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

FINAL GUIDANCE

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NOTICE

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

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ACRONYMS USED IN THIS GUIDANCE

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

PREFACE

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

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

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

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

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

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

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

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

1.0 INTRODUCTION

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

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

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

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

1.1 Purpose of Guidance

In summary, this guidance is intended to:

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

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

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

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

1.2 Expectations and Objectives for Ground-Water Cleanup

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

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

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

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

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

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

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

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

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

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

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

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

1.3 Lessons Learned

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

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

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

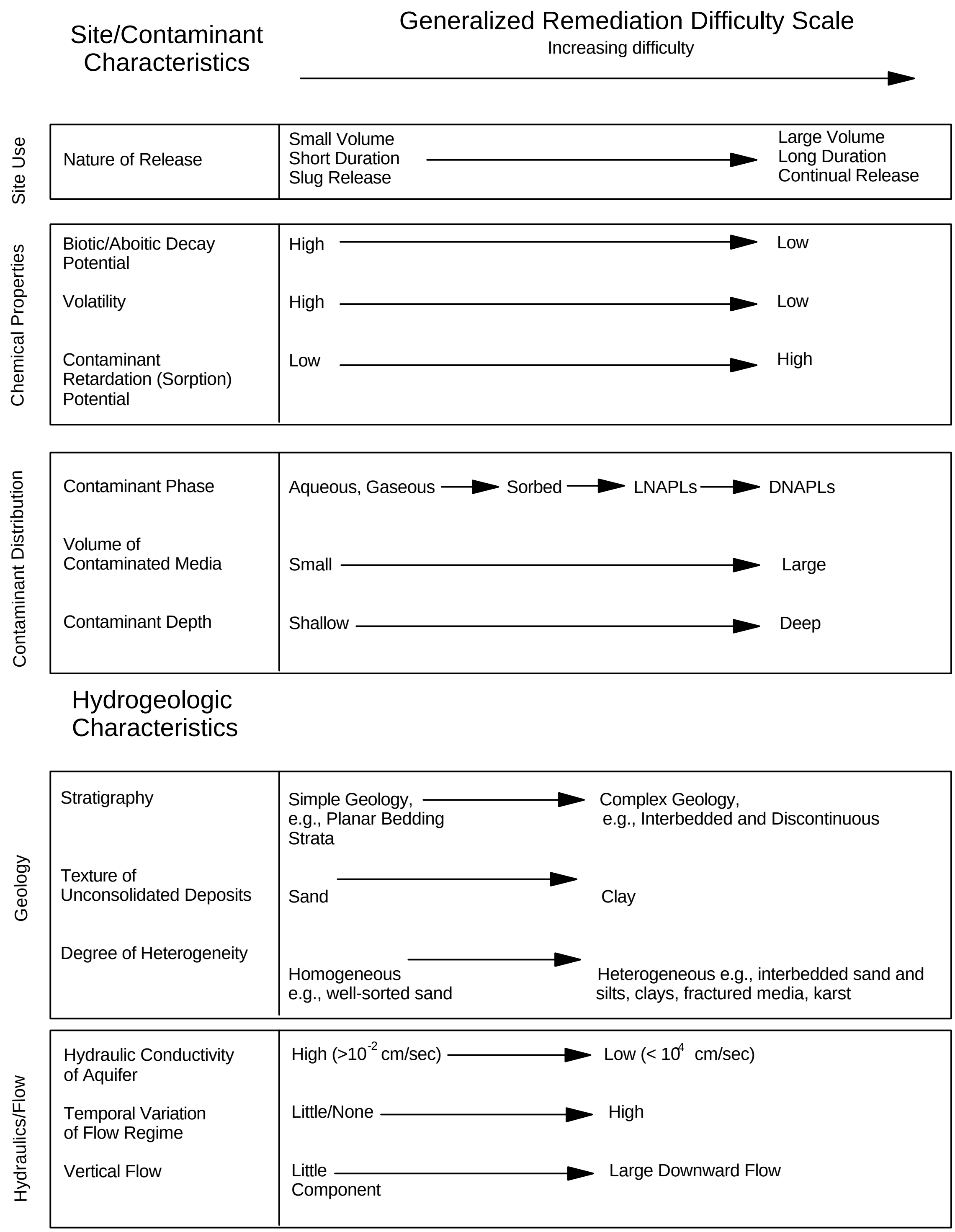
1.3.2 Factors Limiting Restoration Potential. At many sites, restoration of ground water to cleanup levels defined by applicable or relevant and appropriate requirements (ARARs) or risk-based levels may not be possible over all or portions of the plume using currently available technologies. Two types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

- Hydrogeologic factors, and
- Contaminant-related factors.

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

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

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



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

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

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

2.0 PRESUMPTIVE RESPONSE STRATEGY

2.1 Definition and Basis for Strategy

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

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

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

Highlight 1. Presumptive Response Strategy

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

Highlight 1 is a presumptive strategy for contaminated ground water.

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

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

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

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

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

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

Highlight 2. Early Actions That Should Be Considered

Prevent exposure to contaminated ground water:

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

Prevent further migration of **contaminant plume**:

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

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

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

Provide additional site data:

- Assess restoration potential
- Combine actions with treatability studies

potential should be assessed prior to establishing objectives for the long-term remedy (see Section 1.3.3).

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

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

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

2.2 Phased Response Actions

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

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

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

in one ROD. A second decision document could
still be required if evaluation of the first phase

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

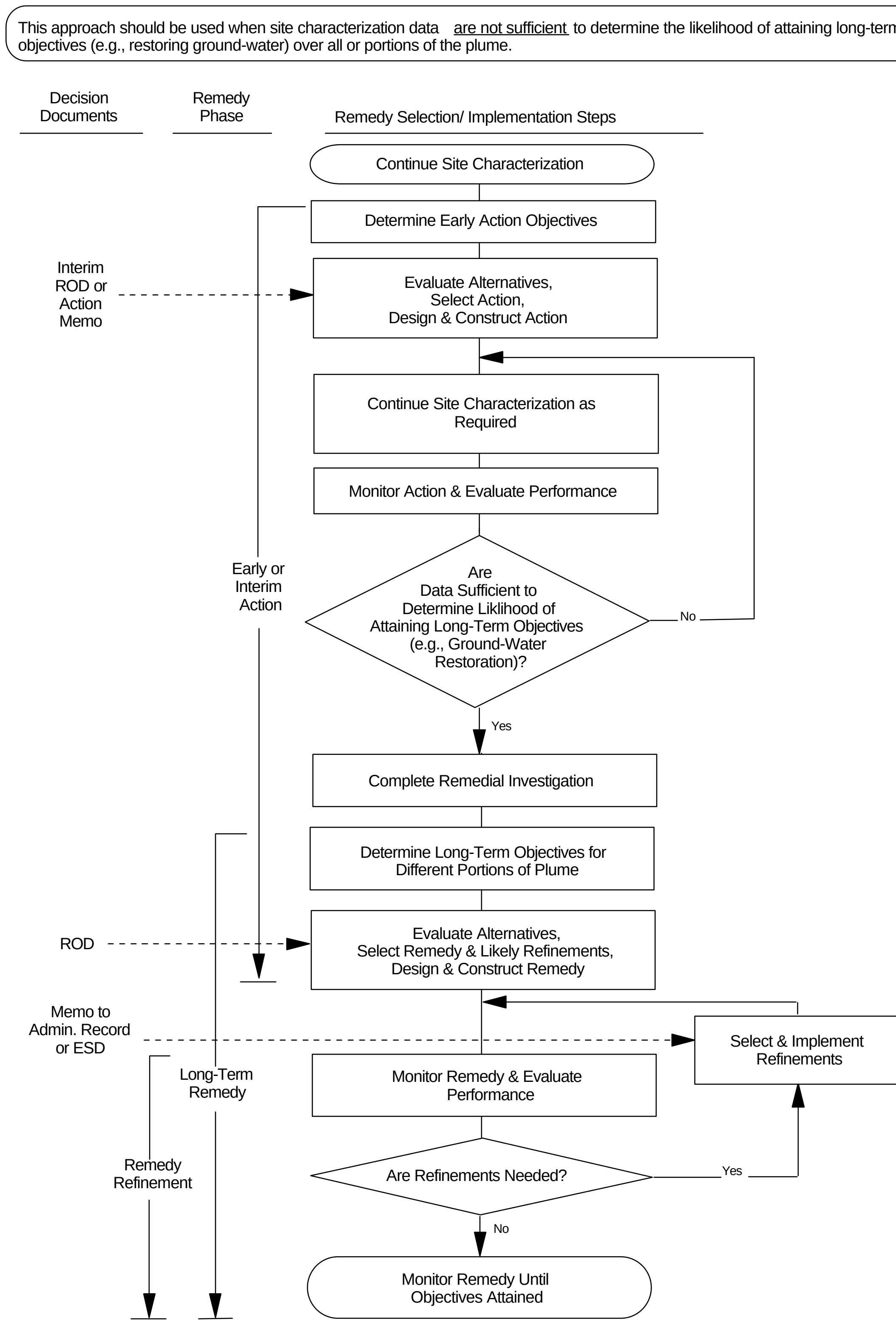
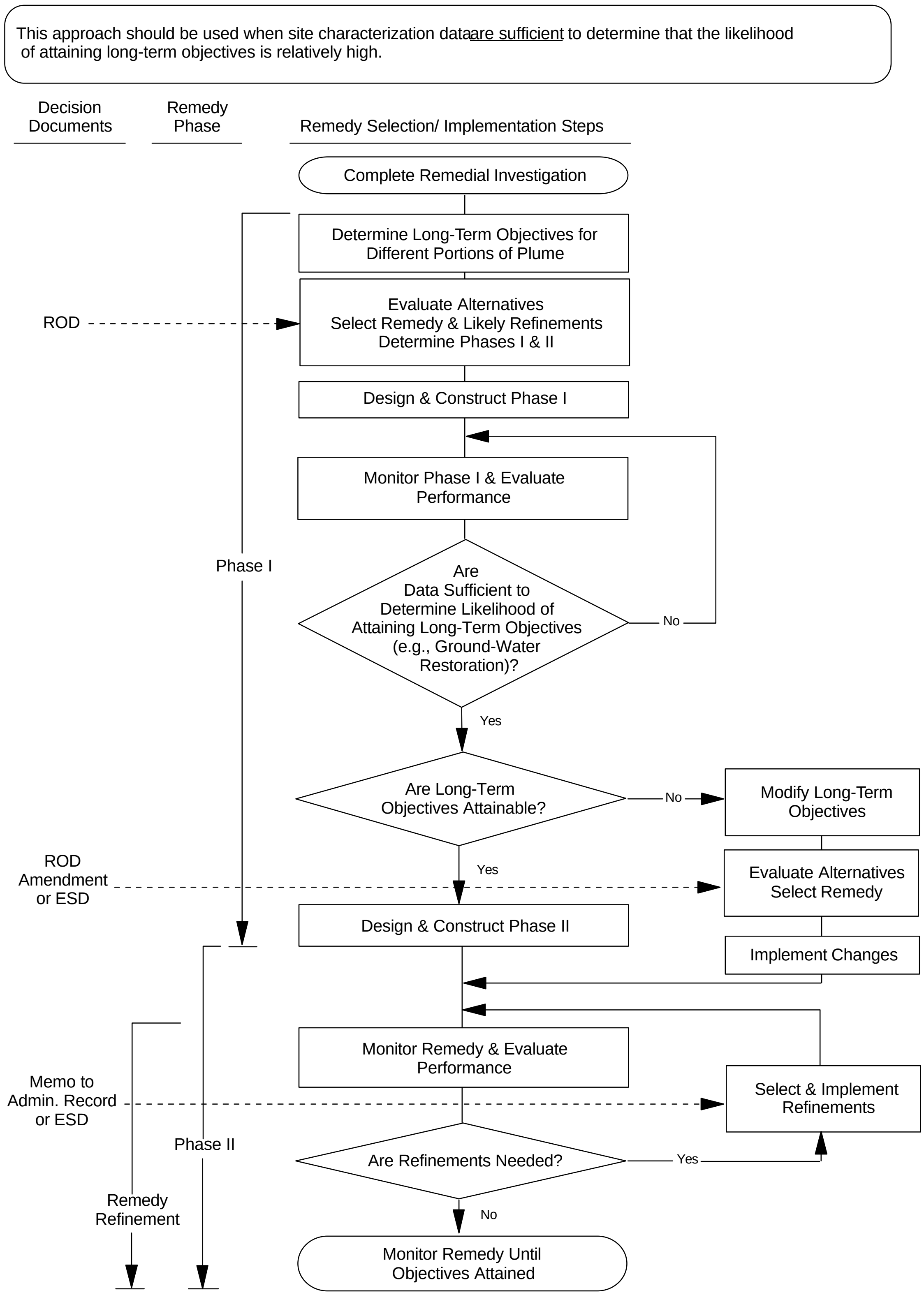


Figure 3. Phased Ground-Water Actions: Long-Term Remedy Implemented in Phases



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

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

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

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

2.3 Post-Construction Refinements

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

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

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

Highlight 3. Remedy Refinements for Extraction/Treatment Remedies

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

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

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

2.4 Integrating Response Actions

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

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

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

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

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

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

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

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

2.5 Strategy for DNAPL Sites

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

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

- DNAPL zone, and the

- Aqueous contaminant plume.

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

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

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

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

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

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

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

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

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

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

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

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

2.6 Areas of Flexibility in Cleanup Approach

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.0 PRESUMPTIVE TECHNOLOGIES

3.1 Presumptive Technologies for Ex-Situ Treatment

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

Highlight 4. Presumptive Technologies For Treatment Of Extracted Ground Water

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

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

For treatment of dissolved **metals**:

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

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

- A combination of the technologies listed above

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

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

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

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

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

3.2 Basis for Presumptive Technologies

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

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

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

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

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

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

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

- A range of chemical, physical and biological treatment methods should be included in the presumptive technologies, because air stripping and granular activated carbon, alone or combined, may not provide cost effective treatment (see Section 3.4.5) for all organic contaminants.

- These methods destroy organic contaminants as part of the treatment process instead of transferring them to other media, which reduces the quantity of hazardous treatment residuals (e.g., spent carbon) that will require further treatment.

- Ongoing research and development efforts, by EPA and others, are expected to increase the cost effectiveness of these treatment methods.

3.3 Remedy Selection Using Presumptive Technologies

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

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

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

1. Separation of mineral solids and/or immiscible liquids from the extracted ground water during initial treatment (pretreatment);

2. Treatment of **dissolved contaminants**;

3. Treatment of vapor phase contaminants from the extracted ground water or those generated during treatment;

4. Separation of solids generated during treatment;

5. Final treatment of **dissolved contaminants** prior to discharge (polishing); and

6. Treatment of solids generated during treatment.

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

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

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

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

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

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

- The remedy selection process is further streamlined, since final selection and the accompanying detailed analysis for these technologies is performed only in the RD not in both the FS and the RD, minimizing duplication of effort;

- Site information collected during the RD can be used to make final technology selections as well as to design the treatment train, which facilitates selection of the most cost effective technologies (see Section 3.4.5);

- The likelihood that changes in the treatment train will be made during the RD is explicitly recognized in the ROD; and

- The time and resources employed in the FS can focus on other components of the ground-water remedy that have more direct influence on attainment of **remedial objectives** for contaminated ground water (see Section 1.0).

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

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

3.4 Information Needed for Selecting Technologies

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

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

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

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

NOTE: Further detail is provided in Appendix C3.

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

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

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

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

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

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

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

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

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

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

3.5 Treatment Technologies for Aquifer Tests

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

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

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

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

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

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

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