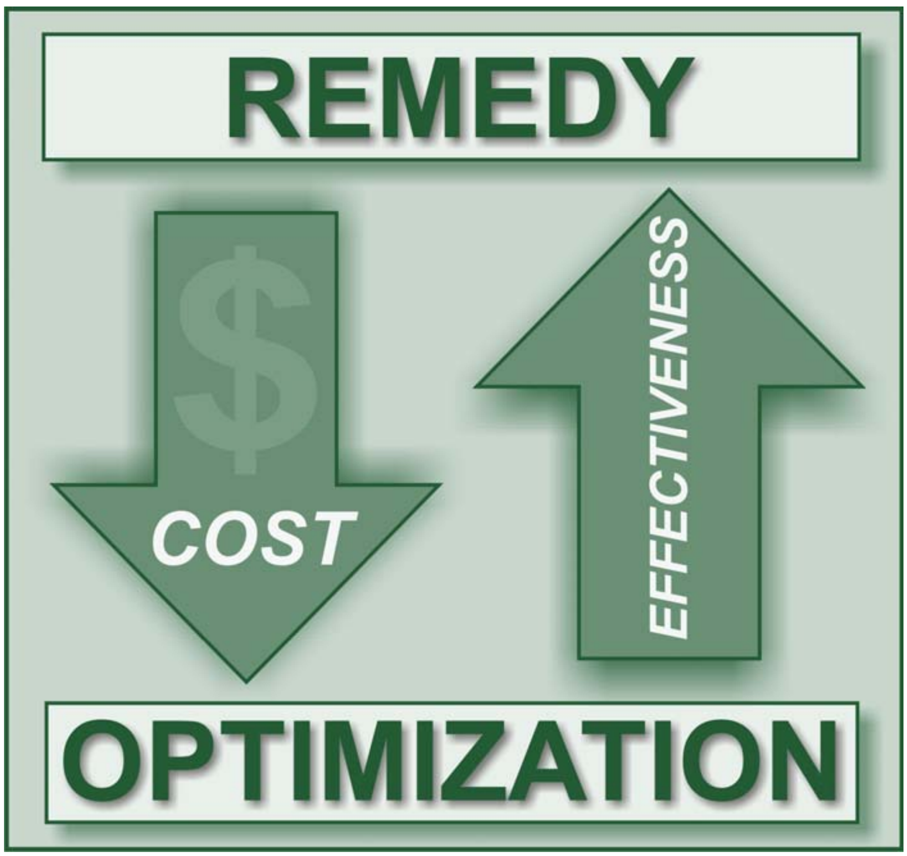
Optimization Strategies for Long-Term Ground Water Remedies
(with Particular Emphasis on Pump and Treat Systems)



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DISCLAIMER

This document provides references to models and processes in use by outside parties and other Federal Agencies. Mention of these models and processes does not imply endorsement for specific purposes.

This fact sheet is not intended to be a detailed instruction manual. In addition, this fact sheet is not a regulation; therefore, it does not impose legally binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. The document offers technical information to EPA, states and others who manage or regulate long-term ground water remedies as part of any cleanup program. EPA and State personnel may use other approaches, activities and considerations, either on their own or at the suggestion of interested parties. Interested parties are free to raise questions and objections regarding this document and the appropriateness of using these recommendations in a particular situation, and EPA will consider whether or not the recommendations are appropriate in that situation. This fact sheet may be revised periodically without public notice. EPA welcomes public comments on this document at any time and will consider those comments in any future revision of this document.

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PREFACE

This fact sheet discusses the principles and techniques for optimizing long-term ground water remedies, with particular emphasis on optimizing pump and treat (P&T) systems. It is part of a series of fact sheets that the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) is preparing to assist the ground water remediation community to effectively and efficiently design and operate long-term ground water remedies. This series is available at www.cluin.org/optimization and consists of the following fact sheets, plus others that will be available in the future.

- *Elements for Effective Management of Operating Pump and Treat Systems*
  OSWER 9355.4-27FS-A, EPA 542-R-02-009, December 2002

- *Cost-Effective Design of Pump and Treat Systems*
  OSWER 9283.1-20FS, EPA 542-R-05-008, April 2005

- *Effective Contracting Approaches for Operating Pump and Treat Systems*
  OSWER 9283.1-21FS, EPA 542-R-05-009, April 2005

- *O&M Report Template for Ground Water Remedies (with Emphasis on Pump and Treat Systems)*
  OSWER 9283.1-22FS, EPA 542-R-05-010, April 2005

- *A Cost Comparison Framework for Use in Optimizing Ground Water Pump and Treat Systems*, EPA 542-R-07-005, May 2007

- *Options for Discharging Treated Water from Pump and Treat Systems*, EPA 542-R-07-006, May 2007

The ideas contained in this series of fact sheets are based on professional experience in designing and operating long-term ground water remedies and on lessons learned from conducting optimization evaluations called Remediation System Evaluations (RSEs) at sites with P&T systems. RSEs have been conducted at Superfund-financed sites, Resource Conservation and Recovery Act (RCRA) sites, and leaking underground storage tanks sites. Reports from RSEs conducted by EPA are available at www.cluin.org/optimization.

The content of these fact sheets is relevant to almost any long-term ground water remedy, particularly those that involve P&T. Therefore, these documents may serve as resources for managers, contractors, or regulators of any P&T system, regardless of the regulatory program.

Access to a wider range of EPA documents is available at www.cluin.org.

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TABLE OF CONTENTS

A. INTRODUCTION

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Federal agencies have conducted optimization evaluations at approximately 100 operating pump and treat (P&T) systems since 2000 and have successfully identified hundreds of opportunities for improving effectiveness in protecting human health, reducing remedy life-cycle cost, and speeding progress toward site closure. The widespread use of optimization at operating ground water remedies by Federal agencies and the identification of these opportunities suggests value in communicating optimization to a broader environmental community.

This fact sheet has been prepared to assist environmental case managers from Federal and State agencies, environmental program managers from private organizations, and environmental contractors with optimization of operating long-term ground water remedies, particularly those that involve pump and treat. It discusses the benefits of optimization, components of a typical optimization evaluation, and components of an optimization program that utilizes such evaluations. Specific optimization evaluation processes that have been implemented by various Federal agencies are highlighted.

For the purpose of this document, "optimization" refers to efforts associated with improving a remedy's effectiveness in protecting human health and the environment, improving efficiency (i.e., improving cost-effectiveness while maintaining the same or higher level of effectiveness), and speeding progress toward site closure. Similarly, an "optimization evaluation" refers to an evaluation conducted by an *independent party* (i.e., a party not associated with historical site activities and current operation) on a remedy with the purpose of identifying opportunities for improving remedy effectiveness, improving efficiency, and speeding progress toward site closure. Although independent reviews of other phases of work such as remedial investigations and remedial designs also provide for greatly improved remedies, this fact sheet focuses specifically on optimization of operating remedies.

A reference section is included at the end of this document to direct readers to additional sources of information on optimization and the concepts discussed in this document.

B. BENEFITS OF OPTIMIZATION

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The 2004 Edition of EPA's *Cleaning up the Nation's Waste Sites: Markets and Technology Trends* (*U.S. EPA*, 2004b) indicates that P&T has been selected as a remedy at 67% of the sites on the National Priorities List (NPL) with ground water contamination. This translates to over 700 NPL sites with P&T systems, of which approximately 90 are owned and operated by EPA (*U.S. EPA*, 2001, 2002a). P&T is also used as a ground water remedy at sites in other cleanup programs. For example, the same document reports that a study of a subset of 186 RCRA sites indicated that 133 of those sites involved treatment of ground water contamination and 116 of those 133 (87%) used P&T. With approximately 2,000 RCRA sites with ground water contamination, the number of RCRA sites with P&T is likely several times higher than 116. Given the potential receptors near many of these sites, the relatively high recurring costs associated with operating these remedies, and the many additional sites with P&T that are part of other State and Federal cleanup programs, identifying opportunities to improve effectiveness, efficiency, and progress toward site closure is of paramount importance.

Potential opportunities for improvement identified in optimization evaluations do not imply a deficiency in the work of the system designers, system operators, or site managers. Rather, they generally result from analysis of operational data unavailable to the original designers, from site conditions that have changed over time, and/or from improved knowledge of ground water and remediation technology. The following are examples of potential opportunities for improvement that illustrate the various benefits of optimization.

Example of Potential Opportunities to Improve Effectiveness in Protecting Human Health and the Environment

A site impacted with chlorinated volatile organic compounds had an operating P&T system that was designed to provide hydraulic containment of the contaminant plume and prevent the migration of contaminants to downgradient receptors. Although the system design included a detailed capture zone analysis using a ground water flow model, the validity of this model and the design had not been verified by analyzing data during operation of the P&T system. The optimization evaluation team discussed the target capture zone with the site team and identified existing data that could be used to interpret actual capture. As part of the evaluation, a preliminary capture zone analysis was conducted, illustrating that the degree of capture was uncertain and likely less than indicated in the design, primarily due to lower than expected recovery from the extraction wells. The optimization team suggested a well rehabilitation program to improve the well yields and a reevaluation of capture after the yields improve. In the event that sufficient improvement in the well yields is not evident, the optimization evaluation team suggested locations for additional extraction wells that would likely provide adequate capture without exceeding the capacity of the treatment system.

Example of a Potential Opportunity to Improve Efficiency

A former wood treating facility had both a pilot and full-scale P&T system operating to contain a contaminant plume and remove non-aqueous phase liquid. The two systems had identical treatment components, but the full-scale system had 50 times the treatment capacity. The optimization evaluation suggested discontinuing operation of the pilot system, piping all extracted water to the full-scale system, and simplifying the full-scale system. By implementing the recommendation, the site team was able to eliminate the extra costs associated with operating a parallel treatment system. In addition, because the bioreactor in the treatment train reliably met discharge standards, the site team was able to discontinue treatment of the bioreactor effluent with granular activated carbon (GAC) and eliminate the costs associated with frequent GAC replacements. The full-scale system without the granular activated carbon has effectively treated all extracted water and has continued to meet discharge requirements, indicating that this cost-reducing measure has maintained an equal level of effectiveness. Savings of over $100,000 per year likely will be realized.

Example of a Potential Opportunity to Speed Progress toward Site Closure

A P&T system had been operating at a site for approximately 10 years. It had been effectively containing site-related contamination and reducing contaminant concentrations. Concentrations in all site monitoring wells had decreased below cleanup standards, but concentrations had consistently remained approximately one order of magnitude above standards in the extraction well located near the historic source area. An optimization evaluation suggested a limited investigation of the historic source, an air sparging pilot test, and establishing criteria that, if achieved, would allow active remediation to be discontinued. The investigation indicated limited soil contamination in the saturated and unsaturated soil, and the designed pilot air sparging system will likely fully address the remaining contamination. Addressing this source area may now allow discontinuation of all site-related active remediation in less than six months; whereas continued P&T was forecasted to continue for up to 10 more years.

C. COMPONENTS OF A TYPICAL OPTIMIZATION EVALUATION

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A number of approaches have been developed within the Federal government and private sector to implement optimization evaluations that are consistent with the definition provided in the introduction of this fact sheet. Some of these approaches are described in Section D, and although each approach implements an optimization evaluation in a different manner, these approaches generally share common components, including the following:

- evaluation team development
- scheduling and logistics
- document review
- site visit and interviews
- data analysis and draft report preparation
- site team review
- report finalization

This section describes these various common components of optimization evaluations employed by EPA and other Federal agencies.

Evaluation Team Development

An optimization evaluation team is comprised of experts in various fields who are independent of current site activities. This independence allows the team members to bring a fresh perspective to the site and to analyze data and provide recommendations without bias. The evaluation team therefore will not benefit from recommendations that result in more work for the site team or will not lose work or revenue from recommendations that result in a lower level of effort. The evaluation team is generally comprised of experts, or has immediate access to experts, in the following fields:

- environmental policy and regulations
- hydrogeology
- environmental engineering
- risk assessment
- contracting
- chemistry (including geochemistry)
- health and safety
- cost estimating
- biology

In some cases, a single team member may have expertise in multiple categories. The size of the team depends on the optimization evaluation approach that is being used. A team may consist of as few as two individuals with different areas of expertise and immediate access to other individuals that have expertise in the remaining areas.

The team members often are directly responsible for conducting the site interviews and preparing the optimization evaluation report. Therefore, these individuals often have strong communication and critical thinking skills that allow them to communicate their questions effectively during site interviews and to communicate their findings and recommendations effectively in the report.

Scheduling and Logistics

An optimization evaluation generally takes several months from initial contact to a final optimization evaluation report. A time frame for typical evaluation is presented in Exhibit 1. The process begins with initial contact between a representative of the evaluation team and the project manager for the site to be evaluated. During this initial contact the evaluation team representative provides background on the evaluation process, and often provides a short document with the following information:

Exhibit 1

Time Frame for a Typical Optimization Evaluation	
Week 1	Initial contact and scheduling
Weeks 1-3	Site team gathers documents for evaluation team
Week 3	Evaluation team receives documents from site team
Weeks 3-4	Evaluation team reviews documents
Week 5	Evaluation team visits site and/or conducts interviews of site team
Weeks 5-10	Evaluation team analyzes site information and generates draft report
Weeks 10-13	Site team reviews draft report and provides feedback
Weeks 13-16	Evaluation team finalizes report based on comments from site team

- background on the evaluation process
- a typical site visit agenda (Exhibit 2)
- the types of documents that the evaluation team typically reviews (Exhibit 3)
- expected format of the final optimization evaluation report

An example of such an introductory document is provided as Appendix A.

An information sheet to be completed by the project manager can also be provided during this initial contact. The project manager can use this sheet to provide general background about the site, describe particular issues that may be a focus for the evaluation team, indicate recent upgrades or modifications that may not be described in the site documents, and provide a breakdown of operations and maintenance (O&M) costs. An example of a site information sheet is provided as Appendix B.

Together, the site project manager and the evaluation team leader determine the site documents that will be transferred to the evaluation team for review, which site stakeholders will participate in the evaluation process, and the date and time for the site visit and interviews. Exhibit 4 indicates the site stakeholders that typically attend optimization evaluations. The site project manager generally takes the responsibility for coordinating the schedules of the other site stakeholders, informing them of the evaluation, and often providing the introductory document to each of them.

Document Review

Once the evaluation team acquires the relevant site documents, they review the documents to become familiar with the site and generate questions to be answered during a site visit and/or site interviews. Exhibit 5 provides a list of topics that the evaluation team might consider during the document review.

Site Visit and Interviews

Most optimization evaluations include a site visit where the evaluation team tours the operating remedy. The duration of the visit depends on the size and complexity of the site and the specific remedy that is being evaluated. It also depends on the optimization evaluation process. In general, the length of a site visit will increase with the number of participants and the detail of the evaluation. For most sites, a site visit of one to two days in length is often sufficient.

Generally, the site stakeholders indicated in Exhibit 4 are present and are interviewed by the evaluation team during the site visit. The interviews generally take the form of a large discussion group led by the evaluation team, and during the tour of the remedy, the evaluation team often has the opportunity to interview individual site stakeholders directly. For some sites, the optimization evaluation may include a conference call rather than a site visit. The determination as to whether an evaluation should include a site visit is often made at the programmatic level and is discussed further in Section D.

Exhibit 2

Typical Agenda for a One-Day* Site Visit for an Optimization Evaluation of a P&T System

<u>Morning Discussion</u>. Typically, an evaluation site visit begins at the site in the morning with a discussion of the site history, remedy objectives, site conceptual model, contractor’s scope of work, significant milestones reached at the site, and significant changes in approach or strategy taken at the site. During this time participants refer to site documents, site maps, and monitoring results.

<u>Afternoon Discussion</u>. Upon returning from lunch, the site project manager, contractor, and plant operator leads a tour of the site and the ground water treatment plant where the evaluation team asks detailed questions regarding specific elements of the remedy and their performance. After the site tour, discussions are held to determine a rough breakdown of site-related costs. Potential options for either augmenting or replacing the current remedy are also discussed.

<u>Debriefing</u>. The discussion on costs typically ends in the late afternoon and a general debriefing session follows before the group disbands for the day.

** Site visit duration can be extended, if necessary.*

Exhibit 3

Types of Documents Typically Reviewed by the Optimization Evaluation Team

- Remedial Investigation Report (in some cases)
- Decision documents
  - Superfund Record of Decision (ROD)
  - Superfund Explanation of Significant Differences (ESD)
  - RCRA Permit
  - Consent or unilateral order
- Design documents and O&M manual
- Recent O&M reports (weekly, monthly, etc.)
- Recent semi-annual and annual reports with current and historical sampling data
- Previous evaluations or reviews (including previous optimization reviews or Five-Year Reviews)
- Any other reports or documents the site managers feel are pertinent to the site
- Breakdown of annual O&M costs

The site interviews (whether part of a site visit or a conference call) involve many questions, and it is important that the questions are not posed in a manner that suggests criticism. The site interviews are meant as an information-gathering tool for evaluation and not to pass judgment on previous or current activities. At the onset of the site visit and/or interviews, the evaluation team may provide an introduction to prepare the site team for questions.

For larger, more complicated sites, the evaluation team may ask questions that are related to the entire site rather than just the remedy that has been selected for evaluation. For example, although a P&T system at a site might be designed to address ground water contamination, the evaluation team might ask questions relating to current or past soil remediation measures. Although the focus of the evaluation may be the P&T system, impacted soil could affect the performance of a P&T system. The flexibility to look beyond the evaluated remedy to other components of the site generally allows the evaluation team to provide recommendations that are more appropriate both for the evaluated remedy and for the site as a whole.

During the site visit and/or site interviews, it is common for the evaluation team to identify additional information or site documents that would be helpful in developing recommendations. An evaluation team representative and the project manager may communicate after the visit to coordinate the transfer of this additional information to the evaluation team.

The site visit and/or interviews will generally conclude with coordinating the transfer of this additional information and a debriefing from the evaluation team. Often, the evaluation team will provide preliminary thoughts on its findings and likely recommendations. However, it is emphasized that the thoughts are preliminary and, upon further evaluation, may change.

Exhibit 4

Site Stakeholders that Typically Participate in an Optimization Evaluation

- Facility project manager (if any)
- Federal regulatory case manager and technical support staff (if any)
- State or local regulatory case manager and technical support staff (if any)
- Organization's optimization liaison (if any)
- Site contractor project manager
- Site contractor technical lead
- One or more representatives of organization's management
- Remedy operator (particularly for complex systems)

Data Analysis and Draft Report Preparation

Following the site visit and/or interviews, the evaluation team performs various technical analyses to evaluate performance and alternatives to the current site operations, equipment, or remediation technology. These analyses generally begin with a detailed look at the site conceptual model to verify its validity and determine if there are any data gaps that should be addressed. Other analyses are site-specific and might include (but are not limited to) the following:

- evaluation of vertical and horizontal plume delineation

- preliminary evaluation of plume capture, including identification of a target capture zone and interpreting capture using a simple water budget, potentiometric surface maps, water level pairs, concentration trends in downgradient wells, or previously conducted ground water modeling results

- review of historical monitoring data, the current monitoring program, and the potential for changing sample locations, frequency, sampling technique, or target parameters

- comparison of design influent concentrations and flow rate to actual influent concentrations and flow rate

- comparison of actual treatment effectiveness and cost relative to design estimates

- comparison of actual treatment effectiveness and cost relative to that of other potential remedial technologies

- evaluation of O&M costs and level of effort for the subject site compared to O&M costs and level of effort for similar sites

- evaluation of remedy performance against remedy objectives and expectations

- consideration of an "exit strategy" for the remedy and potential transition remedies that may occur between discontinuation of the current remedy and eventual site closure

The draft report is compiled within a set time frame and can vary in length and detail depending on the parameters of the organization's optimization program. Exhibit 6 provides a common format for a detailed optimization report (perhaps 30 to 40 pages) and indicates how a more streamlined optimization report (perhaps 5 to 7 pages) would differ. As is evident from Exhibit 6, the recommendations are often categorized into the following groups:

- recommendations to enhance effectiveness in protecting human health and the environment

- recommendations to reduce life-cycle costs while maintaining or improving remedy effectiveness

Exhibit 5

Topics Typically Considered by the Evaluation Team During Document Review and Site Interviews

Site conceptual model

- Contaminant sources, fate, and transport
- Hydrogeologic framework
- Adequacy of existing site characterization
- Previous and current remedies
- Remedy goals

Protectiveness

- Receptors and exposure pathways
- Receptor sampling
- Plume capture
- Performance monitoring
- Institutional controls
- Site fencing, health and safety, etc.

Extraction/Injection Systems

- Confirmation of components and specifications
- Performance relative to design specifications
- Associated sampling and analysis
- Maintenance, fouling, etc.

Treatment System

- Confirmation of components and specifications
- Performance relative to design specifications
- Downtime
- Operator responsibilities and level of effort
- Chemicals and material usage
- Utilities
- Process monitoring
- Water discharge and waste disposal
- Exceedances and accidental releases
- Recurring technical problems
- Opportunities for system simplification

Costs

- Confirmation and clarification of O&M costs
- Estimation of life-cycle costs
- Actual costs vs. original cost estimates
- Primary cost drivers
- Opportunities for reducing cost, and challenges in implementing those opportunities

Site closure

- Potential alternative remedies
- Remaining source removal/control needs
- Exit strategy for system and system components
- Site-specific milestones towards site closure
- Legal and programmatic considerations

- recommendations for technical improvement
- recommendations to speed site closure

Estimates of capital costs and changes to annual costs are provided for each recommendation. The evaluation team generally prepares the draft report within 30 to 45 days of the site visit unless preparation was delayed by the transfer of additional material to the evaluation team after the site visit.

Site Team Review

The review of the draft report is generally coordinated through the site project manager, and the evaluation team encourages the project manager to share the report with those who participated in the evaluation process (including the site contractor) and perhaps others. Each reviewer generally provides their comments in writing, and the project manager compiles these comments into one comprehensive set for the evaluation team, ideally within 30 days of receiving the draft report. It is expected that if there are any questions or concerns regarding the recommendations made in the draft report that they are clearly documented in the reviewer's comments so that the evaluation team can reconsider the recommendation. Exhibit 7 provides a list of items to consider when reviewing a draft optimization evaluation report before it is finalized.

Exhibit 6

Common Formats for Full-Scale and Streamlined Optimization Evaluation Reports

Introduction. Details the purpose of the visit, the evaluation team members, other participants, documents reviewed, site location, history, major features, hydrogeology, plume extent, etc.

Description of the Remediation System. Describes the major components of the remedy, such as the extraction and treatment systems

System Objectives, Performance and Closure Criteria. Includes a summary of the remedial action objectives for site and associated cleanup and discharge standards

Findings and Observations. Includes system and component performance, recurring problems, capture zone evaluation, contaminant delineation, and concentration trends

Evaluation of the System Effectiveness. Evaluates treatment of ground water, surface water, air, and soils

Recommendations. Includes recommendations to improve remedy effectiveness, reduce life-cycle costs, improve technical operations, and speed progress toward site closure (includes a summary of the estimated costs and cost savings associated with each recommendation)

A streamlined evaluation report typically includes a brief introduction and then focuses on findings and recommendations. A streamlined report generally relies on other existing site documents to provide background information.

Final Report Preparation

Upon receiving one comprehensive set of comments, the evaluation team finalizes the report and provides a response to comments. During this process, the evaluation team addresses the concerns of the reviewers. However, because it is an independent evaluation, the evaluation team does not compromise its professional integrity to meet the concerns of the reviewers. If any of the reviewers' comments are not implemented, a response-to-comments document is used to document the reasons. Generally, if the optimization evaluation report is written clearly and professionally, and the site team is committed to optimizing the remedy, then there are few concerns that are not addressed in the final report. However, in the rare instances where concerns are not easily addressed, a solution can often be provided by an organization's management, especially if a representative of management has been participating in the optimization process.

D. OPTIMIZATION APPROACHES DEVELOPED AND USED BY THE FEDERAL AGENCIES

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Remediation System Evaluations (RSEs)

The U.S. Army Corps of Engineers Hazardous, Toxic, and Radioactive Waste Center of Expertise (HTRW CX) developed the RSE process for evaluating remedies that are owned and operated by the Army. As part of this development, a series of checklists were prepared to assist RSE teams. The checklists are available electronically (*USACE*, 2005).

The U.S. EPA has adopted the process for use in its nationwide program for optimization of Superfund-financed long-term remedies. An RSE team typically includes three or four experts and a one to two day site visit. An RSE report is typically 30 to 40 pages in length and provides site background, findings from the RSE process, and optimization recommendations. A typical RSE report is consistent with the description in Exhibit 6. In 2007, the cost for an RSE was $25,000 to $30,000, excluding the costs for the site project manager and contractor to provide information and attend the site visit.

Exhibit 7

Items to Consider when Reviewing a Draft Optimization Evaluation Report Prior to Finalizing the Report

- Is the background information provided in the report factual/accurate? Does the document provide adequate background for the reader (full-scale report) or does it adequately reference existing documents for background (streamlined report)?
- Are all of the evaluation participants mentioned?
- Does the report indicate the documents that were reviewed? Were the appropriate documents provided to the evaluation team?
- Does the report demonstrate that the optimization evaluation team gained a superior understanding of the remedy and site/facility conditions that directly affect the remedy? Are the recommendations appropriate for the remedy?
- Do you agree with the recommendations? If not, do you disagree with the spirit of the recommendations or specific details?
- Are the recommendations clearly written and understandable? Would additional clarification be helpful?
- Do you generally agree with the approximate cost estimates provided with the recommendation? Are there site-specific costs or considerations that have not been included?
- Is there wording that may be misinterpreted by the general public or those unfamiliar with the site that should be changed?
- Did you share this draft report with relevant site stakeholders for their review? Do you agree with their feedback?
- Does the report clearly state that the findings and recommendations are the opinion of the evaluation team and are not legally binding requirements?

EPA has also piloted the RSE process at leaking underground storage tank sites and Resource Conservation and Recovery Act (RCRA) Corrective Action sites. For more information on EPA's application of the RSE process, visit the following website: http://www.cluin.org/optimization.

Streamlined Remediation System Evaluations (SRSEs or "RSE-lites")

To streamline the optimization process and reduce the cost for optimization evaluations at some sites, EPA developed the RSE-lite process. This process is similar to the RSE process but uses a conference call for site interviews rather than a site visit. Typically, two experts, rather than three, form the optimization evaluation team, and either a full RSE report or a streamlined report can be prepared. The streamlined RSE report does not include the background sections. Rather, it is approximately five to seven pages in length and focuses on findings and recommendations from the evaluation. The cost for an RSE-lite depends on the complexity of the site and reporting. It can range from $10,000 to $15,000 (2007 dollars), excluding the costs for the site project manager and contractor to provide information and attend the site visit. An RSE-lite can be converted into a full-scale RSE if further analysis is needed and funding is provided. EPA has piloted the use of the RSE-lite at Superfund-financed, leaking underground storage tank, and RCRA Corrective Action sites.

Remedial Process Optimization (RPO) Evaluations

The Air Force Center for Environmental Excellence developed the Remedial Process Optimization (RPO) approach as a systematic way to assure that remedial actions are focused on the appropriate goals and are periodically evaluated for performance and cost. The RPO process advocates annual limited Phase I RPO reviews of performance and cost data by the site manager (with oversight from a supervisor) as a means of screening sites for optimization evaluations. If needed based on Phase I results, more intense Phase II evaluations are conducted by an independent team of experts. The Phase II process includes the identification of alternatives to improve performance and possible proposal of alternative remedial goals. The RPO team typically involves approximately 10 experts visiting a site for more than a week and authoring the report while on the site. Substantial data analysis is conducted and the resulting report can be hundreds of pages in length, including appendices. An RPO Phase II typically addresses several operating units (e.g., remedies) on a particular site, and the cost may exceed $100,000 (2007 costs, excluding the costs of the site team). For more information, refer to the *Air Force RPO Handbook* (*AFCEE/ERT and DLA*, 2001).

Navy Guidance for Optimizing Remedial Action Operation (RAO)

The Navy has prepared guidance on the periodic optimization of remedial actions. The optimization evaluation is scheduled considering the need for submitting funding requests and for meeting requirements under CERCLA or RCRA. The guidance suggests annual reviews of the systems and the involvement of the regulatory agencies. A particular team composition and schedule are not provided; rather, a seven-step process that ranges from reviewing remedial objectives to preparing a report and implementing an optimization strategy is described. More information can be obtained from the *Guidance for Optimizing Remedial Action Operation* (*NFESC*, 2001).

Other Initiatives

A number of private sector organizations have developed optimization evaluation processes to evaluate their own remedies or as a service to others. However, it is beyond the scope of this document to describe these private sector initiatives.

E. COMPONENTS OF AN OPTIMIZATION PROGRAM

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Optimization evaluations are generally implemented as part of an organization's overall optimization program. To be effective, an optimization program generally considers the following:

- program documentation and communication
- updated database of cost and technical information for each site within the organization
- site selection for optimization evaluations
- selection of an optimization team and/or contractor
- timing and integration of optimization evaluations with respect to other organization practices
- defined optimization evaluation process
- follow-up of optimization evaluations and tracking of progress toward considering and implementing recommendations
- involvement of management
- funding for implementation of recommendations

This section describes each of these considerations. For an example of an optimization program, the reader is directed to the U.S. EPA *Action Plan for Ground Water Remedy Optimization*, OSWER 9283.1-25 (*U.S. EPA*, 2004a), which describes how the U.S. EPA is implementing its own optimization program.

Program Documentation and Communication

Effective optimization programs are well-documented and have been communicated to all relevant staff within the organization as well as any interested stakeholders (as applicable). There is generally a memorandum or report that outlines the components and expectations of the program. This memorandum is generally distributed and a central repository (perhaps a webpage) is established where the memorandum and supporting documents are readily accessible. In addition, a central point of contact for the program is established and there are liaisons or intermediate points of contact for each of the various divisions within the organization that might be participating. The central point of contact and the liaisons are instrumental in selecting sites to receive evaluations, scheduling and overseeing evaluations, assisting with policy issues, and tracking optimization progress for the program.

Updated Database of Cost and Technical Information for Each Site within the Organization

To implement the optimization program, it is helpful to have a database of site information that allows optimization program directors to determine the universe of sites within the organization.

Establishing a baseline of information for each of the sites helps program directors allocate optimization resources to high priority sites, and updating it routinely helps with tracking results from the optimization program. The information sheet in Appendix B includes much of the information that might be included in the database.

Site Selection for Optimization Evaluations

For organizations with a large number of sites, resources (both time and funding) may be limited to address all sites in a timely manner. As a result, it is helpful to prioritize the sites in terms of potential benefit from optimization. Often, high priority sites include those that have high life-cycle costs and those that have concerns with respect to protecting human health and the environment. The presumption is that the cost savings or performance improvements justify the investment in the optimization evaluation. If there are concerns regarding protecting human health and the environment, the cost of the remedy is generally a secondary consideration.

The following types of sites are often good candidates for optimization evaluation, and consideration of these site types may help an organization determine which sites are the highest priorities for evaluation:

- sites where there are known or suspected shortcomings with respect to protection of human health and the environment
- sites where annual O&M costs exceed the cost of the evaluation by an order of magnitude
- sites where a remedy has stagnated or has not performed to expectations and additional measures are required
- sites where there is disagreement between the regulator and the facility with regard to a remedial approach
- sites where a new or modified remedial approach is being considered
- sites that will likely be divested or transferred to another party and either party would like an independent perspective of the site
- sites where further analysis is preferable before determining a budget for future expenses or financial assurance

Some organizations may choose to implement two types of optimization evaluations: a full-scale, detailed evaluation for the more complex sites (with respect to either cost or effectiveness) and a streamlined, lower-cost evaluation for the more straightforward sites. The determination of whether or not a site receives a full-scale or a streamlined optimization evaluation is site-specific but generally involves two considerations:

- Are the annual O&M costs and/or life-cycle costs prohibitively low for investing in a full-scale evaluation?
- Are there unique aspects of the site or complexities that are pertinent to the evaluation and can only be fully appreciated when viewed in person? These unique aspects or complexities may include the following:
  - an old, but complex treatment system that does not have an O&M manual
  - access issues that may affect the placement of new extraction or monitoring wells
  - potential nearby receptors that are not well described in site documents
  - upcoming decisions regarding the remedy that include relocating remedy components
  - on-site documents that are not permitted to leave the site
  - site complexities that would be difficult to discuss without directing attention to figures, maps, etc.

Assuming a remedy will operate for a number of years (e.g., a P&T system) , an organization may choose to conduct a full-scale evaluation if the annual cost of the remedy exceeds the entire cost of the evaluation (both site team and evaluation team expenses) by an order of magnitude. If the annual costs are less than an order of magnitude of the evaluation cost, the organization may opt for a streamlined evaluation.

Selection of an Optimization Team/Contractor

Each organization can choose who will conduct the independent optimization evaluations of the ground water remedies. In some cases, organizations may choose members of their own staff (who are independent of direct site activities). In other cases, organizations may choose to select an optimization contractor. In either case, the quality of the evaluation will generally depend on the quality and expertise of the evaluation team. Important factors to consider when selecting a team are discussed in Section C of this document. The U.S. Army Corps of Engineers has developed a sample scope of work to assist in hiring an optimization evaluation contractor. This sample language is available on the U.S. Army Corps of Engineers website:

http://www.environmental.usace.army.mil/library/guide/rsechk/rsechk.html

Timing and Integration of Optimization Evaluations with Respect to Other Organization Practices

It is generally beneficial to schedule optimization evaluations when there is enough information to review regarding remedy performance but early enough for implementation of recommendations to improve performance or reduce costs. For P&T systems, optimization evaluations may be appropriate after one or two years of system operation. During these first two years of operation, data are collected that will help evaluate remedy performance and cost-effectiveness. After recommendations are implemented, the system can operate at a presumably higher level of effectiveness relatively early in the remedy life-cycle. Organizations may also want to conduct optimization evaluations in conjunction with other reviews or prior to planning or revising a long-term O&M budget. For example, for Superfund sites, the optimization evaluations can be conducted in conjunction with the Five-Year Review process.

Because remediation technologies, site conditions, and regulatory climates change, it is often beneficial to conduct optimization evaluations of P&T systems and other long-term remedies on a routine basis, perhaps every two to five years, depending on the changes associated with the site.

Follow-up of Optimization Evaluations and Tracking Progress toward Considering and Implementing Recommendations

Because optimization programs have a cost associated with them and because optimization does not actually occur without implementing changes, the optimization program should have a follow-up component to track the progress each site is making with respect to implementing the recommendations from an optimization evaluation. The follow-up generally involves the site project manager, the evaluation team, organizational management, and optimization program director. This broad involvement often provides site managers with the opportunity to receive assistance in overcoming obstacles to implementing recommendations, whether that assistance involves direction from management or clarification on a recommendation from the evaluation team.

The follow-up and tracking generally involves noting the following:

- concerns regarding protection of human health and the environment
- recommendations that will be implemented
- recommendations that will not be implemented and the reason why
- cost of implementing the recommendations and comparing the cost to the estimates provided during the optimization evaluation
- significant changes in the remedy performance, site conditions, community involvement, and regulatory climate
- changes in annual O&M costs and how they compare to the baseline costs collected prior to optimization
- funding requests for implementing optimization evaluation recommendations

Involvement of Management

Organizations that are committed to optimization generally involve management in the optimization process. This involvement of management indicates to the site project manager that management supports optimization and expects results. By participating, management can also help with decisions that may be out of the control of the site project manager, such as requests for additional funding or making changes to the system that may be dependent on recent or upcoming changes to organizational policy. It is particularly important to include management if the optimization program is being administered by one division of the organization and the sites and site managers belong in a different (perhaps parallel) division.

Funding for Implementation of Recommendations

A number of the recommendations that result from optimization evaluations require capital expenditures to implement. In some cases, these capital expenditures will fund modifications that are necessary to provide adequate protection to human health and the environment. In other cases, these capital expenditures will fund modifications that will reduce annual and life-cycle costs. For both types of recommendations, optimization will not occur without implementation, so it is important that organizations provide the funding to implement recommendations, particularly those with the highest priority.

F. TOOLS TO SUPPORT OPTIMIZATION

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This section provides a list of existing support tools for optimization. Some of these tools can help site managers pro-actively manage their site, others are meant to assist optimization evaluation teams, and others are intended to provide further detailed analysis beyond the scope of a traditional optimization evaluation.

General Optimization Information

Factsheets and Handbooks

- *Remedial Process Optimization Handbook* (*AFCEE/ERT and DLA*, 2001)
- *Guidance for Optimizing Remedial Action Operation (RAO)*, (*NFESC*, 2001)
- *Elements for Effective Management of Operating Pump and Treat Systems* (*U.S. EPA*, 2002b)
- *Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation* (*ITRC*, 2004)
- *Cost-Effective Design of Pump and Treat Systems* (*U.S. EPA*, 2005a)
- *Effective Contracting Approaches for Operating Pump and Treat Systems* (*U.S. EPA*, 2005b)
- *O&M Report Template for Ground Water Remedies (with Emphasis on Pump and Treat Systems)* (*U.S. EPA*, 2005c)
- *A Cost Comparison Framework for Use in Optimizing Ground Water Pump and Treat Systems* (*U.S. EPA*, 2007a)
- *Options for Discharging Treated Water from Pump and Treat Systems* (*U.S. EPA*, 2007b)

Checklists

- *USACE Remediation System Evaluation (RSE) Checklists* (*USACE*, 2005)

Websites

www.frtr.gov/optimization

The Federal Remediation Technologies Roundtable (FRTR) promotes Federal interagency cooperation to advance remediation technologies. The optimization website provides a repository of information on remedial process optimization approaches and case studies as well as information on other more specific forms of optimization including monitoring and simulation optimization.

www.cluin.org/optimization

This website is sponsored by the U.S. EPA Office of Superfund Remediation and Technology Innovation. The webpage provides information on EPA's optimization efforts, including over 25 RSE reports from EPA and non-EPA sites, as well as other optimization information.

www.epa.gov/superfund/action/postconstruction/optimize.htm

EPA refers to the time period following remedy construction as "post-construction completion". This website provides EPA Remedial Project Managers (RPMs) with fundamental information on guiding sites through the post-construction completion process, including O&M and remedy optimization. The website includes fact sheets, guidance, and EPA memorandums that pertain to the post-construction completion period.

Ground Water Modeling Optimization

Ground water modeling optimization is one of many specific technical activities that may be appropriate as either a stand-alone action or as a follow-up action to optimization of an entire P&T system. Modeling optimization attempts to minimize cost or time needed to achieve a remedial objective using computer models of subsurface processes. These models may simulate only the movement of ground water (hydraulic or flow models) or may simulate both the movement of ground water and the transport of contaminants (transport models). The modeling is typically done by a professional that runs one combination of well locations and flow rates at a time. The model is repeatedly run in a "trial and error" fashion until the modeler determines that a certain combination most effectively achieves the goals. However, this process is usually very labor intensive, and algorithms have been developed that work in conjunction with existing ground water models to try many more combinations of well locations and flow rates than a single modeler could perform in the same time (perhaps hundreds to thousands more combinations). In the process, the algorithms quantify the optimal solutions to specific problems subject to specific constraints. Such algorithms yield a much higher probability of locating a truly "optimal" answer. These tools can be applied to systems in design or to existing systems that are being optimized.

There are two primary modeling optimization approaches for P&T systems: ground water flow (hydraulic) modeling optimization and contaminant transport modeling optimization. Hydraulic optimization has been more widely available and applied for a longer time than transport optimization. After a flow model is developed, it typically costs under $20,000 (2007 costs) and is generally applicable to optimization problems pertaining to plume containment. Transport optimization is complex and few personnel currently perform this, though many efforts are underway to transfer this technology to the environmental consulting community. The cost for such work is several times the cost of flow optimization, and use of this optimization approach generally applies to optimization problems that include aquifer restoration. For more information on modeling optimization, including descriptions of demonstration projects and the codes described above, visit the following website:

http://www.frtr.gov/optimization/simulation.htm

Monitoring Program Optimization

Monitoring costs often represent a substantial fraction of the cost of O&M at remediation sites. As with other aspects of the system, the efforts for monitoring of both the subsurface and above-ground systems can be optimized for adequacy and cost-effectiveness. Although monitoring programs are generally evaluated as part of an optimization evaluation, more thorough monitoring optimization is sometimes beneficial.

The Livermore National Laboratory developed the “Cost Effective Sampling” process to address objectively the issue of adequate sampling frequency. This approach weighs the considerations described above in recommending sampling frequencies. The recommendations can be modified based on non-technical factors (*Ridley and MacQueen*, 2001). The MAROS software (*AFCEE*, 2005) developed for the Air Force also has the capability to assess sampling frequencies.

Monitoring wells installed during the site characterization phase are often part of the monitoring network, and are often not optimal for monitoring the performance of ground water extraction. The analysis of the adequacy of the monitoring network is often done by professional judgment, though quantitative analysis using a statistical approach (e.g., geostatistics) can be very useful if a large network (e.g., >20 wells) is present. The MAROS software (*AFCEE*, 2005) has capabilities to quantitatively assess the network, and other software using the kriging method can quantify the value added by sampling only selected wells. Additional information on the use of kriging and other techniques for monitoring network optimization is available at the following website:

http://www.frtr.gov/optimization/monitoring.htm

Monitoring at some sites has been conducted over many years and the methods used may have been adequate at the time the program was initiated, but new methods may be available that would provide data that meet quality needs at a reduced cost. For example, high-speed pumping based on well volume criteria or use of bailers may be replaced with low-flow sampling or passive diffusion bag samplers (PDBs), resulting in substantial labor and water-disposal cost savings if site conditions are appropriate. In some cases, the current sampling methods do not provide data of adequate quality. For additional information on alternatives to current sampling procedures, refer to the *Field Analytical Technologies Encyclopedia* (*FRTR*, 2005) and "Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers" (*Yeskis and Zavala*, 2002). Information on application of PDBs is available from the Interstate Technologies Regulatory Council (*ITRC*, 2004), and information on low-flow sampling is available from the U.S. EPA Office of Research and Development (*Puls and Barcelona*, 1996).

A number of documents have also been developed to support monitoring optimization, including *Methods for Monitoring Pump-and-Treat Performance* (*U.S. EPA*, 1994), *Road Map to Long-Term Monitoring Optimization* (*U.S. EPA*, 2005d), and others accessible electronically from the following website:

http://www.frtr.gov/optimization/monitoring.htm

G. SUMMARY

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This document provides an overview of optimization for operating long-term ground water remedies. It discusses the benefits of optimization, details the components of a typical optimization evaluation, and discusses the key aspects of an optimization program that incorporates optimization evaluations. "Optimization" as defined in this document refers to efforts used to improve a remedy's effectiveness in protecting human health and the environment, reducing life-cycle remedy costs, and speeding progress toward site closure. The optimization processes discussed are based on independent evaluations that are conducted by a team of experts. This document is geared toward the general environmental community and highlights optimization tools that may be helpful to that community.

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APPENDIX A:

Appendix A is an example of a brief document used to introduce optimization evaluation participants to the optimization process. This example is used by the U.S. EPA as part of its nationwide program to optimize operating Superfund-financed long-term ground water remedies.

An Introduction to Remediation System Evaluations (RSEs) and "RSE-lites"

Background

As part of a nationwide effort between 2000 and 2003, the EPA Office of Solid Waste and Emergency Response commissioned a total of 27 optimization evaluations called Remediation System Evaluations (RSEs) to be conducted at Fund-lead pump and treat (P&T) systems in each of the ten EPA Regions. In addition, one RSE was conducted at a Responsible Party Superfund site. This nationwide optimization effort enabled EPA Headquarters to assist the EPA Regions and individual site managers with management and operation of their Fund-lead P&T systems.

To include optimization in part of a larger post construction-complete strategy for the Fund-lead P&T systems, the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) has commissioned additional optimization evaluations. Both RSEs and a streamlined form of RSEs called "RSE-lites" will be used.

What are the Differences between RSEs and RSE-lites?

An RSE involves an independent team of experts (i.e., individuals that are not associated with the evaluated site) reviewing site documents, visiting the site for a full day, and compiling a draft report (typically 30-40 pages) that includes recommendations to improve the system. The draft report is generally available for review within 45 days of the site visit. Upon review by the site manager and other stakeholders that report is finalized. The observations made and the recommendations given are not intended to imply a deficiency in the work of the designers, operators, or site managers but are offered as constructive suggestions. The recommendations obviously have the benefit of the operational data unavailable to the original designers.

An RSE-lite is a very similar process but differs from an RSE in two primary ways.

- An RSE-lite does not include a site visit. Rather, the evaluation team conducts interviews with the site team in a conference call. The conference call allows the site team and evaluation teams to communicate but reduces the cost of the evaluation and facilitates scheduling.

- An RSE-lite report is streamlined relative to an RSE report. Site and remedy background, general findings, and recommendations are provided, but the report is not as detailed as a full scale RSE report.

If during an RSE-lite, it is determined that a site visit and more detailed evaluation is required, they can be arranged through technical assistance or by extending the RSE-Lite into a full-scale RSE.

What Documents does the Evaluation Team Typically Review?

For either process, the evaluation team typically reviews the following site documents/information:

- Remedial Investigation Report
- Feasibility Study Report
- Record of Decision (ROD)
- ROD Amendments and Explanation of Significant Differences (ESDs), if any
- Design documents and O&M manual
- Recent O&M reports (weekly, monthly, etc.)

- Recent semi-annual and annual reports
- Previous 5-year reviews
- A summary of system changes or modifications that are not described in site documents
- Any other reports or documents the site managers feel are pertinent to the site

What is Typically Included in an RSE or RSE-lite Report?

A typical RSE or RSE-lite report includes the following sections:

- General site background
- Description of the pump and treat system and any other operating remedies at the site
- A summary of the site objectives
- Findings from the visit including performance of individual components of the remedy
- A review of the site's effectiveness in protecting human health and the environment
- Recommendations to
  - improve effectiveness
  - reduce costs
  - improve technical operation
  - gain site closure
- Suggested approach to implementing recommendations

The primary difference between RSE and RSE-lite reports is the level of detail.

What are some Typical Questions that are Asked During an RSE or RSE-lite?

The following questions are examples of questions asked during an RSE. This list of questions is by no means a complete list of all questions that will be asked. In many cases, these questions are used to generate discussion and to lead the RSE team toward more direct and detailed questions.

1. Please provide a history of the site that brings us to the present time. Please try to include any significant changes in the approach or strategy taken at the site including ROD Amendments and ESDs (if any). Please note that many aspects of this site history will provide discussion points.

2. What is the conceptual model for the site? For example, what are/were the sources of contamination? Where are/were they located? What processes/mechanisms were involved in arriving at the currently observed conditions? Consider horizontal and vertical transport, contaminant degradation, recharge, ground water extraction, etc.

3. What are the site objectives as specified in the ROD? Is the remedy achieving those objectives? If so, what monitoring is being done to confirm this? If not, what steps, if any, have been taken to modify the remedy or the ROD?

4. What are the discharge limits for the treatment plant? Which contaminants provide the most difficulty in meeting these limits? Are the discharge limits consistently exceeded?

5. What is the current exit strategy for the site? How has this strategy changed over time? What elements of the remedy have led to these changes?

6. What is the current work plan for analysis of aquifer and process monitoring data? Does this work plan involve analysis of plume capture, changes in the plume area or extent, or other indicators of effectiveness? Does this plan include criteria for reducing monitoring locations or frequency over time?

7. What is the current schedule for turning the site over to the State? What are the concerns, if any, of the State?

8. What is the total annual O&M cost for the site? Without divulging the contractor's proprietary information, please provide approximate estimates as to how this total cost is distributed among the following categories:

   - Oversight, project management, technical support, and reporting
   - Operator labor
   - Sampling and analysis
   - Utilities
   - Materials/consumables
   - Disposal costs

APPENDIX B:

Appendix B is an example of a site information form that can be used to collect baseline information on operating pump and treat systems. This example is used by the U.S. EPA as part of its nationwide program to optimize operating Superfund-financed long-term ground water remedies.

Date: ______________ Filled Out By: ______________________________

A. Site Location, Contact Information, and Site Status

1. Site name	2. Site Location (City and State)	3. EPA Region

4a. EPA RPM	5a. State Contact
4b. EPA RPM Phone Number	**5b. State Contact Phone Number**
4c. EPA RPM Email Address	**5c. State Contact Email Address**

5. Is the ground water remedy an interim remedy or a final remedy? Interim ☐ Final ☐

6. Is the site EPA-lead or State-lead with Fund money? EPA ☐ State ☐

B. General Site Information

1a. Date of Original ROD for Ground Water Remedy	1b. Dates of Other Ground Water Decision Documents (e.g., ESD, ROD Amendment)
2a. Date Remedy is Operational and Functional (O&F)	**2b. Date for Transfer to State**

3. What is the primary goal of the P&T system (select one)?	4. Check those classes of contaminants that are contaminants of concern at the site.
☐ Contaminant plume containment	☐ VOCs (e.g., TCE, benzene, etc.)
☐ Aquifer restoration	☐ SVOCs (e.g., PAHs, PCP, etc.)
☐ Containment and restoration	☐ metals (e.g., arsenic, chromium, etc.)
☐ Well-head treatment	☐ other

5. Has NAPL or evidence of NAPL been observed at the site? Yes ☐ No ☐

6. What is the approximate total pumping rate?

7. How many active extraction wells (or trenches) are there?	8. How many monitoring wells are regularly sampled?
9. How many samples are collected from monitoring wells or piezometers each year? (e.g., 40 if 10 wells are sampled quarterly)	10. How many process monitoring samples (e.g., extraction wells, influent, effluent, etc.) are collected and analyzed each year? (e.g., 24 if influent and effluent are sampled monthly)

11. What above-ground treatment processes are used (check all that apply)?

☐ Air stripping	☐ Metals precipitation
☐ Carbon adsorption (liquid phase)	☐ Biological treatment
☐ Filtration	☐ UV/Oxidation
☐ Off-gas treatment	☐ Reverse osmosis
☐ Ion exchange	☐ Other

12. What is the approximate percentage of system downtime per year? <10% ☐ 10 - 20% ☐ >20% ☐

C. Site Costs

1. Annual O&M costs

O&M Category	Actual Annual Costs for FY03	Actual Annual Costs for FY04	Projected Annual Costs for FY05
Labor: project management, reporting, technical support			
Labor: system operation			
Labor: ground water sampling			
Utilities: electricity			
Utilities: other			
Consumables (GAC, chemicals, etc.)			
Discharge or disposal costs			
Analytical costs			
Other (parts, routine maintenance, etc.)			
O&M Total			

The O&M total should be equal to the total O&M costs for the specified fiscal years, including oversight from U.S. Army Corps of Engineers or another contractor. For costs that do not fit in one of the above cost categories, include them in the "Other" category. If it is not possible to break out the costs into the above categories, use the categories as best as possible and provide notes in the following box.

2. Non-routine or other costs			

Additional costs beyond routine O&M for the specified fiscal years should be included in the above spaces. Such costs might be associated with additional investigations, non-routine maintenance, additional extraction wells, or other operable units. The total costs billed to the site for the specified fiscal years should be equal to the O&M total plus the costs entered in item 2.

Notes on costs:

D. Five-Year Review

1. Date of the Most Recent Five-Year Review	

2. Protectiveness Statement from the Most Recent Five-Year Review

- ☐ Protective
- ☐ Not Protective
- ☐ Protective in the short-term
- ☐ Determination of Protectiveness Deferred

3. Please summarize the primary recommendations in the space below.

E. Other Information

If there is other information about the site that should be provided, please indicate that information in the space below. Please consider enforcement activity, community perception, technical problems to be addressed, and/or areas where a third-party perspective may be valuable.

NOTICE:

This document may be downloaded from EPA's Clean Up Information (CLUIN) System at http://www.cluin.org. Hard copy versions are available free of charge from the National Service Center for Environmental Publications (NSCEP) at the following address:

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