1 Introduction

1.1 Why Was This Document Developed?

Groundwater extraction and treatment (aka Pump & Treat (P&T)) is not a new remediation technology, and it is still used for the cleanup of contaminated sites. The driving premise of this document is that these systems need to be evaluated, optimized, and adapted to changing site conditions throughout their life cycle. The goals of P&T optimization are to improve the effectiveness and efficiency of the remedy, maintain or improve receptor protection, ensure adequate maintenance, reduce cost and liability, reduce the environmental footprint, and make the remedy more resilient to environmental changes. This document presents an overview of the P&T optimization process and the tools and resources available to help the user achieve these goals.

This document provides an understanding of adaptive management as a key to optimization and presents a technical framework for conducting optimization efforts at P&T sites. The document addresses optimization of P&T in all phases of remediation, from site investigation through P&T termination. The Interstate Technology and Regulatory Council (ITRC) P&T optimization team acknowledges that optimization of P&T may not achieve all site goals, and this document provides support for transition or termination or both (Section 5) when optimization indicates that P&T may not be the solution, or sole solution, going forward. The Target Audience is discussed in Section 1.2.

As part of the process of developing this document, the ITRC P&T optimization team conducted a survey to understand the states' needs, issues, and concerns with P&T systems. The survey included the following two questions:

1. What are your agency's primary needs with P&T guidance? (Q3)

Top Three State Needs
1 – Exit Strategy Evaluation Guidance (77%)
2 – Performance Evaluation Guidance (74%)
3 – Process Optimization Guidance (63%)

2. What are your primary issues/concerns with P&T systems? (Q4)

Top Five State Issues/Concerns
1 – Not being able to meet regulatory end points in a reasonable time frame (65%)
2 – Moving toward an exit strategy (61%)
3 – Decision criteria on transitioning from Pump and Treat to a different remedy (60%)
4 – Concerns about constituent rebound, potential or experienced, after system shutdown (54%)
5 – Long-term maintenance (54%)

The states' responses demonstrate the need for information and guidance on optimization of P&T systems and transitioning from P&T to either another technology or to remedy completion. A well-developed P&T optimization program addresses each of these issues and concerns. Full responses to the state survey can be found in Appendix E.

1.2 Audience

The primary audience for this guidance document is project managers, operations managers, risk managers, and site investigators. This may include federal, state, tribal, and local agency employees; contractors to these agencies; and potentially liable parties and their engineers and consultants. Generally, anyone involved in designing, building, operating, or optimizing P&T systems would benefit from this guidance.

Additional audiences that may find this guidance useful include regulatory agency managers and other stakeholders, which could include members of the public and other interested parties. This guidance is intended to provide stakeholders with a better understanding of the optimization process and principles of P&T systems.

1.3 What Is Pump and Treat?

The United States Environmental Protection Agency's (USEPA's) Community Guide to Pump & Treat provides the following definition: "Pump and treat is a common method for cleaning up contaminated groundwater containing chemicals such as industrial solvents, metals, and fuel oil. Groundwater is pumped from wells or trenches to an aboveground treatment system that removes the contaminants. Pump and treat systems also help keep the contaminant plume from spreading by pumping contaminated water toward the wells. This pumping helps prevent contaminants from reaching drinking water wells, wetlands, streams, and other natural resources" (USEPA 2021[XVSKUSWM] USEPA. 2021. "Community Guide to Pump and Treat." Office of Land and Emergency Management. https://semspub.epa.gov/work/HQ/401617.pdf.).

P&T systems may use a single method of removing contaminants from groundwater, such as granular activated carbon (GAC), or multiple methods, such as air stripping and GAC. The method used depends on the concentration of the contaminant and on whether multiple contaminants are present. The pumping system is designed to capture contaminated groundwater to limit contaminate migration. Aquifer restoration can be achieved by drawing back or treating the contaminated groundwater until regulatory levels are achieved and, where possible or desirable, returning treated groundwater to the aquifer (USEPA 1990[98TP6JQ3] USEPA. 1990. "Basics of Pump-and-Treat Ground-Water Remediation Technology." U.S. Environmental Protection Agency. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryID=125940.).

P&T has been used since the beginning of the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) programs in the late 1970s and early 1980s, respectively. P&T systems were identified as a primary method of remediation of contaminated groundwater and remain a major priority for both RCRA and CERCLA programs. As state programs developed in the 1980s and 1990s to mirror or complement the RCRA, Superfund, Underground Storage Tank, and other federal programs, P&T systems were adopted by the states. P&T systems are used on federal- and state-lead cleanup projects, responsible party–lead projects, and voluntary cleanup projects.

Potential Pump and Treat Objectives

- Source/Mass Removal
- Containment/Plume Control
- Aquifer Restoration

Source: USEPA's Basics of Pump-and-Treat Ground-Water Remediation Technology

Benefits of the National Optimization Strategy

(Not intended to be comprehensive)

- Achieving better and more cost-effective site characterization
- Improving remedy evaluation and selection
- Improving remedy protectiveness
- Improving alignment of site activities with site remedial action objectives
- Reducing costs
- Providing information to assist with the preparation of Five-Year Reviews
- Proactively identifying potential impediments to site completion
- Accelerating project and site completion
- Addressing community concerns
- Incorporating newer and greener technologies into site cleanups
- Providing site teams with tools and strategies for more effective site decision-making
- Building consensus among site stakeholders
- Providing independent technical input that cross-pollinates expertise among sites
- Improving data and information management practices
- Improving timeliness, utility, and objectivity of data in decision-makers' hands

Adapted from the USEPA Office of Solid Waste and Emergency Response (OSWER) Directive 9200.3-75 September 2012

P&T systems have evolved over time. P&T systems have been deployed at a wide range of sites that vary in their geology and the nature of the contaminants. This variability places different limitations on the effectiveness of P&T systems. Initially, many P&T systems were designed to be the sole cleanup technology. Conditions at some sites, however, proved that P&T systems alone could not achieve cleanup goals (FRTR 2020[M6TQYWH3] FRTR. 2020. "Technology Screening Matrix: Groundwater

Pump and Treat." Federal Remediation Technologies Roundtable. https://frtr.gov/matrix/Groundwater-Pump-and-Treat/.). P&T systems often had capture zones that were smaller than intended, which allowed a portion of the impacted groundwater to continue to migrate (Cohen et al. 1997[93N64ILB] Cohen, Robert M., James W. Mercer, Robert M. Greenwald, and Milovan S. Beljin. 1997. "Design Guidelines for Conventional Pump-and-Treat Systems." U.S. Environmental Protection Agency. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=90422.). Other systems experienced rising contaminant concentrations (referred to as "rebound") after pumping was terminated. Some P&T systems reached equilibrium (aka asymptotic conditions) before or after pumping was terminated. These and other limitations have been the drivers for the need to optimize, transition, or terminate P&T systems. This document does not address every variability or eventuality, but it does provide general guidance on optimizing P&T systems. ITRC has a range of documents that address optimizing sites with other treatment technologies (see the ITRC Remediation Process Optimization webpage).

1.4 What Is Pump and Treat Optimization and Why Is It Needed?

The Office of Superfund Remediation and Technology Innovation (OSRTI) provides this definition of optimization:

> Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress toward site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness (USEPA 2012[Y7NCWKHT] USEPA. 2012. "Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion." Office of Superfund Remediation and Technology Innovation (OSRTI). https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100GI85.txt.).

Optimization can be needed because site or regulatory conditions may change as the remedy progresses. Changing conditions may increase project risk, environmental risk, or both (ITRC 2004[JKA62F2T] ITRC. 2004. "Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation." Washington, D.C.: Interstate Technology & Regulatory Council, Remediation Process Optimization Team. https://itrcweb.org/teams/projects/remediation-process-optimization., ITRC 2011[U4PDZV64] ITRC. 2011. "Project Risk Management for Site Remediation." Washington, D.C.: Interstate Technology & Regulatory Council, Remediation Risk Management Team. https://itrcweb.org/Guidance/GetDocument?documentID=88.). P&T systems designed and installed years ago may no longer adequately address the conditions currently present at the site. For example, mechanical systems age and can become inefficient over time. Groundwater elevation may change, making the P&T system less efficient. Operational strategies put in place may no longer be the best for current conditions. New contaminants or lower action limits for existing contaminants may not be effectively treated by the existing system. USEPA conducts long-term response actions (LTRA) for up to 10 years for certain remedies. After the LTRA period, remedy operation and maintenance (O&M) becomes the responsibility of the states. Optimization can help ensure that these remedies are performing effectively and cost-efficiently at the time of transfer. Plans to reuse or redevelop property may also drive optimization. In some cases, the redevelopment may provide the funds required to conduct optimization investigations. These are just some of the reasons a site might be a prime candidate for optimization.

At any stage of remediation, risk may be minimized through optimization as presented in this document. The earlier the optimization is implemented, the more impact the optimization can have on the ultimate outcome (USEPA 2012[Y7NCWKHT] USEPA. 2012. "Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion." Office of Superfund Remediation and Technology Innovation (OSRTI). https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100GI85.txt.). The USEPA states that a major goal of optimization is to perform optimization reviews as early in the project as possible so that the benefits will carry through a project's life cycle. The USEPA also encourages optimization at any stage of the remediation—if you inherit an older project, it is not too late to optimize (USEPA 2012[Y7NCWKHT] USEPA. 2012. "Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion." Office of Superfund Remediation and Technology Innovation (OSRTI). https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100GI85.txt.).

1.5 Navigating the Document

This document presents P&T optimization by identifying key areas of the optimization process and issues that impact the remediation process. This guide builds on the knowledge and experience gained from optimization efforts by the USEPA, other federal agencies, state agencies, private industry, and prior ITRC optimization and risk management teams. But this guide to performance-based P&T optimization is organized in a fresh way. The audience can use the entire document, front to back, as a guide to optimization or jump to an area of interest specific to their project needs.

1.5.1 Document Sections

Section 2, LIFE CYCLE OPTIMIZATION FRAMEWORK FOR PUMP AND TREAT SYSTEMS—Section 2 provides a framework for conducting optimization during the life cycle of a P&T system, from initial site assessment through design, implementation, O&M, and remedy transitioning or site completion. This section also provides an interactive tool for decision-makers who need to determine whether an optimization effort may be warranted at a given site. The interactive tool is intended to help users assess the performance of the targeted system, identify any optimization needs, and find additional information in the appropriate section of this document.

Section 3, PUMP AND TREAT PERFORMANCE EVALUATION—Section 3 describes how to conduct a performance-based evaluation of a P&T system and the evaluation steps that should be completed before optimizing the P&T system. The section includes what an evaluation comprises, objectives as drivers, how to design an optimization investigation, assessment of performance and effectiveness, and options analysis.

Section 4, PROCESS OPTIMIZATION AND MANAGEMENT FOR EVOLVING SITE CONDITIONS—Section 4 gets to the "how to" of optimizing P&T systems. Additional information is provided on the importance of optimization, including the question of when to conduct optimization. The section reviews the published optimization methods, identifies optimization tools, optimizing existing systems, well and monitoring networks, alternatives and enhancements to P&T, cost estimating, and implementation recommendations.

Section 5, TRANSITION AND TERMINATION—Section 5 provides decision-making support to help transition and termination of P&T. The assumptions for this section are that the performance evaluation has been completed, the P&T system has been optimized, and the P&T system will not achieve the remedial objective or is no longer needed. Considerations for transitioning to other technologies and processes and termination of the P&T system are presented here.

Section 6, INTEGRATING SUSTAINABLE AND RESILIENT REMEDIATION INTO OPTIMIZATION—Section 6 discusses sustainability and resiliency issues that should be considered during optimization for both new and existing systems. Variations to conventional P&T, reuse and reinjection of groundwater, sustainable and green best management practices, energy conservation, implementation of green energy systems, recycling, and resiliency are included.

Section 7, REGULATORY PERSPECTIVE—Section 7 identifies regulatory considerations that may impact optimization options, costs, and timelines. Regulatory issues must be considered at all phases of remediation and during any optimization effort.

Section 8, STAKEHOLDER CONSIDERATIONS—Section 8 identifies the people and organizations that are impacted or potentially impacted by the remediation project or who have an interest in the project as stakeholders. Risk communication, ongoing engagement, initiating or renewing engagement, and explaining the optimization process and decision-making to stakeholders are included in this section.

The *Optimization Life Cycle Navigation Diagram* is a navigation tool that allows the user to visualize the optimization process and navigate this document. The three main concepts that span the project life cycle (Stakeholder Considerations, Regulatory Considerations, and Sustainable Resilient Remediation) are shown in the outer circle. Key optimization processes are in the blue boxes. The arrows show the relationships among the optimization concepts. The figure is interactive; click on a topic to navigate to that part of the document.

Optimization Life Cycle Navigation Diagram

1.5.2 Appendices

Appendices to this document include supplemental information and additional resources as outlined below.

Appendix A, COMMON CONCEPTS, provides in-depth descriptions of concepts that are common throughout the document such as modeling, conceptual site model, calculations, conveyance system, and treatment system activities.

Appendix B, CASE STUDIES, provides several selected case studies to show real-world experiences with performance evaluation, process optimization, system transition, sustainable and resilient remediation, and regulatory and stakeholder considerations.

Appendix C, INTERACTIVE CHECKLISTS, provides optimization checklists used by Section 2, including the interactive tool checklists. These can be used to assemble and evaluate site-specific data for optimization opportunities.

Appendix D, EXISTING OPTIMIZATION PROGRAMS, provides an inventory and description of existing optimization programs at the federal and state level.

Appendix E, STATE SURVEY, provides all the details on questions and responses to the team's state survey. This survey is referenced throughout the document. The survey provides insight into the states' P&T optimization needs, experiences, and regulations or guidance.

Appendix F, ACRONYMS, provides the long forms of the acronyms, abbreviations, and initialisms used in this document.

Appendix G, GLOSSARY, provides definitions of technical or potentially confusing terms used in the document.

Appendix H, TEAM CONTACTS, provides the contact information for team and section leaders who helped prepare this document.

Appendix I, ACKNOWLEDGMENTS, expresses appreciation to the individuals and organizations who supported the development of this document.

Appendix J, DOCUMENT FEEDBACK, allows users to provide feedback on this document.

1.6 Limitations

This guidance document is intended to describe scientifically sound methods for establishing technically defensible optimization. It is intended to describe appropriate methods and approaches to optimize P&T systems. The focus of this document is the performance-based optimization of P&T systems. This guidance document is intended to inform and support decision-making and complement existing guidance documents. The regulatory framework and the policies of the agency with jurisdiction over the site should be reviewed to ensure compliance with applicable regulations, policies, and guidance.