
- During preliminary stages of the FS
- During detailed evaluation in the FS

This iterative approach allows for flexibility to respond to new data and to changes in the project and should ultimately result in a detailed evaluation of a limited number of alternatives. The factors used to evaluate the alternatives and select a ground-water remedy are discussed in Chapter 6 of this guidance.

5.2 Remedial Action Objectives

Response objectives are site-specific, initial cleanup objectives that are established on the basis of the nature and extent of the contamination, the resources that are currently and potentially threatened, and the potential for human and environmental exposure. Table 5-1 presents a partial list of remedial action objectives for contaminated ground water at Superfund sites. While this list covers many of the situations encountered at Superfund sites, other remedial action objectives may be appropriate because of site-specific conditions.

Remedial action objectives are site-specific, quantitative goals that define the extent of cleanup required to achieve the response objectives. They include the preliminary cleanup levels, the area of attainment, and the restoration time frame. Remedial action objectives are generally developed in the initial phase of the FS and are used as the framework for developing detailed remedial alternatives. The objectives are formulated to achieve the overall goal of the Superfund program to protect human health and the environment by restoring potentially usable contaminated ground water to, and protecting usable uncontaminated ground water at, levels that are safe for current and potential users and environmental receptors. The specificity of these objectives may vary depending on the availability and quality of site information, site conditions, and the complexity of the site.

5.2.1 Area of Attainment

The area of attainment defines the area over which cleanup levels will be achieved in the ground water. It encompasses the area outside the boundary of any waste remaining in place and up to the boundary of the contaminant plume. An example of the area of attainment is illustrated in Figure 5-1. Usually, the

Table 5-1. Potential Response Objectives for Ground Water

- Prevent exposure to contaminated ground water
  - Provide an alternate water supply for the population that has existing wells affected by the contaminant plume
  - Establish institutional controls to restrict access to the contaminant plume
- Protect uncontaminated ground and surface water for current and future use
  - Prevent contamination of existing wells that could be affected by the plume and in adjacent ground water
  - Minimize migration of contaminants within the ground and surface water
  - Minimize migration of contaminants to adjacent ground and surface water
- Restore contaminated ground water for future use
  - Reduce contaminant concentrations within the area of the plume to levels that are safe for drinking
- Protect environmental receptors
  - Reduce contaminant concentrations in the plume to levels that are safe for biological receptors that may be affected at the ground-water discharge point.

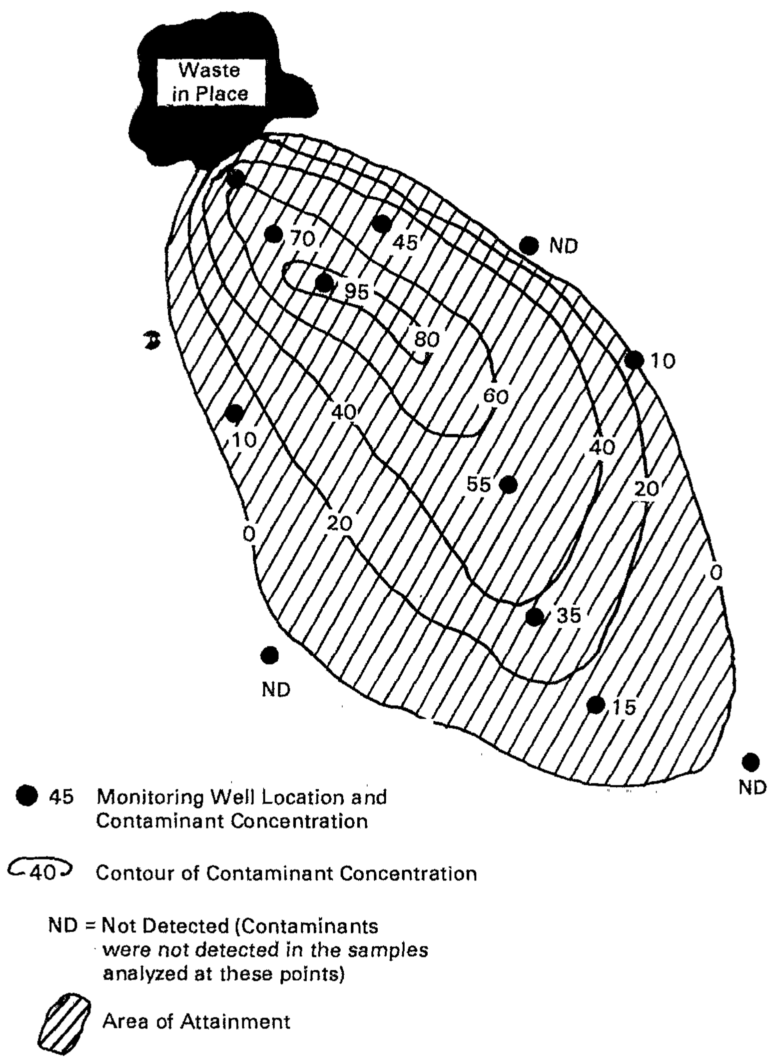


Figure 5-1 Conceptual Diagram of Waste Source, Containment Plume, and Attainment Area.

boundary of the waste is defined by the source control remedy. For example, if the source is removed, the entire plume is within the area of attainment. On the other hand, if waste is managed or contained onsite, the ground water beneath the waste management area is not within the area of attainment. Cleanup levels should be achieved throughout the area of attainment.

5.2.2 *Restoration Time Frame*

The restoration time frame is defined as the period of time required to achieve selected cleanup levels in the ground water at all locations within the area of attainment. Factors that can affect the choice of technologies, which in turn affects the restoration time frame, include the following:

- Technical limits to extracting contaminants--this factor must be evaluated first to determine the restoration time frame that is practicable for the site
- The feasibility of providing an alternate water supply
- The potential use and value of the ground water--successively higher classes of ground water should be remediated more rapidly
- The effectiveness and reliability of institutional controls
- The ability to monitor and control contaminant movement

These factors are explained in the following paragraphs.

5.2.2.1 Technical Limits to Extracting Contaminants

The rate at which an aquifer can be restored through extraction and treatment is affected by contaminant-soil interactions, the nature of the contaminants, and the physical conditions of the site and contaminant plume. For all chemicals present in the ground water there is an equilibrium between the amount of the chemical that is sorbed to the aquifer material and the amount dissolved in the ground water. The rate at which the chemical desorbs as clean water is drawn into the contaminated zone as a result of pumping will limit the pumping rate that can effectively remove the contaminants. As discussed in Chapter 3, in many cases this rate can be estimated by calculating partition coefficients for the contaminants using saturated soil core analyses and incorporating this information into models to estimate the restoration time frame.

The presence of dense nonaqueous phase liquids (DNAPLs) also may affect the extent to which contaminants can be removed from the ground water; points of accumulation are difficult to identify, and unless the well screen is located in the nonaqueous liquid phase, the contaminant will only be extracted slowly as it dissolves into the ground water.

Naturally, the nature of the source, the size of the plume, and the transmissivity of the aquifer also will directly affect the restoration time frame. For example, leaching of contaminants from large areas contaminated at low concentrations or from non-homogeneous fills with undetermined hot spots may continue to affect the ground water and should be accounted for to the extent possible in estimating the restoration time frame. Estimating the restoration time frame will be difficult if the site is not adequately characterized during the RI; it will be especially difficult if the action to address the source has not yet been determined.

Models can be used as a tool to estimate the restoration time frame feasible for the site, accounting for site-specific factors, as described in Chapter 3 and exemplified in Exhibit 3-5.

Once technical limits to extracting contaminants have been assessed, restoration time frames for remedies can be evaluated relative to this limit.

5.2.2.2 Feasibility of Providing an Alternate Water Supply

For sites at which ground-water users are currently or potentially affected by the continued migration of a contaminant plume before remedial measures are likely to be effective, the feasibility of providing an alternate water supply during the remedial action and the characteristics of any potential alternate water sources should be evaluated. The following issues should be addressed:

- The time and cost required to develop an alternate water supply
- The quality of the alternate water supply
- The reliability of the alternate water supply, particularly in terms of susceptibility to contamination
- The sustainable quantity, or safe yield, of the water supply, considering the water use demands of those current users affected by the site, any current or potential competing demands, as well as any water rights issues
- Whether the alternate water supply is itself irreplaceable (i.e., is there a backup to the alternate source)

A readily accessible water supply of sufficient quality and yield that is protected from sources of contamination may reduce the importance of rapid remediation, providing more flexibility to select a response action that requires a longer time to achieve the cleanup level. The presence of a backup source to the alternate water supply adds substantially to the reliability of an alternate supply.

5.2.2.3 The Potential Use and Value of the Ground Water

If ground water contaminated from a Superfund site is not currently used but is a potential source of drinking water (Class IIB), the potential need should be evaluated in terms of the following:

- Timing, i.e., when a demand for the ground water is anticipated
- The magnitude of the potential need, i.e., volume per day
- The type of need, e.g., drinking water, irrigation, manufacturing, etc.
- The availability and characteristics of other water sources in the same area

If a demand for high-quality ground water (e.g., drinking water) is anticipated in the near future and other potential sources are either not available or are of insufficient quality or quantity, remedial alternatives that rapidly achieve cleanup levels are preferred.

Predicting potential need is difficult. Reasonable assumptions on type, timing, and volume of potential need for the contaminated ground water should be made to guide decisions concerning the restoration time frame.

5.2.2.4 Effectiveness and Reliability of Institutional Controls

Institutional controls implemented at the State or local level that restrict ground-water use should be implemented as part of the response action at all sites at which exposure poses a threat to human health. In addition, institutional controls may be used to prohibit offsite extraction of ground water if extraction would increase contaminant migration.

The following kinds of institutional controls have been established in some states and localities and may be considered to prevent exposure to contaminated ground water:

- Regulatory restrictions on construction and use of private water wells, such as well construction permits and water quality certifications
- Acquisition of real property by the government from private entities (acquisition must be exercised in accordance with EPA Delegation 14-30; concurrence by EPA headquarters is required)
- Exercise of regulatory and police powers by governments, such as zoning and issuance of administrative orders
- Restrictions on property transactions, including negative covenants and easements
- Nonenforceable controls, such as well-use advisories and deed notices

Property ownership may allow extension of the restoration time frame but does not alleviate responsibility for achieving cleanup levels throughout the area of attainment. For new ground-water users, licensing of well drillers, well construction permits, well construction and location standards, and water quality certification programs are generally effective, as are regulations of new development and property transactions. However, the institutional control cannot be deemed effective without considering the specific circumstances; it depends on the specific site, the State and local authorities, and any private parties that are involved. Zoning could also be used, though it is generally the jurisdiction of the local planning or zoning board.

For existing ground-water users, advisories could be issued, but their reliability generally is limited. Administrative orders also could be issued.

The effectiveness and reliability of these controls should be evaluated when determining whether rapid remediation is warranted. If there is adequate certainty that institutional controls will be effective and reliable, there is more flexibility to select a response action that has a longer restoration time frame. Conversely, if it is unclear that an authority will establish institutional controls, or that an effective and reliable enforcement mechanism is in effect, emphasis should be placed on response actions that more rapidly restore the ground water. Institutional controls should be monitored periodically to ensure the effectiveness of the response actions. Exhibit 5-1 is an example of institutional controls used by the State of New Jersey.

5.2.2.5 Ability to Monitor and Control Contaminant Movement

Complex flow patterns may reduce the effectiveness of a remedial action. The ability to monitor and control the movement of contaminants in ground water depends on the properties and volume of the contaminants, the complexity of the hydrogeology, and the quality of the hydrogeologic investigation. If the hydrogeology is relatively simple and the ground-water flow paths and the distribution of contaminants in the ground water are well characterized, predictions of remedial action performance are more reliable. This increased reliability provides greater flexibility to select a remedial alternative that requires more time to achieve cleanup levels.

If flow patterns are complex and the hydrogeologic system is difficult to characterize, the potential for unanticipated migration pathways to develop increases, which may reduce the effectiveness of the remedial action. Remedial actions should be designed to prevent, as quickly as possible and to the extent practicable, further spread of a plume in these complex systems. However, some hydrogeologic systems, such as mature karst areas and areas with fractured bedrock, may make remediation of ground water impracticable.

5.3 General Response Actions

After developing cleanup levels and other remedial action objectives, response actions that are consistent with the remedial action objectives are identified. Categories of general response actions for contaminated ground water include active restoration, containment through hydraulic control, and limited or no active response. These actions should be combined, if appropriate, with institutional controls to protect human health until such time that contaminants in ground water have been reduced to a level that is safe for consumption. The application of these general response actions is discussed below.

5.3.1 Active Restoration

Active restoration usually reduces ground-water contaminant levels more rapidly than plume containment or natural attenuation. Factors that

Exhibit 5-1. Institutional Controls in New Jersey

New Jersey has implemented its authority to regulate access to contaminated ground water for the purpose of protecting public health. The state has delineated the boundaries of 19 areas where ground-water supplies are not potable because of chemical contaminants. The authority under which the New Jersey Department of Environmental Protection (DEP) makes these designations is a State statute that requires well drillers to secure a permit before constructing any ground-water wells. These designated areas have been established by the DEP on the basis of well sampling and other data obtained by DEP geologists. The Bureau of Water Supply issues restrictions for two types of areas:

- Those areas in which wells are contaminated or are likely to become contaminated within 2 to 3 years without remedial action
- Those areas in which wells are likely to become contaminated within 10 years without remedial action

The DEP's practice is to deny any well permit application to construct a private well in any restricted area.

The DEP has been given the authority to issue or deny a well-construction permit. On the basis of the DEP's own interpretation, it either (1) denies or (2) conditionally approves permit applications in those areas that have been designated as well-restriction areas. The DEP has not issued regulations governing practices and procedures for reviewing well-construction permits but was scheduled to propose and adopt such regulations in late 1986. It is expected that the regulations will include a section on permit denials, with language to the effect that "reasons for denying a permit include...the site where the well is planned has been designated by DEP as an area where wells cannot be constructed."

Well drillers apply for construction permits on forms provided by the DEP. It is at this stage that DEP screens out applications for wells from the restricted areas. The DEP generally denies those permits on the basis of the formal designation. However, sometimes applications for wells in the restricted areas are reviewed by DEP geologists for alternative construction methods. In some cases, the driller has been allowed to proceed with well construction on the condition that the well be drilled into a deeper, uncontaminated aquifer and that the driller conform to special construction procedures, i.e., casing the upper aquifer to prevent cross contamination. Although there is no surveillance or enforcement of the permitting requirements, officials in charge of the program state that it is successful.

potentially favor the use of active restoration include:

- Mobile contaminants
- Moderate to high hydraulic conductivities in the contaminated aquifer
- Effective treatment technologies available for the contaminants in the ground water

5.3.1.1 Extraction and Treatment

An extraction system can be used to remove contaminated ground water. This is followed by treatment, if required, and discharge or reinjection back into the aquifer. Extraction can be achieved by using pumping wells, French drains, or trenches. Pumping may be continuous or pulsed to remove contaminants after they have been given time to desorb from the aquifer material and equilibrate with ground water. Treatment may involve air-stripping, carbon adsorption, and biological treatment, depending on the physical/chemical properties of the contaminants.

5.3.1.2 Innovative Technologies

Because extraction and treatment systems may not be able to remediate ground water to health-based levels in a reasonable time frame for some contaminants or in some zones where contaminants have saturated the aquifer material, innovative methods may be considered alone or in conjunction with extraction to reduce contaminants below the level at which they have reached equilibrium with the saturated soil and to treat or contain the source of contamination. Methods that are in the developmental stage for ground water treatment and source control include biorestoration, soil flushing, steam stripping, ground-water pumping in conjunction with soil vacuum extraction, and in situ vitrification. These technologies are briefly described in the following paragraphs. The fact that most in situ technologies require extensive pilot testing to ensure their viability at a particular site should be considered during the RI/FS.

Biorestoration relies on microorganisms to transform hazardous compounds into innocuous materials. Almost all organic compounds and some inorganic compounds can be degraded biologically if given the proper physical and chemical conditions and sufficient time. Biological processes are particularly useful for detoxifying aqueous solutions containing dilute concentrations of hazardous materials. Biorestoration can be enhanced by using the native microorganisms and injecting nutrients, including oxygen, or by injecting microorganisms to the subsurface environment. Some organic compounds readily biodegrade, while other molecules degrade at a much slower rate. Some organic compounds are toxic to microorganisms or inhibit their activity. Special methods may be necessary to enhance biorestoration of these compounds. The toxicity of degradation by-products should also be considered. In some cases, such as with the degradation of trichloroethylene to vinyl chloride, the by-products are more toxic than the parent compound. Exhibit 5-2 presents an example of the use of biorestoration at a pharmaceutical plant.

Soil flushing refers to applying a liquid flushing agent to contaminated soil to physically or chemically remove contaminants. The flushing agent is allowed to percolate into the soil and enhance the transport of contaminants to ground-water extraction wells for recovery. The extracted solvent may then be treated and recycled. Water is normally used as the flushing agent; however, other solvents may be used for contaminants that are tightly held or only slightly soluble in water. Solvents are selected on the basis of (1) their ability to solubilize the contaminants and (2) their environmental and human health effects. Thus, it is important to know the chemistry and toxicity of the surfactant. It is also important to understand the hydrogeology of the site to ensure that contaminants will be extracted once they are mobilized. This technology is most applicable for soluble organics and metals at a low-to-medium concentration that are distributed over a wide area. This technology can reduce the time required to complete ground-water cleanup.

In situ steam stripping is an innovative technology used to enhance the volatilization of organic compounds in the soil. Steam is injected and mixed into the ground through specially adapted hollow core drill stems. Volatilized organic compounds rise to the surface and are collected via a blower system. The collected gases are treated to condense the organics and trap the remainder on activated carbon. Once treated, the gases are reheated and reinjected. This technology allows for a high degree of organics to be removed in a relatively short time.

Soil vapor extraction has been used at several sites to augment ground-water extraction and treatment. This technology can be applied using a variety of system designs, depending on site conditions. A vacuum is applied to subsurface soils in the unsaturated zone and in dewatered portions of the saturated zone. The extracted vapor or soil gas contains volatile contaminants that can be either vented directly to the atmosphere or collected in a vapor-phase carbon adsorption system. The system may consist of a single extraction well screened in the contaminated zone, or it may include inlet wells that direct air flow through a particular interval. Figure 5-2 illustrates how this type of system might be designed for a leaking underground storage tank. At this time, no generally applicable design guidelines can be provided because the design and operation of soil vapor extraction is an emerging technology.

There are many factors to be considered in deciding if soil vapor extraction should be tried, such as:

- Types of volatiles
- Concentration
- Quantity of volatiles
- Volume and depth of contaminated soil
- Depth to ground water
- Physical characteristics of the contaminated soil, particularly stratification and permeability
- Surface of the contaminated area

Some considerations that may be useful are:

- Depth of contaminated soil--it may be more practical to trench across the area of contamination and install perforated piping in the trench bottom than to install vapor extraction wells.
- Short-circuiting of air from the ground surface to the vapor extraction intake--it may be possible to cap or cover the surface to limit the short circuiting.
- Flow nets--model the pressure drops and flow of air through the soil, and include provisions in the design to enhance the flow through the areas of maximum concern.
- Staged soil vapor extraction installation--design and install the system in phases to maximize the effectiveness of inlet and outlet locations.
- Air emissions--there are several ways that air emissions can be limited and controlled (e.g., use of carbon adsorption units).

In situ vitrification (ISV) is a thermal treatment process that converts the contaminated area into a chemically inert, stable glass and crystalline product. Electrodes are inserted into the area to be treated, and a conductive mixture of flaked graphite and glass frit is placed among the electrodes to act as the starter path. An electric potential is applied to the electrodes, establishing an electric current in the starter path. The resultant power heats the starter path and surrounding material above the fusion temperature of soil. The graphite starter pad is consumed by oxidation, and the current is transformed to the molten soil. As the vitrified zone grows, it incorporates nonvolatile elements and destroys organic compounds by pyrolysis. Any water present is vaporized. The pyrolyzed by-products migrate to the surface of the vitrified zone, where they combust in the presence of oxygen. A hood placed over the processing area is used to collect the combustion gases, which are drawn off and treated in a separate system. The ISV technology has been demonstrated

Exhibit 5-2. Biorestoration at Biocraft Laboratories

Biocraft Laboratories is a small synthetic penicillin manufacturing plant located on a 4-acre site in an industrial park in Waldwick, New Jersey. Several years ago contamination was discovered in the shallow aquifer below the site. The contamination consisted of a mixture of methylene chloride, acetone, n-butyl alcohol, and dimethyl aniline.

Biocraft evaluated several cleanup alternatives and settled on a biodegradation process. The system included the following:

- Collecting the contaminated plume downgradient of the source in a slotted-pipe collection trench and two interceptor wells
- Treating the collected ground water in a surface aerobic biological treatment system
- Injecting the treated water upgradient of the source in two slotted-pipe recharge trenches to flush the soil of contaminants
- Stimulating in situ biodegradation of contaminants in the subsurface by injecting air through a series of aeration wells along the path of ground-water flow

The system has proven to be quite effective. After 3 years of operation, the contaminant plume was reduced by approximately 90 percent.

at full scale at sites containing PCBs, plating wastes, and process sludges. For ground water, it is probably only practicable for shallow, discontinuous, low-productivity zones because of the additional energy required for vaporization.

5.3.2 Plume Containment or Gradient Control

Plume containment refers to minimizing the spread of a plume through hydraulic gradient control, which can be either active (e.g., by using pumping wells or French drains) or passive (e.g., by using a slurry wall). These options rely on the prevention of exposure for the protection of human health. Slow contaminant removal (for gradient control systems) or natural attenuation may gradually achieve cleanup levels within the contained area. Conditions that potentially favor the use of a containment alternative include:

- Ground water that is naturally unsuitable for consumption (e.g., Class III aquifers)
- Low mobility contaminants
- Low aquifer transmissivity
- Low concentrations of contaminants
- Low potential for exposure
- Low projected demand for future use of the ground water

5.3.3 Limited or No Active Response

This category of response action includes two distinct alternatives: (1) a natural attenuation alternative that includes monitoring and institutional controls that should be developed in many cases as a point of comparison; and (2) wellhead treatment or provision of an alternate water supply with institutional controls, when active restoration or containment is not feasible or practicable.

5.3.3.1 Natural Attenuation with Monitoring

Natural attenuation relies on the ground water's natural ability to lower contaminant concentrations through physical, chemical, and biological processes until cleanup levels are met. Natural attenuation generally is a long-term response action that continues until cleanup levels have been attained throughout the area of attainment, when the site can be removed from the National Priorities List. Natural attenuation should be carried through the detailed analysis as a point of comparison, but it is not generally recommended except when active restoration is not practicable, cost-effective, or warranted because of site-specific situations; e.g., Class III ground water is contaminated. A natural attenuation response action generally includes monitoring to track the direction and rate of movement of the plume, as well as responsibility for maintaining effective, reliable institutional controls to prevent use of the contaminated ground water. The use of institutional controls should not, however, substitute for active response measures, unless such measures have been determined not to be practicable based on the balancing of tradeoffs among alternatives that is conducted during the selection process. Conditions that potentially favor the use of natural attenuation include the factors listed under Section 5.3.2, as well as conditions appropriate under CERCLA Section 121(d)(2)(B)(ii) (discharge to surface water). For example, when contaminants are expected to attenuate to health-based levels in a relatively short distance or when there is a narrow strip of land between the discharge stream where contaminant levels are not expected to increase,

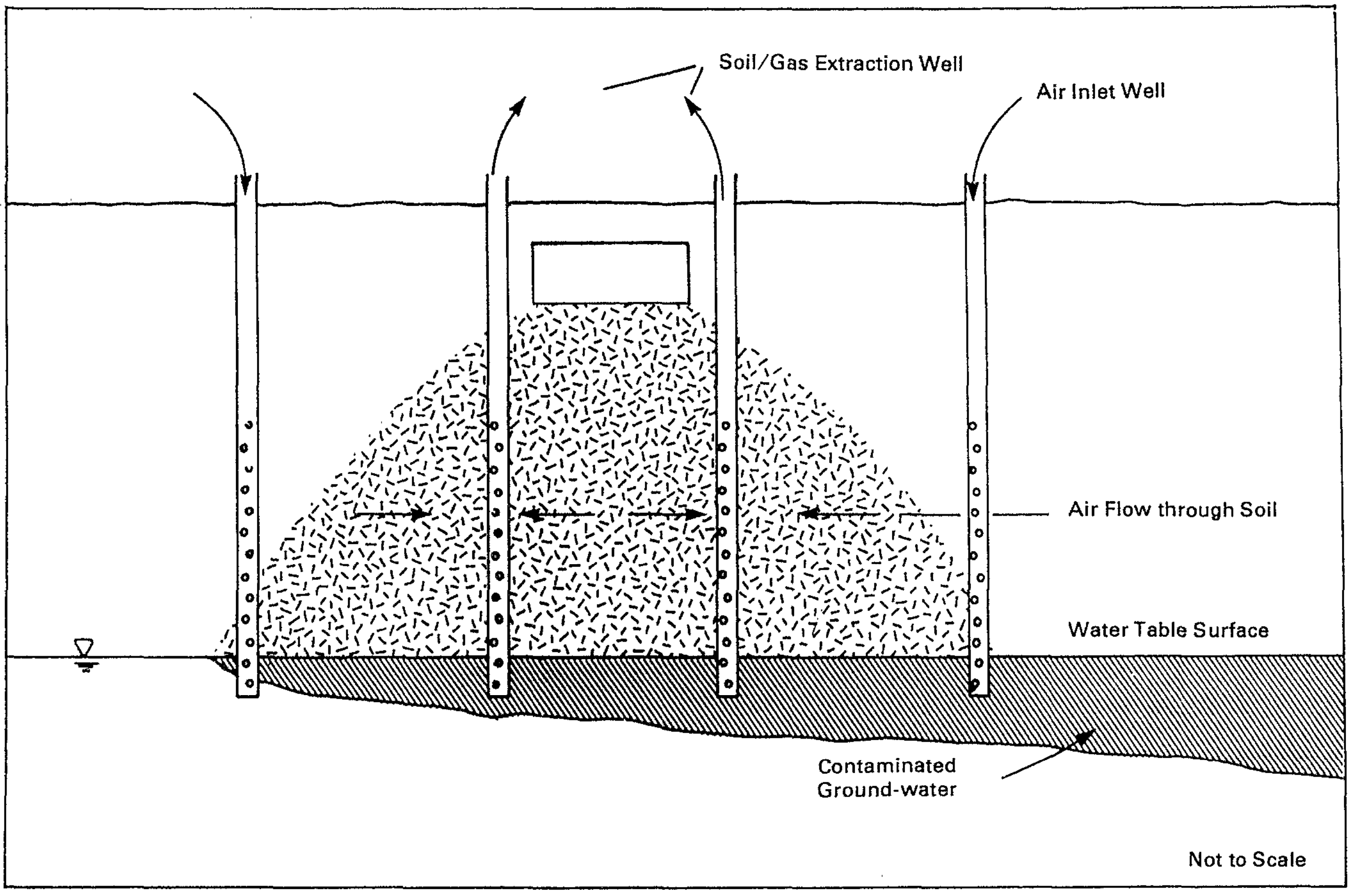


Figure 5-2. Schematic of a Soil Vapor Extraction System.

natural attenuation may be the most practicable response.

5.3.3.2 Special Situations Requiring Wellhead Treatment or Alternate Water Supply and Institutional Controls

There are special situations when it may not be practicable or feasible to fully restore ground water. Widespread plumes, hydrogeological constraints, contaminant-related factors, and physical/chemical interactions may limit the effectiveness of active restoration. Natural attenuation and wellhead treatment with monitoring and institutional controls may be the only feasible remedies for these sites. A technical impracticability waiver from meeting an MCL in drinkable ground water may be needed in these circumstances. If levels of contaminants are projected to attenuate, a waiver may not be necessary if cleanup levels will be achieved in a reasonable time frame (i.e., less than 100 years).

Widespread plumes that frequently cannot be remediated feasibly can result from the following situations:

- Sites in industrial areas where shallow ground water is easily contaminated--In these cases, remediation may be difficult because the ground water could easily be recontaminated and specific point sources cannot be identified. This does not include the case where separate sources can be identified, which should be addressed using the multiple source ground-water policy described in Appendix B.
- Mining and pesticide sites--These sites have high volumes of wastes that generally cover large areas.

Hydrogeological constraints that can limit the effectiveness of active restoration occur when plumes migrate into formations from which they cannot easily be removed. Although some level of contaminant reduction can usually be achieved, complete restoration to health-based levels may not be feasible. These situations include:

- Contaminant migration into fractured bedrock
- Contaminant migration into karst aquifers
- Sites at which the transmissivity of the aquifer is less than 50 ft^2/day

Contaminant-related factors include situations where the nature of the contaminant makes restoration difficult. For example, when DNAPLs migrate to ground water, they frequently sink to the less permeable material at the base of the aquifer, accumulating in isolated areas above the less permeable material. Generally, these contaminants can only be removed by extraction directly at the points of accumulation, which often cannot be identified practicably. In such cases, a remedy involving extraction wells or an interceptor trench between the site and any drinking water wells to collect the DNAPLs as they dissolve may be the only feasible remedy.

Physical/chemical interactions, such as partitioning, can limit the effectiveness of restoration. As discussed in Chapter 3, the rate at which contaminants desorb from the aquifer material limits the rate at which the aquifer can be restored. Factors that influence sorption include the length of time the contaminants have been in contact with the aquifer material and the organic content of the soil. Sometimes the organic content of the soil is artificially increased by the presence of long-chain hydrocarbons in the plume.

5.4 Formulating and Screening Alternatives

A range of remedial technologies can be combined under a particular general response action. Figure 5-3 provides an overview of some of the technologies available for a ground-water remedial action. Alternatives are developed from combinations of these various process options.

Examples of remedial alternatives include the following:

- *Active restoration*--Three extraction wells pumping at a rate of 10 gpm to a carbon adsorption unit and discharging to a POTW
- *Plume containment*--Installation of a bentonite barrier wall and use of well construction permits to prevent new well installation within the area of the plume
- *Natural attenuation*--Monitoring of ground water for 10 years when contaminant levels are expected to attenuate to health-based levels
- *No Active Response*--Development of ACLs and issuance of well-construction restrictions

The components that are incorporated in a remedial alternative can include extraction, containment, treatment, discharge, and institutional controls. Information on the uses and limitations of these technologies is presented in EPA's *Handbook for Remedial Action at Waste Disposal Sites* (U.S. EPA, 1985a).

The final step in the alternative development process is to develop a limited number of alternatives. In general, the approach for developing alternatives applies to Class I and Class II ground water. Class III ground water is treated separately and is described in Section 5.4.2.

5.4.1 Ground Water That is a Current or Potential Source of Drinking Water

A rapid remedial alternative generally should be developed for ground water that is a current or potential source of drinking water. This alternative should achieve the selected cleanup level throughout the area of attainment within the shortest time technically feasible. Additional alternatives should be developed to ensure that a wide range of distinctive hazardous waste management strategies are evaluated at most sites. Natural attenuation to health-based levels often is a baseline alternative for comparison with other alternatives.

Typically, three to five alternatives will be carried through to detailed analysis. Screening criteria that can be used to evaluate and narrow the range of alternatives are as follows:

- *Effectiveness* in reducing contaminant levels in the plume, attaining ARARs or other health-based levels, and protecting human health and the environment
- *Implementability* with respect to technical and administrative feasibility of the alternatives and the availability of needed technologies and services
- A general *cost* analysis to identify alternatives that are significantly more costly than other alternatives that achieve the same level of plume reduction

For ground water, a screening step is often unnecessary because active restoration, containment, and natural attenuation alternatives normally will be evaluated.

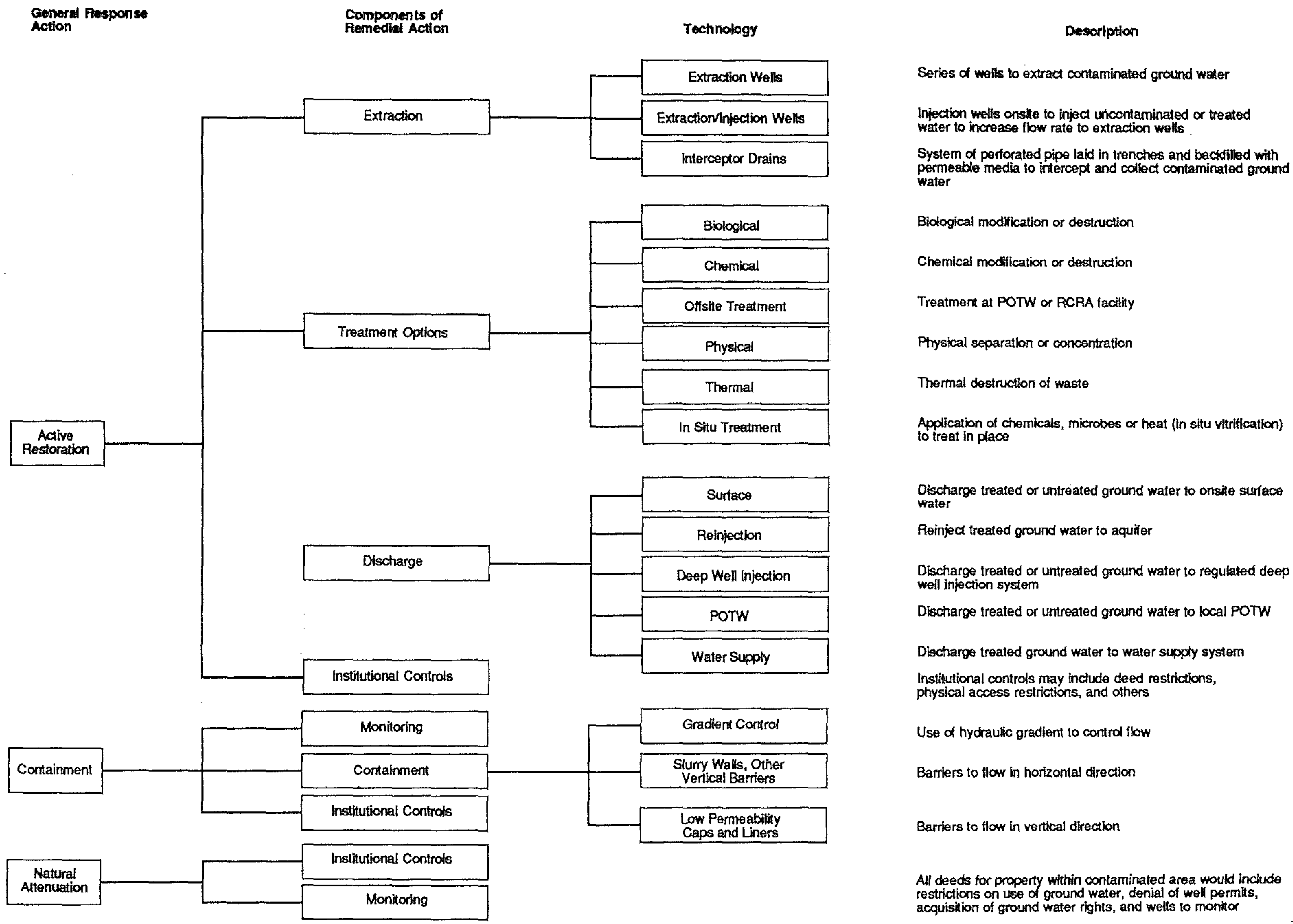


Figure 5-3 General Response Actions and Process Options for Ground Water.

Alternatives that do not meet ARARs or protect human health and the environment should be screened out, as should alternatives that are orders of magnitude more costly than other protective alternatives, or that pose implementability problems that are high relative to other protective alternatives, as reflected by the cost and time needed to surmount the problem.

5.4.2 *Ground Water That Is Not Current or Potential Drinking Water*

If a Superfund site has ground water that is unsuitable for human consumption i.e., Class III, a limited number of alternatives should be developed on the basis of the specific site conditions. Environmental receptors that are potentially affected or other beneficial uses such as agricultural or industrial uses, will often be the critical factors used when selecting cleanup levels. Also, the spread of contamination to uncontaminated drinkable ground water should be prevented, as should further migration from the source. If Class III ground water is interconnected with ground water that is a current or potential drinking water source, i.e., Class I or Class II, remediation may be required to protect the higher use ground water. The range of ground-water remedial alternatives developed for Class III ground water will usually be relatively limited, and the evaluation will be less extensive than for Class I or Class II ground water.

Chapter 6
Detailed Analysis of Alternatives and Selection of Remedy

6.1 Introduction

During the detailed analysis, remedial alternatives that have been retained from the alternative development phase are analyzed against nine evaluation criteria, which are described in this chapter. The purpose of the detailed analysis is to compare alternatives so that the remedy that offers the most favorable balance among the nine criteria can be selected. This chapter discusses these evaluation criteria and how they may apply to sites with ground-water contamination. An example of how the criteria are used at a particular site is presented in the case study, found in Appendix A.

6.2 Evaluation Criteria

The analysis of a remedial action for ground water is made on the basis of the following nine evaluation criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The first two criteria are actually requirements; the selected remedy must protect human health and the environment and attain ARARs or provide grounds for invoking a waiver. Alternatives are analyzed using the next five criteria to determine how they compare to one another and to identify tradeoffs between them. The final two criteria are modifying considerations and can only be evaluated in the FS to the extent that the affected state and community have submitted formal comments at this point in the process. Typically, these considerations will not be taken into account until the ROD is prepared following the public comment period on the proposed plan and RI/FS report.

Chapter 7 of the *RI/FS Guidance* (U.S. EPA, 1988c) presents a recommended format for conducting the detailed analysis. The basic features of each of the alternatives are described. Then, a comparative analysis is undertaken to examine the relative performance of the alternatives under each of the nine criteria. A narrative discussion and summary table are prepared for each part of the detailed analysis. The recommended remedy must be protective, attain ARARs, be cost-effective, and use permanent solutions and treatment technologies to the maximum extent practicable, which is determined primarily by balancing the next five criteria, as modified by state and community acceptance.

6.2.1 Overall Protection of Human Health and the Environment

This criterion addresses whether the remedy is protective of human health and the environment considering the site's characteristics. The remedy's long-term effectiveness and permanence, short-term effectiveness, toxicity, mobility, and volume reduction affect the evaluation of this criterion. How each alternative achieves protection over time and whether site risks are eliminated, reduced, or controlled are also analyzed.

At sites with ground-water contamination, overall protection from ground-water contaminant exposure is based largely on the certainty that a remedy can achieve and maintain cleanup levels.

6.2.2 Compliance with ARARs

Unless a waiver has been obtained for a particular ARAR or an ACL under Section 121(d)(2)(B)(ii) has been obtained for a chemical-specific ARAR, the selected remedy must comply with all location-, action-, and chemical-specific ARARs.

Six waivers to meeting ARARs are contained in CERCLA. They include the following:

- Interim remedy
- Greater risk to human health and the environment
- Technical impracticability
- Equivalent standard of performance
- Inconsistent application of State requirements
- Fund-balancing

These waivers and their potential use at sites with ground-water contamination are explained below.

6.2.2.1 Interim Remedy

An interim remedy can be part of the final remedy or it can be a partial remedy that is implemented while the final remedy is under construction or while the necessary arrangements for the final remedy (e.g., obtaining permits) are made. This waiver generally would not be used for ground-water contamination situations unless the ARAR for an operable unit that was taken as a final action was being waived. For example, long-term storage of treatment residuals while a process for managing the residuals is being arranged may require a waiver of applicable land disposal restrictions.

6.2.2.2 Greater Risk to Human Health and the Environment

If meeting an ARAR requires a remedial action that could increase health or environmental risk, and that remedial action was considered solely to meet an ARAR, the ARAR should be waived. Also, the effect on public and worker safety of implementing such a remedy should be assessed. For example, if State air standards require that a carbon adsorption unit be placed on an air-stripper designed to remove volatiles from contaminated ground water, but naturally occurring radionuclides in the ground water accumulate on the carbon to the extent that risk levels increase, it may be appropriate to waive the ARAR.

Factors that should be considered when invoking this waiver include the magnitude, duration, and reversibility of the adverse effects. In addition, the implications of meeting or not meeting an ARAR must be weighed before the waiver can be justified.

6.2.2.3 Technical Impracticability

Technical impracticability implies an unfavorable balance of engineering feasibility and reliability. The term "engineering perspective" used in CERCLA implies that cost, although a factor, is not generally a major factor in the determination of technical impracticability. This waiver may be used when neither existing nor innovative technologies can reliably attain the ARAR in question; or attainment of the ARAR is not practicable from an engineering perspective. For ground-water remedies, technical impracticability may be measured in terms of restoration time frame. A time frame beyond 100 years would generally warrant the technical impracticability waiver.

6.2.2.4 Equivalent Standard of Performance

This waiver is used when an ARAR is stipulated by a particular design or operating standard, but equivalent or better results (e.g., contaminant levels, worker safety, or reliability) could be achieved using an alternative design or method of operation.

It is anticipated that this waiver will generally be inappropriate for ground-water remedies, as most ARARs for ground-water are chemical specific rather than action specific.

6.2.2.5 Inconsistent Application of State Requirements

This waiver is intended to prevent unreasonable restrictions from being imposed on remedial actions. A standard must be promulgated in order for it to be an ARAR. This waiver is used in two situations: (1) when State requirements have been developed and promulgated but never applied because of their lack of applicability in past situations (such requirements should not be applied in CERCLA actions if there is evidence that the state does not intend to apply them to non-CERCLA actions that are otherwise similar); and (2) when State standards have been variably applied or inconsistently enforced.

The consistency of application may be determined by:

- Similarity of sites or response circumstances (nature of contaminants or media affected, characteristics of waste and facility, degree of danger or risk, etc.)
- Proportion of non-compliance cases (including enforcement actions)
- Reason for non-compliance
- Intention to consistently apply future requirements as demonstrated by policy statements, legislative history, site remedial planning documents, or State responses to sites at which EPA is the lead agency. Newly promulgated requirements are presumed to embody this intention unless there is contrary evidence.

6.2.2.6 Fund-Balancing

The Fund-balancing waiver may be invoked when meeting an ARAR would entail extremely high costs in relation to the added degree of protection or reduction of risk afforded by that standard and when remedial action at other sites would be jeopardized (because of lack of funds) as a result. The following criteria should be considered when invoking the Fund-balancing waiver for ARARs:

- *Cost*--Fund balancing is only appropriate if the relative level of the cost is high.
- *Availability of Superfund Monies to Respond to Other Sites*--Projections should show that significant threats from other sites may not be addressed under the current level of Superfund monies.

6.2.3 *Long-Term Effectiveness and Permanence*

The next criterion used to evaluate and compare alternatives is long-term effectiveness and permanence. This criterion addresses how well a remedy maintains protection of human health and the environment after remedial action objectives have been met. Components of analyzing long-term effectiveness include examining the magnitude of residual risk and the adequacy and long-term reliability of management controls. For example, a ground-water remedy involving recharge might be selected because recharge preserves the ground water as a resource while the remedy is in place as well as after the action is terminated. The source control action will also affect the long-term effectiveness of the ground-water remedy since actions that do not fully address migration from the source or that have a lower probability of reducing or eliminating contaminant migration to ground water will ultimately reduce the effectiveness of the ground water action. The probability of attaining cleanup levels, particularly in complex or technically limiting situations such as those described in Section 5.3.3.2, should also be considered under this criterion.

6.2.4 *Reduction of Mobility, Toxicity, or Volume*

The anticipated performance of treatment technologies used in the alternatives is evaluated under this criterion. The amount of hazardous material destroyed or treated and the amount remaining onsite is assessed, along with the degree of expected reduction in mobility, toxicity, or volume. In addition, the degree to which the treatment is reversible is evaluated. For ground water, this might be evaluated by calculating the proportion of the contaminant plume that is remediated. This criterion is also related to the preference for treatment as a principal element. In determining whether the preference is satisfied, all of the principal threats posed by the site must be considered. Ground-water contamination will typically comprise a principal threat at many Superfund sites, but if source or soil threats are also present, treatment only of ground water would not satisfy the preference.

6.2.5 *Short-Term Effectiveness*

The effectiveness of the alternative in protecting human health and the environment during construction and implementation is assessed under the short-term effectiveness criterion. The length of time required to achieve protection, the short-term reliability of the technology, and protection of the community and of workers during remediation are considered. The time frame for plume removal is analyzed with reference to onsite and offsite human and environmental exposure points. This evaluation should include consideration of short-term and cross-media impacts that may be posed during implementation of the remedy. Short-term effects such as the disruption to residential neighborhoods or sensitive environments caused by construction of a slurry wall, for example, should also be evaluated.

6.2.6 *Implementability*

The technical and administrative feasibility of alternatives as well as the availability of needed goods and services are evaluated to assess the remedy's implementability. The factors that make up the implementability criterion are as follows:

- Ability to construct, operate, and maintain the technology; e.g., a slurry wall generally is more difficult to construct than a ground-water extraction system alone and thus may receive a less favorable evaluation under this criterion.
- Ability to phase in other actions, if necessary; e.g., a ground-water extraction system implemented prior to the source control action may restrict the type of source control actions that could be implemented.
- Ease of undertaking additional remedial actions, if necessary; e.g., the capacity of an air-stripper and its ability to treat larger volumes of ground water may make it a more favorable option than an alternative using a system limited to low ground-water flow rates.
- Ability to monitor the effectiveness of the remedy; e.g., variations in ground-water monitoring requirements, the length of time that monitoring is required, the frequency of monitoring, and the depth of monitoring might be compared for different alternatives.
- Ability to obtain approvals and permits from other agencies (for offsite actions); e.g., obtaining approval to discharge to a POTW may be more difficult than meeting the substantive NPDES requirements for discharging to surface water.
- Coordination with other agencies; e.g., certain remedies may require more coordination with local agencies, such as approval to discharge to a POTW.

- Availability of hazardous waste treatment, storage, and disposal facilities to dispose of treatment residuals, and their capacity; e.g., remedies that generate ground-water treatment residuals such as sludges or spent carbon may be less favorable under this criterion than remedies that do not.
- Availability of necessary equipment and specialists; e.g., innovative treatment techniques may be less implementable than treatment techniques that are in common use.

6.2.7 Cost

Capital and operation and maintenance costs are evaluated for each alternative. These costs include design and construction costs, remedial action operating costs, other capital and short-term costs, costs associated with maintenance, and costs of performance evaluations, including monitoring. All costs are calculated on a present worth basis.

6.2.8 State Acceptance

This analysis will usually be deferred to the ROD following receipt of public comments. During the FS, it is limited to formal comments made by the state during previous phases of the RI/FS. Technical and administrative issues that the state may have concerning each alternative action are identified and analyzed. Features that the state supports, features that the state may have reservations about, and features that the state opposes are discussed.

6.2.9 Community Acceptance

The evaluation of community acceptance is analogous to the evaluation made for State acceptance and generally is deferred until ROD preparation. Comments received from the public are assessed to determine aspects of each remedy that are supported or opposed.

6.3 Selection of Remedy

The selection of a remedial action from among alternatives is a two-step process. First, a preferred alternative is identified and presented to the public in a proposed plan along with the supporting information and analysis for review and comment. Second, the lead agency reviews the public comments, consults with the support agency to evaluate whether the preferred alternative is still the most appropriate remedial action for the site, and makes a decision.

As discussed in Section 6.1, the remedies are selected by balancing the nine evaluation criteria. First, it should be confirmed that all alternatives provide adequate protection of human health and the environment and either attain or exceed all of their ARARs or provide grounds for invoking a waiver of an ARAR. As part of the balancing, total costs of each alternative should be compared to the overall effectiveness each affords. The costs and the overall effectiveness of the alternatives should be examined to determine which alternatives offer results proportional to their costs. This might be accomplished by comparing the relative plume reduction to the cost for various restoration alternatives.

The preferred alternative is selected by evaluating the relative long-term effectiveness; short-term effectiveness; reduction in toxicity, mobility, or volume; implementability; and cost of the alternatives. The alternative that represents the best combination of those factors deemed most important to the site will be chosen. In performing the necessary balancing, the preference for remedies involving treatment as a principal element must be considered. The proposed plan will identify the alternative that appears to offer the best balance of the tradeoffs among the alternatives in terms of the criteria and confirm the expectation that all statutory requirements would be satisfied.

In making the final selection, the balancing is reassessed in light of any new information or point of view expressed in the comments. The relationship between costs and overall effectiveness is reexamined and the balancing analysis is reevaluated, this time taking into account not only the preference for treatment as a principal element, but also the modifying considerations of State and community acceptance. After this step, either the original preferred alternative or another cost-effective alternative that provides a better combination of the balancing criteria is selected. Using this process, the selected remedy will represent the protective, cost-effective solution for the site or problem that uses permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable. This finding, along with a discussion of how each of the statutory requirements are satisfied, should appear in the ROD.

Typically, a ROD for ground-water action should include the following components:

- A summary of the site characterization and baseline risk assessment performed in the RI
- A summary of the alternatives examined in detail and the comparative analysis undertaken in the FS
- Remedial action objectives defined in the FS; for the selected remedy, the ROD should describe:
  - Cleanup levels
  - Area of attainment
  - Estimated restoration time frame

- A description of technical aspects of the remedy, such as the following:
  - Expected pumping and/or flow rates
  - Number of extraction wells
  - Treatment process
  - Control of cross-media impacts
  - Management of residuals
  - Gradient control system description
  - Type of institutional controls and implementing authority

In many cases, the performance of remedies for restoring contaminated ground water can only be evaluated after the remedy has been implemented and monitored for a period of time. The remedial action objectives should be presented as estimates or ranges so that a reasonable degree of change can be accommodated during the design and implementation without having to develop a new ROD. A variation of this is to allow for a reasonable degree of change in the goal of the remedy based on experience gained during remediation. For example, a ground-water extraction and treatment remedy might include two scenarios: (1) ground-water extraction continues until cleanup goals are attained or (2) ground-water extraction continues until contaminant levels in the extracted water reach a constant value or asymptote (e.g., contaminant mass is no longer being removed at significant levels), at which point portions of the plume that remain above the cleanup levels are managed through containment and use of institutional controls. This type of remedy has been used in the underground storage tank program.

The information that should be presented in the ROD for an interim action operable unit can be found in Appendix C.

Chapter 7
Evaluating Performance and Modifying Remedial Actions

7.1 Introduction

Even when a detailed hydrogeologic investigation has been performed, the complex behavior of contaminants in ground water, combined with the heterogeneity of hydrogeologic systems, make predicting the effectiveness of remediation difficult. This chapter presents a conceptual discussion of evaluating performance and modifying remedial actions. Administrative requirements associated with changes in a remedial action and elements of a performance evaluation program are identified and discussed.

Performance evaluations of the full-scale remedial action, based on the monitoring data discussed in Section 7.4, are conducted periodically to compare actual performance to expected performance. The frequency of performance evaluations should be determined by site-specific conditions. Conducting performance evaluations and modifying remedial actions is part of a flexible approach to attaining remedial action objectives. Decisions can be verified or modified during remediation to improve a remedy's performance and ensure protection of human health and the environment.

7.2 Modifying Decisions

Figure 7-1 represents a decrease in contaminant concentration over time for three ground-water remedial actions of varying effectiveness. Line A represents a remedial action that is meeting design expectations, and the desired cleanup levels are predicted to be reached within the anticipated time. Line B represents a remedial action that is predicted to achieve the cleanup levels, but the action will have to be operated longer than anticipated. Line C represents a remedial action that will not achieve the desired cleanup levels for a long time, if ever, without modifying the remedial action. Performance evaluations provide information about whether remedial action objectives can be met using the selected alternative.

Performance evaluations should be conducted 1 to 2 years after startup to fine-tune the process. More extensive performance evaluations should be conducted at least every 5 years. After evaluating whether cleanup levels have been, or will be, achieved in the desired time frame, the following options should be considered:

- Discontinue operation
- Upgrade or replace the remedial action to achieve the original remedial action objectives or modified remedial action objectives
- Modify the remedial action objectives and continue remediation, if appropriate

The performance evaluation program may indicate that the remedial action objectives have been met and the remedy is complete. In other cases, operational results (e.g., contaminant mass removal has reached insignificant levels) will demonstrate that it is technically impracticable to achieve cleanup levels in a reasonable time, and a waiver to meeting ARARs may be required. Additional information, onsite conditions, or other factors may indicate that cleanup levels can be adjusted to less stringent levels and still protect human health and the environment.

These options provide the decision-maker with flexibility to respond to new information and changing conditions during the remedial action. Figure 7-2 illustrates this flexible decision process.

7.3 Modifications to Records of Decision

Three types of changes can occur in a remedy following ROD signature: minor changes, significant changes, and fundamental changes. Minor changes, such as the decision to move the location of a well or minor cost or time changes, are those technical or engineering changes that do not significantly affect the overall scope, performance, or cost of the alternative and fall within the normal scope of changes occurring during the remedial design/remedial action engineering process. Such changes should simply be documented in the post-decision document file and, optionally, can be mentioned in a remedial design fact sheet, which is often issued as part of the community relations effort. Significant changes to the remedy in terms of scope, performance, or cost are explained in an Explanation

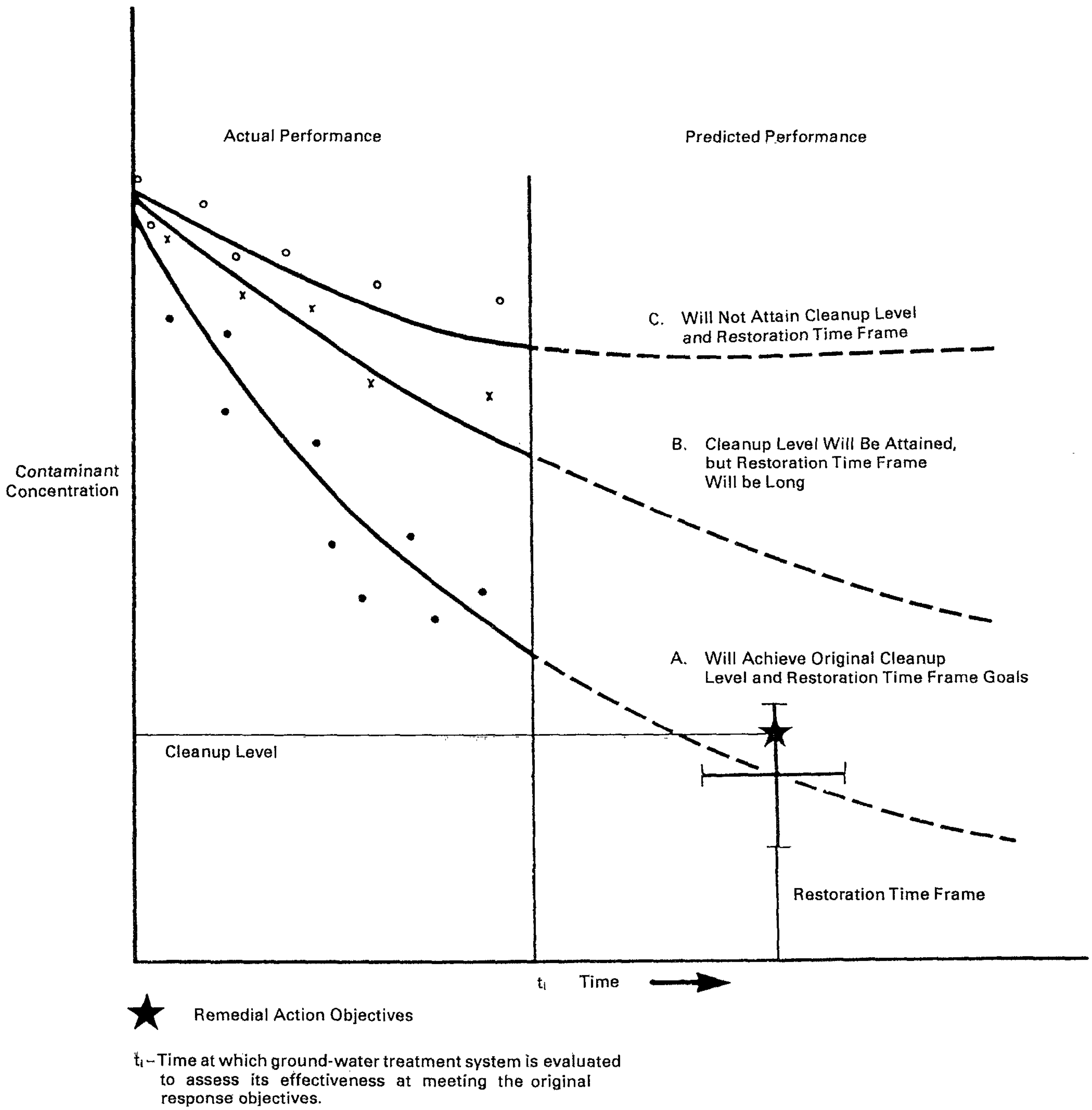


Figure 7-1 Predicting Remedial Action Performance from Monitoring Data.

of Significant Differences provided for under CERCLA Section 117(c). This document describes the differences and what prompted them and is announced in a newspaper notice. This is placed in the administrative record for the site, along with the information that prompted the change. Significant changes involve a component of the remedy, such as a change in the volume of contaminated ground water that must be addressed, or a switch from air stripping to carbon adsorption in a ground-water pump and

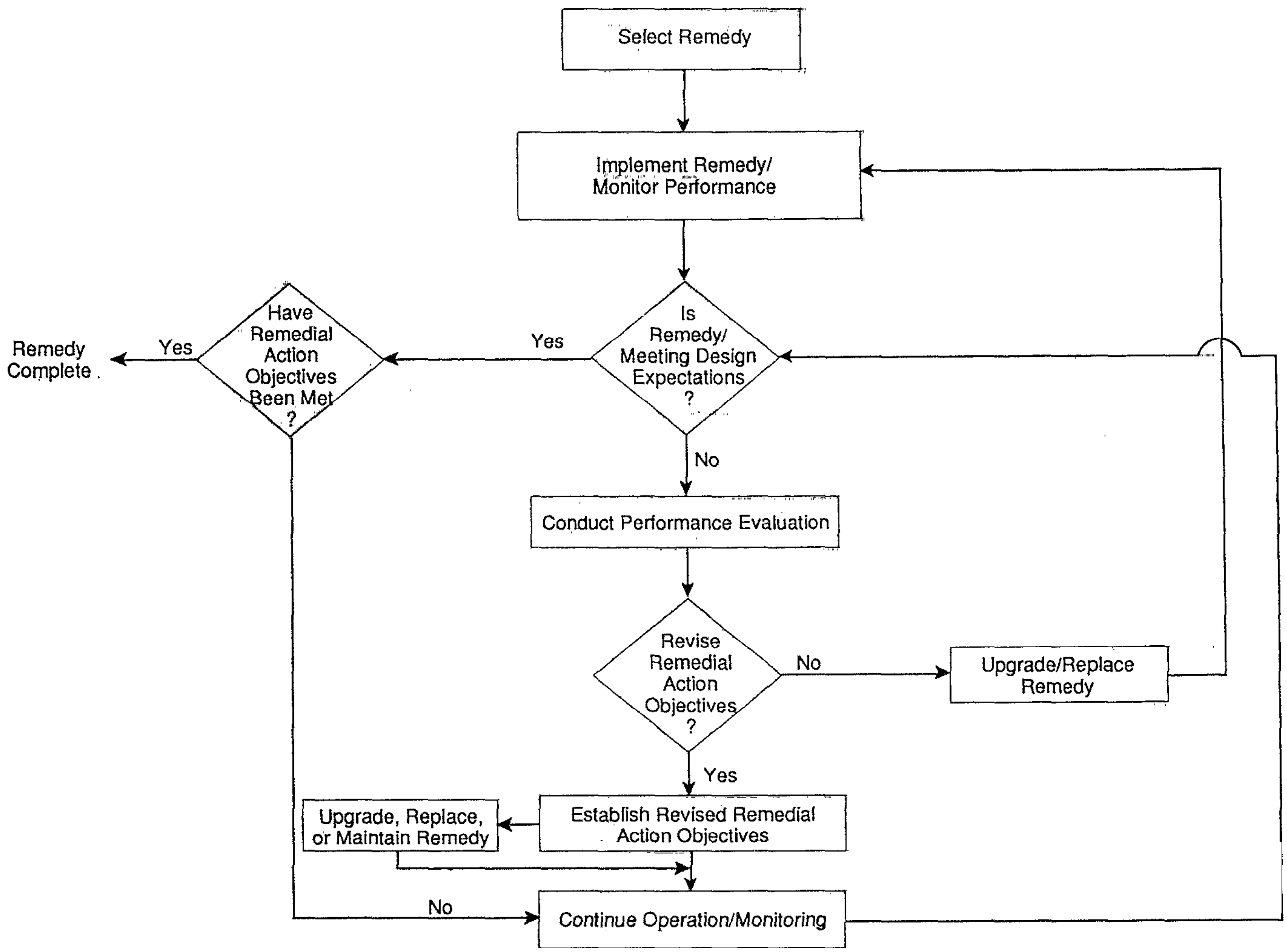


Figure 7-2 Flexible Decision Process for Ground-Water Remedial Actions.

treat remedy, but do not fundamentally alter the hazardous waste management strategy represented by the selected remedy.

Fundamental changes are changes in the overall waste management strategy for the site; they require amendments to the original ROD. A change from active restoration to passive restoration would be considered a fundamental change. Procedures for amending a ROD are the same as for issuing a ROD. They include the following:

- Preparation of a proposed amendment
- Issuance of a newspaper notice announcing the proposed amendment
- A public comment period
- Finalization of the amendment

- Preparation of a responsiveness summary
- Placement of the amendment and responsiveness summary into the administrative record
- Publication of a newspaper notice announcing finalization of the amendment

7.4 Performance Monitoring

This section provides guidelines for using ground-water monitoring data to evaluate performance. It does not provide detailed information on technical aspects of ground-water monitoring, such as well installation techniques or sampling procedures. The *TEGD* (U.S. EPA, 1986e) is one resource for this information.

The monitoring system should be designed to provide information that can be used to evaluate the effectiveness of the remedial action with respect to the following:

- Horizontal and vertical extent of the plume and contaminant concentration gradients, including a mass balance calculation, if possible
- Rate and direction of contaminant migration
- Changes in contaminant concentrations or distribution over time
- Effects of any modifications to the original remedial action
- Other environmental effects of remedial action, such as saltwater intrusion, land subsidence, and effects on wetlands or other sensitive habitats

7.4.1 Well Locations

Because ground-water contamination problems are site specific, the number and locations of monitoring wells must suit site conditions and the remedial action selected. In general, wells should be located upgradient (to detect contamination from other sources), within the plume (to track the response of plume movement to the remedial action), and downgradient (either to verify anticipated responses or to detect unanticipated plume movement). Also, monitoring should reflect both horizontal and vertical ground-water flow. If a containment system is used, wells or other detection devices should also be located where contaminant releases are most likely to occur.

7.4.2 Sampling Duration and Frequency

A determination that the remedial action is complete may require a statistical analysis of contaminant levels. The Office of Policy, Planning, and Evaluation is preparing guidance for using statistics to assess ground-water monitoring data. Also, OSW has prepared guidance for using statistics to evaluate ground-water monitoring data at RCRA sites (U.S. EPA, 1987m). This guidance may provide useful information for Superfund sites as well.

The intervals between sampling events should be shortest at the beginning of the remedial action. In many cases, monthly sampling intervals may be reasonable during the first year. Data collected during the first year may be used to assess gaps in the data, further characterize the aquifer, identify locations for additional monitoring, and evaluate sources of uncertainty, such as sampling, analysis, and site conditions.

The recommended long-term frequency for sampling depends in part on the effectiveness of the remedial action as determined through the ongoing monitoring program. If monitoring shows a steady, predictable decrease in contaminant concentrations in the aquifer, reducing the sampling frequency may be reasonable. The determination of long-term sampling frequency may also depend on the rate of plume migration, the proximity of downgradient receptors, and the variability of the ground-water data and the degree of confidence needed for achieving the cleanup level at a specific location. Quarterly sampling may be reasonable for long-term monitoring at some sites.

Monitoring data provide the basis for determining when remedial action objectives have been met and when the remedial action is complete. Special analytical services may be needed in some cases to confirm cleanup levels that are lower than the standard detection limit. Operation should continue for a limited time after cleanup levels have been achieved. In many instances, contaminant levels in the aquifer increase when pumping is terminated because contaminants are allowed to re-equilibrate in the ground water. This phenomenon would be observed if the rate at which ground water was removed through pumping is greater than the rate of desorption of contaminants. Monitoring programs should therefore ensure that ground water is sampled until any residual contaminants could have desorbed from the aquifer material.

7.4.3 Source Control Monitoring

Another goal of performance monitoring is to ensure that any source control action completed at the site effectively prevents further degradation of ground water. To achieve this goal, it may be necessary to monitor the unsaturated zone using techniques such as soil-gas monitoring to detect contaminants before they reach the ground water.

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Appendix A
Case Study with Site Variations

A.1 Site Location and Background

The Hypo-Thetical site, located on 50 acres near a suburban area in the Midwest, is an industrial landfill that received heavy commercial use. On the basis of interviews and the site history, it is believed that the hazardous wastes disposed at the site were organic solvents from a solvent recycling firm that has since ceased operation. Apparently, the firm also used a small area of the site to clean auto interiors with organic solvents.

Currently, nearby residents use wells for drinking water; 50 active wells have been identified in the area. The ground water is not an irreplacable source of drinking water because domestic water use could economically be tied into a municipal water supply system that relies on surface water reservoirs from a nearby mountain range. For this reason, the ground water used for drinking water is classified Class IIA for the purpose of the Superfund remedial activities.

A.2 Ground-Water Considerations During Scoping

During scoping, several questions were raised to assist in planning the RI/FS. These are identified and discussed in the following paragraphs.

What Is the Existing Information?

The following important information, related to exposure pathways, the hydrogeology of the site, and contaminants disposed at the site, was known during the scoping phase:

- Nearby residents are potentially exposed through the drinking water ingestion pathway. Heavy population growth is anticipated in the area; developers (HazVelop, Inc.) have already approached the county regarding residential development of the site in 5-acre parcels, in which homeowners would use private wells and septic fields.
- Potential exposure pathways to workers at commercial facilities near the site have not been identified.
- On the basis of existing drinking water well logs, shallow and deep ground water have been identified. The deep ground water, lying approximately 130 feet below the surface, is used for drinking water and is classified Class IIA. From a purview of the available well logs and a study of county and State hydrogeologic publications, the deep ground water appears to flow to the southeast. The shallow ground water, which has not yet been classified, was assumed to flow to the southeast as well, since the topography of the site slopes in this direction.

  The shallow zone, which appears to be perched on a clay layer, was noted at about 20 feet below the surface in some wells logs. In addition, well construction details indicate that gravel packs in some of the domestic wells extend from the shallow to the deep zones, thus providing a conduit for vertical movement of contaminants from the shallow zone.
- The site is located on glacial outwash.
- During the site inspection, an inlet to an underground storage tank was found. The tank was probably used to store solvents.
- Soil analyses conducted during the site inspection indicate that contaminants are probably limited to VOCs. At the conclusion of the site inspection, it was not clear if there were hot spots at the site that could be defined.

Is a Removal Action Warranted at the Site?

Domestic well samples taken during the site inspection indicated no contaminants above removal action levels; and a removal action did not appear justified based on the available site information. A fence was constructed to restrict public access to the facility.

What Are the Potential Exposure Scenarios?

To evaluate potential exposure scenarios, several ground-water monitoring wells were installed and screened in the shallow saturated zone. They were located in an area that is expected to be downgradient of the source. Contaminants were detected at the maximum concentrations shown in Table A-1. Aside from those expected to have originated from the site, no contaminants were

Table A-1. Concentrations of Chemicals in Ground Water Hypo-Thetical Site

Chemical	Range of Concentrations Reported[a] (µg/l)
Volatile Organic Compounds	
Benzene	20 - 120
Bromodichloromethane	5 - 56
Carbon disulfide	10 - 67
Chloroethane	15 - 1,000
1,1-Dichloroethene	50 - 1,900
Trans-1,2-dichloroethene	37 - 1,000
Methylene chloride	10 - 80
Phenol	20 - 1,500
Tetrachloroethene	45 - 650
1,1,1-Trichloroethane	12 - 1,500
Trichloroethene	6 - 1,200
Vinyl chloride	45 - 500
Phthalates	
Bis(2-ethylhexyl)phthalate	10 - 90
Di-n-butyl phthalate	8 - 45
Inorganics	
Aluminum	440 - 600
Barium	99 - 200
Calcium	10,300 - 20,750
Copper	20 - 80
Iron	999 - 1,500
Lead	5 - 7
Magnesium	4,000 - 7,000
Manganese	70 - 80
Nickel	2 - 5
Potassium	1,500 - 2,000
Sodium	6,550 - 10,000
Zinc	32 - 50

[a]Excludes samples in which the contaminant was not detected.

detected above health-based levels in the shallow ground water; therefore, it has been classified Class IIB, a potential source of drinking water. High contaminant levels near the underground tank indicate that the tank leaked or that some solvent was spilled when the tank was being filled.

The potential exposure scenarios that were identified during scoping include the following:

- Direct contact with contaminated soil by trespassers, including children who play at the site and teenagers who use the site for dirt biking
- Inhalation of VOCs from the vadose zone by nearby residents and workers (subsequent air sampling performed onsite indicated that contaminants are not present at detectable levels)
- Ingestion of contaminated ground water if the deep ground water is or becomes contaminated or if the shallow aquifer is used

What Are the Probable Ground-Water Response Objectives?

For both deep and shallow ground water, the ground-water response objectives are as follows:

- Prevent exposure to any contaminated drinking water
- Prevent contamination of the deep ground water, if it is indeed uncontaminated
- Restore contaminated ground water for future drinking water use

What Data Should Be Collected?

Data collected during the RI will be used to assess exposure from ground water and to characterize contaminant behavior in ground water as it affects remedy selection. Many of the ground-water remedies appropriate for this site require ground-water extraction. The data that should be collected to assess exposure include domestic well samples and monitoring well samples in both the deep and the shallow ground water. The data-collection effort that will be undertaken to characterize contaminant behavior as it affects remedy selection and its estimated costs include:

- Monitoring wells and piezometers in the deep and shallow ground water to determine the extent of contamination and interconnection between the aquifers at a cost of approximately $1,500 per well for the shallow wells and $6,000 per well for the deep wells
- TOC and contaminant concentrations in saturated soil cores to evaluate partitioning to the soil phase at a cost of $3,000 per sample for the analyses of volatiles, semi-volatiles, total metals, cyanide, and major cations and anions
- Aquifer test data to determine aquifer response and extraction effectiveness at a cost of approximately $15,000
- Contaminant degradation information

A.3 Removal Action

During the RI, after several private wells had been sampled and soil and ground-water data had been analyzed, it was determined that a removal action for ground water based on action levels or site-specific considerations was not warranted and that interim actions and a final action were appropriate.

A.4 Interim Action

As an interim action, the tank was drained and excavated and the surrounding soil was excavated and stored in a tank on the site. A vapor extraction system was installed in the excavated area, and the pit was backfilled. Low rate pumping of ground water was also initiated in this area. The low rate was used to ensure that pumping in this area would not increase contaminant migration from other source areas. After ensuring that the substantive requirements of the local POTW would be met, ground water was treated using an air stripper with a granular activated carbon system for air releases and discharged to a storm drain. As part of the RI, a well survey of the area was completed and an abandoned deep well screened in both the shallow and deep ground water was identified downgradient of the contaminant plume. A second interim action to seal the abandoned well was implemented.

To take these interim measures, a ROD, containing the information summarized in Table A-2, was prepared, and the five statutory requirements, listed below, were addressed:

- The action protected human health and the environment by reducing expansion of the plume, hence decreasing the likelihood of exposure. Contaminated soil was stored in a tank on the site; access was limited to workers.
- ARARs were not attained in the ground water, but final action to reach ARARs will be facilitated by the actions. Contaminated ground water was treated to specified pretreatment levels before being discharged to the storm drain. In addition, air monitoring of the aeration system indicated that releases did not exceed the levels specified by State regulations.
- The ground-water extraction system was relatively low in cost since the pumping rate was low. Both actions were cost-effective according to cost comparisons between (1) immediate prevention of plume expansion and (2) long-term remediation of a much larger plume that would be initiated 2 to 3 years after completion of the RI/FS and remedy design and construction.
- The extracted ground water was treated to required levels and thus met the statutory preference for treatment. The well seal also met the statutory requirement for permanent solutions to the maximum extent practicable.
- The interim action permanently and significantly reduced the volume of hazardous waste by removing and treating contaminants in soil and ground water.

While this interim action was being implemented, site characterization work continued, and the boundaries of contaminated soil and ground water were delineated. The interim action also aided the site investigation by providing aquifer parameters based on data from the pumping well. In addition to providing the hydraulic conductivity of the shallow aquifer, a nearby observation well screened in the deeper saturated zone indicated minimal interconnection between the upper and lower zones in this area.

A.5 Summary of the RI Report

Constituents found in the soil and the ground water include 1,1-dichloroethene (1,1-DCE), 1,1,1-trichloroethane (TCA), trichloroethene (TCE), tetrachloroethene (PCE), benzene, methylene chloride, vinyl chloride, and other volatile organic compounds (VOCs), as well as phenol, bis(2-ethylhexyl)phthalate (DEHP), and di-n-butylphthalate.

In the soil, identified hot spots represent approximately 4,000 cubic yards of contaminated soil (see Figure A-1). The concentration of VOCs in these hot spots is approximately 10,000 to 100,000 ppb. The volume of soil that is contaminated in addition to the 4,000 cubic yards is about 20 acre-feet (approximately 2 acres of soil contaminated to an average depth of 10 feet).

A continuous clay layer lies beneath the site, separating the shallow aquifer from the deep aquifer over several acres. Boring logs indicate that its thickness ranges from 15 to 20 feet, beginning at a depth of 40 to 45 feet below the surface. A silty sand layer with hydraulic conductivity of approximately 10^{-3} cm/sec occurs above and below the clay layer. The unconfined shallow aquifer is perched above the clay layer. Although the hydraulic conductivity of the clay is low (10^{-7} cm/sec), the presence of solvents can increase the conductivity. Consequently, monitoring of the lower aquifer continued throughout the investigation and implementation of the remedy. The clay layer drops to the southeast; consequently, the unconfined shallow ground water moves to the southeast, flowing at an estimated rate of 150 feet/year, as determined from the low-rate pumping test of the shallow ground water. At this rate, the plume will reach the edge of the clay layer and potentially contaminate the deep ground water in approximately 13 years, assuming there is no contaminant retardation because of sorption. The unconfined deep ground water moves to the southeast within the silty sand formation.

The deep ground water is not currently contaminated, but the shallow ground water is. There is a localized TCE plume with concentration levels in the 10,000 ppb range. This plume is believed to be related to the interior auto-cleaning activities at the site. A larger second plume covers 20 acres of the site. This plume contains a greater variety of the contaminants listed in Table A-1 and is believed to result from poor

Table A-2. Evaluation of the Operable Unit Taken as an Interim Action

Criterion	Tank Removal, Vapor Extraction System, and Ground-Water Extraction	Sealing Abandoned Well
Protects Human Health and the Environment	Yes, reduces spread of contaminants to potential exposure points.	Yes, reduces spread of contaminants to potential exposure points.
Meets ARARs	Meets ARARs for ground-water discharge; does not meet ARARs in the aquifer (i.e., health-based cleanup levels).	Yes, meets State well-sealing standards.
Is Effective Over the Short-term	Removal of tanks would prevent further source migration, soil-gas and ground-water extraction would reduce contaminant levels at the site and limit further contaminant migration. Action would also increase the short-term effectiveness of the final remedy.	Sealing the well would eliminate the potential for contaminant migration through this conduit in the short term.
Is Effective Over the Long-Term	Promotes long-term effectiveness by reducing contamination at the site.	Sealing the well would eliminate the potential for contaminant migration through this conduit in the long term.
Reduces Toxicity, Mobility, or Volume	Reduces volume by removing and treating high concentration zone	Not applicable to the scope of the action
Is implementable	Action can be implemented with minimal disruption of the ongoing investigation. Installation and monitoring of extraction systems will probably aid in the implementation of the final remedy.	Requires coordination between the water district, the municipal water suppliers, and the well owner. Details for the well sealing were discussed and agreed to at a meeting between the involved parties.
Is Cost-Effective	Action is expected to significantly reduce cost of final remedy at the site by reducing the volume of contaminated material to be remediated and by providing valuable design and operation information.	Action is considered to be of low cost compared to the cost of remediation if the contaminants migrate to the deeper zone.
Meets State's Acceptance	Yes, state approved.	Yes, state approved.
Meets Community's Acceptance	Yes, community strongly supports any action to remediate the site as early as possible, preventing contaminant migration.	Yes, community strongly supports any action to remediate the site as early as possible, preventing contaminant migration.

Comments: In addition to meeting the necessary statutory mandates, there was sufficient information to determine that these actions would not exacerbate the site problem and that the action would be consistent with the final remedy for the site, the goal of which is to reduce contaminant concentrations in the plume to heatlh-based levels.

management practices at the solvent recycling facility. The degradation characteristics of the contaminants vary; some of the organics degrade under natural conditions. Benzene, vinyl chloride, and phenol are relatively degradable, whereas the chlorinated methanes and ethanes are not.

The silty sand layers above and below the clay layer contain considerable organic material (8 percent), which increases the sorption potential of organic contaminants. Subsequently, a large fraction of contaminants with high organic carbon partition coefficient (K_{OC}) values, such as DEHP, will sorb onto the sediments. Assuming that the partitioning of the contaminants is currently at equilibrium, desorption of contaminants from the soil will occur with extraction of contaminated ground water. Contaminants with lower K_{OC} values will desorb at a faster rate than those with higher values. Initially, the rate of partitioning is governed by mass action. Therefore, an increased rate of extraction will enhance desorption until desorption becomes rate limiting. The concentration of contaminants at which desorption becomes rate limiting was estimated and is discussed in Section A.7, in conjunction with indicator chemicals.

A.6 Establishing Preliminary Cleanup Levels

Contaminant-Specific ARARs and TBCs

Two kinds of contaminant-specific ARARs exist for several of the contaminants detected at the site: Primary MCLs and State Unacceptable Pollutant Levels (UPLs). MCLs exist for eight of the contaminants detected at the Hypo-Thetical site, and UPLs exist for five.

Table A-3 presents contaminant-specific ARARs and TBC requirements applicable to the site. Cleanup

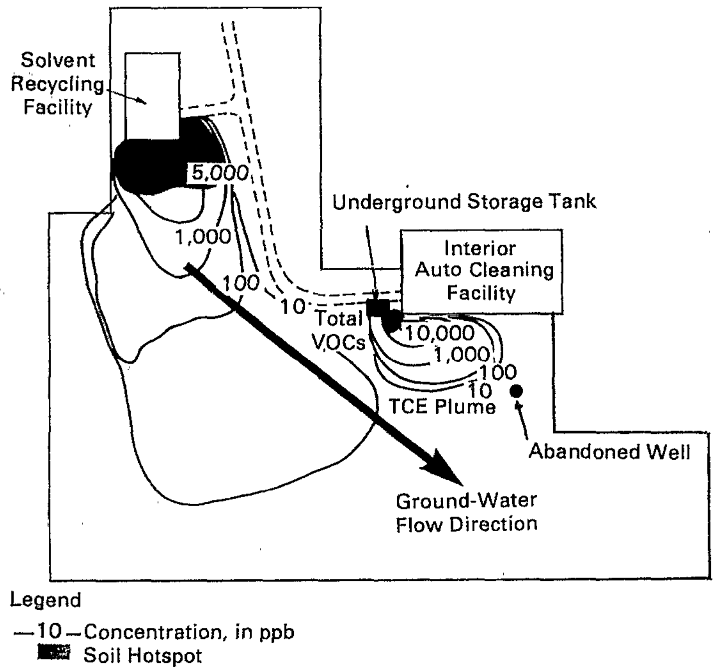

Figure A-1. Distribution of Contaminants Hypo-Thetical Site.

levels should be set for the following contaminants that exceed these standards or criteria:

- Benzene
- DEHP
- 1,1-DCE
- 1,2-DCE
- Iron
- Manganese
- Methylene chloride
- Phenol
- PCE
- 1,1,1-TCA
- TCE
- Vinyl chloride

Preliminary cleanup levels for benzene, 1,1-DCE, 1,1,1-TCA, TCE, and vinyl chloride are set at the MCL level for protection of health.

For iron and manganese, preliminary cleanup levels were set at the secondary MCL level for protection of welfare (these contaminants make drinking water taste bad). Since at naturally occurring background levels these metals were detected above the MCLs, it is not necessary that the remedial action selected address these contaminants. However, the treated effluent must meet the POTW's pretreatment program requirements for these contaminants.

The UPL level for DEHP was written 4 years ago. It is not clear on what basis this standard was promulgated. It has never been enforced because of the widespread presence of DEHP at industrial areas throughout the state. For these reasons, the remedial project manager for the Hypo-Thetical site employed an ARAR waiver for the DEHP UPL and will propose a cleanup level corresponding to the 10^{-6} risk level.

For methylene chloride and PCE, the State UPLs will be the basis for the cleanup levels. For phenol, the preliminary cleanup level will correspond to the RfD. For 1,2-DCE, the preliminary cleanup level will be based on the lifetime health advisory. When an MCL is promulgated, the cleanup level will be reassessed and may be changed to reflect the MCL.

Assessing Aggregate Effects

Table A-4 presents estimates of the carcinogenic and noncarcinogenic effects if the contaminants present at the Hypo-Thetical site are remediated to the preliminary cleanup levels. Aggregate carcinogenic risk is 2×10^{-4}, and an evaluation of the appropriate risk level will be made. For noncarcinogenic effects, the hazard index is 1.2, and the preliminary cleanup levels for the noncarcinogens will be further reduced.

To attain a risk level of 10^{-6}, the starting point for the aggregate risk level for carcinogens, the preliminary cleanup levels for key contaminants (those contributing most to the aggregate risk level, i.e., 1,1-DCE and vinyl chloride) would have to be reduced by a factor of 1,000 (i.e., 1,1-DCE to 0.007 ppb and vinyl chloride to 0.02 ppb). In evaluating whether these levels should be used at the site the following factors that indicate increased flexibility to use a less stringent aggregate risk level were considered:

- The potential for human exposure from other pathways is minimal; contaminated soil will be remediated, and air emissions above health-based levels are not anticipated
- There are no exposures above health-based levels actually occurring at this time
- There are no sensitive populations or special environmental receptors in the area around the site
- Cross-media effects are not anticipated

Table A-3
CONTAMINANT-SPECIFIC ARARs AND TBC REQUIREMENTS
HYPO-THETICAL SITE
All Values in ug/l

Chemical	Maximum Concentration Reported	Maximum Contaminant Level: Primary (Health)	Maximum Contaminant Level: Secondary (Welfare)	Maximum Contaminant Level: MCLG	Maximum Contaminant Level: Proposed MCLG	State Unacceptable Pollutant Levels	Concentration Corresponding to 10^{-6} Level for Carcinogens[a]	Concentration Corresponding to RfDs for Non-Carcinogens[a]	Health Advisories Lifetime 70 kg Adult	Water Quality Criteria, Ingestion of Drinking Water Only: Toxicity Protection	Water Quality Criteria, Ingestion of Drinking Water Only: 10^{-6} Excess Cancer Risk
Barium	200	1000	--	--	1500	--	--	1750	1500	--	--
Benzene	120	5	--	0	--	--	1	--	--	--	0.67
Bis(2-ethylhexyl)-phthalate (DEHP)	90	--	--	--	--	10	50	700	--	21000	--
Bromodichloromethane	56	100	--	--	--	--	--	700	--	--	--
Carbon disulfide	67	--	--	--	--	--	--	3500	--	--	--
Copper	80	--	1000	--	1300	--	--	--	--	1000	--
1,1-Dichloroethene (1,1-DCE)	1900	7	--	7	--	7	0.06	315	7	--	0.033
t-1,2-Dichloroethene (1,2-DCE)	1000	--	--	--	70	--	--	--	70	--	--
Di-n-butyl phthalate	45	--	--	--	--	--	--	3500	--	44000	--
Iron	1500	--	300	--	--	--	--	--	--	--	--
Lead	7	50	--	--	20	10	--	50	--	50	--
Manganese	80	--	50	--	--	--	--	--	--	50	--
Methylene chloride	80	--	--	--	--	5	5	2100	--	--	0.19
Nickel	5	--	--	--	--	--	--	700	150	15.4	--
Phenol	1500	--	--	--	--	--	--	1400	--	3500	--
Tetrachloroethene (PCE)	650	--	50	--	0	25	--	350	10	--	0.88
1,1,1-Trichloroethane (TCA)	1500	200	--	200	--	--	--	3150	200	19000	--
Trichloroethene (TCE)	1200	5	--	0	--	--	3	--	--	--	2.8
Vinyl chloride	500	2	--	0	--	--	0.015	--	--	--	2
Zinc	50	--	5000	--	--	--	--	7350	--	5000	--

[a] Assumes ingestion of 2 l/day and body weight of 70 kg.

[b] It is not required that all standards and criteria be identified; once an ARAR or TBC has been identified upon which a preliminary cleanup level can be based, identifying contaminant-specific ARARs and TBC requirements can stop. However, the aggregate effects levels generally should be determined for the site as they may affect selection and cleanup levels.

Table A-4
AGGREGATE RISK
HYPO-THETICAL SITE

Chemical	Preliminary Cleanup Level (ug/l)	Carcinogens: Carcinogen Classification	Carcinogens: Excess Lifetime Cancer Risk at Preliminary Cleanup Level	Systemic Toxins: RfD (mg/kgday)	Systemic Toxins: Daily Intake (DI) (mg/kgday)	Systemic Toxins: DI/RfD at Preliminary Cleanup Level
Benzene	5	A	7×10^{-6}	-	-	-
Bis-2-ethylhexylphthalate	10	B2	2×10^{-7}	0.02	0.001	0.05
1,1-Dichloroethene	7	C	1×10^{-4}	0.009	0.0002	0.02
Methylene chloride	5	B2	1×10^{-6}	0.06	Neg.	Neg.
Phenol	1400	-	-	o.04	0.04	1.0
Tetrachloroethene	25	B2	4×10^{-5}	0.02	0.001	0.05
1,1,1-Trichloroethane	200	-	-	0.09	0.006	0.07
Trichloroethene	5	B2	2×10^{-6}	-	-	-
Vinyl chloride	2	A	1×10^{-4}	-	-	-
Sum			2×10^{-4}			1.2

Exposure Assumptions:
Body weight = 70 kg
Drinking water ingestion rate = 2 l/day
Exposure period = 70 years
Neg. = Negligible

- The hydrogeology of the site is well defined and ground-water flow paths can be estimated with adequate precision
- Proven technologies will be used to remediate the site
- The detection/quantification limits for 1,1-DCE and vinyl chloride, even using available special analytical techniques, do not permit measurement of concentrations at levels corresponding to the 10^{-6} risk level.

These factors suggest the selection of less stringent cleanup levels. However, because benzene and vinyl chloride are known human carcinogens, and because institutional controls are not expected to be reliable, the appropriate aggregate risk level is the 10^{-5} level. To attain a hazard index of 1.0 for noncarcinogenic effects, the preliminary cleanup level for phenol will be reduced to obtain a ratio of daily intake (DI) to RfD of 0.8. The concentration of phenol corresponding to this level is 1,120 ppb.

In summary, the cleanup levels at the site are as follows:

- Benzene--5 ppb
- DEHP--51 ppb
- 1,1-DCE--0.7 ppb
- Methylene chloride--5 ppb
- Phenol--1,120 ppb
- PCE--25 ppb
- 1,1,1-TCA--200 ppb
- TCE--5 ppb
- Vinyl chloride--0.2 ppb

Special analytical services would be required to confirm cleanup levels had been attained for 1,1-DCE and vinyl chloride since these concentrations are below the practical quantification limits achieved by standard procedures used in the contract laboratory program.

These ground-water cleanup levels were also used to determine the solid cleanup levels based on migration to ground water. A leaching test was performed on the soil to determine what residual contaminant levels could remain onsite without contaminating ground water above health-based levels.

A.7 Developing and Screening Remedial Alternatives

Source Control Action

Soil contaminated at levels greater than 10,000 ppb (4,000 yd^3) was excavated and incinerated offsite. A vacuum extraction system was installed to remove the remaining volatile organic compounds present at greater depths to levels that would not pose a threat to the ground water.

Selecting Indicator Chemicals

Indicator chemicals were selected to be used in the FS on the basis of mobility and toxicity information (see Table A-5). K_{OC} values are known for 11 organic compounds. Contaminants with low K_{OC} values are more mobile than contaminants with high K_{OC} values.

These ground-water cleanup levels were also used to determine the soil cleanup levels based on migration to ground water. A leaching test was performed on the soil to determine what residual contaminant levels could remain on site without contaminating ground water above health-based levels.

Because a localized TCE plume is emanating from the auto interior cleaning area, TCE was selected as one of the indicator chemicals. To predict movement of the contaminant plume originating from the solvent recycling facility, indicator chemicals were selected, as explained below:

- Benzene was detected at its highest concentration at the border of the plume. Because of its unusual occurrence (i.e., at the edge of the plume) benzene was selected as an indicator chemical.
- 1,1-DCE was the most widely distributed chemical and is relatively mobile.
- PCE is relatively immobile and is widespread. It is expected to be the most resistant to extraction.
- Vinyl chloride was widely distributed and is highly toxic.

On the basis of column studies conducted during the RI, it was determined that desorption is rate-limiting (and hence, continuous ground-water pumping is not efficient) for the contaminants in this particular soil when the concentrations found in ground water are as follows:

- TCE--20 ppb
- Benzene--10 ppb
- 1,1-DCE--10 ppb
- PCE--50 ppb
- Vinyl chloride--10 ppb

Developing Remedial Alternatives

Area of Attainment. Since all source areas will actively be remediated and no waste will be managed onsite as part of the final remedy, the area of attainment will be the entire site, including the source area.

Table A-5
CONTAMINANTS DETECTED IN GROUND WATER
CONCENTRATION, TOXICITY, AND MOBILITY
HYPO-THETICAL SITE

Chemical	Range of Concentrations Reported in Ground Water[a] (µg/l)	Cleanup Level (µg/l)	Mobility K_{oc}[b] (ml/g)
VOLATILE ORGANIC COMPOUNDS			
Benzene	20 - 120	5	83
Bromodichloromethane	5 - 56	-	-
Carbon disulfide	10 - 67	-	54
Chloroethane	15 - 1,000	-	-
1,1-Dichloroethene	50 - 1,900	0.7*	65
Trans-1,2-Dichloroethene	37 - 1,000	350	59
Methylene chloride	10 - 80	5	8.8
Phenol	20 - 1,500	1,120*	6.2
Tetrachloroethene	45 - 650	25	364
1,1,1-Trichloroethane	12 - 1,500	200	152
Trichloroethene	6 - 1,200	5	126
Vinyl chloride	45 - 500	0.2*	57
Phthalates			
Bis (2-ethylhexyl)phthalate	10 - 90	10	170,000
Di-n-butyl phthalate	8 - 45	-	-
INORGANICS			
Aluminum	440 - 600	-	-
Barium	99 - 200	-	-
Calcium	10,300 - 20,750	-	-
Copper	20 - 80	-	-
Iron	999 - 1,500	-	-
Lead	5 - 7	-	-
Magnesium	4,000 - 7,000	-	-
Manganese	70 - 80	-	-
Nickel	2 - 5	-	-
Potassium	1,550 - 2,000	-	-
Sodium	6,550 - 10,000	-	-
Zinc	32 - 50	-	-

[a] Samples in which the contaminant was not reported are excluded.

[b] The organic carbon partition coefficient $= \frac{\text{mg contaminant/kg of organic carbon}}{\text{mg contaminant/liter of solution}}$

*Cleanup level was reduced because of aggregate effects.

Restoration Time Frame. To estimate the shortest possible restoration time frame, a ground-water model was run several times using various estimates of two parameters, porosity and hydraulic conductivity, to predict the ground-water flow rate. Estimated levels were based on data gathered when ground water contaminated by the underground tank was pumped as an interim action. It showed that the estimates of ground-water flow were precise to approximately 50 percent.

The quickest feasible restoration time frame is estimated to be 10 years, plus or minus 5 years. This rate is possible if seven extraction wells pump at the maximum rate of ground-water flow for 2 years and are then pulse-pumped for approximately 8 years. Enhanced *in situ* biodegradation of ground-water contamination will be initiated at the same time as pulsed pumping. A second alternative using pulsed pumping and enhanced biodegradation with three extraction wells is estimated to restore ground water in 12 years plus or minus 5 years.

Screening. Enhanced biodegradation alone was removed from consideration during screening because it presented minimal benefits over natural attenuation. Containment of contaminated ground water was initially considered; however, it was determined to be too costly and not feasible since the site was expected to be developed.

Alternative Development. Table A-6 summarizes pertinent information regarding the site.

The following three ground-water alternatives were developed for detailed analysis:

- *Alternative 1*: Natural attenuation with monitoring--If the source is removed, natural attenuation is predicted to eliminate the plume from the site within 40 years. However, the plume would simply migrate and disperse downgradient of the site. The nearest surface water body into which the plume could discharge is approximately 1 mile away. Monitoring would continue throughout the 40-year period. While institutional controls would be effective onsite, institutional controls downgradient of the site would probably be unreliable.

- *Alternative 2*: Pump and treat with three extraction wells--For some of the contaminants, the kinetics of desorption from the soil matrix to the ground water would be slower than the maximum pumping rate of the ground water. For this reason, intermittent pumping at three extraction wells was proposed. Ground water would be pumped continuously for approximately 2 years, and then a pulse/relax cycle would be initiated. Ground water would be treated using carbon adsorption to meet required pretreatment levels and discharged into a nearby storm sewer. Enhanced biodegradation would also be used to attain health-based cleanup levels. This alternative is predicted to achieve cleanup levels in 12 years, plus or minus 5 years.

- *Alternative 3*: Pump and treat with seven extraction wells--This alternative is similar to the previous alternative, except that treated ground water would be reinjected to enhance contaminant movement. Again, biodegradation and pulsed pumping would be used after a period of continuous pumping to reduce residual contamination to health-based levels. This alternative is predicted to require 10 years, plus or minus 5 years, to reach cleanup levels.

A.8 Detailed Analysis

The three alternatives were analyzed using the nine evaluation criteria. The natural attenuation alternative was rejected because it is only marginally protective and does not reduce mobility, toxicity, or volume. The State was also opposed to this option because of the need for long-term access restrictions of ground-water usage in the area.

Both pump and treat alternatives are protective and meet all ARARs. However, the more aggressive seven-well pump and treat alternative may be less flexible for incorporating design changes as additional information on pumping influence is obtained. If the wells are not placed in optimal areas, more wells may have to be added. By starting with a smaller number of wells and supplementing the system as information is obtained, a more cost-effective remedy may result. In addition, the seven-well pump and treat alternative is more expensive. Although the seven-well pump and treat alternative is predicted to reach cleanup levels faster than the three-well alternative, the uncertainty of the effect of reinjection makes the remedy less reliable. It was determined that the three-well alternative should be implemented on the basis of its overall balance of the evaluation criteria. At the end of 1 year, the performance of this alternative will be evaluated, and if its performance is poor, the alternative will be upgraded with additional wells and possibly a reinjection well. Table A-7 summarizes the pertinent considerations relating to the five criteria that were balanced.

Additional action-specific ARARs with which the selected remedy must comply are listed below:

- The County POTW's pretreatment program is applicable to discharge of the treated water to the sewer system

Table A-6
HYPO-THETICAL SITE SUMMARY

Type of Site--Industrial landfill, underground solvent storage tank

Local Land Use--Residential

Ground-Water Use--Upper aquifer--potential drinking water source; lower aquifer--current drinking water source; 50 wells in the area; some screened through both aquifers; municipal supply available

Soils--VOC contamination; hot spot of 4,000 yd^3; low-level contamination of 20 acre-feet

Ground-Water Response Objectives

- o Prevent exposure to contaminated drinking water
- o Prevent contamination of deeper aquifer
- o Restore contaminated ground water for future use

Soil Response Objectives--Prevent risk from soil ingestion, prevent contamination of ground water.

Data Needed

- o Wells and piezometers in deep and shallow aquifers to determine extent of contamination
- o Saturated zone soil contaminant concentrations and TOC to determine partition coefficient
- o Aquifer pump test to determine hydraulic conductivity and estimate capture zones
- o Contaminant degradation information

Removal/Interim Action Taken--Remove tank and surrounding soils; vapor extraction, and ground-water pumping; seal abandoned well

ARARS--Nine MCLs and Five State UPLs

Ground-Water Remedial Alternatives

- o Natural attenuation
- o Two pump and treat scenarios

Table A-7. Summary of Detailed Analysis Hypo-Thetical Site-Balancing Criteria

Alternative	Short-Term Effectiveness	Long-Term Effectiveness	Reduction of Mobility, Toxicity, or Volume (MTV)	Implementability	Present Worth Cost
Natural attenuation	Presents a higher risk to the community over the short-term; does not cause exposure to workers; does not cause environmental impacts, restoration time frame is 40 years	Potential for exposure from residual contamination because institutional controls such as deed restrictions are not effective. Risk for carcinogens is at the high end of the protective risk range ($2x10^{-4}$) and the HI is above 1.0.	No treatment;no destruction; no reduction of MTV; residual contamination is high	Deed restrictions are unreliable; ease of taking additional actions is high; ability to monitor is high; ability to obtain approvals from other agencies is high; no coordination problems	$500,000
Pulsed pumping, 3 well points, air-stripping, enhanced biodegradation	Reduces risk to the community over the short-term; potentially small exposure to workers; does not cause environmental impacts, restoration time frame is 12 years.	Residual risk is 10^{-5} for carcinogens, and the HI for systemic toxicants is 1.0	Contaminants are treated; quantitative residual contamination is below cleanup levels	Biodegradation may not work; ease of undertaking additional actions is good; ability to monitor is high; other approvals can be obtained; coordination with other agencies is moderate	$3,000,000
Pulsed pumping, 7 well points, air-stripping, reinjection, enhanced biodegradation	Reduces risk to the community over the short-term; potentially small exposure to workers; does not cause environmental impacts; restoration time frame is 10 years	Regional risk is 10^{-5} for carcinogens, and the HI is 1.0	Contaminants are treated, residual contamination is below cleanup levels	Biodegradation may not work; ease of undertaking additional actions is poor; ability to monitor is uncertain because of difficulties in predicting the effect of reinjection; approval of underground injection is questionable; coordination with other agencies is moderate.	$5,000,00

- The State air toxics regulations are applicable to air-stripping.

A.9 Variations in Site Conditions

Variation 1: Surface Water

If a stream had been on the site and contaminated ground water currently or potentially discharged to the stream, potential exposure pathways related to surface water would have been identified. These would have included the following:

- Direct contact with contaminated surface water for people swimming and playing in the stream either at the site or downstream of it
- Ingestion, by humans, of aquatic organisms that have become contaminated through bioconcentration or ingestion of contaminated surface water
- Ingestion and bioconcentration of contaminated surface water by aquatic organisms
- Ingestion, by terrestrial organisms, of aquatic organisms that have become contaminated through bioconcentration or ingestion of contaminated surface water

Response objectives related to surface water would also be identified and would include preventing exposure to contaminated surface water and contaminated aquatic organisms, protecting environmental receptors, and restoring contaminated surface water.

Additional data collection would include taking surface water and sediment samples upstream and downstream of the site. If contaminants were found in the surface water or sediments, samples of edible fish portions would be taken to determine if aquatic organisms were being affected.

Regardless of the analytical results of these samples, an ACL under CERCLA Section 121(d)(2)(B)(ii) would not be considered at this site because institutional controls preventing exposure to contaminated ground water would not be reliable enough to ensure that wells would not be constructed in the upper aquifer or to the lower aquifer without preventing cross-contamination. If necessary, access to the surface water in areas where contaminant levels exceed standards would be restricted, and signs warning that fish may be contaminated would be posted.

Cleanup levels would be determined on the basis of standards and criteria for drinking water consumption, WQC for fish ingestion and drinking water ingestion, and WQC for effects to aquatic organisms. These are shown in Table A-8.

A comparison of the WQC in Table A-8 to the cleanup levels presented in Section A-6 indicates that a cleanup level for copper would be determined on the basis of aquatic effects. Otherwise, cleanup levels would not be changed.

Variation 2: Class I Ground Water

If the ground water had been Class I, i.e., if no alternate supply were available and the plume had reached nearby residents' wells, a removal action consisting of wellhead treatment would have been implemented. An interim action consisting of wellhead treatment would be completed if levels in the wells did not reach removal action trigger levels but were contaminated above health-based levels. Wellhead treatment would probably involve carbon absorption because of the nature of the contaminants. This treatment would be less intensive than air stripping with respect to operation and maintenance. Because the time frame would have more significance, the seven-well alternative would be chosen. Since this alternative involves recharge of treated ground water it has the added benefit of preserving the resource, in this case, an important consideration under the short-term effectiveness evaluation criteria.

If the plume had not yet reached the wells but was projected to reach them within 2 to 3 years, an interceptor well or trench would be constructed near the leading edge of the plume, early in the RI/FS process. This would prevent the plume from reaching the wells while the RI/FS was being completed and the final remedy was being selected. The well or trench would be pumped to maintain contaminant concentrations below health-based levels and would have only a minimal effect on plume movement. These actions would be coordinated with the operators of the private and municipal wells. Another option that might be considered would be alternating pumping patterns at the existing wells to limit the extent of any plume expansion.

Variation 3: Class III Ground Water

If the total dissolved solids (TDS) concentration at the site exceeded 10,000 milligrams per liter, the ground water would not have been usable as a drinking water source. If the ground water was not interconnected to the drinking water aquifer and did not discharge to a stream, the ground water at this site would not have served any other beneficial uses, such as irrigation, and so it would have been classified Class III. Natural attenuation would have been the selected alternative. However, if the ground water discharged to surface water, protection of aquatic organisms would have been a remedial response objective. In this case, cleanup levels would have been established to prevent effects to aquatic organisms.

If the ground water was found to be interconnected to a drinking water aquifer, cleanup levels would be determined on the basis of health-based levels attained at the point of interconnection. Although natural attenuation may be appropriate in this case, it

Table A-8
HEALTH-BASED CRITERIA RELATED TO SURFACE WATER
HYPO-THETICAL SITE

Chemical	WQC for Protection of Human Health-- Drinking Water and Fish Ingestion, ppb	WQC for Protection of Aquatic Organisms--Fresh Water Organisms, ppb
Benzene	0.66 (C)	5300 (a)
DEHP	10,000 (S)	---
Chloroform	0.19 (C)	1240 (c)
Copper	---	12 (c)
Dichloroethenes	0.033 (C)	11600 (a)
1,2-DCE	0.94 (C)	20000 (c)
Iron	300 (S)	1000 (c)
Manganese	50 (S)	---
Methylene chloride	0.8 (C)	---
PCE	18,400 (C)	840 (c)
1,1,1-TCA	2.7 (C)	---
TCE	2 (C)	21900 (c)
Vinyl chloride		---

a = Acute effects
c = Chronic effects
C = Carcinogenic effect (1×10^{-6} excess lifetime cancer risk)
S = Systemic toxic effect

would be critical to ensure that wells constructed in the deeper aquifer would not enhance chemical movement from the shallow to the deeper zone. This could be accomplished by enforcing a requirement that any new wells be constructed with a seal in the upper portion of the well.

Variation 4: Complex Hydrogeology

If the shallow aquifer had been in a low permeability formation, it is possible that ground-water extraction using extraction wells would not have been feasible. Trenches, French drains, or well points would have been considered to extract ground water. Alternatively, dewatering the shallow aquifer and using vapor extraction could have been considered.

If the site had been in karst terrain, data collection activities would have been different than for other types of aquifers. A dye tracer study to determine ground-water conduits in the subsurface would have been considered.

Variation 5: Inorganic Contaminants

If contaminants at the site had included metals, additional treatment options would have been considered. Biodegradation or air-stripping probably would not have been feasible, and containment would not have been acceptable because of the development pressures at the site. The remedial alternatives that would have been analyzed in the detailed analysis would have involved ground-water extraction and treatment, possibly using ion-exchange or precipitation. Because metals are relatively immobile and inhibit biodegradation, the restoration time frame would have been longer. A technical feasibility waiver would be used, if necessary, for residual contamination that remains above health-based levels. Restrictions on well construction, as described in Variation 3, would be implemented for the area. In addition, ground water downgradient from the plume and upgradient from any active drinking water wells would be monitored as a warning system to prevent chemical migration to the wells.

Variation 6: Reliable Institutional Controls

If institutional controls such as requiring new well permits or restricting access to the aquifer were more reliable, a remedy relying on institutional controls such as natural attenuation would still not be selected, because a feasible and implementable remedy is available, and the aquifer is a potential drinking water source. However, if the ground water discharged to nearby surface water and the resulting contaminant levels in the surface water were not statistically significant, an ACL, as described in Section 4.5, would be considered.

Appendix B

Strategy for Addressing Ground-Water Contamination from Multiple Sources Involving Superfund Sites

The Office of Emergency and Remedial Response (OERR) has developed a strategy for ways in which the Superfund program can address ground-water contamination from multiple sources (National Priorities List (NPL) sites and other sources). The strategy presents an approach for determining when an alternate water supply should be provided, what type of source control and ground-water response actions should be taken, and implications of this strategy for listing and deleting sites from the NPL.

The flexible approach presented in this strategy is an initial step toward the development of more detailed guidance as the program gains experience with such situations.

Exhibit B-1 presents an example of a multiple-source plume.

Superfund Remedial Strategy for Ground-Water Contamination from Multiple Sources

Purpose

This strategy presents an approach for addressing ground-water contamination at sites contaminated from multiple sources, including sources on the NPL. This strategy is an initial step toward the development of more detailed guidance as the Superfund program gains experience with such situations.

Background

The goal of CERCLA and its related regulations, standards, and criteria is to protect human health and the environment. The objectives of the Superfund program are consistent with this goal.

The Superfund program is now confronting numerous issues and problems involving NPL sites associated with ground-water contamination caused by multiple sources such as the Biscayne Aquifer and South Valley, New Mexico. Current Superfund responses to multiple source ground-water contamination problems would provide for cleanup and control of CERCLA priority releases only. Releases from sources not addressed by CERCLA could continue to contaminate the general area, making Superfund remedial action less effective. To obtain an effective remedy for ground-water contamination caused by multiple sources, the response actions must be broader in scope and involve organizations and authorities outside the Superfund program.

Given the potential magnitude of multiple source ground-water contamination problems and the fact that Superfund resources are finite, the Superfund program needs to adopt a strategy that will set priorities and establish a sequence of remedial and enforcement actions that will appropriately address these problems. A fully effective response generally will involve the Superfund program working with other involved parties to clearly define their respective remedial roles and responsibilities. This recommended approach should be consistent with other environmental laws.

Overview of Approach

This approach proposes that the Superfund program work cooperatively with other responsible entities to achieve comprehensive remedies at multiple source ground-water contamination sites but accept primary responsibility for coordinating all involved parties during the source identification phase of work.

The Superfund program should begin its coordinating effort once multiple source ground-water contamination is suspected. The program should coordinate an initial scoping plan for source identification that would include limited sampling. Locations of possible sources may be determined through two surveys: (1) a survey of contributors to and users of the affected ground water (termed a contributor/user assessment) that will help identify the other parties that must be involved in the formulation of an effective remedy; and (2) a survey of potential sources such as solvent storage facilities located at or upgradient of the area of contamination. Often, a local agency has the necessary resources to complete these surveys, and the role of the

Exhibit B-1. A Multiple Source Plume in the Biscayne Aquifer

The Biscayne aquifer, a highly permeable limestone and sandstone aquifer, is the sole underground source of drinking water for 3 million residents of southeast Florida.

Three Biscayne aquifer Superfund sites were identified in Dade County. Because the three sites affect the same general area of the aquifer, they are treated as one "management unit." The three sites include the Varsol Spill site, the Miami Drum site, and the 58th Street Landfill. Ongoing spills from other sources also contaminate the aquifer.

During the preliminary assessment/site inspection, EPA took a lead role in coordinating response to the contamination problem because the Superfund sites were believed to be the primary contributors to the ground-water contamination. An extensive study to characterize the affected area of the Biscayne aquifer has been completed.

At the Varsol Spill site, it was determined that there are no longer any traces of soil contamination at the site. Presumably, the contaminants volatilized. A ROD proposing no source control actions was signed in 1985. At the Miami Drum site, extensive contamination was found. Excavation and offsite disposal of contaminated soil was recommended as an operable unit in a ROD signed in 1982. An enforcement decision document for the northwest 58th Street landfill was completed in 1987 and proposed closure of the landfill and provision of an alternate water supply to residents near the site who use private wells.

The ground-water remedy proposed for the Biscayne Aquifer Superfund Site ROD that was signed in 1985 includes adding air-stripping to the existing water treatment systems and operating additional municipal wells to recover contaminated ground water and provide potable water.

Other agencies that have been involved in the effort include:

- The State Department of Environmental Regulation
- The State Department of Health
- The Agency for Toxic Substances and Disease Registry
- The Dade County Department of Environmental Resources Management
- Two adjacent counties

These agencies formed a Technical Advisory Committee (TAC) that made decisions through consensus management. In addition to working on Superfund-related issues, the TAC also put together the Biscayne Aquifer Protection Plan, a 20-point plan devised to prevent additional contamination of the aquifer. The provisions of this plan include such items as regulating land use, regulating storage tanks, adopting emergency spill provisions, recycling oil, and ground-water monitoring. Now that the studying and planning phases have been completed, the TAC meets less frequently.

The Dade County Department of Environmental Resources Management is a well-established organization with considerable professional talent. It receives no Federal money for this effort. The State's role is relatively limited--the State's water management districts and development plans must be consistent with the Protection Plan.

Superfund program staff is to maintain coordinating and support functions.

Superfund will implement appropriate remedial actions related to NPL sites once an RI/FS is completed. At this point, the Regional Administrator, in consultation with the Assistant Administrator of the OSWER, should evaluate the appropriateness of the Superfund program, retaining primary responsibility for coordinating the ground-water response action for all sources. This decision may be determined by factors such as the contribution of Superfund sources relative to other sources, as well as the availability and willingness of other involved parties to initiate action.

If the Superfund program does not take the lead responsibility, the program will work in cooperation with other involved parties to formulate and implement an effective solution to the multiple source ground-water problem. If the Superfund program retains lead responsibility, it will work with the other involved parties to develop a multiple source ground-water response plan, which would include written commitments from each party to take specific remedial actions that, when combined, would result in an effective remedy for the entire ground-water contamination problem. An appropriate community relations program will be conducted throughout this process.

Challenges Associated with Ground-Water Contamination Caused by Multiple Sources

If ground-water contamination has occurred because of multiple sources, remedial decisions become more complex. Some of the many technical, administrative, and financial considerations that may result when multiple source ground-water contamination exists are as follows:

- Greater technical difficulty of remedial action may result from complex mixtures of hazardous constituents.
- The effectiveness of institutional controls may decrease because of multiple land owners.
- Applicability and responsibility of other statutory and regulatory authorities may be increased.

Table B-1 lists the types of sources that may potentially contaminate ground water but may not be CERCLA-priority releases.

Table B-1. Potential Sources of Multiple Source Ground-Water Contamination

1. Major Point Sources
   - Abandoned hazardous waste land disposal units
   - Industrial NPDES facilities
   - Municipal NPDES facilities
   - Land-spreading of municipal sludge
   - Non-regulated holding ponds for industrial waste (including mine tailings)
   - Air pollution (smelter operations, etc.)
   - RCRA-permitted TSD facilities
   - Federal Facilities
   - State-lead sites that have been deferred from listing on the NPL because of state action
   - Abandoned dry wells
2. Non-Point Sources
   - Agricultural runoff (infiltration)
   - Urban runoff (infiltration)
   - Air Pollution (acid rain)
   - Irrigation return
3. Multiple Point Sources
   - Underground storage tanks
   - Fuel spills
   - Commercial establishments (e.g., laundries)
   - Septic tanks
   - Sewer exfiltration

Listing Sites and Determining Response Approach

A specific preliminary assessment/site investigation (PA/SI) work plan may be expanded when ground-water contamination is found in significant amounts in wells upgradient of the source being investigated. The detection of contaminants in the upgradient wells suggests multiple source ground-water contamination.

The Superfund program should be responsible for coordinating the expanded PA/SI activities. This leadership role would entail assigning responsibility for obtaining data.

To identify sources of contamination and to list potential sources as priorities for undertaking enforcement activities, it may be necessary to consider the contribution of the source to the overall ground-water contamination problem as well as the planned sequence of remedial actions. A list of potential sources should be assembled on the basis of site-specific information. Such information could include the volume of chemicals used by each potential source and the locations of the sources relative to the site. Once the list of potential sources has been assembled and it has been determined which sources are most likely to have affected ground water, a limited sampling program can be instituted. Sampling programs for source identification may be coordinated by the Superfund office.

It is important that sampling programs conducted by or under the direction of agencies other than EPA also follow a valid QA/QC plan. Quality-assured data can be used to prove liability for ground-water remedial actions. Even cooperative potentially responsible parties (PRPs) should follow strict QA/QC procedures to ensure reproducible results and because their data are open to challenge from other PRPs when the plume is from multiple sources.

After potential sources have been identified, activities may include, but are not limited to, identifying the following:

- Targets for PA/SI work
- Areas for NPDES compliance inspections and possible permit tightening
- Areas for intensified RCRA inspection
- Areas for Toxic Substances Control Act inspection
- Areas in which State environmental programs should be examining permits, inspecting for compliance with their regulations, and upgrading permits, where needed
- Areas in which the State and local health departments should be inspecting for compliance with their regulations
- Local inspections by county and city organizations to ensure compliance of and adequate coverage by their regulations

Source identification efforts should be scheduled before the RI/FS is begun for any interim actions or operable units. To the extent possible, PRP-lead RI/FSs and removals should be used. Before the ROD is signed for the first operable unit, it is important that the enforcement case be developed.

This is particularly important if the cost of the operable unit is high.

Priorities for enforcement activities that pertain to multiple sources should be based on the severity of release from each source. If more than one source is on the NPL, the program may consider combining the RI/FSs for these sites, if appropriate.

Another possible approach for the investigation phase, which has been used in some of the regions, is to require investigation under RCRA authority as specified in Section 3013 of RCRA. Under this authority, EPA can order the owner/operator of a facility at which hazardous waste is or has been treated, stored, or disposed, to perform monitoring, testing, or analyses necessary to determine the nature and extent of a potential hazard at the site to human health and the environment. Also, if contaminated ground water discharges to a navigable stream, using the enforcement authority under the CWA should be considered.

Major Remedial Options for Sites Associated With Contaminated Ground Water

Three types of remedial actions are considered at sites with ground-water contamination from a single source:

- Provision of alternate water supplies (including wellhead treatment)
- Source-control measures
- Ground-water remedies

These three types of actions may involve similar components. The first decision at a site will be whether to provide an alternate water supply. Ideally, the source control remedy and the ground-water remedy decisions should be made simultaneously to obtain the most cost-effective remedy for the site. It may not be possible, however, to make these decisions together at sites in which multiple sources contribute to ground-water contamination.

Alternate Water Supply

Public health is endangered when contaminants in drinking water supplies exceed health-based limits. Public health protection can be ensured with the provision of an alternate water supply that could include a wide range of actions, such as wellhead treatment, well relocation, selective use of wells, connection to an existing system or surface water source, and so forth.

An alternate water supply will be provided with Superfund resources if an NPL site is found to be a significant contributor to the contaminated drinking water source. The NPL site might be considered a significant contributor if the type of contaminants from the site are detected at a receptor point. Specific trigger levels and a methodology for determining whether a potential drinking water threat exists have been developed by the Superfund program (U.S. EPA, 1987f, 1987j).

In addition, Superfund resources will be used to provide an alternate water supply if the need to alleviate the public health threat posed by contaminated drinking water outweighs the need to identify and quantify all contributing sources.

Source Control

Actions taken to minimize or prevent the spread of contaminants from the source are termed source control actions. These types of actions include source removal, in situ treatment, and containment. In general, the Superfund program seeks to prevent or minimize all source releases to protect public health and the environment.

It is preferred that the Superfund program make a remedial decision for an NPL site that concurrently addresses source control and ground water. However, the length of time required to formulate a final ground-water remedy for all sources by obtaining written commitments from other involved parties (possibly through lengthy negotiations) and for developing a multiple-source ground-water response plan may require that an interim source-control measure or an operable unit for an NPL site be implemented. This interim remedy would be designed to minimize further source migration while a multiple source response plan is being developed.

The final source-control decision could be delayed until the ground-water remedy is selected. The advantage of this recommended approach is that source migration is temporarily minimized until the final ground-water decision is made. Thus, Superfund resources generally would not be used for more permanent source control remedies unless such actions are necessary and effective. The disadvantage of this approach is that a more permanent remedy may be more difficult to implement (retrofit) if an interim measure has already been implemented. This factor must be evaluated to determine whether an interim source-control measure should be implemented.

Ground-Water Remedies

When ground-water contamination is caused by multiple sources, the amount of resources Superfund is willing to commit to the ground-water remedy will be derived in large part from the extent to which contamination from NPL sites contributes to the total ground-water problem. This is often difficult to determine and may have to be estimated or negotiated. The willingness and capability of the other involved parties to take actions to address contamination for which they are responsible may also be a factor in determining resource allocation.

Schedule

The following factors should be balanced when scheduling operable units at multiple source ground-water contamination sites:

- Remedial action priorities (see Chapter 3)
- Enforcement priorities
  - Timing of field investigations to develop the enforcement case
  - Additional data needs for enforcement
  - Timing of operable units
  - Relative costs of the operable units

Remedial action priorities take precedence over enforcement priorities. However, enforcement actions can improve the timeliness and extent of overall site remediation.

The following remedial action activities should support the enforcement function to the extent practicable:

- Setting schedules for operable units
- Collecting data for remedial action evaluation or design
- Identifying sources

As mentioned previously, a multiple-source ground-water response plan should be developed to define the appropriate ground-water remedy. This plan would also detail specific actions to be taken by each party. If participation by other entities is essential to effective ground-water remediation, the Superfund program will not implement its portion of the selected remedy unless the other entities commit to implementing their own remedial actions. Superfund enforcement authority should be considered when cooperation is not voluntary.

The elements of a multiple-source ground-water response plan include:

- Summary and analysis of contributor/user assessment (performed in part for the source-control decision)
- Goals for ground water (use, value)
- Available restrictions on ground-water uses:
  - Ban on new drinking water wells unless adequate pretreatment is provided
  - Closure of existing wells unless adequate pretreatment is provided or notices are posted
  - Restriction of industrial/agricultural uses, as necessary
- Control plan for existing regulated sources:
  - RCRA facilities
  - NPDES industrial discharges
  - Small businesses
  - Non-point and multiple point sources, e.g., underground storage tanks, small commercial enterprises, septic tanks, agricultural runoff
- Control Strategy for all other sources contributing to areawide ground-water contamination:
  - NPL–Enforcement- and Fund-lead
  - Industrial discharges
  - Small businesses
  - Non-point sources
- Definition of roles and responsibilities, and a schedule for action by:
  - Individual parties
  - Federal, State, and local authorities
- Written commitment to take designated remedial action by all involved parties

Appendix C
Documenting an Interim Action

The ROD justifying an interim action is less detailed than a ROD for a final remedial action. In particular, fewer alternatives are considered because, in most cases, the decision that a particular scope of the interim action would be beneficial is based on best professional judgment. The five statutory findings discussed in Section 2.2 must be made; however, the discussions should be limited to the scope of the interim action itself. For example, an interim pump and treat system might be instituted to limit contaminant migration, even though health-based levels in the ground water will not be met. Institutional controls to prevent consumption of such ground water should accompany the interim action. In addition, the nine criteria should be evaluated to compare a limited number of alternatives. The ROD should contain the following sections:

- A statement of the problem
- The objectives of the remedy
- The alternatives briefly evaluated using the nine criteria and the reasons for selecting the alternative of choice
- Statutory findings
- A responsiveness summary

Statement of the Problem

This section of the ROD describes the reason for implementing an interim action. If an interim action is implemented to reduce plume migration, characteristics of the plume are described. If an interim action is implemented to reduce exposure, the affected population is identified, and the concentrations of the contaminants of concern are listed.

Objectives of the Remedy

This section states how an interim action responds to the problem. It also describes the relationship between the interim action and final remediation.

Alternatives Evaluated and Rationale for Selecting the Interim Action

A limited number of alternatives is described and evaluated on the basis of their ability to meet the objectives of the interim action. The selected interim action is justified following a brief discussion of the nine evaluation criteria (presented in Chapter 6) and the benefits of taking the action. (See Table A-2 in the case study for an example of this evaluation.) In addition, the following points should be made:

- The interim action is necessary or appropriate to stabilize the site, control the source, prevent further degradation, prevent exposure, or otherwise significantly reduce threats to human health and the environment.
- The interim action will not exacerbate the site problem.
- The interim action is consistent with the final remedy.
- There is a commitment to evaluate additional information and select a final remedy within a specified time frame.

Statutory Findings

The five statutory findings presented below are evaluated with respect to the proposed action, and a demonstration of their consistency within the scope and goals of the overall remedy is presented. In some instances, however, such as when an alternate water supply is provided, some statutory requirements (such as reduction of mobility, toxicity, or volume) may not be pertinent to the scope of the action. The five statutory findings include:

- *Protection of human health and the environment*–The remedy is shown to be protective in relation to the stated goals of the action. Human health and the environment must be protected during implementation, and the remedy must mitigate or fully control risks for the site problem that is addressed by the action. For example, an alternate water supply must prevent exposure to ground-water contamination, but it need not address other threats from the site; an interim action that contains the plume need not remediate ground water. As appropriate, interim actions can be justified by the need to take rapid action. Short-term effects from residual contamination or effluent disposal are also addressed.

- *Attainment of ARARs*--Action-specific ARARs that pertain to the interim action technology are identified, and it is shown that ARARs related to the treatment and disposal of effluent, for example, are met. ARARs pertaining to the storage of hazardous waste may be waived using the interim remedy waiver, which is described in Chapter 6. Other ARARs relating to short-term effectiveness and protectiveness of the remedy, however, generally cannot be waived. Cleanup levels for the site typically are not established since interim actions are not final. Thus, an interim ground-water action need not achieve chemical-specific ARARs in ground water.

- *Cost-effectiveness*--Capital, O&M, and present-worth costs are presented. In addition, it is shown that the costs of the interim action are proportional to the effectiveness of the action.

- *Use of alternative technologies and permanent solutions to the maximum extent practicable*--This finding is discussed in the context of the overall site management strategy as well as for the interim remedy itself. The reason for implementing an interim action is presented, along with a showing that the interim action is consistent with the final remedy. The need for quick action becomes a factor when determining if a treatment technology is practicable.

- *Reduction of mobility, toxicity, or volume*--Interim actions designed to address hot spots or prevent plume migration through treatment meet this criterion, while those that reduce exposure to contaminants generally do not. For example, pump and treat actions reduce the volume of contaminated groundwater, while alternate water supplies do not reduce mobility, toxicity, or volume.

Responsiveness Summary

The responsiveness summary of the ROD summarizes the problem and its mitigation and provides responses to comments received from interested parties. A summary of the statutory requirements and how they are met is also included.

Appendix D
Basic Ground-Water Equations

This appendix presents two models that can be used to estimate the time required to restore the water and soil in a contaminated aquifer to the desired cleanup level for a given chemical. The first model, the batch flushing model, is based on a series of consecutive discrete flushing periods. Each flushing period consists of enough clean water, introduced at a known rate, to fill the pore space in a given volume of aquifer. Values of contaminant concentration for both soil and water are calculated following each flushing period. The second model, the continuous flushing model, enables values of concentration to be calculated at any arbitrary time increment, regardless of the volume of water flushed through the aquifer.

Batch Flushing Model

The soil contaminant concentration for any flush, i, can be calculated from the following equation:

$$Cs_{(i)} = Cs_{(i-1)} - \frac{Cw_{(i-1)}n}{\rho_b} \quad (1)$$

where:

$Cs_{(i)}$ = the soil total volatile organics (TVO) concentration after i flushes, mg/kg

C_w = the concentration of TVO in the water in equilibrium with the soil, mg/l

n = the porosity of the soil

ρ_b = the bulk density of the soil, mg/l

Once the soil TVO concentration is calculated, the TVO concentration in the ground water is calculated by the following formula:

$$Cw_{(i)} = \frac{Cs_{(i)}}{K_d} \quad (2)$$

where:

K_d = distribution coefficient

Once equation (2) is evaluated, the value for $Cw_{(i)}$ can be entered into equation (1) as $Cw_{(i-1)}$ to calculate the soil concentration after the next flush. This is repeated until the soil and ground water reach the desired concentrations. The time required for each aquifer flush is obtained by dividing the control volume by the pumping rate, and the number of flushes can then be converted into the time required for restoration. It should be noted that soil and ground-water concentrations are related and cannot be independently set because the model assumed equilibrium concentrations for both phases.

Several assumptions are inherent in the use of this model:

- The total mass of contamination is in chemical equilibrium between the solid (soil) and the liquid (ground-water) phase.
- The use of K_d implies that the adsorption/desorption isotherm is linear. Equation (2), however, can be replaced by any nonlinear isotherm function as long as the chemical equilibrium assumption is not violated.
- The concentration of the contaminant in the water used to flush the aquifer is less than or equal to the desired cleanup level, and regardless of concentration, this level remains constant during the entire flushing process.
- No other chemical reactions occur that interfere with the adsorption/desorption process.

For the particular case described in Figure D-1, calculations based on this model yield a value of 27 years for aquifer restoration to a level of 80 ppb TVO. Note, the solution plots as a straight line because Equation (2) is linear.

Continuous Flushing Model

In this model, ground water is continuously pumped out of the control volume into the treatment system, and the treated water is continuously recharged to the control volume. This process acts to dilute the ground water. The pumping flow rate multiplied by the concentration of the contaminants in the ground water will yield the mass of VOCs pumped out in a given time interval. The mass of VOCs leaching into the ground water from the soil is a function of the leaching rate constant developed from the leaching column study. The time increment, t, was arbitrarily set at 1 day. The model recalculates a new soil and ground-water contaminant concentration for every day of pumping. The equations for the model can be written as follows:

Ground-water VOC mass at time t = Ground-water VOC mass at time (t-1)
- Mass of VOCs pumped out
+ Mass of VOCs leached into ground water from soil (3)

$$Mw_{(t)} = Mw_{(t-1)} - Qcw_{(t)}\,T + M1_{(t:t-1)} \quad (4)$$

$$Cw_{(t)} = \frac{Mw_{(t)}}{V} \quad (5)$$

where:

$Mw_{(t)}$ = mass of VOC in ground water at t, kg

$Mw_{(t-1)}$ = mass of VOC in ground water at the previous day, t-1, obtained from the previous day's calculation, kg

Q = ground-water pumping rate, 1/day

$Cw_{(t)}$ = concentration of VOCs in ground water, kg/l

T = time period of one iteration, which is set to 1 day

$M1_{(t:t-1)}$ = mass of VOCs that leach out from the soil and into the ground water from the time interval from (t-1) to (t), calculated from a first-order decay equation using the dynamic leaching rate constant derived from the laboratory data shown in Figure D-2, kg

V = control volume of aquifer, D-2

By using this model, a prediction of 9 years for the restoration time frame for the site was obtained, as seen in Figure D-3.

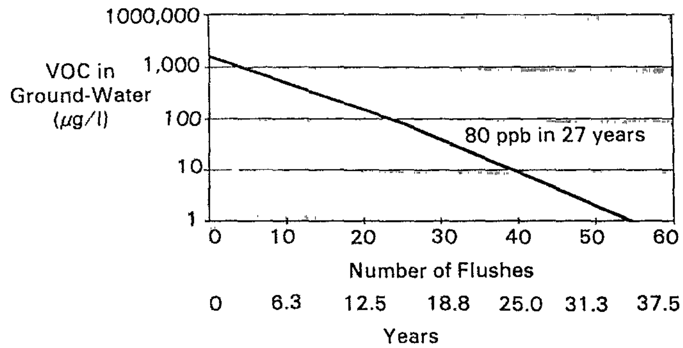

Figure D-1. Prediction of Ground-Water Restoration Time Frame Using the Batch Flushing Model

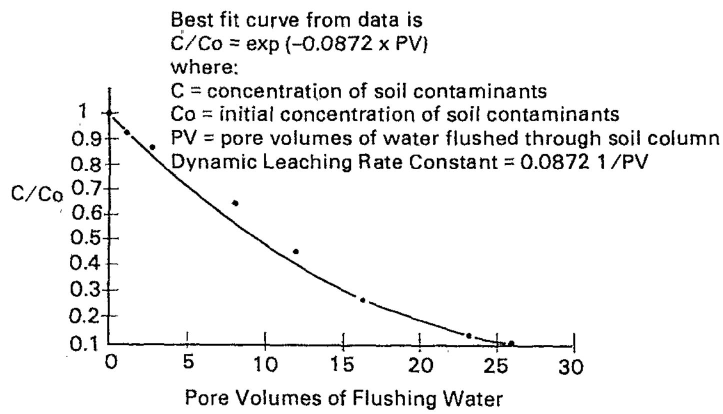

Figure D-2. Results of Leaching Column Study for Determination of the Dynamic Leaching Rate Constant

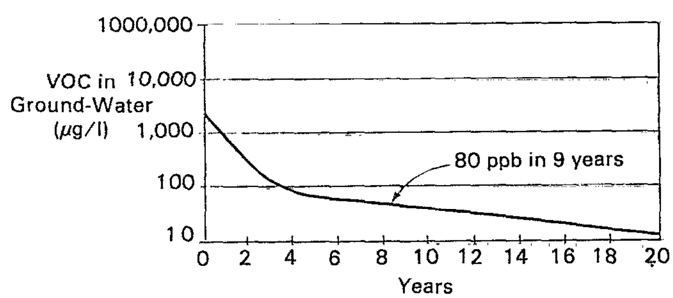

Figure D-3. Prediction of Ground-Water Restoration Time Frame Using the Continuous Flushing Model

Appendix E

Tables of U.S. EPA Water Standards, Criteria, and Guidelines for Establishing Ground-Water Cleanup Levels

Table E-1
U.S. EPA DRINKING WATER STANDARDS, CRITERIA, AND GUIDELINES FOR PROTECTION OF HUMAN HEALTH
All values presented in this table must be confirmed
As of August 1, 1988
(ug/l)

This document provides a summary of information in the Superfund Public Health Evaluation Manual, the Integrated Risk Information System (IRIS) outputs, and other source documents. Only source documents should be referenced in the ROD. For additional information contact your regional coordinator or the Office of Information Resources Management.

					These Columns Must Be Verified by IRIS		Water Quality Criteria for Protection of Human Health(g)						
							Ingestion of Drinking Water Only		Ingestion of Drinking Water and Aquatic Organisms		Ingestion of Aquatic Organisms Only		
Chemical	Practical Quantification Limits (a)	MCL (b)	MCLG (c)	Proposed MCLG(d)	Concentration at 10^{-6} Risk Level (e,f)	Concentration at RfD Level (e,f)	Threshold Toxicity Protection	10^{-6} Cancer Risk	Threshold Toxicity Protection	10^{-6} Cancer Risk	Threshold Toxicity Protection	10^{-6} Cancer Risk	ODW Health Advisory(h) Lifetime 70 kg Adult
Acenaphthene	10	-	-	-	-	-	20	-	-	-	-	-	-
Acenaphthylene	10	-	-	-	-	-	-	-	-	-	-	-	-
Acetone	100	-	-	-	-	3500	-	-	-	-	-	-	-
Acrolein	5	-	-	-	-	-	540	-	320	-	780	-	-
Acrylamide	-	-*	-	0	-	-	-	-	-	-	-	-	-
Acrylonitrile	5	-	-	-	0.06	-	-	0.063	0.058	-	-	0.65	-
Alachlor	-	-*	-	0	-	350	-	-	-	-	-	-	-
Aldicarb	-	-*	-	9	-	45.5	-	-	-	-	-	-	10
Aldrin	0.05	-	-	-	-	1.05	-	0.0012	-	0.000074	-	0.000079	-
Aluminum	-	50†	-	-	-	-	-	-	-	-	-	-	-
Anthracene	10	-	-	-	-	-	-	-	-	-	-	-	-
Antimony, total	30	-	-	-	-	14	146	-	146	-	45000	-	-
Arsenic, total	10	50*	-	50	-	-	-	0.025	-	0.0022	-	0.0175	-
Asbestos	-	-*	-	7.0(k)	-	-	-	0.030(k)	-	0.030(k)	-	-	-
Barium, total	20	1000*	-	1500	-	1750	-	-	1,000	-	-	-	1500
Benzene	2	5	0	-	1	-	-	0.67	-	0.66	-	40	-
Benzidine	-	-	-	-	0.0002	-	-	0.00015	-	0.00012	-	0.00053	-
Benzo(a)anthracene	10	-	-	-	-	-	-	j	-	j	-	j	-
Benzo(a)pyrene	10	-	-	-	-	-	-	j	-	j	-	j	-
Benzo(b)fluoranthene	10	-	-	-	-	-	-	j	-	j	-	j	-
Benzo(k)fluoranthene	10	-	-	-	-	-	-	j	-	j	-	j	-
Benzo(g,h,i)perylene	10	-	-	-	-	-	-	j	-	j	-	j	-
Beryllium, total	2	-	-	-	-	175	-	0.0039	-	0.0068	-	0.117	-
alpha-BHC	0.05	-	-	-	-	-	-	0.013	-	0.0092	-	0.031	-
beta-BHC	0.05	-	-	-	-	-	-	0.023	-	0.0163	-	0.0547	-
gamma-BHC (Lindane)	0.05	4*	-	0.2	-	10.5	-	0.017	-	0.0186	-	0.0625	2
Bis-2-chloroethylether	10	-	-	-	0.03	-	-	-	-	0.03	-	1.36	-
Bis(2-ethylhexyl) phthalate	10	-	-	-	50	700	21,000	-	15,000	-	50,000	-	-
Bromodichloromethane	1	100(i)	-	-	-	700	-	-	0.19	-	15.7	-	-
Bromoform	2	100(i)	-	-	-	700	-	-	-	-	-	-	-
2-Butanone (MEK)	10	-	-	-	-	1,750	-	-	-	-	-	-	170
Cadmium, total	1	10*	-	5	-	-	10	-	10	-	-	-	5
Carbofuran	-	-*	-	36	-	175	-	-	-	-	-	-	36
Carbon disulfide	5	-	-	-	-	3,500	-	-	-	-	-	-	-
Carbon tetrachloride	1	5*	0	-	0.3	24.5	-	0.42	-	4	-	6.94	-
Chlorobenzene	2	10†	-	60	-	-	488	-	488	-	-	-	300
Chlordane	0.1	-*	-	0	0.027	1.75	-	0.022	-	0.00046	-	0.00048	-
Chloride	-	250,000†	-	-	-	-	-	-	-	-	-	-	-
Chloroform	0.5	100(i)	-	-	-	350	-	0.19	-	0.19	-	15.7	-
2-Chloronaphthalene	10	-	-	-	-	-	-	-	-	-	-	-	-
2-Chlorophenol	5	-	-	-	-	-	-	-	-	-	-	-	-
3-Chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium (total)	10	50*	-	120	-	-	-	-	-	-	-	-	120
Chromium (hexavalent)	-	-	-	-	-	175	50	-	50	-	-	-	-
Chromium (trivalent)	-	-	-	-	-	35,000	179,000	-	170,000	-	3,433,000	-	-
Chrysene	10	-	-	-	-	-	-	j	-	j	-	j	-
Color	-	15 units†	-	-	-	-	-	-	-	-	-	-	-
Copper, total	60	1,000*†	-	1300	-	-	1,000	-	-	-	-	-	-
Corrosivity	-	noncorrosive†	-	-	-	-	-	-	-	-	-	-	-
Cyanide	40	-	-	-	-	700	200	-	200	-	-	-	154

Table E-1
(Continued)

Chemical	Practical Quanti-fication Limits (a)	MCL (b)	MCLG (c)	Proposed MCLG(d)	These Columns Must Be Verified by IRIS: Concentration at 10^{-6} Risk Level (e,f)	These Columns Must Be Verified by IRIS: Concentration at RfD Level (e,f)	Water Quality Criteria for Protection of Human Health(g) — Ingestion of Drinking Water Only: Threshold Toxicity Protection	Ingestion of Drinking Water Only: 10^{-6} Cancer Risk	Ingestion of Drinking Water and Aquatic Organisms: Threshold Toxicity Protection	Ingestion of Drinking Water and Aquatic Organisms: 10^{-6} Cancer Risk	Ingestion of Aquatic Organisms Only: Threshold Toxicity Protection	Ingestion of Aquatic Organisms Only: 10^{-6} Cancer Risk	ODW Health Advisory(h) Lifetime 70 kg Adult
DDD	0.1	-	-	-	-	-	-	-	-	-	-	-	-
DDE	0.05	-	-	-	-	-	-	-	-	-	-	-	-
DDT	0.1	-	-	-	-	17.5	-	0.0012	-	0.000024	-	0.000024	-
2,4-D	10	100*	-	70	0.01	350	-	-	-	100	-	-	70
DBCP	5	-	-	0	-	-	-	-	-	-	-	-	-
Dibenzo(a,h)anthrancene	10	-	-	-	-	-	-	j	-	j	-	j	-
Dibutylphthalate	2	-	-	-	-	3,500	44,000	-	34,000	-	154,000	-	-
1,2-Dichlorobenzene(o)	2	-*/10†	-	-	-	-	470	-	400	-	2,600	-	620
1,3-Dichlorobenzene(m)	5	-/5†	-	-	-	-	470	-	400	-	2,600	-	620
1,4-Dichlorobenzene(p)	2	75/5†	75	-	-	-	470	-	400	-	2,600	-	75
1,2-Dichloroethane	0.5	5	0	-	0.4	-	-	-	-	0.94	-	243	-
1,1-Dichloroethene	1	7	7	-	0.06	315	-	0.033	-	0.033	-	1.85	7
cis-1,2-Dichloroethene	-	-*	-	70	-	-	-	-	-	-	-	-	70
trans-1,2-Dichloroethene	1	-*	-	70	-	-	-	-	-	-	-	-	70
Dichloromethane	5	-	-	-	5	2,100	-	0.19	-	0.19	-	15.7	-
1,2-Dichloropropane	0.5	-*	-	6	-	-	-	-	-	-	-	-	-
Dichloropropene	5	-	-	-	-	10.5	87	-	87	-	14,000	-	-
Dieldrin	0.5	-	-	-	-	-	-	0.0011	-	0.000071	-	0.000076	-
Diethyl phthalate	5	-	-	-	-	28,000	-	-	350,000	-	1,800,000	-	-
Dimethyl phthalate	5	-	-	-	-	-	350,000	-	313,000	-	2,900,000	-	-
3-3'-Dichlorobenzidine	20	-	-	-	-	-	-	-	-	0.01	-	0.02	-
2,3-Dichlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4-Dichlorophenol	5	-	-	-	-	105	3,090	-	3,090	-	3,090	-	-
2,5-Dichlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,6-Dichlorophenol	10	-	-	-	-	-	-	-	-	-	-	-	-
3,4-Dichlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4-Dimethylphenol	5	-	-	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	0.2	-	-	-	-	-	-	0.11	-	0.11	-	9.1	-
Dioxane	150	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Diphenylhydrazine	-	-	-	-	0.05	-	-	0.046	-	0.042	-	0.56	-
Endosulfan	0.1	-	-	-	-	1.75	138	-	74	-	159	-	-
Endosulfan sulfate	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Endrin	0.1	0.2	-	-	-	-	1	-	1	-	-	-	0.32
Epichlorohydrin	-	-*	-	0	3	70	-	-	-	-	-	-	-
Ethylbenzene	2	-*/30†	-	680	-	3,500	2,400	-	1,400	-	3,280	-	680
Ethylenedibromide	5	-*	-	0	-	-	-	-	-	-	-	-	-
Ethyleneglycol	-	-	-	-	-	70,000	-	-	-	-	-	-	7000
Fluoranthene	10	-	-	-	-	-	188	-	42	-	54	-	-
Fluorene	10	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	-	2,000†	-	-	-	-	-	-	-	-	-	-	-
Foaming agents	-	500†	-	-	-	-	-	-	-	-	-	-	-
Halomethanes	-	0.10	-	-	-	-	-	0.19	-	0.19	-	15.7	-
Heptachlor	0.05	-*	-	0	0.008	17.5	-	0.011	-	0.00028	-	0.00029	-
Heptachlor epoxide	1	-*	-	0	0.004	0.455	-	-	-	0.00028	-	0.00029	-
Hexachlorobenzene	0.5	-	-	-	-	-	-	0.021	-	0.00072	-	0.00074	-
Hexachlorobutadiene	5	-	-	-	0.5	70	-	0.45	-	0.45	-	50	-
Hexachlorocyclopentadiene	5	-	-	-	-	245	206	-	206	-	14,800	-	-
Hexachloroethane	0.5	-	-	-	3	35	-	-	1.9	-	-	8.74	-
Hexane	-	-	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	10	-	-	-	-	-	-	-	-	-	-	-	-
Iron, total	-	300†	-	-	-	-	-	-	-	-	-	-	-
Isophorone	10	-	-	-	-	-	5,200	-	5,200	-	520,000	-	-
Lead, total	10	50	-	20	-	-	50	-	50	-	-	-	-
Manganese, total	-	50†	-	-	-	-	-	-	50	-	100	-	-
Mercury (alkyl)	2	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (inorganic)	-	2*	-	3	-	-	10	-	0.144	-	0.146	-	1.1
Methoxychlor	2	100*	-	340	-	-	-	-	100	-	-	-	340

Table E-1
(Continued)

Chemical	Practical Quanti-fication Limits (a)	MCL (b)	MCLG (c)	Proposed MCLG(d)	These Columns Must Be Verified by IRIS: Concentration at 10^{-6} Risk Level (e,f)	These Columns Must Be Verified by IRIS: Concentration at RfD Level (e,f)	Water Quality Criteria for Protection of Human Health(g) — Ingestion of Drinking Water Only: Threshold Toxicity Protection	Ingestion of Drinking Water Only: 10^{-6} Cancer Risk	Ingestion of Drinking Water and Aquatic Organisms: Threshold Toxicity Protection	Ingestion of Drinking Water and Aquatic Organisms: 10^{-6} Cancer Risk	Ingestion of Aquatic Organisms Only: Threshold Toxicity Protection	Ingestion of Aquatic Organisms Only: 10^{-6} Cancer Risk	ODW Health Advisory(h) Lifetime 70 kg Adult
2-Methyl-4-chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Methyl-4-chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Methyl-6-chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone (MIBK)	5	-	-	-	-	1,750	-	-	-	-	-	-	-
4-Methylphenol	10	-	-	-	-	-	-	-	-	-	-	-	-
Nickel, total	50	-	-	-	-	700	15.4	-	13.4	-	100	-	150
Nitrate-N	-	10,000	10,000	-	-	35,000	-	-	-	-	-	-	10,000
Nitrite-N	-	-	1,000	-	-	3,500	-	-	-	-	-	-	1,000
Nitric oxide	-	-	-	-	-	3,500	-	-	-	-	-	-	-
Nitrobenzene	10	-	-	-	-	17.5	19,800	-	19,800	-	-	-	-
n-Nitrosodimethylamine	10	-	-	-	-	-	-	0.0014	-	0.0014	-	16	-
n-Nitrosodiethylamine	10	-	-	-	-	-	-	0.0008	-	0.0008	-	1.2	-
n-Nitrosodi-n-butylamine	10	-	-	-	0.006	-	-	0.0064	-	0.0064	-	0.587	-
n-Nitrosopyrrolidine	10	-	-	-	0.02	-	-	0.016	-	0.016	-	91.9	-
n-Nitrosodiphenylamine	10	-	-	-	7	-	-	7.0	-	4.9	-	16.1	-
Odor	-	3 units†	-	-	-	-	-	-	-	-	-	-	-
Oxamic acid	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB's	50	-*	-	0	-	-	-	0.013	-	0.000079	-	0.000079	-
PAHs	-	-	-	-	-	-	-	0.0031	-	0.0028	-	0.031	-
Pentachlorobenzene	10	-	-	-	-	28	-	-	74	-	85	-	-
Pentachlorophenol	5	-*/30†	-	220	-	1,050	1,010	-	1,010	-	-	-	220
pH	-	6.5-8.5	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	10	-	-	-	-	-	-	-	-	-	-	-	-
Phenol	1	-	-	-	-	1,400	3,500	-	3,500	-	-	-	-
Pyrene	10	-	-	-	-	-	-	-	-	-	-	-	-
Radium-226 and 228	-	5(n)††	-	-	-	-	-	-	-	-	-	-	-
Selenium, total	20	10*	-	45	-	-	10	-	10	-	-	-	-
Silver, total	70	50*/90†	-	-	-	105	50	-	50	-	-	-	-
Styrene	1	10†	-	140	-	7,000	-	-	-	-	-	-	140
Sulfate	-	250,000†	-	-	-	-	-	-	-	-	-	-	-
2,3,7,8-TCDD	0.005	-	-	-	-	-	-	1.8e-7	-	1.3e-8	-	1.4e-8	-
Tetrachloroethene	0.5	-*	-	0	-	350	-	0.88	-	0.80	-	8.85	10
1,1,2,2-Tetrachloroethane	0.5	-	-	-	0.175	-	-	0.17	-	0.17	-	10.7	-
2,3,4,6-Tetrachlorophenol	10	-	-	-	-	1,050	-	-	-	1	-	-	-
Thallium, total	10	-	-	-	-	-	17.8	-	13	-	48	-	-
Toluene	2	-*/40†	-	2,000	-	10,500	15,000	-	14,300	-	424,000	-	2,420
Total dissolved solids	-	500,000†	-	-	-	-	-	-	-	-	-	-	-
Toxaphene	2	5*	-	0	-	-	-	0.026	-	0.00071	-	0.00073	-
2,4,5-TP	2	-*	-	-	-	-	-	-	-	10	-	-	52
1,2,4-Trichlorobenzene	10	-	-	-	-	700	-	-	-	-	-	-	-
1,1,1-Trichloroethane	5	200	200	-	-	3,150	19,000	-	18,400	-	1,030,000	-	200
1,1,2-Trichloroethane	0.2	-	-	-	0.6	7,000	-	0.60	-	0.6	-	41.8	-
Trichloroethene	1	5	0	-	3	-	-	2.8	-	2.7	-	80.7	-
2,4,5-Trichlorophenol	10	-	-	-	-	3,500	-	-	2,600	-	-	-	-
2,4,6-Trichlorophenol	5	-	-	-	1.75	-	-	1.8	-	1.2	-	3.6	-
Vanadium	40	-	-	-	-	315(l)	-	-	-	-	-	-	-
Vinyl chloride	2	2	0	-	0.015	-	-	2	-	2.0	-	525	-
Xylene	5	-*/20†	-	440	-	350	-	-	-	-	-	-	400
Zinc, total	20	5,000	-	-	-	7,350	5,000	-	-	-	-	-	-

Table E-1
(Continued)

a. Source: 52 FR 25947. Practical quantification limits presented are for standard analytical methods. It may be appropriate to use different analytical methods to achieve lower quantification limits in some cases.
b. 40 CFR 141 and 143.
c. 40 CFR 141.50.
d. 50 FR 46936; November 13, 1985.
e. Integrated Risk Information System database.
f. *Assuming drinking water ingestion of 2 liter/day and body weight of 70 kg.*
g. 45 FR 79318-79379; November 28, 1980.
h. U.S. EPA, Health Advisories, March 1987.
i. Based on the standard for total trihalomethanes of 100 ug/l.
j. Based on criteria for polycyclic aromatic hydrocarbons (PAHs).
k. Million fibers/liter.
l. For vanadium pentoxide.
m. See also U.S. EPA "Comparisons of Office of Drinking Water and Office of Water Regulations and Standards for 307(A) Toxic Pollutants" for updated volumes of priority pollutants.
* MCL will be proposed in the Federal Register in 1988. MCLs will also be proposed for aldicarb sulfoxide, aldicarb sulfone, atrazine, and dibromochloropropane.
† Secondary MCL.
†† n = pCi/l.

Table E-2
U.S. EPA WATER QUALITY CRITERIA FOR PROTECTION OF AQUATIC LIFE
As of September 2, 1986
(ug/l)

	Concentration			
	Freshwater Acute Criteria	Freshwater Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria
Acenapthene	1,700[b]	520[b]	970[b]	710[b]
Acrolein	68[b]	21[b]	55[b]	-
Acrylonitrile	7,550[b]	2,600[b]	-	-
Aldrin	3.0	-	1.3	-
Alkalinity	-	20,000	-	-
Ammonia	CRITERIA ARE pH AND TEMPERATURE DEPENDENT			
Antimony	9,000[b]	1,600[b]	-	-
Arsenic (pentavalent)	850[b]	48[b]	2,319[b]	13[b]
Arsenic (trivalent)	360	190	69	36
Bacteria	FOR PRIMARY RECREATION AND SHELLFISH USES			
Benzene	5,300[b]	-	5,100[b]	700[b]
Benzidine	2,500[b]	-	-	-
Beryllium	130[b]	5.3[b]	-	-
BHC	100[b]	-	0.34[b]	-
Cadmium	3.9[a]	1.1[a]	43	9.3
Carbon tetrachloride	35,200[b]	-	50,000[b]	-
Chlordane	2.4	0.0043	0.09	0.004
Chlorinated benzenes	250[b]	50[b]	160[b]	129[b]
Chlorinated naphthalenes	1,600[b]	-	-	7.5[b]
Chlorine	19	11	13	7.5
Chloroalkyl ethers	238,000[b]	-	-	-
Chloroform	28,900[b]	1,240[b]	-	-
2-Chlorophenol	4,380[b]	2,000[b]	-	-
4-Chlorophenol	-	-	29,700[b]	-
4-Chloro-3-methyl phenol	30[b]	-	-	-
Chromium (hexavalent)	16	11	1,100	50
Chromium (trivalent)	1,700[a]	210[a]	10,300[b]	-
Copper	18[a]	12[a]	2.9	2.9
Cyanide	22	5.2	1	1
DDT	1.1	0.001	0.13	0.001

Table E-2
(Continued)

	Concentration			
	Freshwater Acute Criteria	Freshwater Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria
DDE	1,050[b]	-	14[b]	-
TDE	0.06[b]	-	3.6[b]	-
Demeton	-	0.1	-	0.1
Dichlorobenzenes	1,120[b]	763[b]	1,970[b]	-
1,2-Dichloroethane	118,000[b]	20,000[b]	113,000[b]	-
Dichloroethylenes	11,600[b]	-	224,000[b]	-
2,4-Dichlorophenol	2,020[b]	365[b]	-	-
Dichloropropane	23,000[b]	5,700[b]	10,300[b]	3,040[b]
Dichloropropene	6,060[b]	244[b]	790[b]	-
Dieldrin	2.5	0.0019	0.71	0.0019
2,4-Dimethyl phenol	2,120[b]	-	-	-
Dinitrotoluene	330[b]	230[b]	590[b]	370[b]
2,3,7,8-TCDD	<0.01[b]	<0.00001[b]	-	-
1,2-Diphenylhydrazine	270[b]	-	-	-
Endosulfan	0.22	0.056	0.034	0.0087
Endrin	0.18	0.0023	0.037	0.0023
Ethylbenzene	32,000[b]	-	430[b]	-
Fluoranthene	3,980[b]	-	40[b]	16[b]
Guthion	-	0.01	-	0.01
Haloethers	360[b]	122[b]	-	-
Halomethanes	11,000[b]	-	12,000[b]	6,400[b]
Heptachlor	0.52	0.0038	0.053	0.0036
Hexachloroethane	980[b]	540[b]	940[b]	-
Hexachlorobutadiene	90[b]	9.3[b]	32[b]	-
Lindane	2.0	0.08	0.16	-
Hexachlorocyclopentadiene	7[b]	5.2[b]	7[b]	-
Iron	-	1,000	-	-
Isophorone	117,000[b]	-	12,900[b]	-
Lead	82[a]	3.2[a]	140	5.6
Malathion	-	0.01	-	0.01
Mercury	2.4	0.012	2.1	0.025

Table E-2
(Continued)

	Concentration			
	Freshwater Acute Criteria	Freshwater Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria
Methoxychlor	-	0.03	-	0.03
Mirex	-	0.001	-	0.001
Naphthalene	2,300[b]	620[b]	2,350[b]	-
Nickel	1,800[a]	96[a]	140	7.1
Nitrobenzene	27,000[b]	-	6,680[b]	-
Nitrophenols	230[b]	150[b]	4,850[b]	-
Nitrosamines	5,850[b]	-	3,300,000[b]	-
Parathion	-	0.04	-	0.04
PCBs	2.0	0.014	10	0.03
Pentachlorinated ethanes	7,240[b]	1,100[b]	390[b]	281[b]
Pentachlorophenol	55[b]	3.2[b]	53[b]	34[b]
Phenol	10,200[b]	2,560[b]	800	-
Phthalate esters	940[b]	3[b]	2,944	3.4[b]
Polynuclear aromatic hydrocarbons	-	-	300[b]	-
Selenium	260	35	410	54
Silver	4.1[a]	0.12	2.3	-
Sulfide	-	2	-	2
Tetrachlorinated ethanes	9,320[b]	-	-	-
1,1,2,2-Tetrachloroethane	-	2,400[b]	9,020[b]	-
Tetrachloroethanes	9,320[b]			
Tetrachloroethylene	5,280[b]	840[b]	10,200[b]	450[b]
2,3,5,6-Tetrachlorophenol	-	-	-	440[b]
Thallium	1,400[b]	40[b]	2,130[b]	-
Toluene	17,500[b]		6,300[b]	5,000[b]
Toxaphene	1.6	0.013	0.07	-
Trichlorinated ethanes	18,000[b]	-	-	-
1,1,1-Trichloroethane	-	-	31,200[b]	-
1,1,2-Trichloroethane	-	9,400[b]	-	-
Trichloroethylene	45,000[b]	21,900[b]	2,000[b]	-

Table E-2
(Continued)

	Concentration			
	Freshwater Acute Criteria	Freshwater Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria
2,4,6-Trichlorophenol	-	970[b]	-	-
Zinc	320[a]	47	170	58

[a]Hardness dependent criterion (100 mg/l used).

[b]Insufficient data to develop criteria. Value presented is the L.O.E.L.--lowest observed effect level.

Appendix F
Sample Letter to Obtain Property Access

[date]

PRP Name
Street Address
City.........

Re: ________________ Superfund Site

Dear __________:

As you may know, the U.S. Environmental Protection Agency (EPA) is conducting a Remedial Investigation/Feasibility Study in the [Site name] area to determine both the sources and extent of [ground water/soil/air] contamination. This contamination has resulted from the improper disposal of [chemicals] that pose a threat to the public health and the environment.

The EPA is scheduling [soil/soil gas/air/ground water, etc.] sampling activities on properties in your area. The sampling is designed to determine if contamination is present in [shallow soils/surface water/ground water/the air]. This sampling activity is scheduled to occur sometime during the week(s) of [date]. EPA's current plans call for [a type of sampling, e.g., soil borings; installing a ground water monitoring well for subsequent sampling; air sampling] to take place on your property at [address] on [day/week/during this time] (or) EPA will need to secure access to a portion of your property for approximately [weeks/months] to complete construction of a [well/facility].

Your cooperation is requested in giving EPA representatives access to your property to complete this sampling/construction activity. In order for us to plan successfully, we would appreciate your signing this letter below and returning it in the envelope provided. You may wish to keep a copy for your records. When the sampling program is completed the EPA will furnish you with the test results of samples taken on your property.

The sampling will consist of [specify details of activity]. The [soil/soil gas/surface water/ground water/air] sampling on your property should not take more than ___ [hours/days]. Our work there may involve some disturbance of the [soil/pavement/vegetation/sprinkler systems] on you property [including drilling small holes/digging a temporary trench, etc.]. We will take care to restore your property to substantially the same condition that existed prior to the work. All holes will be filled and regraded.

[Optional paragraphs 1-7 (may be used in follow-up letter)]:

We understand that you have some concerns about EPA entering your property and conducting the above activities. You may be concerned about:

[1] liability for damages, injuries, and indemnification;
[2] danger to your health;
[3] the level and quality of restoration to your property;
[4] split samples to be provided by EPA;
[5] the availability of test results for the site;
[6] the legal consequences of denying access to EPA;
[7] special considerations that you have requested.

The EPA is taking the above action because of its responsibility to respond to contaminated sites under the Comprehensive Environmental Response, Compensation and Liability

Act (Superfund), 42 U.S.C. Section 9601. If you have any questions, please call me at (415) 974-xxxx, or contact [name] of our Office of Regional Counsel at (415) 974-xxxx. Thank you for your cooperation.

Sincerely,

[Name]
Remedial Project Manager

Enclosure

. . . .

PLEASE SIGN BELOW AND RETURN THIS LETTER IN THE ENCLOSED ENVELOPE

My signature below acknowledges that I have read this letter and agree that EPA, their representatives or contractors, may enter my property during the week of [date] to conduct the activities specified above.

________________________________ ____________________
Signature Date

____
Address

OPTIONAL PARAGRAPHS

[1] I understand that you have expressed some concerns about indemnification for personal injury or property damage as a result of EPA conducting the above activities on your property. You should be aware that the EPA does not enter into indemnification agreements with landowners. However, EPA does have a written agreement with ___________, our contractor, requiring it to carry a comprehensive insurance policy to cover claims for personal injury, death, or property damage to third parties. In addition, should the claim exceed the policy limit, set at a minimum of [$(1,000,000)] per occurrence, the EPA has agreed to pay for any excess liability. If this does not provide adequate compensation, the only direct remedy against the EPA is to file a claim under the Federal Tort Claims Act, 28 U.S.C. Sections 2671-2680.

[2] I understand that you have expressed concern about this site presenting a health threat. At this time, EPA is not aware of any immediate health threat posed to you from this site. In addition, EPA has taken precautions to minimize any potential health threat to both the on-site workers and off-site residents during field activities. A Health and Safety Plan, a document available to the public, has been developed for this site to insure that adequate monitoring is conducted to determine the level of protective clothing required for on-site workers and any potential exposures to off-site residents. You will be notified if contaminants are detected at the site boundaries above safe levels. The site will be secured to minimize exposure to non-EPA personnel. Therefore, EPA field activities are not expected to pose a health threat to any of the residents in your area.

[3] I understand that you have expressed concern regarding the level and quality of restoration of your property. During the course of EPA's field activities, there is the possibility that your property may be disturbed. EPA will restore your property in the event of this disruption. The restoration will be at the level of current construction practices and will attempt to remedy any disruption. Examples of this restoration will be to fill and patch any damaged concrete or asphalt and replant any landscaping. We would like to work with you during our activities to minimize any disturbance to your property.

[4] I understand that you have expressed concern regarding the samples obtained from your property. At your request, we will provide to you free of charge a portion of the [air/water/soil] sample in an appropriate container. If you wish to compare the results from your sample with EPA's results, you must follow the protocols listed in the [site name] Quality Assurance/Quality Control Plan, a document that can be made available to the public. These protocols include the specific type of laboratory testing and shipping procedures required. If you wish to obtain a sample, please notify me at least 48 hours before the field work begins.

[5] I understand that you have expressed concern regarding the availability of test results from the site. The results of tests from your property will be sent to you as a matter of course when these results have been received and verified by EPA. If you wish, you may obtain the sample results from tests conducted at other locations within the [site name] upon request.

[6] You should be aware that the Superfund law specifically gives EPA a right to access private property in Section 104(e)(4)(A). This section states that "any officer, employee, or representative is authorized to inspect and obtain samples from any vessel, facility, establishment, or other place or property or from any location of any suspected hazardous substance or pollutant or contaminant." You may be subject to a civil penalty of up to $25,000 for each day that you fail to grant access to the EPA.

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