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DEPARTMENT OF THE AIR FORCE
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MEMORANDUM FOR DISTRIBUTION

FROM: HQ ACC/CEVR
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SUBJECT: United States Air Force Presumptive Remedy Engineering Evaluation/Cost Analysis (PREECA) 2nd Edition

1. This package contains your copy of the subject document. Please issue this material to the person(s) responsible for Environmental Restoration requirements.

2. The PREECA builds on the ongoing efforts of several organizations. A primary goal of the Department of Defense (DoD) Installation Restoration Program is to achieve early and substantial risk reduction at sites posing significant risk to human health and the environment.

3. The PREECA 2nd Edition continues to support the DoD goal by standardizing a significant portion of the remedy selection process. Please note the following areas which were included in this edition:

a. A technology criteria document was added for Multi-Phase Extraction which is one of the newest EPA approved presumptive remedy technologies for treating volatile organic compound (VOC) contamination in both groundwater and vadose zones.

b. An example Site Specific Action Memorandum (SSAM) replaced Part III of the original PREECA.

c. Information on EPA approved presumptive remedy application of military landfills was added to the Capping technology criteria document.

d. The Groundwater Pump and Treat for Containment Technology was renamed Groundwater Containment.

4. If you have any questions or comments or require additional copies, please contact Ms. Margaret Patterson by phone, (757) 764-6249, or e-mail <pattersm@hqaccce.langley.af.mil>.

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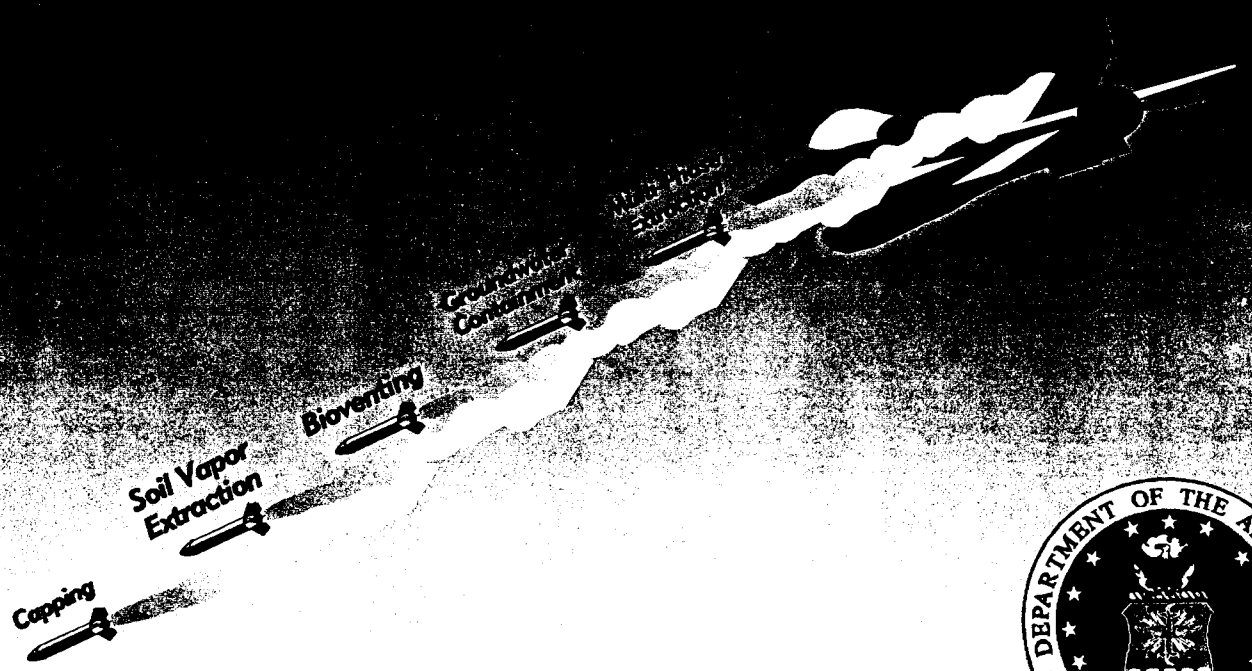
Presumptive Remedy Engineering Evaluation/ Cost Analysis (PREECA)



High Risk Sites

FINAL

May 1997

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UNITED STATES AIR FORCE PRESUMPTIVE REMEDY ENGINEERING EVALUATION/COST ANALYSIS (PREECA)

2ND EDITION

FINAL

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OMAHA, NEBRASKA 68102-4978

15 May 1997

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ACKNOWLEDGMENTS

This Air Force Presumptive Remedy Engineering Evaluation/Cost Analysis (PREECA) builds on the past efforts of several organizations. In particular, Radian would like to acknowledge the pioneering work of EPA Region IX and CH2M Hill, Inc., at the South Indian Bend Wash (SIBW) Superfund site in Tempe, Arizona. This was the first site in the country to advance and utilize the "plug-in" approach. Radian also acknowledges the extensive efforts currently ongoing at McClellan AFB, California. The McClellan AFB Installation Restoration Program (IRP) has embraced the presumptive remedy "plug-in" approach and was the first site to implement a "plug-in" presumptive remedy EE/CA for soil vapor extraction (SVE). Mitre Corporation was instrumental in producing this document. In addition, both Radian and CH2M Hill have continued the implementation of the "plug-in" approach at McClellan through the production of a basewide remedial investigation (RI) report and a basewide vadose zone feasibility study (FS), respectively.

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1.0 INTRODUCTION

1.1 Objective and Purpose

A primary goal of the Department of Defense (DoD) Installation Restoration Program (IRP) is to achieve early and substantial risk reduction at sites posing significant risk to human health and the environment. This document supports the DoD goal by standardizing a significant portion of the remedy selection process, so that streamlined implementation of cleanup actions at high-risk Air Force sites can occur.

The Air Force presumptive remedy Engineering Evaluation/Cost Analysis (PREECA) is a "plug-in" remedy selection document designed to be utilized by all Air Force installations. It establishes the contaminated site conditions and technology criteria that high-risk Air Force sites must meet in order to take a non-time-critical removal action with the following presumptive remedies; bioventing, soil vapor extraction (SVE), groundwater containment, capping, and the multi-phase extraction technologies. The multi-phase extraction (MPE) technologies include two-phase extraction (TPE), low-vacuum dual-phase extraction (LVDPE), and high-vacuum dual-phase extraction (HVDPE). The overall goal, strategies, objectives, actions, and measures of success for this PREECA initiative are detailed in Figure 1-1.

1.2 Benefits of PREECA Approach

A primary benefit of utilizing this PREECA is the significant time savings realized in selecting and implementing a cleanup remedy at high-risk sites. This streamlined remedy selection process is compared with the standard IRP approach in Figure 1-2. As shown in the figure, the PREECA process saves several time-consuming steps. Other direct benefits of this approach are:

- Facilitates early and substantial risk reduction at high risk sites.
- Improves the consistency and predictability of the remedy selection process for DoD, regulatory agencies, and the public.
- Minimizes regional regulatory agency discrepancies in remedy selection.
- Maintains consistency with Superfund Accelerated Cleanup Model (SACM) and presumptive remedy guidance.

1.3 Background

USEPA's (EPA) Superfund Accelerated Cleanup Model (SACM) promotes the rapid reduction of risk at sites posing the greatest threat to human health and the environment through the use of removal actions. SACM was initiated by EPA to streamline and accelerate the remedy selection and site cleanup process in order to facilitate early "risk reduction." EPA recognized that this risk reduction could be more easily achieved through the "removal process" than the "remedial process." **Unlike the remedial process where cleanup standards must be documented in the Record of Decision (ROD), cleanup standards do not have to be set for removal actions to commence.** Thus, the removal action mechanism provides the necessary flexibility to be implemented across various EPA regions and states.

The standard Comprehensive Environmental Response and Liability Act (CERCLA) process for implementing a non-time-critical

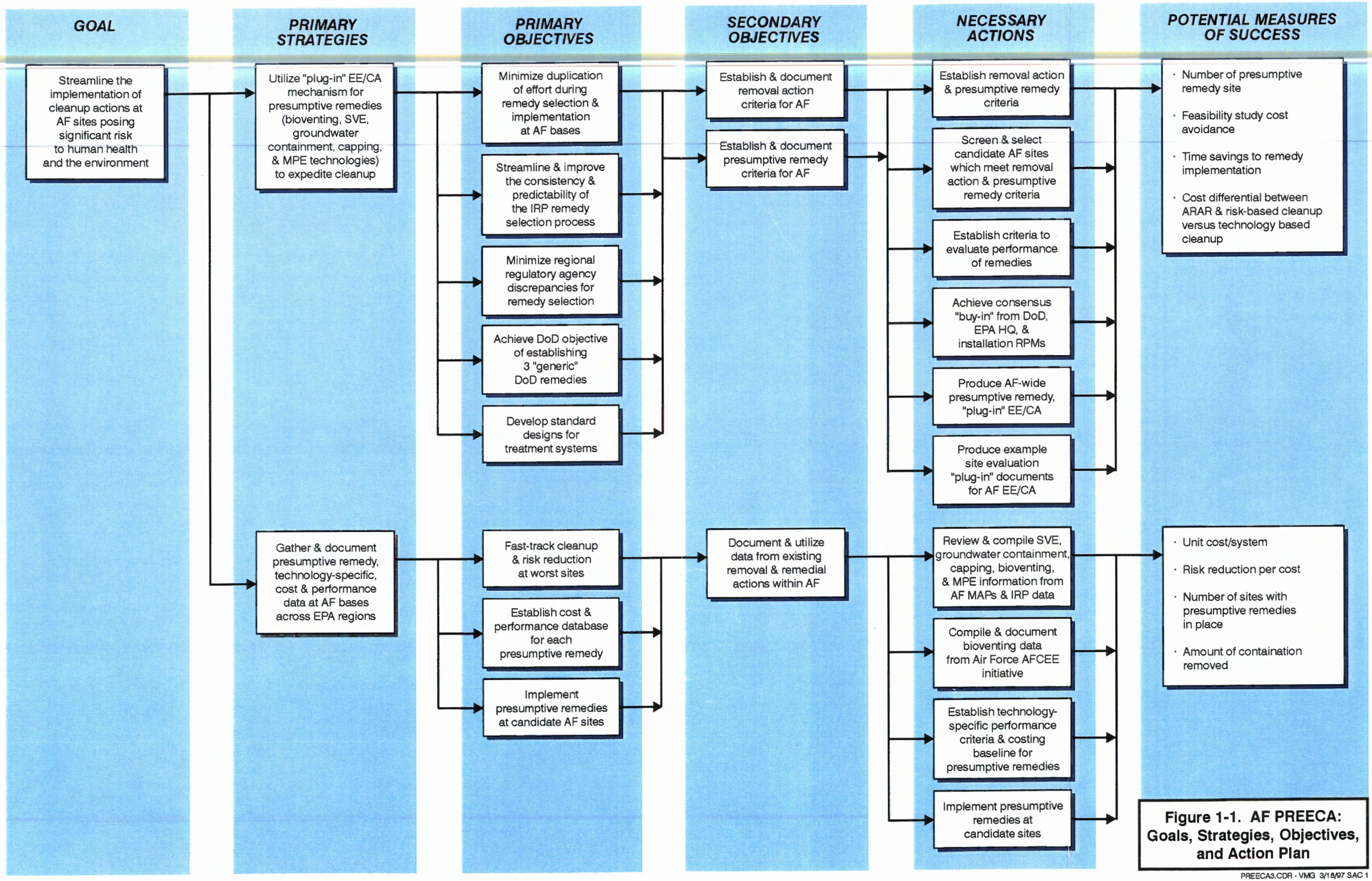

Figure 1-1. AF PREECA: Goals, Strategies, Objectives, and Action Plan

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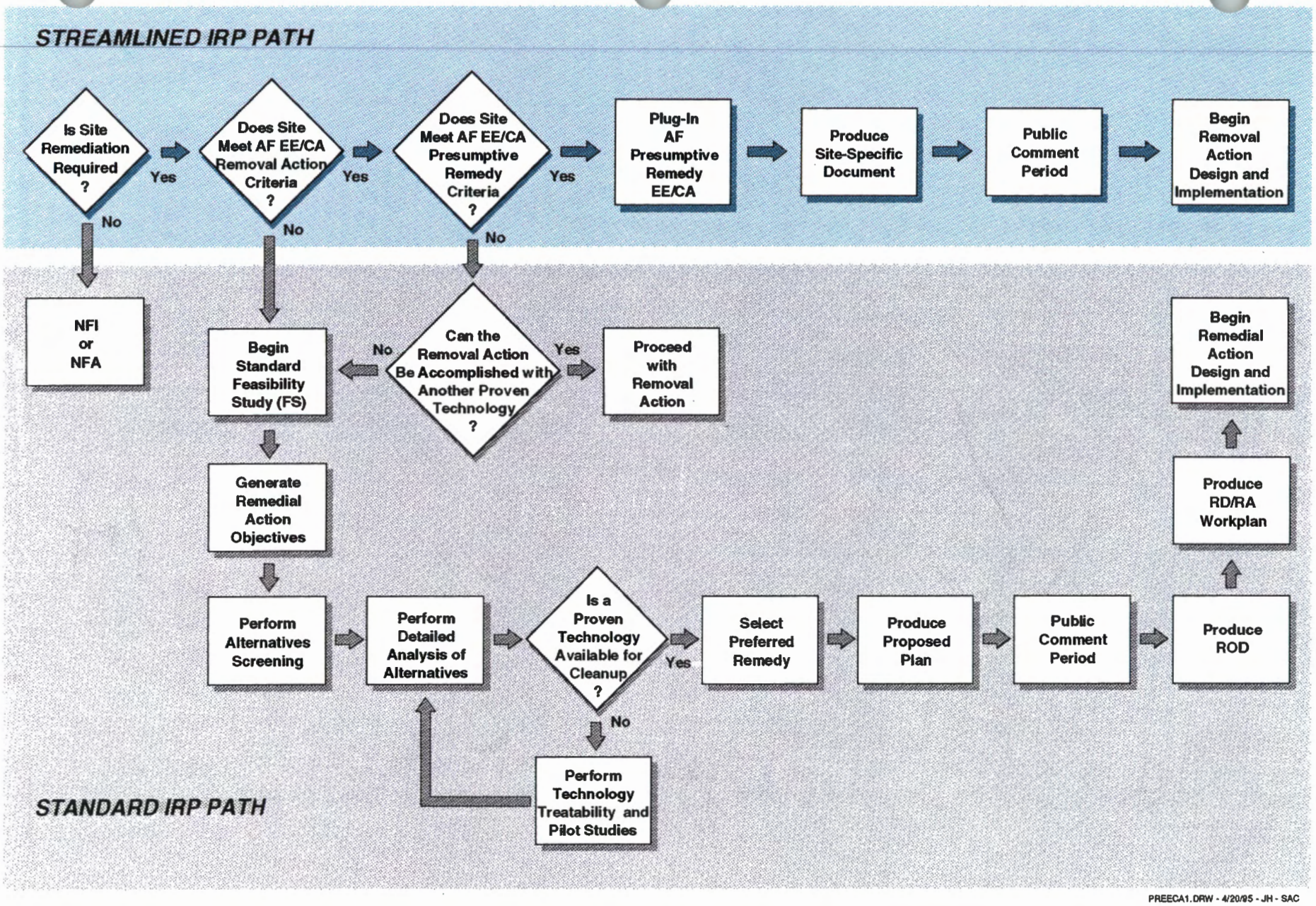


Figure 1-2. Air Force (AF) Presumptive Remedy EE/CA Streamlined Remedy Selection

removal action is shown in the left side of Figure 1-3. After the collection of site characterization data which indicates a need for action, the criteria and justification for the removal action and the selected cleanup remedy are documented in an EE/CA. The EE/CA serves as a focused remedial investigation/feasibility study (RI/FS) and it is subject to regulatory agency and community review and approval. Once the review process is complete, the removal action documentation is finalized with an action memorandum, and site cleanup begins. This entire process is repeated if future sites or operable units (OU) at an installation require a separate removal action.

Presumptive remedy removal action procedures may be applicable at an Air Force site that is not subject to CERCLA regulations. An Air Force site subject to Resource Conservation and Recovery Act (RCRA) regulations as a result of the Federal Facilities Compliance Act (1992) may adopt the PREECA approach in conducting a Corrective Measures Study (CMS). There are clear similarities between the CERCLA RI/FS process (left side of Figure 1-3) and the RCRA corrective action process (right side of Figure 1-3). Protection of human health and the environment is the principal driving force for each process. Differences exist between the two processes; however, the encouragement of early response actions and the similar purposes of removal actions and interim corrective measures provide a common basis for the use of the PREECA approach to expedite remediation under CERCLA or RCRA authority. Throughout this document, the use of streamlined procedures to take action are considered appropriate under CERCLA or RCRA regulations. Terminology developed under CERCLA will be used most frequently to simplify the presentation.

The standard CERCLA non-time-critical removal action process has been modified in this PREECA. It has been combined with two innovative remedy selection frameworks to further streamline and standardize the process: presumptive remedies and the "plug-in" approach. **The primary result of this modification is that the PREECA can serve as a "generic" remedy selection document for all Air Force installations, so that separate EE/CAs do not have to be written when a removal action can be justified for a contaminated site.** These concepts, along with detailed explanations of the modified process, will be covered in Sections 2.0-4.0 of this document.

1.4 Scope of the PREECA Process

Although the purpose of the PREECA is to facilitate early and substantial risk reduction at contaminated Air Force sites, the document is only applicable to a defined subset of potential remedies and site conditions. It is not intended that this PREECA encompass the entire range of site conditions and remedies which could be encountered at Air Force installations. **Furthermore, this document is intended to be utilized for high and medium risk sites only, and should not be employed at sites where the need for cleanup actions is not readily apparent.**

Past Air Force IRP experience has shown that the majority of sites are contaminated with halogenated and aromatic Volatile Organic Compounds (VOCs), e.g., TCE, PCE, and BTEX, and non-VOCs such as metals and PCBs. Thus, the PREECA is focused on remedy alternatives which can satisfy the majority of these common contaminant situations, namely: in situ bioventing, soil vapor extraction,

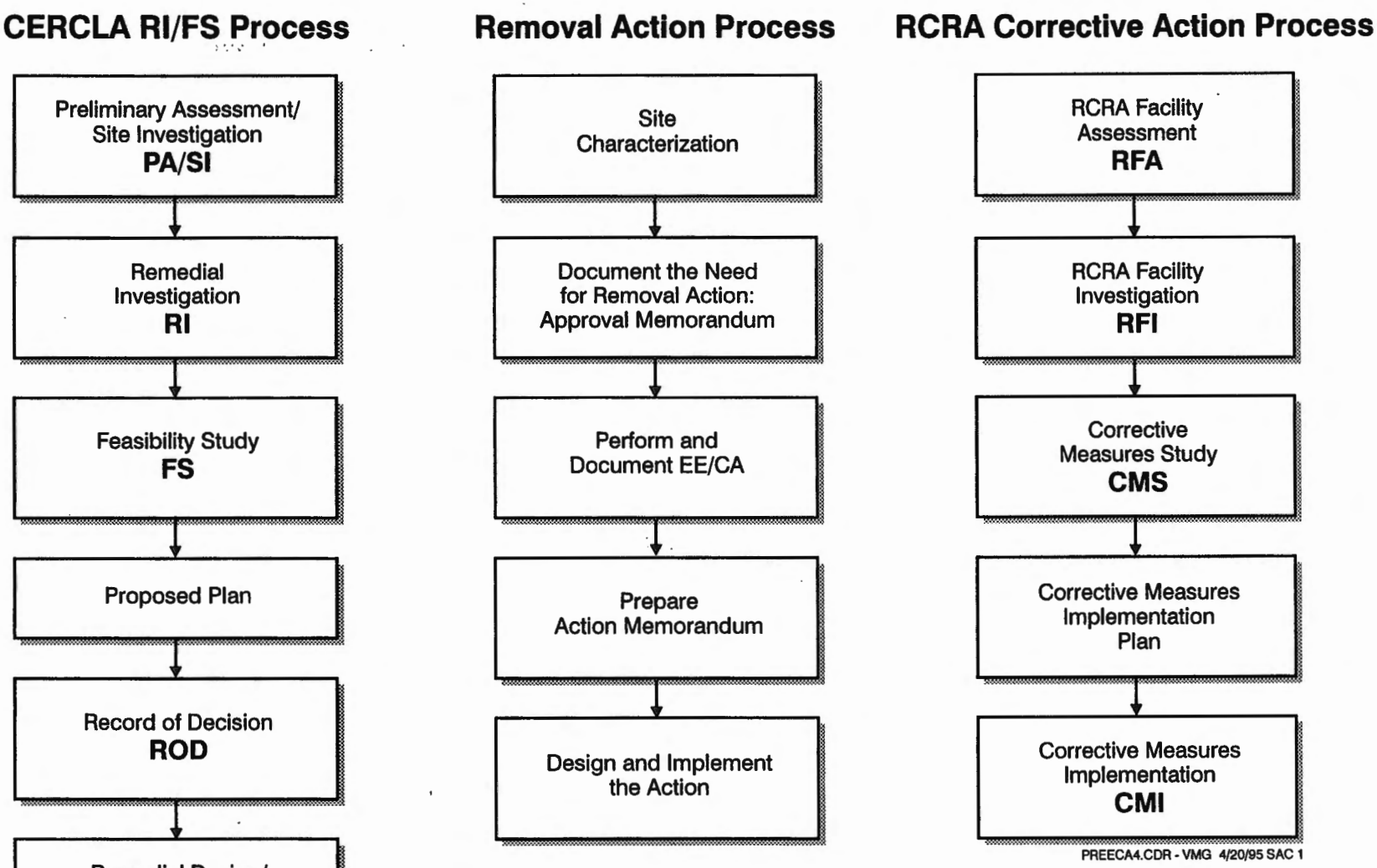


Figure 1-3. Comparison of CERCLA Remedial Investigation/Feasibility Study, CERCLA Removal Action, and RCRA Corrective Action Processes

groundwater containment, capping, and the multi-phase extraction technologies.

The PREECA is intended to be updated as new presumptive remedy technologies are established. The Air Force is currently gathering extensive cost and performance data at multiple contaminated sites for intrinsic groundwater remediation and bioslurping. If warranted, this data will be used to justify each technology as a presumptive remedy, and to document and establish their effective range of application as done with the new addition of the MPE technologies. The PREECA can then be updated to reflect this new information.

1.5 PREECA Format and Content

This document is a standardized "decision framework" that specifies the criteria and associated decision logics necessary to implement a removal action utilizing a presumptive remedy technology. Figure 1-4 depicts the organization of the Air Force PREECA. The overall document is intended as a "how-to" mechanism, and as such heavily references existing guidance documents where possible. These references should be consulted for detailed explanations of the various topics covered in this PREECA. Also available are three videos that describe PREECA entitled: Volume 1: Executive Summary; Volume 2: Introduction; and Volume 3: Implementation.

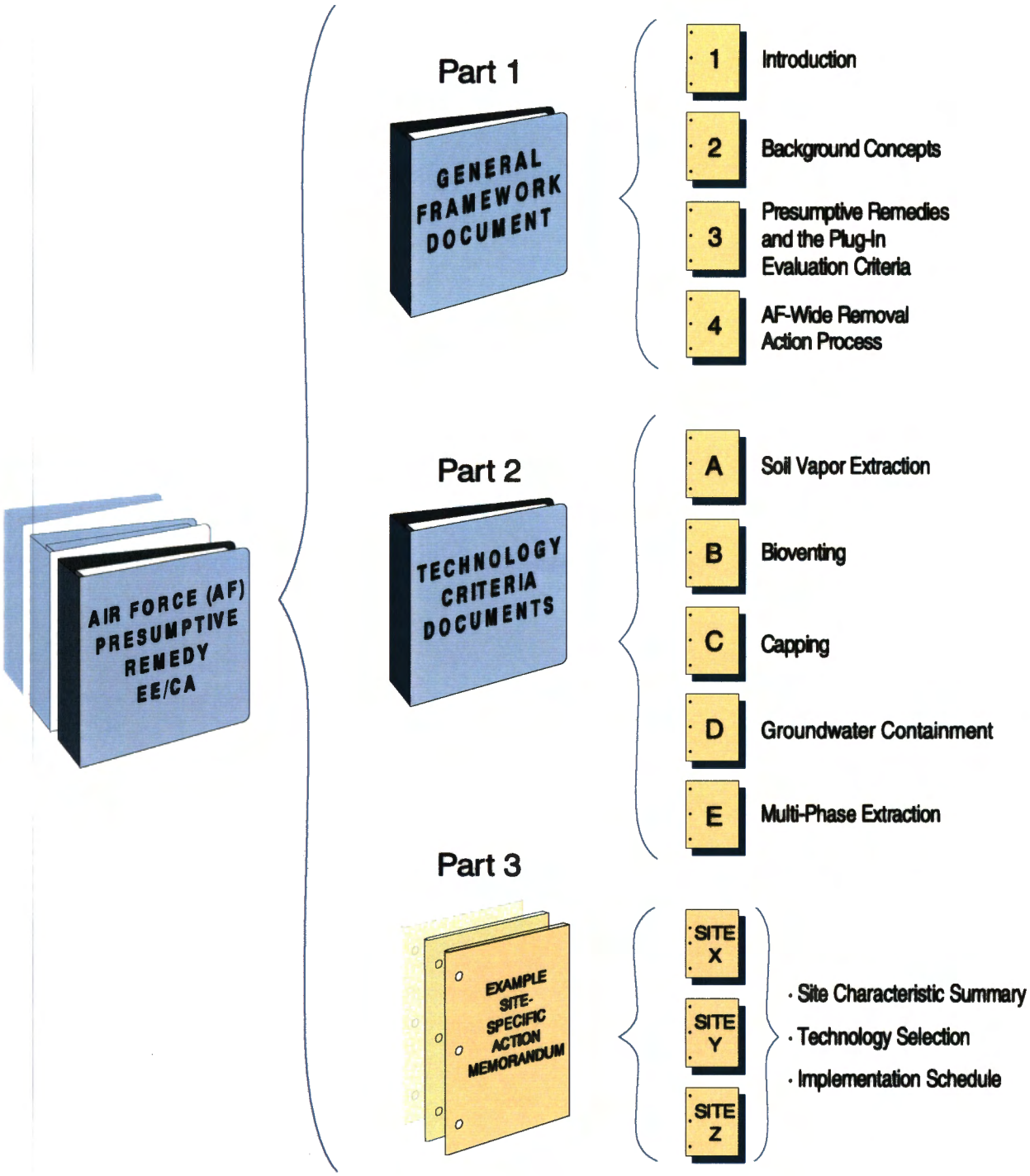
1.5.1 Part I

Part I is the general framework document for the Air Force PREECA. It provides the "road map," guidance, and instructions for implementing a non-time-critical removal action at Air Force sites. In addition to providing the rationale and background for Air Force-wide implementation, this part establishes the removal action and presumptive remedy criteria which sites must meet in order to "plug-in." This part serves as the functional EE/CA, and it also includes the regulatory agency and community review process.

Section 1.0 of Part I is the introduction of the overall PREECA concept and scope. It is intended to provide the project goals, objectives, and benefits, a brief background of removal actions, the scope of the PREECA process, and the format and contents of each part.

The purpose and objective of Section 2.0 is to introduce and explain the 6 elements and concepts integral to the PREECA approach. These are: the non-time-critical removal action process, the Superfund Accelerated Cleanup Model (SACM), the Air Force Accelerated Cleanup Program (ACP), risk reduction, presumptive remedies, and the "plug-in" approach. Within the "plug-in" approach description is an explanation of site and remedy profiles. Overall, Section 2.0 provides the foundation for the technical evaluation and detailed process descriptions included in Sections 3.0 and 4.0.

Section 3.0 of this part explains the scope and objectives of non-time-critical removal actions; provides the justification and evaluation of presumptive remedy alternatives; establishes site and remedy profiles; and provides the decision logic for performing a "plug-in" determination. This section is the heart of the PREECA document and serves as the generic remedy selection justification which all Air Force installations must reference when implementing this process at a candidate site.



Note: A three volume video series is available on the PREECA including the Executive summary video, the Introduction video, and the Implementation video

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Figure 1-4. AF PREECA Organization

Finally, Section 4.0 is intended to serve as the "how-to-guidance" for implementing a non-time-critical presumptive remedy removal actions at Air Force sites. Each step of the process is discussed and explained so that installation level personnel can implement this PREECA where applicable.

1.5.2 Part II

Part II is a presumptive remedy technology handbook and is composed of five technology protocol sections: bioventing, SVE, groundwater containment, capping, and MPE. It is designed to provide supporting technology-specific justification and detail not included in Part I. In addition to providing general descriptions of each presumptive remedy technology, this document provides the detailed technology criteria which are necessary for a complete remedy profile evaluation. Part II also incorporates a conceptual design, documents the range of costs associated with implementing a presumptive remedy technology, and discusses operation and maintenance considerations.

1.5.3 Part III

Part III contains an example site-specific action memorandum (SSAM) used at Seymour Johnson AFB. The site-specific action memoranda are documents that must be written for each site or source area grouping to be "plugged-in" to the Air Force-wide removal action. These short (e.g., 40-45 pages), focused documents support the "plug-in" determination and provide additional removal action justification and rationale for each candidate site as specified in Parts I and II. The site-specific action memoranda also establish the removal action implementation schedule, technology performance criteria, and "cleanup goals." Action memoranda are equivalent to Proposed Plans in the CERCLA remedial process. They can be developed to meet the requirements of Corrective Measures under RCRA. They must be formally reviewed by local regulatory agencies and the community for acceptance prior to beginning the removal action.

2.0 PREECA COMPONENTS AND CONCEPTS

Six components and concepts, consisting of a regulatory process and supplementary initiatives, are integrated in this guidance to facilitate achievement of this goal. These components and concepts are: the non-time-critical removal action process, the Superfund Accelerated Cleanup Model (SACM), the Air Force Accelerated Cleanup Program (ACP), risk reduction, presumptive remedies, and the "plug-in" approach.

Because of parallel concepts and purposes among the components, they can be integrated to increase the speed and efficiency of cleanup without adding unnecessary weight to the effort. Figure 2-1 illustrates the integration of the components to provide a mechanism that can quickly move from problem recognition to solution. This mechanism, the Air Force PREECA, is designed to streamline the normal CERCLA remedial investigation/feasibility study (RI/FS) or Corrective Measures Study process without compromising effectiveness, protection of human health or the environment, or public involvement.

The remainder of this section explains the origins of each of the components and the parallelism of their purposes. All components were initiated through federal agency regulations, guidance, or directives because of their potential for time and cost savings in the cleanup process. There are no conflicts among the individual components that would prevent integration and successful use of the assembled whole.

2.1 Removal Action Process

The removal action process was established in the National Contingency Plan (Section 300.415) (NCP, 1990) and CERCLA (104) (CERCLA, 1992) with the stated purpose of taking actions "necessary to prevent, minimize, or mitigate damage to public health, welfare or the environment." Eight general types of removal actions are identified in the NCP; they are:

- Prevention or abatement of actual or potential exposure of nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants;
- Prevention or abatement of actual or potential contamination of drinking water supplies or sensitive ecosystems;
- Stabilization or elimination of hazardous substances in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release;
- Treatment or elimination of high levels of hazardous substances, pollutants or contaminants in soils largely at or near the surface that may migrate;
- Minimization or elimination of the effects of weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or to be released;
- Elimination of threat of fire or explosion;
- Determination of availability of other appropriate federal or state response mechanisms to respond to the release; and
- Mitigation or abatement of other situation or factors that may pose threats to public health, welfare, or the environment.

It is clear from the actions identified that protection of public health, welfare, and the environment are the focus of the removal action process. However, baseline

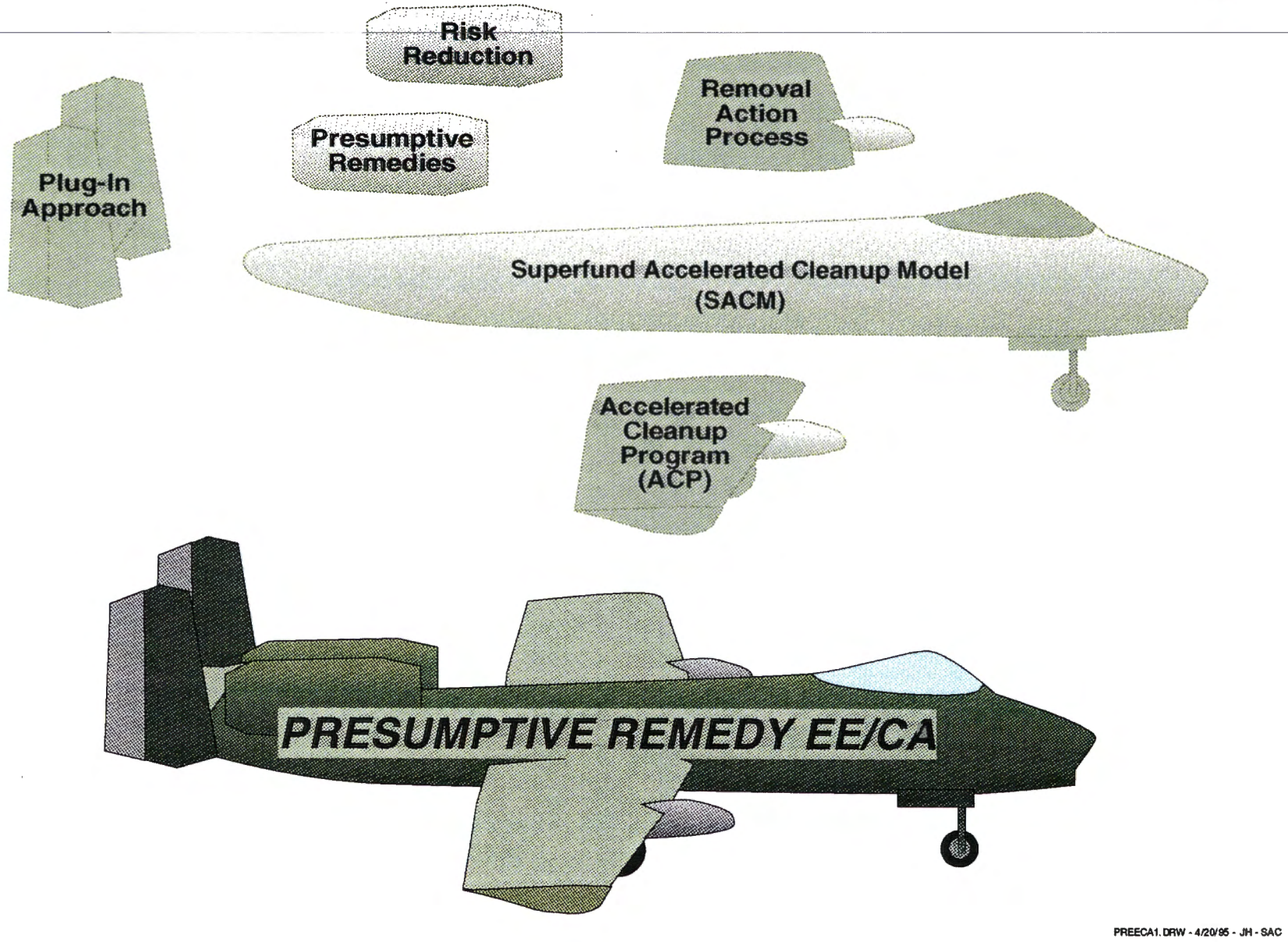


Figure 2-1. Development of the AF Presumptive Remedy EE/CA

quantitative human health or ecological risk assessments are not required to support the removal action decision process. Imminent hazards to public health and welfare or the environment, for example, a spill of hazardous chemicals or the entry of hazardous concentrations of contaminants to a water supply well, are justification to implement a removal action response. Evidence that an Applicable or Relevant and Appropriate Requirement (ARAR) has been or will be exceeded may also be adequate justification to warrant a removal action. If neither imminent hazards or ARAR exceedance is identified for a site, an exposure assessment or qualitative risk assessment that supports one or more of the eight types of removal actions may indicate the need to initiate the removal action response.

Three categories of removal actions are provided for in the regulations depending on the type of situation, the urgency and threat of the release or potential release, and the timeframe in which action must be initiated: 1) emergency, 2) time-critical, and 3) non-time-critical. Emergency and time-critical removal actions are those which should be implemented within 6 months of identification because the potential risks from contaminants may reach a sufficiently high level within that time interval.

Non-time-critical actions, the removal action category proposed for this PREECA initiative, are actions that require more than six months to plan and implement. However, for the purposes of this PREECA initiative non-time critical actions should not require more than 12 to 24 months to implement. Although emergency and time-critical actions are implemented more rapidly than the accelerated procedures in this guidance can achieve, the presumptive remedies described in Parts I and II may also be appropriate for those response actions.

The process to be followed for **non-time-critical actions** at Air Force sites is illustrated in Figure 2-2. Although there are a number of steps in the process, they can be taken rapidly.

A significant time-saving benefit of the removal action process is the ability to initiate it at various stages of the overall IRP process, such as the Preliminary Assessment (PA), Site Inspection (SI), or a later stage of remedial investigation (RI). If it is discovered that a site meets removal action criteria and action can be implemented in a period of 12 to 24 months, the presumptive remedy removal action process is a viable option. Sites that have proceeded through the RI and are in the feasibility study (FS) stage will probably not benefit from the mechanism described in this document; however, selection of a presumptive remedy through the plug-in component (see Sections 2.5 and 2.6) may provide a savings in resources that would be consumed during the FS in remedial alternative development and comparative analysis for those sites.

Important steps in the removal action process for non-time-critical actions are:

- **Removal Site Evaluation**—This is the data gathering step, which includes the PA and, if necessary, the SI, to identify the source and nature of the contaminant release, to assess the magnitude of the threat to public health, and to determine the need for a removal action. Readily available information is used initially to determine the urgency of the response and the need for additional site profile information to assist in the selection of a presumptive remedy.

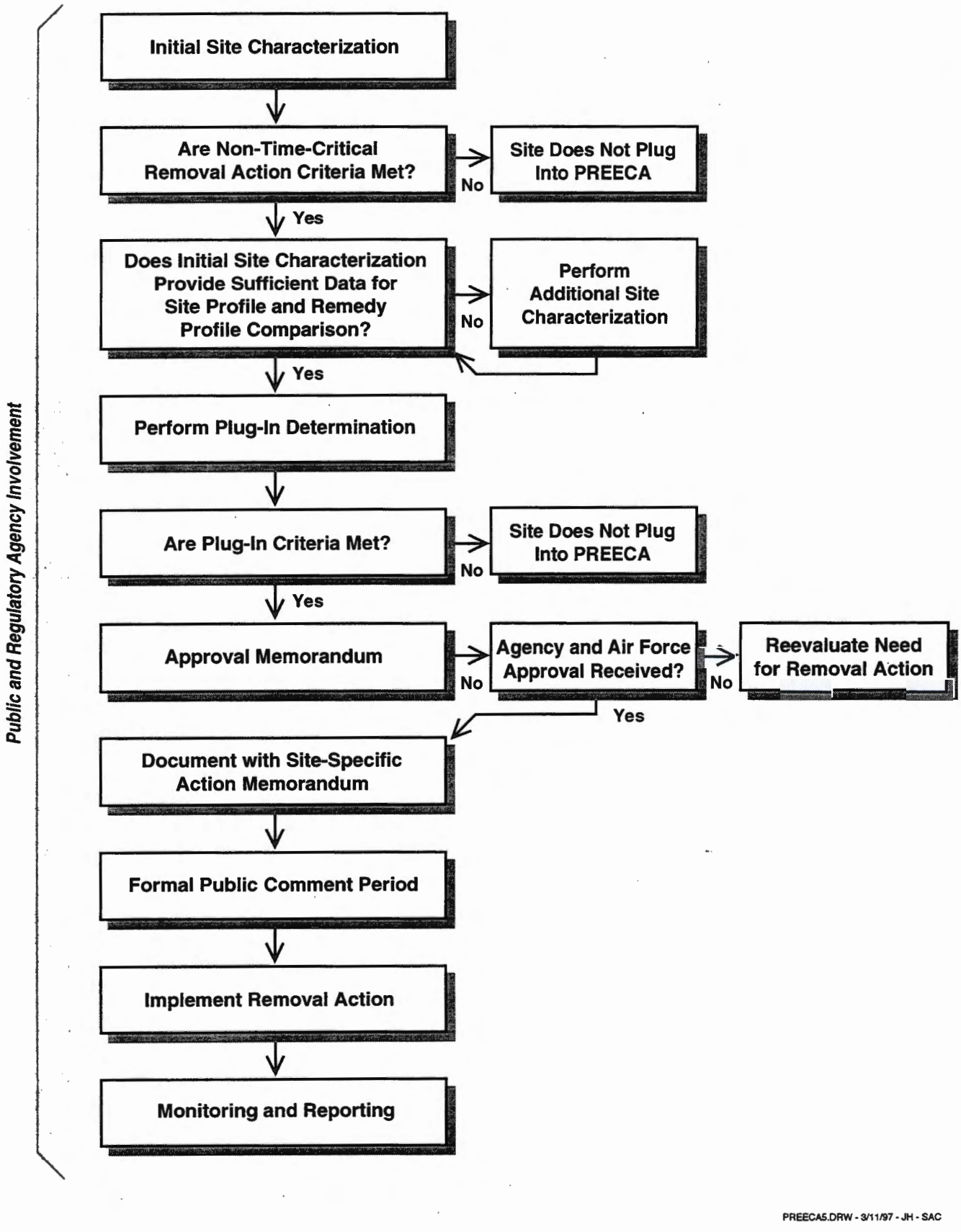


Figure 2-2. Process for Non-Time-Critical Removal Actions at Air Force Sites

- **EE/CA Approval Memorandum**—This short, focused document is prepared after the site evaluation to record the need for a non-time-critical action and the intent to proceed to action through an engineering evaluation/cost analysis (EE/CA). The document is used to secure regulatory agency and management approval of the EE/CA. It records the decision that the site meets NCP criteria for a non-time-critical action and provides information pertaining to site background, health and environmental threats, and the consequences that would result if no action were taken or if the action were delayed.

- **EE/CA**—The goals of this document, required for all non-time-critical removal actions (NCP, 300.415(b)(4)(i)) (NCP, 1990), are to identify the objectives of the removal action and to analyze the removal action alternatives for effectiveness, cost, and implementability. The EE/CA is similar to the RI/FS for remedial action sites but is more focused and thus less comprehensive. The presumptive remedy "plug-in" procedures introduced and described in Section 3.0 have the greatest impact on the completion of the EE/CA. Preparation and approval of this document can be shortened through implementation of these procedures.

- **Public Involvement**—The public is involved in the removal action process, at a minimum, through an announcement describing the EE/CA and a public comment period in a major local newspaper. Additional involvement of the public through public meetings is also recommended.

2.2 Superfund Accelerated Cleanup Model

The Superfund Accelerated Cleanup Model (SACM) was adopted in 1992 to more quickly reduce acute risks at Superfund sites and restore the environment over the long term. Key components of SACM are:

- One-step site screening and qualitative risk assessment at the front end of the process;

- Regional management teams to lead all sites to early action to reduce immediate risks to human health and the environment, and/or long-term cleanup to restore the environment; and

- A combined approach including enforcement, community relations, and public involvement throughout the cleanup process.

A primary purpose of SACM is to increase immediate risk reduction at a larger number of sites than previously achieved with the Superfund process. Distinctions between "remedial" and "removal" action programs that had existed under the pre-SACM process were removed. This facilitates a primary benefit of SACM, namely, all site assessment takes place within one program. The single assessment process addresses all threats to health and safety posed by exposure to contaminants. The action that will achieve early risk reduction is preferred under SACM.

Because of this recent initiative in Superfund, the removal action process has taken on greater importance. The removal action process for non-time-critical actions offers the potential to alleviate health or environmental risks in a shorter time period than the

RI/FS process. The intent of SACM can be more fully achieved if presumptive remedies are adopted in development of the EE/CA for the removal action.

2.3 Accelerated Cleanup Program

The Accelerated Cleanup Program (ACP) for the Air Force/Air Combat Command is an initiative which exploits the flexibility and streamlining opportunities presented by U.S. EPA's SACM. The overall goal of the ACP is to remove current programmatic and administrative hindrances within the IRP in order to reduce program costs by 20% while simultaneously reducing the time required to complete site cleanup. Currently three installations, Holloman AFB, NM, Ellsworth AFB, SD, and Shaw AFB, SC, are the primary participants within this program.

The strategy of the ACP is founded on the following three components:

- Promote real-time decision-making, reduce review times, and accelerate program planning by using empowered on-site project teams composed of the installation RPM, regulatory agencies, and contractors;
- Ensure realistic cleanup scenarios through the establishment and implementation of risk-based cleanup levels tied to the current and most probable future land uses of each Air Force site; and
- Promote cradle-to-grave responsibility and accountability for site cleanup, minimize project handoffs, and streamline actions through the use of Total Environmental Restoration Contracts (TERCs).

The PREECA is a remedy selection mechanism which is consistent with the goal of the ACP. It streamlines the selection of appropriate cleanup remedies and helps to speed the site toward closure.

2.4 Risk Reduction

As previously stated, risk reduction is an important driver of the removal action, SACM and ACP programs. Human health or ecological risks may result from exposure to contaminants released in the environment at Air Force sites. Removal or containment of contaminants that pose the greatest environmental risk reduces the risk potential. Although carcinogenic or non-carcinogenic risk values may not have been calculated for a site that qualifies for removal action, risk reduction can be qualitatively estimated for a proposed removal action.

Reducing the mass or concentration of a hazardous contaminant in the environment normally reduces the potential risk that the contaminant could pose. If the contaminant exists in a pathway (air, surface water, groundwater) to which the people or animal life may be exposed, removing the contaminant from the pathway or cutting off the pathway in a removal action decreases the potential risk. Although it is desirable to remove and decrease the toxicity of a contaminant in a pathway before there is potential for exposure, cutting off the pathway through groundwater containment or through capping of soil with an impermeable barrier is also a viable method of risk reduction.

The presumptive remedies for removal actions that are presented in this guidance are capable of reducing human health or environmental risks, if properly implemented. Therefore, the qualitative reduction

in risk that would result after implementing one of the remedies is an additional benefit of adopting the mechanism outlined in this guidance.

2.5 Presumptive Remedies

2.5.1 Definition and Background

Presumptive remedies are remedial technologies that have been repeatedly chosen for implementation at sites which share similar conditions and characteristics. The development of the presumptive remedy concept is an outgrowth of historical Superfund remedy selection trends. Analysis of these trends at hazardous waste sites across the country has shown that the same remedy is often selected for sites sharing similar characteristics. In other words, the remedy or technology can be "presumed" for various site categories. This is the foundation of the presumptive remedy concept.

Drawing on this nationwide experience base, the U.S. EPA Office of Solid Waste and Emergency Response (OSWER) issued the first nationwide guidance for the implementation of presumptive remedies at hazardous waste sites in September 1993 (OSWER, 1993a). In effect, presumptive remedies can be viewed as the "best available technology" for a given set of site conditions. Currently, U.S. EPA presumptive remedy guidance exists for sites with volatile organic compound (VOC) contamination in soil, ex-situ treatment technologies for contaminated groundwater, municipal landfill sites, military landfill sites, wood treater sites, and MPE technology selection for VOCs in soil and groundwater.

The objective of the presumptive remedy initiative is to streamline site investigations and accelerate the remedy selection process, and this is consistent with the objectives of the NCP, CERCLA, RCRA corrective action process, and the SACM. The primary benefits of utilizing presumptive remedies are time and cost savings associated with streamlined remedy selection, along with improvements in the predictability and consistency of the process.

2.5.2 Presumptive Remedy Utilization in the Remedy Selection Process

The primary uses of presumptive remedies within the remedy selection process are to focus data collection toward the anticipated cleanup remedy, and to streamline and minimize the number of alternatives which must be considered within a focused feasibility study or EE/CA. **Once it has been determined that the site or sites are of the type for which presumptive remedies have been developed, the technology alternatives analysis need only consider the no action alternative and the presumptive remedy itself. Thus, the evaluation of alternatives is greatly streamlined.**

2.5.3 Air Force Presumptive Remedy Technologies

Consistent with current U.S. EPA presumptive remedy guidance documents, U.S. Air Force remedy selection experience, and technology-specific cost and effectiveness data, the following technologies have been designated as presumptive remedies for Air Force sites: Bioventing, Soil Vapor Extraction, Groundwater Containment, Capping, and the Multi-Phase Extraction Technologies. A detailed justification and evaluation of each technology is included in Sections 3.3 and 3.4 of this part, and the technology-specific protocols are contained within Part II.

2.6 Plug-In Approach

The plug-in approach is an innovative method for establishing a standardized decision framework to integrate decision-making processes. This approach is consistent with CERCLA, RCRA, the NCP, and the mandate to protect human health and the environment. The objective of the plug-in approach is to exploit the commonality between sites by establishing preset conditions and criteria for implementing removal and remedial actions; and it is most effectively used in a decision environment where multiple sites share similar physical and contaminant characteristics.

2.6.1 Background and Historical Precedent

The initial development and use of the plug-in approach was accomplished by the U.S. EPA at a CERCLA-regulated site in Tempe, Arizona (Indian Bend Wash – South). A plug-in FS for sites contaminated with VOCs in the vadose zone was completed in June 1993. This FS recommended SVE as the final remedy. A subsequent plug-in Record of Decision (ROD) was signed in September 1993.

Two additional applications of the plug-in approach have been utilized at McClellan AFB, California. In November 1993, a SVE presumptive remedy plug-in EE/CA was finalized for the installation. This document provides the framework for taking non-time-critical removal actions at sites which are grossly contaminated with halogenated VOCs.

2.6.2 Plug-in Versus Traditional Remedy Selection Approach

The traditional remedy selection process, within CERCLA and RCRA, is site or operable unit-specific. Generally, the complete nature and extent of contamination at a site must be established, and then several remedial alternatives are evaluated to determine the appropriate cleanup remedy. Within CERCLA this process is accomplished through the remedial investigation/ feasibility study (RI/FS) and subsequent ROD, and for RCRA the corresponding elements are the RCRA facility investigation/corrective measures study (RFI/CMS). This same decision process is repeated for each site or operable unit requiring a cleanup action; thus, multiple time-consuming remedy selection documents are usually required for each installation.

By comparison, the plug-in approach preselects a remedy which can address a range of site conditions, i.e., physical and contaminant characteristics. This is accomplished through the development of a "decision-framework". The framework is a set of decision logics that establish the criteria which a site must meet in order to be amenable to treatment by the specific technology or treatment train. Once a site meets the criteria, it can "plug-in" to the remedy without having to repeat the remedy selection process. In other words, the conditions for implementing a specific remedy need only be established once in the plug-in document.

The primary benefits of this approach are obvious. The remedy selection process is consistent, streamlined, and faster. **Also, sites need not have complete nature and extent of contamination defined prior to selecting a remedy and taking cleanup actions.** Once data collection is sufficient to confirm the site characteristics "match" the plug-in criteria, the remedy is selected and cleanup can begin. This is illustrated in Figure 2-3.

The plug-in approach can be applied to a site at any Air Force installation or to several

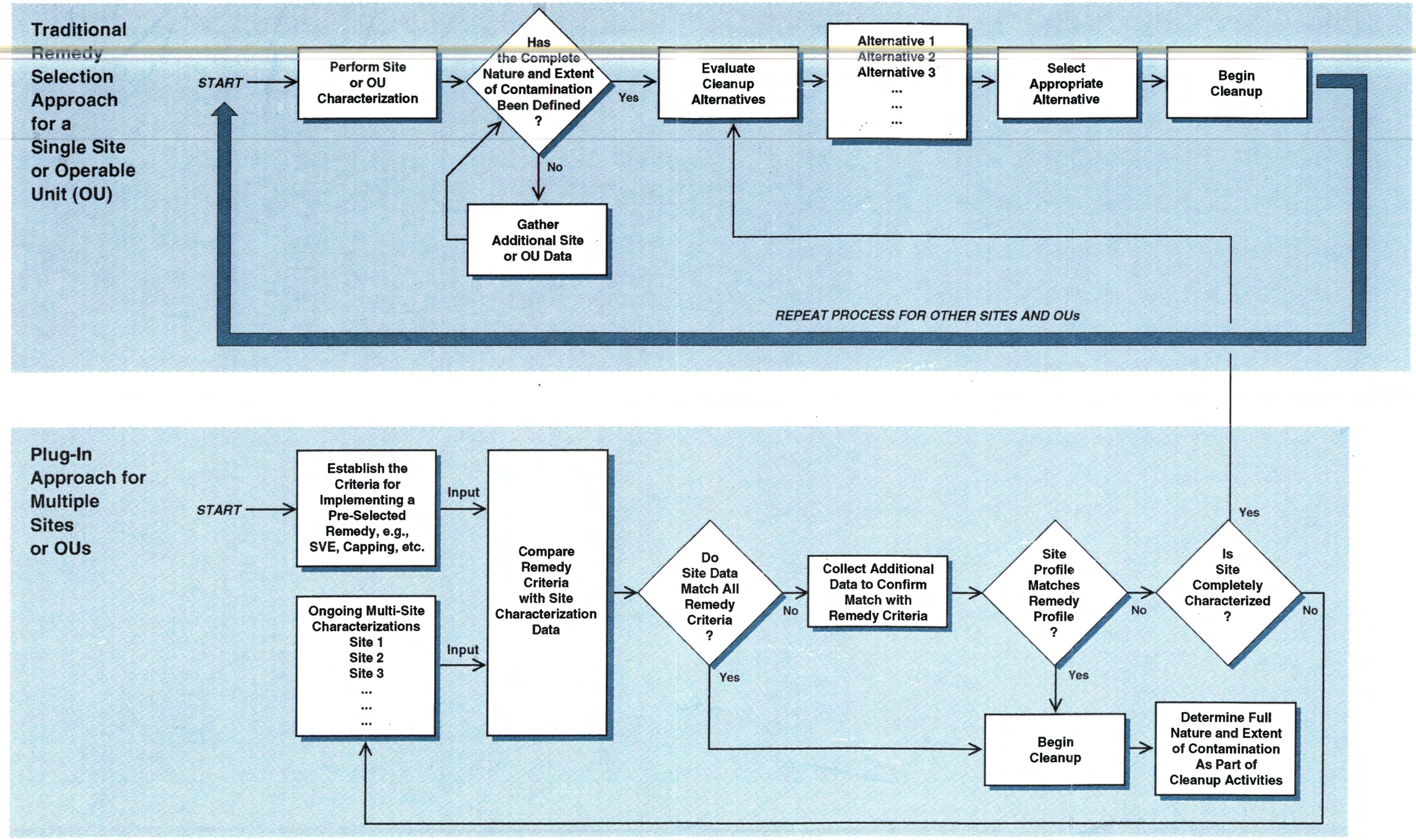


Figure 2-3.
Traditional Versus Plug-In Approaches

sites in the same installation. Time and effort are saved because the remedy selection is minimized. However, an action memorandum documenting the remedy decision will be required for each site.

2.6.3 Plug-in Concepts and Application

2.6.3.1 Site and Presumptive Remedy Profiles

The technical basis of the plug-in approach is the establishment of site and distinct remedy profiles. The site profile defines the various physical and contaminant conditions and parameters at a site. The distinct presumptive remedy profile includes the range of conditions that a single remedial alternative or treatment train can effectively address. If the site profile can be addressed by the remedy profile, then the site "plugs in" to the decision document, and cleanup can begin.

2.6.3.2 Presumptive Remedy Plug-in Application

This concept, within the framework of the Air Force presumptive remedy EE/CA, is illustrated by Figure 2-4. During remedy selection, a site profile is "constructed" from the characteristics, attributes, and contaminant data of each site. This site profile is then evaluated against the presumptive remedy profile. If the presumptive remedy profile "encompasses" the conditions specified by the site profile, then the site can "plug-in" to the EE/CA document. If the site cannot "plug-in," then other remedial alternatives must be evaluated and a separate decision document produced.

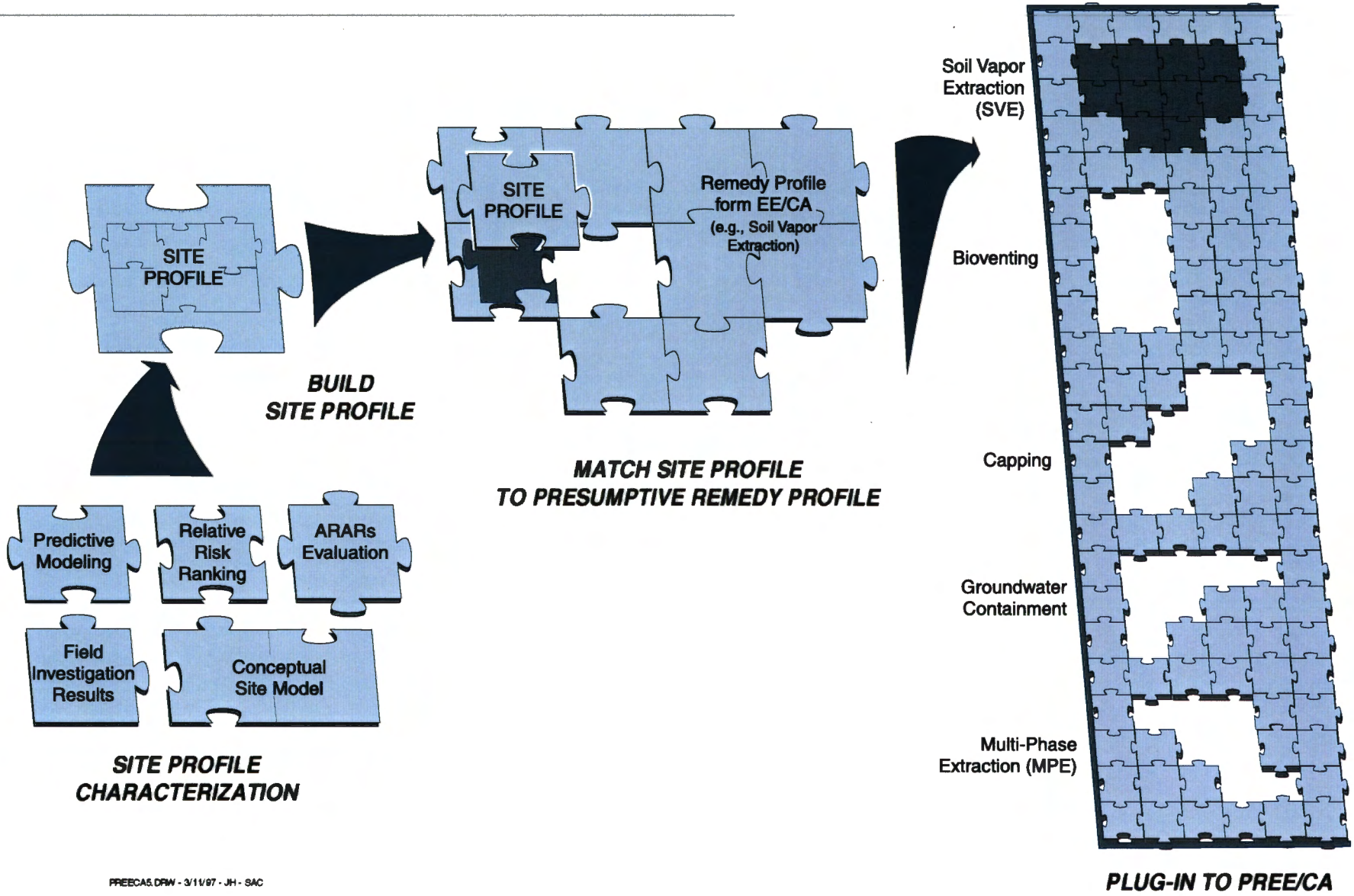


Figure 2-4. Presumptive Remedy and Plug-in Approach

3.0 AIR FORCE PREECA REMEDY SELECTION JUSTIFICATION AND METHODOLOGY

The overall purpose of Section 3.0 is to establish the "generic" and standardized evaluation and justification for implementing a presumptive remedy, non-time-critical, removal action. **It is intended that Air Force installations will not have to repeat this detailed evaluation in order to implement an action at a specific site. They simply need show that their site meets the criteria specified in this section.**

The contents of Section 3.0 include explanations of the scope and objectives of non-time-critical removal actions; justification and evaluation of presumptive remedy alternatives; establishment of site and remedy profiles; and the decision logic and process for performing a "plug-in" determination. This is the heart of the PREECA document and serves as the generic remedy selection justification which all Air Force installations must reference when implementing this process at a specific site. Figure 3-1 illustrates the decision points and overall flow of the Air Force PREECA process.

3.1 Defining the Removal Action

To define the removal action, the scope and objectives of the removal action must be determined. Developing scope and objectives for the removal action is an iterative process. To fully apply the presumptive remedy plug-in approach, the scope and objectives of the action must match the capabilities of the identified remedies. Specific scope and objectives adequate to address the problem are the starting point for the EE/CA.

3.1.1 Scope

The scope of the non-time-critical removal action should include one or a combination of presumptive remedies that will attain the objectives of the action. The removal action scope may be "interim" or "final." In either case, the scope must meet the objectives developed for the action. It is not necessary to perform an initial screening or comparative analysis of removal action alternatives, as would occur in a typical EE/CA or feasibility study, because presumptive remedies that will meet the objectives have already been identified. Therefore, the scope of the removal action in the EE/CA is focused on the presumptive remedy profile that will meet the objectives.

The objectives and scope of the non-time-critical removal action should be stated in the EE/CA Approval Memorandum described in Section 4.1.2. The memorandum statement should inform all agencies and the public of the problem and the approach to be taken.

3.1.2 Removal Action Objectives

Typical objectives for a non-time-critical removal action address the threat to human health or the environment that has occurred or will occur if the removal action is not implemented. The objectives should specifically identify the contaminant or contaminants, the contaminated medium, the exposure route, and actual or potential receptors. One objective of the action should be reduction of risk that exists or may soon exist because of the presence of the contaminant in an exposure pathway. It is not necessary that one of the objectives of the action be attainment of a specific ARAR, since a longer term action may be implemented after the removal action to attain an ARAR. However, if attainment of ARARs can be

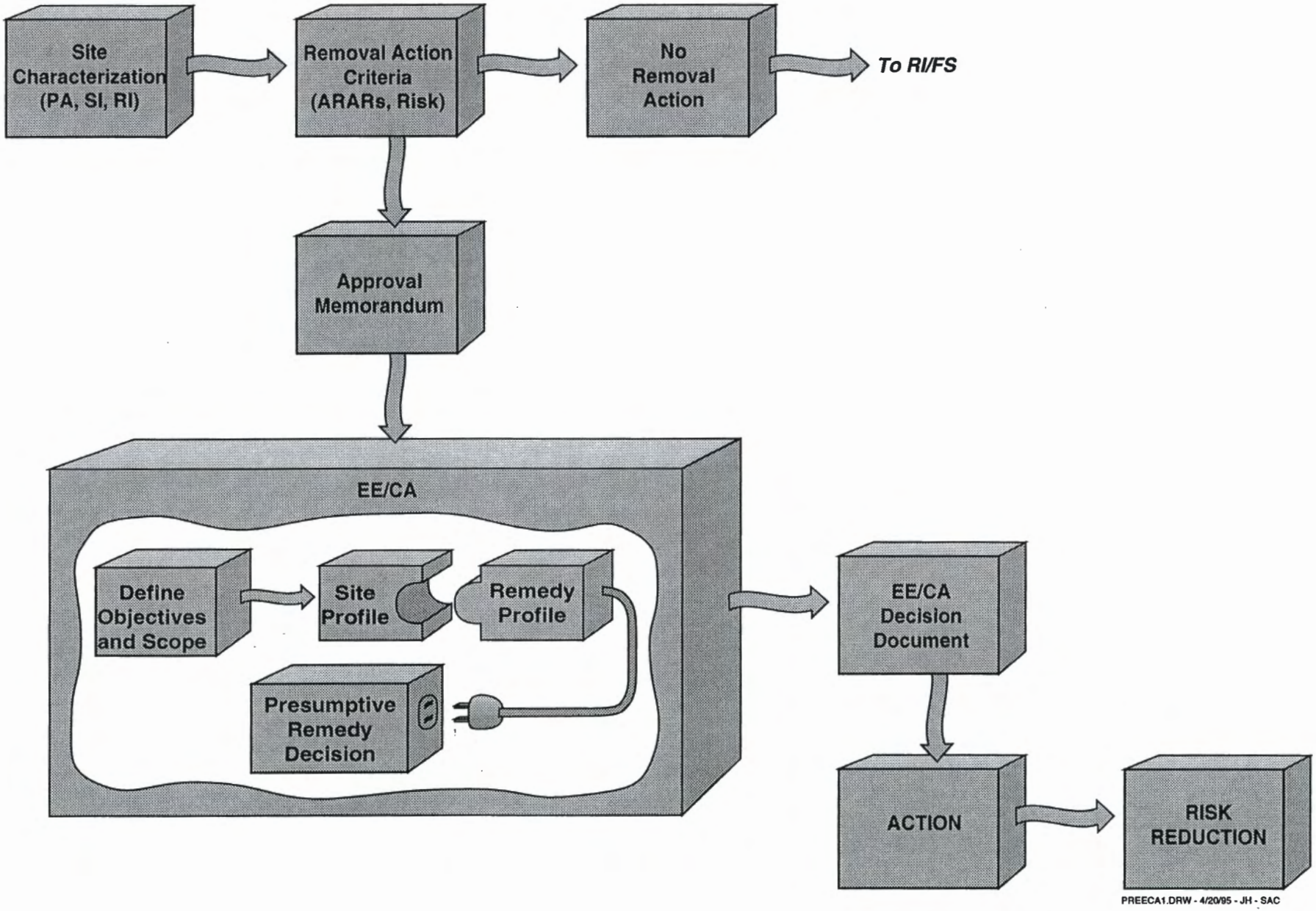


Figure 3-1. Presumptive Remedy EE/CA Flow Path

achieved through implementation of one of the presumptive remedies, this is a worthwhile goal.

The specific removal action objectives should not be beyond the capabilities of the presumptive remedy considered. The capabilities of each remedy are explained in Section 3.4, Evaluation of Presumptive Remedy Technologies, and in Part II of this guidance. If the selected remedy has the capability to attain the objectives, then there is potential for "plugging in" to the PREECA. If there is not reasonable assurance that a presumptive remedy profile can meet the objective of risk reduction or attainment of an ARAR for a contaminant, a remedy beyond the presumptive list should be considered.

3.2 Candidate Site Profiles

To select the appropriate presumptive remedy or remedies, a site that meets non-time-critical removal action criteria should be sufficiently characterized to allow comparison of the site profile with the specific profile of the presumptive remedy. The site profile consists of geologic, hydrologic, contaminant, and other physical parameter information for the site that is necessary to compare with a presumptive remedy profile. Details of remedy profiles and the selection of a specific remedy are described in Section 3.5 and Part II of this PREECA. The types of information needed for site profiles are described in Table 3-1.

Essential site profile information presented in Table 3-1 must be available before a comparison with a remedy profile is performed. Therefore, it is needed pre-EE/CA, before a site can be matched to a presumptive remedy. Less important site profile information can be estimated before the EE/CA and confirmed post-EE/CA through data collection during removal action design. Pre-EE/CA and post-EE/CA site profile information is identified in the table.

3.3 Presumptive Remedy Technology Descriptions

Each of the presumptive remedy technologies: SVE, bioventing, groundwater containment, capping, and MPE are described in the following subsections.

3.3.1 SVE

In September 1993, the U.S. EPA designated SVE as the primary presumptive remedy for sites with VOC contamination in the vadose zone (OSWER, 1993b). The justification for SVE as a presumptive remedy is based on a review of all RODs for VOC contaminated sites from 1986-1991. This review found that SVE was the selected remedy in 62 of the 88 cases.

Soil vapor extraction technology involves extraction of VOCs from the vadose zone using a series of extraction wells connected to either a vacuum blower or pump by a piping and manifold network. A schematic of an example in situ SVE system is shown in Figure 3-2. This system physically removes VOC contaminants from the subsurface by inducing air flow past VOC-contaminated soils and partitioning contaminants into the vapor phase due to a mass transfer driving force. The contaminants are then brought to the surface through the extraction wells and treated with an appropriate off-gas system. The off-gas from the vacuum system is routed through various treatment systems (i.e., activated carbon, catalytic oxidation, adsorptive resins, etc.) depending on contaminant type, concentrations, and flow rates. This technology is described in more detail in Part II.

Table 3-1. Common Site Profile Parameters[a]

Information Type	Condition or Parameter	Remedy	When Needed	Collection Method	Acceptable Data
Geologic	Soil types and homogeneity	All	Pre-EE/CA	Subsurface drilling and description	Estimated
	Presence of rock in contaminated area	All	Pre-EE/CA	Subsurface drilling and description	Estimated
	Depth to groundwater (thickness of vadose zone)	All	Pre-EE/CA	Subsurface drilling to groundwater	Measured
	Average soil gas permeability above groundwater	SVE, bioventing, MPE	Pre-EE/CA	Soil permeability testing	Measured
	Percent saturation (water-filled porosity)	SVE	Pre-EE/CA	Field observations confirmed by laboratory tests	Measured
	Total organic carbon content	SVE	Post-EE/CA	Analyses of soil samples	Measured
	Carbon dioxide and oxygen in soil gas	Bioventing	Pre-EE/CA	Soil gas measurements	Measured
Contaminant	Approximate distribution of concentrations	All	Pre-EE/CA	Soil, soil gas, or groundwater analyses	Estimated
	Vapor pressure for VOCs in soil gas	SVE, MPE	Pre-EE/CA	From published data	Measured
	Henry's Law Constant	SVE, MPE	Pre-EE/CA	From published data	Measured
	Approximate lateral depth and extent	All	Pre-EE/CA	Sampling and analysis of affected media	Estimated
	Separate phase liquids in soil or groundwater	Groundwater containment, SVE, capping, MPE	Pre-EE/CA	Sampling and analysis of affected media	Measured
Hydrology	Horizontal and vertical gradients in groundwater	Groundwater containment	Pre-EE/CA	Water level measurement in monitoring wells	Measured
	Hydraulic conductivity, K in saturated zone	Groundwater containment	Pre-EE/CA	Aquifer tests	Measured
	Temporal (daily to annual) water level fluctuations	Groundwater containment, MPE, bioventing, SVE	Pre-EE/CA	Water level measurement in monitoring wells	Measured
	Surface water influences—infiltration or water level changes	Groundwater containment, MPE, bioventing, SVE	Pre-EE/CA	Water level measurement in monitoring wells and rivers or ponds	Measured
Other parameters	Extent of existing surface covering	All	Pre-EE/CA	Observation of paving/foundations over contaminated areas	Estimated
	Permeability of existing surface covering	All	Pre-EE/CA	Measurements during soil gas permeability testing or in laboratory	Estimated
	Location of nearby or adjacent structures of buildings	All	Pre-EE/CA	Site observation	Estimated

[a] For details of parameter measurements see specific Sections on each presumptive remedy in Part II.

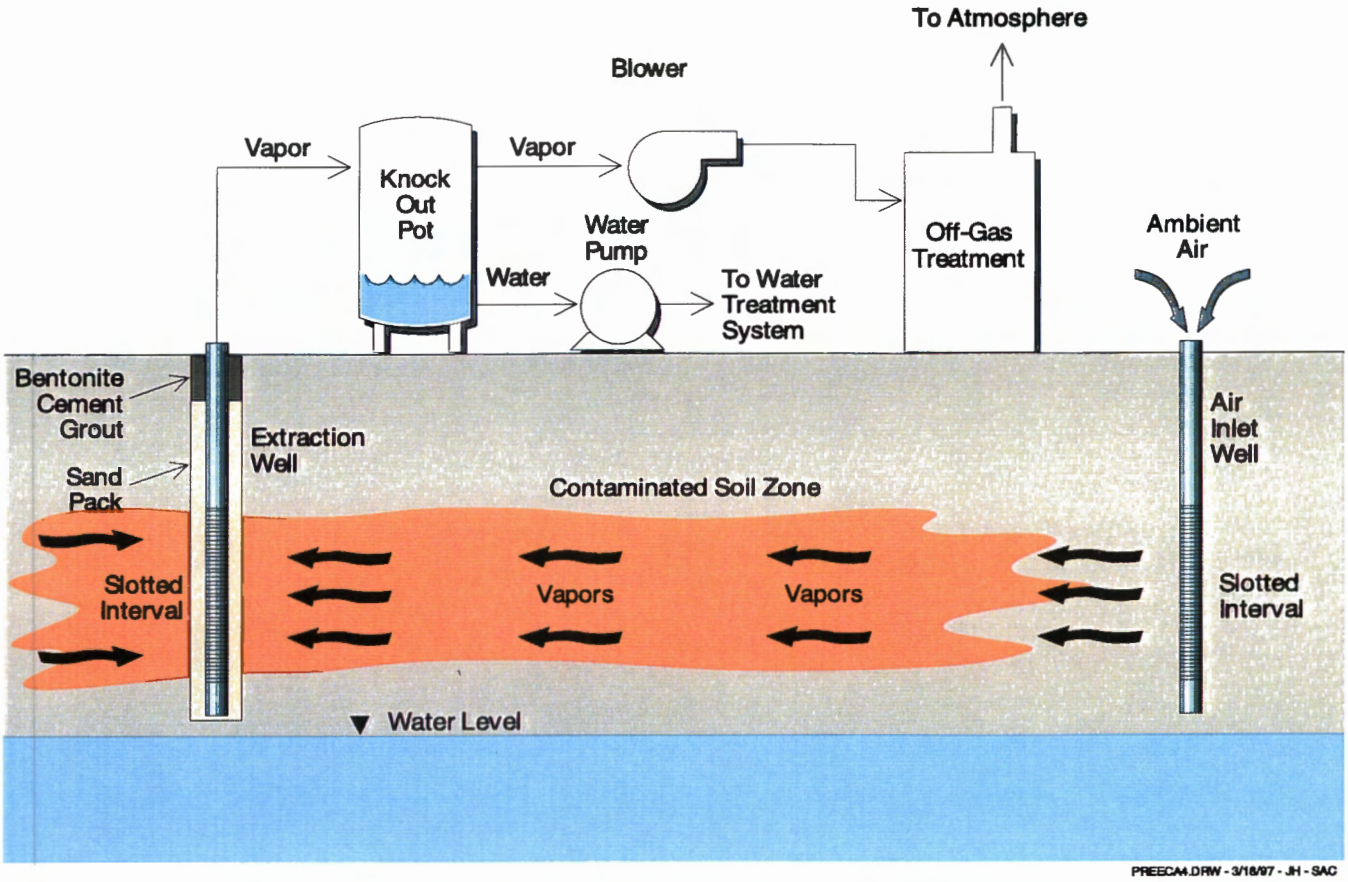


Figure 3-2. SVE System with Air Inlet Well

3.3.2 Bioventing

Per the guidance and technology protocol from the Air Force Center for Environmental Excellence (AFCEE), in situ bioventing is the presumptive remedy for Air Force sites contaminated with petroleum-based compounds.

Bioventing is the process of providing oxygen to subsurface soils in order to promote in situ biodegradation of petroleum hydrocarbon contamination by indigenous microorganisms. Its implementation has been endorsed by EPA's Risk Reduction laboratory, and the Deputy Assistant Administrator of EPA's Office of Solid Waste and Emergency Response (OSWER).

The overall effectiveness and cost of this technology has been proven by AFCEE via pilot-scale systems demonstrations at 137 sites across the Air Force, with expanded systems operating at 110 of those sites.

Bioventing utilizes similar technology to SVE except that air is injected into a well to provide the naturally occurring microbes with enough oxygen to maintain aerobic degradation of fuels and related, nonhalogenated hydrocarbons. This technology is depicted schematically in Figure 3-3. A bioventing system typically includes a series of injection wells and/or extraction wells connected to a blower system by a piping network. The major advantage of bioventing is the destruction of the contaminant occurs in situ. Therefore, there is often no requirement for off-gas treatment. However, the rate of contaminant degradation is dependent on site conditions such as existing nutrient levels and ambient temperature and may result in significantly longer remediation times. This technology is explained in more detail in Part II.

Although both bioventing and SVE involve venting air through the subsurface, the primary objectives of each technology are different. SVE systems are designed to maximize volatilization of contaminants in order to facilitate extraction to the surface for further treatment. Bioventing seeks to minimize the volatilization of contaminants so that they may be biodegraded in situ. Thus, the air flow rates for bioventing are substantially lower than those of SVE.

3.3.3 Capping

Within the presumptive remedy guidance for municipal landfills, surface capping is included as a component of the containment remedy (OSWER, 1993c). Capping was also selected as the remedy in 62 RODs documented before 1992. In December 1996, the EPA issued guidance on application of the presumptive remedy for CERCLA municipal landfill site to appropriate military landfills (OSWER, 1996a). The remedy is often combined with groundwater pump and treat remedies, and other in situ vadose zone options such as SVE.

Capping of a site involves the installation of an impermeable layer. The decision to cap a site is primarily based on two factors; the future land use of the site, and the cost or technical feasibility of treating the contaminants. The primary purposes of caps are to eliminate surface exposure pathways, reduce infiltration of precipitation, and minimize leaching of contaminants to groundwater.

The lifetime of caps is expected to range from 30 to 50 years. Although they are effective in reducing infiltration, caps will not completely prevent infiltration.

Capping is a remedial alternative that can be used where containment is the presumptive remedy for minimizing migration of contaminants from the vadose zone into the groundwater or into surface receptors via

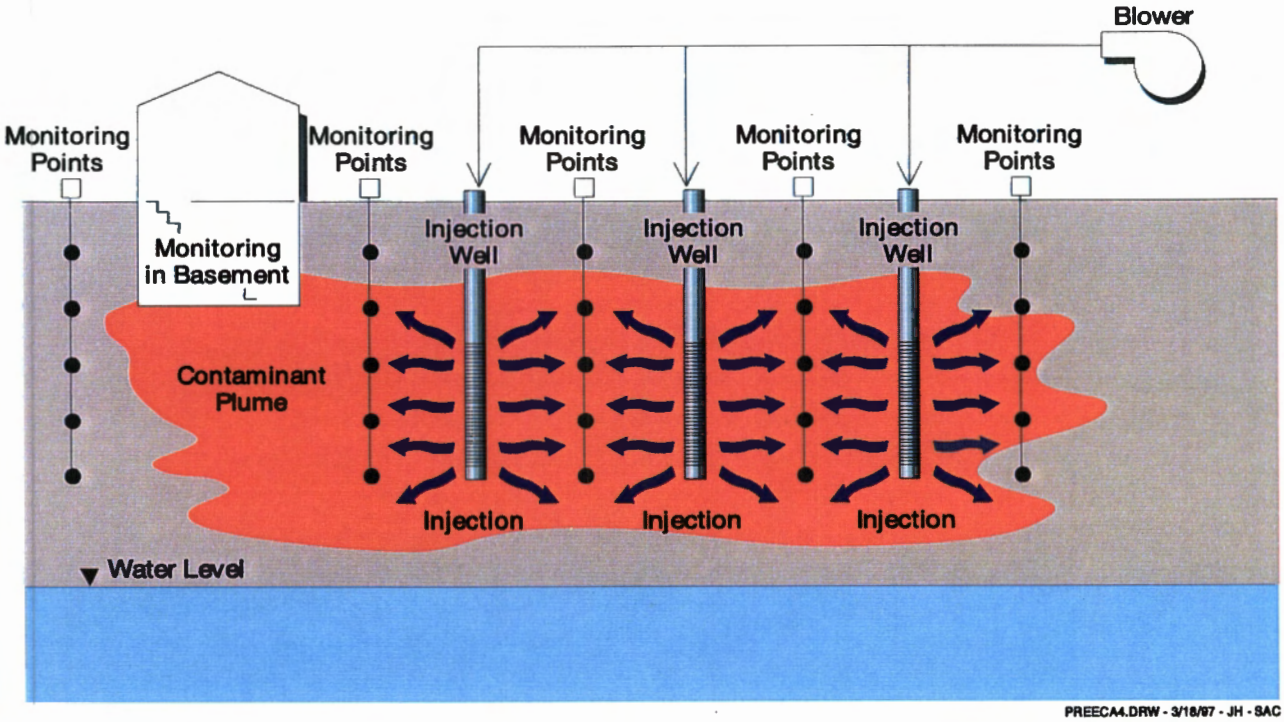


Figure 3-3. Illustration of Bioventing System Components

erosion. Caps types most commonly used are multi-layer RCRA and non-RCRA caps, such as the soil/clay cap, the asphalt cap, and the concrete cap. A typical cross-section of a multi-layer cap is shown in Figure 3-4. The multi-layer RCRA cap consists of four distinct layers and is required when capping source areas that contain RCRA hazardous waste. In field studies of various cap designs, the RCRA cap was the most effective of all designs in controlling deep percolation, but it was not 100% effective (Warren, 1995). **For source areas that do not contain RCRA hazardous waste, a non-RCRA cap should be used.**

3.3.4 Groundwater Containment

Groundwater containment has been determined to be the presumptive remedy for municipal landfills by the U.S. EPA (OSWER, 1993c). Within this guidance, source area groundwater control for plume containment is specified. Often this source area control is accomplished via the groundwater containment technology, and this is supported by the fact that this remedy is included at more than 90% of sites with final RODs. Although groundwater containment has not been designated as a presumptive remedy for sites other than landfills, remedy selection experience supports its use as a presumptive remedy for a wide range of dissolved contaminants. However, the successful use of intrinsic remediation at a number of Air Force sites suggests that this remedy should be considered before groundwater containment for plumes containing dissolved fuel hydrocarbons. Intrinsic remediation is not applicable for dissolved metals or solvents. **The Air Force Center for Environmental Excellence (AFCEE) has issued protocols for the application of intrinsic remediation for groundwater plumes contaminated by fuels and chlorinated hydrocarbons. This PREECA primarily addresses groundwater contaminated with halogenated VOCs, semivolatiles, and metals.**

Groundwater containment is simply the extraction and treatment of contaminated groundwater for the purpose of preventing the further migration of contaminants and its associated degradation of larger volumes of uncontaminated groundwater. Typically, extraction is accomplished via vertical or horizontal wells or trenches. The water is treated aboveground, and then discharged to a surface conveyance or reinjected into the aquifer. Figure 3-5 depicts a groundwater containment system with air stripping for aboveground treatment, and discharge to a local POTW.

Groundwater containment is typically accomplished using a submersible pump in a well screened below the contaminated groundwater level. The contaminated groundwater is extracted and pumped to the surface where it is treated to remove the contaminants, and clean water discharged (usually to a sewer system, surface drainage, or reinjected into the groundwater). Pump and treat for containment specifically involves preventing one contaminated groundwater zone from migrating into an area of uncontaminated (e.g., drinking water supply) or less contaminated groundwater. This can include both "leading edge" and "hot spot" containment. Leading edge containment involves installation of extraction wells to prevent the contamination from reaching potential receptors (e.g., residential water wells, water supply wells, other connected aquifers, etc.). Hot spot containment would be used in cases where an area of particularly high contaminant concentrations has been identified (e.g., contaminant source

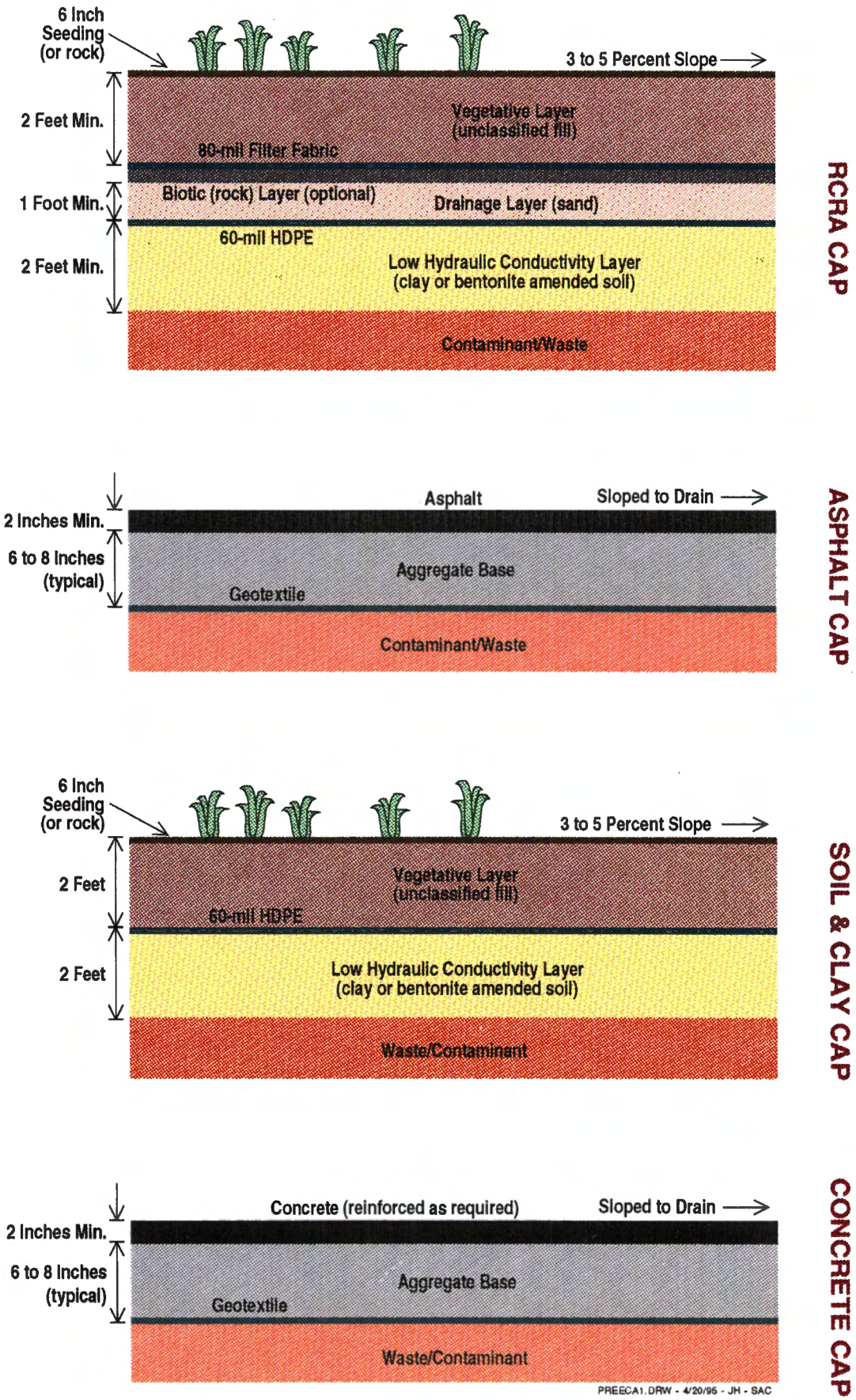


Figure 3-4. Examples of Several Cap Cross-Sections

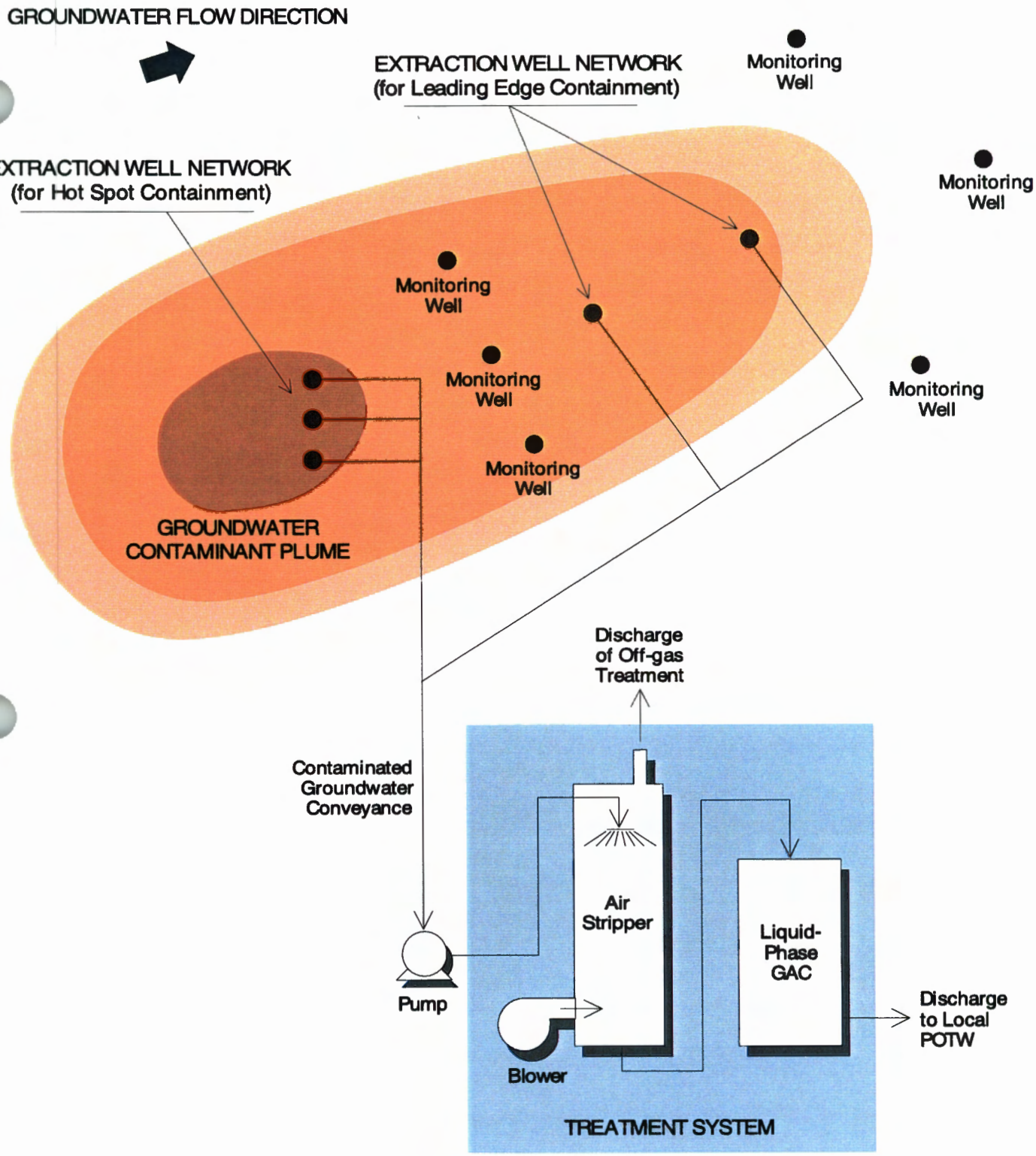


Figure 3-5. Overview of a "Full Plume" Groundwater Containment System

into the groundwater). Hot spot containment typically would be done where another remediation strategy (e.g., intrinsic remediation) is being used on other, lower level contamination in the aquifer. The groundwater containment technology has been used extensively in situations where groundwater contamination represents an imminent hazard to a receptor or other water source, since there are no practical alternatives in many cases.

3.3.5 Multi-Phase Extraction

The U.S. EPA designated MPE as one of the technologies under the presumptive remedy for sites with VOC contamination in both the vadose and saturated zones (OSWER, 1997). The justification for the MPE as a presumptive remedy is based on full-scale and pilot scale MPE system studies that have been implemented at Air Force Bases around the country.

The MPE process was developed for the remediation of VOCs and other contaminants in low to moderate permeability subsurface formations. The process is a modification of the conventional soil vacuum extraction (SVE) technology.

MPE is an enhancement of the traditional SVE system. Unlike SVE, MPE simultaneously extracts both groundwater and soil vapor. The groundwater table is lowered in order to dewater the saturated zone so that the SVE process can be applied to the newly exposed soil. This allows the volatile compounds sorbed on the previously saturated soil to be stripped by the induced vapor flow and extracted. In addition, soluble VOCs present in the extracted groundwater are also removed.

MPE is a generic term for technologies that extract soil vapor and groundwater, simultaneously. Under this generic term, two technologies are included; the two-phase extraction technology (TPE) and the dual-phase extraction technology (DPE). Both technologies extract groundwater and soil vapor from a single well. They can both be considered tools in the MPE toolbox for VOC remediation.

The TPE technology employs a high vacuum (approximately 18 to 26 inches of mercury) extraction blower to extract both groundwater and soil vapor from an extraction well. A suction pipe is lowered into the extraction well to extract the soil vapor and groundwater from the subsurface. A typical two-phase type system is illustrated in Figure 3-6.

For some TPE methods, turbulence generated within the suction pipe facilitates the transfer of aqueous phase contaminants to the vapor phase (up to 98% stripping).

By comparison, the DPE technology employs a submersible pump to extract the groundwater, and a high vacuum (approximately 18 to 26 inches of mercury) or low vacuum (approximately 3 to 12 inches of mercury) extraction blower is used to extract the soil vapor as illustrated in Figure 3-7. For DPE wells, a sump is installed at the bottom of the well to prevent cavitation of the submersible pump.

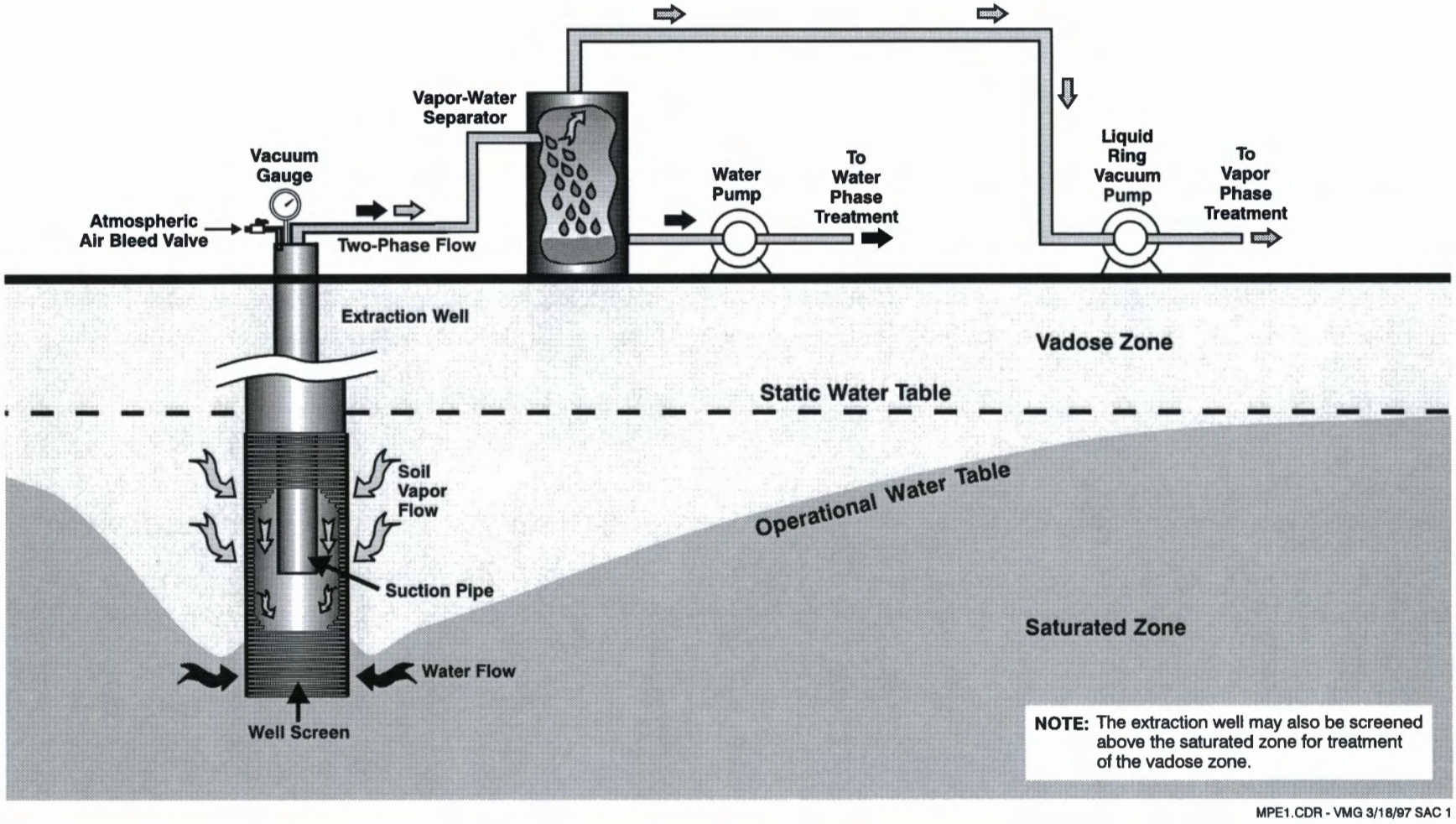


Figure 3-6. Schematic of a TPE System

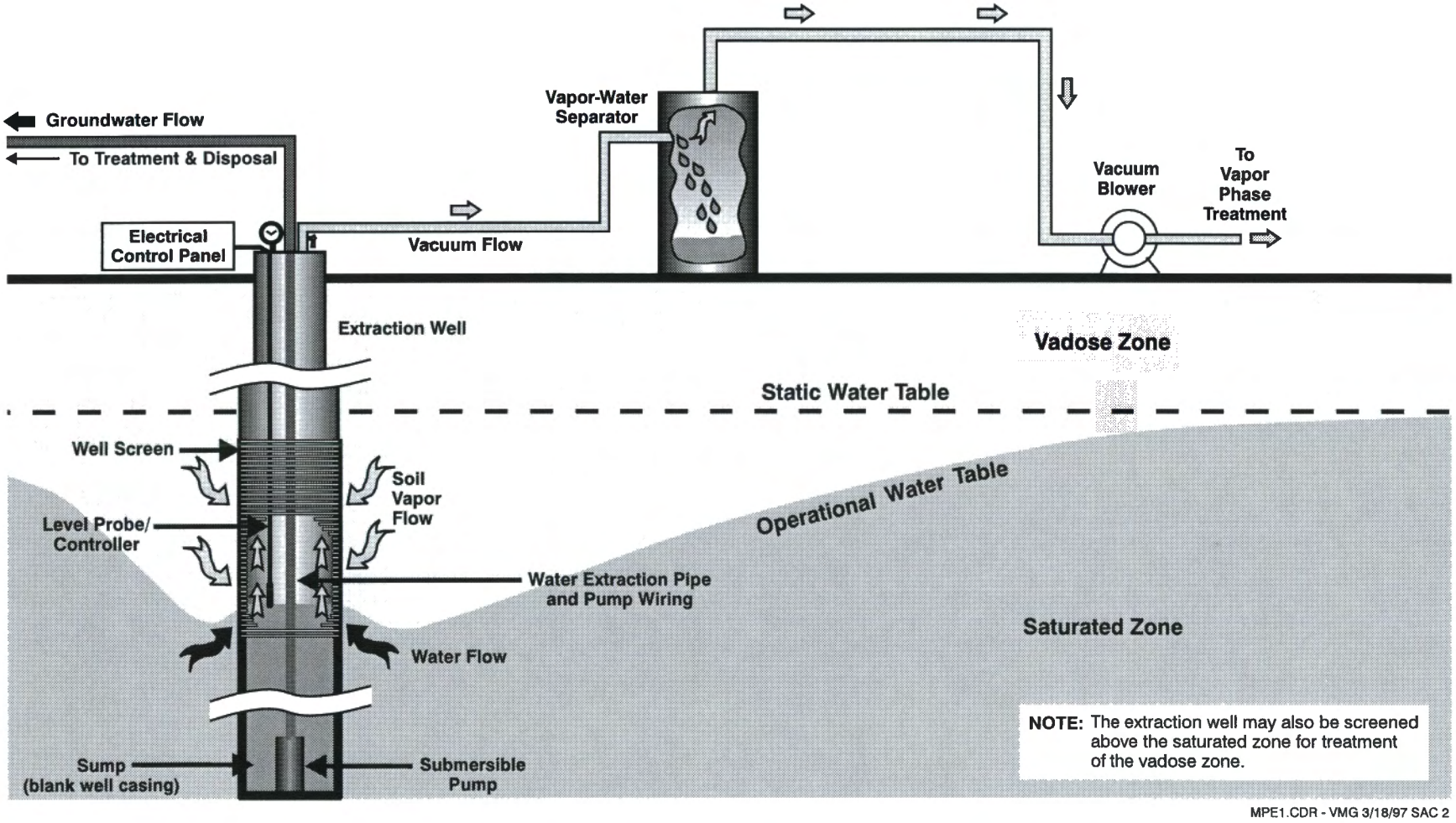


Figure 3-7. Schematic of a DPE System (Low Vacuum or High Vacuum)

3.4 Evaluation of Presumptive Remedy Technologies

Evaluations of each technology for effectiveness, implementability, and cost versus the no action alternative are described in Table 3-2. The definitions of effectiveness, implementability, and cost used in the comparison are provided below:

- **Effectiveness**: Refers to the ability of the remedy to provide protection of human health and the environment during both the construction and implementation period and after completion of the remedial action.

- **Implementability**: Refers to the technical and administrative feasibility of a remedy, including the availability of materials and services needed to carry out a particular option.

- **Cost**: Evaluates the estimated capital, operating, and maintenance costs of each presumptive remedy technology.

3.5 Distinct Presumptive Remedy Profiles

Site-specific conditions may indicate that a single or a combined application of presumptive remedies are necessary in order to take action at a site. As such, five distinct remedy profiles have been prepared for inclusion in this EE/CA. These remedy profiles do not encompass all types of contaminated sites within Air Force. They are necessarily focused on a subset of conditions in order to streamline and expedite the remedy selection and implementation process. Table 3-3 is a summary of the five presumptive remedy profiles based on contaminant type and associated pathway. Figures 3-8 through 3-12 present simplified conceptual site models and associated site profile and remedy profile data requirements necessary to implement each of these distinct presumptive remedy profiles. Detailed discussions of the technologies and remedy profiles are included in Part II.

3.6 Air Force PREECA Plug-in Determination and Implementation

The overall decision logic for determining if a site "plugs-in" to the Air Force PREECA is shown in Figure 3-13. This is the process that each Air Force installation must complete in order to justify a non-time-critical presumptive remedy removal action encompassed by the Air Force PREECA. The details of this figure are explained below.

3.6.1 Plug-In Evaluation

Items 1-15 in Figure 3-13 are the steps necessary to complete a plug-in evaluation for a specific Air Force site. This evaluation determines that a removal action is justified at the site and whether the site profile can be addressed by one of the five distinct remedy profiles from Section 3.5.

3.6.1.1 Is Data Adequate to Establish Relative Risk (Items 1-2)?

The first step in the process is to ensure that adequate data on site and contaminant characteristics are available to establish the qualitative relative risk ranking (Items 1-2). The three primary data needs are the identification of contaminants and potential receptors which are associated with the three primary pathways; surface, vadose zone, and groundwater. The establishment of a relative risk ranking cannot be completed

Table 3-2. Evaluation of Presumptive Remedy Technologies Versus the No Action Alternative

	Soil Vapor Extraction	Bioventing	Capping	Groundwater Containment	Multi-Phase Extraction
Effective-ness	• Proven history of effectively removing VOC contamination from the vadose zone. • Selected as the remedy of choice in 62 of 88 RODs signed between 1986 and 1991. • Removal rates typically range from 85% to 99% removal. • Alternative would also include follow-on monitoring to verify that any residual concentrations do not pose a threat to human health or the environment. *The no action alternative will not provide any controls on the contaminants. Although the contamination will disperse and degrade to some extent, there is no assurance that the VOCs will not present a risk via groundwater, volatilization to the atmosphere, or worker exposure. The no action alternative is therefore not effective at protecting human health and the environment either in the short or long term.*	• Demonstrated to effectively degrade fuel and BTEX hydrocarbons in the vadose zone at over 120 Air Force sites. • Estimates of the initial degradation rate from two USAF sites are reported to be between 1 and 6 grams of hydrocarbon degraded per kilogram soil per year (AFCEE, 1994). • Degradation rate may vary based on factors such as nutrient levels and temperature. *The no action alternative will not provide any controls on the contaminants. Although the contamination will disperse and degrade to some extent, there is no assurance that the VOCs will not present a risk via groundwater, volatilization to the atmosphere, or worker exposure. The no action alternative is therefore not effective at protecting human health and the environment either in the short or long term.*	• Can be almost 100 percent effective at eliminating surface contact and erosion impacts. • Selected as the appropriate remedy in 62 RODs prior to 1992. • With good maintenance, a cap can be effective in reducing contaminant migration resulting from infiltration. • Actual contaminant migration rates (if any) after the cap is in place will depend significantly on specific site and chemical parameters. *The no action alternative will not be effective at preventing migration of any type of mobile compound to any of potential exposure pathways identified above.*	• The extensive use of this technology as the selected remedy in previous RODs demonstrates the ability to implement this technology in a wide range of conditions. • Extensively proven as an effective method for containment of contaminated groundwater. • Selected as remedy of choice at more than 90 percent of sites with final RODs. • Effectiveness will vary depending on site-specific conditions such as permeability, flow rate, and contaminant concentration. *In situations where pump and treat for containment are typically required, i.e., an imminent risk has been identified, the no action alternative would not be effective at reducing that risk.*	• Proven history of effectively removing VOC contamination from the vadose zone and groundwater. • Recommended as a pre-sumptive remedy technol-ogy under the EPA's VOC presumptive remedy. • Full scale and pilot scale studies performed at USAF sties achieved removal rates up to 24 lbs/day (Oswer, 1997). • Where applicable, MPE removal rates shown to be dramatically higher than traditional groundwater pumping. *The no action alternative will not remove or control contami-nants. Although the contami-nation may disperse or degrade to some extent, there is no as-surance that VOCs in the soil and groundwater will not pres-ent a risk via groundwater, volatilization to atmosphere, or worker exposure. The no action alternative will not be effective at protecting human health or environment either in the short term or long term.*

Table 3-2. (Continued)

	Soil Vapor Extraction	Bioventing	Capping	Groundwater Containment	Multi-Phase Extraction
Implementability	• Readily implementable as proven at numerous sites across the country. • Would include drilling and constructing extraction, monitoring, and injection wells as needed, laying the transfer piping from the wells to the blower system, and connecting the blower system to the off-gas treatment system. • Can be implemented underneath many existing surface structures, requires a relatively small footprint for process equipment, and utilizes readily available equipment. *Implementability is not applicable to the no action alternative.*	• Essentially the same as the SVE alternative and would also include drilling and construction of extraction, monitoring, and injection wells as needed, laying the transfer piping from the wells to the blower system, and connecting the blower system to the off-gas treatment system (if needed). • Can be implemented underneath existing surface structures, requires a relatively small footprint for process equipment, and utilizes readily available equipment. *Implementability is not applicable to the no action alternative.*	• Implementability of installing a cap is generally good with few technical limitations. • Cap construction uses standard earthmoving and road building equipment that should be readily available. • The construction materials, asphalt, soil and clay, concrete, and synthetic membranes are all standard construction materials and are readily available. • The local availability of low permeability clays may cause increased cost to that alternative if additional shipping charges are required. • The primary problems with implementing a cap are the physical limitations of the site (e.g., structures or equipment that cannot be moved). *Implementability is not applicable to the no action alternative.*	• This technology can be implemented at almost any type of contaminated groundwater condition. • The equipment and materials required to implement this technology are readily available. The only limitations would be physical site constraints. *Implementability is not applicable to the no action alternative.*	• Implementability of installing MPE is generally good with a few technical limitations. • Would include drilling and construction of extraction and monitoring wells, laying transfer piping to blower system, installation of groundwater pumps (DPE only), connection to blower system, construction of extracted vapor and groundwater treatment system. • The equipment and materials required to implement this technology are readily available. The only limitations would be physical site constraints. • Some specific hardware and extraction well configurations associated with MPE technologies are patented. Use of these will require compliance with those patent requirements. *Implementability is not applicable to the no action alternative.*

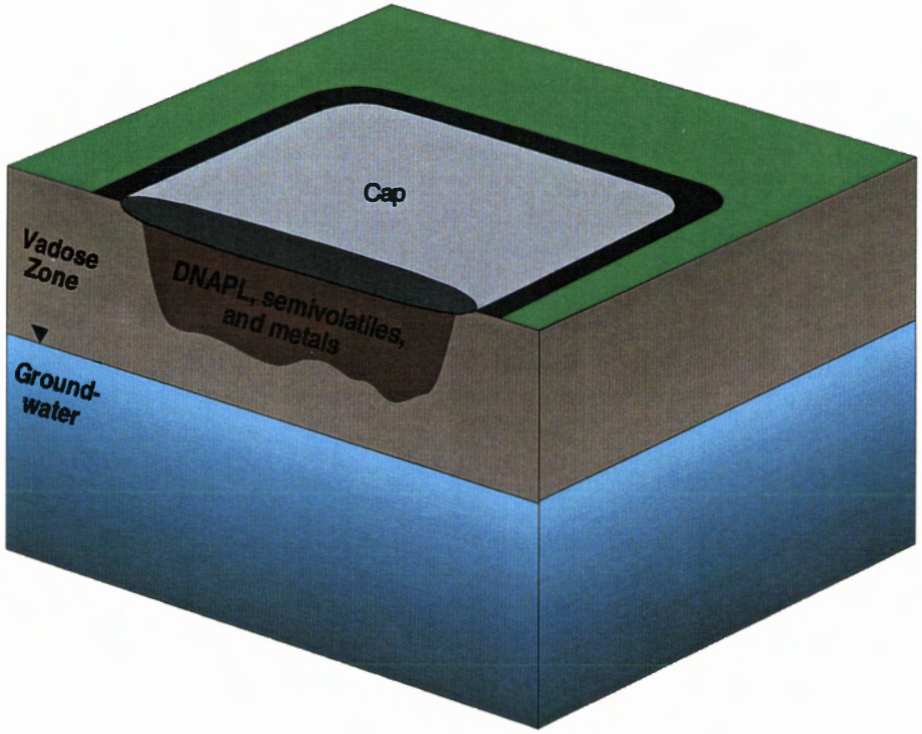
Table 3-2. (Continued)

	Soil Vapor Extraction	Bioventing	Capping	Groundwater Containment	Multi-Phase Extraction
Cost	• Costs for implementation of an SVE system vary from $10 to $40 per cubic yard based on site and contaminant conditions but are significantly less than the $300 to $400 per cubic yard for ex-situ treatment and disposal (incineration, thermal desorption, and filling, etc.). • Primary variables include the extracted concentration (will determine the required off-gas treatment technology), the duration of the remedial action, and the soil conditions. • If the off-gas is in the concentration range where it can be cost effectively treated with carbon, the costs can be significantly less. Costs on a dollar per ton of soil remediated are almost always significantly less than other, primarily ex-situ technologies. *No direct costs would be incurred for the no action alternative.*	• Costs to implement bioventing are significantly lower than most other treatment technologies because it can be implemented in situ, it uses standard, off-the-shelf equipment, and it typically requires either minimal or no off-gas treatment. • Treatment costs have been estimated at from $10 to $60 per cubic yard of soil depending primarily on the total volume to be treated and the initial contaminant concentration. As with SVE, these costs are subsequently less than ex-situ treatment and disposal technologies.	• Capital costs associated with capping are primarily dependent on the size and type of cap required. • Operating and maintenance (including long-term monitoring) of the cap will primarily be dependent on the size of the cap and the monitoring requirements but these costs should not be significantly different between options. • Between 12,000 ft^2 and 250,000 ft^2 capital costs for asphalt caps and soil and clay caps typically range between $1 and $8 per ft^2. • Capital costs for concrete caps and RCRA caps in the same size range are usually $5 to $11 per ft^2. Costs per square foot will increase for caps that are smaller than the above range and decrease for larger area caps.	• Costs for implementing a groundwater containment system can vary from less than 10 cents to more than $2 per 1,000 gallons of treated water based on the number, depth, and type of extraction wells, the types of contaminants, and the volume of water to be handled. • In cases where these parameters are not favorable, groundwater containment can usually be implemented but the costs increase to the extent that other alternatives may be more cost effective (e.g., point of use treatment).	• Typical costs for implementing MPE may vary from $110 to $3,300 per pound of extracted contaminants. These costs are highly dependent on contaminant concentrations. Sites with low contaminant concentrations tend to cost more per pound of contaminant removed. • Costs are also highly dependent on water and vadose zone characteristics, groundwater and vapor flow rates, as well as design and operation of the system. *No direct cost would be incurred for no action alternative.*

Table 3-2. (Continued)

	Soil Vapor Extraction	Bioventing	Capping	Groundwater Containment	Multi-Phase Extraction
Cost (con't.)		• Long-term operating and final site closure costs are still being developed, however, under some conditions it might be more cost-effective to operate the system as an SVE unit until the vapor concentrations drop off and then operate the system as a bioventing system. *No direct costs would be incurred for the no action alternative.*	*No direct costs would be incurred for the no action alternative.*	• The system installed at the Twin Cities Army Ammunition Plant in New Brighton, Minnesota (U.S. Army Environmental Center, 1993) included 48 monitoring wells, 17 return wells, and 16 extraction wells that pumped 1.4 billion gallons of VOCs between October 1991 and September 1992. The total life cycle costs (capital and operating and maintenance costs) for the system was estimated to be 42 cents per 1,000 gallons of treated water. *No direct costs would be incurred for the no action alternative.*	

CAPPING



CONTAMINANTS

Non-VOCs (DNAPL, semi-volatiles, and metals) and landfills.

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone). Hydraulic conductivity.
Contaminant:	Approximate distribution of concentrations. Lateral depth and extent. Separate phase in liquids in soil. When DNAPL present: Henry's Law Constant. Vapor pressure.
Waste:	Type of waste Size/volume History
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings.

APPLICABILITY

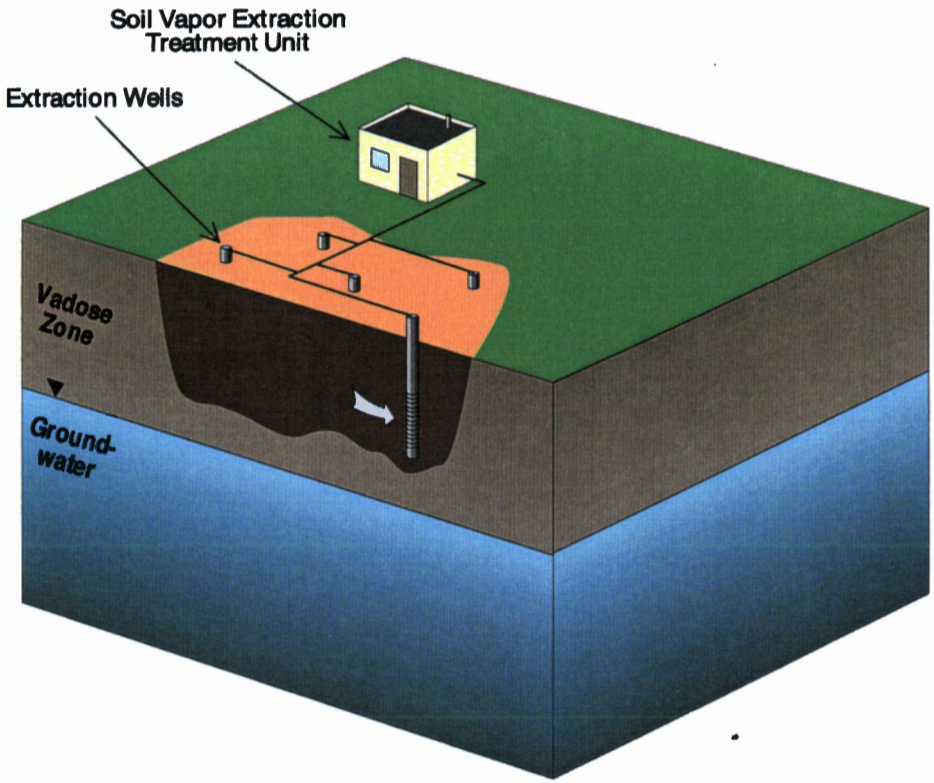
This remedy consists of placing an engineered, low permeability cap over landfills or areas containing contaminated soil. This remedy eliminates surface exposure pathways and minimizes leaching of contaminants to groundwater through the reduction of infiltration. Generally, this is applicable at sites contaminated with DNAPL, metal, or semivolatile soil contaminants, or landfills containing municipal or low hazard military-specific waste. The options within this remedy profile contain both RCRA and non-RCRA caps; however, RCRA caps would only be implemented at those sites containing RCRA hazardous waste.

PRESUMPTIVE REMEDY PROFILE NEEDS

- DNAPL, semi-volatile, or metal contamination in the vadose zone;
- Area of contamination soil less than 24 acres (excluding landfill);
- Volume of waste less than 100,000 cubic yards;
- Municipal or low-level hazard military-specific waste;
- Depth of contamination greater than 18 feet below ground surface (BGS) and/or total volume of contaminated soil greater than 1,800 cubic yards for a hazardous waste or greater than 7,500 cubic yards for a non-hazardous waste;
- Existing structures can be removed and future land use can be restricted;
- Henry's Law constant of contamination less than 0.01 (DNAPL only);
- Vapor pressure of contaminant at 20 degrees Celsius less than 1.0 mm Hg (DNAPL only);
- Geology is complex and soils are heterogeneous (DNAPL only); and
- Hydraulic conductivity of subsurface less than 10^{-4} cm/sec (DNAPL only)

Figure 3-8. Summary of the Capping Presumptive Remedy

SOIL VAPOR EXTRACTION



CONTAMINANTS

Halogenated VOCs

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone). Average soil gas permeability above groundwater. Percent saturation (water-filled porosity).
Contaminant:	Approximate distribution of concentrations. Vapor pressure for VOCs in soil gas. Henry's Law constant. Lateral depth and extent. Separate phase liquids in soil.
Hydrology:	Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes.
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings.

APPLICABILITY

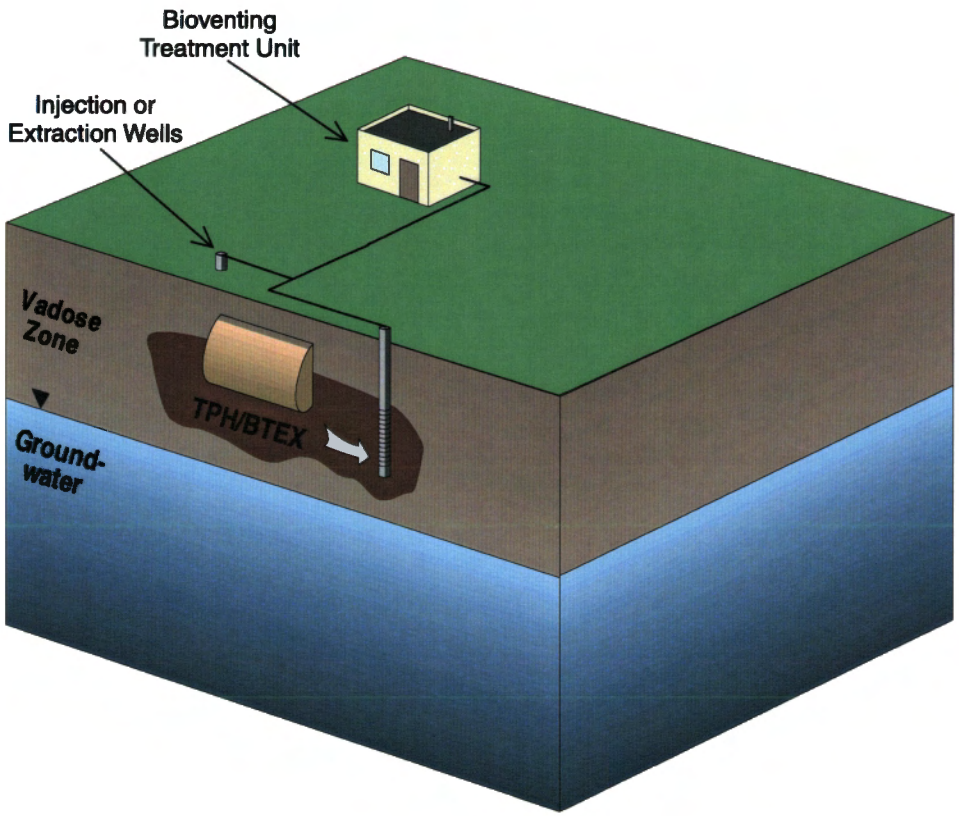
This remedy as previously described is applicable at sites with volatile organic compound (VOC) contamination in the vadose zone, particularly halogenated VOCs. It is applied singularly at those sites where the VOC contaminant source areas have not yet migrated to the groundwater, and the VOC contaminants are the only compounds which require cleanup.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Halogenated hydrocarbon containment in the vadose zone;
- Average soil gas permeability greater than 1 x 10^{-3} darcies;
- Average percent saturation of the vadose zone less than 60%;
- Depth to groundwater or contamination greater than 5 feet;
- Henry's Law constant of contaminant at 20 degrees Celsius greater than 0.01 (dimensionless); and
- Vapor pressure of contaminant at 20 degrees Celsius greater than 1.0 mm Hg.

Figure 3-9. Summary of the Soil Vapor Extraction Presumptive Remedy

BIOVENTING



CONTAMINANTS

TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contaminated area. Depth to groundwater (thickness of vadose zone). Average soil gas permeability above groundwater.
Contaminant:	Approximate distribution of concentrations. Lateral depth and extent.
Hydrology:	Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes.
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings. Soil pH. Soil nitrogen and phosphorus contents. Soil moisture content. Carbon dioxide and oxygen in soil gas.

APPLICABILITY

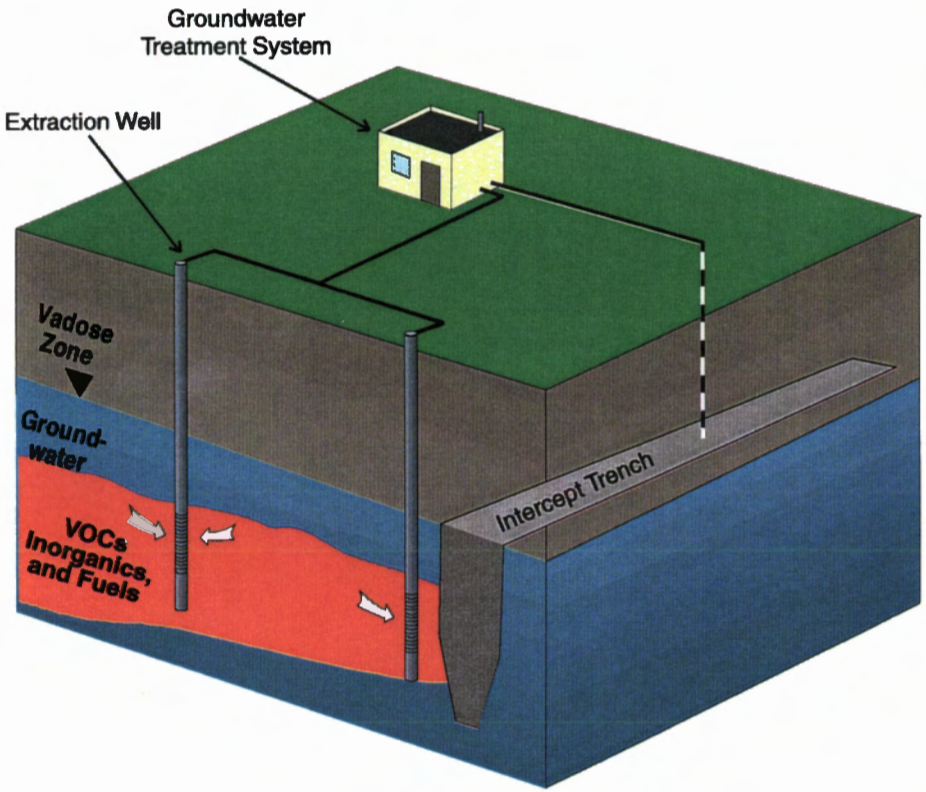
Bioventing, as a stand-alone remedy, is applied at sites where the petroleum hydrocarbon and associated BTEX contamination in the vadose zone are the only contaminants of concern.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Fuel, BTEX, or TPH contamination (i.e., non-halogenated hydrocarbon) in the vadose zone;
- Soil permeability greater than 1×10^{-1} darcies;
- Initial soil pH between 5 and 9;
- Initial soil moisture content between 5 and 25%;
- Initial soil total Kjeldahl nitrogen content of 20 mg/kg soil;
- Initial soil total phosphorus content of 3 mg/kg soil; and
- Unsaturated gravels and sands, with minor clays and silts, thoroughly fractured bedrock.

Figure 3-10. Summary of the Bioventing Presumptive Remedy

GROUNDWATER CONTAINMENT



CONTAMINANTS

VOCs, semi-volatiles, inorganics, or TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone).
Contaminant:	Separate phase liquids in groundwater. Horizontal and vertical distribution of dissolved contaminants in the aquifier.
Hydrology:	Horizontal and vertical gradients in groundwater. Hydraulic conductivity, K, in saturated zone. Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes. Sources of recharge and discharge areas.
Other Parameters:	Location of nearby or adjacent structures or buildings.

PRESUMPTIVE REMEDY PROFILE NEEDS

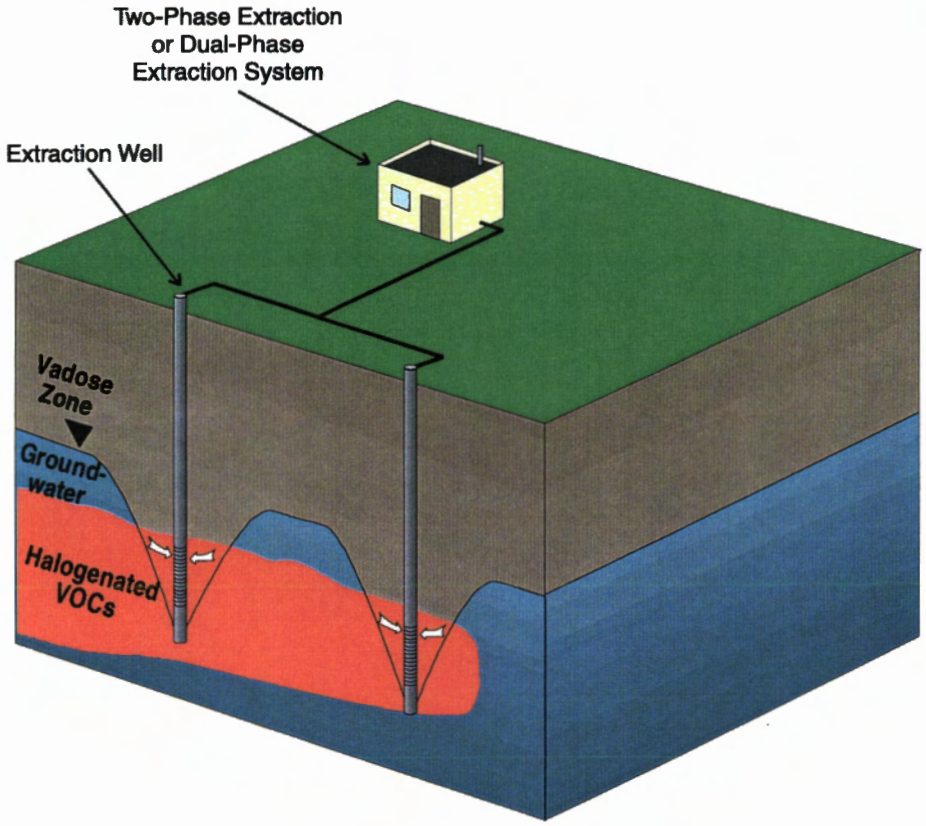
- Source of discharge point of contamination not active or remediated;
- Concentration of halogenated VOCs are less than 1% of maximim solubility;
- Solubility of contaminants is greater than 10 mg/l;
- Absorption coefficient is less than 10,000 l/kg;
- Total volume of groundwater contamination plume is greater than 1,000 gallons and less than 5 billion gallons;
- The target volume is contained in porous deposits (i.e., sands, gravels, with minimal interlayered silts, and clays) or highly fractured or weathered bedrock, and/or average hydraulic conductivity is 10^{-4} cm/sec in the saturated zone;
- Natural carbon fraction is less than or equal to 0.01;
- Natural groundwater velocity is greater than 10^{-7} meters/second and less than 10^{-4} cm/sec in the saturated zone;
- Water level fluctuation is less than 10 feet/year and 3 feet/day;
- Surface water provides upgradient recharge and minimal flood potential;
- The target plume is either underlain by an aquitard in an unconfined water table zone, or is confined between aquitards.

APPLICABILITY

This remedy is applicable for dissolved phase contaminated groundwater plumes which have migrated away from the overlying vadose zone source area. Contaminants of concern include pesticides, metals, and semi-volatile compounds. Halogenated VOCs would not be applicable unless study has determined MPE is not effective. Petroleum or fuel related contaminants would not be applicable unless an intrinsic remediation study has determined that intrinsic remediation and natural attenuation are not sufficient to contain groundwater contamination migration or leading edge of the plume has already impacted an identified receptor.

Figure 3-11. Summary of the Groundwater Containment Presumptive Remedy

MULTI-PHASE EXTRACTION



CONTAMINANTS

Halogenated VOCs or TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Air permeability of vadose zone. Depth to groundwater (thickness of vadose zone).
Contaminant:	Henry's Law constant. Horizontal and vertical distribution of dissolved contaminants in the saturated and vadose zones. Vapor pressure. Maximum depth of targeted contamination.
Hydrology:	Groundwater production rate.
Other Parameters:	Location of nearby or adjacent structures or buildings.

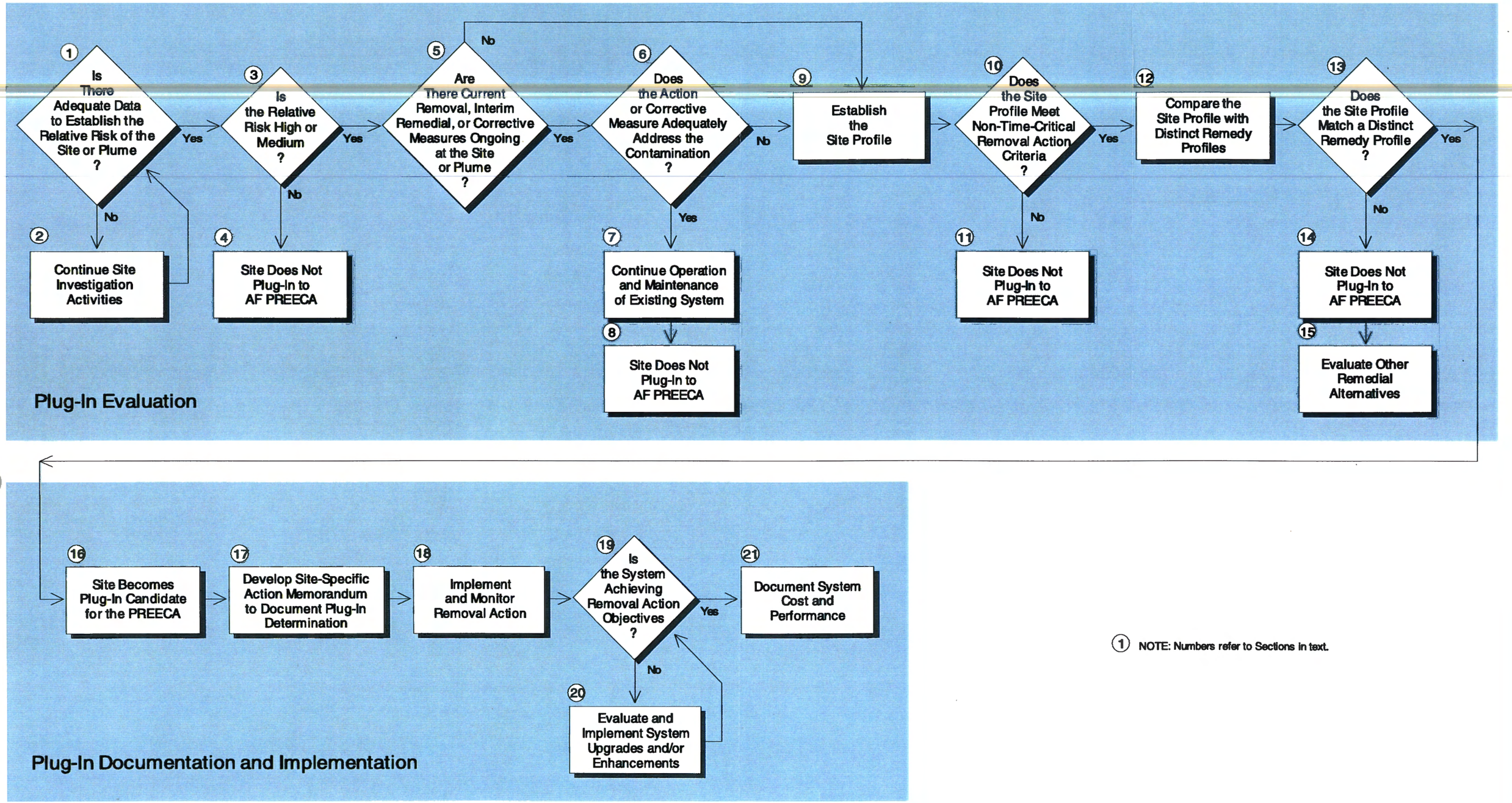
APPLICABILITY

The primary application of this remedy is for halogenated VOCs in soil and groundwater. This remedy utilizes the dual-phase extraction (DPE) and two-phase extraction (TPE) technologies for contaminant removal. Petroleum or fuel related contaminants are applicable when an intrinsic remediation study has determined that intrinsic remediation, or natural attenuation are not sufficient to contain and/or effectively treat groundwater and/or soil contamination.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Halogenated VOCs in vadose zone and/or groundwater;
- Non-halogenated VOCs and/or TPH/BTEX where timely cleanup is required;
- Henry's Law constant of contaminants greater than 0.01 at 20 degrees Celsius;
- Vapor pressure of contaminants greater than 1.0 mm Hg at 20 degrees Celsius;
- Geology from sands to clays; and
- For vadose zone application, air permeability of vadose zone between moderate to low permeability.

Figure 3-12. Summary of the Multi-Phase Extraction Presumptive Remedy



(1) NOTE: Numbers refer to Sections in text.

Figure 3-13.
Plug-In Determination

Table 3-3. Air Force PREECA Distinct Presumptive Remedy Profiles

Remedy Profile No.	Contaminants and Associated Pathway		Presumptive Remedy Profiles				
	Surface and/or Vadose Zone Pathway	Groundwater Pathway	Capping	Soil Vapor Extraction	Bioventing	Groundwater Containment	Multi-Phase Extraction
1	Non-VOCs	None	✓				
2	VOCs	None		✓			
3	TPH/BTEX	None			✓		
4	None	Non-VOCs				✓	
5	None	VOCs					✓
6	VOCs	VOCs					✓
7	TPH/BTEX and Non-VOCs	None	✓		✓		
8	VOCs and Non-VOCs	None	✓	✓			
9	Non-VOCs	Non-VOCs	✓			✓	
10	VOCs	VOCs and Non-VOCs		✓		✓	✓
11	VOCs and Non-VOCs	VOCs and Non-VOCs	✓	✓		✓	

a given pathway, and the associated receptors identified. If the relative risk cannot be determined, then additional site investigation and data gathering (Item 2) is necessary.

3.6.1.2 Is the Relative Risk High or Medium (Items 3-4)?

Per the criteria and scope of this effort discussed in previous sections, removal or interim remedial actions and corrective measures should only be considered for those sites that pose a high risk to human health and/or the environment. Sites with low risk would not be suitable for early action.

3.6.1.3 Is Remedial Action Currently Ongoing (Items 5-8)?

This step involves review of other cleanup actions that may be in place at candidate sites. For sites where actions are adequately addressing contaminant problems, additional efforts would not be necessary. However, for sites with current actions ongoing that are ineffective or only partially effective, presumptive remedy enhancements or additions may be necessary in order to achieve remedial objectives.

3.6.1.4 Does the Site Profile Meet Non-time-critical Removal Action Criteria (Items 9-11)?

Once it has been established that the site poses a potentially significant risk, a more detailed site profile should be established. This profile is essentially a site conceptual model that is "constructed" from the site profile parameters in Table 3-1. The profile is then compared with non-time-critical removal action criteria to ensure that early action is necessary. These criteria are discussed and presented in Section 4.2 of this document. If the site does not meet these criteria, then it does not plug-in to the Air Force PREECA.

3.6.1.5 Does the Site Profile Match a Distinct Remedy Profile (Items 13-15)?

After determining that the site profile meets removal action criteria, the next step is to compare the site profile with the associated presumptive remedy and distinct remedy until analytical sampling results are available for profile criteria and conditions. If the site profile cannot be addressed by the presumptive remedies described in this document, then the site does not plug-in to the Air Force PREECA, and other alternatives must be evaluated within the overall Installation Restoration Program (IRP). Detailed criteria and conditions for the remedy profiles are contained in Part II of this document. Examples for matching site profile parameters to remedy profile parameters are shown in Section 4.4, Tables 4-1 through 4-5 of Part 1 of this document.

3.6.2 Plug-in Documentation and Implementation (Items 16-21)

Once the plug-in evaluation is successfully completed, this determination must be documented in a site-specific action memorandum prior to beginning the removal action. After installation of the presumptive remedy system, monitoring of overall effectiveness in achieving remedial goals and objectives must be performed and documented.

3.6.2.1 Develop Site-Specific Action Memorandum (Item 17)

The site specific action memorandum is produced to document that the plug-in candidate site satisfies the non-time-critical removal action and remedy profile criteria, as established in this Air Force PREECA. The action memorandum must undergo a formal public comment period of at least 30 days along with a response to comments prior to finalization.

3.6.2.2 Implement and Monitor the Removal Action (Items 18-20)

Once the site-specific action memorandum has been approved by authorized Air Force and regulatory agency personnel, the presumptive remedy action can be designed and implemented. Monitoring is required to ensure compliance with removal action goals and objectives. If the system does not achieve these goals, then enhancements and/or upgrades should be evaluated for implementation.

3.6.2.3 Document System Cost and Performance Effectiveness (Item 21)

Long-term system performance should be documented for future reference. This data will be compiled from Air Force sites across the country in order to establish a database of technology-specific cost and effectiveness information. It can also be used to justify technology-based cleanup standards in those instances where presumptive remedy technology and its associated enhancements cannot achieve desired goals.

4.0 SITE-SPECIFIC REMOVAL ACTION IMPLEMENTATION PROCESS

This section describes the procedures for implementing the PREECA at Air Force sites, and is intended to be a "how-to" guidance section. Figure 4-1 is a flow chart that illustrates the PREECA removal action process. A summary of this figure is provided below.

After an initial site characterization is performed and a site profile is created, the site profile is used to determine if the removal action and presumptive remedy approach is warranted. Public involvement should be initiated early in the removal action process in order to gain acceptance and approval of the approach. Documentation of the site characterization and the removal action determination is presented in an approval memorandum. This document is essentially a short letter to applicable regulatory agencies which states the intent of the installation to initiate a non-time-critical removal action.

After agency and public approval, additional site characterization data may be collected to further develop the site profile. If the site profile is matched to the technology remedy profile, then the site "plugs-in" to the PREECA. The plug-in process and the selection of a PREECA technology is then documented in the site-specific action memorandum. After the PREECA technology is presented for the formal public comment period, implementation of the removal action begins. Monitoring and reporting is required during operation of the treatment system. The following sections provide supporting detail on the necessary steps for implementing a removal action using the PREECA approach.

4.1 Site Profile

4.1.1 Initial Site Characterization

Site-specific information is needed to develop site profiles to determine if a removal action and the presumptive remedy approach are warranted. The site profiles may be created using information collected during an initial site characterization. The information that should be collected for the site profile during this characterization is listed below:

- Site description and background;
- Source, nature, and extent of known contamination;
- Risk evaluation information; and
- Information from previous removal or interim remedial actions (if any).

This data may be available from preliminary assessments, site inspections, or remedial investigations. Several potential sources of site information are listed in "Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA" (U.S. EPA, 1993b).

This information should identify the contaminants, provide data to make a removal action determination, and provide data to select a potential presumptive remedy for the site. The criteria for determining if a non-time-critical removal action is warranted is provided in Section 4.2.

4.1.2 Approval Memorandum

Documentation of the initial site profile created using the initial site characterization is provided in the approval memorandum. The approval memorandum is a short letter that serves several important functions:

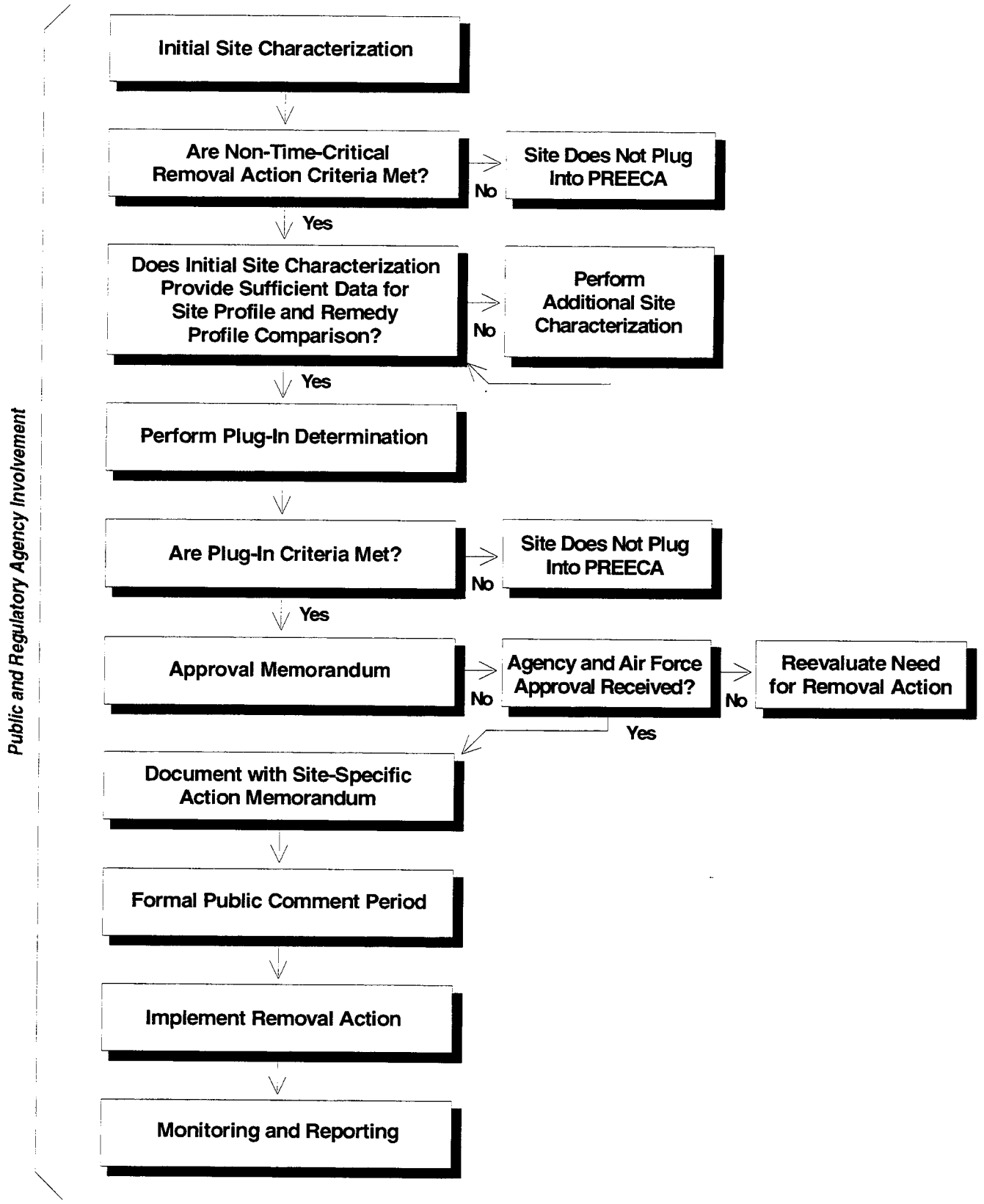


Figure 4-1. Process for Non-Time-Critical Removal Actions at Air Force Sites

- Provides detailed information pertaining to the site background; threats to public health, welfare, or the environment; and estimated project cost;
- Provides finding of an actual or threatened release from the site (documents the initial site evaluation prior to additional investigation); and
- Documents that the site meets the NCP criteria for a non-time-critical removal action, or RCRA criteria for interim corrective measures.

The approval memorandum should be submitted to regulatory agencies and public representatives for review, comment, and approval.

4.1.3 Detailed Site Characterization

Once the approval memorandum is accepted, a more detailed site characterization may need to be performed. A detailed site characterization should be completed if the initial site profile does not contain sufficient information for the remedy profile comparison. The additional site characterization should further identify the contaminants and provide data to determine whether a presumptive remedy is feasible for the site. The specific data needs for each technology may be found in the technology descriptions in Part II of this document. The additional site characterization should:

- Collect data to support the selection of the presumptive remedy.
- Collect data that will minimize further data collection during the remedial design stage.
- Perform a streamlined, qualitative risk evaluation if not already completed. This effort is similar in nature to the DoD Relative Risk Evaluation Program.
- Complete a site profile that is compared to the remedy profile to determine if the site "plugs-in" to the PREECA.

4.2 Removal Action Criteria

To implement a presumptive remedy EE/CA, a site on an Air Force facility must first meet the criteria for non-time-critical removal actions (Section 2.1). The eight types of conditions or hazards established in the NCP (Section 300.415) and CERCLA (Section 104) that would warrant removal actions do not specifically identify contaminated media, contaminant types, or concentrations. However, it is important that only those sites that pose a medium to high risk to human health and/or the environment be included in this PREECA initiative. The methodology in the following paragraphs will assist Air Force personnel in deciding on the need for a removal action.

4.2.1 Removal Action Decision Methodology

Time Factor. The time interval between the discovery of hazard and its impact on the public or environment is critical in the decision to take a removal action. To conform to the guidance for removal actions, the threat of human or environmental exposure to contaminants should rapidly increase from ambient levels in a period of 24 months or less. If the threat will reach unacceptable levels within six months of the time of discovery, an emergency or time-critical action that does not require an EE/CA should be implemented. If an unacceptable hazard or risk will occur within seven to 24 months, a non-time-critical action, requiring an EE/CA, may be

the correct choice. If unacceptable risk levels will not be reached until after 24 months, the removal action process may not be applicable for the site.

An example of conditions warranting an emergency action is TCE seeping from the subsurface through the bank of a stream that provides drinking water to the local community. The time interval of the potential threat posed by these conditions would be too short to conduct an EE/CA for a non-time-critical response.

A non-time-critical action would be considered if a TCE-contaminated groundwater plume exceeding acceptable health-risk concentrations was discovered migrating from an Air Force facility toward a water supply well. If groundwater velocity calculations indicated that the plume would reach the well in 7 to 24 months, preparation of an EE/CA to implement a non-time-critical removal action would be justified. If the plume is unlikely to reach the well in less than 2 years, the typical RI/FS process would be an appropriate path to follow.

Human Health or Environmental Threat. The determination of the magnitude of the human health or environmental threat is an important part of the removal action decision. Two potential methods available for estimating the magnitude of the threat are an exceedance of an Applicable or Relevant and Appropriate Requirement (ARAR) or a screening risk assessment. **It must be clearly evident that the site will require cleanup before deciding on the removal action approach.**

ARARs. If an ARAR for soil, groundwater, surface water, or air is exceeded, that exceedance may be sufficient justification to decide on a removal action. To make a removal action decision on the basis of a ARAR, each Air Force facility must have at least a preliminary list of contaminant-specific ARARs with which to compare contaminant concentration data. Regulatory agencies at the federal, state, or municipal level may have established concentration levels for soil, water, or air that determine if a cleanup action should be taken. **The ARAR concentration levels are generally a level of contaminant concentration that will result in an unacceptably high health or environmental risk; however, not all ARARs are based on an unacceptable risk level.** An example of ARARs that apply to all Air Force sites in the US are Primary Maximum Contaminant Levels for Drinking Water established in the Safe Drinking Water Act (U.S. EPA, 1992). It is beyond the scope of this guidance to summarize state or local ARARs for each Air Force site; however, a listing of federal ARARs is provided in Appendix A. Cleanup or "action levels" for specific contaminants, established by U.S. EPA, state or local government agencies, may also be considered ARARs that could justify a removal action.

Early Action for Risk Reduction. If no known ARARs or action levels are exceeded, there may be justification to implement a removal action to reduce risk or potential exposure or hazards to human populations, animals, or the food chain. The SACM guidance recognizes risk reduction as a valid justification for taking early actions through a non-time-critical removal action. During a CERCLA PA, SI, or the early stages of an RI, or a RCRA RFA or RFI, data may not be adequate to perform a quantitative human health or ecological risk assessment for a contaminated site. The U.S. EPA and a number of state agencies have developed guidance documents which specify the quantity and quality of data

necessary for risk assessment. The guidance most appropriate for the Air Force facility should be consulted to determine if site data are sufficient for a risk calculation. If adequate data are not available for a site under consideration, "screening level" health risk assessment or exposure evaluations have also been developed by regulatory agencies to reach risk decisions with limited data. **Before proceeding toward a removal action decision with screening level risk assessment procedures, the procedures must be acceptable to regulatory agencies that are involved in facility oversight.**

An example of screening health risk assessment that has been applied to all Air Force sites is the DOD Relative Risk Evaluation, which is a method of categorizing potential human health or ecological risks on the basis of limited site data. A high category relative risk ranking during the PA, SI, or RI may be used to justify a site removal action, if the data used in the ranking are appropriate for the site.

Another screening approach to determine if a site's risk warrants a removal action is presented in the *Rational National Standards Initiative (RNSI): Pathways and Parameters Evaluation Report*. The objective of this initiative is to establish risk-based cleanup goals for all Air Force sites. These cleanup goals are based on the site's most probable land use category, and are calculated via a screening risk assessment methodology. If a site's contaminant data exceeds the RNSI cleanup goals, a non-time-critical removal action may be justified.

If there are doubts that a contaminant is currently posing unacceptable risks or hazards or that one of the identified presumptive remedies can reduce the risk or meet an ARAR, a presumptive remedy removal action decision will not be appropriate. Although the contamination identified at an Air Force site initially meets the criteria for a removal action, additional investigation, followed by a RI/FS report, may be an acceptable course of action. If contaminant concentrations and site conditions do not indicate that an action should be implemented within 24 months, a complete RI/FS or Corrective Measures Study (CMS) process may be a more reasonable course of action. Early actions or removal actions are warranted if those actions "could eliminate the majority of human risk" from a site (SACM, 1992).

The decision to initiate an EE/CA and the justification for the necessity of a removal action should be documented in the EE/CA Approval Memorandum. The memorandum should be prepared by the Air Force site environmental team; however, the action proposed in the memorandum should also be approved by the lead regulatory agency and distributed to all regulatory agencies concerned with the Air Force site. The public living near or working on the site should also be informed of the decision to take the early action.

4.3 Public Involvement

The objective of community relations activities is to promote active communication between the communities affected by the removal action. Public involvement should be initiated as early in the removal action process as possible. Public involvement activities consist of presentations to the restoration advisory board (RAB) or other community representatives. The presentations will enable public participation in planning, decision making, and implementation. Public involvement activities also include the release of fact sheets to

describe removal action progress and announce upcoming events; the release of site-specific documents for public review and comment; and public meetings on site-specific documents.

Public involvement is comprised of two forms of activities; community relations activities and administrative record activities. Community relations activities are designed to incorporate the information needs of the community into the communication schedule for the removal action.

Administrative record activities provide a chronicle for the removal action and a record of public participation in the removal action selection. These activities are listed below:

Community Relations Activities

- Designate community relations spokesperson;
- Conduct community interviews;
- Prepare a community relations plan (CRP);
- Establish information repository; and
- Provide public notice of availability of PREECA and site-specific action memorandum.

Administrative Record Activities

- Establish the administrative record file (file should contain approval memorandum, PREECA, site-specific action memorandum, etc.);
- Publish notice of availability of the administrative record file;
- Hold public comment period for the approval memorandum, PREECA, and site-specific action memorandum; and
- Develop written response to significant comments.

4.4 Plugging-in to the PREECA

A critical step in the use of the Air Force PREECA process requires a match between the site profile and the profiles for one or more of the presumptive remedies. The remedy profiles consist of information, descriptions, and quantitative physical data that define the conditions under which the presumptive remedy will be effective. Remedy profiles are composed of a range of values and conditions. Site profiles are "constructed" from the parameters in Table 3-1 that have been measured or have been observed at an Air Force site. Several examples of profile matching are provided in Tables 4-1 through 4-5.

If a site profile matches a remedy profile, the site can plug-in to the PREECA. The remedy profiles for each presumptive remedy are guidelines for the most effective, implementable, and least costly applications. If a site profile contains one parameter that is outside of the range of the most reasonable remedy profile, it may be possible to select the remedy for a specific site. Selection of remedies that do not match site profiles may cause costs to be greater than anticipated or may result in non-attainment of removal action objectives. Therefore, selection of a remedy that does not match the site profile introduces uncertainty in the success of the removal action; however, additional uncertainty may be warranted if the removal action is interim and will be followed by a final action.

4.5 Site-Specific Action Memorandum

The site-specific action memorandum (SSAM) provides a written record of

Table 4-1. Soil Vapor Extraction Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Vapor pressure of contaminant in soil	> 1.0 millimeters of mercury at 20 degrees C	Benzene, toluene, xylenes, TCE, or PCE in soil gas	Polychlorinated biphenyls or JP-4 fuel
Henry's Law Constant (vapor conc./aqueous conc.)	> 0.01 at 20 degrees C	Benzene, toluene, xylenes, TCE, or PCE in soil gas	JP-4 fuel, fuel oil, hydraulic oil
Soil types in contaminated zone	Homogeneous or with minor variations	Homogeneous sands with a few 6-inch clay or silt layers	Heterogeneous; 3 to 5-foot-thick clay or silt interbeds between sands
Average vadose zone permeability	> 1×10^{-3} darcies	2×10^{-3} to 5.5×10^{-3} darcies	0.5×10^{-4} to 0.8×10^{-3} darcies
Depth to groundwater	> 5 feet	15 to 100 feet	3 to 5 feet
Average percent saturation (water-filled soil porosity)	< 60 %	20 to 55%	60 to 80%

Table 4-2. Bioventing Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Contaminants	Total petroleum hydro-carbons, nonhalogenated hydrocarbons, BTEX	Gasoline concentrations in soil; benzene concentrations in soil gas	TCE and carbon tetrachloride concentra-tions in soil and soil gas
Contaminant Distribution	1 to 100 feet below ground surface	10 to 55 feet below surface	> 100 feet below surface
Geology and Soils	Unsaturated gravels and sands with minor clays and silts; thoroughly fractured bedrock	30 feet of sands with few interbedded 3 to 6-inch silt layers from surface to water table	Sand, silt, and clay layers in equal proportions above the water table
Average soil gas permeability	> 0.1 darcies	2 to 3 darcies	0.05 darcies
Average soil pH	5 to 9	7.5	10.1
Average nitrogen in soil (Kjedalh method)	≥ 20 mg/kg	25 mg/kg	10 mg/kg
Average total phosphorus in soil	≥ 3 mg/kg	6 mg/kg	1 mg/kg
Soil moisture	5 to 25%	15%	70%

Table 4-3. Capping Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Contaminants	Metals/Semivolatiles/ DNAPL/Municipal landfill waste	PCBs, chromium, and lead > acceptable risk levels in surface soils	TCE and BTEX compounds throughout vadose zone
Volume of classified hazardous waste	> 1,800 cubic yards	15,500 cubic yards of PCB contaminated soil (hazardous waste)	1,700 cubic yards of PCB (hazardous waste)
Volume of nonhazardous waste	> 7,500 cubic yards	8,000 cubic yards of DNAPL (non-hazardous waste) contaminated soil	4,000 cubic yards of DNAPL (non-hazardous waste) contaminated soil
Depth of contamination	> 18 feet below surface	Contaminant/waste 15 to 25 feet below surface	Contaminant/waste 0.5 to 10 feet below surface
Area of contamination (excluding landfill area)	< 24 acres	10 to 15 acres	27 acres
Volume of landfill waste	> 100,000 cubic yards (2 acres, 30 feet deep) of waste	200,000 cubic yards of municipal waste	5,000 cubic yards of waste

Table 4-4. Groundwater Containment Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Contaminants	Primarily dissolved inorganic constituents or semi-volatiles; also volatile organic compounds, TPH, and BTEX	Chromium > MCLs; any metals concentration > MCLs	Organic compounds as separate phase or > 1% of maximum solubility
Contaminant distribution	In groundwater > 3 feet below surface and < 400 feet below surface	Groundwater plume 10 to 75 feet below surface	Groundwater plume 1 to 3 feet below surface
Hydrogeology	Homogeneous sands or highly fractured/ weathered bedrock	Fine to coarse-grained sands with minor silt lenses	Interbedded fine-grained sands, clayey silts, and silty clays
	Average < 1 % total organic carbon	0.1 to 0.9 % total organic carbon	2 to 10 % total organic carbon
Hydrology	Drawdown at maximum pumping rate less 67% of aquifer thickness	15 feet of drawdown in 30-foot thick aquifer	45 feet of drawdown in 50-foot thick aquifer
Natural groundwater velocity	$> 10^{-7} < 10^{-4}$ meters per second	2×10^{-7} to 5×10^{-5} meters per second	1×10^{-10} to 5×10^{-9} meters per second
Water level fluctuation	< 10 feet per year, < 3 feet per day	5 feet per year or 0.5 feet per day	25 feet per year
Contaminated volume	> 1,000 gallons, < 5 billion gallons	10 million gallons	500 gallons

Table 4-5. Multi-Phase Extraction Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Contaminants	1. Halogenated VOCs 2. Non-halogenated VOCs and/or TPH (where timely clean up required)	TCE in soil and groundwater	PCBs in soil and groundwater
Contaminant location	1. Below groundwater table 2. Both above and below groundwater table	Both above and below groundwater table	In vadose zone only
Henry's Law Constant (vapor conc./aqueous conc.)	> 0.01 at 20° C	TCE	JP-4 fuel
Vapor pressure of contaminants in soil	> 1.0 millimeters of mercury at 20° C	TCE	PCBs
Geology below groundwater	Sandys to clays	Silty clay	Gravels and cobbles

decision for selecting a PREECA technology. This is a focused document which should generally not exceed 45 pages in length. This document is the counterpart to the action memorandum document described in EPA guidance, and an example SSAM is provided in Part III of this document. Typically, the SSAM's primary functions are to:

- Substantiate the need for a removal action;
- Identify the selected removal action; and
- Explain the rationale for the removal action selection.

Although the PREECA parallels the standard EE/CA document described in EPA guidance, the PREECA is a non-site specific document. As such, it does not include site-specific characterization data and conditions. The PREECA establishes the removal action and technology criteria, i.e., site and remedy profile characteristics, which sites must meet in order to "plug-in" and begin cleanup. **The site-specific action memorandum is the document which demonstrates that a site meets the PREECA requirements.** All site-specific information that is not provided in the PREECA will be presented in this document. The additional information to be presented in the site-specific action memorandum is listed below:

- A summary of site characterization data described in Section 4.1;
- Identification of removal action scope, goals and objectives for the site;
- Justification that the site "plugs-in" to the Air Force PREECA; and
- A conceptual design of the selected Presumptive Remedy(s) alternative.

The site-specific action memorandum shall be submitted for public and agency comments as described in Section 4.3. A public comment period of at least 30 days will be held, after which time, formal response to comments will be provided. The comments and responses should be incorporated in the final site-specific action memorandum prior to implementation of the selected remedy.

4.6 Removal Action Implementation

Clear, measurable, removal action objectives must be defined in the site-specific action memorandum prior to implementation. During implementation, adequate equipment, procedures, instrumentation, and monitoring must be included to determine if these objectives are being met. During operation, a routine evaluation of the success at meeting these objectives is required. This cycle of collecting data, evaluating system performance versus the removal action objectives, and making required adjustments or modifications should continue throughout the life of the project. In some cases the objectives may need to be refined based on the data obtained during operation.

Removal action implementation typically consists of a number of standard phases including; planning/evaluation, permitting, design, construction, start-up, and operations. In order to minimize project delays and cost overruns, an analysis of the schedule should be performed to identify critical path items for each phase of the project, e.g., air permits, land use permits, equipment delivery, and subcontracting for construction. The anticipated duration of each component, along with the interrelationship between items must also be considered. For instance, permit applications cannot be submitted until the 50% design is done, or equipment cannot be purchased

until design and permitting are substantially complete. The completion of this analysis can identify the milestones that are schedule and cost critical to the project, and allow for contingency planning to avoid or minimize project obstacles.

The permitting requirements for a given removal action should already have been identified in the ARARs analysis. During or immediately after the removal action selection has been finalized, appropriate regulatory agencies should be contacted to verify the specific permitting requirements and regulatory timeframes required.

More detailed, technology-specific information on system design, and potential system enhancements and costs are discussed for each technology in Part II, Section 2.0.

4.7 Monitoring and Reporting After Implementation

Process monitoring for each technology will need to be incorporated into the design and costing of any of the five presumptive remedy profiles addressed in this document and in Part II. The primary purpose of the monitoring will be to determine the effectiveness of the technology in meeting its removal action objectives. At a minimum, this will include the following types of information for each technology. **Additional process parameters will need to be monitored to assure proper operation of the specific system and equipment at a given site.**

- **Bioventing**—Subsurface oxygen and degradation product (e.g., carbon dioxide) concentrations; air injection or extraction flowrates; effluent gas concentrations, residual vadose zone contaminant concentrations; subsurface moisture content; infiltration rates into the groundwater (if any); and destruction removal effeciency of the selected off-gas treatment option (if any).

- **Capping**—Increases in groundwater concentrations for target analytes (indicating that excessive infiltration has occurred); surface water or sediment sampling to determine if contaminant transport due to erosion has been eliminated; surface subsidence measurements; and cap integrity (e.g., surface cracking, holes, etc.).

- **Groundwater Containment**—Downgradient groundwater monitoring to determine if the groundwater containment system is being effective at containing the target contaminant source (this includes contaminant sampling and water level data); pumping rates from each extraction/injection well; and aboveground treatment system influent and effluent flowrates and contaminant concentrations.

- **MPE**—Influent and effluent contaminant concentrations; system flowrate; individual wellhead flowrates; subsurface vacuum measurements; residual vadose zone and groundwater contaminant concentrations; and destruction removal efficiency (DRE) of the selected groundwater and off-gas treatment options.

In addition to providing the required system operation and performance data to regulatory agencies and surrounding community representatives, installations should cross-feed this data to other Air Force sites and throughout the Air Force. This cost and performance data will support continued use of presumptive remedies and help to establish technology-based cleanup standards. This effectiveness reporting

should include the specific objectives for the project, the data collected to determine if the objectives were met (including quality assurance/quality control information), and a summary of the conclusions.

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1.0 INTRODUCTION

1.1 Detailed Description of Part II

Part II is the presumptive remedy technology handbook, and is composed of five technology protocol sections; SVE, bioventing, groundwater containment, capping, and MPE. It is designed to provide supporting technology-specific justification and detail not included in Part I. In addition to providing general descriptions of each presumptive remedy technology, this document provides the detailed technology criteria which are necessary for a complete remedy profile evaluation. Part II also incorporates a conceptual design, documents the range of costs associated with implementing a presumptive remedy technology, and discusses operation and maintenance considerations.

1.1.1 Part II Objectives

The primary objectives for Part II are:

1. To provide base remedial program managers (RPMs) with adequate technology selection criteria to determine if a presumptive remedy technology or treatment train will be applicable to a given contaminated site; and

2. To provide base RPMs with adequate technical and cost information to begin planning for implementation of the selected presumptive remedy technologies.

As a secondary objective this document provides references that can be used as a starting point for developing site-specific design information.

1.1.2 Part II Outline

Section 1.0 of Part II is similar in scope and intent to the introductory section of Part I. This section introduces the PRE ECA goals, concept, and scope, and provides the overall format and content of the associated documents.

Section 2.0 of Part II contains the summary of criteria and conditions for the five remedy profiles presented in Section 3.5 of Part I. **As described in Part I, each remedy profile is composed of a range of site criteria and conditions which the remedy can effectively treat and address. In order for a site to "plug-in" to the PREECA, the remedy profile must "encompass" the conditions and criteria of the site profile.**

Sections 3.0-6.0 of Part II provide detailed technology profiles for SVE, bioventing, capping, groundwater containment, and MPE. Each of these sections is intended to act as a "technology reference handbook" and assist in the selection and implementation of a presumptive remedy. Along with a presumptive remedy technology selection flow diagram, each technology profile includes:

- Technology executive summary;
- Technology background and description section;
- Technology-based application criteria;
- Technology application limitations;
- Design and operating information;
- Cost data; and
- Technology enhancement information.

2.0 PRESUMPTIVE REMEDY PROFILE SUMMARIES

As described in Sections 3.0 and 4.0 of Part I, there are three primary steps for determining if a site "plugs-in" to the Air Force PREECA:

1. "Construct" the site profile. This is composed of the physical and chemical conditions and parameters existing at the site.

2. Verify that the site profile meets the criteria for a non-time critical removal action.

3. "Match" the site profile conditions to the corresponding remedy profile in order to verify that the remedy can effectively treat the site.

Table 2-1 of this section contains the summary of remedy profile parameters and conditions for each of the five remedy profiles introduced in Section 3.5 of Part I. As previously stated, the parameters and criteria specified in Table 2-1 constitute the "effective range of treatment conditions" for each of the five remedies. In order for a site to "plug-in" to this Air Force PREECA the site profile parameters and conditions must "match" those of the corresponding remedy profile.

Table 2-1. Remedy Profile Summary

Technology	Remedy Profile Summary
SVE	- Halogenated hydrocarbon contamination in the vadose zone; - Average soil gas permeability greater than 1×10^{-3} darcies; - Average percent saturation of the vadose zone less than 60%; - Depth to groundwater or contamination greater than 5 feet; - Henry's Law constant of contaminant at 20 degrees Celsius greater than 0.01 (dimensionless); and - Vapor pressure of the majority of the contaminant at 20 degrees Celsius greater than 1.0 millimeters Mercury (mm Hg).
Bioventing	- Fuel, BTEX, or THC hydrocarbon contamination (i.e., non-halogenated hydrocarbon) in the vadose zone; - Soil gas permeability greater than 0.1 darcies; - Initial soil pH between 5 and 9; - Initial soil moisture content between 5 and 25%; - Initial soil total Kjedalh nitrogen content of $\geq$ 20 mg/kg soil; - Initial soil total phosphorus content of $\geq$ 3 mg/kg soil; and - Unsaturated gravels and minor clays and silts, thorougly fractured bedrock.
Capping	- DNAPL, semivolatile, metal/inorganic contamination in the vadose zone; or - Municipal or low hazard military waste; - Area of capping contaminated soil less than 24 acres (excluding landfills); - Depth of contamination greater than 18 feet below ground surface (BGS) and/or total volume of contaminated soil greater than 1,800 cubic yards for a hazardous waste or greater than 7,500 cubic yards for a non-hazardous waste; - Volume of waste less than 100,000 cubic yards; - Construction will not impact environmentally sensitive areas; - Existing structures can be removed and future land use can be restricted; - Henry's Law constant of contaminant at 20 degrees Celsius less than 0.01 (dimensionless) (for DNAPL only); - Vapor pressure of contaminant at 20 degrees Celsius less than 1.0 mm Hg (for DNAPL only); - Geology is complex and soils are heterogeneous (for DNAPL only); and - Hydraulic conductivity of subsurface $< 10^{-4}$ cm/sec (DNAPL only).
Groundwater Containment	- Organics and/or inorganics in the groundwater; - Source or discharge point of contamination remediated or not active; - Concentration of halogenated VOCs are less than 1 percent of maximum solubility; - Solubility of contaminants is greater than 10 milligrams per liter; - Adsorption coefficient is less than 10,000 liters per kilogram; - Total volume of groundwater contaminant plume is greater than 1,000 gallons and less than 5 billion gallons; - The target plume is contained in porous deposits (i.e. sands, gravels with minimal interlayered silts and clays) or highly fractured or weathered bedrock and/or average hydraulic conductivity is 10^{-4} centimeters per second for the saturated zone; - Natural organic carbon fraction is less than or equal to 0.01; - Natural groundwater velocity is greater than 10^{-7} meters per second and less than 10^{-4} meters per second; - Water level fluctuation is less than 10 feet per year and 3 feet per day; - Surface water provides upgradient recharge and minimal flood potential; and - The target plume is either underlain by an aquitard in an unconfined water table zone or is confined between to aquitards.
MPE	- Halogenated VOCs or TPH/BTEX in groundwater and/or vadose zone; - Henry's law constant of contaminants greater than 0.01 at 20° Celsius; - Vapor pressure of contaminants greater than 1.0 mm Hg at 20° Celsius; - Geology between sands and clays; and - Air permeabilities of soil above groundwater is moderate to low permeability ($k < 0.1$ darcy).

SOIL VAPOR EXTRACTION
PRESUMPTIVE REMEDY CRITERIA DOCUMENT

2nd Edition

FINAL

PART II: SECTION 3.0

15 MAY 1997

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SOIL VAPOR EXTRACTION

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3.0 SOIL VAPOR EXTRACTION TECHNOLOGY PROFILE

The U.S. EPA has determined that soil vapor extraction (SVE) is the presumptive remedy for volatile organic compound (VOC) contamination in the vadose zone. This determination is documented in "Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds In Soil" (OSWER, 1993). Inclusion of SVE as a presumptive remedy was based on extensive experience with SVE being chosen as the selected technology in 62 of 88 RODs for VOCs-only in the soil (EPA, 1993) and a successful record for remediating sites with VOC contamination in the vadose zone.

SVE has a number of benefits for remediation of VOCs in the vadose zone including:

- In-situ extraction of VOCs with minimal site disturbance;
- Cost-effective remediation of large volumes of contaminated soil;
- Effective at extracting significant quantities of VOCs in a relatively short time;
- Post-treatment residual contaminant quantities are typically small enough to prevent further contaminant migration into groundwater or volatilization to the atmosphere; and
- Can easily be implemented with standard, readily available equipment.

3.1 Soil Vapor Extraction Executive Summary

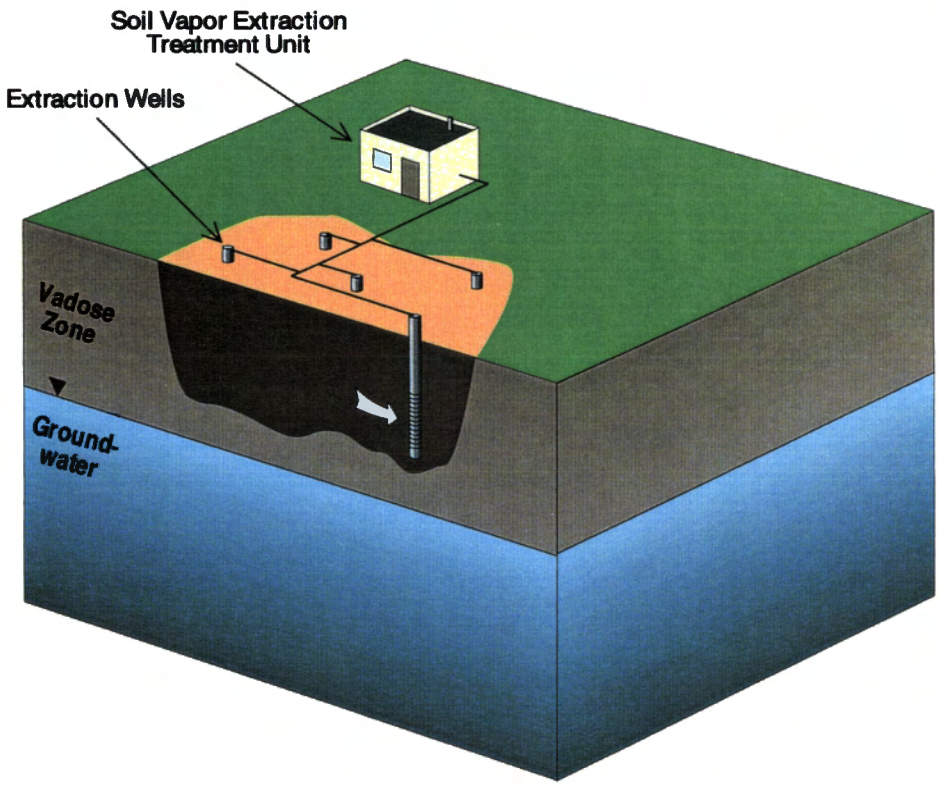
SVE is the process of extracting contaminant vapors from the vadose zone by drawing vapors and air through the soil by pulling a vacuum on an extraction well. Figure 3-1 provides an illustration of a typical system along with summary data on applicability, site profile needs and the presumptive remedy profile. Figure 3-2 provides a decision logic flow diagram that can be used in determining if a site is a SVE presumptive remedy site.

Costs for a typical SVE site are reported as $10 to $150 per ton of soil remediated (EPA, 1993). Costs will be heavily dependent on the concentrations and extent of contamination, the number and depth of extraction wells, and the type of off-gas treatment used. Detailed cost information is provided in Section 3.7.

3.2 SVE Technology Description

VOC contamination in the vadose zone generally consists of VOCs in four different phases, soil gas vapor, dissolved in the water phase, sorbed to the soil particles, and as free product. Under static conditions each of these phases will often be close to equilibrium with little net contaminant transfer between phases. SVE induces air flow through the contaminated soils, replacing saturated vapor with "clean" air. This upsets the equilibrium between the phases and results in a mass transfer driving force from the water, sorbed, and free product phases into the vapor phase that is continuously extracted. The SVE process typically continues until the contaminant concentrations in the non-vapor phases are reduced to the point where the mass transfer driving force is not significant enough to overcome the other forces that hold the contamination in the other phases (e.g., adsorption of the molecules to the soil particles, diffusion limited, etc.). Figure 3-3 shows typical contaminant extraction rates over time including pulsed operation during the lower removal phase.

SOIL VAPOR EXTRACTION



CONTAMINANTS

Halogenated VOCs

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone). Average soil gas permeability above groundwater. Percent saturation (water-filled porosity).
Contaminant:	Approximate distribution of concentrations. Vapor pressure for VOCs in soil gas. Henry's Law constant. Lateral depth and extent. Separate phase liquids in soil.
Hydrology:	Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes.
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings.

APPLICABILITY

This remedy as previously described is applicable at sites with volatile organic compound (VOC) contamination in the vadose zone, particularly halogenated VOCs. It is applied singularly at those sites where the VOC contaminant source areas have not yet migrated to the groundwater, and the VOC contaminants are the only compounds which require cleanup.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Halogenated hydrocarbon containment in the vadose zone;
- Average soil gas permeability greater than 1 x 10^{-3} darcies;
- Average percent saturation of the vadose zone less than 60%;
- Depth to groundwater or contamination greater than 5 feet;
- Henry's Law constant of contaminant at 20 degrees Celsius greater than 0.01 (dimensionless); and
- Vapor pressure of contaminant at 20 degrees Celsius greater than 1.0 mm Hg.

Figure 3-1. Summary of the Soil Vapor Extraction Presumptive Remedy

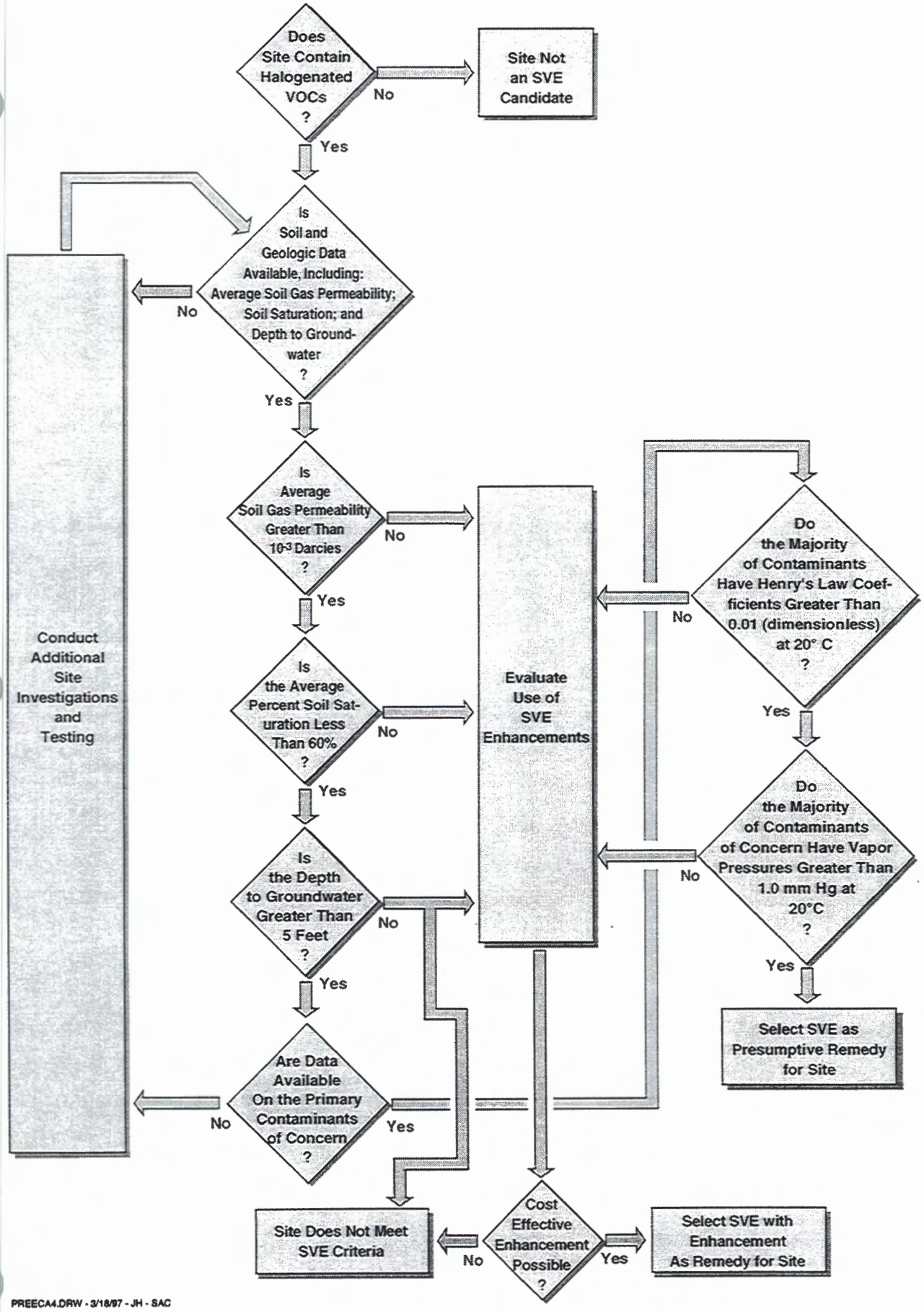


Figure 3-2. SVE Flow Diagram

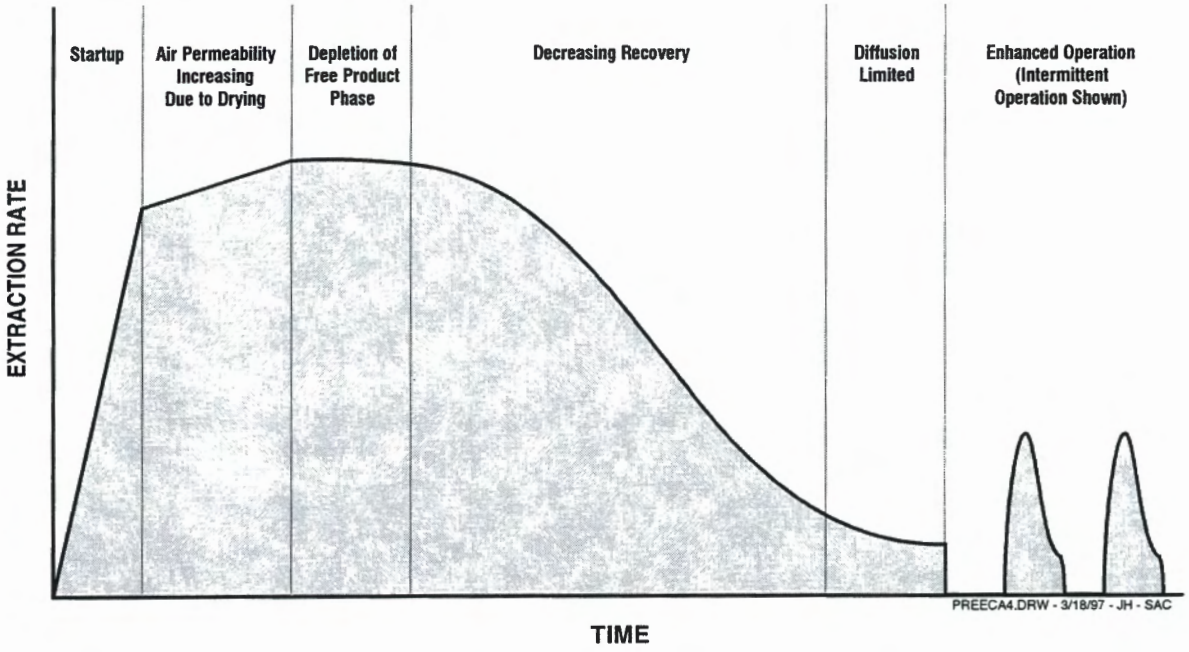


Figure 3-3. Typical Contaminant Extraction Profile for SVE

A typical SVE system consists of the following components:

- Soil vapor extraction well(s);
- Transfer piping and manifolds;
- Vapor-liquid separator vessel;
- Vacuum blower; and
- Off-gas treatment system.

Figure 3-4 provides an overview of an SVE system.

3.3 SVE Technology-Based Application Criteria

SVE technology has been proven successful at removing VOCs in the vadose zone over a wide range of conditions at different sites. For the purposes of using SVE as a presumptive remedy for VOCs in the vadose zone, the recommended selection criteria are based on previous experience indicating a high probability of SVE effectively extracting the contamination. Where site conditions meet or are within a reasonable range of these criteria, SVE is suggested for that site. Where a site does not fall within a reasonable range of these criteria, it does not mean that SVE cannot be used; instead, it is recommended that an enhancement be considered or a more detailed evaluation be conducted in order to justify its use. The SVE technology-based application criteria address contaminant, soil, and site characteristics. The site criteria that are suggested for a basic SVE system (without enhancements) are presented in Table 3-1.

SVE has been shown to be effective on both halogenated and non-halogenated VOCs. However, bioventing is usually less expensive at remediating non-halogenated VOCs (particularly fuel related VOCs). As a result, SVE is not the presumptive remedy for non-halogenated VOC sites. SVE should still be considered if faster remediation times are required.

Table 3-1
SVE Technology-Based Application Criteria

Criteria Parameter	Guideline Value
Average Air Permeability of the Vadose Zone	> 1 x 10^{-3} darcies[1]
Average Percent Saturation	< 60 percent
Depth to Groundwater or Contamination	> 5 feet
Henry's Law Constant of Majority of Contaminants	> 0.01 at 20°C (dimensionless)[2]
Vapor Pressure of Contaminant	> 1.0 mm Hg at 20°C

[1] Soil Gas Permeability: 1 darcy = 1 x 10^{-8} cm^2
[2] Dimensionless Henry's Law Constant in the form: (concentration in gas phase) ÷ (concentration in liquid phase).

A detailed discussion, including associated equations, of the application and design parameters is provided in the SVE Technology Reference Handbook (EPA, 1991) and "A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil-Venting Systems" (P.C. Johnson, et. al., 1990). Refer to these documents for information on the type of testing and calculation methods used to determine average air permeability and other key design parameters. Contaminant characteristics can be found in standard reference documents such as the "Handbook of Chemistry and Physics" (CRC Press, 1986) or "Superfund Public Health Evaluation Manual" (EPA, 1986).

If the site profile consists of a variety of conditions (e.g., some contaminated soils with permeabilities greater that 10^{-3} darcies and some with less than 10^{-3}darcies) or contaminants, then an evaluation of the

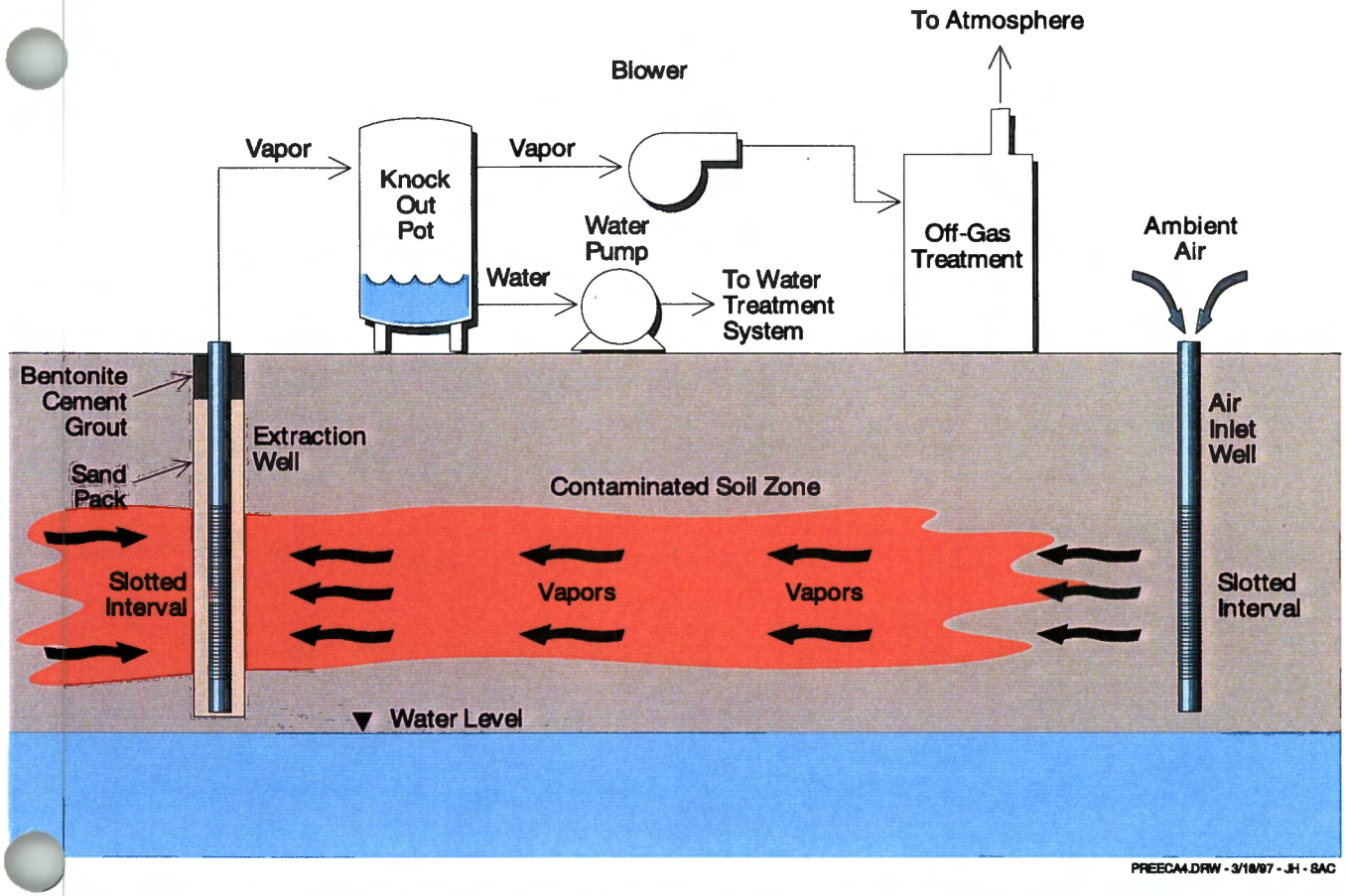


Figure 3-4. SVE System with Air Inlet Well

relative amount of contamination that would be within the guideline values should be determined. The decision to use SVE as a presumptive remedy should be made assuming it will be effective on only the portion of the site contamination which is approximately within these guideline values. While SVE may be successful in conditions outside of the given guideline values, additional evaluation should be conducted to verify that SVE is the most appropriate technology or to determine if SVE should be combined with an enhancement (e.g., hot air injection). Typically, conditions outside this range will result in an increase in cost and/or project duration and a decrease in effectiveness.

Pilot testing is recommended prior to implementing an SVE system. The pilot test consists of pumping a vacuum from a well screened above the water table and measuring:

- The induced vacuum produced at various locations from the well to determine the air permeability and radius of influence;
- Extracted vapor contaminant concentrations;
- Vapor flow rate; and
- Induced vacuum at the wellhead.

This information can be used to determine the air permeability of the contaminated zone and to compare the actual extraction rate with the estimated theoretical extraction rate. Pilot testing procedures are provided in a number of the references including P.C. Johnson, 1990, and Hinchee, R.E. et. al., 1992.

The contaminant, soil, and site characteristics are discussed below.

3.3.1 Contaminant Characteristics

Vapor Pressure: Vapor pressure provides an indication of the degree to which the liquid phase chemical will volatilize to the gas phase at equilibrium, i.e., the driving force for the chemical to move from the pure liquid to the gas phase for extraction by the SVE system. Vapor pressure is highly dependent on temperature and is usually expressed in pressure units (e.g., mm Hg, atmospheres) at a given temperature.

Henry's Law Coefficient: The Henry's Law coefficient is related to the materials' vapor pressure and its solubility in water, and provides an indication of the relative partitioning of the chemical between the gas phase and the solution. It provides a measure of how readily the material will move from the aqueous phase to the vapor phase. Henry's Law coefficients are also highly temperature dependent and are expressed both as dimensionless or in terms of partial pressure above a solution with a given concentration (atm-m^3/mol). Values in atm-m^3/mol can be converted to the dimensionless form by using the ideal gas law (multiply by a conversion factor of approximately 40.9).

3.3.2 Soil Characteristics

Gas Permeability: Air permeability is a measure of the ability of vapor to move through a porous media. It is a function of the available void volume of the soil that will provide a flow path for the gas flow. This is generally a function of the soil type and the percent saturation. Fine soils (e.g., clay) generally have much smaller void volumes and thus lower soil permeability than course soils (e.g., sands). Similarly, as water fills the soil void volume (i.e., the percent saturation increases), the available void volume for gas flow and the soil permeability is decreased. Air permeabilities

are typically expressed in darcies (1 darcy = 1×10^{-8} cm^2).

Percent Saturation: As discussed above, the soil permeability decreases as the moisture content increases. This becomes especially important when the percent saturation exceeds 60 percent. At these levels the available void volume is decreased to a point where there is too much pressure drop through the soils to effectively implement SVE.

Both the gas permeability and percent saturation estimates should be validated with actual flow data from pilot testing.

3.3.3 Site Characteristics

Depth to Contamination: The depth to contamination impacts the selection of SVE as a presumptive remedy in two ways. First, if the contamination is very shallow, there are often alternate methods for removing the contaminants that are more cost effective than SVE (e.g., excavation and disposal and biotreatments such as landfarming). Secondly, the effectiveness of SVE at shallow depths is frequently reduced by short-circuiting of the air flow from the surface. SVE may still be an effective remedial approach even for shallow contamination under some conditions where an existing cap is already in place, such as under existing buildings.

While SVE may work for conditions that are outside of these criteria, sites that meet these criteria are considered because they have the highest probability of successful SVE implementation.

3.4 Application Limitations

For sites that meet the application criteria the only technology-specific limitation identified is the difficulty in remediating contamination down to extremely low concentrations and this is dependent on site-specific chemical and soil conditions. As the contaminant concentration is reduced to low levels (< 500 ppm), the effects of sorption and dissolution become more prominent and additional extraction becomes more difficult (P.C. Johnson, et. al., 1990) although levels as low as 10 ppm have been reported for some highly volatile compounds. After a period of operation, the SVE process will become diffusion limited. Basically, this is where the remaining contaminants are trapped in pore spaces with no air flow directly across the molecules. The contaminants must diffuse out of the soil particle pores into the flowing air stream to be removed. At this point alternative strategies should be evaluated such as intermittent extraction, bioventing, or intrinsic remediation.

Diffusion limited conditions can also be caused by the geology of the site. For example, SVE will not be effective where air cannot be drawn past the liquid phase contaminant because it is present in cracks and fissures of a rock formation.

Other potential issues include the use of SVE at sites where LNAPL is present or where contamination from adjacent sites could be drawn on-site. In the case of LNAPL, extraction of the contaminant in liquid form will generally be much faster and more cost-effective than SVE and subsequent air pollution control. An SVE system can also draw contaminants on-site from adjacent contaminated areas. If this appears to be a potential problem, the use of a vapor barrier (an air inlet source that limits the induced vacuum such as air injection wells) would typically be required.

Possible logistical limitations could include:

- Noise if the site is near residential areas;

- Land use constraints;
- Space or access limitations; or
- Availability of utilities;

The fact that SVE is implemented in-situ may also present a regulatory problem since cleanup levels can only be determined through random sampling. As a result, routine confirmatory testing may still be required even after remediation.

These factors should be considered on a site-specific basis.

3.5 SVE Design Basis

This section provides a discussion of key SVE design issues. The discussion provides generalized information based on a broad range of conditions experienced with previous SVE systems and will need to be customized for each site. The discussion is provided for each of the following system components:

- Extraction System;
- Collection System;
- Vacuum System; and
- Off-gas Treatment System.

3.5.1 Extraction System

The two primary design parameters for the extraction system are the extraction well placement/spacing and the depth and extent of the extraction well screened interval. Both of these parameters will be based on the extent of the contamination and the air permeability of the vadose zone.

Extraction wells should be placed such that the radius of influence of the extraction wells covers the contaminated vadose zone.

Radius of influence refers to the radial distance to which each extraction well is able to draw adequate flow through the vadose zone to extract the VOCs. For soils with good air permeability (e.g., sandy soils) at depths greater than 20 feet or shallower extraction wells with a good surface seal, typical radius of influence ranges are 10 to 40 meters (Hutzler et. al., 1988). Shallower depths or less permeable soils would reduce these distances.

Radius of influence is generally determined via a pilot test using at least one extraction well with soil vapor pressure monitoring wells or soil probes at varying depths and distances from the well. The lowest pressure differential that is considered adequate to cause extraction of the vapors has been reported to be 0.1 inches of water vacuum.

In addition to the extraction well placement, the location of the screened interval of the extraction well can also be used to "target" the air flow through the portions of the vadose zone where the highest concentrations of contaminants are located. An example of this configuration is shown in Figure 3-5.

If more than one extraction well is used then "dead spots" will be present within the site. Dead spots are the locations in the vadose zone where the vacuum pulled toward both wells is equal and therefore there is no net pressure gradient to cause vapor flow. As a result, there is no flow and no contaminant removal from that zone. Contaminants are typically extracted from dead zones by either reducing the amount of vacuum drawn at each well on an alternating basis (pulsed operation) or installing air injection wells at the dead zone. Pulsed operation is also a common operating scenario as the soil concentrations decrease and the site becomes diffusion limited.

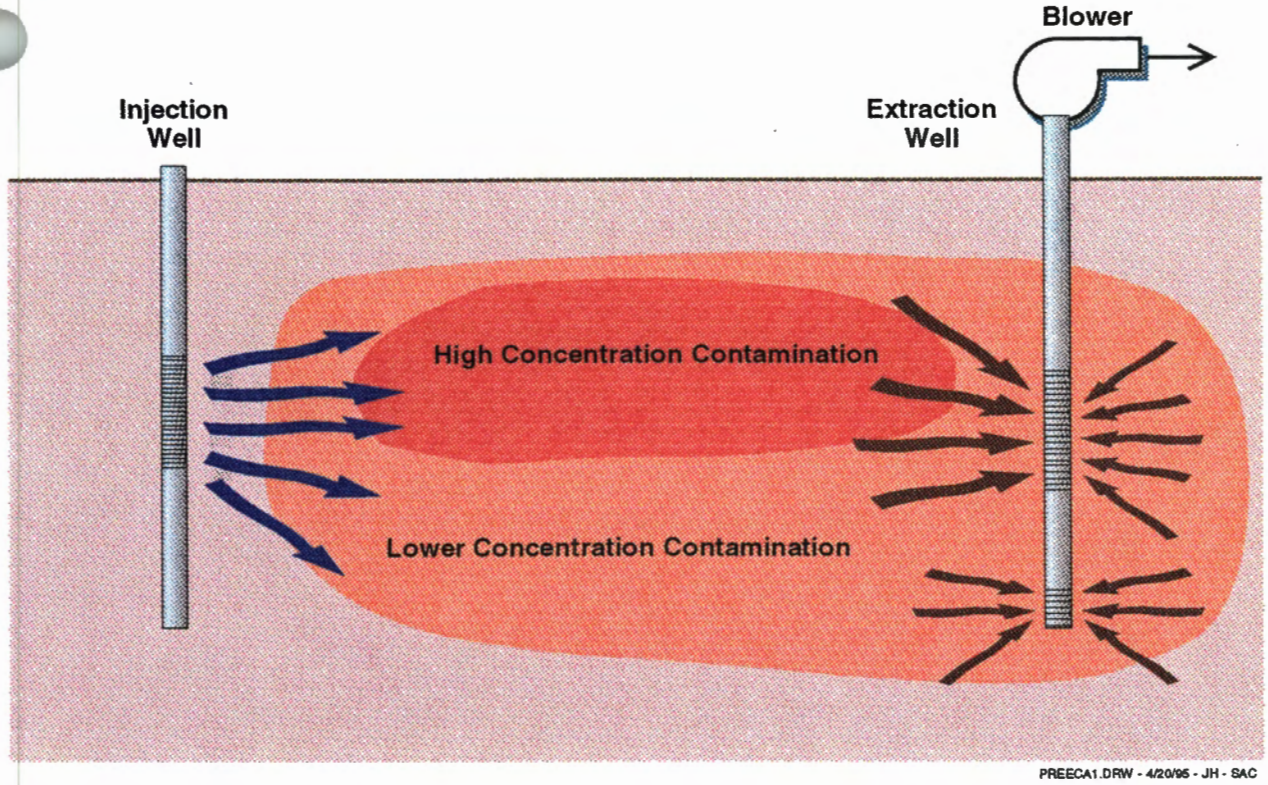


Figure 3-5. "Targeted" Air Flow

Air injection wells should be considered as options that are designed to specifically address conditions where SVE alone is not sufficient. These conditions would include cases where:

- Eliminating flow from the other side of the injection well is desired to avoid drawing contamination from an adjacent site;
- Eliminating "dead spots" where pulsed operation is not feasible or is not allowable;
- Using where "targeted" air flow is desired; and
- Using hot air or steam injection to increase the soil temperature.

SVE systems without an air injection well will typically draw all or most of their vapor from the contaminated zone. This will typically be more efficient and cost-effective than cases where an air injection well is used. All air injection wells should be equipped with flow monitoring and control devices so that the amount of air can be regulated.

Figure 3-4 shows a schematic of a SVE system that includes an optional injection well.

3.5.2 Collection System

The collection system consists of the piping, manifold, knockout pot and auxiliary equipment for transporting the extracted vapors from the wellhead to the vacuum blower. The piping from the extraction wells to the manifold is typically either PVC or steel pipe, although other types of piping can be used. The transfer piping should be equipped with some method of measuring and regulating flow and vacuum, and for taking vapor samples. This will allow for fine tuning of the extraction well network to collect the most contaminants in the least amount of time.

The pipe and manifold sizing should be determined based on the allowable pressure drop in the lines and fittings given the blower sizing and the required well vacuum. Additional consideration should be given to the external conditions that may impact the transfer lines such as climate and installation operations. Consideration should also be given to how condensate will be collected from the piping and manifold system (e.g., collection lines).

The knockout pot function is to remove entrained liquid from the vapor stream prior to the blower and subsequent vapor offgas treatment systems. Entrained liquids can have an adverse effect on the downstream systems in two ways; erosion of the blower system and increased costs for vapor treatment. Increased costs for vapor treatment come from either increased energy costs to vaporize and heat the liquid in a thermal system or by adsorbing on carbon sites in carbon systems and reducing the capacity for VOC adsorption.

The knockout pot functions as a wide spot in the transfer system were the flow velocity is reduced to a point were liquids will no longer be entrained in the stream. A knockout pot is typically equipped with a mist eliminator and liquid pumps run on level controls to send the collected water to appropriate treatment or disposal systems.

3.5.3 Vacuum System

The primary design parameter for the vacuum blower will be the required vacuum and air flow in the extraction wells. This will need to be combined with the pressure losses in the wells and transfer systems and

the back pressure from the downstream processes. Based on the estimated vacuum and flow rate required, either a centrifugal blower or liquid ring vacuum pump will be selected. EPA's SVE Handbook provides general guidelines for a vacuum of 2 inches to 4 inches Hg for gravelly and sandy soils, 3 inches to 8 inches Hg for thick topsoil, and up to 14 inches for clayey soil to produce an equivalent air flow rate. Once the flow and vacuum requirements of the system have been determined, the actual sizing of the equipment is typically done using vendor information such as pump curves and capacity data. The blower(s) should also be equipped with automatic control systems to shutdown the system if key design parameters are exceeded, e.g., high outlet pressure, high load or current, or pressure differential between the blower and the treatment system.

Safety is also a key design issue. The potential for flammable or explosive gases or liquids in the system should be considered early in the process and the system designed appropriately if this potential exists. Consideration of the change in the lower and upper explosive limits under reduced pressure conditions should be accounted for in the system design.

3.5.4 Vapor Treatment

Regulations typically require that the effluent gas from the SVE blowers be treated to destroy or remove the contaminants from the vapor stream prior to discharge. The appropriate regulatory agency should be consulted early on in the process to determine the control level required for the system. Four offgas treatment technologies are discussed in the following sections:

- Adsorption on granular activated carbon (GAC);
- Catalytic oxidation;
- Thermal incineration; and
- Biodegradation.

Each of these technologies/methods have been used commercially, although the systems that generally have been determined to be the most cost effective for the range of concentrations and contaminants usually encountered are GAC and catalytic oxidation. Figure 3-6 provides a representation of the typical concentration ranges where the technologies are most applicable and cost effective. As can be seen in this figure, the concentration range of 10-200 ppmv is the least cost effective. A brief summary of how each technology works along with key issues are provided below.

The range of anticipated soil vapor concentrations that will be encountered throughout the project should be considered when selecting a vapor treatment system. This may result in sequential implementation of more than one treatment system (e.g., catalytic oxidation while high removal rates are occurring followed by activated carbon when the concentrations drop off). If SVE is to be used at multiple sites, it may be the most cost effective to have mobile treatment systems so that one treatment system can provide the vapor control sequentially at multiple sites, thus reducing capital costs.

3.5.4.1 Adsorption on Granular Activated Carbon

Adsorption on GAC occurs by a physical/ chemical process in which Van der Waal's forces bind the molecule to available adsorption sites on the carbon surface. GAC is used because its high surface area allows for significant adsorption over a wide range of concentrations and chemicals. The

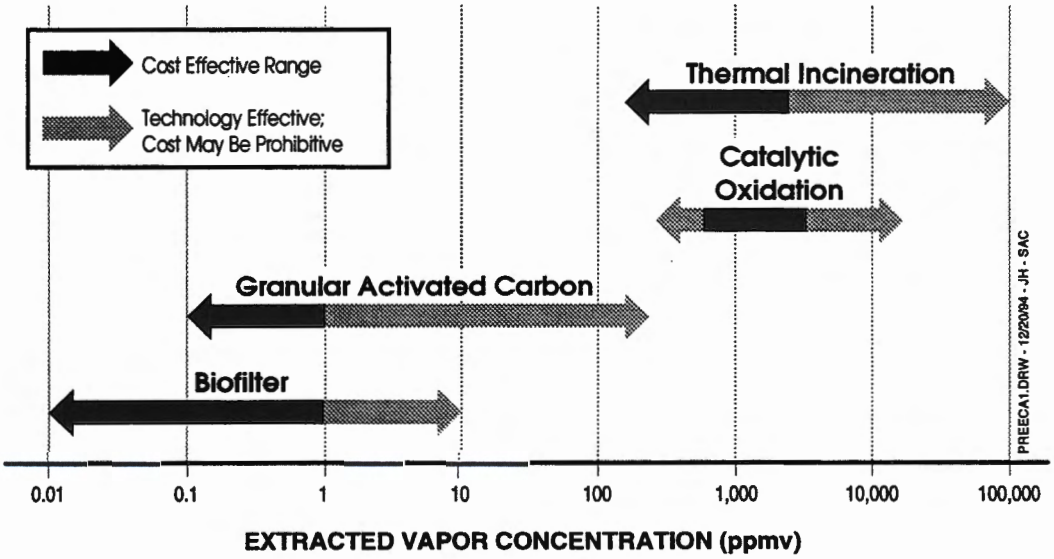


Figure 3-6. Applicability of Vapor Treatment Options

amount of adsorption is determined by the chemical, temperature, and pressure at which the adsorption takes place. The adsorptive capacity is typically shown as an isotherm of pounds contaminant per pound carbon at various constant temperatures over a range of pressures for specific chemicals. Interactions with other chemicals, including water in the form of high humidity, can also impact the chemical specific isotherms by taking up available adsorptive sites. Relative humidity greater than about 50% can begin to significantly reduce the carbon capacity. Vapor is typically heated to reduce the relative humidity when it exceeds 50%. Breakthrough occurs when the capacity of the carbon is exhausted and the contaminant begins exiting the carbon bed. Breakthrough rates are specific to each individual chemical.

If flow, concentration, temperature, and pressure data are provided, carbon vendors can provide an estimate of the capacity and anticipated life of a carbon bed. For complex mixtures, a bench scale test may need to be conducted to better determine the carbon capacity. Vapor is typically heated to reduce the relative humidity when it exceeds 50%. Carbon costs, including disposal/ regeneration and shipping, combined with the anticipated life should be included in the cost evaluation used to compare GAC with alternative control technologies. If carbon purchase and disposal costs become high enough, on-site regeneration may be cost effective using steam or hot air to desorb the contaminants. The contaminant vapors are typically condensed to liquid form and sent to disposal.

Catalytic Oxidation

Catalytic oxidation thermally oxidizes the contaminant molecules primarily to carbon dioxide and water (and acid gases such as HCl and HF if halogens are present). This is done by passing the vapors over an inert catalyst bed typically consisting of a precious metal impregnated on a substrate. The catalyst allows the reaction to occur at much lower temperatures than during normal combustion processes. These systems typically operate at between 700 and 900 degrees F and as a result produce low levels of nitrogen oxides (NOx), and require less energy to operate than conventional thermal incineration. Depending on the energy content of the contaminant stream, the catalytic oxidation system may be able to operate without supplemental fuel. The efficiency of these systems is often enhanced by preheating the inlet vapor stream using heat exchange from the offgas stream. Direct-fired natural gas burners are normally used for start-up and any required supplemental energy. Because of the catalyst costs, catalytic oxidizers usually will have a higher capital cost than a thermal oxidizer although the operating costs are usually lower.

A key consideration for catalytic oxidation systems is the potential for catalyst poisoning or erosion. Materials such as halogens, heavy resins, or heavy solvents can poison or mask the catalyst material requiring either periodic cleaning or costly premature replacement of the catalyst bed. If acid gases are expected (e.g., HCl from chlorinated hydrocarbon combustion), the combustion and downstream components will have to be made out of corrosion resistant material and an acid gas scrubber will be required. Vapor streams containing high particulate levels can have a similar effect by eroding the catalyst material off of the substrate. Additionally, the concentration of the contaminant must be below 25% of the LEL to make sure that the combustion reaction does not get too hot and melt the catalyst (EPA, 1986).

Thermal Oxidation

Thermal oxidizers can be compact and relatively inexpensive. As shown in Figure 3-6, thermal oxidizers are usually more cost effective than carbon or catalytic oxidizers if the concentrations and energy content of the vapor stream are high. The oxidation reaction occurs as a result of direct heating, usually by a gas fired burner, to temperatures of 1400 degrees F or higher. If the energy content is high enough, the system can sustain combustion without the use of supplemental heating.

Thermal NOx can be formed at these temperatures although advances in low-NOx burners have significantly reduced the NOx emissions levels generated by these units. As with catalytic oxidizers, if halogenated VOCs are combusted and acid gases are produced, the system will have to be made of acid resistant materials.

Biofilters

Biofilters are typically soil or compost media that contain microorganisms that are able to degrade the chemical or chemicals of concern. This occurs first by absorption of the VOC molecule into a moist liquid film in the pore spaces of the media where they are metabolized or destroyed enzymatically by the microorganisms. Biofilters have been used extensively for odor control in the sewage treatment industry and have recently been used as offgas control for VOC waste streams. The difficulty in implementation of a biofilter system are those typical of keeping microorganisms alive, including pH, nutrient levels, an adequate carbon source, moisture content, and a relatively constant food source. Often biofilters have limited ability to handle effluent vapor streams with widely varying constituent concentrations. In order to maintain adequate residence time in the bed, the biofilter size often has to be quite large and may be constrained by space considerations. The advantages of the system are that it can obtain high destruction efficiencies for very low costs.

3.6 SVE Operations

Typical SVE system operations will move through a number of phases as shown in Figure 3-3. This requires that the operator routinely assess the performance of the system and make appropriate modifications. Figure 3-7 shows a typical decision loop for the process.

The primary data used to monitor for operational changes will be the extracted gas contaminant concentrations, flow rates, acid gas generation, and system pressures. These data will typically be converted to removal or extraction rates, and the extraction rate used to determine if enhancements or modifications to the system are required. When the remedial objectives appear to have been met based on the extraction rate data, confirmation soil or soil vapor samples are typically taken to verify that residual concentrations are below acceptable cleanup levels. If the site appears to meet the appropriate clean-up levels then it would proceed towards closure.

3.7 SVE Capital and Operating Costs

The capital cost for an SVE system is primarily dependent on the number of extraction wells to be installed and the corresponding vapor flow rate that will be generated from the well. Table 3-2 provides an estimate of SVE system component costs for a typical system. The cost estimates are provided both as a unit cost and as a total cost. The design basis used for this cost would be for a small system of one extraction well, one air injection well, and less than 200 standard cubic feet per minute

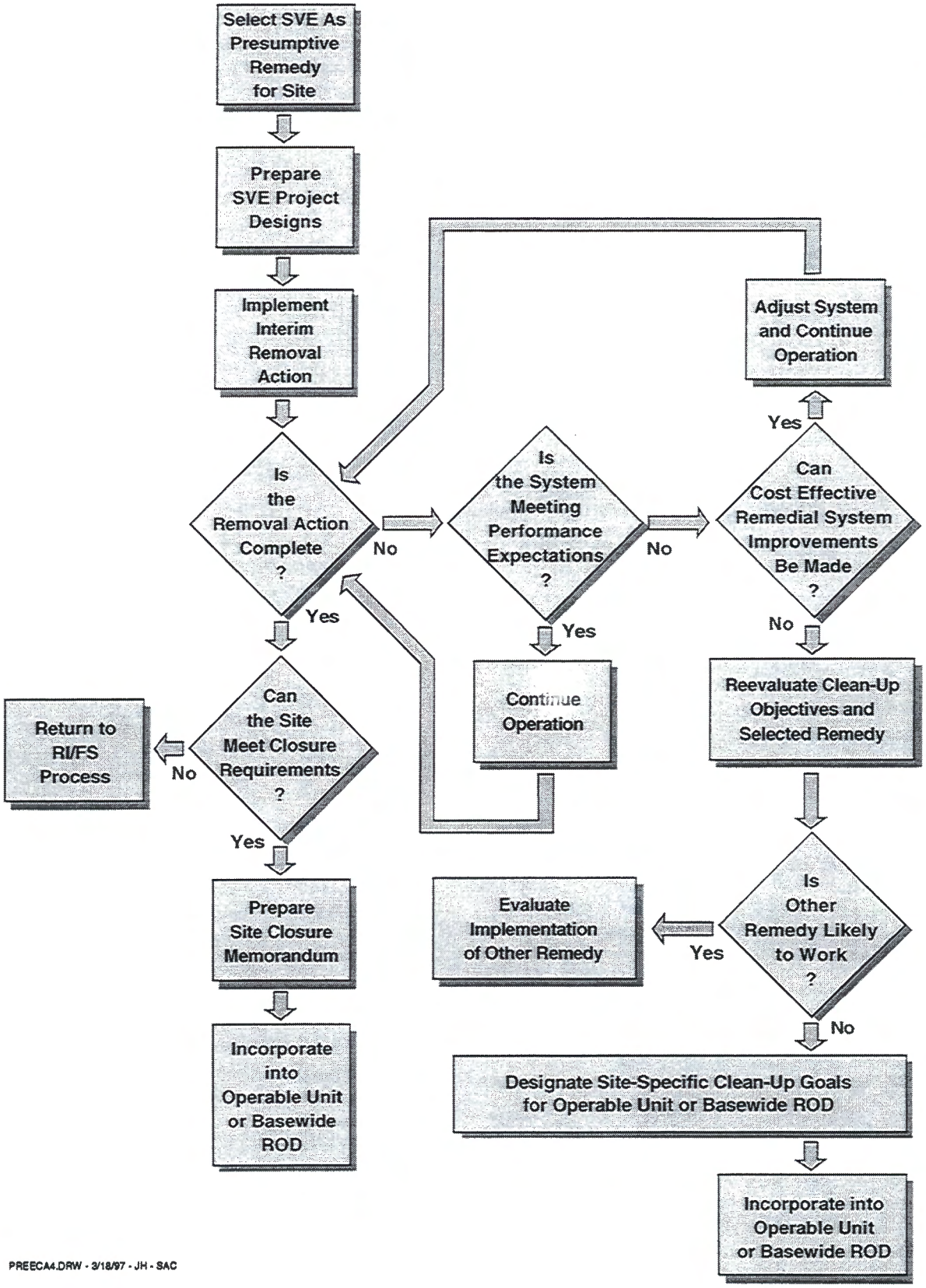


Figure 3-7. SVE Implementation and Operations Flow Diagram

Table 3-2. SVE System Capital and O&M Costs

Item	Design Basis	Unit Cost (Cost Ranges)	Item Cost	Source[1]
Extraction Well Installation	1 well, 100 ft total depth (range)	$100/ft ($75-$120/ft)	$10,000	2 1,2,3
Well Piping & Manifold	200 ft, 4-8" PVC pipe, fittings, supports, and installation	$30/ft	$6,000	1,2
Air Water Separators	1 unit 160 scfm (range 160 – 2,000 scfm)	$600 ($600-$4,000)	$600	2 1,2
Blowers	1 unit 160 scfm (range 160 – 1,600 scfm)	$2,800 ($2,800-$17,000)	$2,800	2
Emission Control Options	Cat Ox for 160 scfm (Cat Ox 800 scfm) (Cat Ox 1,600 scfm) (Carbon 2,000 lbs; 600 cfm) (Steam regen. Carbon – 3 beds) (Auto regen. Carbon beds) (Thermal oxidizer 100 scfm) (Thermal oxidizer 570 scfm)	$180,000 $275,000 $570,000 $11,000 $32,000 $149,000 $23,000 $40,000	$180,000	2 2 2 3 3 3 3 3
Vadose Zone Monitoring	100 ft depth, 2 vzmc/well	$110/ft	$22,000	2
Cluster (vzmc) (3 distinct wells/cluster)		($75-$120)		1,2,3
Injection Wells	1 well, 100 ft total depth (range)	$100/ft depth ($75-$120/ft depth)	$10,000	2 1,2,3
Site Preparation Grading/Equipment Platform	 2,000 ft^3 subgrade concrete	 $6.00/$ft^2$	 $12,000	1
Gas Connection	1,000 ft of 2" polyurethane	$7.50/ft	$7,500	1
Electrical Connection	1,000 ft of buried 4" cable	$5.00/ft	$5,000	1
Transformer	12 Kv to 440 v unit	$13,000	$13,000	1
Water Connection	1,000 ft of buried 2" pvc	$14.00/ft	$14,000	1
Construction Cost Subtotal			**$282,900**	
Bid & Scope Contingents	30% of construction cost (15%-30 %)		$84,880	2 2
Engineering/Design	10% of construction cost (8%-20% of construction cost)		$28,290	1 1,2,3
Mobilization	10% of construction cost		$28,290	1
Permitting and Legal	2% of construction cost		$5,660	2
Services & during construction	8% of construction cost		$22,630	2
Total Capital Costs			**$452,650**	

Table 3-2. (Continued)

Item	Design Basis	Unit Cost (Cost Range)	Item Cost	Source
Natural Gas	Cat Ox Operation – 5,000 therms/yr	$0.60/therm	$3,000	2
Electricity	Power for blowers and use at Cat Ox system	$0.075/kwh	$35,000	2
Water	40 gph[2] x 650 hr/mo x 12 mo/yr	$1.00/10^3 gallon	$312	1
Scrubber Chemicals	17 lb/hr[2] x 650 hr/mo x 12 mo/yr	$0.10/lb	$13,200	2
Scrubber Residual Disposal		$800/each	$800	2
Catalyst Replacement	Annualized cost	$2,400/yr	$2,400	2
Labor (Operations)	80 hr/month	$70/hr	$67,200	
Analytical	Quarterly VZMW Sampling Monthly off gas inlet & outlet, K.O. Water and scrubber blowdown 10% QA/QC samples		$115,000	2
Reporting	1 monthly operations report and $6,000 month prorating of summary report		$72,000	1,2
Total O&M Costs			**$308,900**	

[1] Data Sources: 1 = McClellan AFB, 1993; Basewide Engineering Evaluation – Cost Analysis for Soil Vapor Extraction
2 = McClellan AFB, 1994; Basewide Vadose Zone Feasibility Study
3 = EPA, 1991; Soil Vapor Extraction Technology Reference Handbook

[2] Ratioed from source 1 by 1/15 based on blower flow rates from source 1.

(scfm) of vapor flow rate. These costs would be on the high end of the anticipated cost range on a per well or per scfm basis as an economy of scale would be achieved for a larger system. The unit costs presented in Table 3-2 also includes cost ranges and information for alternative sizes. The costs in the table provide information to prepare an initial cost estimate for planning purposes if basic system sizing data are available. Total capital costs for this system were $452,650. Annual operating, maintenance, and monitoring costs are estimated to be $308,900. The largest annual cost is $115,000 for analytical work associated with system monitoring.

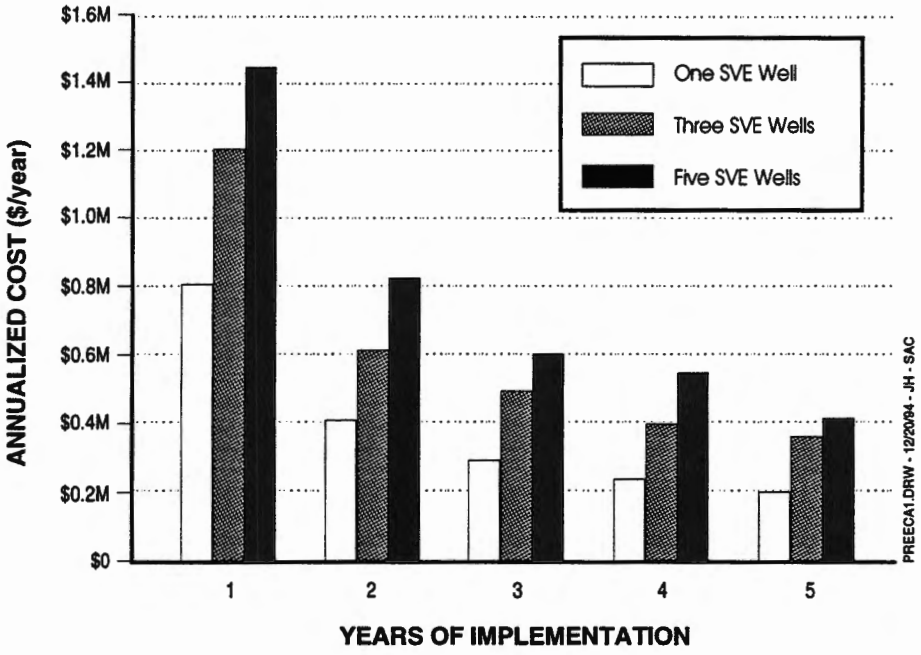
Figure 3-8 shows estimated annualized costs for 1, 3, and 5 wells for 5 years of operation for an SVE system at the Indian Bend Wash Superfund Site in Tempe, Arizona (U.S. EPA, 1993). "Remedial Technology Design, Performance, and Cost Study" (AFCEE, 1992) provides a cost range of from $10 to $40 per cubic yard of contaminated soil. This value will be dependent on the contaminant concentrations, size of the system, and the duration of the remedial action.

3.8 SVE System Enhancements

A number of enhancements to the basic SVE systems can be made to broaden the applicability or improve the performance of the system. These enhancements include hot air injection, steam injection, high vacuum SVE, horizontal extraction wells, capping or surface sealing, or bioventing. Each of these enhancements are designed to overcome specific physical or chemical conditions that make a typical SVE system less viable. If implementation of an enhancement is required to implement SVE at significant cost, a detailed cost analysis and comparison of alternatives should be completed and the system should not be considered a presumptive remedy. Each of the potential enhancements are discussed below:

Hot air or steam injection—Hot air or steam injection are both designed to raise the vapor pressure of the contaminants by increasing the temperature in the contaminated zone. Hot air would typically be generated using a gas fired or electric heater while steam would typically be from a boiler or steam generator. For hot air, the treated exhaust from the blower or the exhaust from a catalytic or thermal oxidizer can be used to minimize the required energy needs. This would involve rerouting a portion of the exhaust gas stream back to an air injection well(s) using insulated pipe or ducting. In the case of steam generation, the exhaust gas could still be utilized to preheat either the inlet water or combustion air for the boiler. It should be noted that steam will eventually condense in the ground and could possibly contribute to increased soil saturation, decreased air permeability, and increased transport of contaminants into the groundwater, if the soil already has a relatively high saturation.

High Vacuum SVE—A high vacuum SVE system typically uses a vacuum pump in place of a blower. This will increase the vacuum levels from about 5 to 15 inches of mercury (in Hg) vacuum to 15 to 25 in Hg vacuum. The higher vacuum will help pull air through higher saturated zones and dewater the vadose zone. This drying effect can also generate soil shrinkage cracks that can also enhance vapor flow. The increased water removal may require the system knockout vessel capacity to be increased. The high vacuum can also be used to extract vapors from formations with low air permeability, which are not highly saturated.



Source: IBW ROD (U.S. EPA, 1993).

Figure 3-8. Annualized Costs for the Soil Vapor Extraction Alternative

- **Horizontal Extraction Wells—** Horizontal extraction wells can be used to enhance contaminant capture if the soil type, contaminant distribution, or the surface land use (e.g., under buildings, roads, or runways) is such that vertical wells would be impractical for extracting the contaminants from the vadose zone. Costs for installing horizontal wells are typically much higher than vertical wells on a "per foot" basis.

- **Capping or ground surface sealing—** Capping or ground surface sealing can be used to minimize air short-circuiting from the surface as opposed to through the contaminated zone. Short-circuiting is most often a problem for SVE systems that are used in shallow zones and where there are high permeabilities to the surface (e.g., sand, soils with preferential flow paths to the surface, etc.). An engineered cap can be expensive as an enhancement but may be required for some land use situations (e.g., traffic areas). Ground sealing using and impermeable membrane or plastic is usually less expensive than an engineered cap but may be difficult to maintain over a long remediation period. **This enhancement should only be considered when surface volatilization of VOCs poses a significant risk to nearby populations; otherwise, it is generally more cost effective to add additional SVE extraction wells.**

- **Bioventing—**Bioventing technology is discussed in detail in other sections of this report as a stand-alone technology. However, biological degradation has not been extensively used on halogenated hydrocarbons and should be considered to be in the developmental stages. If bioventing can be used it can be a low cost method to continue remediation after the point where the concentrations of contaminants are too low for cost-effective SVE operation or at sites with both halogenated VOCs and TPH/ BTEX contamination. The SVE system would remove the VOCs and then can be converted to a bioventing system to remediate the TPH/BTEX. The SVE system can be converted to a bioventing system simply by reducing the air flow rate through the soil to a point where adequate oxygen is being supplied to the soil microbes but where it will not strip volatile compounds into the vapor phase. This configuration results in destruction of the contaminant in-situ often allowing the off-gas treatment system to be shut down and removed.

An estimate of the cost of each enhancement is provided in Table 3-3.

Table 3-3
Cost Estimate of Various SVE Enhancements

Enhancement	Cost of Enhancement
Hot air injection	1.5 to 2.5 times non-enhanced SVE system cost
Steam injection	1.5 to 2.5 times non-enhanced SVE system cost
High vacuum SVE system	1 to 1.5 times non-enhanced SVE system cost
Horizontal extraction wells	1 to 1.5 times non-enhanced SVE system cost
SVE system with ground surface sealing	1 to 1.5 times non-enhanced SVE system cost
Bioventing	0.5 to 1 times non-enhanced SVE system cost
Source: IBW ROD (U.S. EPA, 1993)	

3.9 Annotated References

EPA, 1993. U.S. EPA, Office of Solid Waste and Emergency Response. "Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soil." September. *Provides background and justification for selection of SVE as a presumptive remedy. Also provides comparison of SVE with various evaluation criteria including cost information.*

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U.S. EPA, 1986. "Superfund Public Health Evaluation Manual." EPA 540/1-86/060. *Provides vapor pressure and Henry's Law Constants for a variety of chemicals.*

BIOVENTING
PRESUMPTIVE REMEDY CRITERIA DOCUMENT

2nd Edition

FINAL

PART II: SECTION 4.0

15 MAY 1997

CONTRACT NO. DACA-45-93-D-0027
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BIOVENTING

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4.0 BIOVENTING PROFILE

Bioventing is the process of aerating subsurface soils to promote in situ biodegradation of petroleum-based soil contaminants. Bioventing has widespread application potential because soil microbes are capable of degrading a variety of petroleum products, including jet fuel, gasoline, diesel fuel, and heating oils. Selection of bioventing as a presumptive remedy by the US Air Force was driven by the Air Force's need to remediate approximately 2,000 petroleum-contaminated sites throughout the United States. The Air Force Center for Environmental Excellence (AFCEE) is involved in the operation of several bioventing test sites and has compiled data from these sites. AFCEE's experience forms the foundation of this profile, and supports the following advantages of bioventing:

- In situ treatment greatly reduces the expense and disruption associated with traditional excavation and treatment/disposal methods;
- Bioventing reduces or may even eliminate the expenses of off-gas treatment often required with soil vapor extraction; and
- Bioventing technology is mechanically simple and requires minimal maintenance.

4.1 Bioventing Executive Summary

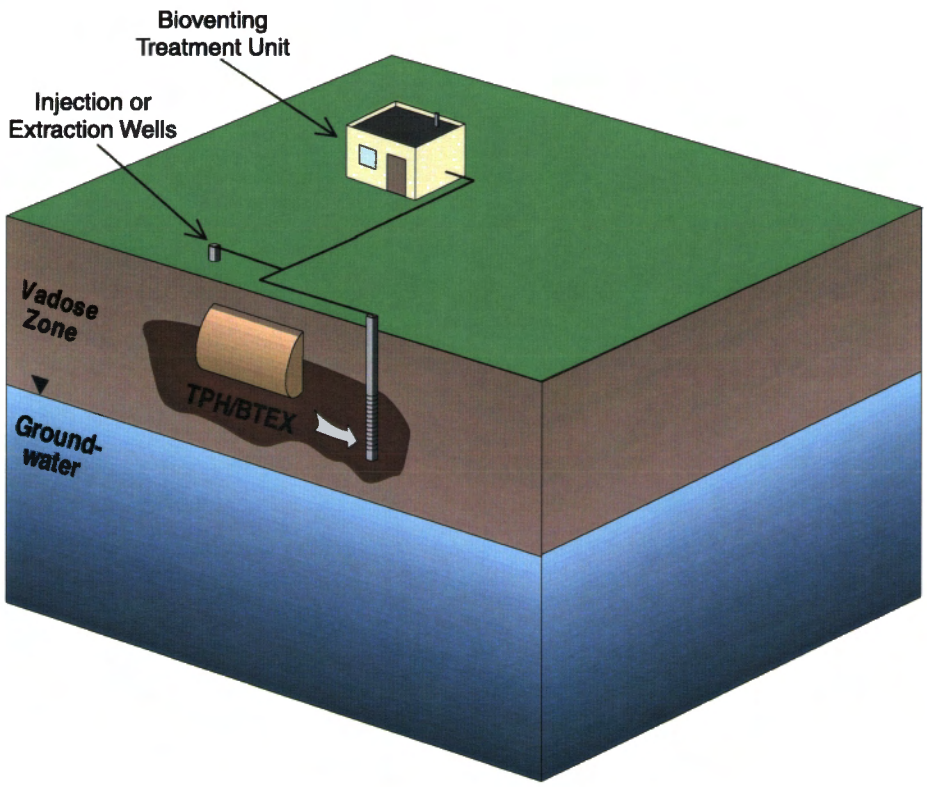
Bioventing is the process of stimulating biodegradation of total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylene (BTEX) in the vadose zone by supplying oxygen to indigenous soil microbes. The oxygen is supplied by either injecting and/or extracting air at low flow rates. Figure 4-1 illustrates a simple bioventing system along with summary information on applicability, site profile data needs, and the presumptive remedy profile. Figure 4-2 provides a decision logic flow diagram that may be used to determine if a site is amenable to bioventing as a presumptive remedy.

Costs to remediate with bioventing range from $10 to $60 per cubic yard of contaminated soil (AFCEE, 1994a). Costs are dependent upon the physical extent of contamination, the contaminant concentrations, and the accessibility of the site.

4.2 Bioventing Description

Bioventing is a technology that stimulates the natural in situ biodegradation of petroleum hydrocarbons in soils by providing oxygen to indigenous soil microbes. It has been shown in almost all cases that these indigenous soil microbes are present at most sites. Petroleum hydrocarbons are generally biodegradable if the naturally occurring microbes acclimate to the fuel as their carbon source and are provided an adequate supply of oxygen and basic nutrients. Natural biodegradation may occur without the aid of a bioventing system, but this is dependent on natural oxygen diffusion rates and is frequently too slow to prevent the spread of contamination. Acceleration of natural biodegradation by providing additional oxygen may be the most cost-effective remediation for hydrocarbon-contaminated sites if remediation is not time-critical. Oxygen is supplied through direct air injection into the soil, through air extraction, or through a combination of air extraction and injection, as illustrated in Figure 4-3. In addition to degradation of adsorbed fuel, volatile compounds are also degraded as vapors

BIOVENTING



CONTAMINANTS

TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contaminated area. Depth to groundwater (thickness of vadose zone). Average soil gas permeability above groundwater.
Contaminant:	Approximate distribution of concentrations. Lateral depth and extent.
Hydrology:	Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes.
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings. Soil pH. Soil nitrogen and phosphorus contents. Soil moisture content. Carbon dioxide and oxygen in soil gas.

APPLICABILITY

Bioventing, as a stand-alone remedy, is applied at sites where the petroleum hydrocarbon and associated BTEX contamination in the vadose zone are the only contaminants of concern.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Fuel, BTEX, or TPH contamination (i.e., non-halogenated hydrocarbon) in the vadose zone;
- Soil permeability greater than 1×10^{-1} darcies;
- Initial soil pH between 5 and 9;
- Initial soil moisture content between 5 and 25%;
- Initial soil total Kjeldahl nitrogen content of 20 mg/kg soil;
- Initial soil total phosphorus content of 3 mg/kg soil; and
- Unsaturated gravels and sands, with minor clays and silts, thoroughly fractured bedrock.

Figure 4-1. Summary of the Bioventing Presumptive Remedy

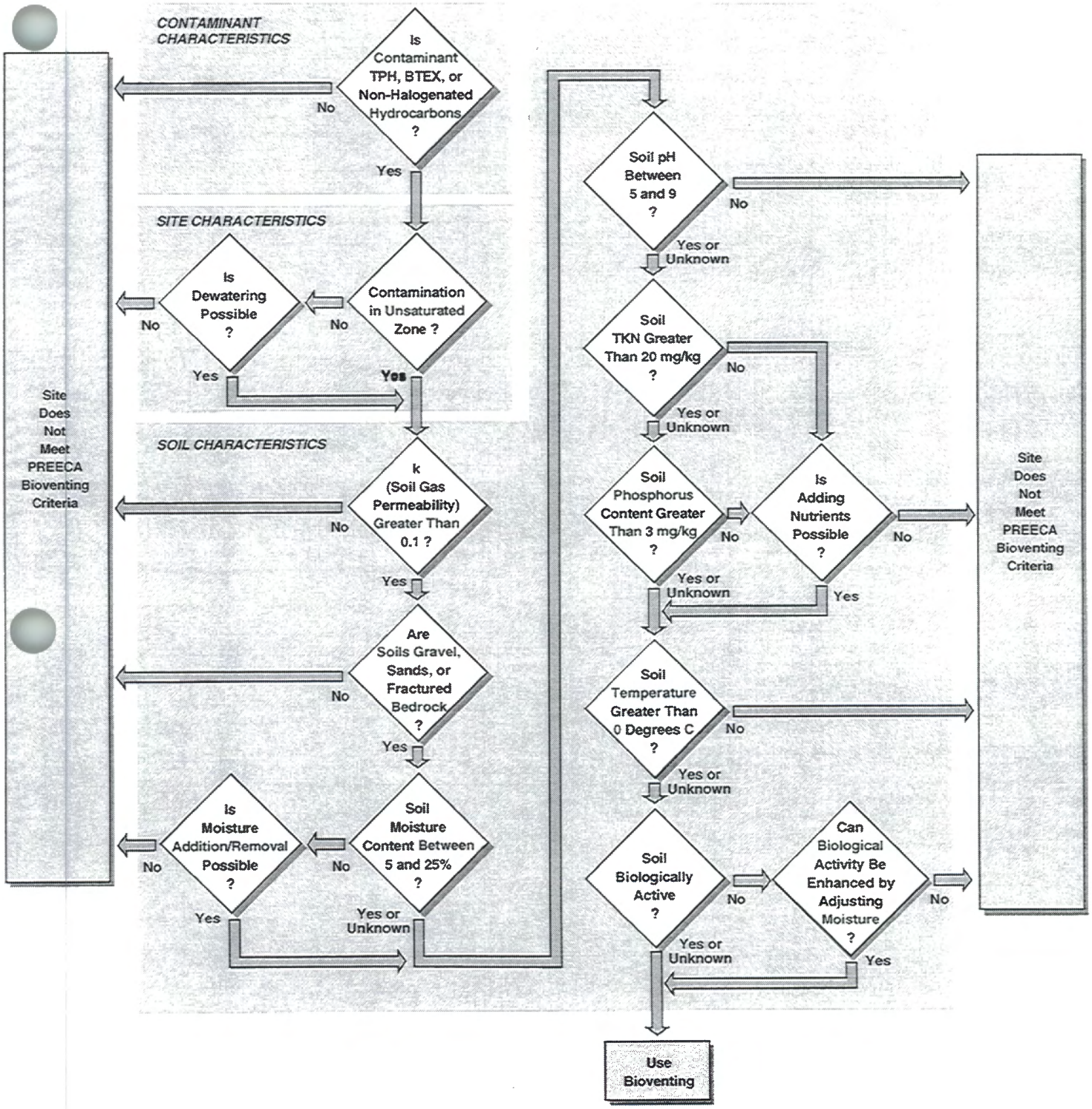


Figure 4-2. Bioventing Decision Logic Diagram

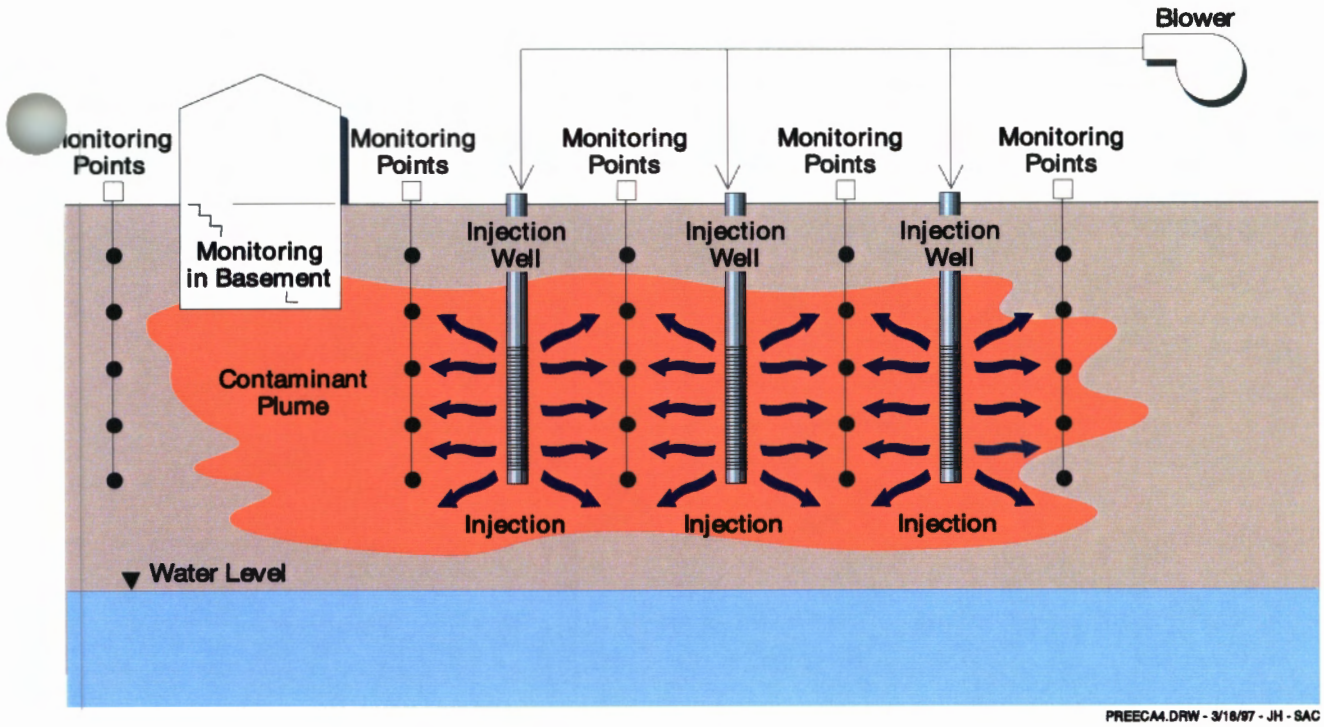


Figure 4-3. Illustration of Bioventing System Components

move slowly through the biologically active soil.

Bioventing is similar to several other remediation technologies, but the difference in technology objectives results in somewhat different system design and operation. Bioventing shares aspects with natural attenuation, enhanced biodegradation, and soil vapor extraction (SVE).

Bioventing, natural biodegradation, and enhanced biodegradation all are based on biodegradation of soil contaminants by soil microbes. Natural biodegradation supplies no additional oxygen or nutrients to in situ microbes, while bioventing transports oxygen with forced air to the vadose zone. Natural biodegradation is limited by oxygen availability, and is much slower than bioventing. Enhanced biodegradation usually occurs in groundwater rather than the vadose zone, and oxygen is usually supplied as hydrogen peroxide or as pure oxygen or hydrogen peroxide dissolved in water. Because sites amenable to enhanced biodegradation are usually not compatible with bioventing systems, enhanced biodegradation will not be discussed further.

Both bioventing and SVE involve venting air through the subsurface, but their primary objectives are different. SVE systems are designed and operated to maximize the volatilization of volatile contaminants. Bioventing systems are designed and operated to maximize aerobic degradation of contaminants with minimal volatilization. The different objectives result in lower air flow rates that provide only enough oxygen to sustain biological activity. While SVE systems may operate at 100 to greater than 1,500 acfm per well, bioventing systems operate at 10 to 50 acfm per well (Dupont, 1993). Also, SVE systems are generally operated continuously. Biodegradation venting systems may be cycled, or "surged," to minimize operating costs and to reduce or eliminate off-gas treatment. When surging a bioventing system, the venting system is operated continuously until the soils are oxygenated to ambient atmospheric levels, then shut off. The system remains off until the soil gas oxygen concentrations have dropped below the level required for aerobic biodegradation (Dupont, 1993). Table 4-1 presents a summary of general design, operational, and application considerations for bioventing systems compared to those of SVE systems. Application considerations are discussed in more detail in Section 4.3.

Several components that may be used in a bioventing system are shown in Figure 4-3 and described below:

- Air blower/vacuum pump.

- Air injection and/or extraction wells placed at the center of the contamination for testing or at the periphery of the contamination for remediation.

- Monitoring points are required to measure oxygen and carbon dioxide concentrations. These monitoring points may also measure hydrocarbon concentrations; however, their primary purpose is to ensure the system operator that enough oxygen is available to the microbes and aerobic degradation is occurring.

- Off-gas treatment, which is frequently activated carbon, but may also be an oxidation unit, biofilter, or other vapor treatment system. For an extraction bioventing system, off-gas treatment is used during the initial startup of the system. Many regulators have allowed the off-gas treatment to be removed after a system has stabilized and the emissions have been shown to meet local air quality requirements. If an off-gas

Table 4-1. Comparison of Bioventing and SVE Considerations

Parameter	Bioventing	SVE
Compound Type	Biodegradable	Volatile at room temperature
Vapor Pressure	—	> 1.0 at 20°C
Henry's Law Constant	—	> 0.01
Depth to Groundwater	—	> 5 ft.
Air Phase Permeability	> 0.1 darcies	> 1 x 10^{-3} darcies
Vent Well Placement	Outside contamination	Within contamination
Operating Mode	Maximum aerobic conditions	Maximum soil gas exchange rate
Operating Flow Rates (per well)	4.6 to 23 actual L/s (10 to 50 acfm)	46 to > 700 actual L/s (100 to > 1500 acfm)
Pore Volumes/d	0.1 to 0.5	1 to 15
Optimal Soil Moisture	5 to 25%	< 60%
Nutrient Requirement	Carbon:Nitrogen:Phosphorus (C:N:P) ≈ 100:10:1	—
Soil Gas O_2 Levels	> 2 vol%	—
Toxicants	Little or none	–

Reference: Dupont, 1993.

treatment unit is not part of the system, air below, above, and around the contaminated zone should be monitored to verify that no contaminants escape the system (Long, 1992).

Once bioventing has been selected (discussed in Section 4.4), it is generally implemented at candidate sites in the following steps described in "Bioventing Performance and Cost Summary" (AFCEE, 1994a).

1. After a work plan and protocol have been prepared, a preliminary soil gas survey is performed to verify that bioventing is necessary, and to determine any areas of low oxygen concentrations. Several sites do not require bioventing—the sites are naturally aerated enough for native microbes to degrade contaminants at a satisfactory rate.

2. Soil and soil gas samples are collected and analyzed to estimate the rate of biodegradation; determine if the soils are permeable enough for oxygen diffusion; and to determine if initial soil nutrients, pH, and moisture are sufficient for biodegradation. If the site is amenable to bioventing, a small air injection test (or pilot test) system is installed and operated for one year. A pilot study may be operated for a shorter testing periods.

3. During the testing period, the site is monitored to determine the oxygen's radius of influence and the respiration rate of the microbes. The respiration rate of the microbes should illustrate whether the contamination is only being moved or dispersed, or if it is actually being biodegraded. At many sites, the radius of influence of a single injection well has encompassed all of the contamination, and full-scale remediation resulted during the 1-year test period.

4. After testing, the soil and soil gas are resampled. The analysis results in recommendations to continue operation of the single injection well, upgrade the system, or sample more soil to confirm that the site may be closed.

4.3 Application Criteria

Test data from 127 Air Force sites has shown biodegradation of fuel and other hydrocarbon contaminants in soils is almost universally enhanced through bioventing. While BTEX and TPH levels are reduced at almost all sites with hydrocarbon-contaminated soils, the selection criteria in Table 4-2 provides site conditions where bioventing is most successful. The decision logic diagram shown in Figure 4-2 may be used in conjunction with Table 4-2. These criteria address contaminant, site, and soil characteristics. They are based on previous and existing bioventing systems with several different site conditions, and represent those sites where bioventing has been consistently successful. For bioventing, it is not always necessary to know every profile parameter. Determining suitability of a site is dependent on the importance of the parameter. Table 4-2 is divided into primary parameters and secondary parameters. To select bioventing, the primary parameters must be known. Although these secondary parameters are important, they are not crucial for choosing this remedy. AFCEE found that most of the 127 Air Force sites tested had these secondary parameters in the range where bioventing is successful.

In cases where site parmeters are unknown, the secondary parameters such as pH may be verified during implementation of the removal action.

Table 4-2. Bioventing Selection Criteria

Criteria	Acceptable Value
Primary Parameters	
Contaminant type	BTEX, TPH, non-halogenated hydrocarbons
Contaminant location	vadose zone, 1 to 100 feet below ground surface
Soil gas permeability (k)	> 0.1 darcies[1]
Geology and soils	Unsaturated gravels and sands with minor clays and silts, thoroughly fractured bedrock
Secondary Parameters	
Initial soil pH	5 to 9
Initial soil moisture.	5 to 25%
Initial soil total Kjedalh nitrogen	≥ 20 mg/kg soil
Initial soil total phosphorus	≥ 3 mg/kg soil
Soil temperature	> 0 degrees Celsius
[1] Soil Gas Permeability: 1 darcy = 1 x 10^{-8} cm^2	

These selection application criteria are used to create the bioventing presumptive remedy profile. This remedy profile is compared to the candidate site profile to determine if the site "plugs-in" to the PREECA. Site profiles and remedy profiles are described in Section 3.0 of Part I of the PREECA. Examples of a remedy profile, a matching site profile, and a non-matching site profile are provided in Table 4-3.

Although a site may not be similar to all of the criteria it may still be effectively remediated by bioventing, the technology selection and evaluation should be more detailed than for sites meeting all of the presumptive remedy criteria. A detailed evaluation should be conducted to determine whether bioventing is the most appropriate technology, or if bioventing should be enhanced or combined with other technologies.

4.3.1 Contaminant Characteristics

Bioventing has been shown to effectively remediate sites contaminated with non-halogenated hydrocarbons. Fuel spills, leaks from underground tanks or pipes, oil/water separators that have overflowed, and other sites contaminated with diesel, oil, jet fuel, gasoline, and petroleum hydrocarbons have shown decreases in BTEX and TPH levels. **At some of those sites, bioventing has successfully remediated the sites to < 5 ppm TPH and < 1 ppm BTEX as shown in Figure 4-4.** Little data has been collected on bioventing treatment of chlorinated contaminants, herbicides, pesticides, nitrates, and sulfates. Also, microbes cannot metabolize metal contaminants.

4.3.2 Site Characteristics

Bioventing is applicable only if the contamination is in an unsaturated zone. The contamination may be either above or below ground water. If the site is saturated, dewatering may be combined with bioventing to remediate the soil, although this situation would require further evaluation. Dewatering is discussed in Section 4-7.

4.3.3 Soil Characteristics

The soil gas permeability should be high enough to provide oxygen to the soil microbes. The darcy value (k) should exceed 0.1. Data for sites with k < 0.1 is very limited. Soil gas permeability is influenced by soil grain size and soil moisture content. Sites composed predominantly of silt and clay show the lowest k values. Figure 4-5 illustrates the relative distribution of fine-grained soil at 98 sites. AFCEE found that even sites composed of 75% to 100% silt and clay may have sufficient permeability to support bioventing (AFCEE, 1994a). Out of the 137 test locations, a combination of

Table 4-3. Bioventing Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Primary Parameters			
Contaminants	Total petroleum hydrocarbons, non-halogenated hydrocarbons, BTEX	Gasoline concentrations in soil; benzene concentrations in soil gas	TCE and carbon tetrachloride concentrations in soil and soil gas
Contaminant Distribution	1 to 100 feet below ground surface in vadose zone	10 to 55 feet below surface in vadose zone	> 100 feet below surface
Geology and Soils	Unsaturated gravels and sands with minor clays and silts; thoroughly fractured bedrock	30 feet of sands with few interbedded 3- to 6-inch silt layers from surface to water table	Silty clay
Average Soil Gas Permeability	> 0.1 darcies	2 to 3 darcies	0.05 darcies
Secondary Parameters			
Average Soil pH	5 to 9	7.5	10.1
Average Nitrogen in Soil (Kjeldahl method)	≥ 20 mg/kg	25 mg/kg	10 mg/kg
Average Total Phosphorus in Soil	≥ 3 mg/kg	6 mg/kg	1 mg/kg
Soil Moisture	*5 to 25%*	15%	70%
Soil Temperature	> 0° Celsius	> 0° Celsius	10° Celsius

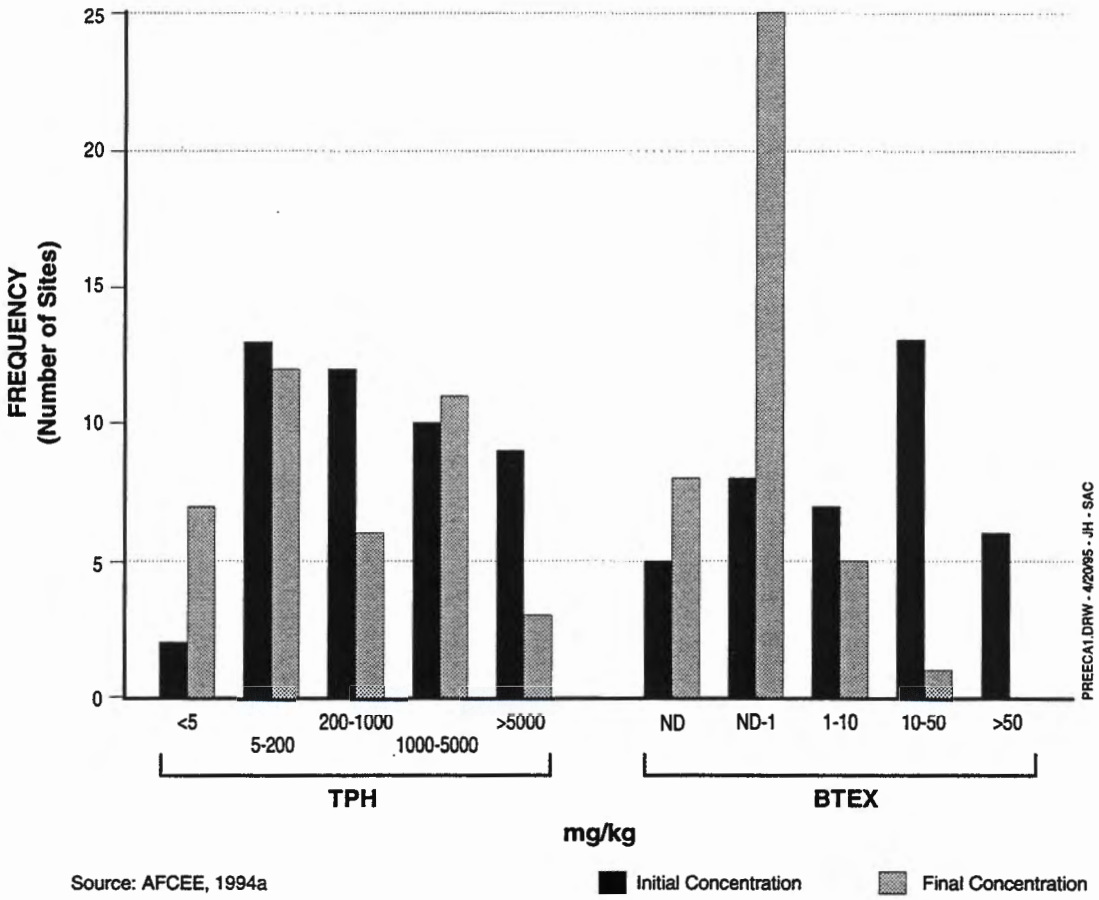
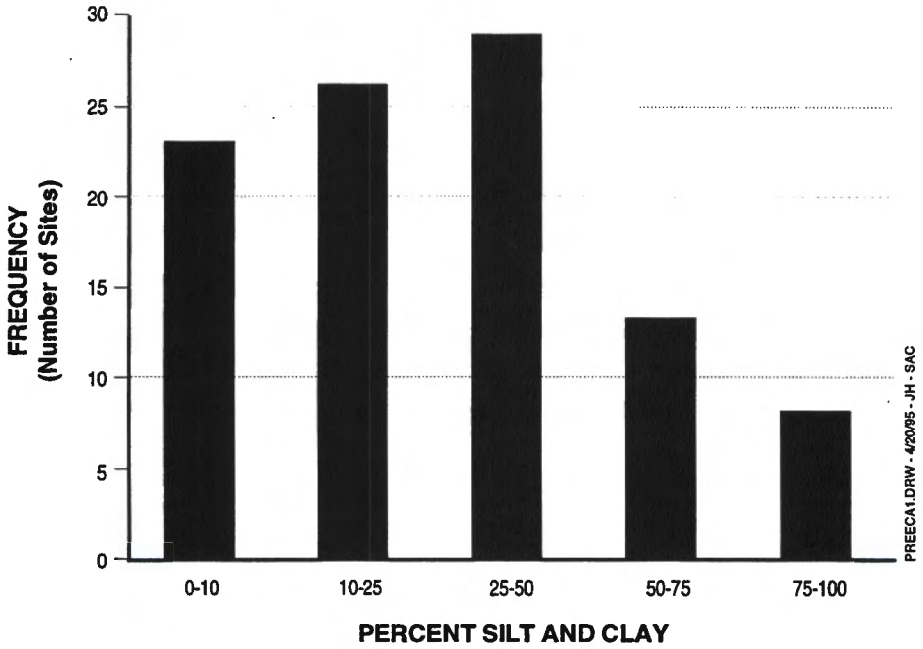


Figure 4-4. Soil TPH Concentration (mg/kg): Initial and 1-Year



Source: AFCEE, 1994a

Figure 4-5. Silt and Clay Content

high moisture content and fine grained soil, which lowered the gas permeability, had made bioventing infeasible at only 2 test locations.

Other soil characteristics necessary to support bioventing are listed below. These are secondary parameters and may be verified during implementation of a pilot study.

- Ideally, the initial soil pH should be approximately between 5 and 9 to support microbial activity. Figure 4-6 shows that many bioventing sites are slightly alkaline. The figure also shows that some bioventing sites fall outside of the optimal range of 5 to 9. Because there are relatively few of these sites, there is not as much data to support bioventing for soils with a pH outside of 5 to 9 (AFCEE, 1994a).

- Ideally, the initial soil moisture content should be between approximately 5-25%. Optimum soil moisture is very dependent on the soil type. High soil moisture content, especially in combination with fine-grained soils, can impede oxygen diffusion. Too little moisture can inhibit microbial activity. Bioventing can work in arid areas with as little as 3-5% soil moisture content, but there is less data to support this. Figure 4-7 shows moisture contents encountered at several bioventing sites (AFCEE, 1994a).

- Initial soil total Kjeldahl nitrogen (TKN) should be around or greater than 20 mg TKN/kg soil. TKN, in addition to phosphorus, are natural nutrients required for microbial activity. Figure 4-8 illustrates that most sites have more than 50 mg TKN/kg in soil (AFCEE, 1994a).

- Initial soil total phosphorus, a natural microbial nutrient, should be around or above 3 mg phosphorus/kg soil (AFCEE, 1994a). The optimal ratio of carbon:nitrogen:phosphorus (C:N:P) has been found to be approximately 100:10:1 (Dupont, 1993).

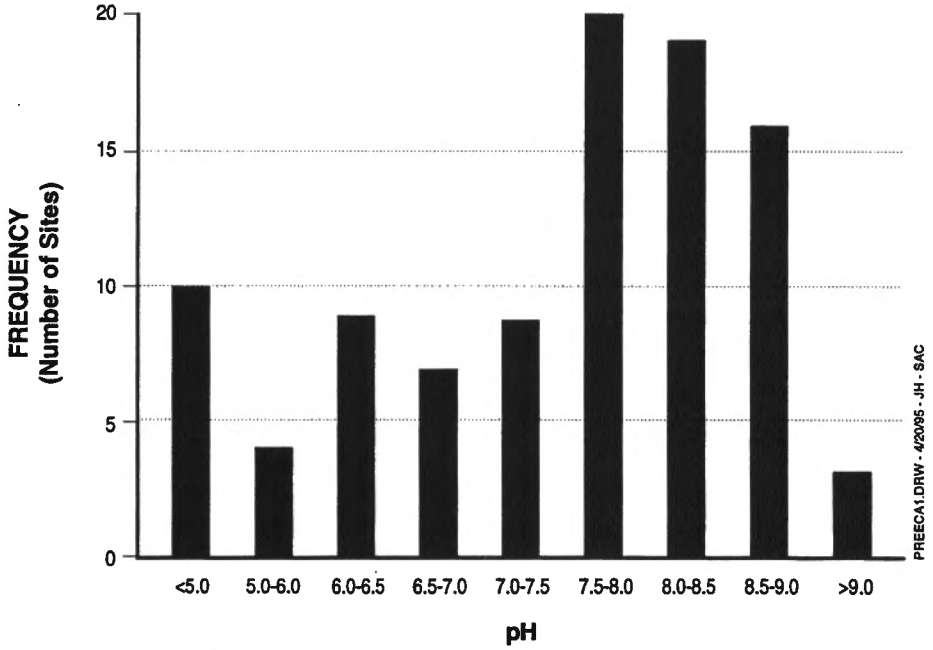
- Soil temperature affects the rate of biodegradation. Biodegradation has been observed between 0° and 25°C, with much faster biodegradation in summer and warmer areas (AFCEE, 1994a, and Leeson, 1993). Depending on time and utilities available, bioventing at very low temperatures may not be cost-effective.

- Soil bioactivity should be quantified to determine the potential for bioventing. This can be done through the analysis of soil gas O_2 and CO_2 composition prior to venting. In general, the more the levels of O_2 are depleted and CO_2 is enriched with respect to background uncontaminated soils at the site, the better the site is suited to bioventing.

Methods for determining bioactivity are described in the literature (Dupont, 1993; Hinchee, 1992a; Downey, 1994). In general, if soil gas and soil core analyses show contamination, but microbial respiration has not yielded O_2 uptake or CO_2 production above background soil levels, microbial activity is inhibited by either toxicants at the site, nutrient limitations, or soil moisture limitations. Unless the microbial activity is hampered by soil moisture limitations, bioventing should generally not be considered. Soil moisture may be increased by watering the site (Dupont, 1993).

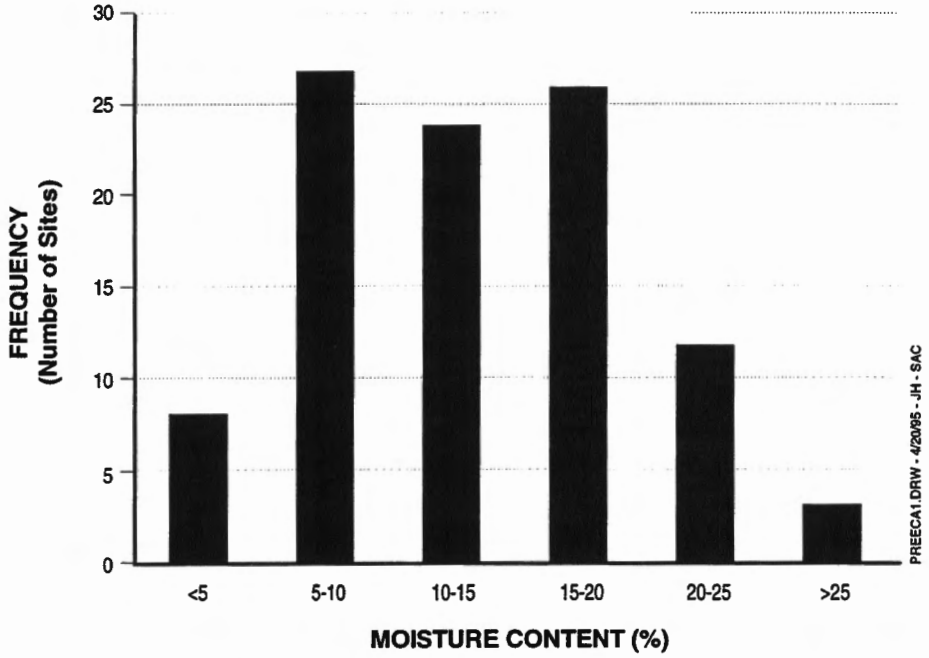
4.4 Limitations

If the selection criteria are met, there are no significant limitations to bioventing;



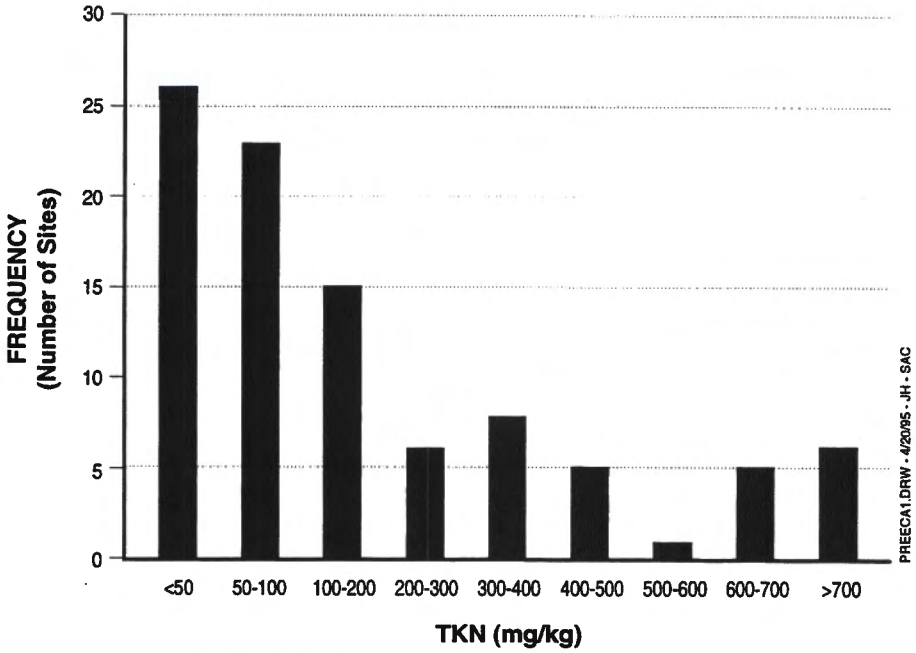
Source: AFCEE, 1994a

Figure 4-6. Initial Soil pH



Source: AFCEE, 1994a

Figure 4-7. Initial Soil Moisture



Source: AFCEE, 1994a

Figure 4-8. Initial Soil Total Kjeldahl Nitrogen

however, site-specific limitation considerations include:

- Remediation time. Bioventing is not a fast treatment option. Contaminant removal rates range from 0.4 to 20 mg/contaminant/kg soil/day (Dupont, 1993; AFCEE, 1994a; Bulman, 1993; Hinchee,1992a). For a spill of 50,000 liters of fuel over 2,000 m^2 to a depth of 2.5 m, bioventing would last from 2 to 11 years. If half of the 50,000 liters could be removed as free product and half of the remaining contamination removed with a SVE system prior to bioventing, the bioventing phase of remediation would last from 6 months to 3 years.

- Obtaining the optimum soil moisture balance. Spring rains or hot dry summers may change the rate of biodegradation, although it is unlikely that microbial activity will cease altogether.

- Alleviating the threat of contaminant volatilization into subsurface structures (basements, cellars, parking garages, etc.). The presence of these structures may necessitate extraction of air near the structure and reinjection at a safe distance. If necessary, makeup air can be added before injection.

- Optimizing airflow. Airflow must be high enough to maintain aerobic conditions for biodegradation, but volatilization should be kept as low as possible.

- Optimizing well placement in conjunction with optimizing air flow. Maintaining a *uniform* O_2 level across the site will minimize stripping soils near the wells, and also minimize oxygen starvation of soils distant from the wells.

4.5 Design Basis

4.5.1 Injection/Extraction Wells

The injection and/or extraction wells and blower system provide airflow through the subsurface. As summarized in Table 4-4, an advantage to injecting air to the subsurface is the reduction of elimination of off-gas treatment. However, the presence of structures may necessitate extraction. Extracting air ensures that volatized compounds will be captured and, if necessary, treated. A combination of injection and extraction provides control in inducing subsurface flow.

Table 4-4. Injection vs. Extraction

Well Type	Advantages
Injection	Little or no off-gas treatment required.
Extraction	Ensures capture of volatilized compounds.

For the first year of operation, only one well is generally installed. The placement and construction of the well for the first year should follow these general guidelines (Hinchee, 1992b):

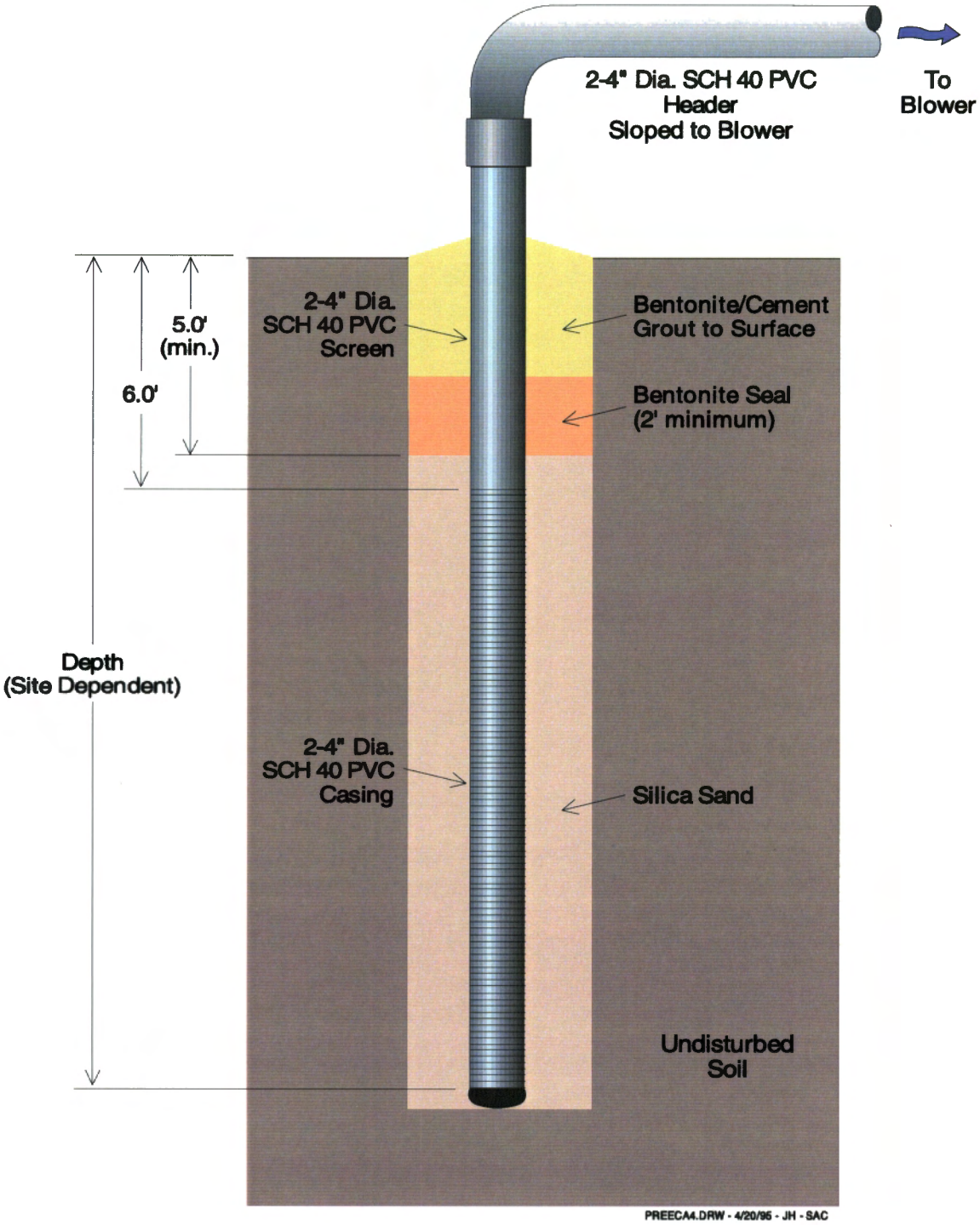
- The well should be located as near to the center of the contamination as possible;

- The diameter should be between 2" and 4", depending on the depth of the groundwater and the ease of drilling;

- The well is normally screened through as much of the contaminated zone as possible; and

- A typical injection well is shown in Figure 4-9.

Future wells are placed along the periphery of the contamination (Dupont, 1993).



Source: Hinchee, 1992b.

Figure 4-9. Injection Well

4.5.2 Air Blower

The type and size of the blower is determined by the soil type, depth and area of contamination, and available power. With a single injection or extraction well, only a single blower is necessary. Two typical blowers that are specified in *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee, 1992b) are described below:

4.5.2.1 Blower 1

- Application: The contamination is in sandy soils and mixed sandy/silt and sandy/clay soils.
- Typical specifications:
  - Explosion-proof regenerative blower,
  - 20 to 90 scfm at 100" to 200" water, respectively,
  - 3 HP explosion-proof motor, and
  - Single-phase 230 volt power source.

4.5.2.2 Blower 2

- Application: The contamination is in predominantly silt and clay soils.
- Typical specifications:
  - Explosion-proof regenerative blower,
  - 50 scfm at 200" water,
  - 5 HP explosion-proof motor, and
  - Single-phase 230 volt power source.

Explosion-proof blowers and motors are required when air is extracted, and may be required for air-injection systems as well. More detail is available in *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee, 1992b), including instrumentation diagrams for injection and extraction. Three-phase motors may also be used in many bioventing applications.

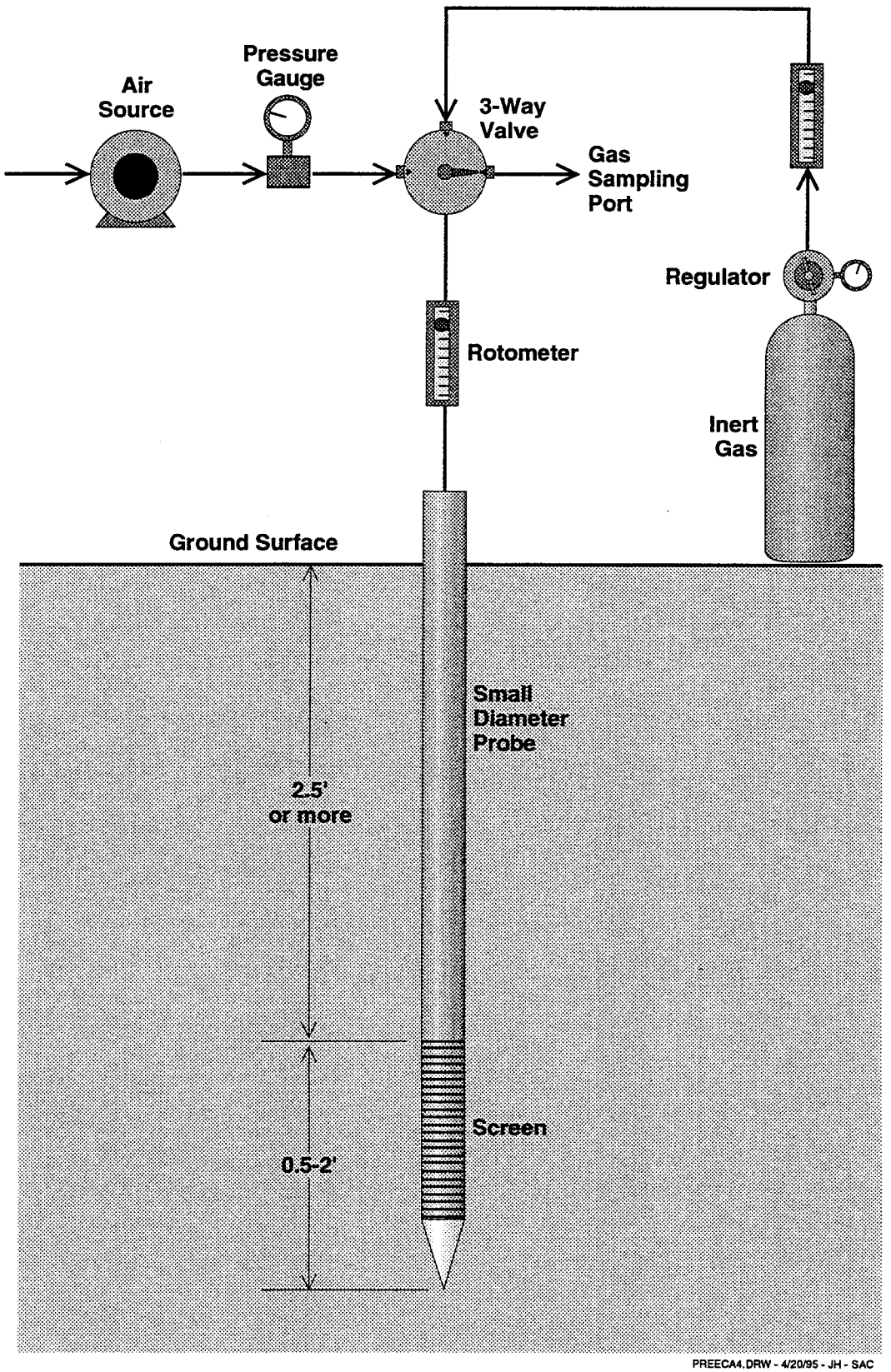
4.5.3 Soil Gas Monitoring Points

Soil gas monitoring points will be used for pressure, oxygen, carbon dioxide, and contaminant measurements. Monitoring points should be installed at a minimum of three locations, with three depths at each location. Depending on site conditions, up to six locations and six or more depths will be necessary. Monitoring points should be located in soils contaminated with > 1000 mg hydrocarbon/kg soil. More detail on monitoring point location, depth, and construction is available in *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee, 1992b). Table 4-5 lists recommended monitoring point spacing, and Figure 4-10 shows a typical gas injection/soil gas monitoring point.

Table 4-5. Monitoring Point Spacing

Soil Type	Depth to Top of Vent Well Screen (ft)[1]	Spacing Interval (ft)[2]
Coarse Sand (k = 100-1,000)	5 10 > 15	5 – 10 – 20 10 – 20 – 40 20 – 30 – 60
Medium Sand (k = 1-100)	5 10 > 15	10 – 20 – 30 15 – 25 – 40 20 – 40 – 60
Fine Sand (k = 0.1-1)	5 10 > 15	10 – 20 – 40 15 – 30 – 60 20 – 40 – 80
Silts (k < 0.1)	5 10 > 15	10 – 20 – 40 15 – 30 – 60 20 – 40 – 80
Clays (k < 0.1)	5 10 > 15	10 – 20 – 30 10 – 20 – 40 15 – 30 – 60

1 Assumes 10 ft. of vent well screen. If more screen is used, use the > 15 ft. spacing.
2 Intervals based on a venting flow rate of range 1 cfm/ft. Screened interval for clays to 3 cfm/ft. Screened interval for coarse sands.
Ref: Hinchee, 1992b



Source: Hinchee, 1992b.

Figure 4-10. Gas Injection/Soil Gas Monitoring Point

4.5.4 Thermocouples

Two thermocouples should be installed at the monitoring point closest to the injection well (Hinchee, 1992b). They should be in at the depth of the shallowest and deepest screen. Thermocouple data may be important for determining temperature-dependencies of biodegradation.

4.5.5 Background Well

The background well is generally used only during the first year to measure background respiration of natural organic matter. It is a test well, and is not installed in the contaminated area. Data from this well do not directly indicate biodegradation of the contaminant, but allow site managers to compare microbial activity in the contaminated area with that in background soil. Soil and soil gas samples from this well yield background carbon, nutrient, O_2, and CO_2, levels and provide data used to determine optimal blower operation.

4.6 Costs

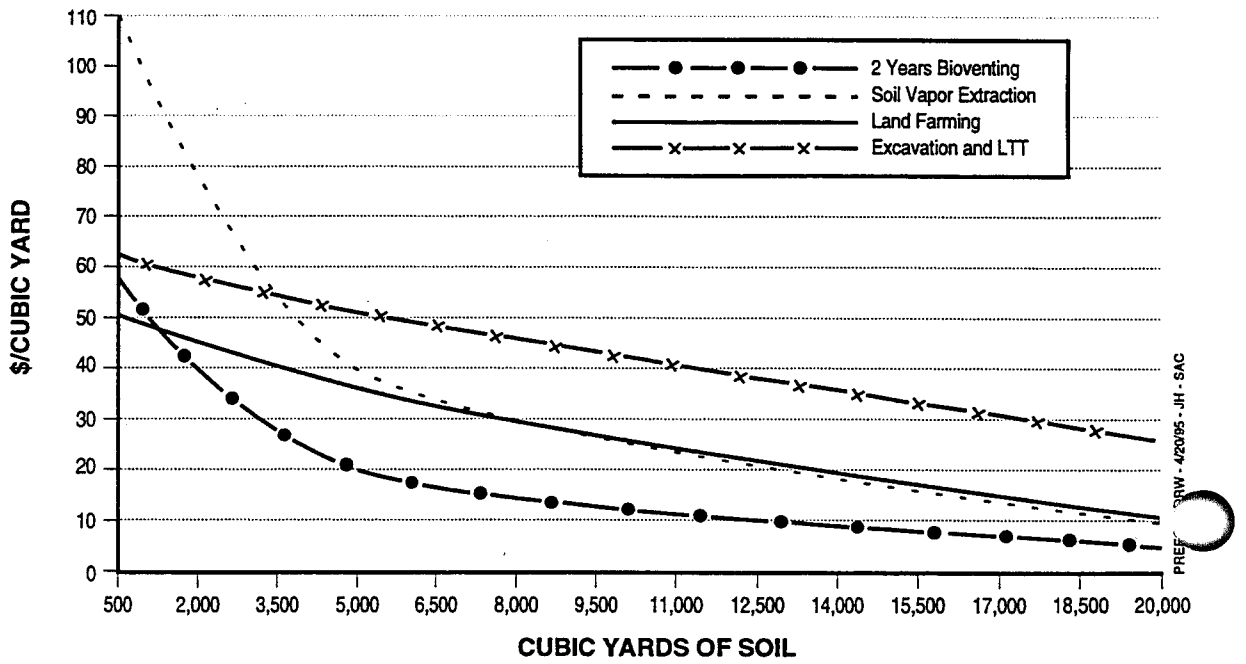
In most situations, bioventing costs compare favorably with SVE costs when utilities are easily accessible. However, bioventing typically lasts much longer than SVE, and at remote sites, bioventing may have much higher total operating costs for the lifetime of the project. The availability of utilities is a significant factor affecting cost. At sites with contamination beneath concrete and buildings, bioventing or possibly SVE may be the only cost-effective treatment option.

AFCEE has determined that the total cost of soil treatment with bioventing is usually between $10 and $60 per cubic yard of soil (AFCEE, 1994). Bioventing at sites larger than 10,000 cubic yards of soil may cost less than $10 per cubic yard, and bioventing at sites smaller than 50 cubic yards may cost more than $60 per cubic yard (AFCEE, 1994). Table 4-6 details costs for bioventing 5,000 cubic yards of soil contaminated with an average of 3,000 mg of JP-4 per kilogram of soil.

Table 4-6. Bioventing Costs

Task	Total $
Site Visit/Planning	5,000
Work Plan Preparation	6,000
Pilot Testing – One bioventing well (15' deep) – One background well (15' deep) – Blower – Site Preparation – Soil gas sampling (VOC, O_2, CO_2)	37,000
Regulatory Approval	3,000
Full-Scale Construction (4 bioventing wells, 15' deep; 4 monitoring wells, 15' deep): – Design – Drilling/Sampling – Installation/Start-up	 7,500 20,000 8,000
Soil Gas Monitoring for Two Years – VOCs – O_2 – CO_2	6,500
Power for Two Years	2,800
Soil Sampling at Two Years – VOCs – O_2 – CO_2	13,500
TOTAL	**$109,300**

Figure 4-11 is a comparison of the remediation cost per cubic yard of soil for bioventing, land farming, excavation/ treatment, and SVE. All costs are based on treating soil contaminated with 3,000 mg of JP-4 per kilogram of soil. The costs for SVE assume thermal destruction of collected vapors. The costs assume utilities are available, and do not include reconstruction of excavated areas.



Source: AFCEE, 1994a

NOTES:
1. Based on treating soil contaminated with 3000 mg JP-4 per kg soil.
2. Assumes thermal destruction of VOCs with SVE system.
3. Assumes utilities available.
4. Does not include costs for reconstruction of excavated areas.

Figure 4-11. Bioventing and Soil Vapor Extraction Comparative Costs

4.7 Enhancements

Bioventing may be enhanced by:

- Dewatering (lowering the water table). Dewatering may be desired if, for example, free product depresses the water table, and is smeared over several feet of soil during its removal, as it was at the site of a diesel spill in Australia (Bulman, 1993). After removal of the free product, the groundwater rose and covered the smeared area. To biodegrade in the smeared area with bioventing, the site was dewatered.

- Adding nutrients. The addition of nutrients usually increases microbial activity in bench-scale tests (McGinnis and Lee, 1994), but benefits have not been demonstrated for in situ biodegradation. Oxygen is usually the limiting element of in situ biodegradation of contaminated soils, rather than nitrogen, phosphorus, or carbon. A carbon source (the fuel) is readily abundant in contaminated soils. Additions of nutrients at Tyndall AFB, FL, Hill AFB, UT, and other sites have resulted in little apparent increase in hydrocarbon degradation rates (AFCEE, 1994a; Dupont, 1991), although nutrients have helped at an Australian site (Bulman, 1993). Although not all sites should be expected to have the optimum ratio of C:N:P = 100:10:1, the challenges associated with efficiently and cost-effectively delivering additional nitrogen or phosphorus prevent its widespread use.

Bioventing may also use more complex air delivery systems than simple injection or withdrawal. Subsurface structures and/or noise considerations may suggest injecting (or extracting) air distant from the site while extracting (or injecting) air at the contaminated site.

4.8 Annotated References

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CAPPING
PRESUMPTIVE REMEDY CRITERIA DOCUMENT

2nd Edition

FINAL

PART II: SECTION 5.0

15 MAY 1997

CONTRACT NO. DACA-45-93-D-0027
PROJECT NUMBER: MUHJ947065

CAPPING

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ATTACHMENT 1 – Guidance for Remediation and Closure (Capping) of Landfills

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5.0 CAPPING

5.1 Capping Executive Summary

The capping remedy consist of placing an engineered, low permeability cap over areas of contaminated soil. The primary purposes of caps are to eliminate surface exposure pathways and minimize leaching of contaminants to groundwater by reducing the infiltration of precipitation. Figure 5-1 provides an illustration of the capping remedy along with summary data on applicability, site profile needs, and the presumptive remedy profile. Figure 5-2 provides a decision logic flow diagram that can be used in determining if a site is suitable for the capping presumptive remedy. Typical caps commonly used are multi-layer RCRA and non-RCRA caps: soil & clay caps, asphalt caps, and concrete caps.

Capital cost for caps typically range between $1 and $12 per square foot of contaminated soil area. Capital costs are primarily dependent on the size of the cap and the type of cap selected. Maintenance and monitoring (O&M) cost vary slightly for each type of cap, but are primarily dependent on the size of the cap and the frequency of required monitoring. Detailed cost information is provided in Section 5.12 of this document.

5.2 Capping Technology Profile

Containment has been determined to be the presumptive remedy for municipal landfills by the U.S. EPA. This determination is documented in "Presumptive Remedies for Municipal Landfill Sites" (U.S. EPA, 1992). Inclusion of capping (as a component of containment) as a presumptive remedy is based on extensive experience with capping being chosen as the selected technology in numerous Record of Decisions (RODs) at landfill sites. Application of this presumptive remedy for military sites is provided in "Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills" (U.S. EPA, 1996).

Capping, as a component of containment, may also be considered a remedy for sites with dense, nonaqueous phase liquid (DNAPL), semivolatile, or metal contamination in the vadose zone. Sites with high or imminent risk of surface exposure from contaminants, or migration of contaminants to surface water or groundwater, are probable candidates for capping.

Capping has a number of benefits as a containment remedy including:

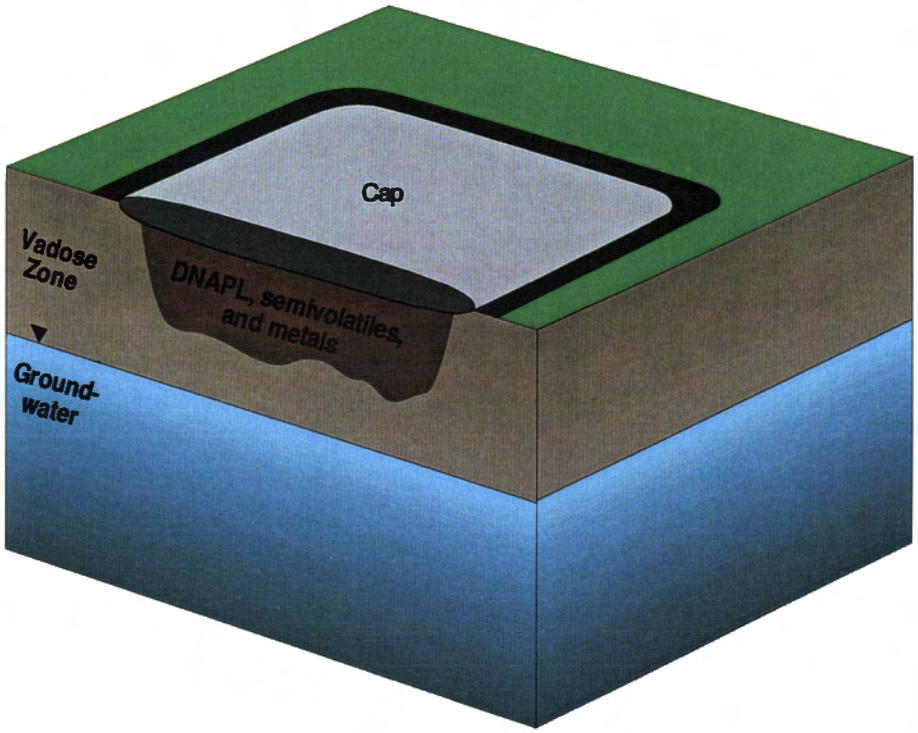
- Eliminates surface exposure (including control of released landfill gases);
- Eliminates migration of contaminants to surface water by controlling surface run-off and erosion;
- Minimizes leaching of contaminants to groundwater by reducing infiltration of precipitation;
- Cost-effective remedy for large volumes of landfill or contaminated soils; and
- Cost-effective remedy for landfills or contaminated soils that lie deep below ground surface.

Capping is an appropriate technology if many of the benefits meet the candidate sites' removal action objectives.

5.3 Capping Technology Description

Surface and subsurface contaminants have the potential to pose human health risk or threaten surface water or groundwater

CAPPING



CONTAMINANTS

Non-VOCs (DNAPL, semi-volatiles, and metals) and landfills.

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone). Hydraulic conductivity.
Contaminant:	Approximate distribution of concentrations. Lateral depth and extent. Separate phase in liquids in soil. When DNAPL present: Henry's Law Constant. Vapor pressure.
Waste:	Type of waste Size/volume History
Other Parameters:	Extent of existing surface covering. Permeability of existing surface covering. Location of nearby or adjacent structures or buildings.

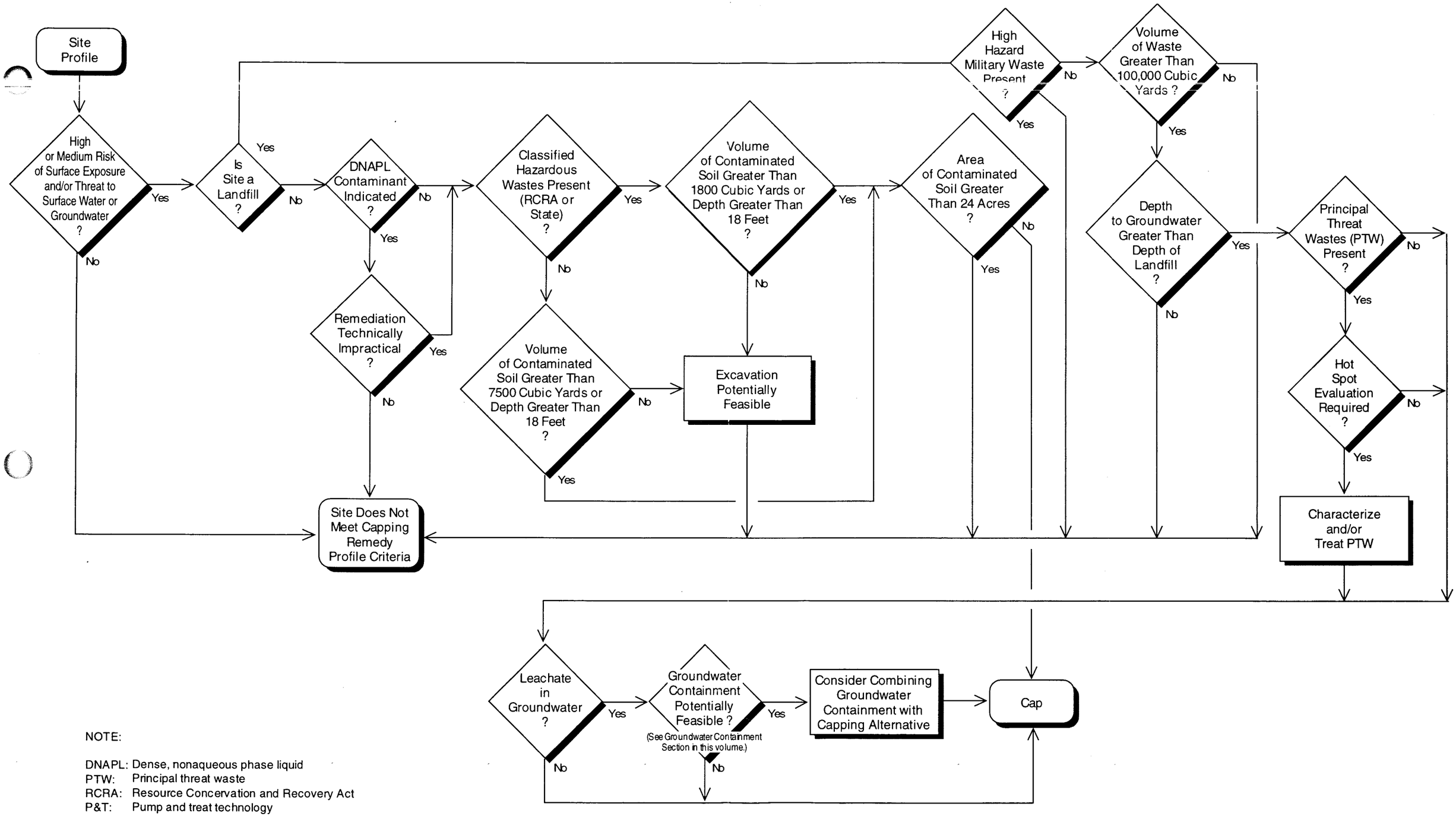
PRESUMPTIVE REMEDY PROFILE NEEDS

- DNAPL, semi-volatile, or metal contamination in the vadose zone;
- Area of contamination soil less than 24 acres (excluding landfill);
- Volume of waste less than 100,000 cubic yards;
- Municipal or low-level hazard military-specific waste;
- Depth of contamination greater than 18 feet below ground surface (BGS) and/or total volume of contaminated soil greater than 1,800 cubic yards for a hazardous waste or greater than 7,500 cubic yards for a non-hazardous waste;
- Existing structures can be removed and future land use can be restricted;
- Henry's Law constant of contamination less than 0.01 (DNAPL only);
- Vapor pressure of contaminant at 20 degrees Celsius less than 1.0 mm Hg (DNAPL only);
- Geology is complex and soils are heterogeneous (DNAPL only); and
- Hydraulic conductivity of subsurface less than 10^{-4} cm/sec (DNAPL only)

APPLICABILITY

This remedy consists of placing an engineered, low permeability cap over landfills or areas containing contaminated soil. This remedy eliminates surface exposure pathways and minimizes leaching of contaminants to groundwater through the reduction of infiltration. Generally, this is applicable at sites contaminated with DNAPL, metal, or semivolatile soil contaminants, or landfills containing municipal or low hazard military-specific waste. The options within this remedy profile contain both RCRA and non-RCRA caps; however, RCRA caps would only be implemented at those sites containing RCRA hazardous waste.

Figure 5-1. Summary of the Capping Presumptive Remedy



NOTE:

DNAPL: Dense, nonaqueous phase liquid
PTW: Principal threat waste
RCRA: Resource Concervation and Recovery Act
P&T: Pump and treat technology

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Figure 5-2.
Capping Decision Diagram

quality. Human health risks may occur with surface exposure or contaminant migration due to weathering and surface run-off. Contaminant migration due to weathering and surface runoff may also threaten surface water quality. Infiltration of precipitation may threaten the groundwater quality through downward migration of contaminants. Figure 5-3 provides a visual representation of surface exposure and contaminant migration that may occur at a landfill or contaminated soil site.

Capping a source area with an impermeable layer controls surface exposure of contaminants, migration of contaminants to surface water, and downward migration of contaminants toward groundwater. Figure 5-3 shows that the cap eliminates surface exposure, prevents migration of contaminant through surface run-off and erosion, reduces the infiltration of precipitation, and minimizes the leaching of contaminants to the groundwater.

Caps that are commonly used are multi-layer Resource Conservation Recovery Act (RCRA) caps, and non-RCRA caps such as the soil/clay cap, the asphalt cap, and the concrete cap. The multi-layer RCRA cap consist of four distinct layers and is required when capping source areas containing RCRA hazardous waste. **For source areas that do not contain RCRA hazardous waste, a non-RCRA cap should be used.**

5.4 Technology-Based Application Criteria for Capping

The capping technology has proven to be a successful means of containment over a wide range of conditions at different sites. Recommended technology-based application criteria have been created for the purpose of selecting capping as a presumptive remedy. The recommended criteria are based on previous experience that indicates capping is an appropriate containment technique. Because a site does not fall within these criteria, that does not mean capping cannot be used. Instead, it is recommended that a more detailed evaluation be conducted than would typically be completed when using the presumptive remedy approach.

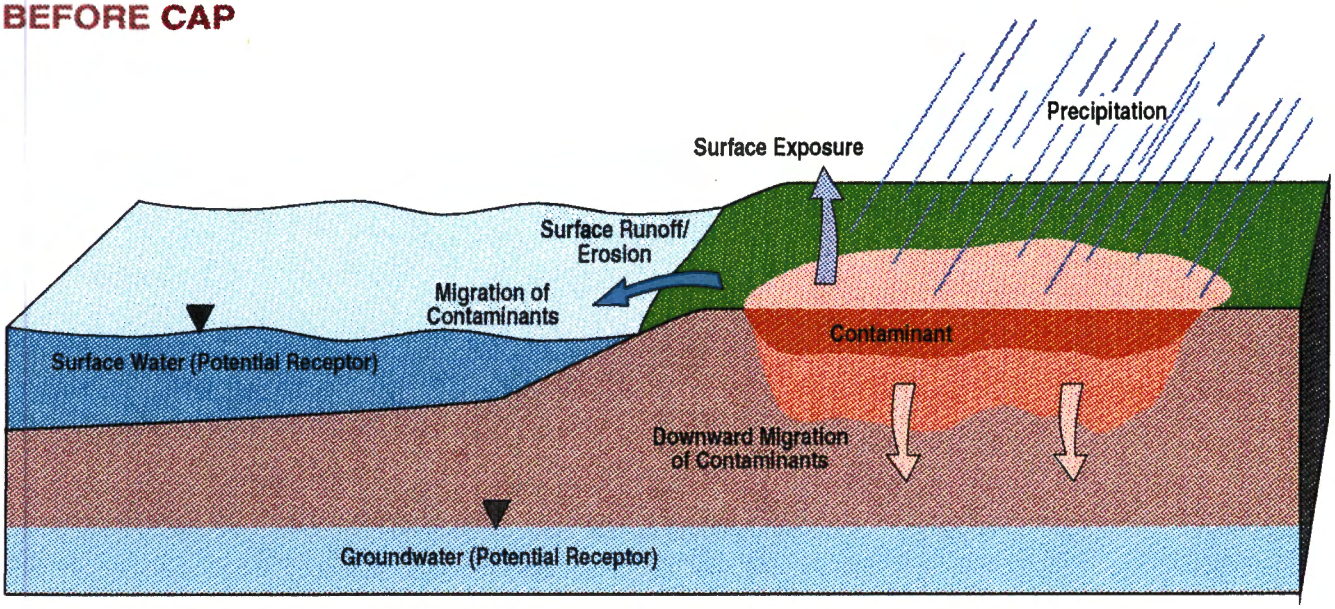
The capping technology-based application criteria are based on a comparison of the technical practicability and cost of removing the contaminants versus capping them in place in order to minimize site risks. These criteria are described in the following sections. Figure 5-2 is a logic diagram that can be used to determine if capping is appropriate for use at a specific site as a presumptive remedy. The logic diagram incorporates these capping technology-based criteria which are discussed in the following sections.

These technology-based application criteria are used to create the capping presumptive remedy profile. This remedy profile is compared to the candidate site profile to determine if the site "plugs-in" to the PREECA. Site profiles and remedy profiles are described in section 3.0 of Part I of the PREECA. Examples of a remedy profile, a matching site profile, and a non-matching site profile are provided in Table 5-1.

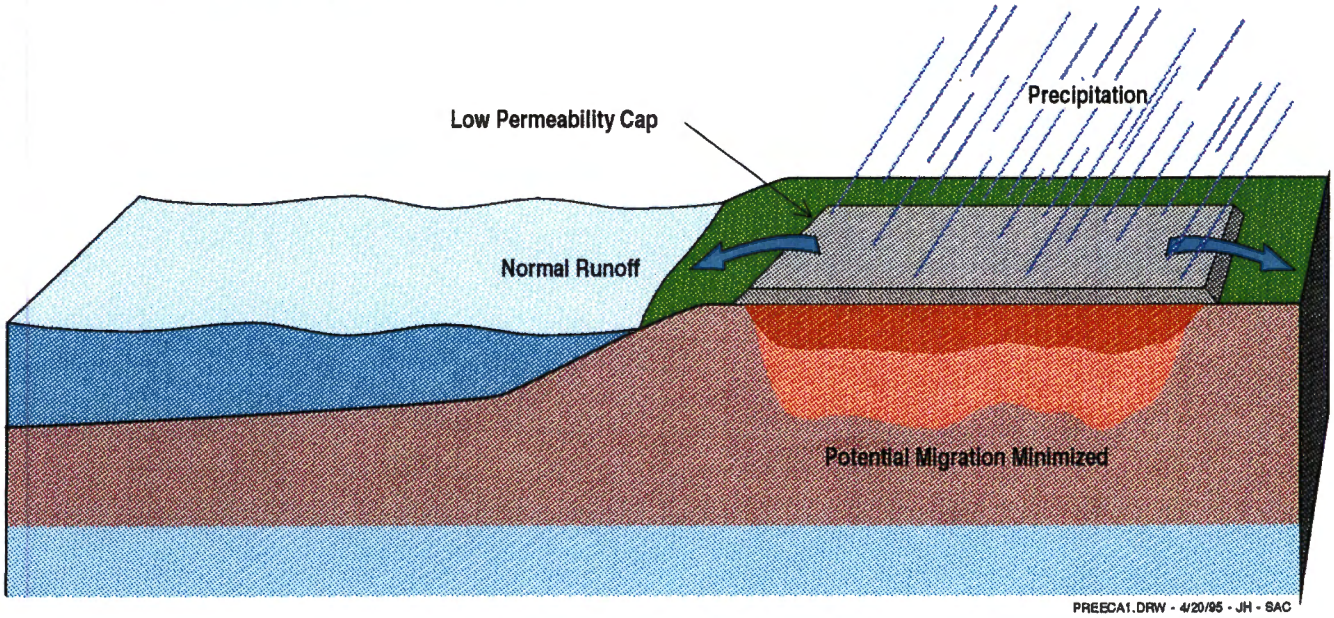
5.4.1 Technical Impracticability of Removing Contaminants

The type of contaminants present on site impacts the selection of capping as a presumptive remedy. Landfills and sites containing metals, semivolatiles, or DNAPL contaminants are often very difficult to remediate and are considered highly suited for capping. Application criteria associated with the technical impracticability of removing certain types of contaminants are

BEFORE CAP



AFTER INSTALLATION OF CAP



BENEFITS OF CAP:

1. **Eliminates surface exposure.**
2. **Prevents migration of contaminant through surface runoff and erosion.**
3. **Reduces infiltration of precipitation, minimizing the leaching of contaminants to groundwater.**

Figure 5-3. Benefits of Capping

Table 5-1.
Capping Example Profiles

Condition or Parameter	Remedy Profile Value	Matching Site Profile	Non-Matching Site Profile
Soil Contamination			
Contaminants	Metals/Semivolatiles/ DNAPL	PCBs, chromium, and lead > acceptable risk levels in surface soils	TCE and BTEX compounds throughout vadose zone
Volume of classified hazardous waste soil	> 1,800 cubic yards of soil	15,500 cubic yards of PCB contaminated soil (hazardous waste)	1,700 cubic yards of PCB (hazardous waste)
Volume of nonhazardous waste soil	> 7,500 cubic yards of soil	8,000 cubic yards of DNAPL (non-hazardous waste) contaminated soil	4,000 cubic yards of DNAPL (non-hazardous waste)
Depth of soil contamination	> 18 feet below surface	Contaminant 15 to 25 feet below surface	Contaminant/waste 0.5 to 10 feet below surface
Area of soil contamination	< 24 acres	10 to 15 acres	27 acres
Landfill			
Volume of landfill waste	> 100,000 cubic yards of waste (2 acres, 30 feet deep)	200,000 cubic yards of waste	40,000 cubic yards of waste
Types of waste	Municipal or low-hazard military specific waste	Construction debris and industrial solid waste (municipal type waste)	Chemical warfare agents (high-hazard military waste)

described below. The application criteria are to be used in conjunction with the logic diagram, Figure 5-2.

Landfills: The fact that a site is a landfill, may warrant the selection of capping as a presumptive remedy. Landfills are often very difficult to remediate due to the heterogeneous nature of landfill waste. Listed below are several criteria that affect the suitability of capping landfills as a presumptive remedy.

- Types of Landfill Waste: If the contents of a landfill contains high-hazard military-specific waste, such as the US EPA's examples shown in Table 5-2, it is recommended that a more detailed analysis be conducted rather than use the presumptive remedy approach. Caution is warranted because site investigation or attempted treatment of these contaminants may pose safety issues for site workers and the community. To determine if military-specific waste are high-hazard (Column C) or low-hazard (Column B), consult the specialist in military waste provided in Table 5-3 as recommended in "Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills" (U.S. EPA, 1996).

- Volume of Landfill Waste: If the volume of the landfill contents are less than 100,000 cubic yards (for example, 2 acres, 30 feet deep), it is recommended that a more detailed analysis be conducted rather than use the presumptive remedy approach.

Table 5-2. Examples of Municipal and Military Specific Waste

Column A: Municipal landfills contain predominantly non-hazardous materials. However, industrial solid waste and even some household refuse (e.g., pesticides, paints, and solvents) can possess hazardous components. Furthermore, hazardous wastes are found in most municipal landfills due to past disposal practices.
Column B: These types of wastes are specific to military bases, but generally are no more hazardous than some wastes found in municipal landfills.
Column C: These wastes are extremely hazardous and may possess unique safety, risk, and toxicity characteristics. Special consideration and expertise are required to address these wastes.

	Military-Specific Wastes	
A Municipal-Type Wastes	B Low-Hazard Military-Specific Wastes	C High-Hazard Military-Specific Wastes
<u>Predominant Constituents</u> Household refuse, garbage, and debris Commercial refuse, garbage, and debris Construction debris Yard wastes <u>Found in Low Proportion</u> Asbestos Batteries Hospital wastes Industrial solid waste Paints and paint thinner Pesticides Transformer oils Other solvents	Low-level radioactive wastes Decontamination kits Munitions hardware	<u>Military Munitions</u> Chemical warfare agent (e.g. mustard, tear agents) Chemical warfare agent training kits Artillery, small arms, warheads Other military chemicals (e.g., demolition charges, pyrotechnics, propellants) Smoke grenades
	Note: The majority of military landfills contain primarily non-hazardous wastes. The materials listed in these columns are rarely predominant constituents of military landfills.	

Table 5-3. Specialists in Military Waste

The installation point of contact will notify the major military command's specialists in military wastes (Explosive Ordnance Disposal Team) for assistance with regard to safety and disposal issues related to any type of military items.

Army chemical warfare agents specialists:

- Project Manager, Non-Stockpile Chemical Material, Aberdeen Proving Ground, Maryland 21010-5401, (410) 671-1083.

Navy ordnance related items specialists:

- The Navy Ordnance Environmental Support Office, Naval Surface Warfare Center, Indian Head, Maryland 20460-5035, (301) 743-4534/4906/4450.

Navy Low-Level Radioactive wastes specialists:

- The Naval Sea Systems Command Detachment, Radiological Affairs Support Office, Yorktown, Virginia 23691-5908, (804) 887-4692.

Air Force Ordnance specialists:

- The Air Force Civil Engineering Support Agency, Contingency Support Division, Tyndall AFB, Florida 32403-5319, (904) 283-6410

Consideration of excavation must balance the long-term benefits of no operations and maintenance cost and unrestricted land use versus the initial high capital cost of construction.

- Depth to Groundwater: If the depth of the landfill is greater than the depth to groundwater as shown in Figure 5-4, it is recommended that a more detailed evaluation be conducted rather than use the presumptive remedy approach. When the depth of the landfill is greater that the depth to groundwater, then landfill leachate and contents have direct contact with groundwater. This condition warrants a detailed evaluation to determine the appropriate removal action. The presumptive remedy approach does not provide an adequate evaluation for this condition.

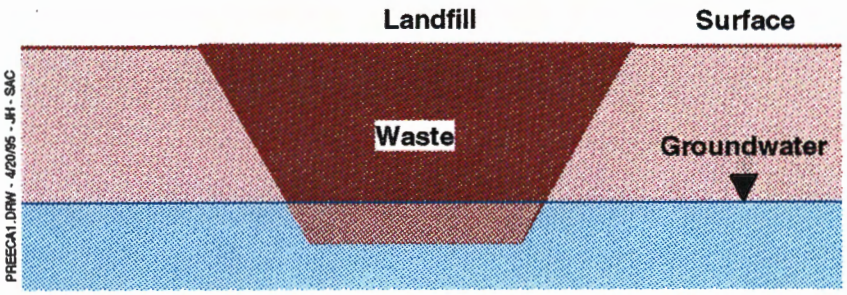
- Presence of Principal Threat Waste (PTW): The presence of PTW within a landfill may require additional characterization and/or treatment of PTW hot spots. Below is the definition of PTW and Table 5-4 lists examples of PTW as defined in "A Guide to Principal Threat and Low Level Threat Waste", (USEPA, 1991).

  – Principal Threat Waste are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. They include liquids and other highly mobile materials (e.g., solvents) or materials having high concentrations of toxic compounds. No "threshold level" of toxicity/risk has been established to equate to "principal threat'. However, where toxicity and mobility of source material combine to pose a potential risk of 10^{-3}or greater, generally treatment alternatives should be evaluated.

Table 5-4
Examples of Principal Threat Waste

Waste that generally will be considered to constitute principal threats include, but are not limited to:
Liquids – Waste contained in drums, lagoons or tanks, free product floating on or under groundwater (generally excluding groundwater) containing contaminants of concern.
Mobile Source Material – Surface soil or subsurface soil containing high concentrations of contaminants of concern that are (or potentially are) mobile due to wind entrainment, volatilization (e.g., VOCs), surface runoff, or sub-surface transport.
Highly-Toxic Source Material – Buried drummed non-liquid waste, buried tanks containing non-liquid waste, or soil containing significant concentrations of highly toxic materials.

- Characterization of PTW Hot Spots: If the presence of PTW is suspected then characterization and/or treatment of the PTW hot spots may be warranted. Refer to Table 5-5 to determine if characterization is warranted as described in "Presumptive Remedy for CERCLA Municipal Landfill Sites" (USEPA, 1993). Capping may still be considered as a presumptive remedy if characterization and/or treatment of PTW hotspots is warranted. All characterization and/or treatment of PTW hotspots should be completed prior to cap construction.



When the depth of the landfill is greater than the depth to groundwater, capping as a presumptive remedy is inappropriate.

Figure 5-4. The Effect of Groundwater at Landfill Sites

Table 5-5
Principal Threat Waste Hot Spot Characterization

If all of the following questions can be answered in the affirmative, it is likely that characterization and/or treatment of hot spots is warranted: 1. Does evidence exist to indicate the presence and approximate location of the waste? 2. Is the hot spot known to be a principal threat waste? 3. Is the waste in a discrete, accessible part of the landfill? 4. Is the hot spot known to be large enough that its remediation will reduce the threat posed by the overall site but small enough that it is reasonable to consider removal?

- Leachate: If leachate from the landfill has contaminated the groundwater, the groundwater containment should be considered as a presumptive remedy in conjunction with capping.

Metals and Semivolatiles: The presence of metal and semivolatile contaminants may warrant the selection of capping as a presumptive remedy. Sites containing metals or semivolatiles are considered highly suited for capping because there are few remedies that can be applied at these sites (e.g. excavation and disposal, solidification, etc.). These remedies are typically not as cost effective as capping for large volumes of contaminants or deep contaminants, except under certain site conditions.

DNAPLs: Below is the definition of DNAPL as described in "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration" (USEPA, 1993):

- DNAPLs are free-phase liquids that are immiscible in and denser than water. DNAPLs comprise a broad class of compounds including creosote and coal tars, polychlorinated biphenyls (PCBs), certain pesticides, and chlorinated organic solvents such as trichlorethylene (TCE) and tetrachloroethylene (PCE).

The indication that DNAPL contaminants are present, may warrant the selection of capping as a presumptive remedy. DNAPLs are often hard to locate and remove from the subsurface. DNAPLs tend to sink through the aquifers and penetrate deeper portions of the aquifers. Removal of DNAPL contaminants may be considered "technically impractical" under certain site conditions. As stated in Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration (USEPA, 1993), "DNAPL sources that cannot practicably be removed should be contained to limit further contamination of groundwater." In cases where it is technically impractical to remove DNAPL contaminants, capping (as a component of containment) may be selected as a presumptive remedy.

Hydrogeologic factors and contaminant-related factors impact the ability to remove DNAPL contaminants from the subsurface. Removal techniques such as free-phase DNAPL removal, vapor extraction, groundwater extraction, and excavation are often impacted by hydrogeologic and contaminant-related factors. These factors are discussed below and are presented in Table 5-6. The particular factor or combination of factors that critically limit the ability to remove DNAPL contaminants (or make them "technically impractical" to remediate) are site specific.

Table 5-6
Capping-Based Application Criteria for DNAPL Sites

Criteria Parameter	Guideline
Complex geology	Interbedded and discontinuous strata
Heterogeneous soils	Interbedded sand and silts, clays, fractured media, karst
Hydraulic conductivity of subsurface	$< 10^{-4}$ cm/sec
Henry's Law Constant of contaminant	< .01
Vapor pressure of contaminant	< 1.0 mm Hg at 20°C

- Hydrogeologic factors: Aquifer and vadose zone remediation may be limited by hydrogeologic conditions such as complex geology, unconsolidated clay deposits, heterogeneous soils, low hydraulic conductivity, high temporal variation (i.e., seasonal variation in the groundwater table, etc.) and a large downward flow component.

- Contaminant factors: Aquifer and vadose zone remediation may be limited by contaminant characteristics such as low biotic/abiotic decay potential, low volatility (vapor pressure and Henry's Law constant), high sorption potential, and the presence of the dense, nonaqueous liquid phase (DNAPL) of the contaminant. It is important to note the DNAPL contaminants can produce subsurface vapors and slowly dissolve in groundwater and produce aqueous-phase contamination. The DNAPL contaminants present in the aqueous and vapor phase may have removal potential.

5.4.2 Physical Site Characteristics for Contaminated Soil

Physical site characteristics such as volume, depth, and area of contaminated soil, impact the selection of capping as a presumptive remedy. These characteristics are presented in Table 5-7 as application criteria and are to be used in conjunction with the decision diagram, Figure 5-2.

Table 5-7
Capping-Based Application Criteria for Physical Site Characteristics for Soil Contamination

Criteria Parameter	Secondary Parameter	Guideline Value
Volume of contaminated soil	Classified hazardous waste	> 1800 yd^3
Volume of contaminated soil	Non-hazardous waste	> 7500 yd^3
Depth of contaminated soil	N/A	> 18 feet bgs
Area of contaminated soil	Excluding landfills	< 24 acres

Volume and Depth of Contaminated Soil: The volume and depth of contamination impacts the selection of capping as a presumptive remedy. If the contamination is small in volume and/or shallow (< 18 feet bgs), there are alternate methods for removing the contaminants that are more cost effective than capping, such as excavation and disposal. The disposal cost for contaminated soil is dependent on whether or not the contaminant is classified as hazardous waste under RCRA or state

requirements. It becomes cost effective[1] to cap classified hazardous waste when the volume exceeds 1,800 yd^3. A larger volume (up to 7,500 yd^3) of non-hazardous soil may be excavated and disposed before capping becomes a more cost effective option. Table 5-8 list the characteristics of RCRA hazardous waste and the types of RCRA hazardous waste. This table may be useful in determining whether contaminants are RCRA hazardous waste. Refer to state guidance to determine if contaminants are classified as hazardous waste under state regulations.

In some cases where smaller volumes of contaminated soil are overlain by clean soils or the contaminants are spread over a large area, capping may still be more cost-effective than other remediation technologies even though the site falls outside of volume criteria. The removal costs are increased by the amount of clean soil that must be handled to remove the contaminated soil.

Area of Contaminated Soil: The area of contamination impacts the selection of capping as a presumptive remedy at sites excluding landfills. For large areas of contamination greater than 24 acres (except at landfill sites), it is recommended that a more detailed evaluation be conducted rather than use a presumptive remedy approach. A detailed evaluation may approach remedy selection at a large site by creating smaller sub-sites.

[1] The contaminant volume guideline values are based on a cost comparison between capping and excavation and disposal. The comparison was presented in McClellan Air Force Base, Basewide Vadose Zone Feasibility Study (CH2M Hill, 1994).

5.4.3 Associated Risk

Sites that do not have potential for surface exposure or pose a threat to surface water or groundwater quality should not be considered for capping using the presumptive remedy approach. The benefits associated with capping may not outweigh the cost for those low risk sites; however, sites with a high and imminent risk of surface exposure or migration of contaminants to surface water or groundwater potentially warrant the selection of capping as a presumptive remedy. Those sites that do not meet the contaminant characteristics criteria but are high risk may use capping as an interim presumptive remedy to reduce associated risk.

5.5 Application Limitations

For sites that meet the application criteria there are site-specific land use limitations that may impact the selection of capping as a remedy. Listed below are a number of site specific issues that must be considered before selecting capping as remedy.

- **Removable existing structures**: Depending on the cap selected and the contaminant, existing structures located near or within the contaminant zone may need to be removed. If a non-RCRA concrete or asphalt cap is selected, the existing structure may be left in place as long as there is no risk of surface exposure or gas production. When a situation warrants structure removal, it must be determined if the structure is removable and if it is cost effective to do so. If it is not feasible to remove the existing structures then another remedy (e.g., solidification) may be more suitable than capping.

Table 5-8. RCRA Hazardous Wastes

Characteristic	Guideline
Ignitability	Flash point < 140 °F
Corrosivity	pH $\leq$ 2.0, or pH $\geq$ 5, or Capable of corroding steel at a rate of more than 0.25 inches per year
Reactivity	A waste that is explosive, reacts violently with water, or generates toxic gases when exposed to water or liquids that are moderately acidic or alkaline
Toxicity	A waste which the Toxicity Characteristic Leaching Procedure (TCLP) test extract contains a concentration of a specified contaminant above its regulatory threshold
F Waste Code	A waste from non-specific sources
K Waste Code	A waste from specific sources (e.g., wastewater treatment sludge from wood preserving processes).
P Waste Code	Acutely hazardous commercial chemical products (commercially pure or technical grade of chemical)
U Waste Code	Toxic commercial chemical products
Solid waste	Any solid waste derived from the treatment, storage, or disposal of a listed waste (F, K, P, U Waste Codes), and any mixture of solid waste and listed waste is a RCRA hazardous waste.

- **Future land use**: The future land use planned for the contaminant zone must be considered when choosing capping as a presumptive remedy. Capping is an appropriate remedy when future land use is very limited. When future land use may not be limited, other remedies (e.g., solidification, and excavation and disposal) may be more suitable than capping.

- **Environmentally sensitive areas**: Capping as a presumptive remedy should not be implemented if construction will impact environmentally sensitive areas (e.g., wetlands, or wildlife habitats). When construction would impact environmentally sensitive area, it is recommended that a more detailed evaluation be conducted rather than use the presumptive remedy approach.

5.6 Selection of Cap

After the decision has been made to implement capping as a presumptive remedy, the type of cap must be selected. For sites containing contaminants not classified as RCRA hazardous waste, a non-RCRA cap is suitable. For sites with contaminants containing RCRA classified hazardous waste (see Table 5-8), a RCRA cap may be required.

At landfill sites, where the contaminants were placed in the landfill prior to November 19, 1980, a non-RCRA cap may be suitable. At landfill sites, where the contaminants were placed in the landfill after November 19, 1980 and the contaminants contain RCRA classified hazardous waste, a RCRA cap may be required.

Figure 5-5 is a logic diagram that illustrates whether a RCRA or a non-RCRA cap may be required. Selection of a RCRA cap will also be dependent on local and lead regulatory agencies.

Table 5-9 summarizes criteria used for selection of an appropriate cap for contaminants containing non-RCRA classified waste.

Table 5-9
Cap Selection for Non-RCRA Classified Wastes

Type of Cap	Site Conditions	Advantages and Disadvantages
Soil/clay cap	May use for applications where structural strength is not required.	Susceptible to cracking, but has self healing properties. Low capital cost.
Asphalt cap	May use for applications where structural strength is required.	Susceptible to weathering and cracking. Low capital cost
Concrete cap	May use for applications where high structural strength is required.	Susceptible to weathering and cracking. Moderate capital cost.

5.7 Description of Selected Caps

Descriptions of several RCRA and non-RCRA caps are given in the following sections. Examples of several cap cross-sections are shown in Figure 5-6.

RCRA Cap

- **RCRA Cap:** As described below, a RCRA cap may consist of three distinct layers with an optional layer. The RCRA cap must meet the minimum requirements as described in "Design and Construction of RCRA/ CERCLA Final Covers" (USEPA, 1991).

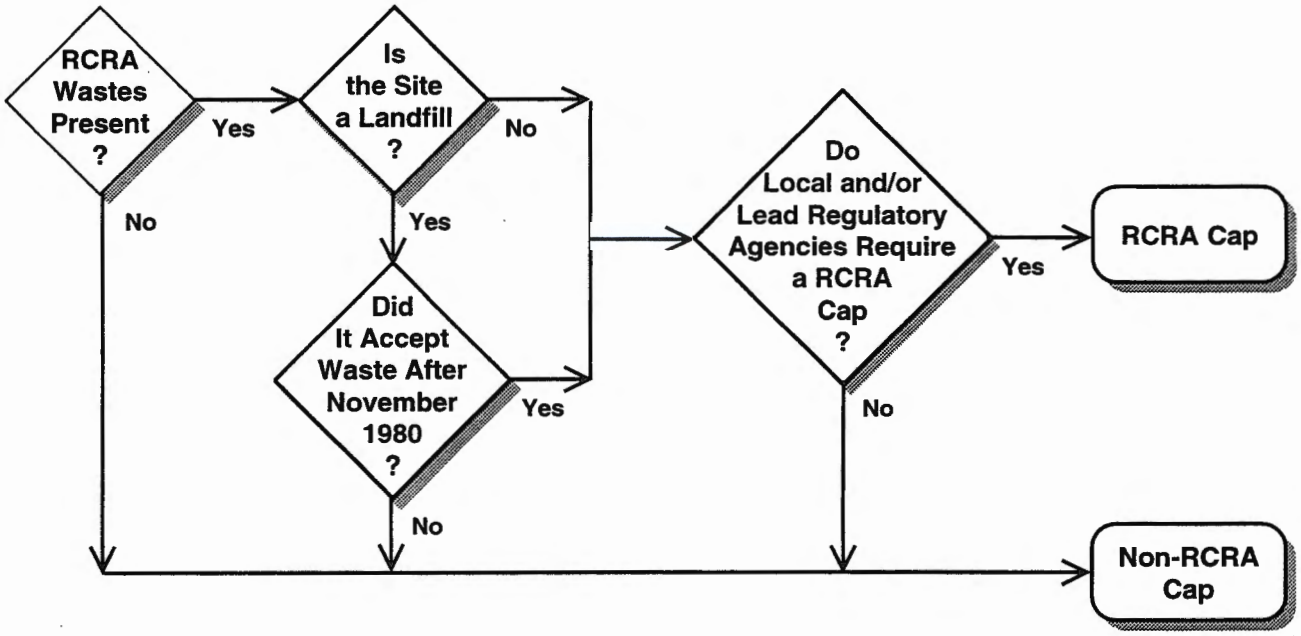


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Figure 5-5. Cap Selection (RCRA or Non-RCRA)

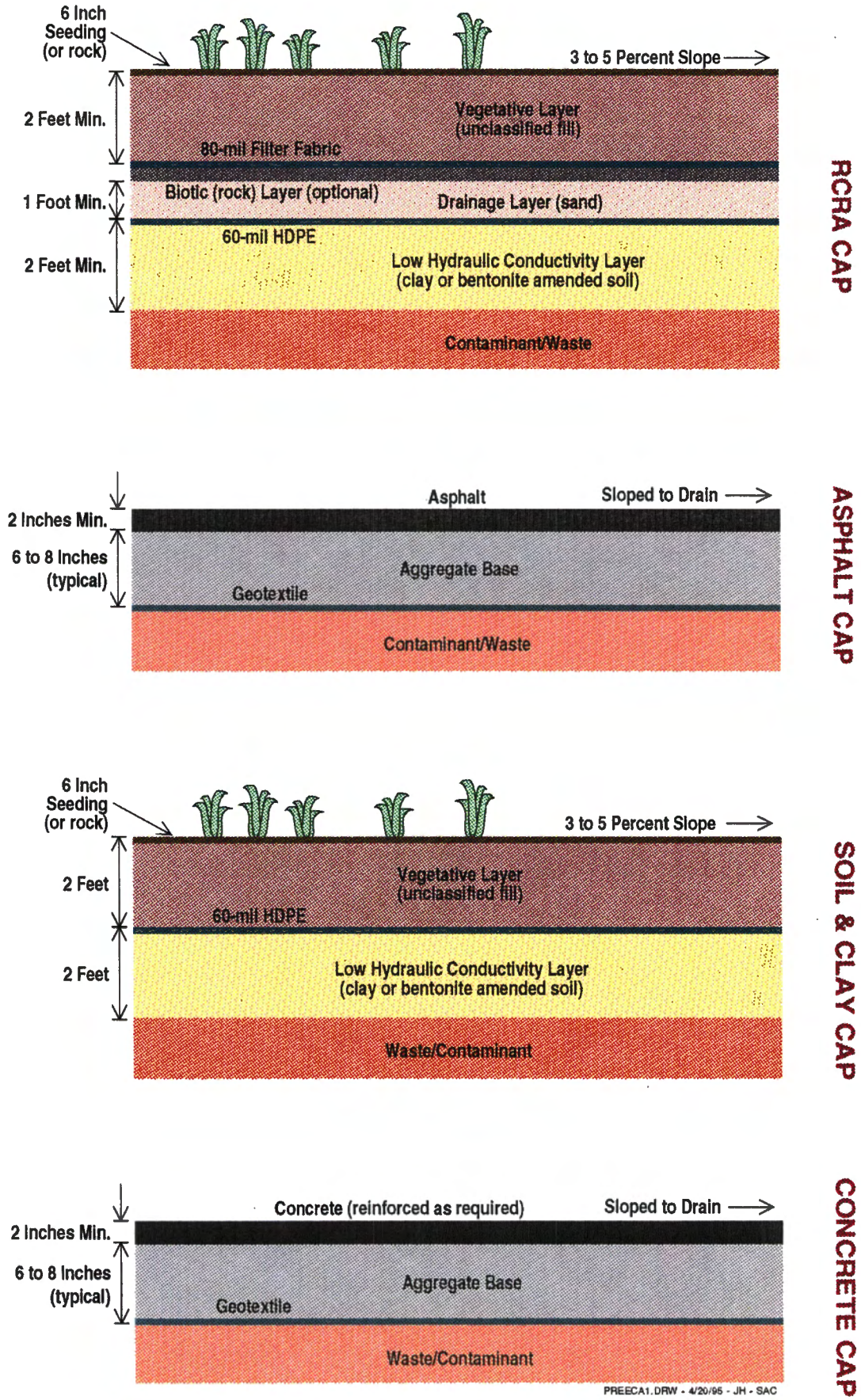


Figure 5-6. Examples of Several Cap Cross-Sections

- **Top, Vegetation/Soil Layer**: A 6-inch top layer with vegetation (or an armored top surface) and a minimum of 24-inches of soil graded at a slope between 3 and 5 percent.

- **Biotic Layer (optional):** An optional biotic layer is suggested for use in arid climates. A biotic barrier of small rock directly beneath the top vegetation layer may stop the penetration of deep-rooted plants and the invasion of burrowing animals. An 80-mil filter fabric may be used to minimize the migration of fines from the overlying top layer to the biotic layer.

- **Drainage Layer**: A minimum 12-inch soil layer having a minimum hydraulic conductivity of 1×10^{-2} cm/sec (sand), or a layer of geosynthetic material having the same characteristics.

- **Low Hydraulic Conductivity Geomembrane/Soil Layer**: A 60-mil high-density polyethylene (HDPE) liner in intimate contact with a minimum 24-inch layer of compacted natural or amended soil with a minimum hydraulic conductivity of 1×10^{-7} cm/sec (clay or bentonite-amended soil).

Non-RCRA Caps

- **Soil/Clay Cap**: As described below the soil/clay cap consists of two distinct layers.

  - **Top, Vegetation/Soil Layer**: A 6-inch top layer with vegetation (or an armored top surface) and 18-inches of soil graded at a slope between 3 and 5 percent.

  - **Low Hydraulic Conductivity Geomembrane/Soil Layer**: A 60-mil geomembrane liner in intimate contact with a 24-inch layer of compacted natural or amended soil with a minimum hydraulic conductivity of 1×10^{-7}cm/sec (clay or bentonite-amended soil).

- **Asphalt Cap**: As described below, the asphalt cap consists of two distinct layers.

  - **Asphalt Concrete Layer**: A minimum 2 inch top layer of asphaltic concrete, sloped to drain.

  - **Base Layer**: A 6 to 8 inch compacted class II aggregate base (3/4-inch minus) underlain by a geotextile to prevent migration of soil fines.

  The asphalt concrete and aggregate base thickness will vary depending on surface loads and the condition of the ground surface.

- **Concrete Cap**: As described below, the concrete cap consists of two distinct layers.

  - **Concrete Layer**: A minimum 2 inch top layer of reinforced concrete, sloped to drain. Steel reinforcement within the concrete is required to provide structural strength and to help resist cracking.

  - **Base Layer**: A 6 to 8 inch compacted class II aggregate base (3/4-inch minus) underlain by a geotextile to prevent migration of soil fines.

  The concrete, aggregate base thicknesses, and reinforcement will

vary depending on surface loads and the condition of the ground surface. Expansion joints will be used to accommodate expansion and contraction when temperature variations occur.

5.8 Cap Design

The caps described above are example cross-sections. The final design of a cap will depend on several site specific factors, such as the type of waste or soil and its potential for differential settlement and subsidence. Gas collection layers, additional surface erosion prevention measures, and subsurface completions may be used when site conditions warrant. Final design of a cap may vary greatly with site conditions. In addition, other materials may be more suitable for a specific site than those cited in this document. The most suitable materials should be used in design of a cap system.

To design a RCRA or non-RCRA cap site specific information must be gathered. As described in "Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites" (USEPA, 1991), the primary data needed for designing caps include the following:

- Depth to groundwater beneath waste/contaminant;
- Availability of cover materials (caps may be high in cost if the desirable materials are not locally available);
- Rate or magnitude of waste and/or soil settlement under cap (changes in waste and/or soil thickness, degree of decomposition, and presence of large, near-surface voids should be known);
- Steepness of proposed slopes;
- Proposed cover soil characteristics (for RCRA or soil/clay caps):
  - Proctor compaction properties,
  - Permeability,
  - Grain size gradation,
  - Shear strength,
  - Atterberg limits, and
  - Field moisture capacity;
- Maximum frost depth at the location of the site;
- Anticipated weather conditions at the site (i.e., temperature, precipitation, wind, etc.);
- Proximity to residential, commercial, or industrial units; and
- Future land use of site.

The use of EPA's computer model, Hydrologic Evaluation of Landfill Performance (HELP), may be used to determine the efficiency of a RCRA or soil/clay cap. The HELP is a computer model that estimates vertical water movement through a landfill cap. The effects of surface water runoff, evapotranspiration, soil moisture storage, and lateral flow through the drainage layer are accounted for to predict the rate of water infiltration through the cap. The HELP model is available from EPA's Risk Reduction and Engineering Laboratory (RREL) in Cincinnati, Ohio.

5.9 Cap Performance

Although caps are effective at reducing infiltration of precipitation, caps will not completely halt infiltration. However, in a field study conducted at Hill Air Force Base in Utah, it was shown that of all the caps tested, the RCRA cover was the most effective. "The RCRA cover, incorporating a

clay hydraulic barrier, was the most effective of all cover designs in controlling deep percolation, but was not 100% effective." (Warren, 1995).

The lifetime of caps usually range between 30-50 years, depending on the design. The life of the cap system will depend heavily on proper maintenance. Several studies have been performed that show natural physical and biological processes can be expected to cause caps to fail in the long-term (> 100 years). "The mechanism of failure include initial flaws in barrier construction, shrink-swell cycles, freeze-thaw cycles, erosion, subsidence, root intrusion, and animal intrusion" (Sutter et. al., 1993).

5.10 Cap Maintenance and Monitoring

Routine inspections and maintenance are required to maintain cap integrity. Routine inspections and maintenance for: erosion, settlement and subsidence, cracking, ponding of surface water, invasion by deep rooted vegetation, and damage by burrowing animals are required. Asphalt and concrete caps may be susceptible to cracking due to differential settlement and temperature variations. RCRA caps and soil/clay caps are typically vegetated with grasses that require periodic mowing, reseeding and re-fertilization.

Because the contaminants/wastes are not being removed or treated, groundwater monitoring is required to assess contaminant migration and attenuation over time. While the groundwater monitoring period is typically 30 years, the actual monitoring period will be influenced by any permit requirements, the stability of the waste, and the cap system. A groundwater well network should be established that tracks changes in the groundwater table and detects migration of contaminants. Monitoring frequencies commonly range from quarterly to annually. However, groundwater should be sampled at a frequency defined by permit requirements, the level of anticipated contamination, and the site conditions. Other types of periodic monitoring that may be required are:

- Leachate head monitoring;
- Leakage monitoring;
- Gas monitoring;
- Leachate tank monitoring; and
- Final cover stability monitoring

5.11 Technology Performance Evaluation

A technology performance evaluation should be conducted periodically to determine if the cap is meeting its removal objections. The evaluation may be performed using information gathered during routine maintenance and monitoring. Listed below are some typical questions for evaluating removal objectives:

- Does the cap control surface exposure?

  This may be determined using information gathered during routine inspections and maintenance. Properly maintained caps that are free of cracks and eroded vegetative layers (if applicable) should control surface exposure.

- Does the cap eliminate migration of contaminants to surface water by controlling surface runoff and erosion?

  This may be determined using information gathered during routine inspections and maintenance. Properly maintained caps that are free of cracks, have sufficient vegetative layers (if applicable), and are properly graded

should control surface runoff and erosion.

- Does the cap minimize the leaching of contaminants to groundwater by reducing infiltration of precipitation?

  This may be determined using information gathered during routine inspections, maintenance, and groundwater monitoring. Properly maintained caps that are free of cracks, invasion by deep rooted vegetation, and damage by burrowing animals should reduce infiltration of precipitation. The leaching of contaminants to groundwater may be evaluated using data collected during groundwater monitoring.

5.12 Cost

Costs associated with capping are categorized as either capital cost or long term maintenance and monitoring (O&M) cost. Capital costs are primarily dependent on the size of the cap and the type of cap selected. O&M costs vary slightly for each type of cap, but are primarily dependent on the size of the cap and the frequency of long-term maintenance and monitoring required.

As the size of the cap increases, the unit capital cost per square foot (ft^2) decreases. Between 12,000 ft^2 and 250,000 ft^2, capital cost for asphalt caps and soil/clay caps typically range between \$1/ft^2 and \$8 ft^2. Capital cost for concrete caps and RCRA caps between 12,000 ft^2 and 250,000 ft^2 typically range between \$5/ft^2 and \$11/ft^2. This relationship is shown in Figure 5-7 and Figure 5-8. The costs presented in these figures were provided in the McClellan Air Force Base, Basewide Vadose Zone Feasibility Study (CH2M Hill, 1994). The capital cost included labor and materials for construction of cap, tax on materials, 20% contingency for construction, 5% for permits and legal fees, 8% construction services, and 8% engineering design cost.

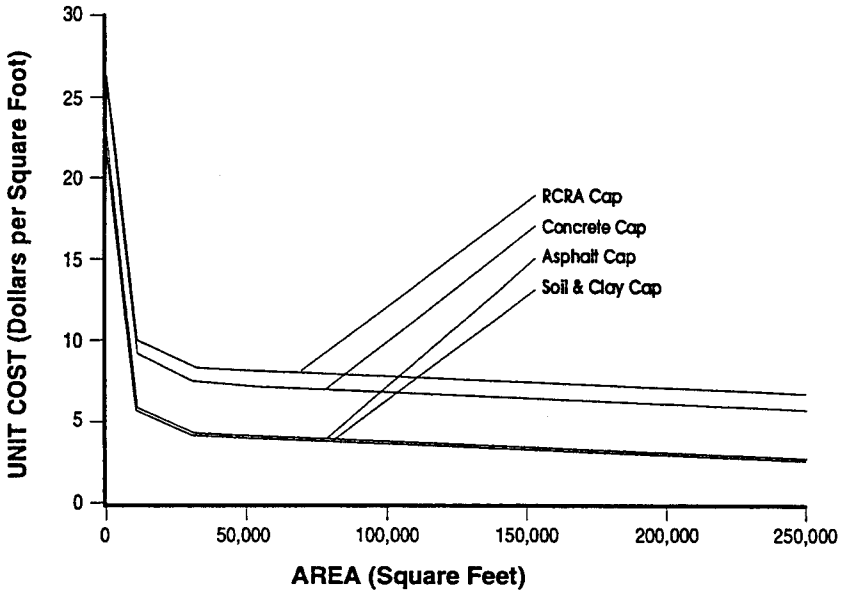
Capital cost may vary with location and available materials. Cost estimates for several soil/clay caps at Shaw Air Force Base ranged between \$6/ft^2 and \$10/ft^2 (Radian Corporation, 1994). These estimates were based on 22.2% indirect, overhead, & profit, 11-12% escalation, 20% contingencies, and 10% project management. These cost were estimated using the U.S. Air Force's cost estimating program, Remedial Action Cost Engineering and Requirements System (RACER).

For larger caps, the capital cost per square foot are typically lower than smaller caps. The capital cost for a 10-acre (445,500 ft^2) asphalt cap at McClellan Air Force Base was estimated between \$2/ft^2 to \$3/ft^2 (Radian Corporation, 1993). This estimate included %15 for engineering design cost, 5% for permits and legal fees, and 15% contingency.

O&M costs tend to increase as the size of the cap increases. O&M cost are also dependent on the amount of maintenance and monitoring that is scheduled for the site.

Figure 5-8 shows typical capital cost and O&M cost (present worth of 30-year O&M) for each type cap relative to its size.

The O&M cost are an estimate and may vary with location, materials, site conditions, performance of the cap, and the scheduled monitoring. The materials used by CH2M Hill to estimate cost may vary slightly from those listed in this report as example cap cross sections. The O&M cost included inspection, periodic maintenance, mowing for RCRA and soil/clay caps, miscellaneous materials for asphalt and concrete caps, and groundwater monitoring. O&M costs are



Source: Basewide Vadose Zone Feasibility Study, McClellan AFB; CH2M Hill, 1994.

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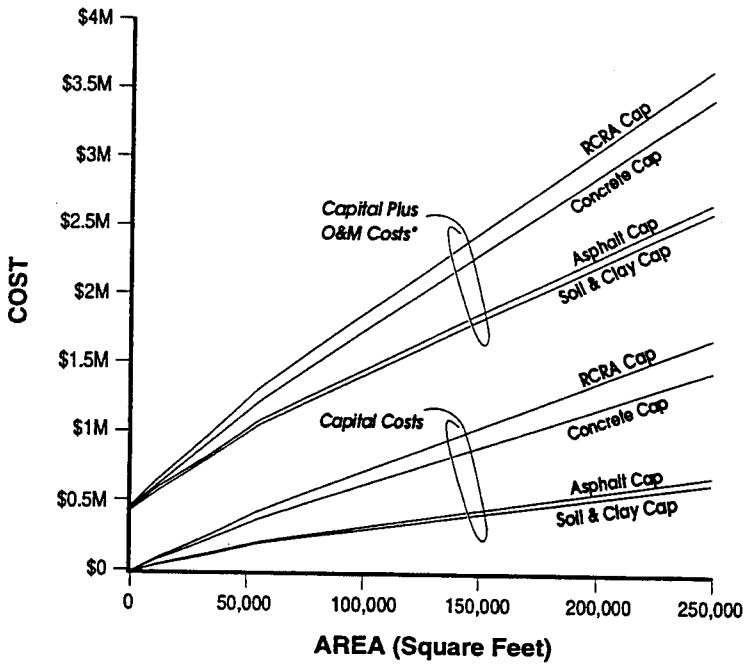
Figure 5-7. Capping Unit Cost



* Present worth of 30-year O&M discount rate 5%.

Source: Basewide Vadose Zone Feasibility Study, McClellan AFB; CH2M Hill, 1994.

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Figure 5-8. Capital and O&M Cost for Caps

provided as net present worth of 30 years of O&M at a discount rate of 5%.

5.13 Supporting Air Force Guidance On Capping

The Air Combat Command (ACC) document "Guidance for Remediation and Closure (Capping) of Landfills, Final Report on Design, Construction, and Maintenance Checklist" (Resource Applications Inc., 1995) is Attachment 1 of this document. The document cited above is used by ACC to assist in the implementation of capping projects. This guidance provides checklists for design, construction, and maintenance of caps; a preliminary questionnaire and decision tree; as well as cost, and a technical statement of work for implementing capping projects. This guidance may be used in conjunction with the PREECA document to implement capping as a presumptive remedy.

5.14 Annotated References

CH2M Hill, 1994. "McClellan Air Force Base, Basewide Vadose Zone Feasibility Study," Sacramento, California. *This document contains detailed cost information on capping. It also contains a general description of the capping technology.*

Department of Air Force. "Effective Remedy Selection at Landfill Sites." *This document presents some basic guidance for selecting a cleanup method for a landfill site.*

Miller, Maj. "Point Paper on Landfill Caps," DSN 240-9001, AFCEE/EST, 1992. *This paper establishes reasons for using caps at landfills.*

Radian Corporation, 1994. "Management Action Plan, Shaw Air Force Base, South Carolina," Austin, Texas. *This document contains cost information on soil/clay caps.*

Radian Corporation, 1993. "Installation Restoration Program (IRP), Operable Unit B1, Remedial Investigation/Feasibility Study (RIFS) for McClellan Air Force Base, California," Sacramento, California. *This document contains cost information on asphalt caps.*

Resource Applications, Inc., and Clean Sites, 1995. "Guidance for Remediation and Closure (Capping) of Landfills, Final Report on Design, Construction, and Maintenance Checklist for United States Air Force, Air Combat Command CES/ESV, Langley Air Force Base, VA," Falls Church, Virginia. June. *This document contains questionnaires, decision logic, statements of work, design checklist, construction checklist, maintenance checklist, and cost information on capping landfills.*

Sutter II, G.W., R.J. Luxmore, and E.D. Smith, 1993. "Compacted Soil Barriers at Abandoned Landfill Sites are Likely to Fail in the Long-Term," Journal of Environmental Quality, 22: 217-226. *This article discusses the mechanisms of long-term failure for caps.*

U.S. Environmental Protection Agency, 1991a. "Seminar Publication: Design and Construction of RCRA/CERCLA Final Covers," EPA/625/4-91/025, Eastern Research Group, Inc., Cincinnati, Ohio. *This document provides detailed design information for RCRA caps and a detailed description of the Hydrologic Evaluation of Landfill Performance (HELP) Model.*

U.S. Environmental Protection Agency, 1991b. "Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites," EPA/540/P-91/001, OSWER Directive 9344.3-1. Office of Emergency and Remedial Response, Washington, D.C. *This document provides detailed description of site information to be collected during investigation and design of caps. This document also provides descriptions of the HELP model and Hot Spot Characterization at landfill sites.*

U.S. Environmental Protection Agency, 1991c. "A Guide to Principal Threat and Low Level Threat Wastes," Superfund Publication 9380.3-06FS. Office of Solid Waste and Emergency Response, Washington, D.C. *This document provides a detailed description for identifying principal threat and low level threat waste.*

U.S. Environmental Protection Agency, 1989a. "RCRA ARARs: Focus on Closure Requirements," OSWER Directive 9234.2-04FS. Office of Solid Waste and Emergency Response, Washington, D.C. *This document establishes when a waste is considered a RCRA hazardous waste and when RCRA is relevant and appropriate.*

U.S. Environmental Protection Agency, 1989b. "Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments," EPA/530-SW-89-047. Office of Solid Waste and Emergency Response, Washington, D.C. *This document provides detailed design information for RCRA caps.*

U.S. Environmental Protection Agency, 1993a. "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration," OSWER Directive 9234.2-25. Office of Solid Waste and Emergency Response, Washington, D.C. *This document provides detailed information for evaluating the removal and containment of dense, nonaqueous phase liquids (DNAPLs).*

U.S. Environmental Protection Agency, 1993b. "Presumptive Remedy for CERCLA Municipal Landfill Sites," EPA/540/F-93/035, OSWER Directive 9355.0-49FS, PB 93-963339. Office of Solid Waste and Emergency Response, Washington, D.C. *This document describes the basis for using capping (as a component of containment) as a presumptive remedy at landfill sites. This document also provides descriptions Hot Spot Characterization at landfill sites.*

U.S. Environmental Protection Agency, 1996. "Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills," OSWER Directive 9355.0-67FS. Office of Solid Waste and Emergency Response. Washington, D.C. December. *This guidance provides a step by step approach to determining when a specific military landfill is an appropriate site for application of the capping presumptive remedy.*

Warren, Ronald W. "Thesis: The Hydrologic Evaluation of Four Cover Designs for Hazardous Waste Landfills," Department of Radiological Health Services, Colorado State University, Fort Collins, Colorado, 1995. *This paper documents a landfill performance study conducted at Hill Air Force Base, Utah.*

ATTACHMENT 1

Guidance for Remediation and Closure (Capping) of Landfills

GUIDANCE FOR REMEDIATION AND CLOSURE (CAPPING) OF LANDFILLS

FINAL REPORT ON DESIGN, CONSTRUCTION, AND MAINTENANCE CHECKLISTS

UNITED STATES AIR FORCE

AIR COMBAT COMMAND
CES/ESV

JUNE, 1995

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Foreword

This Guidance Manual is the result of an ongoing effort by ACC to improve and refine the design acquisition process for landfill caps. Special emphasis was placed on this type of remedial action (RA) because these RAs tend to be the most expensive that we encounter. In addition, a recent design of a large landfill cap would have been more cost-effective if we had been able to exercise tighter management control during the initial stages of design. As a follow-up, ACC decided to develop a comprehensive, yet concise Manual that can be used by both office and field personnel to monitor the various stages of a landfill cap or closure project.

The intent of this Manual is to provide the users with basic questions which would lead them to a systematic assimilation of technical and regulatory information that are essential for starting the planned activity. The checklist will serve as an invaluable tool for personnel involved in any stage of design, awarding of contracts, construction, and maintenance activities related to landfill cover and closure. It was a difficult task to condense the vast literature and regulatory information into these simplified checklists. Therefore, not all of the information is consolidated, but the minimum required data for a good beginning has been included. Section 1 of the Manual presents ACC CES/ESV Policy Statement on remediation and closure (capping) of landfills.

Section 2, "Preliminary Questionnaire and Decision Tree" presents questions related to general background information of the Base. A decision tree has been included to understand various stages of the landfill closure process.

Section 3, "Technical Statement of Work" is intended to provide a boiler-plate Statement of Work. Information includes design specification and other requirements to be addressed by an A-E firm in charge of the design.

Sections 4, 5 and 6 relate to the design, construction and maintenance checklists. The information provided in these three Sections is not limited to landfill cap only, but includes, leachate collection system, gas collection system, survey activities, plans and permits etc.

Finally, Section 7 provides the actual cost of landfill cap that includes design and construction costs.

Users of this Manual are encouraged to forward suggestions and modifications to Mike Battaglia, ESV to improve the usefulness of this Manual.

Robert M. Moore

Robert M. Moore
Chief, Environmental Flight

Langley AFB
June, 1995

ACC CES/ESV
REMEDIATION AND CLOSURE (CAPPING) OF LANDFILLS

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1. POLICY STATEMENT

ACC CES/ESV POLICY STATEMENT ON REMEDIATION AND CLOSURE (CAPPING) OF LANDFILLS

Remediation and closure of landfills will be the most expensive budget item for the Air Combat Command Installation Restoration Program (IRP) over the years to come. To effectively use the available fiscal resources, a systematic approach is required in the planning, design, construction, operation and maintenance of landfill remediation and closure efforts.

Our goal is to achieve a sound economical project development and execution strategy amongst our DoD contract partners, and local environmental agencies who share and help us in the important undertaking of protecting the human health and the environment.

2. PRELIMINARY QUESTIONNAIRE AND DECISION TREE

2. PRELIMINARY QUESTIONNAIRE AND DECISION TREE

I. GENERAL BASE DESCRIPTION

(Recommended sources: MAPS, base records search, PA/SI)

1. What is/was the primary mission of the Base? Please describe.

2. Is the Base or portions of the Base, designated as an NPL? *[Yes/No]*

3. Provide a general description of the Base.

   - Total size (acres)

   - What is/was the period of operation of the Base?

   - Describe the types of facilities and buildings on the Base (industrial, residential, commercial, etc.).

4. Provide general climatological data.

   - Annual precipitation (inches)

   - Temperature information (°F low, median and high)

- Frost Depth (inches)

5. Does the Base contain any important wildlife or habitats? *[Yes/No]*
   If yes, are there:

   - Any sensitive, endangered, or protected wildlife species or habitats?

   - Wetlands (acres)?

6. What types of materials (chemicals) are/were used or stored on the Base?

   - Any liquids *[fuels, other]*?

   - What quantities of materials are/were stored?

     - Bulk quantities?
     - Above-ground?
     - Sizes (appropriate unit of measure)?

     - Underground tanks?
     - Sizes (gallons)?

- Drums or containerized liquids?
- Where stored and used?

7. Are/were any materials or products manufactured on the Base? *[Yes/No]*

   - *If yes*, what is/was manufactured?

8. What type of general "water supply" serves the area?

   - Is the Base water supply from "Base" groundwater? *[Yes/No]*

   - Is the water supply for the surrounding communities, residences or businesses from groundwater? *[Yes/No]*

     - *If yes*, are there numerous wells for individual supplies or large wells for single or a few wells for communal supply? Number of aquifers?

     - How close to the Base are they located?

II. LANDFILL SITE PHYSICAL DESCRIPTION

(Recommended source: original permit)

9. Did the past or current landfill(s) ever receive permits? *[Yes/No]*

   - Describe the type soils bordering the landfill.

- *If yes*, what type of permits?

- Date of original issuance?
- Last expiration?
- Any special conditions or waste restrictions?

10. Does the state have a federally-approved Solid Waste program? *[Yes/No]*

11. During what period did the disposal facility(s) operate?

- Did disposal cease prior to 1 January 1984 and, therefore, is eligible for Defense Environmental Restoration Account (DERA) funding? *[Yes/No]*

- *If no,* did disposal cease prior to 9 October 1991 and, therefore, doesn't fall under Resource Conservation and Recovery Act (RCRA) Subtitle D requirements? *[Yes/No]*

- *If no,* did disposal cease prior to 9 October 1993, the end of the two-year RCRA Subtitle D Phase-in period? *[Yes/No]*

12. Have there been any pre-investigation regulatory actions? *[Yes/No]*

- Inspections by Regulators? *[Yes/No]*
- Site complaints or notices of non-compliance? *[[Yes/No]*

13. Was Superfund Amendments and Reauthorization Act (SARA) Community Right-to-Know information ever compiled and reported? *[Yes/No]*

- Did you accomplish and file appropriate Material Safety Data Sheet (MSDS)? *[Yes/No]*

III. REGULATORY BACKGROUND OF LANDFILL SITE(S)

14. Is the site a "landfill" or a "dump"?

15. Are there multiple landfill sites on the Base? How many?
For each site, describe:

- Type(s) of waste accepted for disposal.

- Any liquid or drummed liquid waste accepted or deposited? *[Yes/No]*

  – *If yes*, describe; this increases the possibility that the landfill will contaminate groundwater.

- Was open-burning used at the site? *[Yes/No]*

  – *If yes*, describe; this decreases the possibility that the landfill will contaminate groundwater.

16. Is there any risk of ordnance/special munitions having been disposed of at the site? *[Yes/No]*

- *If yes*, describe.

17. What is the size of the site in acres?

- Gross area of the total site in acres?

- Area of the disposal site in acres?

- Are disposal sites contiguous or separate?

18. What is the configuration of the landfill?

- Was waste placed predominantly in trenches below grade? *[Yes/No]*
  - *If yes,* what is the estimated depth?

- Is there waste above grade? *[Yes/No]*
  - *If yes,* what is relief above land surface?

19. Are there any odors readily apparent at the landfill site? *[Yes/No]*

- *If yes,* are they consistent across the site or variable *[typical landfill smells or chemical]?*

20. Is a system of groundwater monitoring wells in place immediately adjacent to the landfill site? *[Yes/No]*

- *If yes to either,* describe for each, how long has the system been in place.

21. Describe adjacent contiguous Topography and Physical features and land uses.

- Surface water.
- Railroad Right-of-Way.
- Buildings.

- Others.

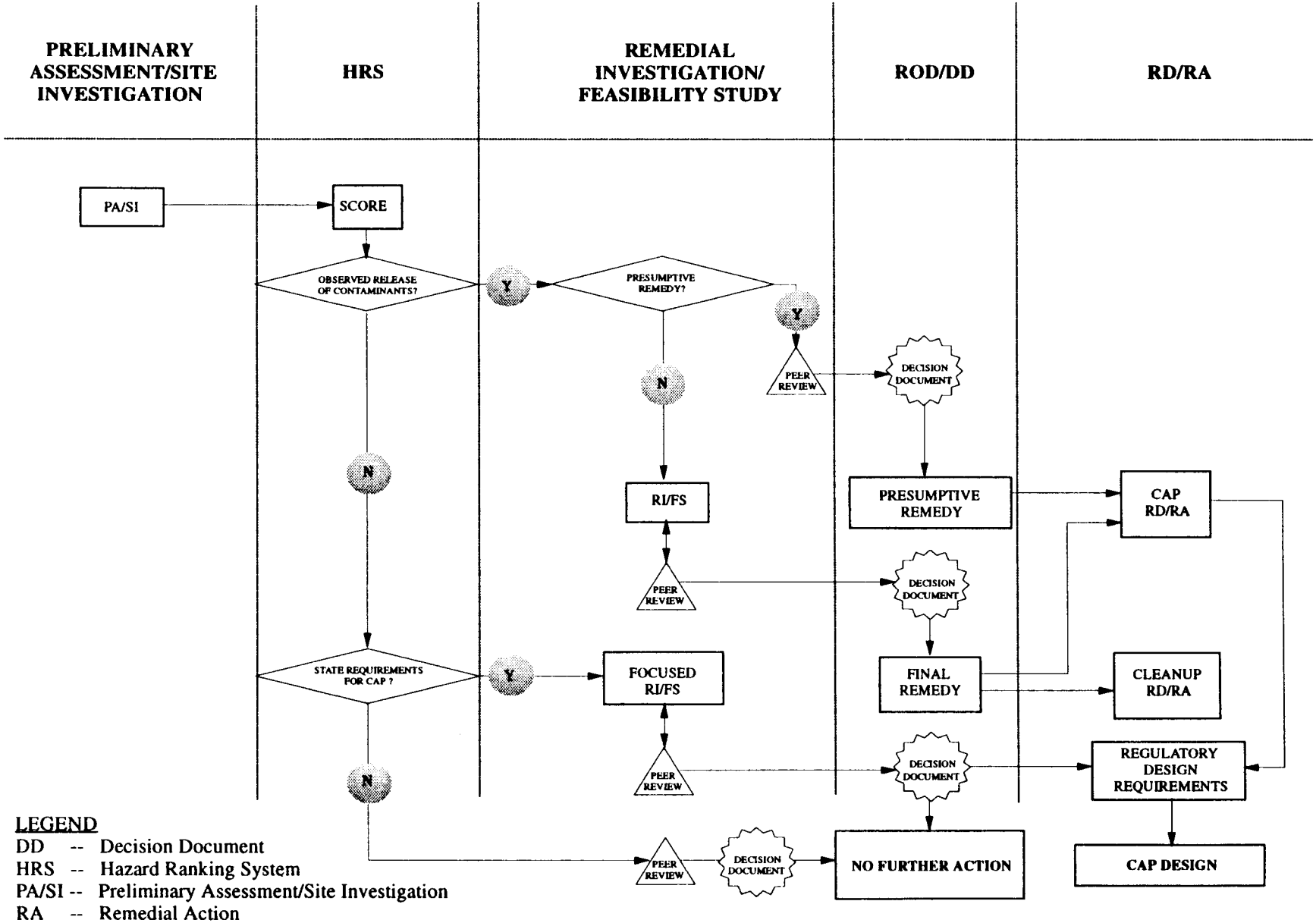
- Has contamination been detected in wells at the landfill? *[Yes/No]*
- Has contamination been detected in wells at the other locations on the Base? *[Yes/No]*
- Were the contaminants the same or similar?

- Were the contaminants consistent with the record of disposal at the landfill? *[Yes/No]*
- Is there any ongoing periodic site maintenance? *[Yes/No]*
  - *If yes*, what type?

22. What is the current land use of the site?

A decision tree has been included to depict the various stages of the landfill closure process.

DECISION TREE



LEGEND

DD -- Decision Document
HRS -- Hazard Ranking System
PA/SI -- Preliminary Assessment/Site Investigation
RA -- Remedial Action
RD -- Remedial Design
ROD -- Record of Decision

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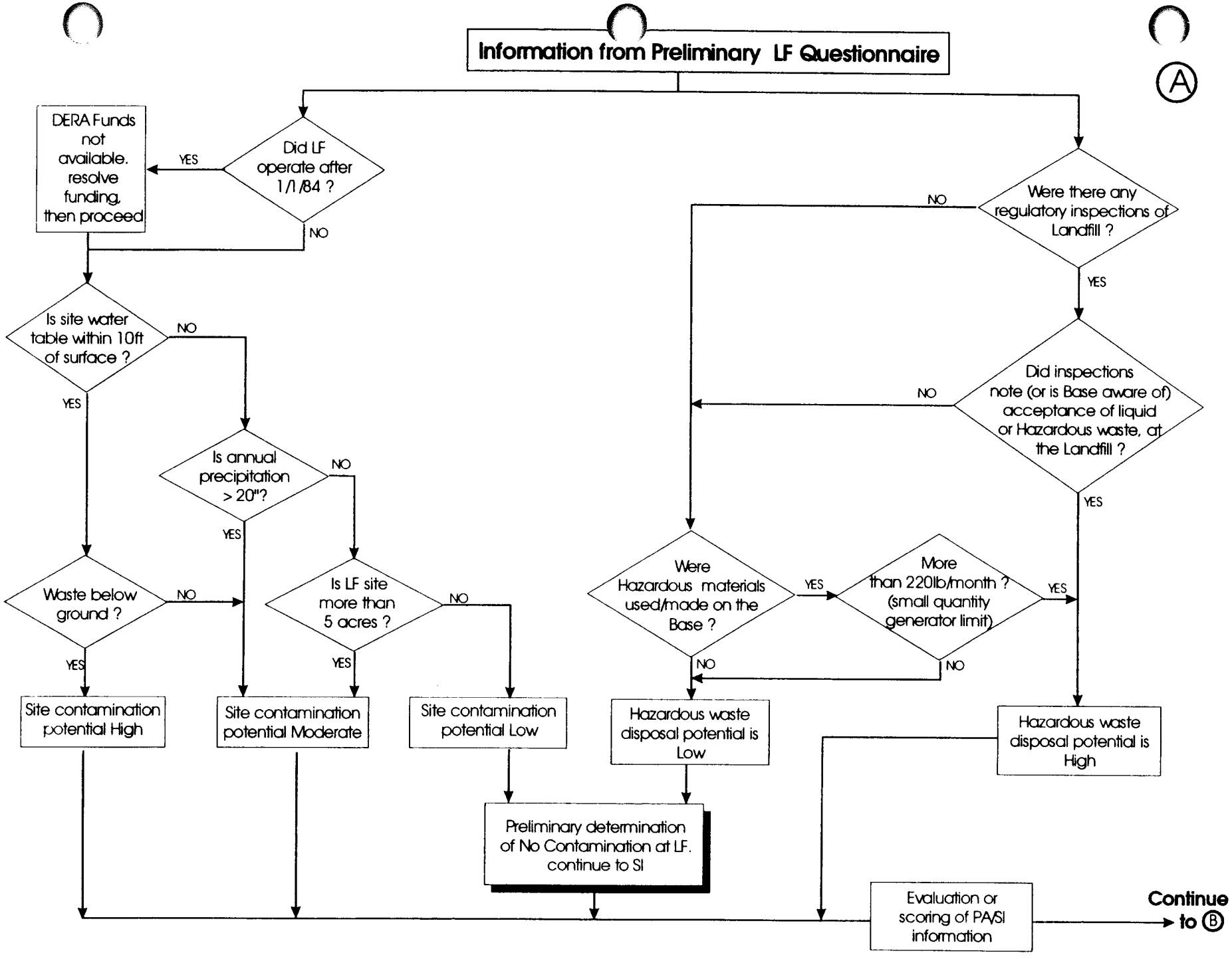
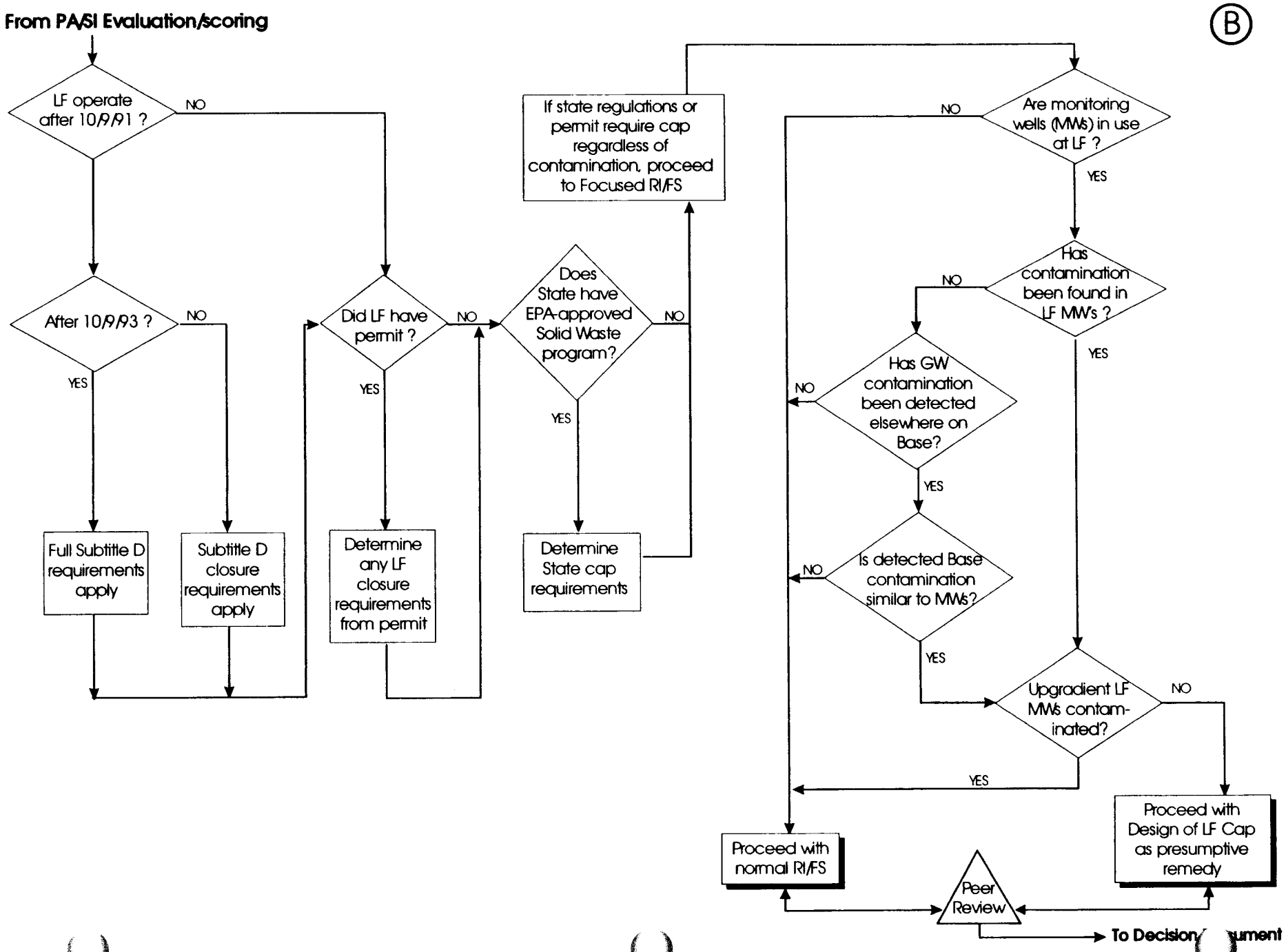

Information from Preliminary LF Questionnaire
A
Did LF operate after 1/1/84 ?
YES
NO
DERA Funds not available. resolve funding, then proceed
Is site water table within 10ft of surface ?
NO
YES
Is annual precipitation > 20"?
NO
YES
Waste below ground ?
NO
YES
Is LF site more than 5 acres ?
NO
YES
Site contamination potential High
Site contamination potential Moderate
Site contamination potential Low
Were there any regulatory inspections of Landfill ?
NO
YES
Did inspections note (or is Base aware of) acceptance of liquid or Hazardous waste, at the Landfill ?
NO
YES
Were Hazardous materials used/made on the Base ?
YES
NO
More than 220lb/month ? (small quantity generator limit)
YES
NO
Hazardous waste disposal potential is Low
Hazardous waste disposal potential is High
Preliminary determination of No Contamination at LF. continue to SI
Evaluation or scoring of PA/SI information
Continue to B


From PA/SI Evaluation/scoring
B
LF operate after 10/9/91 ?
NO
After 10/9/93 ?
NO
YES
Full Subtitle D requirements apply
Subtitle D closure requirements apply
Did LF have permit ?
NO
YES
Determine any LF closure requirements from permit
Does State have EPA-approved Solid Waste program?
NO
YES
Determine State cap requirements
If state regulations or permit require cap regardless of contamination, proceed to Focused RI/FS
Are monitoring wells (MWs) in use at LF ?
NO
YES
Has contamination been found in LF MWs ?
NO
YES
Has GW contamination been detected elsewhere on Base?
NO
YES
Is detected Base contamination similar to MWs?
NO
YES
Upgradient LF MWs contam-inated?
NO
YES
Proceed with normal RI/FS
Proceed with Design of LF Cap as presumptive remedy
Peer Review
To Decision Document

3. TECHNICAL STATEMENT OF WORK FOR LANDFILL CAP DESIGN

3. TECHNICAL STATEMENT OF WORK FOR LANDFILL CAP DESIGN

Purpose:

The purpose of this work is the preparation of a complete, 100% design specifications and plans for the *[insert name of site here]* at *[insert location of site here]*. Design and Construction documents shall include: established submittals at 30%, 60%, 90%, and 100% of design; identification of all regulatory requirements; site topography and existing conditions such as wetlands, surface waters and drainage, roadways and utilities; accommodation for leachate collection and landfill gas management; a complete design analysis, including the identification and evaluation of several design alternatives for the landfill cap design, and; all other categories of work such as mechanical, electrical, civil, and structural, that will be involved in the execution of the design and construction work.

[This statement of work <u>does not</u> include any significant work which may be needed at specific sites to address groundwater/leachate collection or treatment, or any work for sitewide collection or treatment of landfill gas. Passive venting of landfill gas from under the cap <u>is addressed</u>.]

I. Site Characterization

A. Data Provided: *The following information will be provided to the Architect-Engineer:*

1. **Waste Characteristics**: The Architect-Engineer (A-E) will be provided with such information as is available regarding the location of buried wastes, the type and form of those wastes, or the quantity of wastes which will have been buried in the landfill. The Government provides this data for the general information of the Architect-Engineer, and does not warrant the accuracy or utility in the prosecution of the work.

B. Data Requirements: *The A-E will provide the following elements of the work:*

1. **Topography:** Site topography will be prepared by a registered land surveyor, and will include the following information: site contours, surface drainage network and any surface water impoundments, location of other natural or cultural features, and an appropriate coordinate system and boundary locations. In conjunction with the coordinate system, the topographic drawing will identify the benchmarks and horizontal and vertical controls used. Cultural features consist of roadways and transportation features, utility services such as water and sewerage pipelines, telephone and electrical power lines, buildings and other structures. The topographic contour interval will not be greater than two (2) feet, but will be less than two (2) feet, if necessary to adequately show the topographic relief on the site.

2. **Climatic Data:** The A-E will obtain climatic or meteorological information about the site, including daily and monthly average and extreme values for temperature and precipitation, and any designated storm events (*i.e.*, 10-year storm, 25-year storm, etc.) as will be necessary for stormwater management or sediment control calculations. In addition, as appropriate to each site, the A-E will determine the number of days of consecutive winter temperatures less than 32 °F (0 °C) and the maximum depth of frost penetration.

3. **Geology and Soils:** The A-E will obtain all necessary information about the geology and soils of the site that are needed for the design. That information will include, but need not be limited to: conditions underlying the site including groundwater and the depth to the water table, the location of geologic formation outcrops, and the nature of surficial and near-surface deposits. Information about soils will also be developed from the subsurface investigation and other available sources such as U.S. Department of Agriculture soil survey maps.

[Depending on the degree of information already developed for the site, only one of the following paragraphs should be included.]

[For a site with minimal information, include the following . . .]

a) **Subsurface Investigation:** The A-E will develop and execute a Subsurface Investigation Plan to provide any necessary detailed site-specific information on the depth of soils, the engineering characteristics of the soil materials, the location, if appropriate, of the depth to the bedrock or other depth-limiting site condition, groundwater quality and levels, and the hydrogeology of the site. The Government will provide A-E with available information from any previous Subsurface Investigation(s) performed at the site, which shall be incorporated into the Subsurface Investigation Plan developed by the A-E.

[For a site with existing subsurface information which is expected to be sufficient for the remedial design activities, include the following . .]

a) Subsurface investigation: The government will provide the A-E with the following documents which include the results of subsurface investigations previously performed at the project site:

[List the documents here]

The A-E shall review and evaluate the sufficiency of the provided information for the design activities specified in this Statement of Work, or required to accomplish specified activites. In the event that available information is determined to be insufficient, the A-E shall prepare and provide to the government a report that describes the deficiencies in the available information, the additional information needed, the purpose for which the additional infomration is required,

and the A-E's proposed supplemental subsurface investigation plan which would be sufficent to provide that infomation.

b) **Geotechnical Information Development:** The A-E will develop information regarding the geotechnical performance and characteristics of the landfill necessary to adequately determine the design of the landfill cap. That information will include, but not be limited to, the determination of the degree of compaction or consolidation of the emplaced waste materials and the potential settlement of the landfill.

4. **Vegetation and Ecological Information:** The A-E will obtain information regarding the type of naturally-occurring and cultivated vegetation and fauna present in the site vicinity which may be useful or critical to overall design process or which may present additional regulatory requirements.

II. Conceptual Landfill Cap Design

A. **Conceptual Design:** The A-E will prepare a Conceptual Design for the landfill cap based on the Site Characterization information developed and/or provided and the additional information as developed in this section. This Conceptual Design will cover all phases of civil, structural, mechanical, electrical, and other required categories of work which will be involved in the execution of the landfill cap design and construction. A design analysis will be included which shows the work and information considered by the A-E in determining the recommended Conceptual Design. The Conceptual Design will include the following elements:

B. **Project Requirements:** The A-E will investigate and determine the engineering and regulatory requirements of the project, and will determine the extent of work required to properly execute all phases of construction. The minimum technical and performance standards for the landfill cap as specified by the U.S. EPA, the appropriate state, and the procedure by which alternative cap designs will be submitted and approved by the regulators will be specifically identified and described.

C. **Final Site Topography:** As part of the Conceptual Design, the A-E will produce the final site topography, showing all the information described in Section I.

D. **Draft Design Plans and Specifications:** The A-E will develop conceptual designs for the landfill cap construction and will provide those designs for review. The Draft Designs will include:

1. **Draft Grading Plan:** The draft grading plan should delineate the extent of preliminary limits of construction, existing surface water drainage features and how those features will be incorporated or modified in the proposed construction, preliminary sediment control, and stormwater management plans, and a preliminary grading plan for the landfill cap. Calculations supporting these plans will also be provided for review. Those calculations will include:

   - Drainage areas and surface runoff calculations.

- Preliminary stormwater management and drainage calculations.
- Earthwork estimates for cut and fill quantities to accomplish the grading shown on the draft grading plan.

2. **Recommended and Alternative Cap Designs:** The Cap Design will include proposed cross-sections of the landfill cap necessary to meet the Project Requirements. The U.S. EPA Hydrologic Evaluation of Landfill Performance (HELP)[1] model will be used to develop at least five (5) potential designs for the cap, one of which will be the minimum required design specified in the regulatory requirements. Each of the potential cap designs shall be presented for review. In evaluating potential cap designs, the use of natural soils, geomembranes, and geocomposite materials shall be incorporated in varying degrees and combinations to meet the performance requirements of the regulations. Where more than one of the potential cap designs meets the Project Requirements, the A-E will determine the Recommended Cap Design, and include one or more preferred Alternative Cap Designs for additional engineering consideration during the Preliminary and Final Design Phases. Information produced and evaluated by the A-E will be presented in conjunction with the Recommended and Alternative Cap Designs:

- Cap Cross-Sections, showing the individual cap components and dimensions.
- Results of the U.S. EPA HELP model calculations.
- Preliminary estimates of soil quantities, drainage materials, geomembrane, and geocomposite materials required.
- Preliminary cap design construction cost estimates, as specified in Section V.B.
- Preliminary evaluation of the constructability of the cap design, with particular attention given to the construction season, the impact of site weather conditions on construction unit operations, especially the placement and compaction of soil materials, the availability of specialized equipment or trades, and the availability of any soil materials which are proposed to be excavated from on-site, or those which must be obtained off-site.
- *[Include the following (as appropriate) . . .]*

– Leachate Collection and Treatment Systems.

– Landfill Gas Collection and Treatment System Design.

3. **Preliminary Drawing Description and Specifications Outline:** List the number and preliminary titles of the individual drawings anticipated by the A-E to be in the final set of construction documents. Also provided in the Conceptual Design will be an outline of the Construction Specifications, prepared in accordance with the requirements of Section V.D. and such standard sections of the specifications as will be immediately available.

[1] U.S. EPA, Document EPA/600/R-94/168A.

4. **Preliminary Project Cost Estimate:** Estimates will be based on itemized costs, including those previously prepared for the Recommended and Alternative Landfill Cap Designs. The Preliminary Project Cost Estimate shall be provided for the Recommended and any Alternative Cap Designs, and shall incorporate the cap cost estimates in addition to all other associated site construction costs.

III. Design and Construction Documents

A. **Design:** The A-E will prepare Design and Construction Documents for the landfill cap based on the Conceptual Design. These documents will cover all phases of civil, structural, mechanical, electrical, and other required categories of work which will be involved in the execution of the landfill cap design and construction. The design and construction development will be based on accepted engineering practice, and must reflect appropriate technical decision-making by the A-E in finalizing a design based on the recommended Conceptual Design. Documents will include the following elements:

B. **Project Design Requirements:** In this phase of the work, the A-E will further refine the preliminary Project Requirements identified in the Conceptual Landfill Cap Design phase. This refinement will be complete and must result in the identification of all relevant and appropriate requirements being identified by the A-E with which the design, construction, and operation and maintenance of the project must comply. Major items which will be identified include, but are not limited to the following:

- Regulatory Requirements which must be met in the landfill cap design.
- Local, state, and Federal requirements for all work associated with the project.
- Permits and approvals which must be obtained, including an estimate of the schedule requirements typical of the procedures needed to receive those permits or approvals.
- The presence and location of any soils on the site which are appropriate for use in the construction.
- Project Design, Bidding, and Construction Schedule, incorporating the permit and approval schedule information previously identified.

C. **Construction Drawings:** The A-E will prepare complete construction drawings, showing all information necessary for a contractor to bid and construct the project. Drawings will include, but not be limited to the following:

- Vicinity Map: Showing the geographic location and relation of the site to other existing buildings, roads, utilities, etc.
- Site Topography and Survey Information: Showing the topography of the site, the location of the site and construction relative to property lines, the limits of construction, the survey benchmarks at or in the vicinity of the site which were used in the preparation of the topography, the location and coordinates of the survey benchmarks on the site which will be used in the monitoring and construction of the project, and, if used, the

location and coordinates of the construction Baseline for the project. This drawing will be prepared and sealed by a Registered Land Surveyor.

- Landfill Cap Grading Plans:
  1. Sub-Base Preparation Grading Plan(s), showing any required excavation of existing waste, regrading or relocation of existing soil, and areas where additional material must be placed.
  2. Intermediate Grading Plan, if necessary, to show critical grades at top/bottom of geomembrane or low-permeability soil layer.
  3. Landfill Cap Final Grading Plan.
- Landfill Cap Details, including details for the Alternative Cap Design, if included as an alternate bid item, and details for leachate or landfill gas collection, if needed.
- Other Civil, electrical, mechanical Plans and Details:
  1. Sediment and Erosion Control Plans and Details.
  2. Stormwater Management Plans (if needed).
  3. Grading Plans, etc., for any on-site Soil Excavation Areas.

[If Groundwater/Leachate Collection and Treatment and/or Landfill Gas Collection and Treatment is included in the project, add appropriate additional sections here and in subsequent sections.]

D. Design Analysis: The Design Analysis for this phase of the work will include, but not be limited to the following:

- Final mass balance of soil and other materials used in the cap construction and site grading.
- Landfill settlement and slope stability calculations, including an analysis to confirm acceptable safety factors, particularly relative to any potential slip planes at the interfaces of geomembranes, geocomposites, and soil layers.
- Sediment and erosion control calculations, including drainage areas, runoff, and the selection and sizing of sediment control methods and devices.
- Stormwater management calculations, including the sizing of drainage ditches, culverts and storm drains, and stormwater management structures.
- All necessary civil, electrical, mechanical, structural, and other appropriate engineeringcalculations supporting the complete design of the A-E.

E. Construction Specifications: The A-E will prepare specifications for each component element, both materials and methods, of the construction. The Specifications will also include the methods which will be used to provide the Construction Quality Assurance for the landfill cap, especially those which will be used to monitor soil characteristics and

compaction, the liner quality and seaming, and the functioning of any geocomposite materials. The Construction Specifications will also include the following technical Work Plans, as defined by the U.S. EPA:

- Construction Management Plan, including a detailed description of the Construction Quality Assurance/Quality Control procedures that will be followed by the Construction Contractor.
- Health and Safety Plan.
- Quality Assurance Project Plan.
- Other work plans as required.

F. Final Construction Cost Estimate: The final construction cost estimate will be prepared based on the final construction drawings as specified in Section V.B.

IV. Design Progress Submissions

A. Conceptual Design (30% Submittal): The A-E (A-E) will make two progress submissions in the Conceptual Design phase:

1. At 50% of the Conceptual Design, A-E will submit:
   - Conceptual Design Assumptions and Project Requirements
   - Preliminary Grading Plan
   - Potential Landfill Cap Designs being evaluated
   - Preliminary Cost Estimates for evaluated designs

2. At 100% of Conceptual Design, A-E will submit complete information required in Section II. Conceptual Landfill Cap Design

B. Design and Construction Documents (60% and 90% Submittal): The A-E will make two progress submissions in this phase of the work:

1. At 60 % of Design and Construction Document preparation, A-E will submit:
   - At least 60% of the Project Design Requirements and Design Analysis.
   - At least 60% progress on the Grading Plans and all other drawings.
   - At least 60% progress Drafts of Construction Specifications.
   - At least 60% progress on all civil, electrical, mechanical, and structural design design.
   - Updated Preliminary Construction Cost Estimate based on design drawing quantity take-offs.

2. At 90%, A-E will submit:

- At least 90% progress on all Construction Drawings.
- At least 90% progress on the Design Calculations.
- At least 90%of Final Construction Specifications.
- Updated Construction Cost Estimate and Revisions, if any, to Construction Schedule.

C. **Final Submission (100% Submittal):** After the completion of all portions of the project documents, including the incorporation of any review comments, modifications, or corrections identified in the 90% Submittal, the A-E will submit the plans and specifications in electronic form in format(s) and on media as specified by the Government. In addition, the A-E will submit paper copies of the Plans and Specifications as follows: ___ sets of the revised specifications, ___ copies of each drawing, and ___ copies of the cost estimate, bidding schedule, design analysis, and proposed construction schedule. Copies will be excellent quality blue- or black-line on white paper.

V. Miscellaneous Requirements

A. **Design Analysis:** In each phase of the work, the A-E will submit an appropriately detailed design analysis. The design analysis will cover all phases of civil, structural, mechanical, electrical, and other categories of work as required and/or accepted by good engineering practice. The design analysis will show the technical decision-making process, in a logical sequence, which the A-E used in reaching his design in each phase of the work. The Design Analysis will be handwritten, hand lettered, typewritten, or any combination thereof, provided it is legible and clearly expressed.

B. **Cost Estimates:** In each phase of the work, the A-E will submit a Cost Estimate for the construction of the project. The cost estimate will cover all materials and labor costs incident to the planned construction, and will be based on unit prices and quantities determined from the design work performed. These quantity take-offs and unit prices will be of an accuracy and detail appropriate to the level of design refinement in the phase of work. In support of the unit price cost estimate, the A-E will employ such other methods and utilize such sources of cost information consistent with best engineering practice.

C. **Construction Drawings:** Drawings shall be prepared in accordance with standards provided by the Government. The cover sheet for drawings shall include: the ACC logo, Air Force Project number, project description, and Base name.

D. **Technical Specifications:** The A-E will prepare the technical provisions of the specifications in clear, understandable language such that a construction contractor can readily determine the types of materials used and the manner of installation required. The specifications will be prepared to meet Government standards for competitive bidding, and will use applicable Air Force and Corps of Engineers guide specifications. Trade names will not be used.

4. DESIGN CHECKLIST

4. DESIGN CHECKLIST[1]

#	Checklist	Yes	No	Accomplished/ Complete
I. PRE-DESIGN INFORMATION:				
1.	Are any approved preclosure plans or permit documents available for the landfill site?			
2.	Are any approved postclosure plans or permit documents available for the landfill site?			
3.	Is periodic monitoring required at the site? If Yes, identify the source(s) and the available funds for the monitoring. Is periodic maintenance required at the site? If Yes, identify the source(s) and available funds for the maintenance.			
4.	Identify the number of monitoring wells (MWs) located at the site: On-site MWs: Up-gradient MWs: Down-gradient MWs: Is there a need to implement any wellhead protection program?			
5.	Is a site-specific or a Base-Wide Health and Safety Plan (HASP) available? If not, prepare one.			
6.	Is a site-specific or a Base-Wide Sampling and Analysis Plan (SAP) available for the site? If not, prepare one (if sampling is required). Identify the data quality objectives and needs.			
7.	Identify the required media to be sampled, the frequency of sampling, and the number of samples to be collected. **Media** **Frequency** **Number of Samples:** Groundwater (GW) Surface water (SW) Sediment (SE)			

[1] *Checklists are formatted for simple "Yes or No" type responses. However, in some instances, these type of responses may not be applicable or appropriate. Under those circumstances, the user must respond appropriately. It should also be noted that "Yes or No" type responses need to be followed up with appropriate action which is not explicitly included in these checklists.*

Note: *Any standards/criteria mentioned in this document are for minimum requirements. Federal and/or state requirements should be used appropriately.*

#	Checklist	Yes	No	Accomplished/ Complete
	Air/Gas (A/G) Wastes/Sludges/ Leachate (W/S/L)			
8.	What contaminants are monitored? **Media** **Contaminants** GW SW SE A/G W/S/L			
II. DESIGN CONSIDERATIONS:				
1.	Identify the minimum design requirements and the type of **Closure** from the closure plans/permits and relevant regulatory guidance manual. Is EPA presumptive capping design applicable? As a minimum, the contractor/agency in charge of the design should have considered the applicability of the following in the design, besides Applicable or Relevant and Appropriate Requirements (ARARs): - Cover for a hazardous waste landfill (RCRA Subtitle C requirements). - Cover for a non-hazardous waste landfill (RCRA Subtitle D requirements). **Clean Closure**: EPA's standards are based on the assumption that the site will have unrestricted use and require No maintenance after the closure. Use state's standards, if applicable. **Landfill Closure:** EPA's standards are based on the assumption that post closure care and maintenance are required at least for 30 years after the closure. Use state's standards, if applicable. **Hybrid-Clean Closure:** EPA recommends the development of site-specific standards based on the assumption that leachate will not impact the ground water. No covers or long-term monitoring required. Use state's standards, if applicable. **Hybrid-Landfill Closure:** EPA recommends the development of site-specific standards based on the assumption that residual contamination poses a direct contact threat, but the groundwater will not be contaminated. Permeable covers, limited long-term monitoring including groundwater monitoring. Use state's standards, if applicable. What is the proposed landuse for the landfill site?			

#	Checklist	Yes	No	Accomplished/ Complete
2.	Has the contractor developed a conceptual design for the minimum requirements (Base Case) and submitted for regulatory review? Has the contractor provided logical sequence of the technical decision making process? Has the contractor considered alternative designs of equal or superior effectiveness compared to the Base Case design, in which one or more layers comprised of differing materials of construction compared to the Base Case? Has the contractor evaluated the effectiveness of alternative and Base Case conceptual designs? Has the contractor used Hydrologic Evaluation of Landfill Performance (HELP) model to evaluate the effectiveness of alternative design to reduce/eliminate infiltration? Has the contractor compared the quantity take-off costs for each conceptual design (cost estimates include construction, operation, maintenance, annual reporting, end-of-service replacement etc.)? Has the contractor considered cost-effective alternatives in the selection of remedial technologies, if any? Has the contractor considered any innovative technologies for the remediation, if any? Has the contractor considered cost-effective alternatives in the selection of materials?			
3.	Is there a need to implement any run-on and/or run-off control measures to protect the final covers from eroding? Identify the long term operational/maintenance requirements.			
4.	If required, the run-on control system should be designed to prevent flow on to the active portion of the landfill during peak discharge from design storm. A run-off management system should be designed to collect and control at least the water volume resulting from the design storm.			
5.	Identify the various system components designed: **Cover System:** Top soil, filter, drainage layer, liner, etc. **Liquid Management System:** Leachate Collection and Removal System (LCRS -- drainage layer, liners, pipes, leak detection,			

#	Checklist	Yes	No	Accomplished/ Complete
	disposal, monitoring, etc.). **Surface Water Collection and Removal System (SCRS):** Run-off, run-on systems, pipes, etc. **Gas Management System:** Gas collection, venting, removal, monitoring, etc. **Others:** Specify, if any (e.g., remedial action components, monitoring well design, etc.).			
III. DESIGN INFORMATION:				
1.	Has the contractor completed the topographic survey to establish existing landfill elevations, horizontal control, vertical control, landfill boundary survey, project bench mark, etc? Survey must be accomplished by a registered land surveyor or engineer depending on applicable state requirements. All drawings displaying the survey data should display the registration stamp of the registered land surveyor or registered engineer. Are all impacted lands and eleavance requirements restricted to Air Force property?			
2.	For each of the components identified in No. 5 above, check and make sure that the contractor has considered the ARARs to establish the design criteria. For each design criteria established, has the contractor performed checks to indicate the designed values and the design requirements (e.g. stability, settlement, subsidence, permeability, erosion, run-off, run-on, drainage, discharge, etc.)? Has the contractor considered site specific information in the design regarding climate, precipitation, topography, geophysical, surface run-off, geology, hydrology, waste characteristics and nature, degree, and extent of site contamination? Identify the assumptions considered in the design and the factor of safety involved in each assumption. Have the design calculations been signed by a certified Professional Engineer?			
3.	Has the contractor determined the need and provided detailed engineering evaluation (technical and cost/benefit analysis) of the preferred design for the following? Type of vegetative cover			

#	Checklist	Yes	No	Accomplished/ Complete
	Type of soil cover Need for biotic barrier Type of drainage layer material Size and spacing of drainage layer piping system Type of geomembrane Type of low-permeability soil layer Hydraulic conductivity of low-permeability layer Need for soil gas vent layer Type of materials for gas vent layer Use of landfill gas as alternative energy source Slope of landfill cap Quantity and source of grading fill Slope,stability of landfill cap Potential for differential settlement Need for filter or stabilization geotextile at multiple layer interfaces Manufacturer's QA/QC program for geosynthetic materials Construction QA/QC program			
4.	Has the contractor provided specifications for all the materials used in the design so that a construction contractor can readily determine the types of materials and the manner it is to be installed? Do these specifications meet the minimum standards required? Have separate detailed drawings been prepared for all types of civil, mechanical and electrical categories?			
5.	Has the contractor appropriately and adequately addressed and incorporated the comments from the regulatory agencies? Has the contractor prepared the final landfill-closure design and prepared quantity take off cost estimates?			
6.	Have appropriate permits been obtained to proceed with the construction activities? Are any or all of the following permits required for? Digging Surface water discharge Dust control Debris disposal (in case of off-site disposal) Wastewater discharge Air quality Wetlands construction Others (specify, if any)			
7.	What institutional controls are required (such as fences)?			

#	Checklist	Yes	No	Accomplished/ Complete
8.	What are the requirements for design and/or construction critical path method (CPM)?			
9.	What are the Health and Safety Plan (HASP) certification requirements?			
10.	What are the recommendations for Installation oversight staff requirements?			

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5. CONSTRUCTION CHECKLIST

5. CONSTRUCTION CHECKLIST

#	Checklist	Yes	No	Accomplished/ Complete
I. PLANS AND PERMITS:				
1.	Identify the major construction and/or survey activities. Mobilization and preparatory work (including necessary topographical survey) Site work (includes site grading, excavation, placement of fill material, clay liner materials etc.) Demolition and removal Cap/Liner System Leachate Collection and Removal (LCR) System Leak Detection, Collection, and Removal (LDCR) System Surface Water Collection and Removal (SWCR) System Installation of monitoring wells Stability monitoring system Gas collection/venting system Biotic barriers Vegetative layer Access road Solids collection and containment (handling and transportation of contaminated soils, if necessary) Disposal Site restoration Monitoring, sampling, testing and analysis Demobilization Others (specify)			
2.	Are any of the following Plans required ? If Yes, have they been prepared and approved by authorized personnel? Work Plans (WP) Construction Management Plan (CMP) Quality Assurance Plan (QAP) Health and Safety Plan (HASP) Erosion Control Plan			
3.	Have any environmentally sensitive areas/wetlands and other types of lands (burial ground, privately-owned property) been identified close to the construction site that might be affected by the site activities?			
4.	Are any endangered species' habitats or flora and fauna located close to the site that might be affected by the site activities?			

#	Checklist	Yes	No	Accomplished/ Complete
5.	Have appropriate precautions been taken to protect the sensitive areas? Have appropriate permits been obtained to proceed with the construction activities? Are any or all of the following permits required for? Digging Surface water discharge Dust control Debris disposal (in case of off-site disposal) Wastewater discharge Wetlands construction Air quality Others (specify, if any)			
6.	What types of permits/arrangements are required to dispose of the construction debris? Identify the transporter and disposal facility, if any.			
II. CONSTRUCTION OVERSIGHT:				
(a) Management:				
1.	Has a pre-construction conference been arranged to establish local ground rules, both covered (such as labor standards clauses) and not covered by the contract documents (Base regulations)? Identify staff requirements and responsibility for field oversight.			
2.	Will personnel representing Fire Department, Bioenvironmental, Security Police, the Base Civil Engineer, Safety, Communications, Service Center (Corps/AFCEE and Contracting Officer) and MAJCOM participate in the meeting?			
3.	Has a Government team meeting been held beforehand (if necessary), to clarify issues such as Government Furnished Equipment/ Government Furnished Materials (GFE/GFM) and coordination in restricted areas?			
4.	Are delivery requirements for important materials and equipment being met?			
5.	Is the project on schedule? If No, have appropriate changes been made to the CPM/Schedule to reflect changes in the project completion date?			

#	Checklist	Yes	No	Accomplished/ Complete
6.	Does the CPM/Schedule indicate disproportionate amount of work in the last month or two of the contract. If Yes, has the contractor been asked to provide a clarification/justification? Is there a more effective value engineering solution from the contractor? Compare design and construction CPM, if applicable.			
7.	Once started, is the clay cap construction project (if used) scheduled to finish entirely, without interruption? If No, have appropriate arrangements been made to maintain the moisture content of compacted portions of the cap during inactive periods to prevent drying and cracking?			
8.	Is the clay cap construction project scheduled to stop with the onset of winter weather ? If Yes, have appropriate arrangements been made to perform scarification and recompaction of the top 1 foot of the clay cap?			
9.	Have appropriate precautions been taken to protect synthetic membranes (if used) from ultraviolet rays and excessive heat?			
10.	Do equipment and other vehicles travel on the liner? (only the seaming equipment, seam testing equipment, and the minimum number of necessary workers should be allowed on the liner.)			
11.	Has the sub-base for the liner been prepared according to specifications?			
12.	If the time interval between sub-base construction and synthetic membrane installation is greater than 1 month, was an approved herbicide used to inhibit vegetative growth?			
13.	Have the nutrient and liming requirements of the top soil been assessed and correctly met to enhance vegetative growth?			
14.	Has proper approval been obtained from the Contracting Officer, for any change(s) in the construction project as described in the Work Plan?			
15.	Are the additional costs incurred due to the change(s) within approved funding ceilings?			
16.	Has the suggested change(s) been reviewed by appropriate technical personnel?			

#	Checklist	Yes	No	Accomplished/ Complete
17.	Has a competitive contract been considered as an alternate method of implementation to reduce cost of modifications?			
18.	Are all construction activities thoroughly documented in daily log?			
19.	Does the documentation include a summary of all observations, daily inspections, and photo/video logs?			
20.	Does the documentation identify problems encountered during construction and the corrective measures taken?			
21.	Does the documentation list any deviations from design and material specifications -- with justifying rationale?			
22.	Is the documentation reviewed and signed by a registered engineer?			
23.	Closure Report (If required by state)			
(b) Health and Safety:				
1.	Is work safety an active program?			
2.	Are periodic meetings scheduled by the contractor to inform site workers about site conditions and hazards and their responsibilities to work in a safe manner?			
3.	Have <u>all</u> site workers received appropriate safety training and certification?			
4.	Do <u>all</u> site workers wear appropriate and approved protective clothing?			
(c) Quality Assurance/Quality Control (QA/QC):				
1.	The following list shows primary indicators of the quality of the contractor's operations. Indicate whether the contractor's performance has been satisfactory in the following areas: 1. Workmanship and craftmanship			

#	Checklist	Yes	No	Accomplished/ Complete
	2. Overall job cleanup and appearance 3. Daily housekeeping 4. Health and Safety observance 5. Material storage procedures 6. Disposal of debris			
2.	Is a specific testing frequency for the clay cap, during construction, outlined for density, moisture content, permeability, and grain size, etc.? If Yes, has the outline been followed to assure quality control? If No, why not?			
3.	What are the QA/QC requirements for getting duplicate results for these testings? Are any additional testings to be performed by an independent consulting firm (other than the contractor)?			
4.	Were any QC tests performed in a laboratory owned by the contractor and what controls were used to ensure objectivity?			
5.	Was a borrow source investigation conducted to determine whether material for the clay cap and top soil satisfies the requirements of permeability, grain size, and moisture content, etc.?			
6.	Was the Flexible Membrane Liner (FML) tested for sheet thickness, melt index, puncture and tear resistance, density, and bonded seam strength before installation?			
7.	Were the density and smoothness of the sub-base for the FML tested before liner placement?			
8.	Were the delivery tickets of all FML rolls delivered to the site inspected to verify receipt of proper shipments?			
9.	Were the damaged areas of the synthetic membranes repaired? Was each patch up repair tested for proper seaming? Were the numbers of repairs greater than two per 930 sq. in. (maximum allowable) of installed synthetic membrane area?			
10.	Has a grain size analysis been performed for the protective layer for every 730 cu. in. of material used?			

#	Checklist	Yes	No	Accomplished/ Complete
11.	Have samples (at least five) been tested to determine the nutrient and liming requirements of the top soil?			
12.	Have nutrient and seed mix application rates for top soil been supervised?			
13.	Are technical personnel capable of advising the field crew, performing the QC tests in the field, and surveying, available and present during construction?			
14.	Does the supervising engineer conduct routine and unannounced visits during construction?			
15.	Were QC personnel present at all times during compaction since homogeneity of the compacted clay cannot be ensured by performing laboratory tests alone?			
16.	Will QC tests be signed by registered engineers?			
17.	Has final acceptance/certification for completion been obtained from regulatory agencies?			
(d) Warranties and Liabilities:				
1.	Does the construction contract have warranty provisions?			
2.	Does the Base Civil Engineer (BCE) have a composite listing of all warranties in effect from the construction work?			
3.	Was a final inspection conducted before the BCE signed the DD Form 1354?			
4.	Is the BCE responsible for advising the designated contracting officer when to have the contractor return and correct any work under warranty?			
5.	Has the BCE ensured that the problems identified are warranty problems, and not due to abuse or a lack of proper maintenance?			

#	Checklist	Yes	No	Accomplished/ Complete
(g) Maintenance Responsibilities:				
1.	Is a one-year or any other O & M follow-on included in the contractor's agreement?			
2.	Does the contract outline responsibilities of the construction contractor for maintenance required after one year due to defects in the construction?			

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6. MAINTENANCE CHECKLIST

6. MAINTENANCE CHECKLIST

#	Checklist	Yes	No	Accomplished/ Complete
I. CLOSURE DOCUMENTS:				
1.	What are the approved preclosure plans or permit requirements for maintenance and monitoring?			
2.	What are the approved postclosure plans or permit requirements for maintenance and monitoring?			
3.	Is periodic monitoring required at the site? If Yes, identify the source(s) and the available funds for the monitoring. Is periodic maintenance required at the site? If Yes, identify the source(s) and available funds for the maintenance.			
4.	Identify the number of Monitoring Wells (MWs) located at the site: On-site MWs: Up-gradient MWs: Down-gradient MWs: Is there a need to implement any wellhead protection program?			
5.	What are the technical specifications and other general information about the liner material used in the landfill?			
II. MONITORING:				
1.	What types of periodic monitoring is required? Visual Site Inspection Leachate Head Monitoring Leakage Monitoring Groundwater Monitoring Gas Monitoring Leachate Tank Monitoring Final Cover Stability Monitoring Sample Collection and Analysis None What are the monitoring schedule requirements?			

#	Checklist	Yes	No	Accomplished/ Complete
2.	Identify whether any or all of the following are required to be monitored and maintained: Leakage detection and monitoring. Monitoring for settlement. Gas monitoring. Sample collection and analysis (see Design checklist for more information).			
3.	Does the Closure Plan address the need for developing a site-specific Health and Safety Plan (HASP)?			
4.	Is a site-specific HASP available for the site? If not, prepare one.			
5.	Is a site-specific Sampling and Analysis Plan (SAP) available for the site? If not, prepare one (if sampling is required). Identify the data quality objectives and needs.			
6.	Identify; the media to be sampled, the frequency of sampling, and the number of samples to be collected. **Media** **Frequency** **Number of Samples**: Groundwater (GW) Surface water (SW) Sediment (SE) Air/Gas (A/G) Wastes/Sludges/ Leachate (W/S/L)			
7.	What contaminants are monitored? **Media** **Contaminants** GW SW SE A/G W/S/L			
8.	Identify the minimum number and type of QA/QC samples to be collected.			
9.	Identify the locations, media, and number of background samples to be collected.			

#	Checklist	Yes	No	Accomplished/ Complete
10.	Any agency contracted to do the sampling? If No, then what is the minimum number of field personnel and time required for sampling?			
11.	Identify the personnel protective equipment and sample container requirements.			
12.	Identify the type of laboratory required for the analytical work? CLP Laboratory Non-CLP Laboratory Others (specify)			
13.	Any laboratory contracted to do the analytical work?			
14.	Establish lines-of-command and chain-of -custody protocols.			
15.	Identify the holding time for the contaminants to be sampled and the mode of transporting the samples to the laboratory.			
16.	Identify the data reporting and data analyses requirements for the analytical results.			
17.	Identify the record-keeping and notification requirements, and the data storage, and retrieval system.			
III. MAINTENANCE:				
1.	Identify the types of periodic maintenance required? Fire Protection Equipment Access Road Maintenance Leachate Collection System Maintenance Final Cover Maintenance MW Maintenance Data (environmental and other field data) Maintenance None			
2.	Does landfill fire occur frequently at the site?			

#	Checklist	Yes	No	Accomplished/ Complete
3.	Has the access road to the landfill been maintained properly and sufficient funds allocated to maintain proper drainage of interior roads?			
4.	Has the leachate collection system been (pipes, manholes, collection tank, accessories and pumps) cleaned and maintained periodically? Identify the pump maintenance and warranty requirements. Identify the need to follow confined space entry procedures during routine maintenance. If needed, address them adequately in the HASP.			
5.	Has the landfill final cover been protected well against erosion, settlement, stress on vegetation?			
6.	Date of installation of the cover. Date of last inspection and observations, if any. Action taken to correct problems, if any.			
7.	Identify the type of Response Plans that may be required at the site. Emergency Response Plan Leak Response Action Plan			
8.	Date of installation of the liner. Type and nature of manufacturer's warranty for the liner material, if any. Date of last inspection, and observations, if any. Action taken to correct the problems, if any.			
9.	How many repairs were done to the synthetic membranes? Was each patch up repair tested for proper seaming? Was the number of repairs greater than two per 930 sq. in. (maximum allowable) of installed synthetic membrane area?			
10.	Protect and maintain surveyed benchmarks.			

#	Checklist	Yes	No	Accomplished/ Complete
IV. PROGRAMMING:				
1.	Have sufficient funds made available for the following? Monitoring activities identified in Section III. Maintenance activities identified in Section IV. Is funding for O & M based on third party costs? Has funding been set aside for administrative costs and contingencies? Training and Certification for AF employees. Others (specify)			
2.	Is a certificate of closure issued to the local zoning authority?			
3.	Is a survey plot indicating the location and dimensions of landfill with respect to permanently surveyed benchmark submitted to the local zoning authority?			
4.	Identify activity and the contractor/agency involved with the following: Monitoring works Sample collection Laboratory for analytical work Maintenance works (civil, electrical and mechanical) Emergency responses Others (specify)			

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7. COST INFORMATION

7. COST INFORMATION

SIZE (Acres)	DESIGN COST($)		CONSTRUCTION COST($)		LOCATION	REMARKS
	Total	Cost/Acre	Total	Cost/Acre		
2	NA	NA	926,000	463,000	First Piedmont Quarry, VA	
27	159,985	5,925	1,414,916	NA	Operable Unit Nine (LF03) Shaw AFB, SC	State Cap
12	NA	NA	74,000 663,000	7,000 60,000	Forest Waste Disposal, MI	Site restrictions and monitoring Site restrictions, monitoring, and soil cover
8	97,000	12,000	650,000	81,000	McConnell AFB, KS	
120	NA	NA	2,344,000	19,533	LF-02 Minot AFB, ND	RCRA D Cap
26	966,000	37,000	7,400,000	285,000	Fairchild AFB, WA	
44	450,000	10,200	8,900,000	202,000	Whidbey Island, WA	
23	225,000	9,800	5,000,000	217,000	Wright Patterson AFB, OH	

7. COST INFORMATION

Location	Capped Area/Year	Information		Total Cost ($)	Cost ($)/Acre
Region 3: First Piedmont Quarry 719, Chatham, VA	Capped area: 2 acres June 28, 1991	RCRA subtitle C cap	Cap construction	745,107	372,554
			Testing and design	113,426	56,713
			Leachate collection	23,700	11,850
			Institutional control	44,200	22,100
			Total	**926,433**	**463,217**
Region 4: Shaw AFB, Sc	Capped area: 27 acres	LF 03 State Cap	Design	159,985	5,925
			Construction	1,414,916	52,404
			Total	1,574,901	58,329
Region 5: Forest Waste Diposal MI	Landfill 11 acres Lagoons 1 acre March 31, 1988	RCRA cap Site restrictions and monitoring	Alternative (SR) Construction	74,000	6,727
		Site restrictions, monitoring and soil cover	Alternative (SRC) Construction	663,000	60,273
		Site restrictions, RCRA cap and vertical barrier	Alternative (SRCV) Construction	8,006,000	727,818
Region 5: Wright Patterson AFB, OH	23 acres		Design	225,000	9,800
			Construction	5,000,000	217,000
			Total	5,225,000	226,800

Location	Capped Area/Year	Information	Total Cost ($)	Cost ($)/Acre
Region 7: McConnell Air Force Base, KS Landfill 2, Alternative 3	Capped area ≅ 8 acres August 1993	2-ft. bottom layer of compacted clay, 1-ft. top layer of top soil		
		Site preparation		
		Load, haul, spread and compact clay	246,000	30,750
		Spread top soil	283,000	35,375
		Drainage ditches	25,000	3,125
		Vegetation	3,000	375
		Irrigation	28,000	3,500
		Erosion control	5,000	625
		Misc (field office, testing, mobilization)	5,000	625
			55,000	6,875
		Total	**650,000**	**81,250**
		Engineering Cost (15%)	97,000	12,125
		Contingency (25%)	163,000	20,375
Region 8: Minot AFB, ND	120 acres	RCRA D Cap		
		Construction	2,344,000	19,533
Region 8: Widbey Island, WA	44 acres	Design	450,000	10,200
		Construction	8,900,000	202,000
		Total	9,350,000	212,200
Region 10: Fairchild AFB, WA	26 acres	Design cost	966,000	37,000
		Construction cost	7,400,000	285,000

GROUNDWATER CONTAINMENT PRESUMPTIVE REMEDY CRITERIA DOCUMENT

2nd Edition

FINAL

PART II: SECTION 6.0

15 MAY 1997

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GROUNDWATER CONTAINMENT

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6.0 GROUNDWATER CONTAINMENT

6.1 Groundwater Containment Executive Summary

Groundwater containment is simply the extraction of contaminated groundwater through pumping for the purpose of limiting migration of contaminants and degradation of larger volumes of water in the aquifer. Following extraction, groundwater is normally treated in an aboveground treatment system and discharged or injected back into the aquifer.

Typical groundwater containment systems consist of an extraction network, a conveyance and collection system, an extracted water treatment system, and a monitoring system and program. An effective monitoring program is essential to ensure long-term effectiveness of the system and to verify that the containment goals and objectives are being met.

Figure 6-1 is a summary of the groundwater containment presumptive remedy. The figure shows a site conceptual model and describes applicability, contaminants of concern, site profile needs, and presumptive remedy profile needs. Figure 6-2 is a decision logic diagram that can be used to determine if groundwater containment **is a** presumptive remedy that may be used at your site.

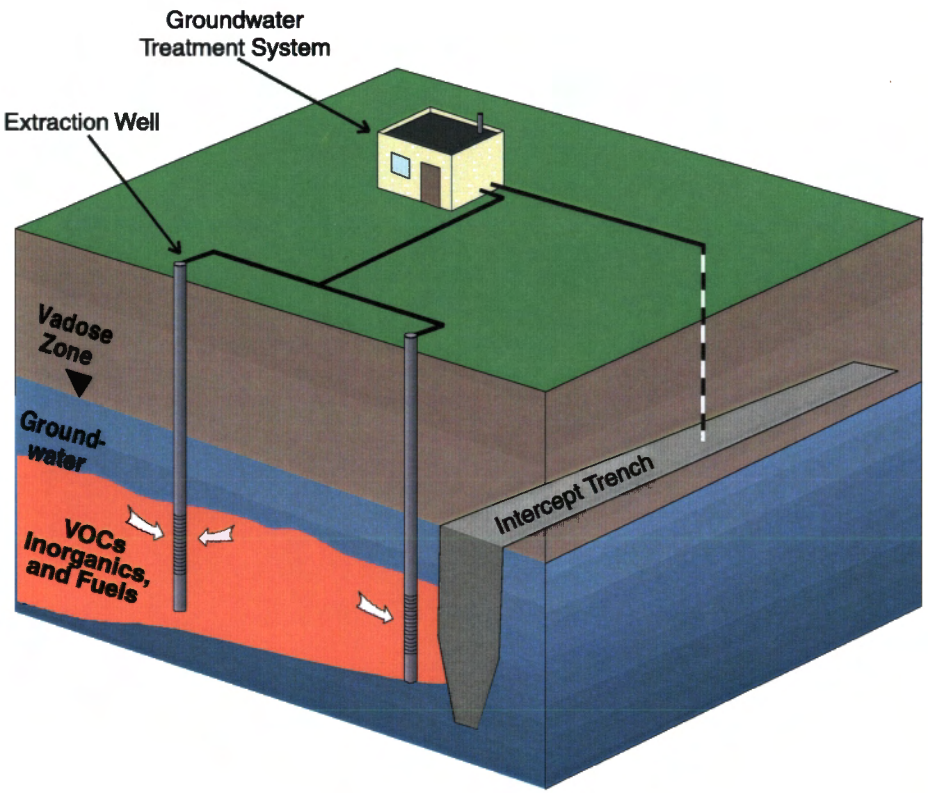
The costs of implementing a groundwater containment system can vary from less than 10 cents to more than $20 per 1,000 gallons of treated water. Costs are highly site specific and are based on the number, depth, and type of extraction wells and trenches; the contaminant type and concentration; and the volume of water to be handled. Computer cost models such as Remedial Action Cost Engineering and Requirements System (RACER) can be used to estimate the price of designing, building, and operating a groundwater containment system.

6.2 Groundwater Containment

Groundwater pumping (or containment) has proven to be appropriate for many hydrogeological conditions, waste types, and chemical properties. It was the technology selected at more than 90% of sites with final Records-Of-Decision. For problems involving significant groundwater contamination, some form of groundwater pumping (whether it be for remediation or containment) has consistently been used and will continue to be used.

However, because of groundwater pumping's limited success at complete groundwater restoration, the U.S EPA has no plans to identify groundwater pumping as a presumptive remedy for groundwater remediation. However, because of its success in containing contamination (either as a stand alone remedy or in conjunction with vadose zone technologies), groundwater containment will continue to be the preferred containment technology for groundwater until another feasible technology is developed. As such, groundwater containment has become a defacto "presumptive remedy" for groundwater contamination containment. Furthermore, groundwater containment is recommended in the U.S. EPA guidance, "Presumptive Remedy Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites". This guidance states that groundwater remediation is to occur in a phased approach. This phased approach includes taking early actions through Action Memos to: 1) prevent exposure to contaminated groundwater, and 2) provide containment of contaminant hot

GROUNDWATER CONTAINMENT



CONTAMINANTS

VOCs, semi-volatiles, inorganics, or TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Presence of rock in contamination area. Depth to groundwater (thickness of vadose zone).
Contaminant:	Separate phase liquids in groundwater. Horizontal and vertical distribution of dissolved contaminants in the aquifier.
Hydrology:	Horizontal and vertical gradients in groundwater. Hydraulic conductivity, K, in saturated zone. Temporal (daily to annual) water level fluctuations. Surface water influences: infiltration or water level changes. Sources of recharge and discharge areas.
Other Parameters:	Location of nearby or adjacent structures or buildings.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Source of discharge point of contamination not active or remediated;
- Concentration of halogenated VOCs are less than 1% of maximim solubility;
- Solubility of contaminants is greater than 10 mg/l;
- Absorption coefficient is less than 10,000 l/kg;
- Total volume of groundwater contamination plume is greater than 1,000 gallons and less than 5 billion gallons;
- The target volume is contained in porous deposits (i.e., sands, gravels, with minimal interlayered silts, and clays) or highly fractured or weathered bedrock, and/or average hydraulic conductivity is 10^{-4} cm/sec in the saturated zone;
- Natural carbon fraction is less than or equal to 0.01;
- Natural groundwater velocity is greater than 10^{-7} meters/second and less than 10^{-4} cm/sec in the saturated zone;
- Water level fluctuation is less than 10 feet/year and 3 feet/day;
- Surface water provides upgradient recharge and minimal flood potential;
- The target plume is either underlain by an aquitard in an unconfined water table zone, or is confined between aquitards.

APPLICABILITY

This remedy is applicable for dissolved phase contaminated groundwater plumes which have migrated away from the overlying vadose zone source area. Contaminants of concern include pesticides, metals, and semi-volatile compounds. Halogenated VOCs would not be applicable unless study has determined MPE is not effective. Petroleum or fuel related contaminants would not be applicable unless an intrinsic remediation study has determined that intrinsic remediation and natural attenuation are not sufficient to contain groundwater contamination migration or leading edge of the plume has already impacted an identified receptor.

Figure 6-1. Summary of the Groundwater Containment Presumptive Remedy

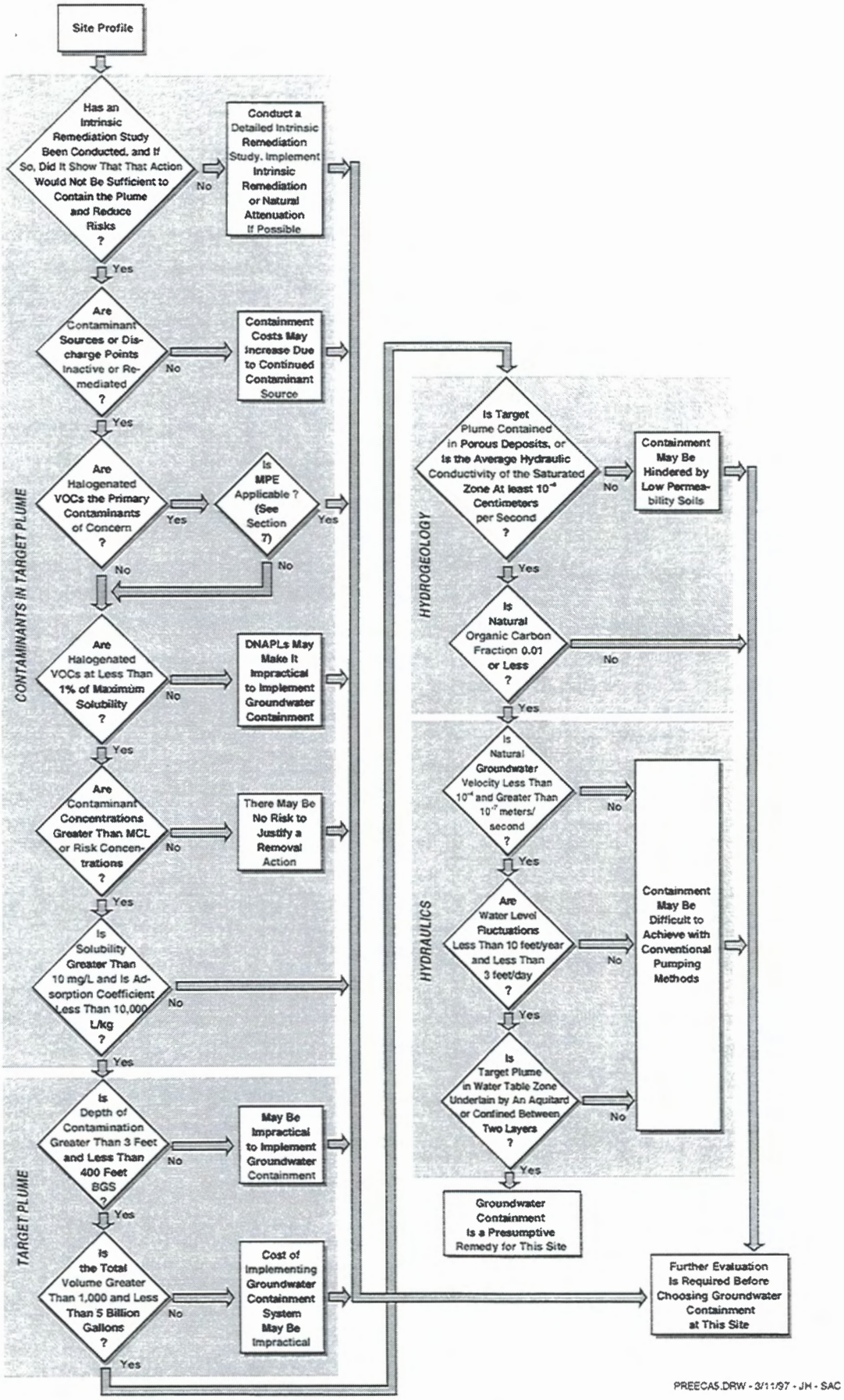


Figure 6-2. Groundwater Containment Decision Logic

spots and plumes until a final remedy can be implemented. **This document focuses on the use of groundwater containment; groundwater pumping for groundwater remediation is not discussed within this document.**

In the past, choosing groundwater containment has been a frequent choice because:

- Groundwater containment is a widely proven and reliable technology;
- There have been no other "widely" demonstrated technologies that will accomplish the same objectives;
- Groundwater containment can be easily used in conjunction with vadose zone remediation technologies (i.e., soil vapor extraction or bioventing) and/or other containment technologies (i.e., capping) to minimize the potential threats to human health and the environment;
- Groundwater containment is versatile and can be used for either contaminant plume "hot spot" or leading edge containment or both; and
- Groundwater containment system components are readily available.

The following sections of this report provide basic guidance on how to determine if, when, where, and how groundwater containment can be used successfully to contain contaminant plumes at a site. Because the success of groundwater containment is very specific to individual site conditions, the information provided should not be considered hard and fast rules. It may also be used to aid in determining:

- If site conditions are favorable for use of groundwater containment as a "presumptive remedy" (i.e., agreement with the remedy profile);
- What data are required to design a groundwater containment system;
- A containment system conceptual design (system configuration) for the site (i.e., what type of extraction network or treatment system may be used at the site); and
- An appropriate monitoring plan to determine containment effectiveness of the system.

6.3 Technology Description

Groundwater containment is simply the extraction of contaminated groundwater, by creating a hydraulic barrier for the purpose of limiting migration of contaminants and degradation of larger volumes of water in the aquifer. Following extraction, groundwater is normally treated in an aboveground treatment system and discharged or injected back into the aquifer. Typical groundwater containment systems include:

- An extraction network, including wells and trenches;
- A collection system, including groundwater pumps and conveyance piping;
- An extracted water treatment system and disposal option; and
- A monitoring system and program.

Figure 6-3 is a schematic of a containment system being used for complete plume containment that includes "hot spot" and

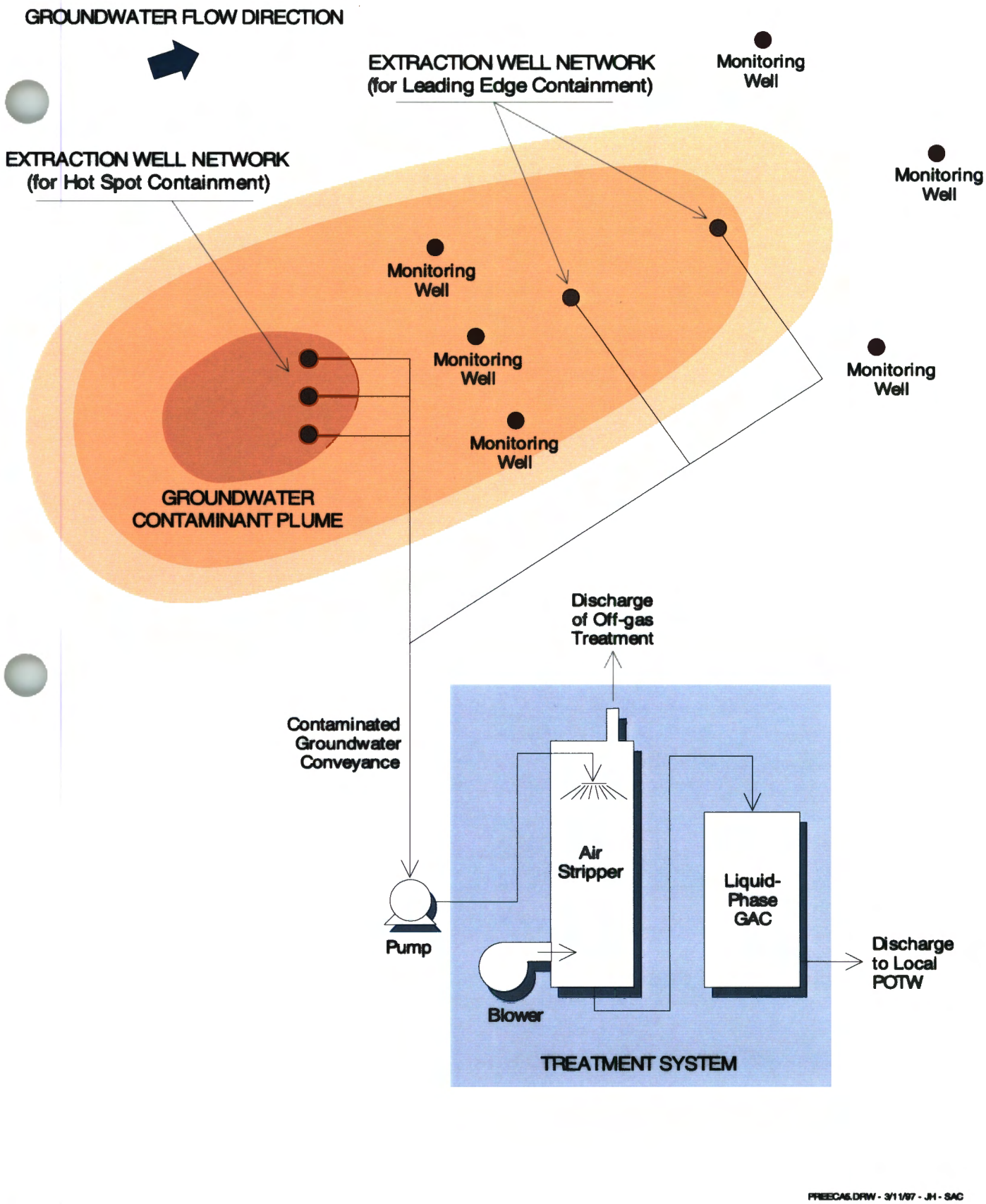


Figure 6-3. Overview of a "Full Plume" Groundwater Containment System

"leading edge" containment. This system incorporates a network of vertical extraction wells for containment and air stripping and liquid phase GAC for extracted water treatment before discharge to the local publicly-owned treatment works (POTW). The site selection criteria, general design methodology, and groundwater containment system component descriptions are provided in the following sections. Figure 6-4 shows a typical site conceptual model.

6.4 Technology-Based Application Criteria (Is groundwater containment suitable for your site?)

Based on the information and logic diagram included in Sections 3.0 and 4.0 of Part I of this PREECA document, it may be evident that groundwater containment technology is a feasible alternative for containment of contaminated groundwater at your specific site. This section provides additional guidance to determine if the site characteristics (i.e., the site profile) agree with the remedy profile for groundwater containment and are favorable for adaption of groundwater containment as a "presumptive remedy".

A description of the site profile, characteristics which are pertinent to designing an effective containment system, is provided in Table 6-1. The remedy profile, consisting of site characteristics that are favorable for groundwater containment as a presumptive remedy, are summarized in Table 6-2. If the site profile data do not fit within the remedy profile optimum-range conditions, an increase in cost, difficulty of implementation, and length of project duration may result. A lack of agreement between several site profile parameters and the remedy profile parameters indicates that groundwater containment is not an effective remedy choice.

As stated in previous sections, the success of groundwater containment is highly site specific; what may work at one site may not work for another. For the purposes of using groundwater containment as a presumptive remedy, the selection criteria (remedy profile) included herein are based on previous experience, and indicate a very high probability that this technology will effectively contain the contamination at a site.

If an initial evaluation of site profile determines that not all characteristics fall within the remedy profile, it does not mean that groundwater containment absolutely should not be used, instead it is recommended that a more detailed evaluation be conducted prior to selecting the groundwater containment presumptive remedy technology. Questions which should be answered during a more detailed site specific evaluation of groundwater containment technology include:

- Is groundwater containment physically and chemically possible at the site?
- Will this presumptive remedy be the most effective technology for containing migration of contaminants in the groundwater before they reach receptors than intrinsic remediation or the MPE technologies (i.e., simultaneous extraction of soil vapor and groundwater)?
- Will groundwater containment reduce contamination and meet containment objectives eliminating imminent and substantial treat to public health or welfare or the environment faster than and more cost effectively than other available extraction technologies?

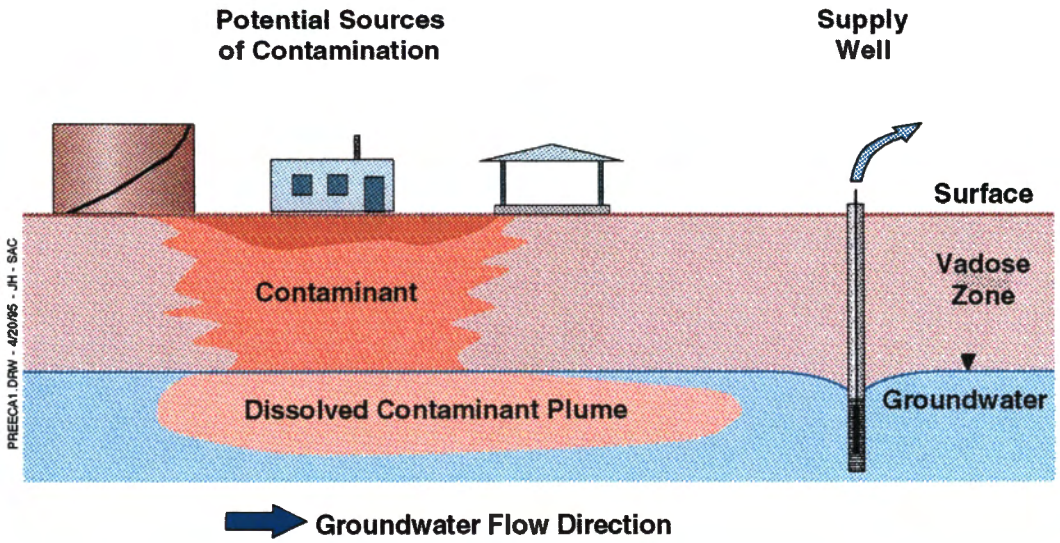


Figure 6-4. Typical Site Conceptual Model

Table 6-1. Site Profile

Site Component	Characteristics	Source of Information
Contaminants in Target Plume	Concentration of semi-volatiles, anthropogenic, inorganic constituents (metals, cyanide, nitrate), VOCs, or fuel hydrocarbons	Monitoring well sample, boring probe sample, or cone penetrometer test (CPT) sample analyses
	Adsorption or retardation potential	Published data for K_{oc} or K_{ow} each contaminant
	Probable source	Site records; RI data
	Target plume depth below surface	Monitoring well and CPT sample analyses
	Target plume width	Monitoring well and CPT sample analyses
	Target plume thickness	Monitoring well and CPT sample analyses
	Horizontal and vertical distribution of contaminants	Monitoring well and CPT sample analyses
Hydrogeology	Depth to saturated zone	Borings, monitoring wells, or CPT
	Thickness and areal extent of porous deposits (sands, silts, clays) or fractured and solid bedrock	Boring lithologic logs, subsurface geophysical logging, CPT
	Presence and depths of aquitards or impermeable layers	Boring lithologic logs, subsurface geophysical logging
	Natural organic carbon fraction in water-bearing deposits	Total organic carbon content analyses or estimates from drilling logs
Hydraulics	Hydraulic conductivity, K_h, of deposits containing Target plume	Aquifer testing: constant discharge pumping or slug tests
	Temporal (daily to annual) water level fluctuations	Water level monitoring in wells
	Confinement in saturated deposits: unconfined to fully confined	Water level measurements in wells and borings
	Surface water effects: recharge from or discharge to river, lake, impoundment, or ocean	Water level measurements in wells at high and low river flow, high and low tide, high and low lake or impoundment level
	Horizontal gradient and flow directions	Water level measurements in wells screened in the same water-bearing zone
	Vertical gradient	Water level measurements in wells horizontally close but screened at different depths
	Production well effects	Changes in water levels of monitoring wells when nearest production wells are active or inactive

Table 6-2. Remedy Profile for Groundwater Containment

Site Component	Characteristics	Optimum Range
Contaminants in Target Plume	Source or discharge point	Not active or remediated
	Halogenated VOCs (where MPE not applicable)	> MCL or acceptable risk concentration, < 1% of maximum solubility
	Inorganic constituents (metals, cyanide, nitrate)	> MCL or acceptable risk concentration
	Petroleum or fuel related constituents (where intrinsic remediation or natural attenuation not applicable)	> MCL or acceptable risk concentration
	Semi-volatile constituents	> MCL or acceptable risk concentration
	Solubility	> 10 mg/L
	Adsorption coefficient	< 10,000 L/kg
Target Plume	Depth	> 3 feet, < 400 feet
	Total volume	> 1,000 gallons, < 5 billion gallons
Hydrogeology	Porous deposits containing Target Plume	Sands, gravels with minimal interlayered silts and clays except as bounding aquitards and/or saturated zone with average hydraulic conductivity of 1×10^{-4} centimeters/second
	Bedrock containing Target Plume	Highly fractured or weathered
	Natural organic carbon fraction	0.01 or less
Hydraulics	Natural groundwater velocity	< 10^{-4} meters/sec (10 feet/day) > 10^{-7} meters/sec (10^{-2} feet/day)
	Water level fluctuation	< 10 feet/year, <3 feet/day
	Surface water	Upgradient recharge, minimal flood potential
	Unconfined	Target plume in water table zone, underlain by aquitard
	Confined	Target plume confined between two aquitards

- Is the cost of groundwater containment reasonable given the project budget or are other alternatives available (i.e., are well-head treatment or providing an alternate water source feasible)?

- Will groundwater containment cause negative impacts or be detrimental to the site if implemented (e.g., are sensitive plant or animal life dependent on the groundwater for life)?

6.4.1 Intrinsic Remediation

Because of budgetary constraints and the limited funds available to implement remedial/removal actions, it is important to consider the less costly alternatives available to contain groundwater contamination than installing and operating a groundwater containment system. For chlorinated solvents and fuel dissolved in groundwater, intrinsic remediation is a less costly alternative that may be considered.

The *Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater* (AFCEE, 1995) and the draft *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (AFCEE, 1996) provides guidance to determine if intrinsic remediation may be used. Intrinsic remediation should always be used when feasible to minimize cost impacts.

6.4.2 Multi-Phase Extraction (MPE)

For sites where the primary contaminants of concern are halogenated VOCs, consider using the MPE technologies presented in Part II, Section 7 of this document. If the site does not meet the MPE application criteria then consider groundwater containment.

6.5 Design Methodology

General design methodology for groundwater containment systems using pumping has been documented in numerous publications. The design methodology presented herein contains excerpts from the U.S. EPA's documents "Basics of Pump-and-Treat Ground-Water Remediation Technology," "A Guide to Pump and Treat Ground-Water Remediation Technology," and "Ground Water Handbook Volume I: Ground Water and Contamination" (U.S. EPA, March 1990, November 1990, and September 1990). Additional references are included in Section 6.8 of this document.

Four basic components should be developed for a successful groundwater containment system:

- Site Conceptual Model;
- Containment Goals and Objectives;
- System Design; and
- Operation and Monitoring Program.

6.5.1 Site Conceptual Model

A conceptual model of the nature and extent of groundwater contamination at a given site and a good understanding of the site profile is needed before an appropriate removal action can be determined. Data should be collected in an iterative process performed in phases where decisions concerning subsequent phases are based on the results of preceding phases. The data required to make informed decisions depends on the processes controlling the contamination and include:

- **A History of the Contamination**—If information is available, a history of the contaminant discharge should be prepared to define the types of wastes present at the site and quantify their

loading to the system. This information will help to determine what type of treatment processes (i.e., air stripping, carbon adsorption) are feasible at a given site.

- **Characteristics of the Subsurface Flow System**—Groundwater flow systems vary with time, season, and pumping strategy. Understanding where groundwater recharges and discharges (mass balance), the laws governing flow (Darcy's Law), and geologic framework through which the flow passes makes it possible to determine groundwater flow characteristics. Other subsurface flow system characteristics include hydraulic conductivity, storage coefficient, mineralogy, organic content, and aquifer thickness. This information will help to determine the number and type of wells needed for containment, optimum well or trench spacing, expected groundwater flowrates, and other parameters needed to design an effective containment system.

- **Chemical and Biological Characteristics of the Contaminant**—Chemical characteristics of contaminants include solubility, density, reactivity, ion exchange capacity, and mobility in aqueous solution. Biological characteristics of contaminants include the potential for naturally occurring transformation and biodegradation. This information will help in determining if groundwater containment will be effective at removing contaminants from the subsurface, loading on the treatment system, and if natural biodegredation will aid in the containment process.

Initially, collecting as much background site data as possible may reduce the amount of time spent gathering data in the field. Accurate information regarding the type of contaminants present and their loading capacity on the system help in designing an effective system. Helpful contaminant information consists of source characterization, including the volume released, the area infiltrated, and duration of the release; concentration distribution of contaminants and naturally occurring chemicals in the groundwater and soil; and processes affecting plume development, such as chemical and biological reactions influencing contaminant mobility. Each step of the groundwater containment strategy is dependent on the decisions reached in the previous step. Therefore it is vital that each step is carefully planned and monitored to allow for modifications.

Understanding the hydrogeology and extent of contamination at a site are important in planning successful field studies. The hydrogeological aspects listed in Table 6-3 are vital in determining if a groundwater system would be an appropriate removal technology for a given site. These aspects include determining the size of the contaminated aquifer, depth to water table, hydraulic conductivity of surrounding aquifer material, and local groundwater use. Methods for determining aquifer properties include a slug test, pump test, and a borehole flowmeter test. The pump test consists of pumping one well and measuring the water level response of surrounding wells. Pump tests sample large aquifer sections. A slug test measures the rate at which the water level in one well returns to its initial state after inducing a rapid water level change by introducing or withdrawing a volume of water. The borehole flowmeter test measures flow direction and rate in a borehole. These tests can indicate the spatial variability of hydraulic conductivity.

Table 6-3. Aspects of Site Hydrogeology

Geologic Aspects	
1.	Type of water-bearing unit or aquifer (overburden, bedrock).
2.	Thickness, areal extent of water-bearing units and aquifers.
3.	Porosity (primary, such as intergranular pore space, or secondary, such as bedrock discontinuities, e.g., fracture or solution cavities).
4.	Presence or absence of impermeable units or confining layers.
5.	Depths to water table; thickness of vadose zone.
Hydraulic Aspects	
1.	Hydraulic properties of water-bearing unit or aquifer (hydraulic conductivity, transmissivity, storativity, porosity, dispersivity).
2.	Pressure conditions (confined, unconfined, leaky confined).
3.	Groundwater flow directions (hydraulic gradients, both horizontal and vertical), volumes (specific discharge), rate (average linear velocity).
4.	Recharge and discharge areas.
5.	Groundwater or surface water interactions; areas of groundwater discharge to surface water.
6.	Seasonal variations of groundwater conditions.
Groundwater Use Aspects	
1.	Existing or potential underground sources of drinking water.
2.	Existing or near-site use of groundwater.

Once data have been collected, the information must be accurately interpreted. There are numerous tools that can be used to interpret data, including geochemical analysis, geostatistical analysis, and mathematical models. Geochemical analysis uses ion speciation models to interpret chemical changes in the aquifer. Geostatistical methods may be used to determine the relationship among various parameters and define the statistical probability of a particular condition. Mathematical models may be used to simulate groundwater flow patterns, contaminant transport, and the changes resulting from a groundwater containment system. Mathematical models include: MODFLOW and RESSQ. These models are used to determine optimum well spacings, screened intervals, and pumping rates needed to contain a contaminant plume.

6.5.2 Containment Goals and Objectives

The second component in designing a groundwater containment system is determining the containment goals and objectives to be accomplished at a given site. This determination may include whether to contain the leading edge of the plume, e.g. if the plume is migrating outside of a base boundary, or to contain the area of highest contamination (the hot spots) to prevent further degradation of larger volumes of water in the aquifer, or both. Contaminant cleanup levels such as maximum contaminant levels (MCLs), alternate contaminant levels (ACLs), or unacceptable health or environmental risk levels will determine the magnitude and duration of containment for a given site.

Groundwater containment specifically involves preventing a contaminated groundwater zone from migrating into an area of uncontaminated (e.g., drinking water supply) or less contaminated groundwater. Leading edge containment involves installation of extraction wells at the front of a contaminated groundwater plume, typically to prevent the contamination from reaching potential receptors (e.g., residential water wells, water supply wells, other connected aquifers, etc.). Hot spot containment would be used in cases where an area of particularly high contaminant concentrations have been identified (e.g., contaminant source into the groundwater). Hot spot containment would typically would be done where another remediation strategy (e.g., intrinsic remediation) is being used on other, lower level contamination in the aquifer.

6.5.3 System Design

Determining the components to incorporate into a groundwater containment system is highly dependent on the conceptual model and containment goals and objectives of the site. The system must be chosen and designed based on field data. The criteria for well or trench design, pumping system, and treatment are dependent on the physical site characteristics and contaminant type.

Design considerations include:

- Type and location of wells and/or intercept trenches, pumps, and piping;
- Well and/or trench installation methods;
- Type, location, and availability of treatment units;
- Discharge or disposal options; and
- Costs.

System components available for use in a groundwater containment system are described in section 6.6 Conceptual System Design. The following paragraphs provide

special considerations when designing a groundwater containment system.

Special care is required to avoid potential problems with well/trench construction materials, especially when dealing with NAPLs. Wells should be designed so that screens may be easily flushed and clogging problems commonly caused by oxidation of manganese and iron can be treated. Aspects to consider when selecting pumps are failure rates, reactivity with contaminants, and ease of maintenance. Backup equipment should be available in the event of failure.

The types of pumping used at a site include continuous and pulsed pumping. Continuous pumping maintains an inward gradient, constantly drawing groundwater towards it. Pulsed pumping consists of alternating periods of time when the pumps are on and off.

Analytical and numerical modeling techniques can be used to evaluate alternative designs, optimal well spacings, and pumping rates. Models can calculate groundwater flow paths, locate contaminant plume fronts, and attempt to simulate contaminant transport. Proper design will ensure that wells are placed in the desired stratigraphic layer so that the correct area will be contained.

6.5.4 Operation and Monitoring Program

The fourth and most significant component for ensuring the long-term effectiveness of the groundwater containment system is frequent monitoring of progress to verify that the containment goals and objectives are being met. Monitoring the system through the use of monitoring wells and piezometers allows the operator to make iterative adjustments to the system in response to changes in subsurface conditions caused by the containment system operation.

Once containment objectives are established and a system is built to meet these objectives, then a monitoring program should be designed to evaluate the success of the system. Uncertainties in subsurface characterization make monitoring a necessary step in pursuing a containment strategy. Continual monitoring of the groundwater containment system allows timely modifications to be made when it is obvious that the system is not achieving prescribed goals. Figure 6-5 provides a flowchart for a typical monitoring program (HWC, 1983).

Monitoring should consist of analyzing the water quality and contaminant movement, and supervising the mechanical operation of the groundwater contaminant system. If monitoring shows that the cleanup objectives are not being met, then changes to the groundwater containment system must be implemented to meet the containment goals. There are three basic components in monitoring.

- Design an appropriate monitoring program to suit the groundwater containment system.
- Actively monitor the system to verify that the containment strategy is meeting the objectives and that equipment is functioning properly.
- Modify the containment strategy to adjust for unexpected contingencies. Specify alternate acceptable goals or change the containment strategy to meet the original goals.

Monitoring criteria important in establishing a successful monitoring scheme for a site

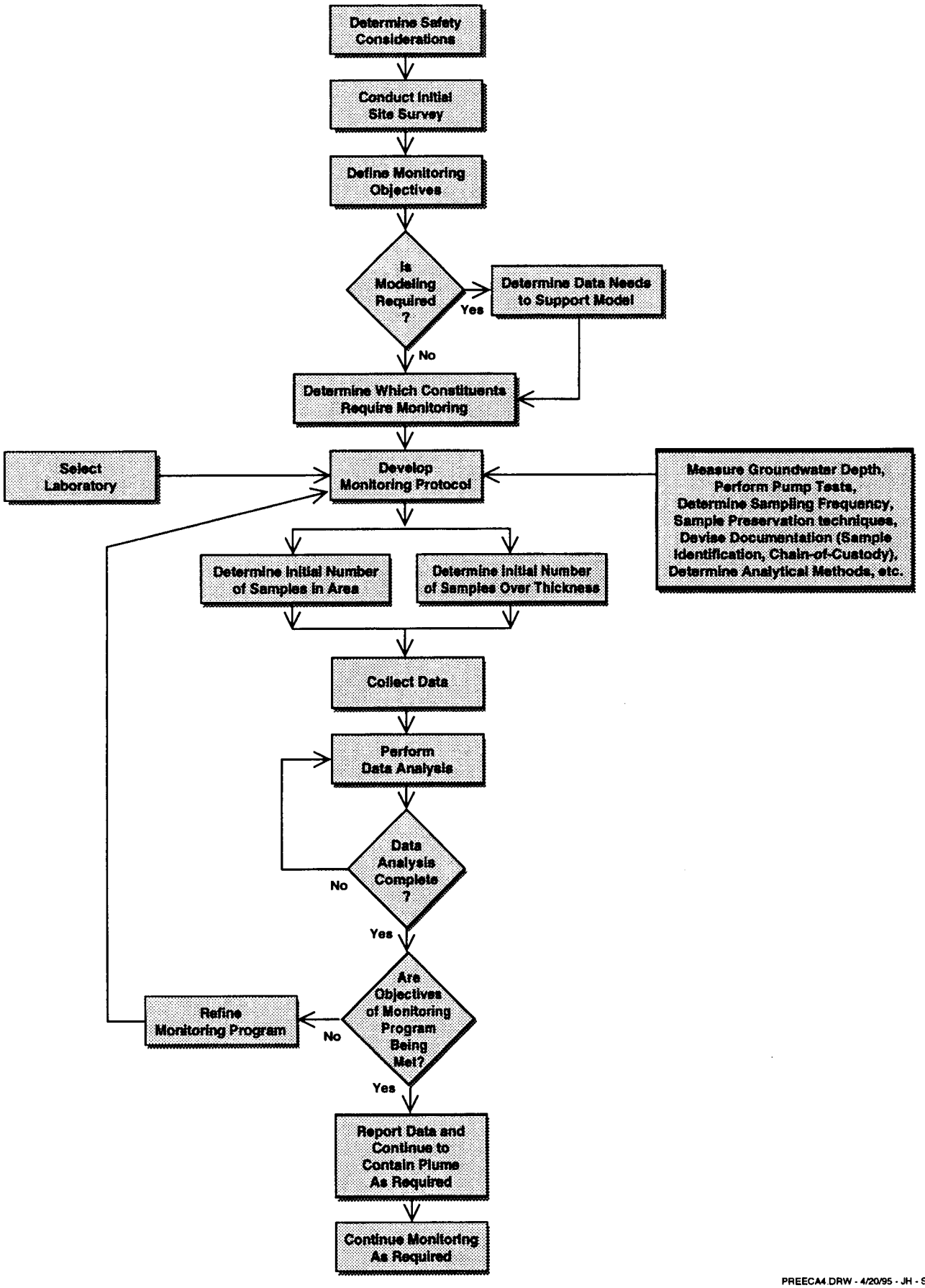


Figure 6-5. Flow Chart for a Typical Monitoring Program

can be divided into three categories: chemical, hydrodynamic, and administrative.

- **Chemical**: A risk-based criterion, including MCLs, ACLs, state levels, detection limits, and natural water quality.
- **Hydrodynamic**: Includes preventing infiltration through the vadose zone, maintaining an inward gradient at the boundary of the contaminant plume, and providing minimum flow to surface water bodies.
- **Administrative Control**: Includes reporting requirements, frequency and character of operational and post-operational monitoring, and land use restrictions, such as drilling and other access-limiting restrictions.

The locations of the monitoring wells are critical to any successful monitoring program. Water level fluctuations and water quality should be measured. Injection and extractions wells change the subsurface in complex ways, requiring continuous monitoring. Determining the flow pattern generated by a groundwater containment system requires field evaluations during the operational phase.

A groundwater containment system may require modifications during the operational phase due to the uncertainties involved in subsurface characterization. Reasons for possible modifications resulting from operational monitoring include:

- Improved estimates of hydraulic conductivity requiring a change in pumping rate or well location;
- Information on chemistry and loading to the treatment system requiring changes in treatment;
- Mechanical failure of pumps, wells, or subsurface plumbing; and
- Adjusting pumping rate or well location to enhance extraction if anticipated progress is not achieved.

6.6 Conceptual System Design

Once it has been determined that groundwater containment is a feasible containment alternative for the site, hydrogeological and chemical data described in previous sections should be used to determine an appropriate system configuration. Typical groundwater containment systems consist of the following:

- An extraction network, including wells and/or trenches;
- A collection system, including groundwater pumps and conveyance piping;
- An extracted water treatment system;
- A treated water disposal/discharge alternative; and
- A monitoring system.

The following sections provide descriptions of extraction and treatment system components and general guidance to aid in determining what type of extraction components and treatment systems are potentially feasible given certain site conditions. The feasibility of implementing the extraction and treatment technologies and disposal/discharge options described in this document should be evaluated on a site specific basis.

6.6.1 Extraction System Components

An extraction network is usually made up of vertical wells, horizontal wells, interceptor trenches, or drains, or a combination thereof which are installed and operated as hydraulic controls to isolate and limit the migration of contaminants. Extraction system components are chosen based on hydrogeological data and nature and extent of contamination. Typical extraction system components are shown on Figure 6-6 and described below.

Vertical Extraction Wells

Vertical extraction wells are the most common extraction component used in groundwater containment systems due to their wide range of usefulness. Vertical wells have been proven effective with shallow and deep contamination, areas of moderate to high hydraulic conductivity, and areas of simple to complicated geology. Also, because vertical wells have been used for some time, the costs associated with installation are relatively low and consistent compared to horizontal wells or interceptor trenches and drains.

Horizontal Extraction Wells

Horizontal wells or directional wells essentially function as an infinite line of vertical extraction wells, and can perform many of the same functions. Horizontal wells should be considered where the use of vertical wells may be limited by a low permeability formation or surface obstructions, or where vertical and horizontal extent of contamination is well defined and can be more efficiently contained by a horizontal well than a vertical well. The use of horizontal wells in environmental applications has not been as common as for vertical wells, and as such the cost of installation may vary greatly by installation technique and depth. The cost of installing horizontal wells could be more than double or triple the cost of installing a vertical well network.

Drains or Intercept Trenches

Drains or intercept trenches are the same as horizontal wells in the way that they function as an infinite line of vertical extraction wells. Drains or intercept trenches should be considered if the contaminated aquifer is close to the surface or if the shallow aquifer is surrounded by material with low hydraulic conductivity. Cost of installation would be dependent on the depth and length of the required trench.

6.6.2 Conveyance/Collection System Components

A conveyance/collection system may include pumps, transfer piping and manifolds, controls, equalization tanks or receptor vessels. The types and sizes of components chosen are based on groundwater extraction rates and contaminant compatibility. Some special considerations are included below.

Pumps should be chosen based on system operating conditions including expected flow rate, and pumping schedule (i.e. pulsed pumping or continuous pumping). Transfer piping should be chosen based on contaminant compatibility, flow rates, and location. Considerations for other conveyance/collection system components such as equalization tanks or receptor vessels and controls may be necessary depending on system design, system operational safety, or system monitoring.

6.6.3 Treatment System Components

An extracted water treatment system can be a combination of many treatment

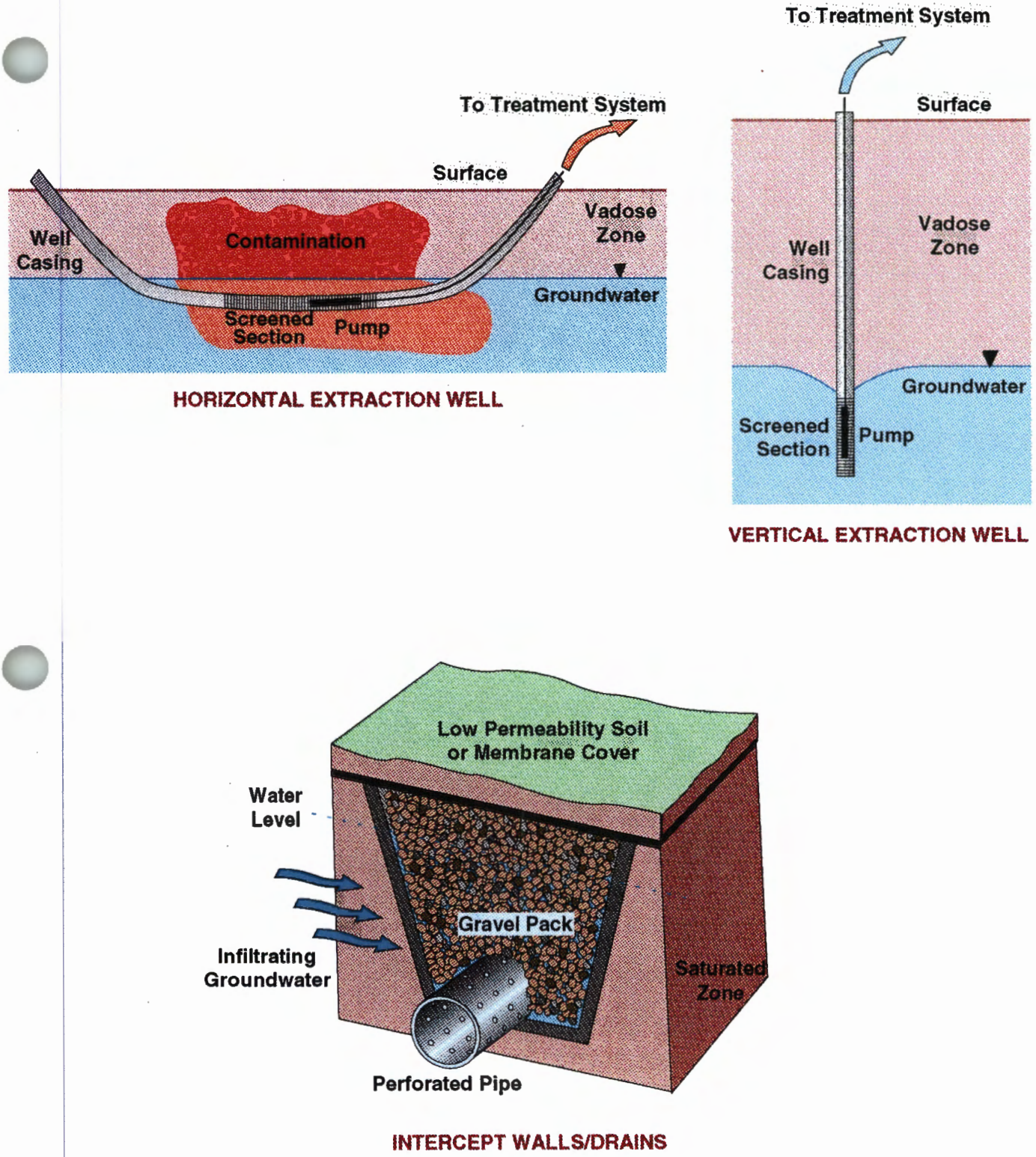


Figure 6-6. Groundwater Extraction Systems

components depending on the characteristics of the contamination. The treatment technologies described below are presented based on the presumptive remedy guidance by the EPA on groundwater treatment technologies. This guidance is called "Presumptive Response Strategy and Ex Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites" (U.S. EPA, 1996). The presumptive remedy guidance recommends air stripping, granular activated carbon, chemical/UV oxidation, and aerobic bioreactors for treatment of organic contaminants; and chemical precipitation, ion exchange/ adsorption, and electrochemical methods for treatment of inorganic contaminants. Each of these technologies are described briefly below (U.S. EPA, 1993; Freeman, 1989). A summary of target compounds and relative range of cost, are provided in Table 6-4. Visual representations of the treatments for organic compounds are shown on Figure 6-7.

Air Stripping

Volatile organics are separated from groundwater by greatly increasing the surface area of the contaminated water and exposing it to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. The target contaminant groups for air stripping systems are halogenated and non-halogenated volatile organic compounds. The technology can be use to treat halogenated and non-halogenated semivolatile organic compounds and fuels, but may be less effective.

Granular Activated Carbon

Groundwater is pumped through a series of canisters containing activated carbon to which dissolved organic contaminants adsorb. The technology requires periodic replacement or regeneration of saturated carbon. The target contaminant groups for liquid-phase granular activated carbon are halogenated, non-halogenated, and semivolatile organic compounds. It is especially effective for polar compounds. The technology can also be used for treating fuel hydrocarbons, and pesticides, but may be less effective.

Chemical Oxidation/Chemical Enhanced Oxidation/UV Oxidation

Chemical oxidation uses oxidizing agents to destroy organic contaminants by altering its chemical state (by removing electrons [or oxidizing it]). Oxidizing agents include sodium hypochlorite, hydrogen peroxide, calcium hypochlorite, potassium permanganate, and ozone. In chemical oxidation, oxidizing agents are mixed with extracted groundwater in a treatment tank where contaminants are destroyed. Target contaminants groups for chemical oxidation are halogenated volatile and semivolatile organic compounds and pesticides. The technology also can be used in treating non-halogenated volatile organics and fuels, but may be less effective. Chemical oxidation may also utilize ultraviolet (UV) light to photochemically oxidize target contaminants.

Aerobic Bioreactors

Contaminants in extracted groundwater are put into contact with microorganisms through attached or suspended biological systems. In suspended growth systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin where microbial population aerobically degrades organic matter and produces new cells. The new cells form a sludge, which is settled out in a clarifier, and the sludge biomass is recycled to the aeration basin. In attached growth systems, such as rotating biological contactors and trickling filters, microorganisms are established on an

Table 6-4. Presumptive Remedy Groundwater Treatment Technologies

Technology	Target Compounds	Relative Costs[a] Overall ($/1000 gallons treated)	Advantages/Disadvantages
Air Stripping	Halogenated and non-halogenated volatile organic compounds and volatile inorganics	Less than $3	Liquid and vapor treatment may be required prior to discharge. Good commercial availability.
Granular Activated Carbon	Halogenated and non-halogenated; volatile and semivolatile organic compounds	Greater than $10	Replacement or regeneration cost for carbon could prohibit use. Good commercial availability.
Chemical Oxidation/UV	Volatile and semivolatile organic compounds and pesticides	$3 - 10	No residual waste produced during treatment. Maintenance of system could be difficult.
Aerobic Bioreactors	Halogenated and non-halogenated volatile and semivolatile organics and fuel hydrocarbons	Less than $3	Solid residuals from sludge processes may require treatment or disposal.
Chemical Precipitation	Dissolved metal or other inorganic ions	$3 – 10[b]	Solid residuals produced. Good commercial availability.
Ion Exchange/ Adsorption	Ionic contaminants, such as dissolved metals	$3 – 10[b]	Solid residuals may be produced and ion-exchange resins are prone to fouling by some organic substances. Good commercial availability.
Electrochemical Methods	Dissolved metals	$3 – 10[b]	Solid residuals produced, but may be reused or sold to reduce other operating costs. Good commercial availability.

[a] Assumed that average pumping costs are $0.25/1,000 gallons of water.

[b] Costs for chemical precipitation, ion exchange, and electrochemical methods were not available in the U.S. EPA's "Remediation Technologies Screening Matrix and Reference Guide," July 1993 Edition. Average costs were assumed for these technologies, actual costs may be lower.

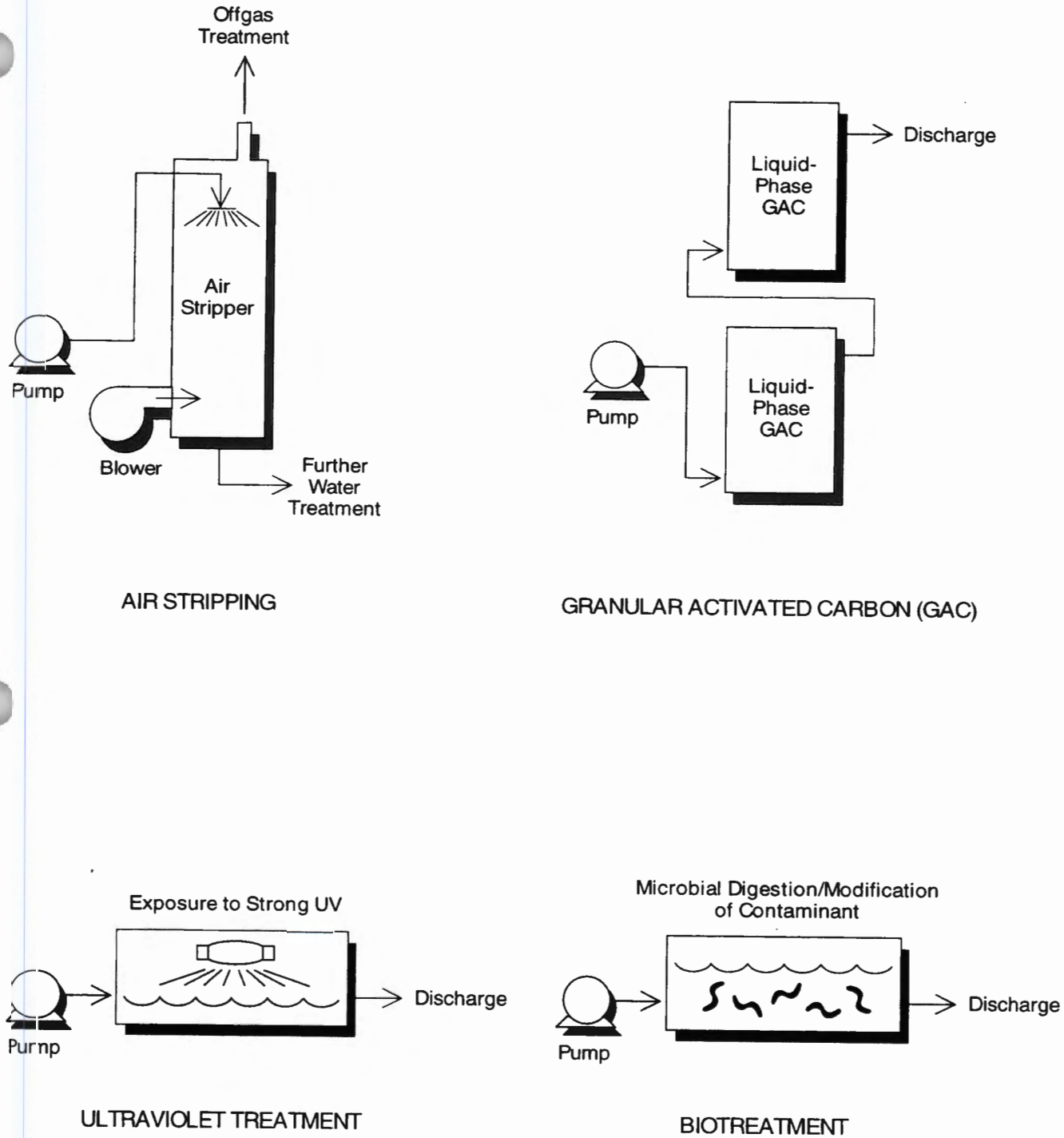


Figure 6-7. Groundwater Treatment Technologies for Organic Compounds

inert support matrix to aerobically degrade groundwater contaminants. The microbial population may either be derived from the contaminant source or from an inoculum of organisms specific to a contaminant.

Attached and suspended systems are often used together. Bioreactors are used primarily to treat non-halogenated volatile and semivolatile organics and fuel hydrocarbons. Halogenated volatiles and semivolatiles and pesticides also can be treated, but the process may be less effective and may be applicable only to some compounds within these groups.

Chemical Precipitation

Chemical precipitation involves adding a chemical precipitant to extracted groundwater to remove inorganic contaminants. The dissolved metals are converted to an insoluble form by a chemical reaction between the soluble metal compounds and the precipitant. The resultant suspended solids are separated out by settling in a clarifier. Chemical precipitants include calcium hydroxide (lime), sodium hydroxide, ferrous sulfide, sodium sulfide, sodium hydrosulfide, sodium carbonate, calcium carbonate, and sodium borohydride. Target contaminant groups are heavy-metals.

Ion Exchange/Adsorption

Ion exchange involves reducing the toxicity of waste by converting it into a form which can be reused, leaving behind a less toxic substance in its place. The contaminants are collected on a resin matrix, and are then recovered from the resin by chemical regeneration with acids or alkalis. This technique has been used for more than 40 years and was initially used to produce high-purity water for boiler makeup. Target contaminant group is metals, but can also be used for nitrates.

Electrochemical Methods

Electrochemical methods are similar to electroplating technologies where conductive electrodes (cathodes and anodes) are immersed in extracted groundwater. A potential is applied, and oxidation-reduction reactions cause the contaminants (metals) to accumulate on the cathode. Metals are then recovered from the cathode by circulating an acidic cleaner through the cell. Target contaminant group is metals.

6.6.4 Treatment System Disposal Options

Treated water disposal/discharge alternatives can include:

- Discharge to Local POTW;
- Discharge to Surface Water;
- Reinjection; and
- Other (Irrigation, Industrial Reuse such as dust control or use as washwater).

The implementability of these options are highly site specific, and should be evaluated on a site specific basis. Visual representations of these options are shown on Figure 6-8.

6.6.5 Monitoring System Components and Monitoring Program

A monitoring program consists of a monitoring system and the associated sampling and analysis activities necessary to verify the system performance. The monitoring system typically includes a series of wells and piezometers and monitoring devices (e.g., water level meters, transducers).

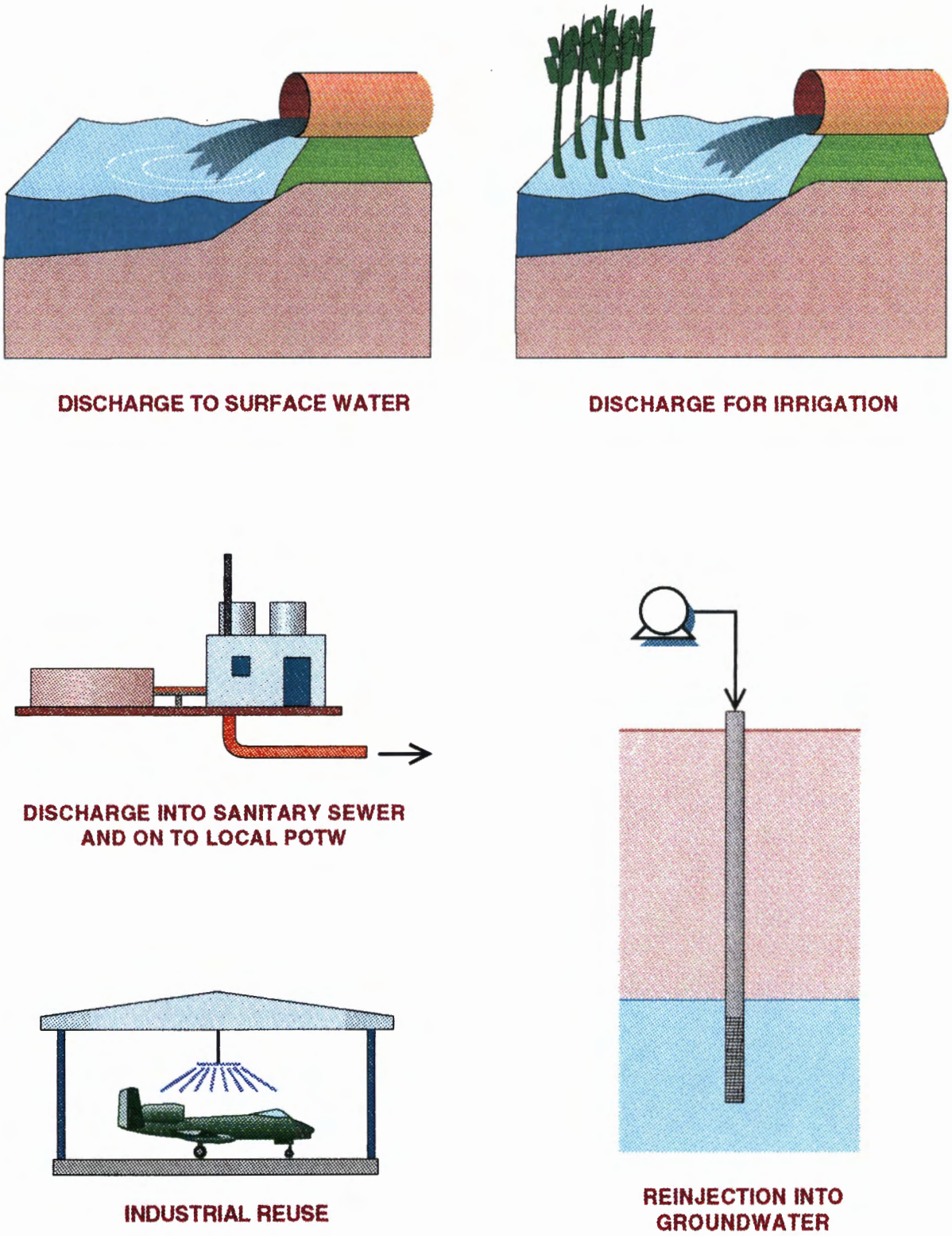


Figure 6-8. Discharge Alternatives

Monitoring wells are similar to vertical extraction wells in the way that they are constructed and installed, but monitoring wells are used for the purposes of monitoring the effectiveness of an extraction/containment system. Radius of influence of the extraction system can be determined by measuring water levels in adjacent monitoring wells. Also, water quality samples collected from monitoring wells help to determine if contaminant containment is being achieved or if unexpected changes in subsurface conditions are taking place in response to the extraction system. Monitoring well placement is critical to a successful monitoring program.

Piezometers are used to measure fluctuations in water levels in the surrounding subsurface over time. Water levels may vary with season or in response to an extraction system, and it is important keep a record of subsurface conditions.

6.7 Costs

Costs associated with installing a groundwater containment system will vary from site to site and are dependent on site characteristics. For the purposes of providing general unit costs for typical groundwater containment system installations, 4 different site scenarios (i.e., sets of groundwater parameters) were run through the "Remedial Action Cost Engineering And Requirements System" (RACER), a cost estimating software. RACER was developed by the U.S. Air Force as a cost estimating and analysis tool to be used to compare the cost of feasible remediation approaches. It has also been used for budgeting and planning purposes. The program includes cost models for various remedial technologies associated with eight site types: fire training areas, landfills, fuel storage facilities, spills and storage areas, disposal pits, waste pits, low-level radioactive waste sites, and surface runoff.

The parameters included in each of the four scenarios are summarized on Table 6-5. Because labor, equipment, and materials costs vary with geographic region, each scenario was run for five regions in the United States: West Coast (McClellan AFB in California); East Coast (Langley AFB in Virginia); South (Brooks AFB in Texas); North (Rantoul AFB in Illinois); and Central (McConnell AFB in Kansas). Cost model results are summarized on Table 6-6. These costs do not include treatment, water disposal, or system monitoring. Order of magnitude treatment costs are included in Table 6-4. In general, unit costs were highest on the west coast and in the north region, and were lowest in the south region. The costs for the four scenarios were based on the following general assumptions:

- Wells were constructed of Schedule 40 PVC;
- Well diameter was 6 inches;
- Well depth was equal to the depth to the base of contamination;
- Soil samples were collected at 5-foot intervals using a split spoon sampler;
- Four well volumes of water were removed from each well during development; and
- One hundred feet of double-walled PVC pipe was used for groundwater transport piping.

Unit costs and other assumptions are described in the RACER users manual and model report for the program (U.S. Air Force, RACER Version 2.0).

Table 6-5. Groundwater Contaminant Scenarios

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Type of Aquifer	Confined	Confined	Unconfined	Unconfined
Depth to Top of Confining Unit (Feet BGS)	50	70	NA	NA
Depth to Bottom of Confining Unit (Feet BGS)	60	85	NA	NA
Formation Type	Unconsolidated	Unconsolidated	Unconsolidated	Unconsolidated
Depth to Groundwater (Feet BGS)	NA	NA	30	35
Depth to Base of Contamination (Feet BGS)	75	130	40	45
Total Flow Rate (GPM)	300	500	20	30
Number of Wells	2	5	2	4
Startup Period (months)	12	12	12	12
Operation and Maintenance Period (months)	12	12	12	12

Table 6-6. RACER Cost Model Results

Cost Description	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Remedial Design (Based on a percentage of the Remedial Action Costs)	$2400 – $3100	$7700 – $9900	$1100 – $3000	$1100 – $3300
Remedial Action (Total Installation of System)	$56,000 – $72,000	$180,000 – $230,000	$25,000 – $35,000	$57,000 – $75,000
Extraction Wells – Unit cost of installation per lineal foot	$180 – $260 (Based on 75-foot wells)	$140 – $190 (Based on 130-foot wells)	$200 – $280 (Based on 40-foot wells)	$190 – $260 (Based on 45-foot wells)
Extraction Pumps – Cost Per Pump	$1800 – $2400 (Based on 15 Horsepower pump, 300 GPM)	$1900 – $2600 (Based on 20 Horsepower pump, 500 GPM)	$4100 – $5200 (Based on 3/4 Horsepower pump, 20 GPM)	$4900 – $6200 (Based on 1 Horsepower pump, 30 GPM)
Electrical Costs During Installation	$12,000 – $15,000	$40,000 – $50,000	$600 – $700	$1,600 – $2,000
1 Year Operation and Maintenance (Equivalent to Electrical Costs for 1 year)	$12,000 – $15,000	$40,000 – $50,000	$600 – $700	$1,600 – $2,000
Total Costs including Remedial Design and Remedial Action (include 1 year of O&M)	$58,000 – $75,000	$190,000 – $240,000	$27,000 – $35,000	$65,000 – $78,000

Costs associated with installing, maintaining, and operating an actual groundwater containment system are provided in Table 6-7 for the Twin Cities Army Ammunition Plant (TCAAP) in New Brighton, Minnesota. The facility uses air stripping to treat extracted groundwater. Costs are provided in 1990 dollars. In summary, the total life cycle costing at TCAAP was estimated to be $0.30 per 1,000 gallons of water treated; and the total cost of operation and maintenance was calculated to be $0.12 per 1,000 gallons (USAEC, 1993).

Table 6-7.
Total Capital and Operating Costs for the Twin Cities Army Ammunition Plant

Capital Costs	
Construction of Treatment Plant	$774,757
Construction of Wells (16 extraction, 48 monitoring, and 17 return wells)	$1,026,406
Construction of Forcemain & Pumphouses (17,800 feet of buried pipe, 16 pumphouses)	$2,386,712
Startup	$358,220
Health and Safety (Medical monitoring of employees)	$110,125
Engineering	$1,575,710
Project Management	$928,267
Overhead & Profit	$874,257
Total Capital Costs	$8,034,454
Operating Costs	
Power (@ $0.04/KWH)	$148,846
Operating Labor	$219,502
Maintenance Labor & Parts	$150,054
Laboratory Charges	$25,175
Other O & M Charges	$39,518
Replacement of Tower Packing ($20,865 occurring every 5 years, annualized at 10% interest)	$5,504
Total Annual Operating Cost	$588,599

6.8 Annotated References

AFCEE, 1994. Air Force Center for Environmental Excellence. "Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Ground Water," Draft 31 July 1994. *This document provides guidance for implementing intrinsic remediation as an alternative to groundwater containment.*

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Freeman, Harry, 1989. "Standard Handbook of Hazardous Waste Treatment and Disposal." *This book provides descriptions of standard groundwater treatment technologies.*

The Hazardous Waste Consultant (HWC), 1983. "How to Design a Ground-Water Monitoring System to Suit Your Needs," July. *This article provides a flowchart for a typical monitoring program.*

U.S. Air Force. "Remedial Action Cost Engineering And Requirements System," Software Version 2.0, User Manual, and Model Report. ENVEST Environmental Cost Engineering. *This software and associated manuals provide basis of cost estimates for 35 remedial technologies and can be used to estimate costs of a Remedial Design, Remedial Action, and Operation and Maintenance, given site parameters.*

U.S. Army Environmental Center, 1993. "Technology Application Analysis—Pump & Treat of Contaminated Groundwater at Twin Cities Army Ammunition Plant New Brighton, Minnesota," December Final. *This document provides performance data and actual costs associated with installing, operating and maintaining a pump and treat system.*

U.S. Environmental Protection Agency and the U.S. Air Force, 1993. "Remediation Technologies Screening Matrix and Reference Guide," EPA/542-B-93-005, Solid Waste and Emergency Response (OS-110W). July. *This document provides a description of some groundwater treatment technologies and provides a relative ranking of the technologies according to cost, effectiveness, implementability, and acceptability.*

U.S. Environmental Protection Agency, 1990a. "A Guide To Pump and Treat Groundwater Remediation Technology (FACT SHEET)," EPA/540/2-90/018, Solid Waste and Emergency Response (OS-110). November. *This document provides a summary of the information provided in EPA/600/8-90/003, Basics of Pump-and-Treat Ground-Water Remediation Technology.*

U.S. Environmental Protection Agency, 1990b. "Basics of Pump-and-Treat Ground-Water Remediation Technology," EPA/600/8-90/003, Robert S. Kerr Environmental Research Laboratory, Ada, OK. March. *This document provides basic information needed to familiarize ones' self with groundwater pump and treat technology for remediation. Discussions include: contaminant fate and transport mechanisms, basic system design methodology, data gathering, and data interpretation.*

U.S. Environmental Protection Agency. "Evaluation of Ground-Water Extraction Remedies Volume I: Summary Report and Volume II: Case Studies 1-19," EPA/540/2-89/054 and 054b, Office of Emergency and Remedial Response Washington, DC. September 1989. *This document provides an evaluation of groundwater pump and treat or containment system as implemented at 19 sites. Specific site characteristics discussed in this evaluation are: primary objectives, number of wells installed, type of treatment used, projected cleanup time, any system modifications, and any pilot testing performed. No costs are included in this report.*

U.S. Environmental Protection Agency. "Handbook Groundwater Volume I: Groundwater and contamination," EPA/625/6-90/016a, Office of Research and Development Washington, DC. September 1990. *This document provides a discussion on groundwater restoration and covers contaminant mobility, site characterization, source control and removal, groundwater collection and treatment systems, and in situ and ex situ groundwater treatment technologies.*

U.S. Environmental Protection Agency. OSWER Directive No. 9234.2-25. "EPA Guidance on Evaluating the Technical Impracticability of Ground-Water Restoration," Richard J. Guimond, Assistant Surgeon General, USPHS Acting Assistant Administrator. September 1993. *This document describes the practical limits of groundwater P&T technology for the purposes of groundwater remediation. Contains descriptions of desirable site parameters which are favorable to groundwater containment technology.*

U.S. Environmental Protection Agency. Directive No. 9283.1-12. "Final Guidance: Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites," EPA/540/R-96/023 PB96-963S08. October 1996. *This document describes the suggested response strategy for all groundwater contamination sites. This document also describes the ex-situ presumptive remedy technologies that are to be used to treat extracted groundwater.*

MULTI-PHASE EXTRACTION
PRESUMPTIVE REMEDY CRITERIA DOCUMENT

2ND EDITION

FINAL

PART II: SECTION 7.0

15 MAY 1997

CONTRACT NO. DACA-45-93-D-0027
PROJECT NUMBER: MUHJ947065

MULTI-PHASE EXTRACTION

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7.0 MULTI-PHASE EXTRACTION (MPE) TECHNOLOGY PROFILE

The U.S. EPA and the United States Air Force (USAF) Air Combat Command (ACC) have determined that multi-phase extraction (MPE) is one of the presumptive remedy technologies for treating volatile organic compound (VOC) contamination in both the groundwater and vadose zones. This determination is documented in "Presumptive Remedy: Supplemental Bulletin Multi-Phase Extraction (MPE) Technology for VOCs in Soil and Groundwater" (EPA, 1997). Inclusion of the MPE technology under the VOC presumptive remedy was based on extensive experience with MPE full scale and pilot studies performed at commercial and USAF sites across the country.

MPE has a number of benefits for remediation of VOCs in both the groundwater and vadose zones including:

- In-situ extraction of VOCs with minimal site disturbance;
- Cost-effective simultaneous remediation of contaminated soil and groundwater;
- Extraction of significant quantities of VOCs in a relatively short time; and
- Increased contaminant removal rates when compared to conventional groundwater pumping.

7.1 MPE Executive Summary

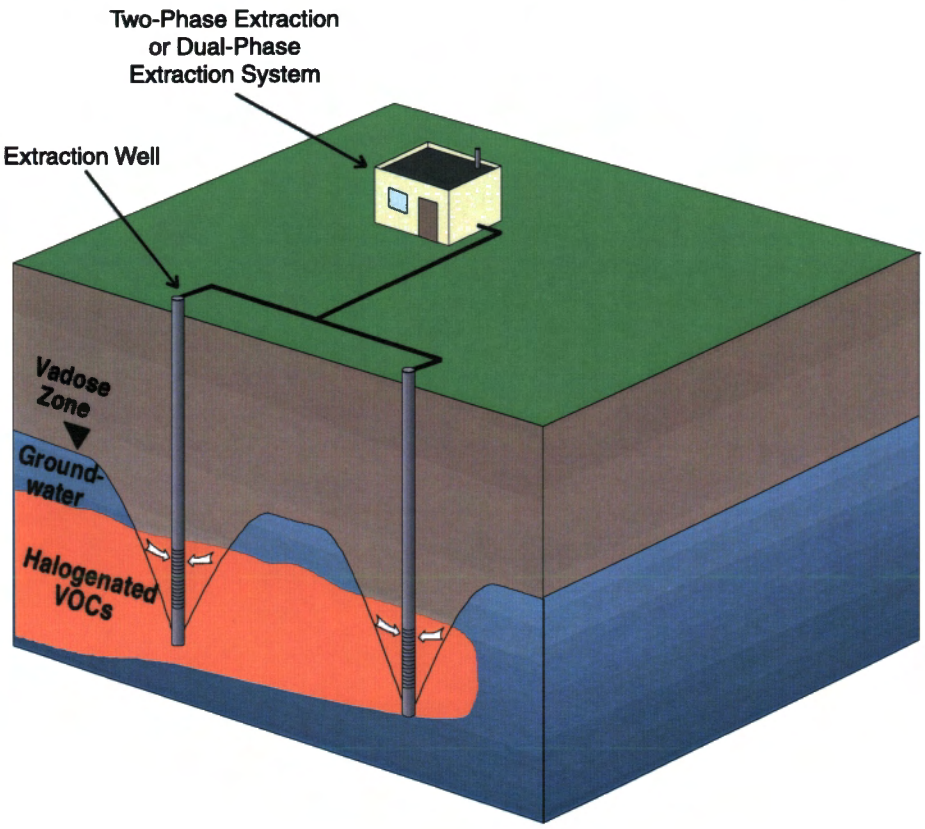
MPE is the process of simultaneously extracting contaminated soil vapor and groundwater from the saturated and/or vadose zones. This is accomplished by dewatering the groundwater table and drawing a vacuum on the newly exposed saturated soils to remove VOC contamination. Several technologies may be used to accomplish the MPE process including: two-phase extraction (TPE), low vacuum dual-phase extraction (LVDPE), and high vacuum dual-phase extraction (HVDPE). Figure 7-1 provides an illustration of a typical MPE system along with summary data on applicability, site profile needs and the presumptive remedy profile. Figure 7-2 is a decision logic diagram that can be used to determine the applicability of the MPE process and the type of MPE technology (TPE, LVDPE, or HVDPE) to be employed at a given site.

The capital cost for an MPE system is highly variable from site to site and is primarily dependent on the number and depth of extraction wells, the corresponding vapor and groundwater flow rates that may be generated from the well, high vacuum or low vacuum application, contaminant concentrations, selected groundwater and vapor treatment methods, and other site conditions. Typical costs of MPE may range from $110 to $3,300 per pound of contaminant removed. Detailed cost information is provided in Section 7.10.

7.2 MPE Technology Description

The MPE process was developed for the remediation of VOCs and other contaminants in low to moderate permeability subsurface formations. MPE simultaneously extracts both contaminated groundwater and soil vapor from the subsurface. The groundwater table is lowered in order to dewater the saturated zone so that a vacuum can be applied to the newly exposed soil. This vacuum induces air flow and allows the VOCs sorbed on the previously saturated soil to be stripped by the induced vapor flow. In addition, soluble VOCs present in the extracted groundwater

MULTI-PHASE EXTRACTION



CONTAMINANTS

Halogenated VOCs or TPH/BTEX

SITE PROFILE NEEDS

Geologic:	Soil types and homogeneity. Air permeability of vadose zone. Depth to groundwater (thickness of vadose zone).
Contaminant:	Henry's Law constant. Horizontal and vertical distribution of dissolved contaminants in the saturated and vadose zones. Vapor pressure. Maximum depth of targeted contamination.
Hydrology:	Groundwater production rate.
Other Parameters:	Location of nearby or adjacent structures or buildings.

APPLICABILITY

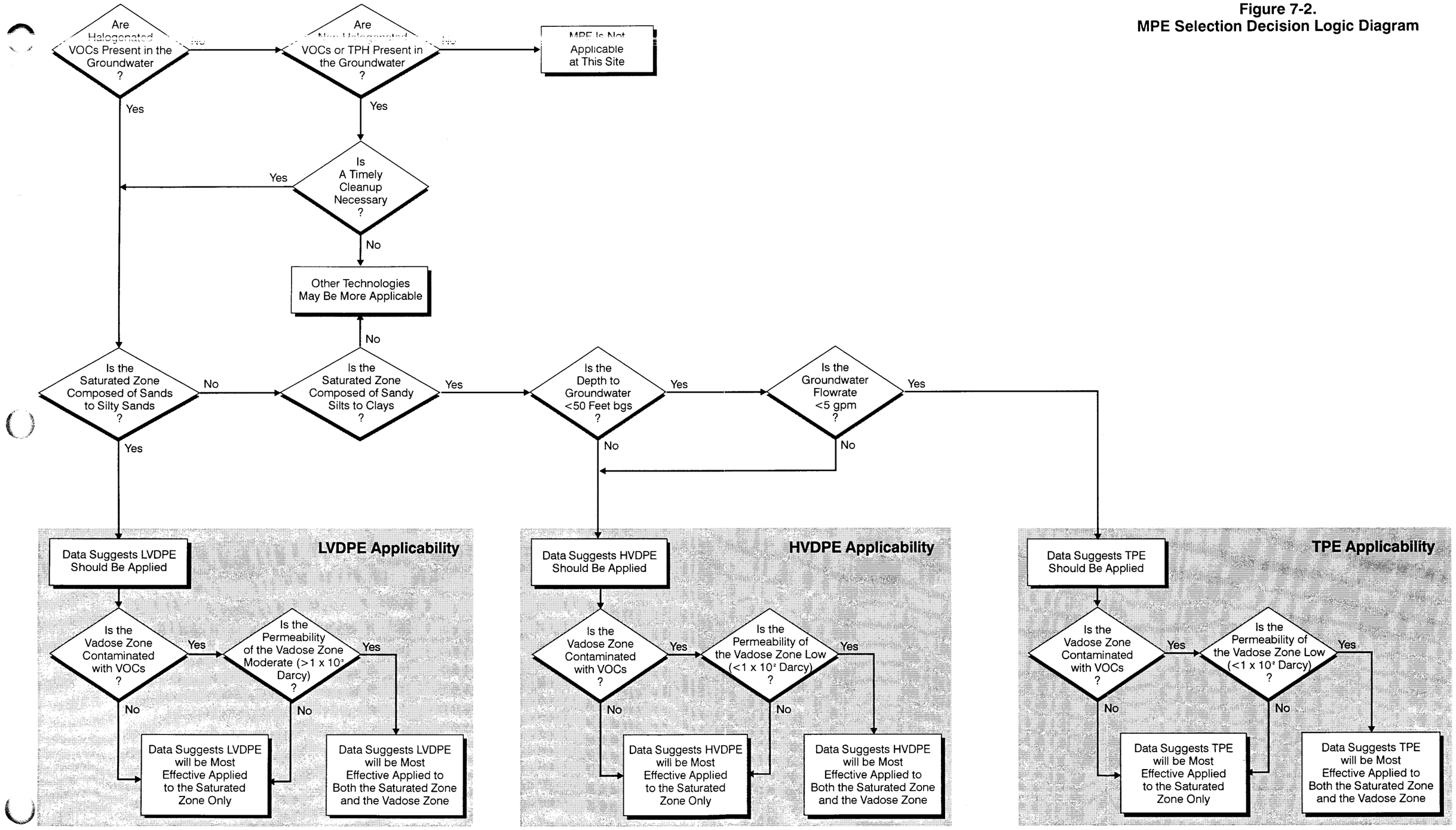
The primary application of this remedy is for halogenated VOCs in soil and groundwater. This remedy utilizes the dual-phase extraction (DPE) and two-phase extraction (TPE) technologies for contaminant removal. Petroleum or fuel related contaminants are applicable when an intrinsic remediation study has determined that intrinsic remediation, or natural attenuation are not sufficient to contain and/or effectively treat groundwater and/or soil contamination.

PRESUMPTIVE REMEDY PROFILE NEEDS

- Halogenated VOCs in vadose zone and/or groundwater;
- Non-halogenated VOCs and/or TPH/BTEX where timely cleanup is required;
- Henry's Law constant of contaminants greater than 0.01 at 20 degrees Celsius;
- Vapor pressure of contaminants greater than 1.0 mm Hg at 20 degrees Celsius;
- Geology from sands to clays; and
- For vadose zone application, air permeability of vadose zone between moderate to low permeability.

Figure 7-1. Summary of the Multi-Phase Extraction Presumptive Remedy

Figure 7-2.
MPE Selection Decision Logic Diagram



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are also removed. Under certain site conditions the vacuum applied to the subsurface may be applied to the vadose zone as well as the saturated zone.

MPE is a generic term for technologies that extract soil vapor and groundwater, simultaneously from a single well. Under this generic term, MPE, the PREECA presents the following technologies:

- Two-phase extraction (TPE);
- Low vacuum dual-phase extraction (LVDPE); and
- High vacuum dual-phase extraction (HVDPE).

The TPE technology employs a high vacuum pump (approximately 18 to 26 inches of mercury [in. Hg.]) to extract both groundwater and soil vapor from an extraction well. A suction pipe is lowered into the extraction well and a vacuum is applied to the suction pipe. The applied vacuum extracts groundwater from the saturated zone and lowers the effective groundwater table. This vacuum also volatilizes and extracts contaminants sorbed on the newly exposed soil located in that dewatered saturated zone. A typical two-phase type system is illustrated in Figure 7-3. For some TPE methods, turbulence generated within the suction pipe facilitates the transfer of aqueous phase contaminants to the vapor phase (up to 98% stripping).

By comparison, the dual phase extraction (DPE) technologies employ a submersible or pneumatic pump to extract the groundwater, and the vacuum is used to only extract the soil vapor as illustrated in Figure 7-4. LVDPE utilizes a low vacuum blower (approximately 3 to 12 in. Hg) and HVDPE utilizes a high vacuum pump (approximately 18 to 26 in Hg.) for vapor extraction. The groundwater pumps extract groundwater from the saturated zone, effectively lowering the groundwater table. The vacuum is then applied to the well to volatilize and extract contaminants sorbed on the newly exposed soil located in that dewatered saturated zone. For DPE applications where a submersible pump is used, a sump is installed at the bottom of the well to prevent cavitation of the submersible pump by providing a standing water column. Under high vacuum conditions, a sump as deep as 20 feet may be required to provide proper water column at the pump intake.

The MPE technologies (TPE, LVDPE, and HVDPE) target remediation of the groundwater zone. Under certain conditions, they also are capable of remediating both the groundwater and vadose zones simultaneously.

Typical MPE systems consist of the following components:

- Extraction well(s);
- Suction pipe (for TPE applications);
- Submersible or pneumatic pumps (for LVDPE or HVDPE applications);
- Transfer piping and manifolds;
- Vapor-water separator vessel;
- Vacuum pump (for high vacuum) or vacuum blower (for low vacuum);
- Vapor phase treatment system (if needed); and
- Groundwater treatment system (if needed).

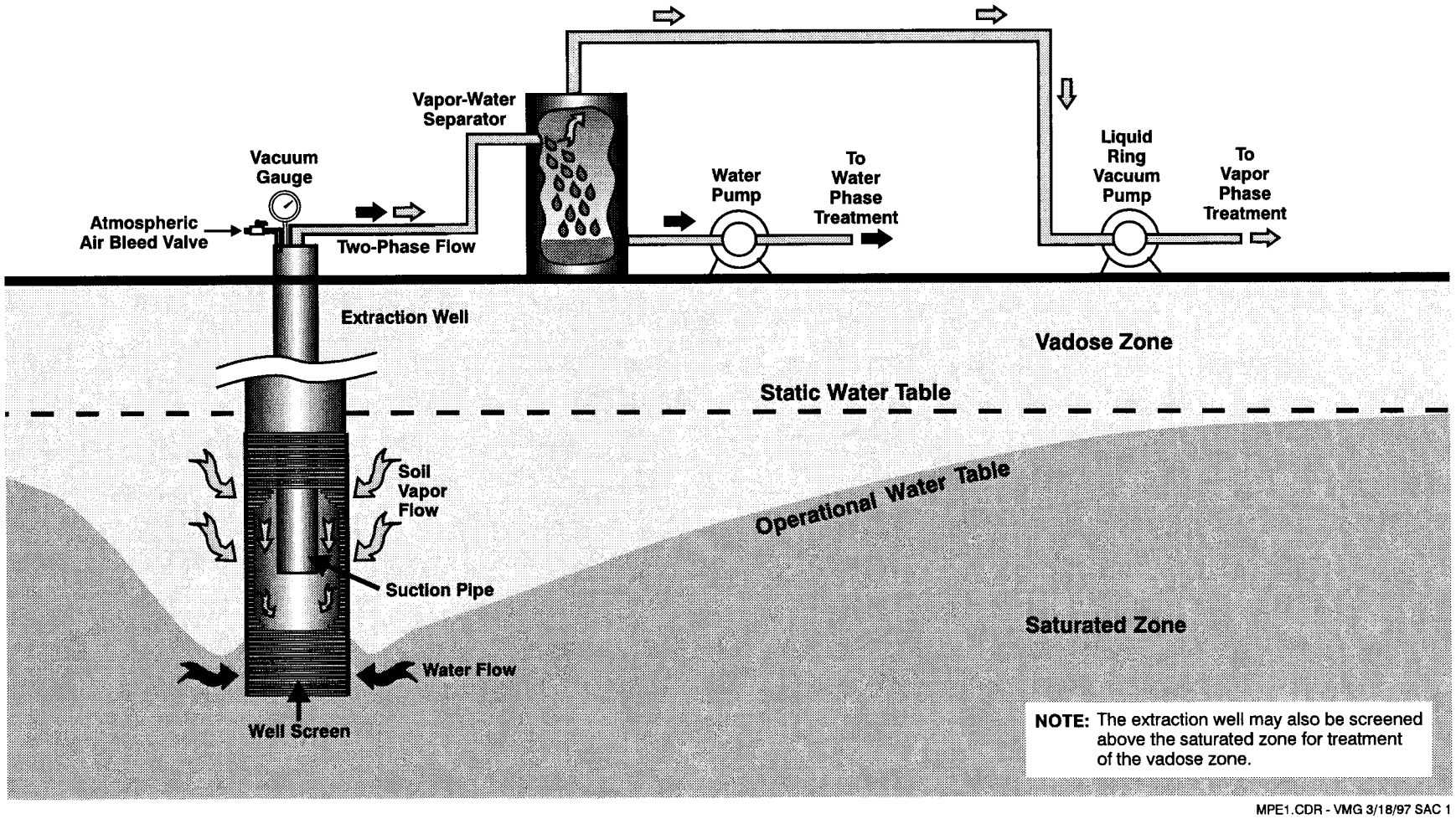


Figure 7-3. Schematic of a TPE System

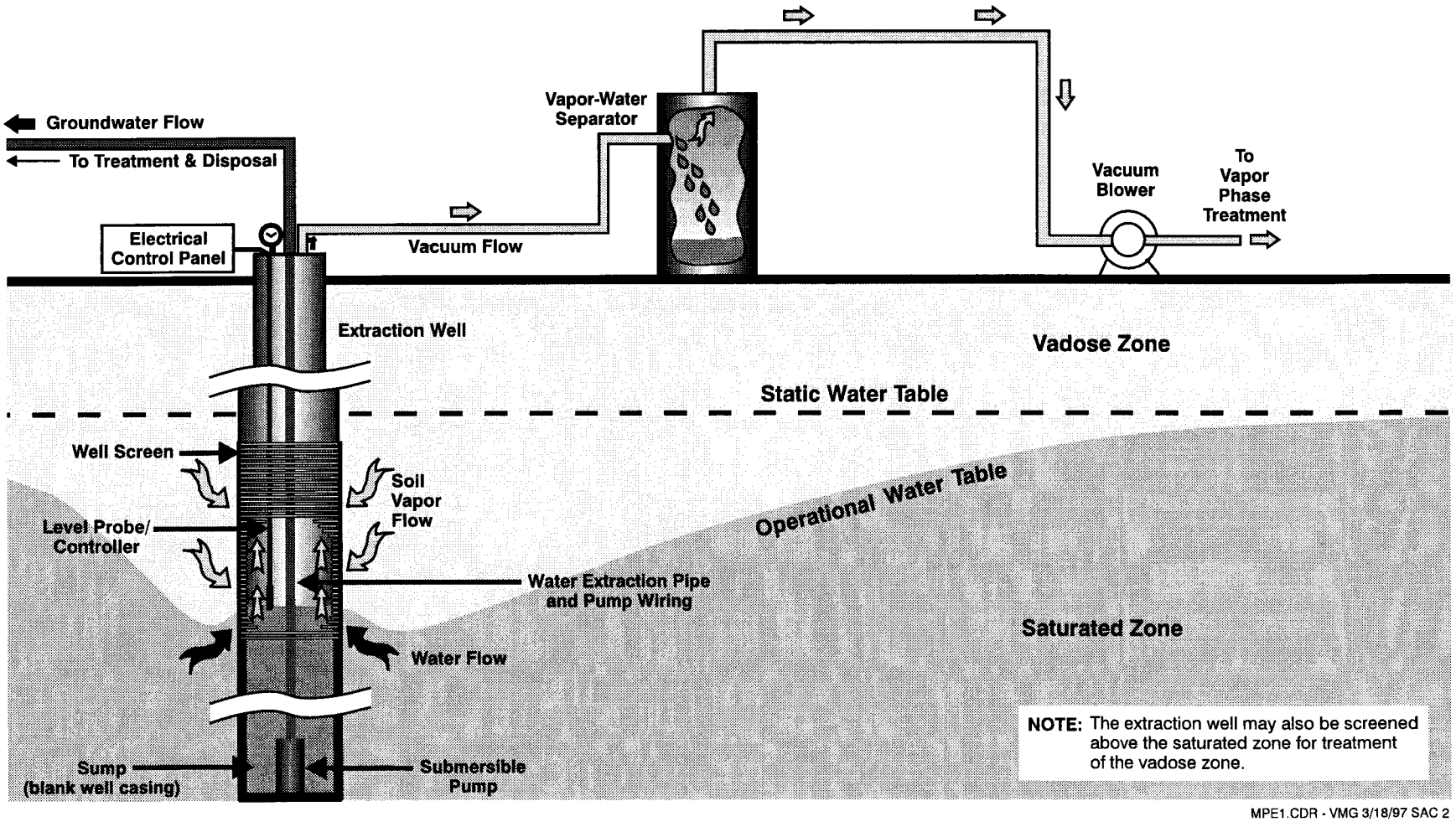


Figure 7-4. Schematic of a DPE System (Low Vacuum or High Vacuum)

7.3 MPE Technology-Based Application Criteria

The MPE technologies have been proven successful at removing VOCs in the vadose and groundwater zones over a wide range of conditions at different sites. For the purposes of using MPE as a presumptive remedy for VOCs, the recommended selection criteria are based on previous experience indicating a high probability of MPE effectively extracting the contamination. Where site conditions meet or are within a reasonable range of these criteria, MPE is suggested for the site. If a site does not fall within a reasonable range of these criteria, it does not mean that MPE cannot be used; instead, it is recommended that an enhancement be considered or a more detailed evaluation be conducted in order to justify its use. The MPE technology-based application criteria address contaminant, soil, and site characteristics. The site criteria that is suggested for basic MPE systems are presented in Table 7-1.

The contaminant and soil characteristics needed for MPE application are discussed below.

7.3.1 Contaminant Characteristics

The MPE technologies have been shown to be effective on both halogenated and non-halogenated VOCs. However, intrinsic remediation or natural attenuation is usually less expensive at remediating non-halogenated VOCs (particularly fuel related VOCs) in groundwater. As a result, the MPE technologies should only be considered for fuel related VOCs where faster remediation times are required or where natural attenuation or intrinsic remediation are not acceptable.

Vapor Pressure: The vapor pressure for the majority of contaminants should exceed 1.0 millimeters (mm) or mercury (Hg) at 20 degrees Celsius. Vapor pressure provides an indication of the degree to which the liquid phase chemical will volatilize to the gas phase at equilibrium, i.e., the driving force for the chemical to move from the pure liquid to the gas phase for extraction by the MPE technologies. Vapor pressure is highly dependent on temperature and is usually expressed in pressure units (e.g., mm Hg, atmospheres) at a given temperature.

Henry's Law Coefficient: The Henry's Law constant for the majority of contaminants should exceed 0.01 at 20 degrees Celsius. The Henry's Law coefficient is related to the materials' vapor pressure and its solubility in water, and provides an indication of the relative partitioning of the chemical between the gas phase and the solution. It provides a measure of how readily the material will move from the aqueous phase to the vapor phase. Henry's Law coefficients are also highly temperature dependent and are expressed both as dimensionless or in terms of partial pressure above a solution with a given concentration (atm-m^3/mol). Values in atm-m^3/mol can be converted to the dimensionless form by using the ideal gas law (multiply by a conversion factor of approximately 40.9).

7.3.2 Soil Characteristics

Geology: The geology in the groundwater zone for MPE application is recommended to be between sands and clays. Soils that are too porous (e.g., gravels and cobbles) are not suitable for MPE. In more porous soil conditions, a cone of depression is not able to form, and soils within the saturated zone

Table 7-1. MPE Technology-Based Application Criteria

Criteria Parameter	Guideline Value
Contaminant	1. Halogenated VOCs. 2. Non-Halogenated VOCs and/or Total Petroleum Hydrocarbons (TPH) where timely cleanup is required.
Contamination location	1. Saturated zone. 2. Both saturated and vadose zones.
Henry's Law Constant of majority of contaminants	> 0.01 at 20 C° (dimensionless)[a]
Vapor pressure of majority of contaminants	> 1.0 mm Hg at 20 C°
Geology of saturated zone	Sands to Clays
MPE Application in Vadose Zone	
Air permeability of vadose zone.	Moderate and low permeability soils (less than 1×10^3 darcies).

[a] Dimensionless Henry's Law Constant in the form: (concentration in gas phase)/(concentration in liquid phase)

are not exposed for contaminant removal. In addition, complex geologic conditions, such as sand and clay layers bounded above and below by impermeable layers, are not recommended for the presumptive remedy application of MPE.

Gas Permeability: For sites where remediation is targeted for the vadose zone. The average air permeability of the vadose zone should be low to moderate. Air permeability is a measure of the ability of vapor to move through a porous media. It is a function of the available void volume of the soil that will provide a flow path for the gas flow. This is generally a function of the soil type and the percent saturation. Fine soils (e.g., clay) generally have much smaller void volumes and thus lower soil permeability than course soils (e.g., sands). Air permeabilities are typically expressed in darcies (1 darcy = 1×10^{-8} cm^2). Sites with highly permeable soil (> 1×10^3 darcies) in the vadose zone (e.g., gravel and cobbles) may short circuit the vacuum process.

7.4 Selecting an MPE Technology: TPE, LVDPE, or HVDPE?

Once it has been determined that a MPE technology will be effective at a site, then the next decision is to determine which variation of MPE will be most effective for contaminant removal. The variations of MPE include:

- Two-phase extraction (TPE);
- Low-vacuum dual phase extraction (LVDPE); and
- High vacuum dual phase extraction (HVDPE).

All of the MPE technologies (TPE, LVDPE, and HVDPE) have optimum site conditions where they are considered to be the most cost effective for VOC contaminant removal. To determine which MPE technology will be most effective at a site, compare the site conditions to the guidelines presented in Table 7-2. These guidelines provide a preliminary assessment of the basic site characteristics that relate to potential treatment effectiveness of TPE, LVDPE, and HVDPE. The average air permeability of the vadose zone need only be considered where one of the MPE technologies is to be applied in the vadose zone. With TPE, LVDPE, and HVDPE, the aquifer must be able to be dewatered for successful application of these technologies.

Generally, the high vacuum (approximately 18-26 in. Hg) applications, HVDPE and TPE, are most effective where the target geologic formations are fine grained (i.e., sandy silts to clays) and, for vadose zone application, have low air permeabilities (less than 1×10^{-2} darcy). TPE is effective at depths less than 50 feet below ground surface (BGS) with low ground water production rates (< 5 gpm). TPE can be applied at greater depth and flow rates. However, the costs (in excess of 10 in. Hg) associated with lifting groundwater from depths greater than 50 feet below ground surface with an applied vacuum tend to be greater than HVDPE. HVDPE has a broader range of application than TPE and is not limited by depth of contamination or typical groundwater flow rates. However, HVDPE does not provide stripping of the groundwater at TPE does.

The low vacuum (3 to 12 in. Hg) application, LVDPE, is more suitable for coarse grained soils (i.e., sands to silty sands) and for vadose zone application, have higher air permeabilities (greater than 1×10^{-3} darcy). Coarse grained soils are more permeable and do not require the higher

Table 7-2. MPE Technology Selection Guide: LVDPE, HVDPE, or TPE

Site Conditions	LVDPE Guideline	HVDPE Guideline	TPE Guideline
Groundwater production rate[a]	Not limited by typical groundwater production rate, however aquifer must be able to be dewatered.	Not limited by typical groundwater production rate, however aquifer must be able to be dewatered.	< 5 gpm
Maximum depth of targeted contamination	Not limited by depth of contaminant.	Not limited by depth of contaminant.	1. Up to 50± feet BGS (for groundwater production < 2 gpm). 2. Up to 20-30 feet BGS (for groundwater production between 2 and 5 gpm).
Geology in saturated zone	Sands to silty sands	Sandy silts to clays	Sandy silts to clays
For MPE Application in Vadose Zone			
Air permeability of vadose zone.	Moderate permeability (greater than 1×10^{-3} darcy)	Low permeability (less than 1×10^{-2} darcy)	Low permeability (less than 1×10^{-2} darcy)

[a] For MPE, the aquifer must be able to be dewatered.

vacuums to induce vapor flow. LVDPE is not limited by depth of contaminants or typical groundwater flow rates.

Figure 7-2 presents a decision logic flowchart that may assist you in the selection of LVDPE, HVDPE, or TPE.

7.5 Pilot Study

Prior to implementation of the chosen MPE technology, a pilot study should be performed by an experienced engineering firm. Proper interpretation of the pilot study results are needed to maximize the effectiveness of MPE. Results from the pilot study may be used to:

- Verify that the chosen MPE technology is effective at contaminant removal;
- Identify whether the other MPE technologies or groundwater pumping would be more effective than the MPE technology tested;
- Verify that the aquifer can be dewatered;
- Verify that the vadose zone (if targeted) may be effectively remediated using MPE;
- Size, design, and cost a full scale MPE system; and
- Estimate contaminant clean up costs and time.

The pilot test consists of extracting water from a well and dewatering the saturated zone using groundwater pumps (LVDPE or HUDPE) or vacuum applied to a suction pipe (TPE). A vacuum is applied to the well, which enables contaminants located in vadose zone and/or the newly dewatered saturated zone to be volatilized and extracted. The pilot study measures:

- The induced vacuum produced at various locations (monitoring points) from the well to determine the vapor radius of influence;
- The groundwater drawdown at various locations (monitoring points) from the well to determine the groundwater radius of influence;
- Extracted vapor and groundwater contaminant concentrations;
- Extracted vapor and groundwater flow rates;
- The head loses in system; and
- Induced vacuum at the wellhead.

7.6 Application Limitations

Ability to dewater the aquifer. For sites that meet the application criteria, one technology-specific limitation identified is the difficulty in remediating sites where the aquifer is difficult to dewater. The success of MPE is dependent on exposing soil in the saturated zone to allow volatilization of contaminants located there. Sites with very high groundwater production rates and/or highly permeable soils are more difficult or more costly to dewater. These sites tend to have little or no groundwater radius of influence. In these cases, the MPE technologies would be operating more like traditional groundwater pump and treat. Additional costs associated with applying a vacuum to the subsurface would not be cost effective.

Ability to sustain vacuum. Another technology specific limitation identified is the effectiveness of remediating sites where it is difficult to sustain a vacuum on the

subsurface formation. The cost effectiveness provided by MPE is dependent on volatilizing contaminants from the subsurface. Sites that are highly permeable will tend to have little or no vapor radius of influence. Highly permeable sites are more susceptible to short circuiting, or drawing in atmospheric air from the surface.

Ability to induce vapor flow. For MPE to be effective, the applied vacuum must be able to induce some vapor flow through the subsurface. Sites with extremely low permeabilities may completely inhibit vapor flow through the subsurface, so that application of MPE would not be cost effective.

Logistics. Other logistical site constraints may interfere with the practicality of implementing MPE at sites. The possible logistical limitations could include:

- Land use constraints;
- Space or access limitations; or
- Availability of utilities.

These factors should be considered on a site-specific basis.

7.7 MPE Design Basis

This section provides a discussion of key MPE design issues. The discussion provides generalized information based on a broad range of conditions experienced with previous MPE systems and will need to be customized for each site. The discussion is provided for each of the following system components:

- Extraction system;
- Collection system;
- Vacuum system;
- Vapor treatment;
- Groundwater treatment;
- Groundwater discharge alternatives; and
- Monitoring program.

7.7.1 Extraction System

The primary design parameters for the extraction system are the extraction well placement/spacing; the depth and extent of the extraction well screened interval; and sizing of the groundwater pumps (for LVDPE or HVDPE). These parameters will be based on the pilot study results including: extent of the contamination, vapor and groundwater radii of influence, and groundwater flow rates.

Extraction wells. The extraction wells should be placed such that the vapor and groundwater radii of influence of the extraction wells include the entire area and extent of the targeted remediation zone . Radius of influence refers to the radial distance to which each extraction well is able to draw adequate flow through the saturated and/or vadose zone to extract the VOCs.

Radii of influence is generally determined via a 4-5 day pilot test using at least one extraction well with soil vapor pressure and groundwater monitoring points at varying depths and distances from the well. The lowest pressure differential that is considered adequate to cause extraction of the vapors has been reported to be 0.1 inches of water vacuum. The lowest water drawdown that is considered adequate to cause extraction of contaminants has been reported to be 0.1 feet.

In addition to the extraction well placement, the location of the screened interval of the

extraction well can also be used to "target" the groundwater and vapor flow through the portions of the saturated and/or vadose zones where the highest concentrations of contaminants are located. Where submersible pumps are used (LVDPE or HVDPE), a sump at the bottom of the well is installed to prevent cavitation of the submersible pump. Under vacuum conditions, a net positive suction head may be maintained (to prevent cavitation of the submersible pump) using a standing water column. Under high vacuum conditions, a sump as deep as 20 feet may be required to provide proper water column at the pump intake.

If more than one extraction well is used then "dead spots" will be present within the subsurface. Dead spots are the locations in the subsurface where the vacuum from both wells are equal and therefore there is no net pressure gradient to cause vapor flow. As a result, there is no flow and no contaminant removal from that zone. Contaminants are typically extracted from dead zones by reducing the amount of vacuum drawn at each well on an alternating basis (pulsed operation) or installing vapor inlet wells.

Groundwater pumps (for LVDPE and HVDPE). Groundwater pumps should be sized based on the groundwater production rate of the well and the head required to transport the water to the treatment system. In design, use the groundwater flow rate produced when the extraction well is drawn down to the desired contaminant target zone. When submersible pumps are used, there should be up to 20 feet of static water column at the intake of the pump. Where existing extraction wells are used and a static water column is not available, pneumatic pumps may be used. However, pneumatic pumps are limited with depth and flow rate.

7.7.2 Collection System

The collection system consists of the piping, manifold, knockout pot, equalization tanks, and auxiliary equipment for transporting the extracted groundwater and soil vapors from the wellhead.

Conveyance Piping. The piping from the extraction wells to the manifold is typically either PVC, HDPE, or steel pipe, although other types of piping can be used. For TPE, a single conveyance line transports the soil vapor and groundwater to the blower, simultaneously. For LVDPE or HVDPE, one conveyance line transports vapor to the vacuum blower and one conveyance line transfers extracted water to a equalization tank. The transfer piping should be equipped with some method of measuring and regulating flow, vacuum, and pressure, and for taking vapor and groundwater samples. This will allow for fine tuning of the extraction well network to collect the most contaminants in the least amount of time.

The pipe and manifold sizing should be determined based on the allowable pressure drop in the lines and fittings given the groundwater pumps or vacuum blower/pump sizing. Additional consideration should be given to the external conditions that may impact the transfer lines such as climate and installation operations. Consideration should also be given to how condensate will be collected from the piping and manifold system (e.g., collection lines).

The Knockout Pot. The knockout pot function is to separate the entrained liquid from the vapor stream prior to vapor and groundwater treatment. Entrained liquids can have an adverse effect on the downstream systems in two ways; erosion of some blower systems and increased costs for vapor treatment. Increased costs for vapor treatment come from either increased energy

costs to vaporize and heat the liquid in a thermal system or by adsorbing on carbon sites in carbon systems and reducing the capacity for VOC adsorption. Usually the knockout pot is located prior to the low vacuum blower. However, under high vacuum systems, the knock out pot may be located before or after the liquid ring vacuum pump, depending on its design.

The knockout pot functions as a wide spot in the transfer system were the flow velocity is reduced to a point were liquids will no longer be entrained in the stream. A knockout pot may be equipped with a mist eliminator. Some knockout pots are equipped with liquid pumps run on level controls to send the collected water to appropriate treatment or disposal systems.

Equalization tank. Equalization tanks are used to collect extracted groundwater prior to treatment. Use of equalization tanks are dependent on the design of the treatment system.

7.7.3 Vacuum System

The primary design parameter for the vacuum blower or vacuum pump will be the required vacuum at the extraction well and vapor flow rate. This will need to be combined with the pressure losses in the wells and transfer systems and the back pressure from the downstream vapor processes. Based on the estimated vacuum and flow rate required, either a centrifugal blower for low vacuum or liquid ring vacuum pump for high vacuum may be selected. Once the flow and vacuum requirements of the system have been determined, the actual sizing of the equipment is typically done using vendor information such as pump curves and capacity data. The vacuum blower/pump should also be equipped with automatic control systems to shutdown the system if key design parameters are exceeded, e.g., high outlet pressure, high load or current, or pressure differential between the blower and the treatment system.

For TPE design, where head losses associated with lifting groundwater with a vacuum are in excess of approximately 10 in. Hg, consider another MPE technology. HVDPE or LVDPE may be more cost effective for contaminant removal at that site.

Safety is also a key design issue. The potential for flammable or explosive gases or liquids in the system should be considered early in the process and the system designed appropriately if this potential exists. Consideration of the change in the lower and upper explosive limits under reduced pressure conditions should be accounted for in the system design

7.7.4 Vapor Treatment

Regulations may require that the effluent gas from the vacuum extraction systems be treated to destroy or remove the contaminants from the vapor stream prior to discharge. The appropriate regulatory agency should be consulted early on in the process to determine the control level required for the system. Four offgas treatment technologies are discussed in the following sections:

- Adsorption on granular activated carbon (GAC);
- Catalytic oxidation;
- Thermal incineration; and
- Biodegradation.

Each of these technologies/methods have been used commercially, although the systems that generally have been determined

to be the most cost effective for the range of concentrations and contaminants usually encountered are GAC and catalytic oxidation. Figure 7-5 provides a representation of the typical concentration ranges where the technologies are most applicable and cost effective. As can be seen in this figure, the concentration range of 10-200 ppmv is the least cost effective. A brief summary of how each technology works along with key issues are provided below.

The range of anticipated soil vapor concentrations that will be encountered throughout the project should be considered when selecting a vapor treatment system. This may result in sequential implementation of more than one treatment system (e.g., catalytic oxidation while high removal rates are occurring followed by activated carbon when the concentrations drop off). If one of the MPE technologies is to be used at multiple sites, it may be the most cost effective to have mobile treatment systems so that one treatment system can provide the vapor control sequentially at multiple sites, thus reducing capital costs.

Adsorption on Granular Activated Carbon

If flow, concentration, temperature, and pressure data are provided, carbon vendors can provide an estimate of the capacity and anticipated life of a carbon bed. For complex mixtures, a bench scale test may need to be conducted to better determine the carbon capacity. Vapor is typically heated to reduce the relative humidity when it exceeds 50%. Carbon costs, including disposal/regeneration and shipping, combined with the anticipated life should be included in the cost evaluation used to compare GAC with alternative control technologies. If carbon purchase and disposal costs become high enough, on-site regeneration may be cost effective using steam or hot air to desorb the contaminants. The contaminant vapors are typically condensed to liquid form and sent to disposal.

Catalytic Oxidation

Catalytic Oxidation is designed to oxidize the contaminant molecules primarily to carbon dioxide and water (and acid gases such as HCl and HF if halogens are present). This is done by passing the vapors over an inert catalyst bed typically consisting of a precious metal impregnated on a substrate. The catalyst allows the reaction to occur at much lower temperatures than during normal combustion processes. These systems typically operate at between 700 and 900 degrees F and as a result produce low levels of nitrogen oxides (NOx), and require less energy to operate than conventional thermal incineration. Depending on the energy content of the contaminant stream, the catalytic oxidation system may be able to operate without supplemental fuel. The efficiency of these systems is often enhanced by preheating the inlet vapor stream using heat exchange from the offgas stream. Direct-fired natural gas burners are normally used for start-up and any required supplemental energy. Because of the catalyst costs, catalytic oxidizers usually will have a higher capital cost than a thermal oxidizer although the operating costs are usually lower.

A key consideration for catalytic oxidation systems is the potential for catalyst poisoning or erosion. Materials such as halogens, heavy resins, or heavy solvents can poison or mask the catalyst material requiring either periodic cleaning or costly premature replacement of the catalyst bed. If acid gases are expected (e.g., HCl from chlorinated hydrocarbon combustion), the combustion and downstream components will have to be made out of corrosion

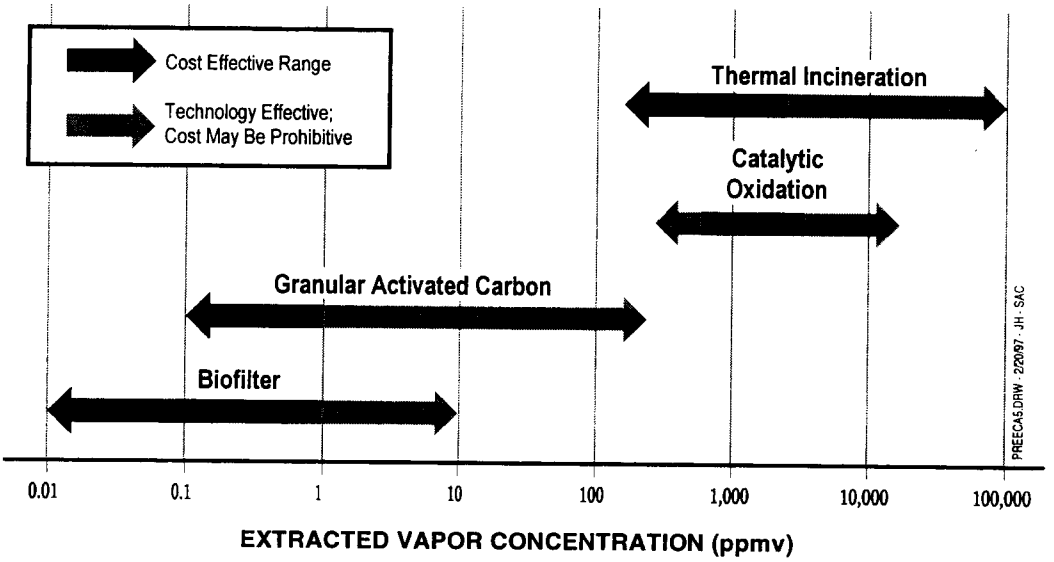


Figure 7-5. Applicability of Vapor Treatment Options

resistant material and an acid gas scrubber will be required. Vapor streams containing high particulate levels can have a similar effect by eroding the catalyst material off of the substrate. Additionally, the concentration of the contaminant must be below 25% of the LEL to make sure that the combustion reaction does not get too hot and melt the catalyst (EPA, 1986).

Thermal Oxidation

Thermal oxidizers can be compact and relatively inexpensive. As shown in Figure 7-5, thermal oxidizers are usually more cost effective than carbon or catalytic oxidizers if the concentrations and energy content of the vapor stream are high. The oxidation reaction occurs as a result of direct heating, usually by a gas fired burner, to temperatures of 1400 degrees F or higher. If the energy content is high enough, the system can sustain combustion without the use of supplemental heating.

Thermal NOx can be formed at these temperatures although advances in low-NOx burners have significantly reduced the NOx emissions levels generated by these units. As with catalytic oxidizers, if halogenated VOCs are combusted and acid gases are produced, the system will have to be made of acid resistant materials.

Biofilters

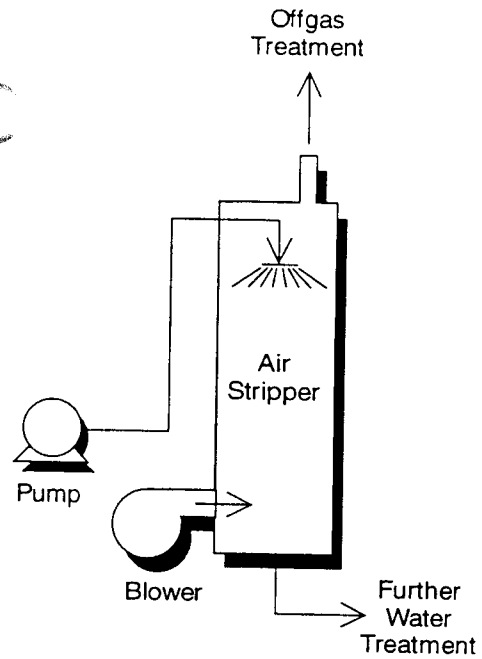
Biofilters are typically soil or compost media that contain microorganisms that are able to degrade the chemical or chemicals of concern. This occurs first by absorption of the VOC molecule into a moist liquid film in the pore spaces of the media where they are metabolized or destroyed enzymatically by the microorganisms. Biofilters have been used extensively for odor control in the sewage treatment industry and have recently been used as offgas control for VOC waste streams. The difficulty in implementation of a biofilter system are those typical of keeping microorganisms alive, including pH, nutrient levels, an adequate carbon source, moisture content, and a relatively constant food source. Often biofilters have limited ability to handle effluent vapor streams with widely varying constituent concentrations. In order to maintain adequate residence time in the bed, the biofilter size often has to be quite large and may be constrained by space considerations. The advantages of the system are that it can obtain high destruction efficiencies for very low costs.

7.7.5 Groundwater Treatment

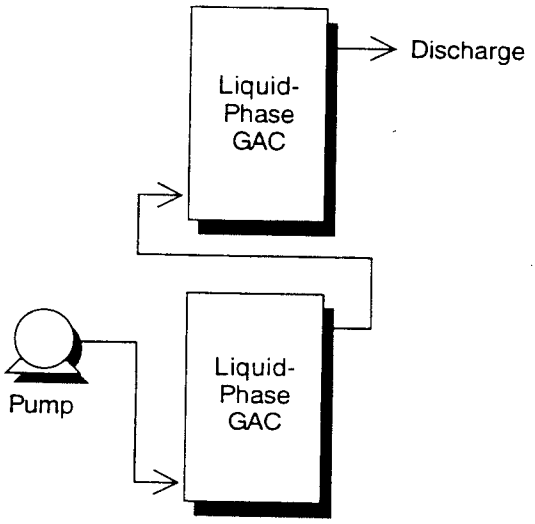
Where groundwater treatment is required, an extracted water treatment system can be a combination of many treatment components depending on the characteristics of the contamination. The treatment technologies described below are presented based on the presumptive remedy guidance published by the U.S. EPA on groundwater treatment technologies. This guidance is called "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites" (EPA, 1996). The presumptive remedy guidance recommends air stripping, granular activated carbon, chemical/UV oxidation, and aerobic bioreactors for treatment of organic contaminants. Each of these technologies are described briefly below (EPA, 1996; Freeman, 1989). Visual representations of the treatments for organic compounds are shown on Figure 7-6.

Air Stripping

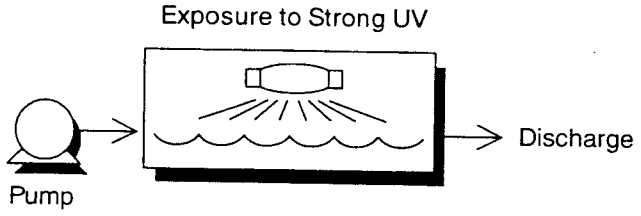
Volatile organics are separated from groundwater by greatly increasing the surface area of the contaminated water and exposing it to air. Types of aeration methods



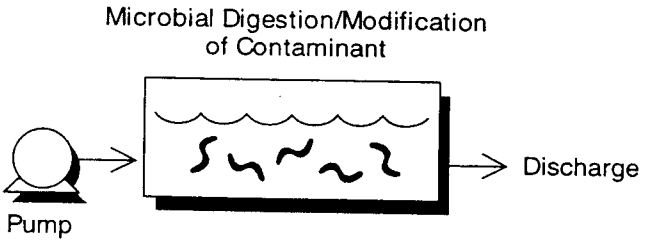
AIR STRIPPING



GRANULAR ACTIVATED CARBON (GAC)



ULTRAVIOLET TREATMENT



BIOTREATMENT

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Figure 7-6. Groundwater Treatment Technologies for Organic Compounds

include packed towers, diffused aeration, tray aeration, and spray aeration. The target contaminant groups for air stripping systems are halogenated and non-halogenated volatile organic compounds. The technology can be use to treat halogenated and non-halogenated semivolatile organic compounds and fuels, but may be less effective.

Granular Activated Carbon

Groundwater is pumped through a series of canisters containing activated carbon to which dissolved organic contaminants adsorb. The technology requires periodic replacement or regeneration of saturated carbon. The target contaminant groups for liquid-phase granular activated carbon are halogenated, non-halogenated, and semivolatile organic compounds. It is especially effective for polar compounds. The technology can also be used for treating fuel hydrocarbons, and pesticides, but may be less effective.

Chemical Oxidation/Chemical Enhanced Oxidation/UV Oxidation

Chemical oxidation uses oxidizing agents to destroy organic contaminants by altering its chemical state (by removing electrons [or oxidizing it]). Oxidizing agents include sodium hypochlorite, hydrogen peroxide, calcium hypochlorite, potassium permanganate, and ozone. In chemical oxidation, oxidizing agents are mixed with extracted groundwater in a treatment tank where contaminants are destroyed. Target contaminants groups for chemical oxidation are halogenated volatile and semivolatile organic compounds and pesticides. The technology also can be used in treating non-halogenated volatile organics and fuels, but may be less effective. Chemical oxidation may also utilize ultraviolet (UV) light to photochemically oxidize target contaminants.

Aerobic Bioreactors

Contaminants in extracted groundwater are put into contact with microorganisms through attached or suspended biological systems. In suspended growth systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin where microbial population aerobically degrades organic matter and produces new cells. The new cells form a sludge, which is settled out in a clarifier, and the sludge biomass is recycled to the aeration basin. In attached growth systems, such as rotating biological contactors and trickling filters, microorganisms are established on an inert support matrix to aerobically degrade groundwater contaminants. The microbial population may either be derived from the contaminant source or from an inoculum of organisms specific to a contaminant. Attached and suspended systems are often used together.

Bioreactors are used primarily to treat non-halogenated volatile and semivolatile organics and fuel hydrocarbons. Halogenated volatiles and semivolatiles and pesticides also can be treated, but the process may be less effective and may be applicable only to some compounds within these groups.

7.7.6 Groundwater Discharge Alternatives

Treated water disposal/discharge alternatives can include:

- Discharge to local POTW;
- Discharge to surface water;
- Reinjection;

- Other (irrigation, industrial reuse such as dust control or use as washwater).

The implementability of these options are highly site specific, and should be evaluated on a site specific basis. Visual representations of these options are shown on Figure 7-7.

7.7.7 Monitoring Program

A monitoring program consists of a monitoring system and the associated sampling and analysis activities necessary to verify the system performance. The monitoring system typically includes a series of groundwater and vapor wells or piezometers and monitoring devices (e.g., water level meters, transducers, magnehelic gauges).

Monitoring wells/piezometers are used for the purposes of monitoring the effectiveness of an MPE system. The groundwater radius of influence of the extraction system can be determined by measuring water levels in adjacent monitoring wells or piezometers. The vapor radius of influence of the extraction system can be determined by measuring the induced vacuum at vapor piezometers. Also, water quality samples collected from groundwater monitoring wells/piezometers and vapor samples collected from the vapor piezometers can help to determine if contaminant removal is being achieved or if unexpected changes in subsurface conditions are taking place in response to the extraction system. Monitoring well/piezometer placement is critical to a successful monitoring program.

Piezometers/monitoring wells are used to measure fluctuations in water levels or vacuum influence in the surrounding subsurface over time. In addition to MPE system subsurface effects, water levels may vary with season and vacuum influence may vary with the atmospheric barometric pressure. It is important to keep a record of these subsurface effects.

7.8 MPE Operations and Performance

The performance of the MPE systems are highly dependent on site conditions including geologic conditions, hydrogeologic conditions, groundwater vapor flow rates, vapor flow rates, contaminant types, contaminant concentrations, and system design. This is illustrated in "Presumptive Remedy: Supplemental Bulletin Multi-Phase Extraction (MPE) Technology for VOCs in Soil and Groundwater" (EPA, 1997) where it shows that the contaminant removal rates in several case studies varied from 2.5×10^{-3} to 24 lbs/day. These removal rates are typically higher than traditional groundwater pumping. In each case study presented, the MPE removal rate was higher than the estimated removal rate of a traditional pump and treat system at the same site. A summary of the results of these case studies are provided in Table 7-3.

Contaminant removal will change as the MPE system operates over time and the site begins to be remediated. This requires that the operator routinely assess the performance of the system and make appropriate modifications. Figure 7-8 shows a typical decision loop for the process.

The primary data used to monitor for operational changes will be the extracted groundwater and vapor contaminant concentrations, groundwater and vapor flow rates, groundwater and vapor radii of influence data, soil vapor and groundwater piezometer concentrations, energy usage, soil vapor and groundwater treatment system efficiencies, and system data. These data will be used to determine if enhancements or modifications to the system are required.

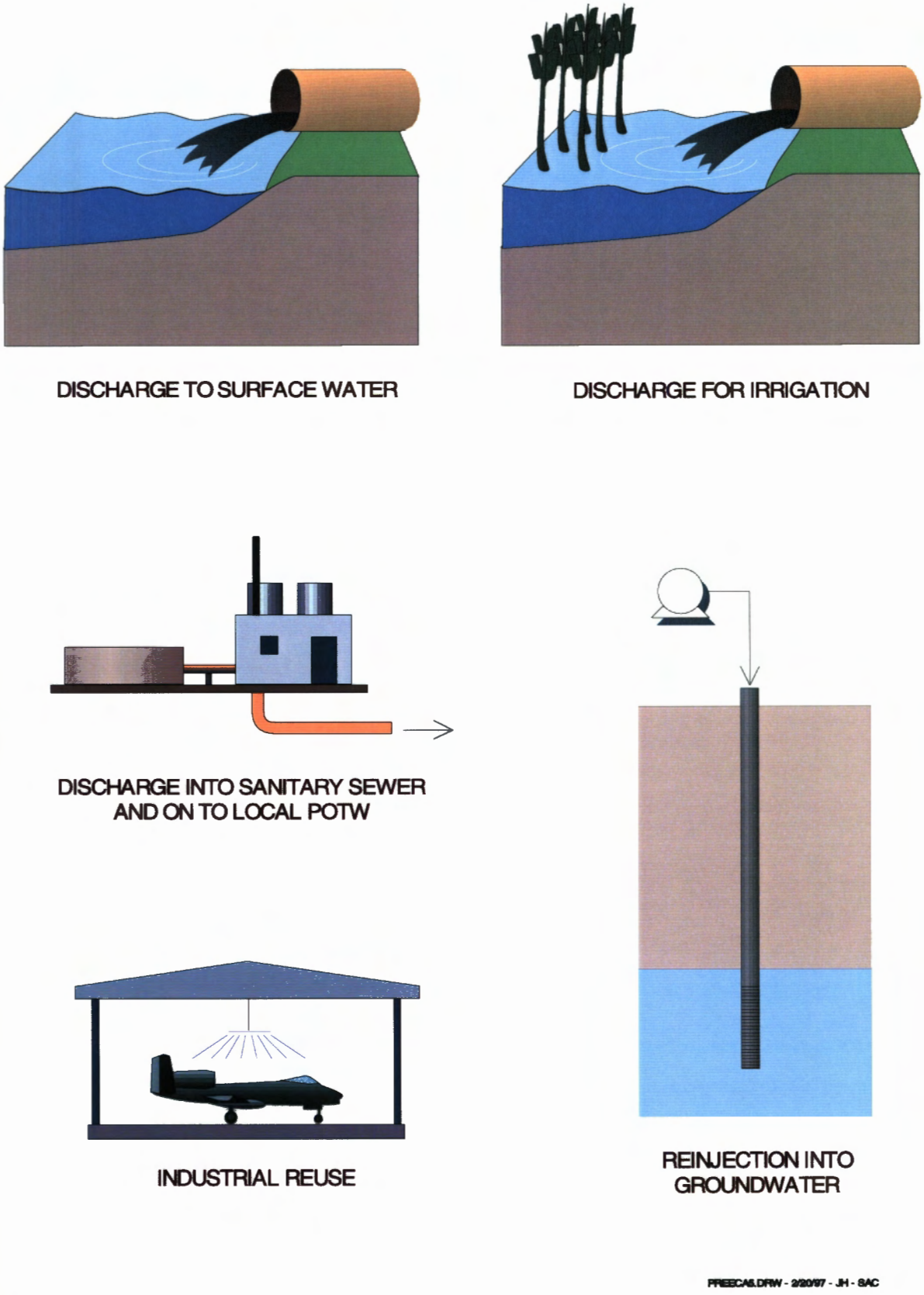

Figure 7-7. Groundwater Discharge Alternatives

Table 7-3. Summary of [illegible]E Case Study Results

SITE	Treatment Type	Depth of Water (ft. BGS)	Lithology		Targeted Contaminant	Groundwater Concentration (µg/L)	Number of Extraction Wells	Depth of Extraction Well (feet bgs)	Effective Well Vacuum (in. of Hg)	Screened Interval (feet bgs)	Total Mass of VOCs Removed (lbs/day)		Groundwater Flowrate (GPM)		Vapor Flowrate (scfm)	Estimated Cost of Contaminant Extraction ($/lb)	Remarks
			Vadose Zone	Saturated Zone							MPE	P&T	MPE	P & T			
DDRW-Tracy OU1	TPE	24.0	silty clay	silty clay	TCE	3.5-6.5	1	31	18	15.5-30.5	2.5×10^{-3}	8.7×10^{-5}	3.5	0.5	13-17	38,000	a
Travis AFB, MW-269	TPE	13.7	silts, clays	silts, clays	TCE	1,030	1	22.5	19-22	11.7-21.7	0.113	0.008	3.72	0.8	6-10	848	
Travis AFB, Ragsdale & V, MW-7	TPE	10.0	silts, clays	silts, clays	TCE, TPH, Benzene	3,700	1	29	17	8.5-28.5	24	0.29	5	2	17	4	
Travis AFB, OSA	TPE	8.0	silty clay	silty clay	TCE, PCE	900	1	29	22.5	8-28	0.875	0.11	0.5	<0.25	3.5-5	110	
Nellis AFB, Site 44	TPE	45.0	silty clay	caliche, silty clay	TCE (VOCs)	1,760	1	60	6.5	30-60	0.39	0.012	1.7	0.8	87-97	351	b
McClellan AFB, Bld.666	TPE	109.0	sandy silt	sandy silt	TCE, PCE, Freon	8,400	1	124.5	20	105.5-124.5	9	0.36	5.2	4	94	58	c
FE Warren AFB, 0U2, EW1	TPE	10.0	clayey, gravelly, silty, sands	clayey sands and clay	TCE	0-150	1	25	9-13	12.7-24.7	0.029	0.011	2.7-3.0	2-3	2-4	3,300	
Ellsworth AFB OU-11, BG-04	TPE	18	sandy silty clay, clayey sand	clayey gravel, pierre shale	TCE	40.5	1	33	9-14	13-23	0.003	0.001	2-3	<2 gpm (estimated)	15-30	32,000	a
Offutt AFB, Bld. 301	LVDPE	50.0	clay	silty sand	TCE	24,600	1	92	9-14.5	50-70	0.7	0.33	3.1	1.5	9-14.5	137	d
McClellan AFB, Bld. 360, EW - 321	LVDPE	112.0	clays, silts	sandy silts, silty sand	TCE (VOCs)	10,500	1	160	10	110-140	11.4	0.28	5.9	2.75	58	245	e
	HVDPE	112.0	clays, silts	sandy silts, silty sand	TCE (VOCs)	10,500	1	160	15	110-140	13.6	0.28	6.7	2.75	78	225	e
McClellan AFB, Bld. 360, MW - 224	LVDPE	112.5	sandy silt	sandy silt	TCE (VOCs)	11,000	1	119.5	10	110-140	0.68	0.08	1.6	0.6	4.5	1,700	f
	HVDPE	112.5	sandy silt	sandy silt	TCE (VOCs)	11,000	1	119.5	24	109.5-119.5	2.54	0.08	1.8	0.6	11	1,290	f

Remarks:
a. High contaminant removal costs are due to low groundwater concentrations.
b. Test results indicate that LVDPE would be more effective than TPE at this site.
c. Test results indicate that HVDPE wold be more effective than TPE at this site.
d. Test results indicate that HVDPE would be more effective than LVDPE at this site.
e. HVDPE and LVDPE shown to be nearly equally cost effective for EW-321 at McClellan
f. HVDPE shown to be most cost effective for MW-224 at McClellan.
N/A = Not applicable

Note: Costs associated with any patent requirements are not included in the cost.

Source: Presumptive Remedy: Multi-Phase Extraction (MPE) Technology for VOCs in Soil and Groundwater (U.S. EPA, 1997)

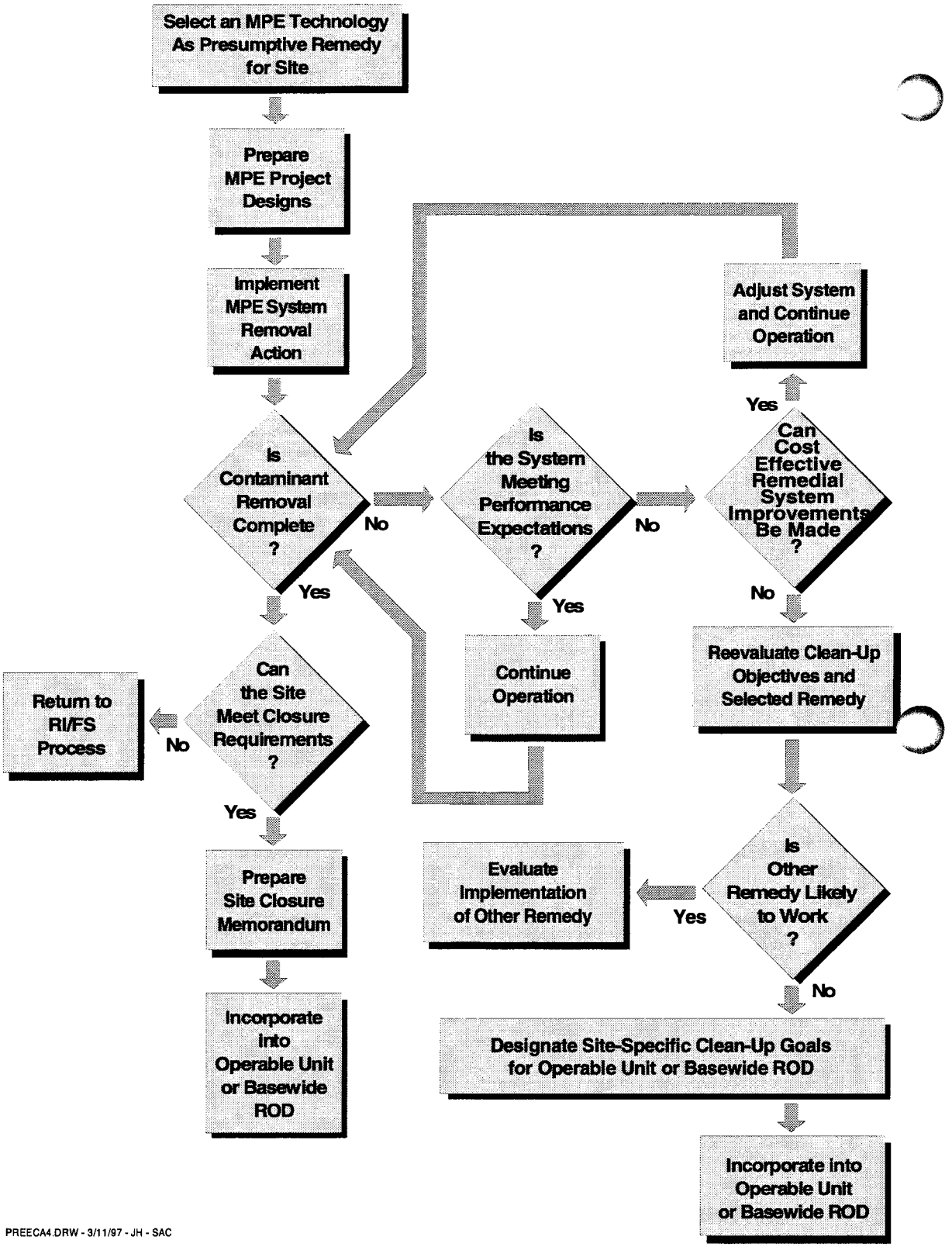

Figure 7-8. MPE Implementation and Operations Flow Diagram

When the remedial objectives appear to have been met based on the extraction rate data, confirmation soil or soil vapor samples are typically taken to verify that residual concentrations are below acceptable cleanup levels. If the site appears to meet the appropriate clean-up levels then it would proceed towards closure.

7.9 Patent Requirements

Some specific hardware and well configurations associated with the MPE technologies are patented. Use of these may require that those patent requirements be met as explained below.

The Xerox Corporation has been issued a U.S. patent for their 2-Phase™ Extraction technology. The term "two-phase extraction" used in this document is a generic term that encompasses Xerox's "2-Phase™ Extraction" technology. For TPE implementation, where Xerox's patent requirements are applicable, royalty and licensing fees should be considered. Royalty fees include a one time installation fee of $5,000 per extraction well. Royalty fees are not applicable to pilot study tests of TPE. Xerox also requires that the TPE system be installed and operated by a licensed operator. The current cost of this license is $20,000. A facility may purchase a less expensive facility-specific license through Xerox that would allow them to use any operator to operate and maintain the system. Facilities interested in a facility-specific license would have to negotiate the terms of the license with Xerox.

7.10 MPE Capital and Operating Costs

The capital cost for an MPE system is highly variable from site to site and is primarily dependent on the number and depth of extraction wells, the corresponding vapor and groundwater flow rates that will be generated from the well, high vacuum or low vacuum application, contaminant concentrations, and other site conditions. This is illustrated in the EPA's Supplemental Bulletin on the MPE technology (EPA, 1997) where it shows that typical costs for contaminant removal in most of the case studies ranged from $110 to $3,300 per pound of contaminant removed. These costs do not include groundwater or vapor treatment. A summary of the results of these case studies are provided in Table 7-3. Table 7-4 provides cost ranges for several typical MPE system components; vapor treatment options; groundwater treatment options; applicable construction, engineering, and royalty fees; and operations and maintenance costs. Only some of the components listed may be needed depending on the MPE system capacity and the selection of LVDPE, HVDPE, or TPE. Vapor and groundwater treatment costs are also highly dependent on the contaminant concentrations and flow rate.

Cost for a TPE system installed at Travis AFB located in Northern California are provided in Table 7-5. This is a simple TPE system, where low vapor (< 25 scfm) and groundwater (< 0.5 gpm) flows are extracted from a single well. This site had several cost advantages including an existing groundwater treatment facility, existing electrical and gas service, and minimal reporting requirements. The capital cost to install this system is approximately $98,450. The estimated cleanup time for this site is approximately 10 months. The costs to operate and maintain this TPE system for 10 months is estimated to be approximately $27,500.

Table 7-4.
Typical Capital and Operations & Maintenance Costs for MPE System

Components of MPE System	
Extraction Well Installation	$75 to 120/ft
Groundwater/Vapor Piezometers (cpt or drilled)	$50 to 120/ft
Conveyance Piping and Manifold	$30 to 90/ft
TPE Unit with Knockout Pot	$15,000 to 30,000
HVDPE Blower with Knockout Pot	$15,000 to 30,000
LVDPE Blower with Knockout Pot	$3,000 to 10,000
Extraction Pumps/Level Control (LVDPE or HVDPE only)	$1,000 to 3,000/well
Equalization Tank (500 to 8,000 gallons)	$500 to 10,000
Bag Filters	$2,000 to 4,000
Site Preparation/Equip Pad	$5,000 to 15,000
Electrical/Controls	$2,000 to 25,000
Utility Hookup (electrical, gas, water)	Varies
Vapor Treatment Options	
Carbon (up to 600 scfm) with Regeneration	$42,000 to 150,000
Cat Ox (160 scfm-800 scfm)	$180,000 to 275,000
Therm Ox (up to 600 scfm)	$23,000 to 40,000
Groundwater Treatment Options	
Air Stripping	< $3/1,000 gallons
Carbon	< $10/1,000 gallons
Chemical/UV Oxidation	$3 to 10/1,000 gallons
Aerobic Bioreactors	< $3/1,000 gallons
Construction, Engineering, and Royalty Fees	
Pilot Study	$50,000 to 120,000
Engineering/Design	8-20% of construction costs
Royalties (some applications of TPE)	$5,000/well
Bid and Scope Contingents	15-30% of construction costs
Mobilization	10% of construction costs
Permitting and Legal	2% of construction costs
Services During Construction	8% of construction costs
Operation and Maintenance Costs (1 Year)	
Labor	$8,000 to 70,000
Electricity (5 hp to 100 hp at $0.75/kwh)	$2,500 to 50,000
Natural Gas (vapor treatment up to 10,000 therms)	Up to $6,000
Materials	Varies
Analytical	Varies
Reporting	Varies

Table 7-5.
Total Capital and Operations & Maintenance Costs for TPE System at Travis AFB

Capital Cost	
Extraction Well Installation (1 at depth of 30 ft)	$4,250
Groundwater/Vapor Piezometers (6 CPT)	$2,500
Conveyance Piping and Manifold (TPE placed at well)	$500
TPE Unit (25 scfm at 25 in. Hg)	$18,000
Site Preparation/Equip Pad	$6,400
Electrical/Controls	$2,000
Utility Hookup (electrical & gas existing at site)	$0
Thermal Oxidation Unit (up to 25 scfm)	$33,000
Groundwater Treatment (existing treatment at facility)	$0
Subcontracts and Mobilization	$5,600
Engineering/Design	$20,000
Permitting and Legal	$1,700
Services during Construction	$4,500
Total Capital Costs	$98,450
Estimated Operation & Maintenance (10 months)	
Labor	$8,400
Electricity (17 hp at $.75/kwh)	$7,500
Gas (5,000 therms at $0.6/therm)	$3,000
Materials	$1,200
Analytical	$6,000
Reporting	$1,400
Total Estimated O&M Costs for 10 Months	$27,500

7.11 Annotated References

CPC Press, 1986. "Handbook of Chemistry and Physics, 66th Edition." *Provides discussion and listing of physical and chemical parameters for various chemicals.*

Freeman, Harry, 1989. "Standard Handbook of Hazardous Waste Treatment and Disposal." Copyright 1989. *This book provides descriptions of standard groundwater treatment technologies.*

U.S. EPA, 1986. "Superfund Public Health Evaluation Manual." EPA 540/1-86/060. *Provides vapor pressure and Henry's Law Constants for a variety of chemicals.*

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U.S, EPA and U.S. Air Force, 1993. U.S. Environmental Protection Agency and the U.S. Air Force, Solid Waste and Emergency Response (OS-110W). "Remediation Technologies Screening Matrix and Reference Guide." EPA/542-B-93-005. July. *This document provides a description of some groundwater treatment technologies and provides a relative ranking of the technologies according to cost, effectiveness, implementability, and acceptability.*

U.S. EPA, 1993. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. "Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soil." September. *Provides background and justification for selection of SVE as a presumptive remedy. Also provides comparison of SVE with various evaluation criteria including cost information.*

U.S. EPA, 1996. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. "Final Guidance: Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites." Directive No. 9283.1-12, EPA 540/R-96/023, PB96-963508. October. *Provides the suggested response strategy for all groundwater contamination sites. This document also describes the ex-situ presumptive remedy technologies that are to be used to treat extracted groundwater.*

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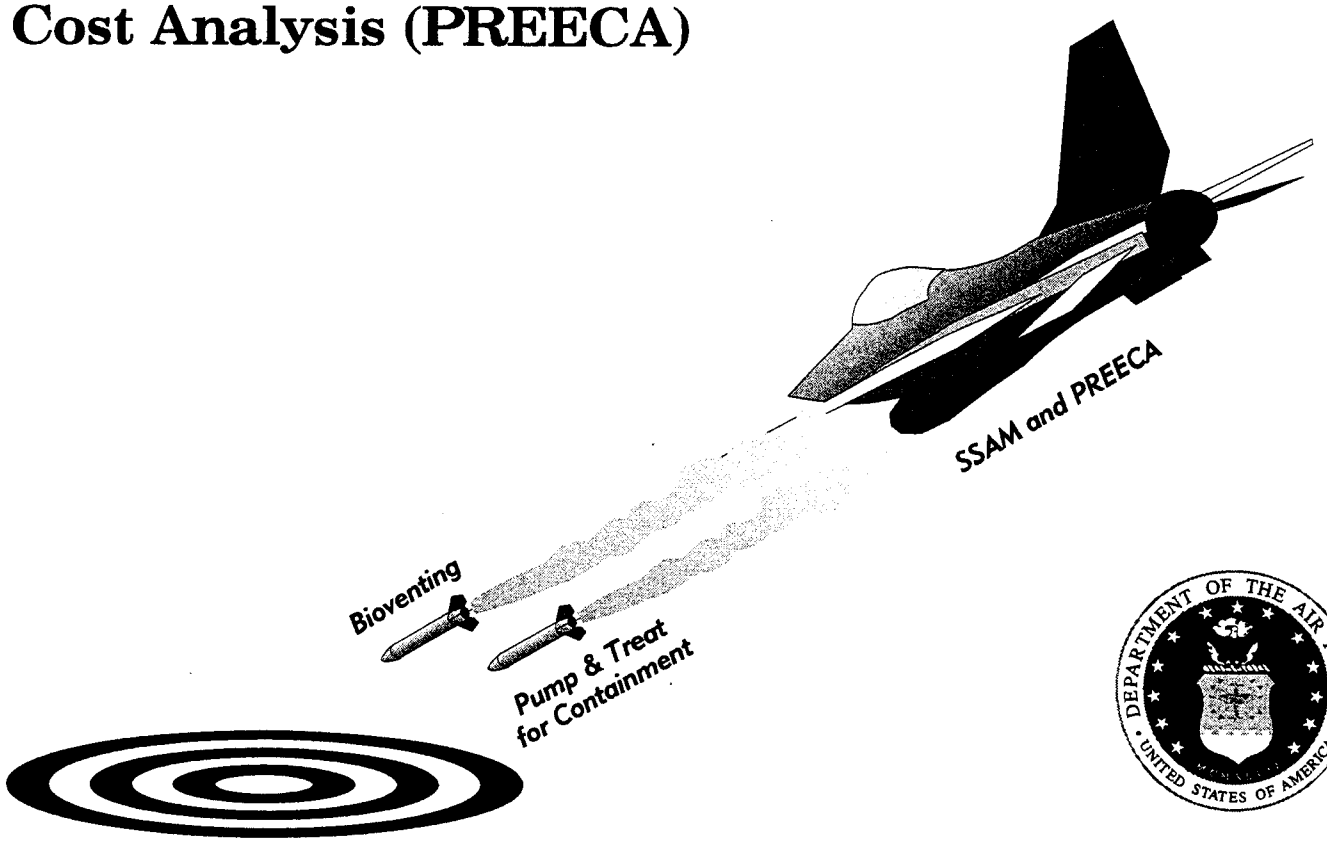
U.S. Air Force. "Remedial Action Cost Engineering And Requirements System." Software Version 2.0, User Manual, and Model Report. ENVEST Environmental Cost Engineering. *This software and associated manuals provide basis of cost estimates for 35 remedial technologies and can be used to estimate costs of a Remedial Design, Remedial Action, and Operation and Maintenance, given site parameters.*

U.S. Air Force, 1994. Air Force Center for Environmental Excellence. "Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Ground Water." Draft 31 July. *This document provides guidance for implementing intrinsic remediation as an alternative to MPE.*

Seymour Johnson AFB, Goldsboro, North Carolina

Site-Specific Action Memorandum (SSAM) for The Tower Road Site (OT-29)

To Accompany the United States Air Force Presumptive Remedy Engineering Evaluation/ Cost Analysis (PREECA)



Final

March 1996

SITE-SPECIFIC ACTION MEMORANDUM FOR THE TOWER ROAD SITE (OT-29)

at

SEYMOUR JOHNSON AIR FORCE BASE
GOLDSBORO, NORTH CAROLINA

FINAL

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ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
ARARs	Applicable and Relevant or Appropriate Requirements
BGS	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DEHNR	North Carolina Department of Environment, Health, and Natural Resources
DoD	Department of Defense
EPA	U.S. Environmental Protection Agency
IRP	Installation Restoration Program
MAP	Management Action Plan
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NCAC	North Carolina Administrative Code
NCP	National Contingency Plan
P&T	Pump and treat
POTW	Publicly-owned treatment works
PREECA	Presumptive Remedy Engineering Evaluation Costs Analysis
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RI/FS	Remedial Investigation/Feasibility Study
RNSI	Rational National Standards Initiative
SACM	Superfund Accelerated Cleanup Model
SSAM	Site-Specific Action Memorandum
TPH	Total Petroleum Hydrocarbons
TPH-Diesel	Diesel Fraction of Total Petroleum Hydrocarbons
TPHV	Volatile Fraction of Total Petroleum Hydrocarbons
USAF	United States Air Force
VOCs	Volatile Organic Compounds

1.0 PURPOSE

This document provides support and justification for the use of bioventing and groundwater pump and treat (P&T) for containment as a "presumptive remedy" interim removal action at the Tower Road Site (site OT-29) at Seymour Johnson Air Force Base (AFB), North Carolina. This action is being conducted to initiate reduction of significant risk to human health, welfare, and the environment posed by contaminants at the site while a final remedial action is being determined for the site. The bioventing portion of this non-time critical interim removal action will promote the removal of petroleum-based contaminants in the vadose zone at the site by enhancing natural in-situ biodegradation of the contaminants; the groundwater P&T for containment portion will prevent groundwater contaminants from further migration into nearby surface water and onto a downstream drinking water source and will limit further degradation of groundwater. This interim action is being conducted for the purpose of aiding in the implementation of a final remedial action plan under the Department of Defense (DoD) United States Air Force (USAF) Installation Restoration Program (IRP). A primary goal of the DoD IRP is to achieve early and substantial risk reduction at sites posing significant risk to human health, welfare, and the environment.

This site-specific action memorandum (SSAM) for site OT-29 accompanies the United States Air Force Presumptive Remedy Engineering Evaluation Costs Analysis (PREECA, Radian Corporation, 1995) to fulfill the requirements of the non-time critical interim removal action process. The PREECA process is designed to streamline the normal Comprehensive Environmental Response and Liability Act (CERCLA) remedial investigation/feasibility study (RI/FS) or corrective measures study process. The PREECA provides a standardized "decision framework" for the remedy selection process, allowing streamlined implementation of cleanup actions at high risk Air Force sites (Radian, May 1995). Other benefits of the PREECA approach are:

- Facilitates early and substantial risk reduction at high risk sites;
- Improves the consistency and predictability of the remedy selection process for DoD, regulatory agencies, and the public;
- Minimizes regional regulatory agency discrepancies in remedy selection; and
- Maintains consistency with Superfund Accelerated Cleanup Model (SACM) and presumptive remedy guidance.

The SSAM for site OT-29 provides additional removal action justification and rationale and demonstrates that the OT-29 site profile fits within the remedy profiles established in the PREECA for use of bioventing and P&T for containment as a presumptive remedy.

The document is organized as follows:

- **Section 2.0** provides background information on site OT-29 conditions including previous remedial investigations and site characterization data;
- **Section 3.0** discusses the potential threats to public health, welfare, and the environment posed by contamination at the site;
- **Section 4.0** presents the justification for conducting an interim removal action at the site (including ARARs, which are discussed in Appendix A);
- **Section 5.0** identifies the objectives for the interim removal action;
- **Section 6.0** presents justification for the use of bioventing and P&T for containment as the presumptive remedy, a conceptual system design, the removal action schedule, and the estimated cost of the interim removal action;
- **Section 7.0** describes the expected change in the situation should action be delayed or not taken;
- **Section 8.0** summarizes the recommendations; and
- **Section 9.0** presents the references used in the preparation of this document.

2.0 SITE CONDITIONS AND BACKGROUND

Investigations conducted at site OT-29 indicate that the soil and groundwater at the Tower Road radar facility are contaminated with petroleum hydrocarbons (TPH) and both aromatic and halogenated volatile organic compounds (VOCs). There is evidence that dissolved TPH has migrated to a small unnamed creek that forms the southern boundary of site OT-29. The conditions and history of the site, which have resulted in the presence of TPH in water of the creek, are described in the following sections.

2.1 Background

Site OT-29 is located in the south-central portion of Seymour Johnson Air Force Base (the base), which is in central Wayne County, south of Goldsboro, North Carolina (Figure 2-1). The base encompasses 3,216 acres and employs approximately 4,600 military personnel.

Site OT-29 comprises approximately two acres in a wooded area of the base, north of the runway and taxiways. The radar facility, consisting of the radar transmitter/receiver and a small building, was constructed on the site in 1989. Activities associated with operation of the radar facility are unlikely to have caused the release of petroleum hydrocarbons or solvents that would account for the contamination discovered at the site. Information supplied by the U.S. Army Corps of Engineers suggests that a topographically low area on site OT-29 may have been a disposal site for unknown volumes of hydraulic fluid, used oils, and aviation gas in the early 1950's. There is no evidence now of the topographically low area.

Northeast of site OT-29 and across Tower Road is a suspected Former Fire Training Pit (FFTP) site (Figure 2-2). With the exception of a four-foot high bermed area on its west side, the site is a flat area with minor depressions in the surface soil. In the 1950's, training exercises at the suspected FFTP site reportedly consisted of releasing and igniting aviation fuel on the soil and then extinguishing the resulting fire. Results of previous investigations suggest that contaminants from the suspected FFTP site may have migrated to the OT-29 site. However, contaminant concentrations detected in the soil and groundwater at the suspected FFTP site are much lower and less frequently detected than those detected at site OT-29 (Rust, 1995). Also, there is no clear evidence that the contaminants from the suspected FFTP site are contributing to contamination beneath the OT-29 site. Therefore, the suspected FFTP site is not discussed in the remainder of this memorandum.

Site OT-29 is flat and unwooded from Tower Road to the treeline that is 25 to 50 feet south of the fence around the radar tower and the edge of the asphalt driveway (Figure 2-2). There is a slope averaging 10 degrees to the southwest from the treeline approximately 120 feet to a break in slope. The slope becomes steeper for a distance of approximately 15 feet extending to the bed of the unnamed creek that forms the southern boundary of site OT-29. Surface runoff from the site drains to the west and south into the creek. The creek contains water throughout the year.

The climate in the Goldsboro area is temperate with hot summers and mild winters. The annual average temperature is 62 degrees F. The area receives 48 inches of precipitation per year mostly as rain. Rainfall is greatest in July and lowest in December and January. The prevailing wind direction is southwest.

Groundwater occurs at 6 to 15 feet below ground surface (BGS) beneath the radar facility and the gently sloping wooded area at site OT-29. Groundwater is in a shallow unconfined aquifer consisting of sand layers of the Black Creek Formation, which underlies most of the base. Evidence of seepage along the banks of the creek on the site indicates that a portion of the groundwater flowing beneath site OT-29 discharges to the creek. Groundwater in the surficial aquifer is classified as GA or GSA, which are existing or potential sources of drinking water (*Classification and Water Quality Standards Applicable to the Groundwaters of North Carolina,* 15A North Carolina Administrative Code [NCAC] 2L). In the Goldsboro area the shallow aquifer is not generally used as a source of drinking water because it is corrosive to metals and contains

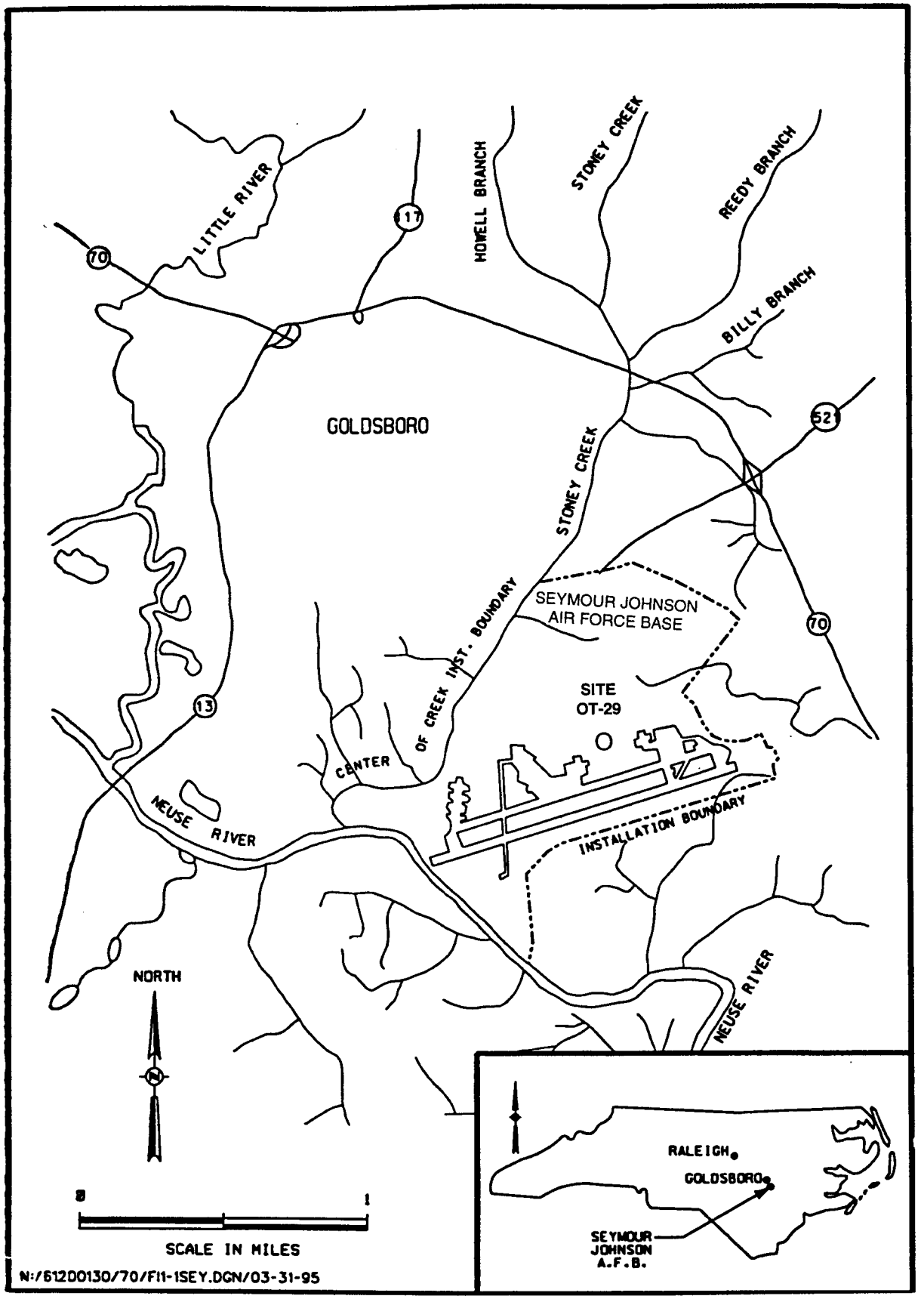

Figure 2-1. Location of Seymour Johnson Air Force Base, North Carolina

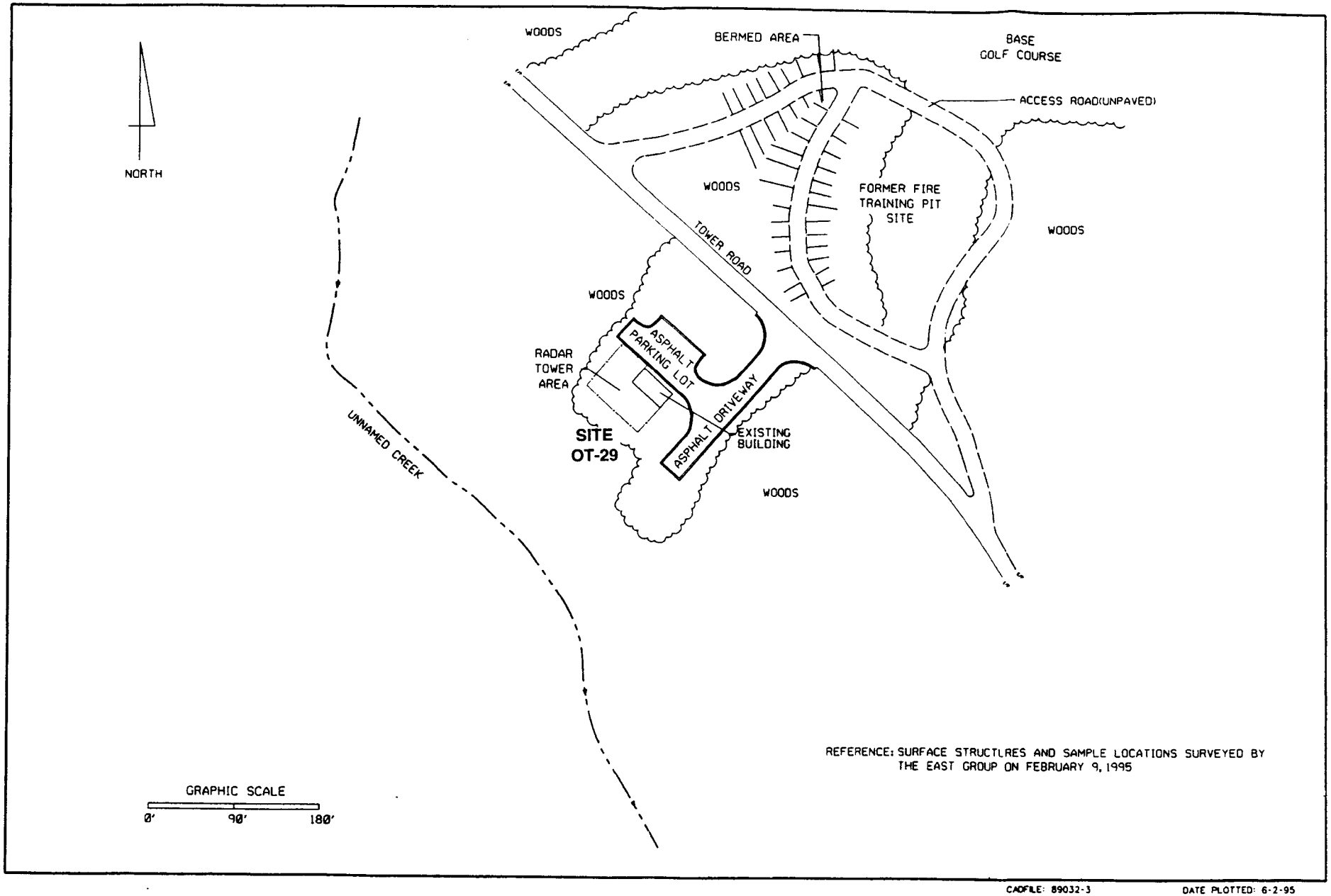

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Figure 2-2. Site OT-29 and FFTP Site Map

elevated concentrations of iron (Rust, 1995). The most important source of groundwater in the Goldsboro area is the Middendorf Formation, which supplies wells screened between 125 and 250 feet BGS.

2.2 Site Characterization

Three remedial investigations have been conducted at Site OT-29. Investigations by Geophex, Ltd. (1989), Precision Environmental Management, Inc. (1990), and Rust Environment and Infrastructure (1995) are summarized in Table 2-1.

A summary of investigations and interpretation of results at Site OT-29 was presented in the draft final *Expanded Site Investigation/RCRA Facilities Investigation, Tower Road Radar Site (OT-29), Former Fire Training Pit Site, and Refueling Maintenance Shop Site* (Rust, 1995). The report indicates that surface and subsurface soil, groundwater, surface water, and sediments in the unnamed creek are contaminated with fuel related hydrocarbons, which include TPH-diesel, volatile TPH compounds, and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds. In addition, halogenated VOCs, beryllium, lead, manganese, and chromium concentrations were detected in shallow monitoring well samples and exceed North Carolina groundwater quality standards. Table 2-2 presents a summary of contaminant concentrations detected in samples collected at site OT-29. As indicated in Table 2-2, 18 contaminants found at the OT-29 site exceed regulatory standards established by the state of North Carolina to protect public health, welfare, and the environment. TPH-concentrations at the site exceed regulatory limits in all media considered (surface soil, subsurface soil, surface water, and groundwater).

The results of the investigations suggest that site OT-29 was a source area for contaminants detected in soil, groundwater, and surface water. Contaminant concentrations in soil indicate that discharges of TPH occurred at or near the surface in the area of MW-TOW-4D, SB-TOW-03, and SB-TOW-08 (Figure 2-3).

Table 2-1. Summary of Remedial Investigations Performed at Site OT-29, Seymour Johnson Air Force Base, North Carolina

Investigation Performed by	Date of Investigation	Work Performed	Investigation Results
Geophex, Ltd.	1989	• Geophysical survey • 35 soil borings • Soil, soil vapor, and stream water analyses	• TPH was detected in soil vapor and soil. • Soil sample from creek bank contained aromatic VOCs and TPH. • 0.5 mg/L toluene was detected in surface water.
Precision Environmental Management	1990	• Constructed 4 monitoring wells • Groundwater sampling/analyses	• Benzene, toluene, ethylbenzene, xylenes (BTEX), trichloroethene, 1,2-dichloroethene, 1,2-dichloroethane and vinyl chloride concentrations exceeded groundwater quality standards. • Chloroform and bromodichloro-methane were also detected.
Rust Environment and Infrastructure	1994	• Direct-push soil vapor and groundwater sampling/analysis • Hand auger soil sampling and analyses • Constructed 4 monitoring wells • Slug testing • Groundwater, surface water, and stream sediment sampling/analyses	• Volatile petroleum hydrocarbons (TPHV), BTEX compounds, halogenated VOCs, and metals occur in a groundwater plume migrating southwest to the creek; BTEX and TPH compounds detected in surface water and sediments; and groundwater flows southwest and a portion of its volume discharges to creek.

Table 2-2. Contaminant Concentrations in Site OT-29 Media that Exceed Regulatory Standards

Medium	Contaminant	Concentration Range Exceeding Standard	Standard Concentration	Origin of Standard
Surface soil	TPH-diesel	81 to 230 mg/kg	40 mg/kg	N.C. DEHNR Action Level
Subsurface soil	TPH-diesel	240 to 5,300 mg/kg	40 mg/kg	N.C. DEHNR Action Level
	Beryllium	2.2 mg/kg	0.15 mg/kg	RBC
	Manganese	745 mg/kg	390 mg/kg	RBC
Surface water	TPH	Sheen on water in creek	Sheen on surface water	15A NCAC 2B
Groundwater	TPH-diesel	130 to 20,000 µg/L	Not detected	15A NCAC 2L
	Benzene	16 to 390 µg/L	1 µg/L	15A NCAC 2L
	Ethylbenzene	33 to 920 µg/L	29 µg/L	15A NCAC 2L
	Toluene	1,800 to 2,100 µg/L	1,000 µg/L	15A NCAC 2L
	Xylenes (total)	770 to 4,800 µg/L	530 µg/L	15A NCAC 2L
	Chloroform	0.86 to 1.4 µg/L	0.19 µg/L	15A NCAC 2L
	1,1-Dichloroethene	12 µg/L	7 µg/L	15A NCAC 2L
	1,2-Dichloroethene	50 to 2,300 µg/L	Not detected	15A NCAC 2L
	1,2-Dichloroethane	0.99 to 520 µg/L	0.38 µg/L	15A NCAC 2L
	Trichloroethene	110 to 140 µg/L	2.8 µg/L	15A NCAC 2L
	Vinyl Chloride	60 µg/L	0.015 µg/L	15A NCAC 2L
	Naphthalene	36 to 180 µg/L	21 µg/L	15A NCAC 2L
	2-Methylnapthalene	5.6 to 26 µg/L	Not detected	15A NCAC 2L
	2,4-Dimethylphenol	450 to 470 µg/L	Not detected	15A NCAC 2L
	4-Methylphenol	140 µg/L	Not detected	15A NCAC 2L
	Beryllium	1.3 µg/L	0.016 µg/L	RBC
	Lead	19.8 to 20.1 µg/L	15 µg/L	15A NCAC 2L
	Manganese	70.7 to 430 µg/L	50 µg/L	15A NCAC 2L
	Chromium	51.1 µg/L	50 µg/L	15A NCAC 2L

Notes:
TPH-diesel = total petroleum hydrocarbons in the diesel range
mg/kg = milligrams per kilogram
µg/L = micrograms per liter
RBC = U.S. EPA Region III Risk-Based Concentration Table, March 7, 1995, residential concentration.
N.C. DEHNR is North Carolina Department of Environmental Health, and Natural Resources, Division of Environmental Management Guidelines established in 1993.

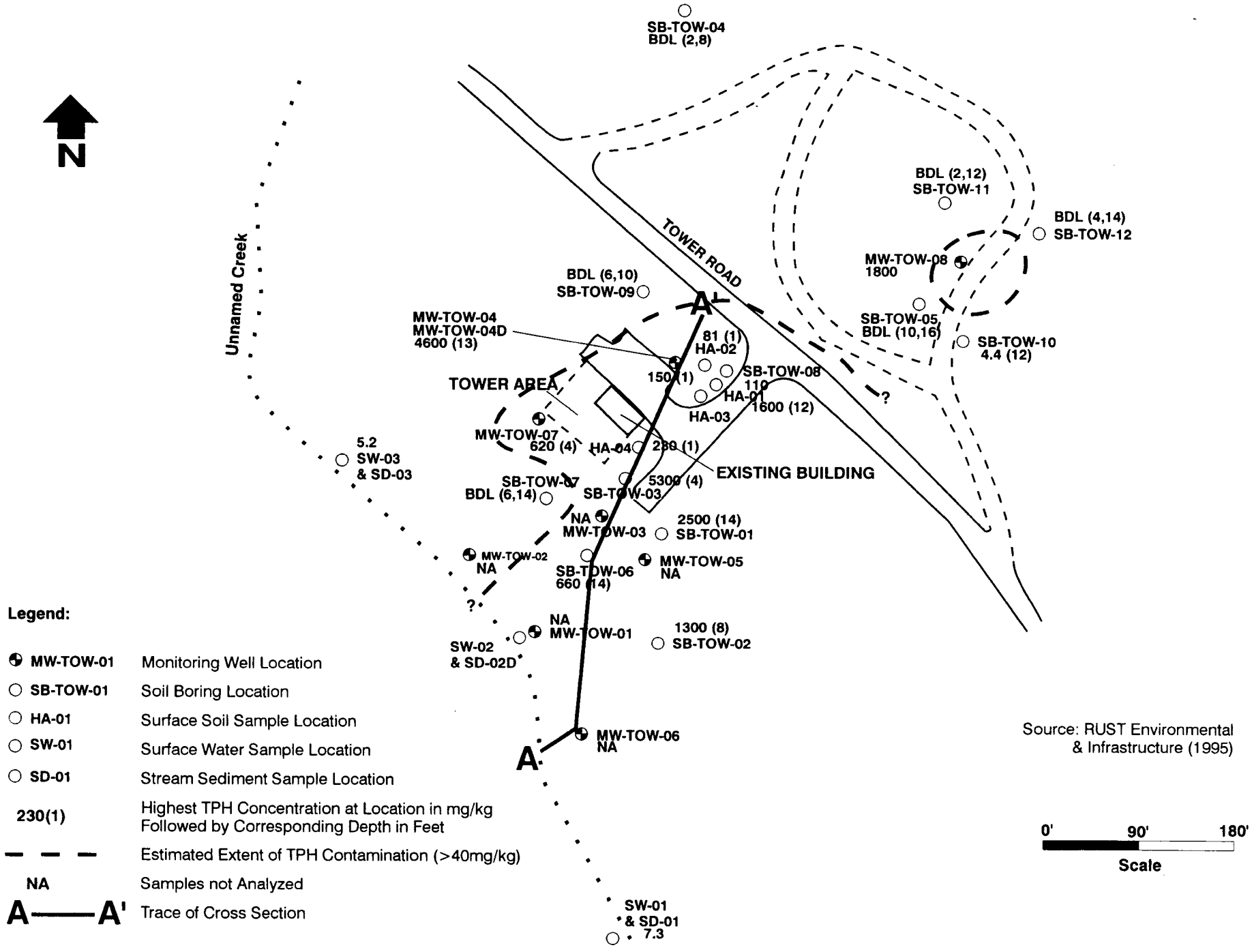

Figure 2-3. Site OT-29 and FFTP Site Soil TPH Concentration Map

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The discharge of petroleum hydrocarbons and solvents occurred before the radar facility was constructed on the Tower Road Site. Site investigations at site OT-29 were initiated after strong petroleum odors were reported by construction workers during installation of the radar tower and associated structures.

Total petroleum hydrocarbons in the diesel range (TPH-diesel) and the benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds were the most frequently detected contaminants in surface and subsurface soil samples at the OT-29 site. Naphthalene was the most frequently detected semivolatile organic compound in soils. The common occurrence of TPH, BTEX, and naphthalene in the soils suggest that petroleum-based fuels were released before the radar station was constructed. The halogenated VOCs detected in soil samples are the solvent compounds acetone, methylene chloride. 1,2-dichloroethene, and 2-butanone that are not related to fuel hydrocarbons. The other organic compounds detected in only one or two samples are: dieldrin (2 samples), bis(2 methylhexyl) phthalate (2 samples), di-N-butyl phthalate (1 sample), and 2,4-dimethylphenol (1 sample). Nine to fifteen inorganic constituents were detected in soil samples. All of the inorganic analytes detected, with the exception of cyanide compounds (two samples, each from a different boring) may be present because they occur naturally in soil grains. Concentrations of inorganic constituents in soil samples do not correlate with concentrations of fuel hydrocarbons or VOCs in soil. Only two inorganic constituent concentrations, beryllium and manganese in SB-TOW-12, exceed an established guidance level or risk-based concentration (RBC); however, no TPH or VOC contaminants that would indicate a relationship to contaminant releases were detected in the sample.

The organic compounds most frequently detected in groundwater samples are: TPH-diesel, BTEX compounds, naphthalene, 1,2-dichloroethene, and 1,2-dichloroethane. The presence of this group of compounds in subsurface soil samples and groundwater beneath OT-29 indicate that the site was the source area for the groundwater contaminants. Additional organic compounds detected in groundwater samples are: chloroform (2 samples), trichloroethene (3 samples), acetone (1 sample), 2-methylnaphthalene (2 samples), 2,4-methylphenol (4 samples), bis(2 methylhexyl) phthalate (1 sample), di-N-butyl phthalate (3 samples), phenol (2 samples), and beta-BHC, a pesticide (1 sample). Ten to fifteen inorganic constituents are consistently detected in groundwater samples. All concentrations of inorganic constituents detected may occur because of dissolution of natural constituents in soil particles by moving groundwater. With the exception of iron and manganese, concentrations of inorganic constituents in groundwater do not correlate with concentrations of organic compounds in groundwater or inorganic constituents in soils above the groundwater surface. Therefore, the concentrations of inorganic constituents in groundwater may represent natural concentrations that are not attributable to contaminant releases at OT-29.

The results of soil, groundwater, and surface water analyses were compared to standards and guidelines in the 1995 Rust report. Groundwater quality is regulated by 15A NCAC 2L; groundwater quality standards are listed with detected contaminant concentrations in Table 2-2. Stream water quality is regulated by 15 NCAC 2B and Federal Water Quality Criteria; the standards applicable to surface water results at site OT-29 are listed in Table 2-2. There are no regulations identifying contaminant concentration limits in soil; however, the North Carolina Department of Environment, Health, and Natural Resources, Division of Environmental Management (DEHNR) has established an action level of 40 milligrams per kilogram (mg/kg) for diesel range TPH concentrations (DEHNR, 1993). TPH concentrations in soil at the site exceed this action level.

Silty to clayey, medium grained sand is the dominant lithology encountered in the subsurface to a depth of approximately 40 feet BGS (See Cross Section A-A', Figure 2-4). Discontinuous lenses of silt and clay occur from surface to approximately 12 feet BGS beneath

the radar facility. During the investigation, slug tests were conducted in four monitoring wells (MW-TOW-04 through MW-TOW-07) at site OT-29 to estimate hydraulic conductivities in the saturated zone. Hydraulic conductivities calculated from the data ranged from 1.12×10^{-4} to 5.88×10^{-4} centimeters per second (116 to 608 feet/year, [Rust, 1995]). The hydraulic gradient of groundwater is 0.005 to 0.007 feet/foot to the southwest beneath the site (Figure 2-5). Assuming an effective porosity of 0.25 for sands beneath OT-29, an average groundwater velocity of 0.025 feet per day was calculated for the range of hydraulic conductivities.

2.3 Nature and Extent of Contamination

The contaminants in the soil, surface water, and groundwater at site OT-29 that exceed North Carolina soil and water quality standards are diesel range-TPH, BTEX compounds, halogenated VOCs, and metals. The greatest concentrations of contaminants have been found in soil or groundwater beneath the probable source area, a 1950's disposal area now partially covered by the Tower Road Radar facility. However, a portion of the contaminant volume that was discharged to soil has reached groundwater, migrated to the southwest, and entered the surface water of the unnamed creek along the southwestern site boundary.

Petroleum hydrocarbons represent the greatest mass of contaminants released at site OT-29. Concentrations of TPH compounds were detected in 14 of the 30 soil samples collected during site characterization investigations. Concentrations of diesel range-TPH that exceed the North Carolina DEHNR guideline of 40 mg/kg were detected in soil from the surface to the water table in an area approximately 300 feet long (north to south) and at least 200 feet wide (Figure 2-3). The extent of TPH contamination that exceeds the DEHNR guideline in soil has not been defined to the east of the radar facility. Cross section A-A' in Figure 2-6 illustrates the vertical extent of TPH contamination.

Much of the mass of TPH contamination probably has remained in soil because of the adsorptive properties of TPH liquid and the properties of the soil in the vadose zone. Volatile compounds that were contained in the petroleum hydrocarbons when they were discharged have entered the vapor phase or have dissolved in percolating water and migrated in soil gas and groundwater. The loss of volatile compounds from the TPH in soil is evident in the high soil vapor concentrations detected in the Geophex investigation (1989) and the concentrations of BTEX compounds detected in groundwater (Rust, 1995). It is likely that the TPH contamination in the soil is undergoing degradation by aerobic bacteria because the soil above the groundwater surface receives oxygen carried by soil gas from unpaved surface areas.

The more volatile compounds, such as BTEX and halogenated VOCs, also pose a concern at site OT-29. The volatile compounds and diesel range-TPH have migrated to groundwater and are present in concentrations exceeding 15A NCAC 2L standards and/or federal Maximum Contaminant Levels for drinking water. The shallow aquifer in which the water quality standards are exceeded is not used for drinking water on the base or in the surrounding communities because of high iron concentrations and corrosiveness; however, the aquifer water is classified as a potential source of water by the State of North Carolina. The lateral extent of TPH, BTEX, and halogenated VOC contamination is not defined on the east side of site OT-29 (Figure 2-7). However, the contaminants have been transported approximately 350 feet to the south and are apparently entering surface water in groundwater seeps or base flow from the aquifer. The vertical extent appears to be limited to less than 40 feet by the absence of contaminants exceeding standards in samples collected from MW-TOW-04D. However, additional data from deep monitoring wells are needed to confirm the lack or extent of vertical contamination.

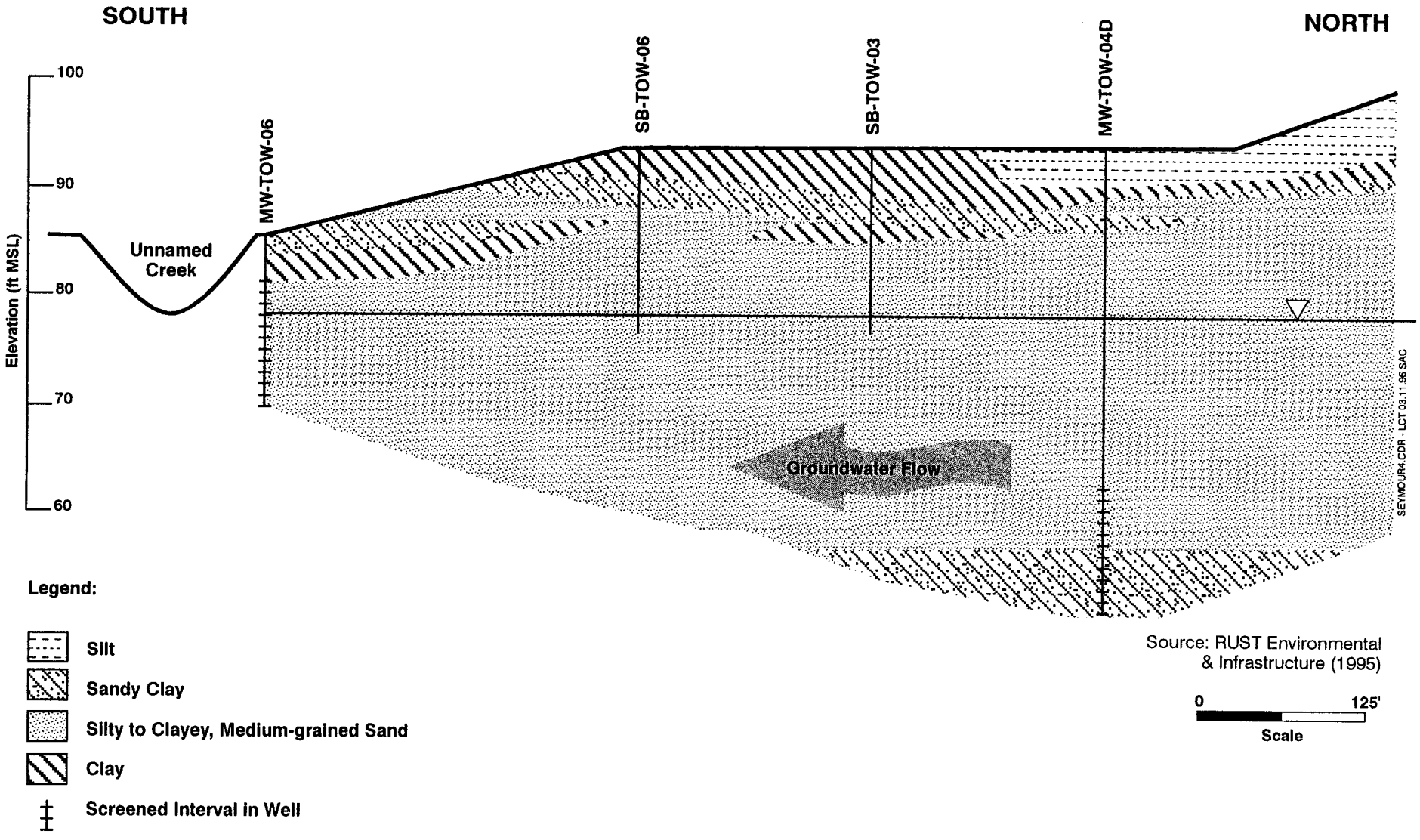


Figure 2-4. Cross-Section A-A' Through Site OT-29

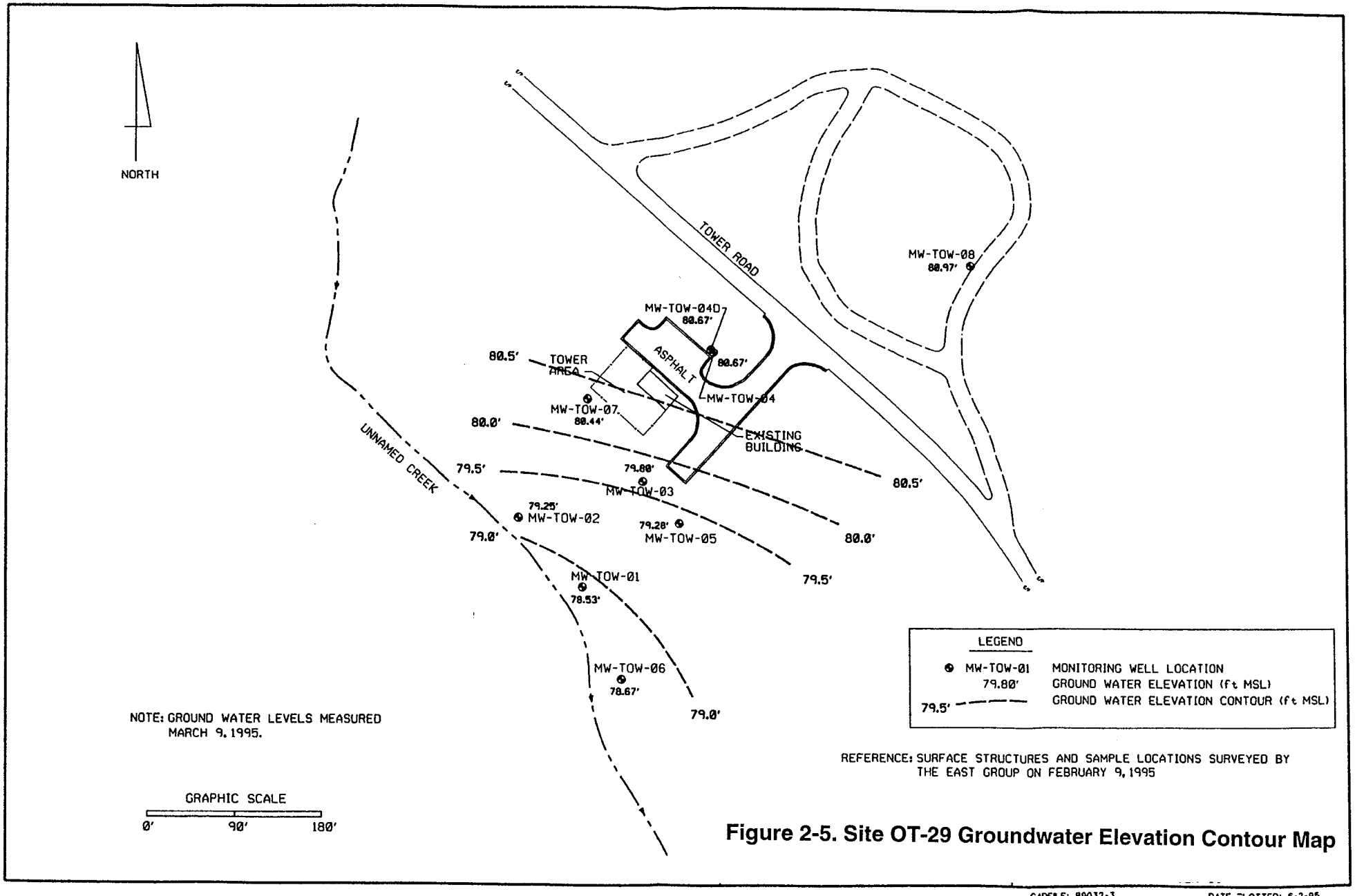
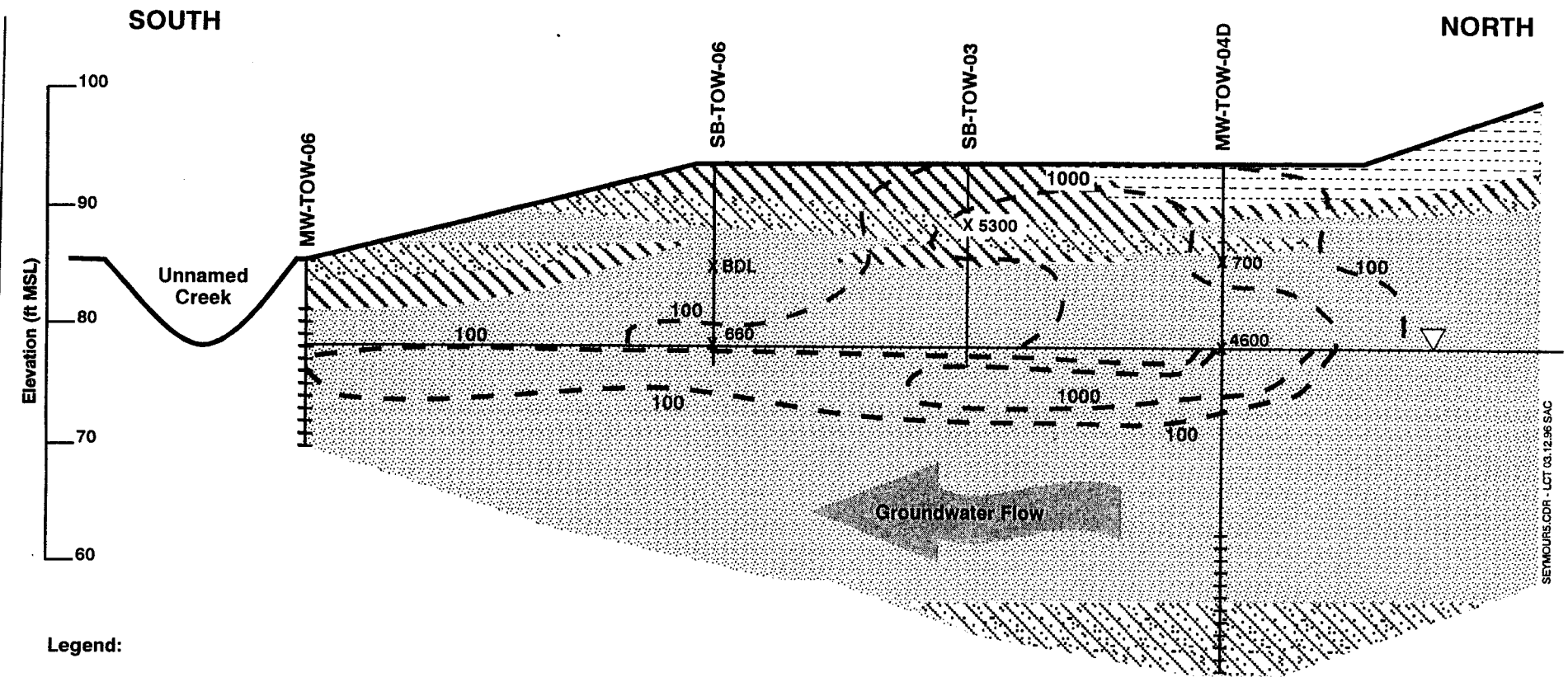


Figure 2-5. Site OT-29 Groundwater Elevation Contour Map



Source: RUST Environmental & Infrastructure (1995)

Analyses performed: January 1995

0 125'
Scale

Legend:

- Silt
- Sandy Clay
- Silty to Clayey, Medium-grained Sand
- Clay
- Screened Interval in Well
- Soil TPH Isoconcentration Contour in mg/kg
- Estimated Groundwater TPH Isoconcentration Contour in $\mu g/L$

Figure 2-6. Subsurface Soil TPH Isoconcentration Map Along Cross-Section A-A'

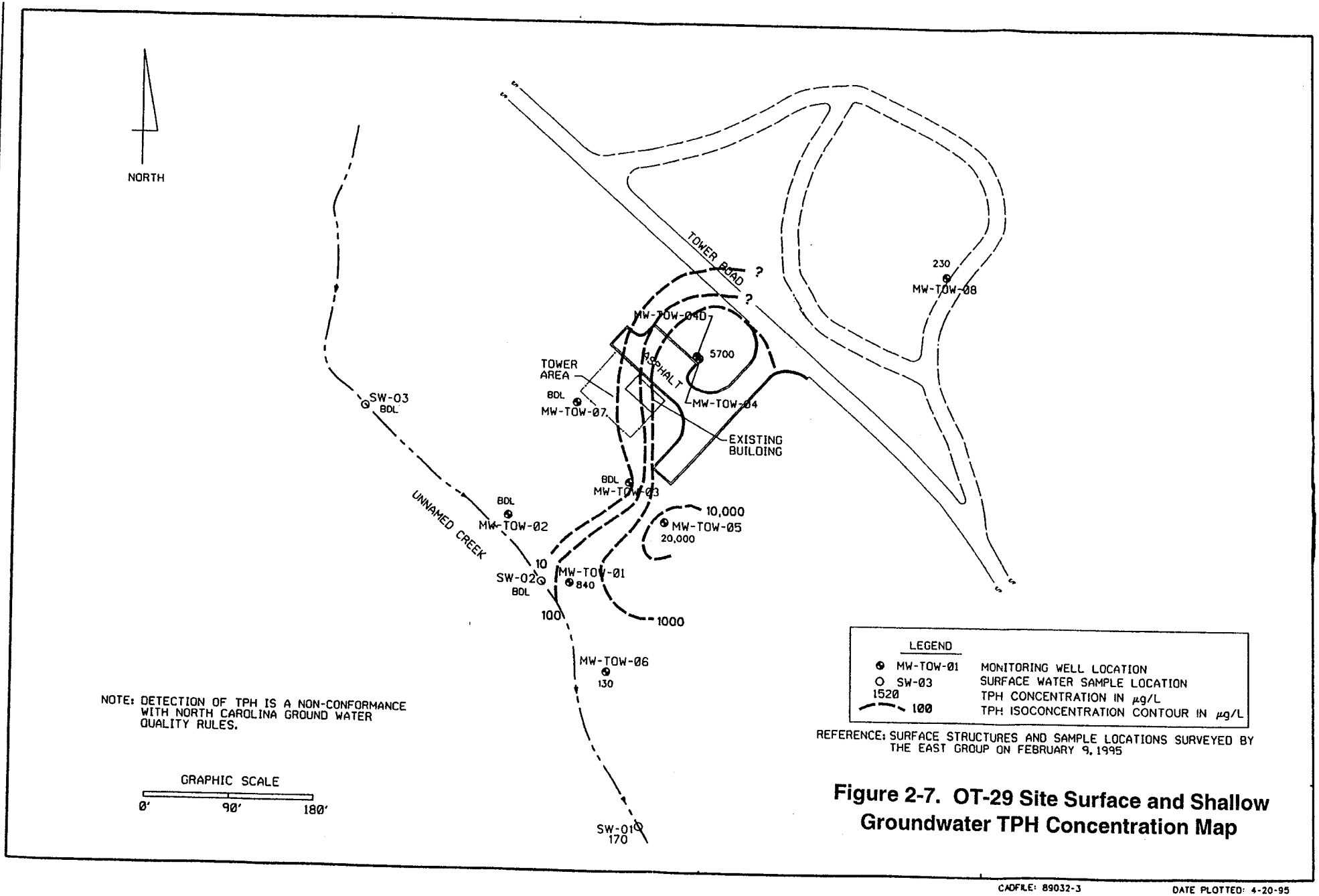


Figure 2-7. OT-29 Site Surface and Shallow Groundwater TPH Concentration Map

Diesel range-TPH and BTEX compounds have been detected in samples of surface water and sediments collected from the unnamed creek downstream from site OT-29. Staining of soil where shallow groundwater seeps into the creek bank and a hydrocarbon sheen on creek water indicate that TPH transported in groundwater from the site is entering the creek. The hydrocarbon sheen exceeds the North Carolina criteria for surface water. Although metals have been detected in groundwater above NC DEHNR standards, no metals concentrations have been detected above standards in surface water from the unnamed creek. The unnamed creek flows into the Neuse River 1.5 miles south of the site OT-29. The Neuse River is a source of drinking water downstream from the base.

3.0 THREATS TO PUBLIC HEALTH, WELFARE, OR THE ENVIRONMENT, AND STATUTORY AND REGULATORY AUTHORITY

Potential threats to public health, welfare, and the environment exist due to contamination of the surface and subsurface soils, surface water and groundwater at the site. Contaminants at the site include TPH, BTEX, VOCs, semi-VOCs, and metals. TPH and BTEX are the main contaminants of concern because of the concentrations and frequency at which these contaminants were detected during previous investigations. The threats to public health, welfare and the environment are discussed below.

3.1 Potential Migration and Exposure Pathways

Potential contaminant exposure and migration pathways that may be present at site OT-29 are shown on Figure 3-1. The fate and transport conceptual model for the site is provided in Figure 3-2.

Potential migration pathways for contaminants present at the site include the following:

- **Percolation/infiltration into and through the soil and into groundwater.** Concentrations of TPH-diesel exist in surface soil at concentrations as high as 230 mg/kg and in subsurface soil at concentrations as high as 5,300 mg/kg. Site characterization data indicate that this contaminant has percolated to the groundwater were TPH-diesel concentrations as high as 20,000 µg/L have been detected. Much of the mass of TPH contamination still remains in the soil and continues to be a source of groundwater contamination.

- **Migration of contaminants from the unnamed creek flowing southwest of site OT-29 to other surface waters and potential drinking water sources downstream.** Diesel range-TPH and BTEX compounds have been detected in samples of surface water and sediments collected from the unnamed creek downstream from site OT-29. Contamination is believed to be coming from shallow groundwater seeps into the creek. The unnamed creek flows into the Neuse River 1.5 miles south of the site. The Neuse River is a source of drinking water downstream from the Base.

- **Volatilization of contaminants into the air caused by the disturbance of soil (i.e. during construction activities or burrowing animals).** Expansion of the radar facility is planned at the site. The construction activities performed in support of the expansion enhance the likelihood of contaminant release and treat to public health, welfare, and the environment.

Potential exposure routes include:

- Ingestion of surface water or groundwater.

- Dermal contact with contaminated surface water or soil. Terrestrial species may contact surface water or soil because of their habitat. Humans may come into contact with surface debris, soil, or surface water during visits to the site or downstream.

- Inhalation may occur when excavation of contaminated areas creates fugitive dusts or VOCs volatilizing into the air.

- The food chain. Ingestion of fruits, vegetables, other plants, or animals (predator/prey) that may bioaccumulate contaminants of concern.

Potential receptors include both human and ecological receptors. Under current land use scenarios, possible on-site receptors include, workers, terrestrial species (including vegetation), and aquatic species. Potential off-site receptors may include off-site residents and ecological receptors. Although there is a potential threat posed by contaminants in all media (i.e. soil, soil gas, and groundwater) it is

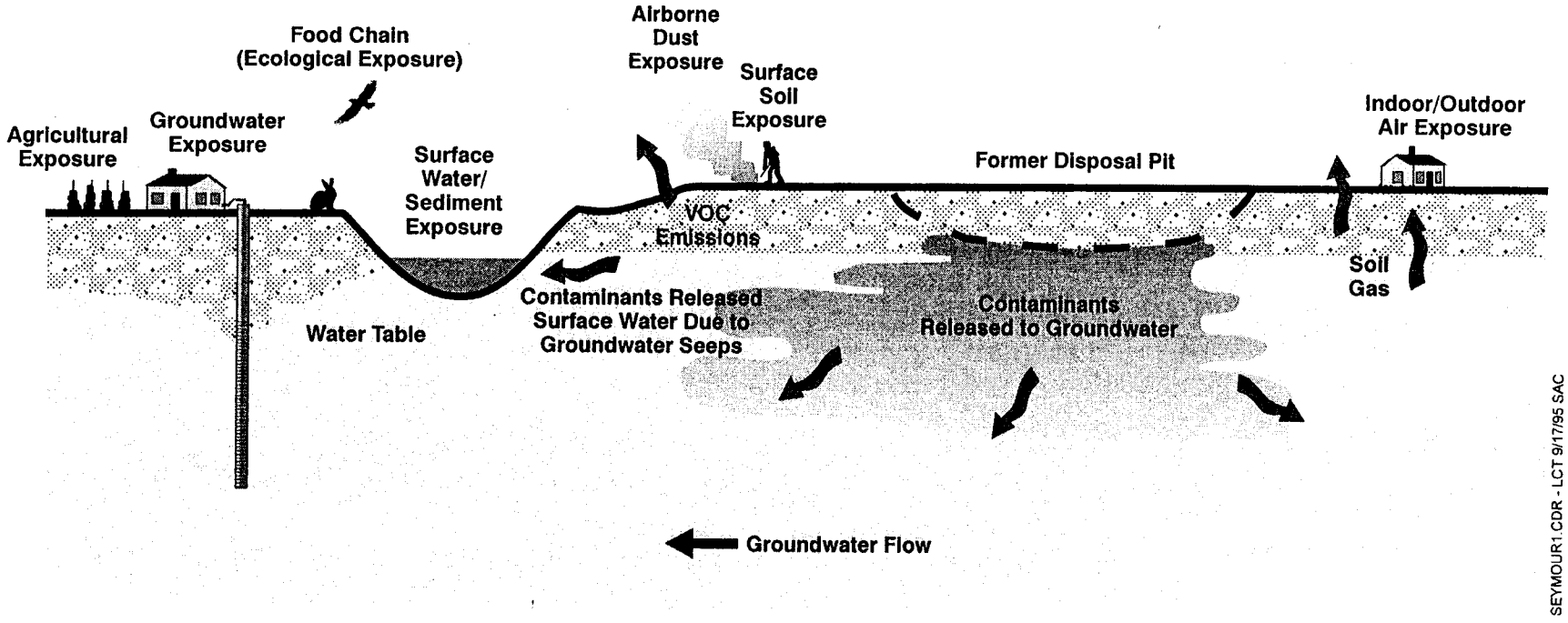


Figure 3-1. Potential Contaminant Exposure and Migration Pathways at Site OT-29

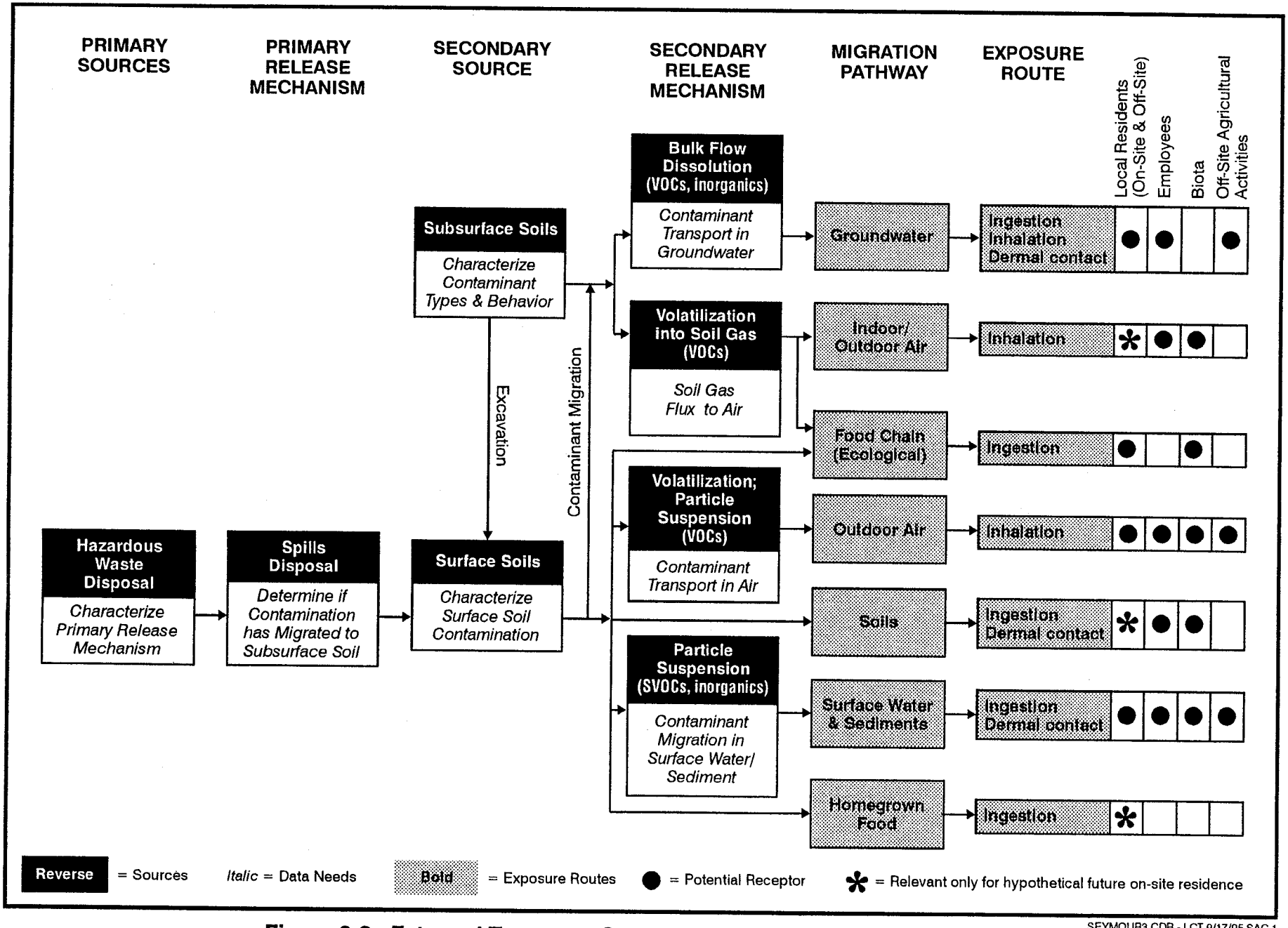


Figure 3-2. Fate and Transport Conceptual Framework for Site OT-29

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3.2 Statutory and Regulatory Authority

As shown in Table 2-2, TPH concentrations exceed the North Carolina DEHNR maximum allowable levels in surface and subsurface soil. Subsurface soil also contains concentrations of beryllium and manganese that exceed U.S. EPA Region III Risk-Based Concentrations (RBCs). For sites such as OT-29, where the contamination is within 5 feet of groundwater, DEHNR has determined that all contaminated soils above the minimum allowable levels require treatment.

Data in Table 2-2 also indicate that TPH concentrations in surface water and groundwater exceed North Carolina DEHNR standards. Groundwater also contained concentrations of BTEX, VOCs, SVOCs, and metals that exceed North Carolina DEHNR standards and RBCs. Based on these exceedences, contamination in surface water and groundwater need to be addressed.

The State of North Carolina is in the process of developing cleanup standards for up to 100 other common contaminants in soil and groundwater. In addition to these standards, health-based cleanup standards for many hazardous waste or constituents in soils and groundwater are also provided in the Management Action Plan (MAP) for Seymour Johnson Air Force Base (Radian, April 1995) and the Rational National Standards Initiative (RNSI) document (Radian, March 1995). The MAP summarizes health-based guidance criteria concentrations provided in the *Interim Final RCRA Facility Investigation (RFI) Guidance, Volume 1 of IV, Development of an RFI Work Plan and General Consideration for RCRA Facility Investigations* (EPA 30/SW-89-031, Waste Management Division, Office of Solid Waste, May 1989). The RNSI document provides site specific cleanup criteria. Benzene detected in groundwater at site OT-29 exceeds the standard of 1 microgram per liter established both in the MAP and RNSI documents. This exceedance indicates that an action is necessary to reduce and abate the risk to public health, welfare, and the environment caused by potential exposure to benzene, a known carcinogen.

4.0 JUSTIFICATION OF REMOVAL ACTION

A removal action is warranted when it is necessary to prevent, minimize, or mitigate damage to the public health or the environment. The National Contingency Plan (Section 300.415) (NCP, 1990) identifies eight general types of removal actions. Of these eight, the following four are applicable to site OT-29.

- **Prevention or abatement of actual or potential exposure of nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants.** Contamination present in surface and subsurface soil, groundwater, and surface water at site OT-29 represent potential exposure risks to nearby human and animal populations.

- **Prevention or abatement of actual or potential contamination of drinking water supplies or sensitive ecosystems.** The Neuse River, a current drinking water supply, is threatened by contaminants transferred from groundwater at site OT-29 to the river via the unnamed creek. Sensitive ecosystems dependent on these sources of water are also being threatened. In addition, groundwater at the site is listed as a potential drinking water source, although it is not used as such.

- **Treatment of high levels of hazardous substances, pollutants or contaminants in soils largely at or near the surface that may migrate.** Contaminants in the soil at OT-29 have migrated to groundwater and surface water.

- **Mitigation or abatement of other situations or factors that may pose threats to public health, welfare, or the environment.** Contamination present in soil, groundwater, and surface water represent a threat to human receptors through exposure during site visits and construction activities, and to ecological receptors through the nature of their habitat. Exposure to off-site receptors may potentially occur due to transport in the stream water to sediment.

In order to abate and minimize the exposure to public health, welfare, and the environment, a removal action is warranted.

4.1 Applicable or Relevant and Appropriate Requirements.

A removal action is also warranted when evidence of a federal, state, or local Applicable or Relevant and Appropriate Requirement (ARAR) has been or will be exceeded. Results from OT-29 site investigations indicate that chemical-specific ARARs have been exceeded, as discussed in Section 2.0.

Section 300.415(I) of the National Contingency Plan (NCP) requires that response actions conducted under CERCLA attain a level or standard of control of hazardous substances that complies with ARARs of the federal environmental laws and more stringent state environmental and facility-siting laws. The removal action discussed in this SSAM will be able to meet, to a practicable extent, the federal, state, and local requirements that govern the design, installation, and operation standards.

A detailed discussion of the potential ARARs identified for this removal action is provided in Appendix A.

5.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

The removal action objectives must be protective of public health, welfare, and the environment and, to a practicable extent, meet ARARs. Potential health hazards exist at OT-29 because:

- Contaminants in the vadose zone are currently migrating to groundwater, surface water, and to a drinking water source downstream of the base; and

- Contaminants in the soil, groundwater, and surface water represent potential exposure pathways to human and ecological receptors.

The following removal action objectives are therefore recommended:

- Maximize contaminant removal from areas of the vadose zone with the highest concentrations in a cost-effective manner.

- Facilitate the reduction of contaminant migration to groundwater and surface water by enhancing removal of contaminants from the vadose zone.

- Intercept and abate the exposure pathways presented by contaminants migrating from the groundwater to the unnamed creek and on to the Neuse River, a source of drinking water.

- Perform removal action in a manner consistent with the land-use objectives for site OT-29, which includes the expansion and continued use of the radar facility.

- Implement a removal action that is consistent with the Management Action Plan for Seymour Johnson Air Force Base (Radian, April 1995).

6.0 SELECTED ACTIONS

A combined system of bioventing and groundwater P&T for containment has been selected as the presumptive remedy for the proposed interim removal action at site OT-29. This interim action focuses on the removal of contaminants from the vadose zone and containment of contaminated groundwater seeps into the unnamed creek which runs south of the site. The justification for selection of bioventing and groundwater P&T for the site is presented below.

This is an interim removal action, which is intended to quickly abate and minimize immediate threats and reduce risks to public health, welfare, and the environment caused by contaminants at the site. While the action will be consistent with the final remedial action for the base, it may not be the final remedial action at the site.

6.1 Selection of the Presumptive Remedy

The bioventing and groundwater P&T for containment remedy profiles are presented in the PREECA, which contains technology based application criteria. The technology based application criteria for bioventing are based on information gathered by the Air Force Center for Environmental Excellence (AFCEE) while performing bioventing studies throughout the country. Part II, Section 4 of the PREECA, presents the a description of the bioventing process and its associated application criteria. These criteria represent conditions at sites where bioventing has been proven to be effective at removing BTEX, TPH, and non-halogenated hydrocarbon contaminants from the subsurface.

By comparing the candidate site profile to the bioventing remedy profile, it is shown whether or not bioventing is an appropriate technology for that site. A comparison of the site-specific information for site OT-29 to the bioventing remedy profile in the PREECA document (see Table 6-1) indicates that bioventing is the most suitable removal action alternative for the BTEX and TPH contaminants in the vadose zone. Although the initial soil moisture, pH, nitrogen content, and phosphorus content are not known for site OT-29, AFCEE's nationwide data show that more than 95% of the sites visited in the Eastern United States have soil conditions (moisture, pH, nitrogen content, and phosphorus content) amenable to bioventing.

Table 6-1. Site Profile and Bioventing Remedy Profile Comparison

Condition or Parameter	Remedy Profile Value	OT-29/FFTP Site Profile
Contaminants	BTEX, TPH, non-halogenated hydrocarbons	TPH-diesel present at 81 to 5,300 mg/kg in vadose zone
Contaminant location	vadose zone	vadose and saturated zones
Soil gas permeability (k)	> 0.1 darcy	assume 0.1 - 1.0 darcies for fine sand[a]
Initial soil moisture	5 to 25%	unknown
Initial soil pH	5 to 9	unknown
Initial soil total Kjedahl nitrogen	≥ 20 mg/kg soil	unknown
Initial soil total phosphorus	≥ 3 mg/kg soil	unknown
Geology and soils	Unsaturated gravels and sands with minor clays and silts, thoroughly fractured bedrock	Unsaturated silty to clayey sands with isolated clay lenses
Soil temperature	> 0 degrees Celsius	> 0 degrees Celsius

[a] Based on Soil Gas Permeability values for soil types presented in Test Plan and Technical Protocol for a Field Treatability Test for Bioventing. (Hinchee, et. al., 1992).

Application criteria for groundwater P&T for containment is presented in Part II, Section 6 of the PREECA and covers a broad range of site conditions (because of the wide range of applicability of groundwater P&T). By comparing the candidate site profile to the groundwater remedy profile contained in the PREECA, it can be shown whether groundwater P&T for containment is an appropriate removal action technology for the site. A comparison of site specific information for site OT-29 to the groundwater P&T for containment remedy profile (see Table 6-2) indicates that groundwater P&T for containment is a suitable removal action alternative to contain groundwater seeps into the unnamed creek.

It is important that the selected remedy satisfy the removal action objectives. Bioventing technology and groundwater P&T for containment can be implemented to satisfy those objectives. By stimulating the natural biodegradation of contaminants within the vadose zone, bioventing will enhance removal of contaminants from the vadose zone. This will facilitate the reduction of contaminant concentration and therefore the migration to groundwater and surface water. It has been demonstrated that bioventing has been successful at removing contaminants down to less than 5 ppm of TPH and to non-detected concentrations for BTEX (AFCEE, July 1994).

Implementation of P&T for containment will control the contaminated groundwater seeps into the unnamed creek thereby reducing further migration of contaminants through surface water to the Neuse River, a drinking water source. Contaminants in the groundwater include TPH-diesel, BTEX, and chlorinated hydrocarbons.

Both technologies can be implemented in a manor consistent with land use objectives for site OT-29. Implementation of the bioventing and groundwater P&T for containment will also act toward meeting federal and state ARARs.

6.2 Conceptual Design

The conceptual design for this interim removal action includes:

- A bioventing system focused on removing contaminants from the suspected source area (hot-spot) in vadose zone.
- A groundwater extraction/drainage trench to limit the migration of contaminants to the unnamed creek via groundwater seeps. A groundwater extraction trench was chosen over conventional extraction well and pump methods because natural groundwater velocity in the area is relatively slow and groundwater would most likely be more effectively collected using a trench.

6.2.1 Bioventing System

The bioventing system will consist of two injection wells, an explosion-proof blower, and seven monitoring wells to monitor the effectiveness of the bioventing system. Six monitoring wells will be placed in the contaminated area and one background monitoring point placed outside the area of contamination. The proposed location for the bioventing wells and monitoring wells is shown on Figures 6-1 and 6-2. This is the area with the highest concentrations of TPH and BTEX in the vadose zone.

This conceptual design/system configuration was based on lithologic and contaminant distribution data, and should be sufficient to enhance contaminant degradation in the suspected source area and areas surrounding the source area. System effectiveness will be monitored continuously throughout the first year of operation. Monitoring reports will be generated (monthly or quarterly) and submitted to the appropriate regulatory agencies for review. Following one year of operation, the overall system effectiveness (contaminant degradation progress and radii of influence) will be evaluated to determine if the bioventing system should be expanded.

All bioventing activities should be performed in accordance with the *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, Revision 2* (Hinchee, 1992). This includes performing a in-situ respiration/air

Table 6-2. Site Profile and Groundwater P&T for Containment Remedy Profile Comparison

Condition or Parameter	Characteristics	Optimum Range - Remedy Profile	OT-29/FFTP Site Profile
Contaminants in Target Plume	Source or discharge point	Not active or remediated	Not active
	Halogenated VOCs	> MCL or acceptable risk concentration, < 1% of maximum solubility	>MCLs and 15A NCAC 2L standards
	Inorganic constituents (metals, cyanide, nitrate)	>MCL or acceptable risk concentration	>MCLs and 15A NCAC 2L standards
	Solubility	> 10 mg/L	All > 10 mg/L
	Adsorption coefficient	< 10,000 L/kg	All < 10,000 L/kg
Target Plume	Depth below ground surface (BGS)	>3 feet, <400 feet	14 to 17 feet BGS
	Total volume	>1,000 gallons, < 5 billion gallons	5.4 to 6.5 million gallons[a]
Hydrogeology	Porous deposits containing target plume	Sands, gravels with minimum interlayered silts and clays except as bounding aquitards and/or saturated zone with average hydraulic conductivity > $1x10^{-4}$ centimeters/second	Silty to clayey sands with clay and silty lenses
	Bedrock containing target plume	Highly weathered or fractured	Not applicable
	Natural organic carbon fraction	0.01 or less	Unknown
Hydraulics	Natural groundwater velocity	10^{-7} to 10^{-4} meters/sec (0.01 to 10 feet/day)	0.025 feet/day[b]
	Water level fluctuation	<10 feet/year and < 3 feet/day	<3 feet/day
	Surface water	Upgradient recharge, minimal flood potential	Upgradient recharge, minimal flood potential
	Unconfined	Target plume in water table zone, underlain by aquitard	Plume in water table zone
	Confined	Target plume confined between two aquitards	Not applicable

[a] The volume of contaminated groundwater in place is 5.4 to 6.5 million gallons. However removal of contaminants in the saturated zone may require the removal of 4 volumes of groundwater to flush contaminants that adsorb on soil grains.

[b] Calculated with the equation $V=K\Delta h/p_e$ where K ranges between 0.49 and 1.6 feet/day, $\Delta h = 0.005$ ft/ft, and p_e is assumed equal to 0.25 for silty and clayey sands.

The calculation sheets for the estimated groundwater extraction rate are included as Appendix B.

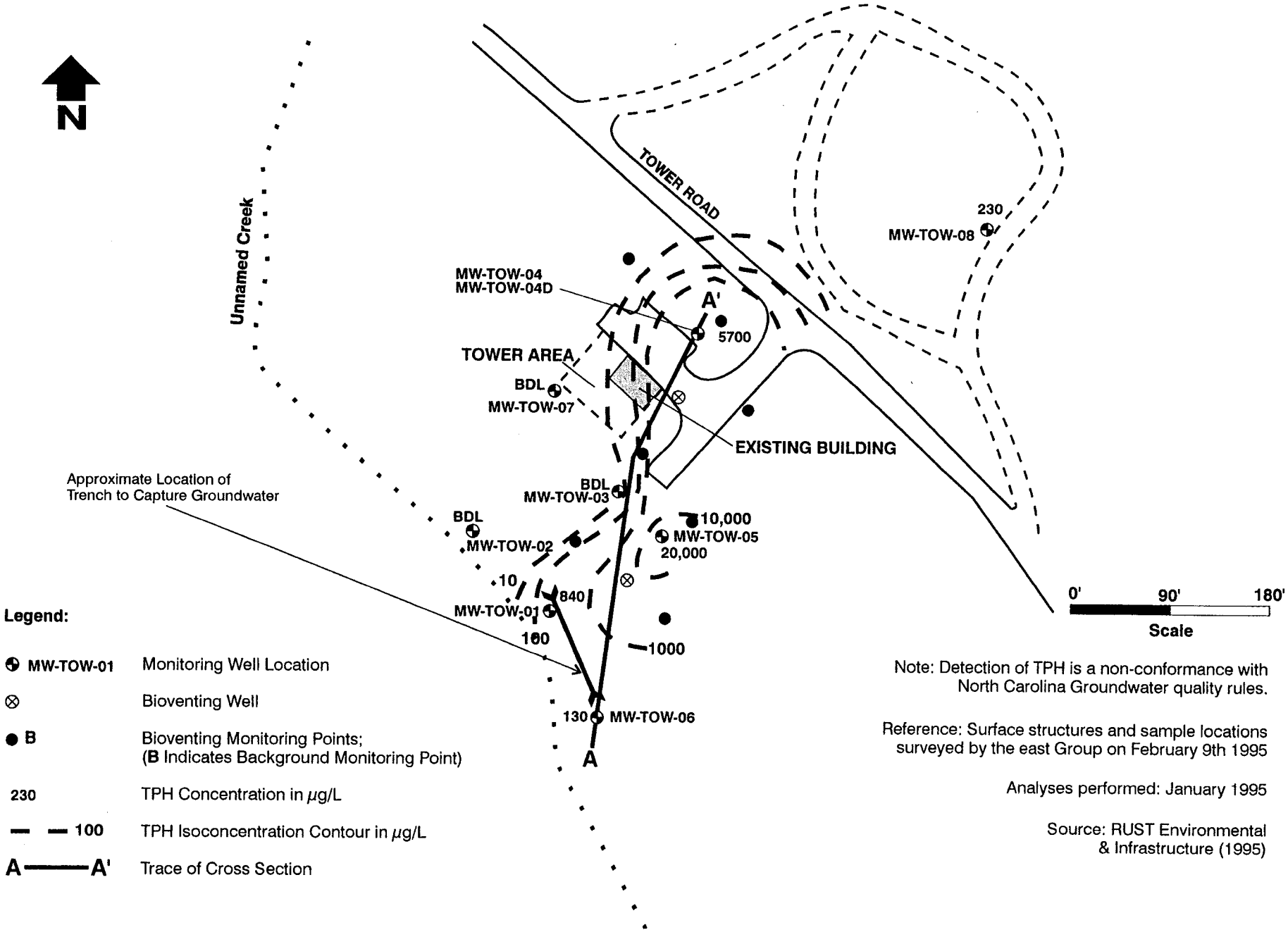

Figure 6-1. Removal Action Conceptual Design

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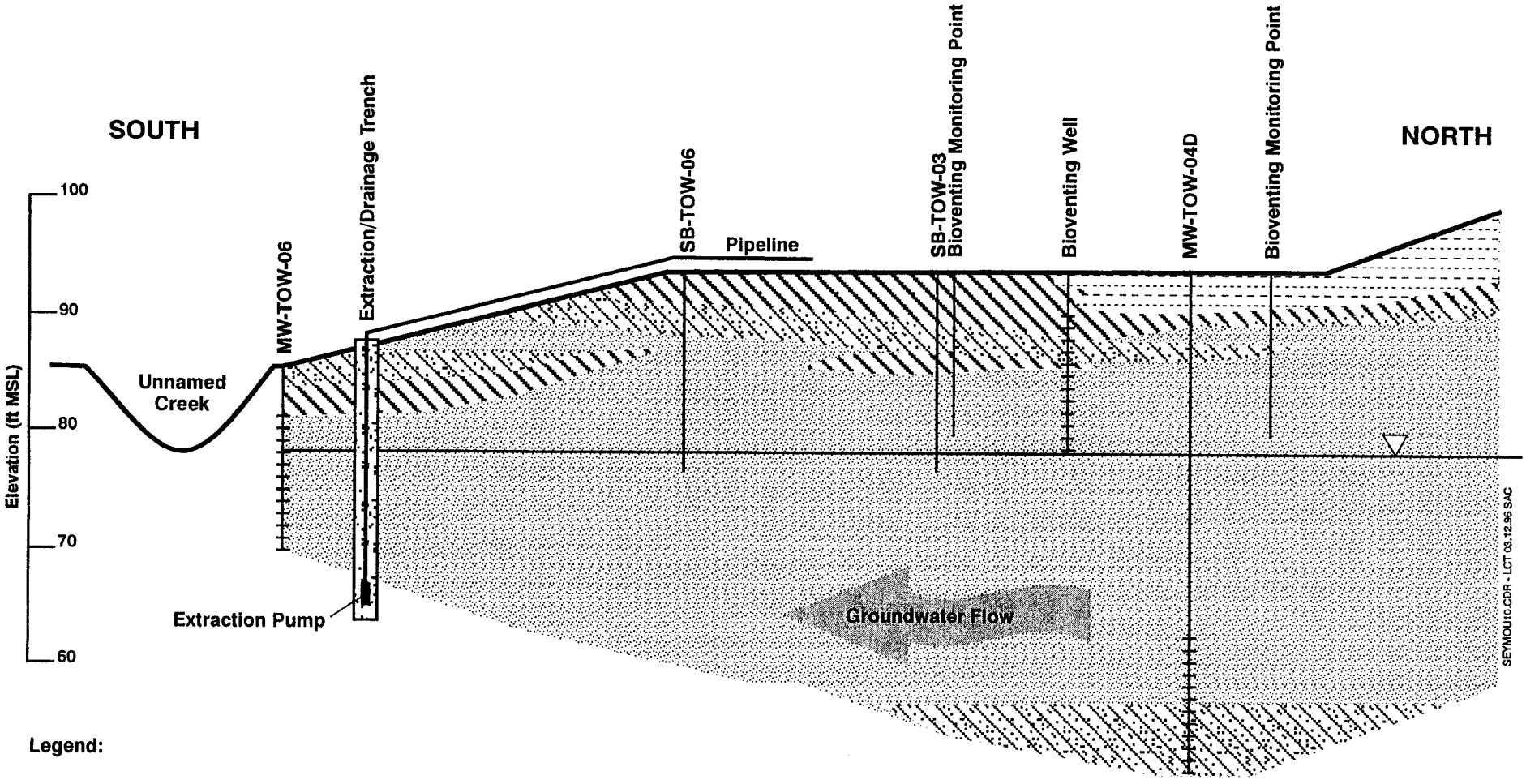

Legend:

- Silt
- Sandy Clay
- Silty to Clayey, Medium-grained Sand
- Clay
- Filter Sand in Trench
- Screened Interval in Well

Source: RUST Environmental & Infrastructure (1995)

Note: Bioventing well and extraction trench locations are approximate

0 125'
Scale

Figure 6-2. Components of Removal Action System on Cross-Section A-A'

permeability test prior to installation of the entire bioventing system to confirm that aerobic biodegradation can be stimulated by bioventing.

6.2.2 Groundwater System

Prior to installation and design of the groundwater extraction trench, additional hydrogeological information (water level fluctuations, total organic carbon, and hydraulic conductivity) should be collected from the site to aid in the design of an effective trench. The proposed location for the groundwater extraction/drainage trench is shown on Figures 6-1 and 6-2. The proposed trench is approximately 60 feet long and encompasses the leading edge of the groundwater plume which seeps into the unnamed creek. In order to contain the seepage, the trench should be approximately 20 feet deep; trench width will vary with trench design and construction materials. The estimated groundwater extraction rate from the trench will be less than one gallon per minute or 1,500 gallons per day. Extracted groundwater will be treated using either air stripping and/or carbon (to remove VOCs) and if necessary, ion exchange resins (to remove metals). The treatment option chosen will be determined by the water discharge option chosen. Currently, several water discharge options are being evaluated including: discharge to the local City of Goldsboro publicly-owned treatment works (POTW); discharge to the creek; on-base irrigation (possibly for the nearby golf-course); on-base industrial reuse (at the nearby Industrial Aircraft Washrack); and reinjection. Although all options are possible, all are not easily implemented. Discharge to the creek and reinjection will require permits that may involve extensive time and labor to obtain and make these options cost prohibitive. Additional details on the final treatment and discharge alternatives chosen for this interim removal action will be discussed in a future work plan.

Base personnel have indicated that additional construction in this area is planned to expand the radar facility. Prior to installation of the bioventing system or groundwater extraction trench the final locations wells must be pre-approved by the Base. In general, however, installation of a bioventing system and extraction trench at site OT-29 area would not be in conflict with Seymour Johnson AFB land use objectives.

6.3 Estimated Costs

The estimated costs for the installation, maintenance, and operation of the bioventing system and the P&T for containment system are included in Tables 6-3 and 6-4. The estimates are based on existing site data, unit costs, and ratio estimates from similar facilities. They are made without detailed engineering data and should be considered order of magnitude estimates only. Estimates of this type would normally be expected to be accurate within plus 50 to minus 30 percent.

The actual design and costs of the bioventing and groundwater P&T for containment system will be dependent on the results of preliminary tests to be performed prior to complete installation of the removal action systems. These tests will provide data on system size and estimated time of operation and maintenance.

The cost estimate for the implementation of the bioventing removal action includes operation and maintenance of the initial bioventing system for one year, after which an evaluation of system performance will be conducted. Because available data suggest that this initial system will be sufficient to remove contaminants in the suspected source area and may also have the ability to affect the less contaminated areas surrounding the source area, costs for the design and expansion of this initial system are not included.

The cost estimate for the implementation of the P&T for containment system includes operation and maintenance of the system for two years. The volume of in place contaminated groundwater is estimated to be 5.4 to 6.5 million gallons. The objective of this interim removal action is to quickly implement a system to limit further migration of contaminants into the unnamed creek and on to the drinking water source until a final removal action is

Table 6-3. Site OT-29 Bioventing System Cost Estimate	
Item	**Estimated cost ($)**
Subcontractor Solicitation and Selection	30,000
Site Visit/Planning	5,000
Work Plan Preparation	10,000
Installation of Bioventing System	80,000
- Two bioventing wells (about 10-15 feet deep)	
- Seven monitoring points (about 10-15 feet deep)	
- Sampling and analyses	
- In situ respiration test	
- Air permeability test	
- Installation and construction oversight	
- Blower, piping, and instrumentation	
- Site preparation	
Operation and Maintenance for One Year	10,000
One Year Evaluation	10,000
- Confirmatory sampling and analyses	
- Evaluation and interpretation of data	
Regulatory Approval	5,000
Documentation of Site Cleanup Progress	10,000
Total	**160,000**

Table 6-4. Site OT-29 P&T for Containment System Cost Estimate	
Item	**Estimated cost ($)**
Subcontractor Solicitation and Selection	30,000
Remedial Design	50,000
- Includes collection of additional hydrogeologic and chemical data	
Removal Action Construction and Operation	300,000
- Site preparation	
- Groundwater extraction trench	
- Discharge to storm sewer/POTW	
- Liquid-phase carbon adsorption and ion-exchange treatment for extracted water	
- Monitoring and sampling and analyses	
Contingency (10% of construction and operation and maintenance costs)	30,000
Project Management (10% of construction and operation and maintenance)	30,000
Total	**440,000**
Costs assume four weeks for construction and 2 years of operation and maintenance.	

implemented at the site. At the estimated extraction rate of 1,500 gallons per day, it would take over 11 years to extract this initial volume, and over 44 years to extract the 4 volumes estimated to be required to flush all contaminants from the saturated zone and remediate groundwater contamination at the site. Four volumes are estimated to be required to flush contaminants because adsorption on soil grains will retard the movement of contaminants by factors of 1.5 to 4.

While this interim removal action is consistent with the overall plan to remediate contaminated areas on the base, it is not necessarily intended to be the final removal action. Therefore, the costs reflect the estimated operation time prior to implementation of a final removal action. If this system is incorporated into a final removal action for the site, additional costs will be incurred to maintain and operate the system for the duration of time necessary to remediate the saturated zone.

6.4 Project Schedule

The schedule presented in Figure 6-3 presents a generic sequence of events necessary to complete the SSAM and implement the interim removal action at site OT-29. Actual dates and durations may vary depending on other activities planned at the site (e.g. construction of an expanded radar facility).

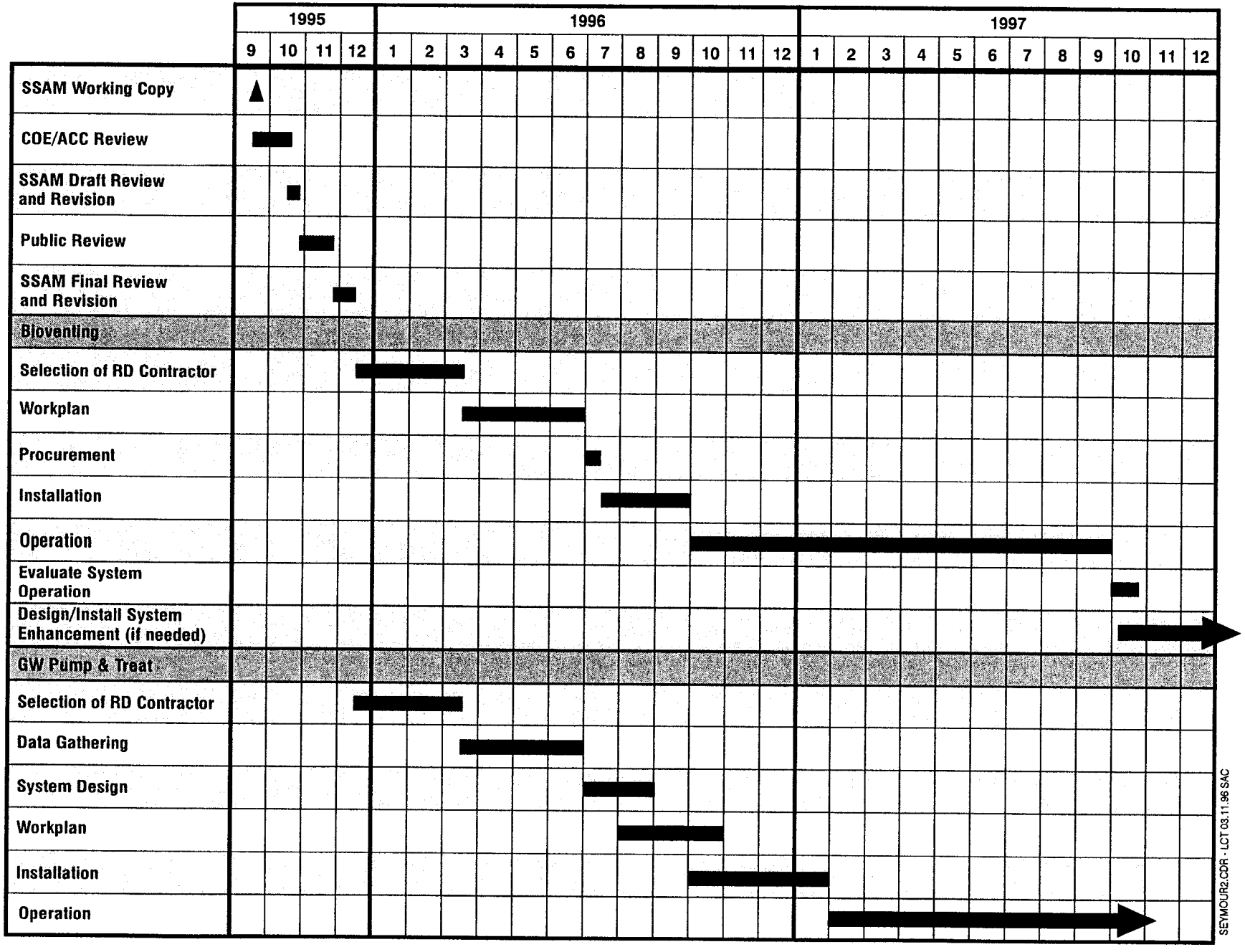

Figure 6-3. Project Schedule

7.0 EXPECTED CHANGE IN THE SITUATION SHOULD ACTION BE DELAYED OR NOT TAKEN

A delay in implementing the proposed removal action or taking no action whatsoever could potentially increase contaminant removal cost and the threat to public health and welfare through the prolonged exposure to contaminants. Contaminants present in the vadose zone will continue to migrate to the groundwater and surface water, where they will be more difficult and costly to remediate.

The area in the vadose zone where TPH-diesel concentrations exceed the North Carolina DEHNR guideline and action level of 40 mg/kg is approximately 300 feet long (north to south) at least 200 feet wide. Concentrations are as high as 5,300 mg/kg in subsurface soils. Observed staining of the soil along the banks of the unnamed creek and a visible sheen on the surface water indicates continued seepage of contaminants from the soil, to the groundwater, and to surface water. A delay in an action or taking no action would result in contaminants continuing to seep from the vadose zone to the groundwater and surface water and onto the Neuse River, which is a source of drinking water, thus, prolonging the exposure to human and ecological receptors and increasing health risks. In addition, the natural interaction of contaminants with soil, percolating rainwater, and surface water will cause contaminants to spread, migrate and increase the volume of contaminated area to be remediated, which will result in higher contaminant removal costs.

8.0 RECOMMENDATION

This SSAM presents the recommended interim removal action to address the vadose zone contamination and groundwater contaminant migration present at the site OT-29. Site characterization studies indicate that the vadose zone and groundwater are contaminated with TPH, BTEX, and trace amounts of chlorinated hydrocarbons. In addition, petroleum hydrocarbons have been discharged to the unnamed creek flowing south of the site.

A comparison of the site characteristics with the technology criteria contained in the bioventing and groundwater P&T for containment remedy profiles in the PREECA shows that these technologies are appropriate presumptive remedy interim removal action alternatives for the site.

The recommended interim removal action includes:

- **Installation and operation of a bioventing system to remove contaminants from the vadose zone.** The bioventing system should be installed in accordance with the *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, Revision 2* (Hinchee, 1992); and

- **Installation and operation of a groundwater extraction trench for the containment of seeps to the unnamed creek.**

- **Collection of additional hydrogeologic data and groundwater treatment data to aid in the design of an effective and efficient extraction system and treatment system.**

Data that should be collected during design are: total organic carbon (TOC) concentrations in vadose zone and saturated zone soils and concentrations of TPH and VOCs in groundwater samples from bioventing well borings. HydroPunch® samples from these borings would assist in delineating the eastern portion of the groundwater contamination. During operation of the extraction trench, water level measurements should be collected in monitoring wells and the trench. Concentrations of TPH and VOCs should be periodically determined in monitoring wells and in hand auger borings west of the creek.

9.0 REFERENCES

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Radian, May 1995. *Presumptive Remedy Engineering Evaluation Cost Analysis (PREECA).* Prepared for U.S. Army Corps of Engineers-Omaha District, Omaha, Nebraska, 68102-4978. May 1995.

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Rust, 1995. Draft Final Expanded Site Investigation/RCRA Facilities Investigation, Tower Road Site (OT-29), Former Fire Training Pit (FFTP), and Refueling Maintenance Shop Site. Prepared for U.S. Army Corps of Engineers, Omaha District, Omaha, Nebraska. June 1995.

A1.0 INTRODUCTION

Federal and state statutes and regulations that have been initially identified as chemical-, location-, and action-specific applicable or relevant and appropriate requirements (ARARs) for the site OT-29 non-time critical interim removal action are presented below.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. If a requirement is not applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not specifically applicable to the site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

CERCLA provides that state requirements may be used as ARARs for Superfund sites. To be considered an ARAR, the state requirement must be promulgated, it must be more stringent than federal requirements, and the state must identify the ARAR in a timely manner.

Section 121(e) of CERCLA states that no federal, state, or local permit is required for remedial actions conducted entirely on-site. Therefore, actions conducted entirely on-site must meet only the substantive and not the administrative requirements of the ARARs. Actions that take place off-site are subject to the full requirements of federal, state, and local regulations.

A2.0 CHEMICAL-SPECIFIC ARARs AND TBCs

Chemical-specific ARARs and TBCs are health-based or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values, in turn, establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment (soil, groundwater, surface water, or air) as a result of the final remedial action selected. Potential chemical-specific ARARs and TBCs are presented in Table A-1.

The ARARs discussed pertain only to the removal action for the attenuation of contaminants and the prevention of containment migration to groundwater and surface water. Because this is an interim action, the ARARs are presented only as a guide to establishing operating parameters. The identification of ARARs is an iterative process; the list of ARARs is expected to change during the various phases of the remedial process and will be updated as appropriate. Final determination of ARARs will be made by Seymour Johnson AFB, in the Record of Decision (ROD), after agency and public review. In addition, if ARARs do not address a particular situation, action, or contaminant, guidance documents may be used as "to be considered" (TBCs) requirements.

A2.1 National Primary Drinking Water Standards

The Safe Drinking Water Act (SDWA), initially enacted in 1974 and most recently amended in 1986, mandates EPA to establish regulations to protect human health from contaminants in drinking water. The legislation authorizes national drinking water standards and a joint federal-state system for assuring compliance with those standards. Maximum contaminant levels and treatment techniques ensure the quality of public drinking water supplies.

The establishment of national drinking water standards is authorized under Title XIV, Part B of the SDWA. EPA has developed two sets of

Table A-1. Potential Chemical-Specific ARARs and TBCs

Standards, Requirements, Criteria, or Limitations	Description	Citation	Comments	Applicability
National Primary Drinking Water Standards	Maximum Contaminant Levels (MCLs) and non-zero MCL goals. MCLs are enforceable standard establishing maximum permissible levels of contaminants in drinking water from a public water system. MCLs are based on health considerations, technological feasibility, economic considerations, and the inclusion of a safety factor to protect sensitive populations. Non-zero MCLGs are not enforceable under SDWA; however they are enforceable under the National Contingency Plan (NCP).	40 CFR Part 141	The alluvial aquifer may be hydraulically connected to the local water treatment plant.	Relevant
Clean Water Act	Establishes ambient water quality criteria that apply to surface waters. The main purpose of the act is to restore and maintain the chemical, physical, and biological integrity of the nation's surface water.	33 USC Section 1251-1376	This regulation may be applicable as it relates to the ability of bioventing and groundwater pump and treat for containment to reduce the potential for migration of contaminants to surface water.	Relevant
North Carolina Guidelines for Investigation and Remediation of Soils and Groundwater	Sets soil and groundwater remediation standards for the state of North Carolina.	NCGS 143-215.1 NCGS 143-215.75 15A NCAC 2N	Establishes maximum soil and groundwater concentrations of contaminants	Relevant
Identification and Listing of Hazardous Waste	Specifies Toxicity Characteristic Leaching Procedures (TCLP) and establishes regulatory levels for organic chemicals.	40 CFR 261	Establishes maximum soil concentrations of leachable compounds to meet MCLs.	Relevant and Appropriate

drinking water standards, referred to as primary and secondary standards: to protect human health and ensure the aesthetic quality of drinking water respectively. Primary standards consist of contaminant-specific standards, known as Maximum Contaminant Levels (MCLs). MCLs are set as close as feasible to Maximum Contaminant Level Goals (MCLGs), which are purely health based goals. Secondary drinking water standards consist primarily of limits used by states to regulate the aesthetic quality of water supplies, and are not enforceable at the Federal level. Part C of Title XIV of the SDWA authorizes the establishment of various programs designed to prevent contamination of underground sources of drinking water.

This regulation should be considered for the site OT-29 site because of the possibility of an interconnection of the aquifer beneath the site with the local drinking water sources.

A2.2 Clean Water Act

The objective of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. This objective is achieved through the control of discharges of pollutants to navigable waters. This control is implemented through the application of federal, state and local discharge standards. The CWA prohibits the unpermitted discharge of any pollutant or combination of pollutants to waters of the United States from any point source. Point sources include any remedial action in which site runoff would be channeled directly to a surface water body via a ditch, culvert, storm sewer, or other means.

This regulation should be considered applicable as it relates to the ability of bioventing and groundwater pump and treat for containment to reduce the potential for migration of contaminants to surface waters.

A3.0 POTENTIAL LOCATION-SPECIFIC ARARs

Potential location-specific ARARs criteria for the site OT-29 removal action are listed in Table A-2. Location-specific ARARs differ from chemical-specific or action-specific ARARs in that they are not closely related to the site's waste characteristics or to the specific remedial action under consideration. Location-specific ARARs pertain to the area in which the site is located. Actions may be required to preserve or protect aspects of the area's environment or cultural resources that may be threatened by the site's existence or by the proposed remedial actions.

The major statutes from which the regulations are derived that contribute to the list of potential location-specific ARARs include the following:

- Resource Conservation and Recovery Act;
- National Archaeological and Historic Preservation Act;
- National Historic Preservation Act;
- Endangered Species Act;
- Clean Water Act;
- Wilderness Act;
- Fish and Wildlife Coordination Act;
- Scenic Rivers Act;
- Marine Protection Resources and Sanctuary Act; and
- Migratory Bird Treaty Act.

Two executive orders are also included: the Executive Order on the Protection of Wetlands, and the Executive Order on Protection of Flood Plains. The 40 CFR 264.18(b) applies to the siting of new hazardous waste treatment facilities within the 100-year flood plain.

To the extent that the removal action will affect historical resources, streams, flood plains, or wetlands, U.S. EPA requires that the potential actions comply with the location-specific requirements. The major statutes and regulations

Table A-2. Potential Location-Specific ARARs for Seymour Johnson AFB OT-29/FFTP Site

Standard, Requirements, Criteria, or Limitations	Description	Citation	Comments	Applicability
Within 61 meters (200 feet) of a fault displaced in Holocene time	All treatment, storage, and disposal of hazardous wastes is prohibited within 200 feet of a Holocene fault.	40 CFR 264.18(a)	There is no evidence of an active fault within 61 meters of the proposed removal action.	Not ARAR
Within 100-year flood plain	Treatment, storage, and disposal for hazardous wastes must be constructed to avoid washouts if located in a 100-year flood plain.	40 CFR 264.18(b)	The proposed location of the pilot study is not located within a 100 year flood plain; however, the unnamed stream and surrounding banks a the southwest portion of site OT-29 may lie within the 100 year flood plain.	May Be Applicable
Within flood plain	Relates to actions that will occur in a flood plain, i.e., lowlands and relatively flat areas adjoining inland and coastal waters and other flood-prone areas. Actions must be taken to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Executive Order 11988, Protection of Flood Plains 40 CFR 6, §6.302(b)	Federal agencies are directed to ensure that planning programs and budget requests reflect consideration of flood-plain management, including the restoration and preservation of such land as natural undeveloped flood plains. If newly constructed facilities are to be located in a flood plain, accepted flood-proofing and other flood control measures shall be undertaken to achieve flood protection.	May Be Applicable
Within salt dome formation, underground mine, or cave	Placement of noncontainerized or bulk liquid hazardous waste is prohibited.	40 CFR 264.18(c)	The Seymour Johnson AFB site does not contain any salt dome formation, underground mine, or caves used for waste disposal. No such disposal is planned.	Not ARAR
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data. Construction on previously undisturbed land would require an archaeological survey of the area. Provides for the preservation of historical and archaeological data.	National Archaeological and Historical Preservation Act (16 U.S.C. Section 469); 36 CFR Part 65 40 CFR §6.301(c)	The proposed removal action will not alter or destroy any known prehistoric or historic archaeological features of the Seymour Johnson AFB site. However, there may be undiscovered actifacts at the site.	May Be Applicable

Table A-2. (Continued)

Standard, Requirements, Criteria, or Limitations	Description	Citation	Comments	Applicability
Historic project owned or controlled by federal agency	If property is included in or eligible for the National Register of Historic Places, actions must be taken to preserve historic properties; planning of action to minimize harm to National Historic Landmarks.	National Historic Preservation Act Section 106 (16 USC 470 *et seq.*); 36 CFR Part 800 40 CFR §6.301.(a)	Site OT-29 is not proposed for listing as a National Historic Landmark. The proposed removal action will not have any impacts on the existing buildings.	Not ARAR
Critical habitat upon which endangered species or threatened species depend	Requires action to conserve endangered species or threatened species, including consultation with the Department of the Interior, Fish and Wildlife Service. Same as federal requirement but includes required consultation with California Department of Fish and Game.	Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 CFR Part 200, 50 CFR Part 402 Migratory Bird Treaty Act (16 U.S.C. 703-712) with list of protected birds in 50 CFR 10.13	There are no identified federally listed, threatened, or endangered species occurring within the OT-29 site boundaries; however, the Red-Cockaded Woodpecker, the Pickering's Dawn Flower, and the Spring-Flowering Goldenrod, threatened species, are native to North Carolina and may be in the area around Seymour Johnson AFB.	May be Applicable
Wetlands	Requires action to minimize the destruction, loss, or degradation of wetlands. Prohibits discharge of dredged or fill material into wetlands without permit. If wetlands are located within the area of proposed federal activities, the agency must conduct a wetlands assessment to identify wetlands and potential means of minimizing impacts. If there is no practical alternative to locating in or affecting the wetland, the Agency shall act to minimize potential harm to the wetland. The Clean Water Act prohibits discharge of dredged or fill material into wetlands without a permit.	Executive Order 11990, Protection of Wetlands (40 CFR 6, §6.302(a) Clean Water Act Section 404; 40 CFR Parts 230, 231	No vernal pools or wetland exist within the OT-29 site boundaries; however, wetlands existing in and around Seymour Johnson AFB.	May be Applicable

Table A-2. (Continued)

Standard, Requirements, Criteria, or Limitations	Description	Citation	Comments	Applicability
Wilderness area	Areas federally owned and designated as wilderness areas must be administered in such a manner as will leave them unimpaired as wilderness and to preserve their wilderness character.	Wilderness Act (16 USC 1131 *et seq.*); 50 CFR 35.1 *et seq.*	Seymour Johnson AFB is not within or adjacent to any federally designated wilderness area.	Not ARAR
Wildlife refuge	Only actions allowed under the provisions of 16 USC Section 668 dd(c) may be undertaken in areas that are part of the National Wildlife Refuge System.	16 USC 668 dd *et seq.*; 50 CFR Part 27	The Seymour Johnson AFB site is not designated as part of the National Wildlife Refuge System.	Not ARAR
Area affecting stream or other water body	Proposed discharges of dredged or fill material into waters of the U.S. are evaluated with respect to impacts on the aquatic ecosystem. Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife will require actions to protect fish or wildlife.	CWA Section 404 40 CFR 230 Fish and Wildlife Coordination Act (16 U.S.C. 661 *et seq.*); 40 CFR 6.302	The activities associated with this removal action should not affect stream or river wildlife.	Not ARAR
Within area affecting national wild, scenic, or recreational river	Activities that affect or may affect any of the rivers specified in Section 1276(a). Avoid taking or assisting in action that will have direct adverse effect on scenic river.	Scenic Rivers Act (16 U.S.C. 1271 *et seq.* Section 7(a)); 40 CFR 6.302(e)	No national wild or scenic rivers are located on the Seymour Johnson AFB site or will be impacted by proposed removal action.	Not ARAR

included in the list of potential location-specific ARARs are described below.

A3.1 Flood Plain Management

The Executive Order on Flood Plain Management requires federal agencies to evaluate the potential effects of actions that may take place in a flood plain to avoid, to the extent possible, adverse effects associated with direct and indirect flood plain development. U.S. EPA's regulations to implement this Executive Order are set forth in 40 CFR 6 §6.302(b). In addition, U.S. EPA has developed guidance entitled *Policy on Flood Plains and Wetlands Assessments for CERCLA Actions,* dated August 6, 1985. This policy would potentially apply if any floodplains are effected by any new construction associated with the removal action at the Base.

Both federal and state solid and hazardous waste statutes have requirements pertaining to location of facilities in flood plain areas. If treatment units or pipelines are located within a 100-year flood zone hazard area, the federal and state requirements governing siting and operation of facilities in the flood plain would be potentially applicable.

A3.2 Historical and Archaeological Resources

The Archeological and Historic Preservation Act establishes procedures to provide for historical and archeological data preservation that might be destroyed through terrain alteration as a result of a federal construction project or a federally licensed activity or program. If removal actions cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archeological data, U.S. EPA would require adherence to the procedures in the statute to provide for data recovery and preservation activities.

The National Historic Preservation Act requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places. It is not anticipated that structures at the Base will be impacted by the proposed removal actions. If an eligible structure could be adversely affected, the procedures for protecting the historic property are set forth in Executive Order 11593 entitled "Protection and Enhancement of the Cultural Environment" and in 36 CFR Part 800, 36 CFR Part 63, and 40 CFR §6.301(c).

A3.3 Wetlands Protection

The Executive Order on Protection of Wetlands requires federal agencies to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists. The U.S. EPA's regulations to implement this Executive Order are set forth in 40 CFR 6, §6.302(a). In addition, the U.S. EPA's *Policy on Flood Plains and Wetlands Assessments for CERCLA Actions*, would also be applicable to actions conducted in wetland areas.

A3.4 Endangered Species Act

Under the Endangered Species Act, remedial actions must avoid jeopardizing the continued existence of listed, endangered, or threatened species or modification of their habitat. If a listed species or their habitat may be affected by a remedial action, consultation with the Fish and Wildlife Service may be necessary. At this time, there are no federally listed, threatened, or endangered species identified within the Seymour Johnson AFB property boundaries. It is anticipated that the proposed removal action will have a less than significant impact on plant and wildlife populations at the site.

A4.0 ACTION-SPECIFIC ARARs

Removal actions may trigger action-specific ARARs and TBCs. These regulations define the performance, design, or other similar action-specific controls or restrictions on activities related to the management of hazardous

substances or pollutants. A summary of the potential action-specific ARARs that relate to the site OT-29 removal action and a description of the requirements associated with each potential ARAR are presented in Table A-3. The action-specific ARARs include technology- and activity-based requirements or limitations on actions taken with respect to hazardous substances at the site. Only the substantive portions of these requirements would apply to on-site actions. However, for off-site actions such as disposal, all applicable laws and regulatory requirements must be met. A more detailed discussion of some of the major ARARs follows.

A4.1 National Contingency Plan (40 CFR 300)

The National Contingency Plan (NCP) is the primary regulation governing CERCLA actions and establishes procedures for implementing the Superfund program. Under CERCLA, remedial actions must protect human health and the environment, be cost-effective, comply with ARARs, and use permanent solutions and alternative treatment technologies to the maximum extent possible.

Another provision under the NCP applies to wastes that are left onsite. If a selected alternative involves leaving waste onsite, then the alternative must be reviewed every 5 years. This requirement would apply to the limited action, capping, and *in situ* solidification alternatives discussed in this FS.

A4.2 Resource Conservation and Recovery Act

Many RCRA requirements are applicable or relevant and appropriate to the alternatives presented in this FS. The RCRA program is a delegable programs; the states may manage the program in lieu of the EPA if the state statutes and regulations are equivalent to or more stringent than the federal statutes and regulations. Therefore, in some cases the applicable or relevant and appropriate RCRA requirement discussed below will be cited as state law and in other cases as federal law, or both.

A4.2.1 Identification and Listing of Hazardous Waste

The key determination that must be made in addressing whether or not RCRA requirements are an ARAR at a CERCLA site is whether the wastes or contaminated material at the site are RCRA or non-RCRA (North Carolina) hazardous waste, in which RCRA or North Carolina hazardous waste regulations may be applicable or relevant and appropriate. A material is a hazardous waste if it is a solid waste, if it is not excluded from regulation, and if it meets one of the following conditions:

- Exhibits, on analysis, any of the characteristics of a hazardous waste, i.e., ignitability, corrosivity, reactivity, and toxicity as determined by a Toxicity Characteristic Leaching Procedure.
- Has been listed as a hazardous waste in the state or federal regulations. These listings specifically include wastes from non-specific sources (F-list), wastes from specific sources (K-list), and discarded chemical products (P- and U-list).
- Is a mixture containing a listed hazardous waste and a nonhazardous solid waste.
- Is derived from a listed hazardous waste.

If a waste is not a listed waste or does not contain a listed waste, the determination as to whether the waste is ignitable, reactive, corrosive, or toxic must be made.

A4.2.2 Treatment

North Carolina does not generally require a permit for in-situ activities. However, a permit may be required on review of removal action work plan.

Table A-3. Potential Action-Specific ARARs and TBCs

Action	Requirements	Citation	Comments	Applicability
Waste Identification	The North Carolina Hazardous Waste Management Rule defines those solid wastes that are subject to regulation as hazardous wastes under subsequent sections.	15A NCAC C13A.0006	All regulations are applicable to any hazardous waste generated, treated, stored, or disposed of at the Seymour Johnson AFB site, including excavated hazardous soil and soil cuttings generated during installation of monitoring wells.	Relevant and Appropriate
Container Storage (Onsite)	Contains holding RCRA or North Carolina hazardous waste (listed or characteristic) for a temporary period before treatment, disposal, or storage onsite or elsewhere (40 CFR 264.10) must be:		These requirements are applicable or relevant and appropriate for any contaminated soil or treatment system waste that might be containerized and stored onsite prior to treatment or final disposal.	Relevant and Appropriate
	• Maintained in good condition. • Compatible with hazardous waste to be stored. • Closed during storage (except to add or remove waste).	40 CFR 264.171 40 CFR 264.172 40 CFR 264.173		
	A container is any portable device in which a material is stored, transported, disposed of, or handled.			
	Inspect container storage areas weekly for deterioration.	40 CFR 264.174		
	Place containers on a sloped, crack-free base, and protect from contact with accumulated liquid. Provide containment system with a capacity of 10% of the volume of containers of free liquid.	40 CFR 264.175		
	Remove spilled or leaked waste in a timely manner to prevent overflow of the containment system.			
	Keep incompatible materials separate. Separate incompatible materials stored near each other by a dike or other barrier.	40 CFR 264.177		
	At closure, remove all hazardous waste and residue from the containment system, and decontaminate or remove all containers, liners.	40 CFR 264.178		

Table A-3. (Continued)

Action	Requirements	Citation	Comments	Applicability
Storage	A generator may accumulate contaminated soil onsite for 45 days without a permit provided: • The generator complies with Title 22 CCR, Division 4.5, North Carolina requirements. • Temporary storage of contaminated soil shall be on 10 mL thick plastic bermed to prevent runoff. A generator who accumulates waste for more than 45 days is an operator of a storage facility and is subjected to associated requirements.	15A NCAC 24.0219 (g)	Applicable to any hazardous waste stored onsite (i.e., hazardous soil, treatment by-products).	Relevant and Appropriate
Tank Systems (onsite)	Facilities that use tank systems for transferring, storing, or treating hazardous waste shall: • Be designed with sufficient shell strength, compatible with hazardous material in contact, and be acceptable for the storing and treatment of hazardous waste. • Be provided with secondary containment with provision for leak detection, including ancillary equipment. • Maintain an emergency response plan to contain leaks or spills and dispose of leaking or unfit tank systems. • Operated with approved closure and post-closure plan.	40 CFR 262 (Subpart 1) 40 CFR 264.192 40 CFR 264.193 40 CFR 264.196 40 CFR 264.197	These requirements are applicable or relevant and appropriate for any facility that uses tank systems for storing or transporting waste.	Relevant and Appropriate
Treatment	No permits are generally required by North Carolina for in-situ remediation activities. However, North Carolina may require permits upon review of work plan.	15A NCAC 2H.0200, 2C	The substantive portions of these requirements are applicable to construction, operation, maintenance, and closure of any physical, biological, or chemical treatment units.	Applicable and Relevant

Table A-3. (Continued)

Action	Requirements	Citation	Comments	Applicability
Waste Disposal	Identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may be land disposed. Treatment of wastes subject to ban on land disposal must attain achievable concentrations by best demonstrated available treatment technologies (BDAT) for each hazardous constituent in each listed waste.	40 CFR 268, Subpart D NCGS 143-215.1	The substantive portions of these requirements are relevant and appropriate to the treatment prior to disposal of any wastes that contain components of restricted wastes sufficiently similar to the regulated waste. Toxicity characteristic waste must be treated to a level at which the waste no longer exhibits the characteristic. If hazardous soil is excavated, treated in a treatment unit, and then redeposited, LDRs may be triggered.	Applicable or Relevant
Air Emissions	Control of air emissions of volatile organics and gaseous contaminants from onsite treatment units of RCRA wastes that contain organic concentrations equal to or greater than 10 ppm by weight is required. RCRA Standards for air emissions from treatment process vents; control devices shall be monitored and inspected to ensure proper maintenance and operation. Standards for air emissions from equipment leaks. Equipment shall be designed to prevent leakage of organic emissions to the atmosphere, North Carolina states that operation of any device that may result in the emission of air contaminants will require an air quality permit.	40 CFR §61 40 CFR §264, Subpart AA 40 CFR §264, Subpart BB NCGS 143-215.108	Emissions from treatment unit(s) will be controlled according to the substantive portions of these requirements. All precautions will be taken to comply with fugitive dust and opacity standards.	Applicable or Relevant

Table A-3. (Continued)

Action	Requirements	Citation	Comments	Applicability
Discharge to Surface Water	Applicable federally approved state water quality standards must be complied with. These standards may be in addition to more stringent federal standards under CWA. Applicable federal water quality criteria for the protection of aquatic life must be complied with. Deposition of fill or dredge material into waters of the U.S. is regulated under the CWA.	CWA Section 304 50 FR 30784 (July 29, 1985) CWA Section 404	Runoff from source areas could reach local creeks. Runoff quality may need to comply with CWA ambient water quality criteria (AWQC). Deposition of fill material (i.e., bank material that may fall into creeks) may occur and may require compliance with the substantive portions of CWA Section 404.	Applicable and Relevant

A4.2.3 Container Storage

The RCRA storage requirements, 40 CFR 264.170 to 264.178, and the North Carolina hazardous waste storage requirements, 15A NCAC13A.0006 will be applicable to the storage of hazardous soil or hazardous treatment byproducts onsite. These regulations include requirements governing the use, management, containment, and inspection of containers holding hazardous waste. The storage of polychlorinated biphenyls (PCBs) wastes is regulated separately under the Toxic Substance Control Act (TSCA).

A4.2.4 Land Disposal Restrictions

The land disposal restrictions, 40 CFR Part 268, will be applicable or relevant and appropriate to discharges of contaminated materials to land. If hazardous soil has been contaminated with a listed or characteristic hazardous waste, then land disposal restrictions (LDR) regulations may apply. A restricted waste can be defined as a waste that cannot be disposed of onto land (e.g., landfill, surface impoundment, waste pile, land treatment facility) unless it is treated prior to disposal.

Treatment standards for restricted waste may be expressed as either levels or methods depending on the waste. The LDRs are applicable when hazardous soil is excavated, treated in another unit (i.e., treatment unit), and placed on land (or disposed of in a unit outside the area of contamination). These requirements would apply to soil that is excavated from the Base and disposed of onsite or offsite. If soil has been capped, consolidated within an area of contamination, or in situ or no treatment has been applied, then the LDRs do not apply because there has been no "land disposal."

Under existing LDR regulations, how soil is treated before being land disposed is determined by the hazardous waste with which it is contaminated. The LDRs also apply to characteristic wastes (including soils that fail characteristic tests). If soil is considered hazardous because of the toxicity characteristic, then it would need to be treated to a level below the TCLP. Soil that has been treated to below the TCLP would no longer be subject to hazardous waste regulations (40 CFR §268.9).

A4.2.5 Air Monitoring for Process Vents and Equipment Leaks

The requirements of 40 CFR 264 Subparts AA and BB and 22 CCR Chapter 15 Articles 27 and 28 may be applicable or relevant and appropriate to onsite treatment units of RCRA wastes that contain organic concentrations equal to or greater than 10 ppm by weight. Control devices will need to be monitored and inspected to ensure proper maintenance and operation. Equipment shall be designed to prevent leakage of organic emissions to the atmosphere.

A more stringent proposed RCRA regulation for tanks and containers limiting air emissions from process vents and equipment leaks will become a potential ARAR once it goes into effect. This regulation would be applicable if treatment of soil is to take place in tanks.

APPENDIX B

GROUNDWATER EXTRACTION RATE CALCULATIONS

RADIAN CORPORATION

GENERAL COMPUTATION SHEET

CLIENT NAME Seymour Johnson AFB
PROJECT NAME OT-29 PREECA

CALCULATION SET		
Prelim.		
Final		
Sheet 1 Of 2		
Charge #		
Rev.	Comp. By	Chk'd By
	JPC	
	Date 10/20/95	Date
	Date	Date

Contaminated groundwater volume calculated from available data

Assume contaminated thickness = 10 ft

NE to SW length ≃ 420 ft.

NW to SE width ≃ 220 ft.

Area of an ellipse = πab

Area of elliptical plume = π (420 ft) (220 ft)

= 290,000 ft^2

Volume of the elliptical plume = Area x 10 ft

= 2,900,000 ft^3

Porous volume = porosity x total volume

if porosity is 0.25 to 0.30

Porous volume = $2.9 \times 10^6 ft^3 \times .25 = 725,000 ft^3$

$2.9 \times 10^6 ft^3 \times .30 = 870,000 ft^3$

1 cubic ft. of H_2O = 7.48 gallons.

Plume water volume = 725,000 ft^3 x 7.48 gal/ft^3

= 870,000 ft^3 x 7.48 gal/ft^3

= 5.4×10^6 to 6.5×10^6 gal.

1-85-18743

RADIAN CORPORATION

GENERAL COMPUTATION SHEET

CLIENT NAME Seymour Johnson AFB

PROJECT NAME OT-29 PREECA

CALCULATION SET		
Prelim.		
Final		
Sheet 2 Of 2		
Charge #		
Rev.	Comp. By	Chk'd By
	Date	Date
	Date	Date

Although there are 5.4×10^6 to 6.5×10^6 gallons of contaminated water greater than 1000 ug/L TPH concentration, the TPH will not migrate to the extraction well in one time interval because of TPH adsorption.

Therefore, to remove the TPH > 1000 ug/L, we assumed 4 pore volumes of groundwater would have to be extracted.

Total volume of groundwater to be removed =
4 X porous plume volume
$= 4 \times 5.4 \times 10^6$ gal $= 22 \times 10^6$ gal
$= 4 \times 6.5 \times 10^6$ gal $= 26 \times 10^6$ gal.

For the PREECA, we estimate 22,000,000 gal.

1-85-18743

APPENDIX C

RESPONSE TO COMMENTS ON DRAFT SSAM

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
Linda Raynor, North Carolina Dept. of Environment, Health and Natural Resources - Division of Solid Waste Mgt. - Superfund Section					
1	General			Based upon the information presented in the 1995 RUST report, this document, and on knowledge of the availability and effectiveness of other treatment alternatives currently being implemented, the proposed presumptive remedy (the combination of bioventing for contaminated soils and pump and treat for containment of the groundwater) may not be the best treatment alternative for this site. The proposed remediation for this site was discussed with Mr. Richard Powers of Washington Regional Office's Groundwater Section, and he agrees that better alternatives may be available. Although bioventing may be a possibility at this site and achieve desired results quickly, the proposed pump and treat for containment of groundwater will not likely accomplish a faster, more effective or less costly cleanup.	Based on discussions held during the conference call on Monday 12 February 1996 between representatives from the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR), the U.S. EPA Region 4, the Omaha Army Corps of Engineers (COE), the Air Force Air Combat Command (ACC), Seymour Johnson Air Force Base, and Radian, all parties agreed that the proposed presumptive remedy (the combination of bioventing and pump and treat for containment) is the best alternative for this interim removal action. The purpose of this interim removal action is to limit BTEX- and TPH- contaminants in groundwater from migrating via seeps into the unnamed creek that runs along the southern boundary of the site and contributes to the Neuse River, a source of drinking water. At this time, these migration and exposure pathways pose the most significant threat to human health and the environment and should be addressed as quickly as possible.
2	General	2-5	Table 2-2	In numerous places throughout this document, a limited list of groundwater contaminants is presented which generally only includes TPH-diesel, BTEX, and halogenated VOCs or chlorinated hydrocarbons. However, other chemicals also exist in the groundwater, such as some semivolatile organics and metals. The text should be adjusted in to present the complete realm of contaminants detected in groundwater, soils, and surface water.	Table 2-2 summarizes all the contaminants detected at or above North Carolina standards in groundwater, soils, and surface water at the site. However, since the purpose of this document is to provide justification for the proposed interim removal action, the text primarily focuses on the contaminants (TPH and BTEX) that are directly addressed by this interim removal action and that pose immediate and significant threat to human health and the environment.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
3	General			The TPH contamination in site soils has only been investigated with respect to the diesel fraction (mid-range) of petroleum hydrocarbons. However, based on site history and site investigative results, the extent of contamination due to the lighter and heavier fuel hydrocarbons should also be investigated. The TPH soil contaminated areas should be defined for all three ranges of petroleum hydrocarbons.	We concur. During the installation of the removal action system components (i.e., injection wells and monitoring wells) additional data should be collected to further define the extent of TPH-contamination at the site.
4	General			The text pages of this report should be double-sided copies rather than single-sided.	We concur. The final action memo has double-sided pages.
1	2.0	2-1	2nd column, 1st paragraph	"Contaminate concentrations detected in the soil and groundwater at the FFTP site are much lower and less frequently detected than those detected at site OT-29 (RUST, 1995); therefore, removal actions at the FFTP site are unwarranted." Since the actual extent of contamination at the FFTP is unknown at this time, the term "unwarranted" is not applicable.	Because of uncertainties regarding extent of contamination at the Former Fire Training Pit (FFTP), the statement that removal actions at that site are unwarranted has been revised.
2	2.0	2-4	1st column, 3rd paragraph & Table 2-1	Need to adjust the text and table to present all site contaminants detected. (See also general comment 2 above.) For example, in Table 2-1, according to the RUST report, the investigative results for Precision Environmental Management's work also should include trichloroethene, chloroform, vinyl chloride, and ethylbenzene. Also in Table 2-1, for Geophex, Ltd.'s work, indicate that the 0.5 mg/L of toluene was detected in <u>surface</u> water.	Table 2-1 has been revised to address the comment.
3	2.0	2-7	2nd column, 1st sentence	Need to adjust according to general comment 2 above.	The text has been revised to address the comment.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
4	2.0	2-11	Last paragraph	"Although metals have been detected in groundwater above action levels, no metals concentrations above action levels have been in surface water from the unnamed creek." Change "action levels" to "standards."	The text has been revised to address the comment.
5	3.0	3-3	Figure 3-2	It is unclear how soil gas flux to the air can affect the ecological food chain. Please clarify.	Animals could be exposed to contaminants in the air though inhalation.
6	3.0	3-4	2nd paragraph	"As shown in Table 2-2, data on concentrations of TPH, BTEX, chlorinated VOCs, and metals present in surface and subsurface soil, surface water, and groundwater exceed the State of North Carolina, DEHNR's minimum allowable levels for these contaminants." "Minimum" should be "maximum" and this statement conflicts with the statement reference in specific comment 4 above regarding the surface water. Please correct as necessary. Also, in the same paragraph, the second sentence pertains to TPH-contaminated soils, thus, the text should specify this point.	Text has been revised to address the comment.
7	4.0	4-1	2nd bullet	Need to specify if any areas of this site are considered as wetlands.	No areas of this site are considered to be wetlands. The reference to threatened wetlands has been deleted.
8	6.0	6-1	1st column, 1st paragraph	"This interim action focuses on for the removal..." remove "**for**".	The word "for" has been deleted.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
9	6.0	6-1	2nd column, 1st paragraph, last sentence	Reference general comment 2 above. Has bioventing been proven to be effective for the other site contaminants also?	Bioventing will enhance the natural in-situ degradation/bioremediation of the other hydrocarbon contaminants present at the site as well. However, bioventing is not as effective for chlorinated hydrocarbons as it is for petroleum hydrocarbons. Bioventing will have no remedial effect on inorganic constituents (metals) in the soil.
10	6.0	6-3	Table 6-2	Insert information on hydraulic conductivities at OT-29 in the profile column. Also, from what information was the value of 0.02 feet/day (regarding site groundwater velocity) obtained?	Hydraulic conductivity values calculated from measurements at OT-29 have been inserted in Table 6-2. Groundwater velocity was calculated as the average for a hydraulic conductivity range of 0.49 to 1.6 ft/day, a horizontal gradient of 0.006 ft/ft, and an estimated effective porosity of 0.25 for the saturated zone beneath OT-29.
11	6.0	6-2 through 6-5		Need to provide the corresponding cross-sections for the plan view of the bioventing injection wells and trench shown on Figure 6-1. These cross-sections should depict the placement of the bioventing injection wells and trench with respect to the subsurface characteristics (lithology and location of water table and creek).	A new cross-section, Figure 6-2, illustrates the conceptual locations and depths of the extraction trench, bioventing well, and monitoring points.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
11 (continued)	6.0	6-2 through 6-5		The text description of the conceptual design is poorly written and confusing, especially page 6-5. Please rewrite to clarify treatment process. In addition, designate the name and location of the POTW, and clarify which water quality limits (POTW influent vs. effluent limits) need to be met before extract groundwater is processed through the POTW. The text refers to the POTW "discharge standards." Please clarify.	The description of the groundwater treatment system conceptual design has been revised. The Air Force and COE are currently evaluating several options for groundwater extracted from site OT-29. These options include: POTW discharge; surface water discharge; industrial reuse; on-base irrigation; and re-injection. Specific details describing the chosen option (including any necessary treatment and/or permits) will be presented in a future work plan. (Concurrent with the design of the interim removal action system, the COE will prepare a work plan to install, operate, maintain, and evaluate the system. This plan will include a complete description of the system, a sampling and analysis plan, and a monitoring plan.) The local POTW is the City of Goldsboro. If the POTW is chosen as the preferred water discharge alternative, the Base will have to treat extracted water to meet the POTW "influent" water quality limits. These limits will be presented in the future work plan.
				Need to indicate the basis for the estimated groundwater extraction rate of 1,500 gallons/day and a trench length of 60 feet.	Calculations supporting these estimates have been attached as Appendix B to the SSAM.
				Need to address the compliance record of the proposed POTW. Is this facility currently meeting its discharge limits?	The Base is currently in compliance with their permit from the City of Goldsboro. However, during wet weather, they exceed the volume discharge limit. As stated above, several discharge options are currently being evaluated. Details of this evaluation will be presented work plan described above.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
12	6.0	6-5	2nd column, 4th paragraph	"Because available data suggest that this initial system will be sufficient to remove contaminants...." What "available data" is this statement referencing?	This specifically refers to contaminant concentrations in groundwater presented in the Draft Final EFI/RFI report prepared by RUST. This section has been revised. Please see response to DEHNR specific comment No. 11.
13	6.0	6-6	Table 6-3	What task(s) does the $5,000 estimated cost for regulatory approval involve?	The "regulatory approval" task includes any coordination/communication by the COE (including meetings) that is necessary to keep the regulatory agencies fully updated of project progress and to facilitate approval of any removal action activities conducted at the site.
14	6.0	6-7	1st paragraph	It is unclear how the estimate of "4 volumes" was obtained. Please clarify. Also, the last two sentences/phrases contain grammatical errors.	The text has been revised to address these comments.
15	6.0	6-7	2nd paragraph	The words "of the" are duplicated. Please correct.	This has been corrected.
16	6.0	6-8	Figure 6-2	Please separate the <u>one</u> timeline presented for the Bioventing Installation/Operation into <u>two</u> separate timelines.	The timeline has been revised.
17	7.0	7-1	2nd paragraph	"A delay....surface water **an** onto the Neuse River..." Correct bolded text.	The work "an" was changed to "and". The text was not bolded.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
18	Appendix A	A-1	1st sentence	Need to change "applicable **and** relevant and appropriate requirements" to "applicable **or** relevant and appropriate requirements."	The text has been revised accordingly.
		A-8		Delete reference to California's RCRA program, this is North Carolina!	The reference has been deleted.
		A-13	1st column, 2nd paragraph	"ISA NCAC" should be "15A NCAC". Also the Toxic Substance Control Act is not "discussed below" as stated in the last sentence of this section.	The text has been revised. The reference to the TSCA discussion has been deleted.
		A-13	2nd column, 1st paragraph	Delete reference to California.	Reference has been deleted.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
Robert H. Pope, U.S. EPA, DoD Remedial Section, Federal Facilities Branch, Waste Management Division					
1	General			Overall, much needed information is missing from the document. EPA concurs that a remedial action must be taken to protect the human health and the environment. However, the chosen remedies may not be the best way to accomplish the goals. Using bioventing to remediate TPH and BTEX at sites with higher silt and clay content has been limited and met with mixed success (PREECA, Part II, p. 38). In fact, the PREECA document clearly states that several parameters that are unknown at the Tower Road Site are needed to insure a successful remediation. Proceeding without knowing these parameters could be a waste of money and time. However, a remediation action must be allowed to make the necessary changes as work proceeds.	As discussed in the 12 February 1996 conference call between the North Carolina DEHNR, U.S. EPA Region IV, Omaha COE, Seymour Johnson AFB, and Radian, additional data can be collected during the installation of the proposed interim removal action system. However, it is not necessary to collect these data prior to choosing the presumptive remedy options. The dominant lithology at the site is a silty, clayey medium grained sand. This lithology, while not considered the "ideal" lithology (gravels and sands), is still amenable to bioventing based on information obtained by the AFCEE during numerous bioventing studies. AFCEE's data further support that the unknown parameters (moisture, nitrogen, pH, and phosphorus) at the site, while important, do not limit the ability to determine if bioventing is a feasible remediation alternative. According to data collected by AFCEE, over 98% (about 137) of the sites encountered in the United States are amenable to bioventing. In many cases, sites with soil moisture, pH, nitrogen, and phosphorus outside of the "ideal" range were still found to be amenable to bioventing. For completeness, these data can easily be collected during implementation of removal action activities.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
2	General			According to the text, the western and southern leading edge and boundary defining the horizontal extent of the groundwater contamination at Site OT-29 is adjacent to the unnamed creek, which is located approximately 180 feet southwest of the site. This statement implies that all of the contamination in the shallow aquifer is discharging into the unnamed creek and, therefore, the creek is acting as a groundwater divide. Elevated concentrations of organic contaminants such as benzene, toluene, ethyl benzene, xylene, trichloroethylene, and 1,2-dichloroethene have been detected in monitoring wells MW-TOW-01 and MW-TOW-06, which are located east (upgradient) of the unnamed creek. Additional monitoring wells should be installed to the west (downgradient) side of the creek in order to determine if the unnamed creek is acting as a groundwater divide thus defining the western and southern boundary of the groundwater plume. In addition, the text should characterize the unnamed creek as being either perennial or intermittent. This information is needed to help evaluate whether the creek can act as an effective groundwater divide.	The text does not state that "all of the contamination is discharging to the creek" nor does it imply a groundwater divide at the creek. Text has been added to clarify the hydraulic relationship between groundwater and the creek.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
3	General			Furthermore, analyses of the direct push and hand auger groundwater samples collected during the Groundwater Quality Survey (GQWS) portion of the Expanded Site Investigation/RCRA Facility Investigation, indicate that BTEX is present in the groundwater along the western bank (downgradient) of the unnamed creek. Full-scan analyses were not performed on the GQWS samples and it cannot be determined if additional hazardous constituents have migrated west of the unnamed creek. Additional groundwater samples should be collected west of the unnamed creek and analyzed for all parameters on the Target Compound List/Target Analyte List (TCL/TAL).	BTEX compounds were detected on the southwest side of the creek because groundwater flows beyond the creek in that direction. Additional groundwater samples monitoring west of the creek may be appropriate to demonstrate the effectiveness of the removal action after design and construction.
1	2.2	2-5	Figure 2-3	Figure 2-3 shows TPH levels in surface and subsurface soil at Site OT-29. However, the figure does not show the extent of contamination to the east of the suspected area of contamination. Additional samples are necessary to the east and southeast of the disposal area to determine the extent of surface and subsurface soil contamination. In addition, the sample collection date is not indicated on the figure. Revised the figure.	The extent of TPH contamination to the east of the suspected area of contamination cannot be delineated because no sample data are available. The sample collection period for the data shown on the figure has been added.
2	2.2	2-8	Figure 2-4	Figure 2-4 does not use the standard symbols for soil types or grain textures. In addition, the random grouping of silt, clayey fine sand, and sandy clay is improper and the term "fill" does not indicate any grain size. Revise the figure.	The figure has been revised to identify soil types consistent with the Uniform Soil Classification System. Graphic symbols for soil types have been revised.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
3	2.3	2-11	Paragraph 1	The text states "the vertical extent is limited to less than 40 feet by the absence of contaminants exceeding the standards in samples collected from MW-TOW-04D." The vertical extent of contamination cannot be determined by a single deep well sample. To adequately determine the vertical extent of contamination at Site OT-29, additional deep monitoring wells should be installed downgradient of MW-TOW-04D and groundwater analyzed for the TCL/TAL.	Text has been revised to address the comment.
4	2.3	2-12	Figure 2-7	Figure 2-7 depicts surface water and shallow groundwater TPH concentrations. The extent of surface water and shallow groundwater TPH concentrations are not adequately defined as depicted because the isoconcentration lines do not completely encircle the area of contamination. Additional samples are needed west of the unnamed creek and north and east-southeast of the suspected disposal area to fully define the extent of contamination based on analytical data. In addition, the isoconcentration lines do attempt to take into account the concentration detected in MW-TOW-08, explain this discrepancy.	The isoconcentration lines cannot be closed on the east because there are no sample data to the east that would allow closing of the lines. Closing of the isoconcentration line around MW-TOW-08 was an error, which has been corrected.
5	5.0	5-1	Bullet 7	What is the "final remedial action plan for Seymour Johnson Air Force Base?" EPA has never heard of or reviewed such a document.	The text has been changed to reference the Seymour Johnson Air Force Base Management Action Plan.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
6	6.0	6-1	Table 6-1	The tables makes clear how much as to be determined about the site. 4 of the 9 parameters are listed as unknown. In other words 44% of the parameters listed in the remedy profile of the PREECA have been determined. In addition, the PREECA lists the preferred geology to be "unsaturated gravels and sands with minor clays and silts." In contrast, the contamination at the OT-29 site is in not only unsaturated silty to clayey sands with isolated clay lenses, but (according to Figure 2-6) also in the undefined "fill", silty, sandy clay, and clay. None of these are the same as gravels and sands with minor clays and silts. This information needs to be determined as soon as possible.	Please see response to EPA- General Comment No. 1. Gravels and sands are considered to be the "ideal" lithology for bioventing. The lithology at the site is not considered to be ideal, but is still amenable to bioventing based on information obtained by AFCEE.
7	6.2	6-2	Paragraph 2	Evaluating the effectiveness of the operation of the system after one year is not acceptable. The operation should be evaluated quarterly for the first year with monitoring reports submitted to the regulatory agencies.	The text has been revised. Operation will be evaluated on a continuous basis. Monthly and/or quarterly monitoring reports will be submitted to the regulatory agencies to document system effectiveness and project progress.
8	6.2	6-3	Table 6-2	The table indicates that the target plume at Site OT-29 is approximately 14 to 17 feet deep. Please indicate the units for the depth (for example, below ground surface or above mean sea level). Also, the vertical extent of contamination is not adequately defined at Site OT-29 because it was defined from the sample analysis of only one deep monitoring well (MW-TOW-04D). The depth of the target plume must be recalculated when additional deep monitoring wells are installed and more groundwater samples are collected and analyzed.	The depth indicated in the table is to the top of the target plume. It is not intended to represent vertical plume extent. The modifying phrase "below ground surface" has been added to depths in the table.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
9	6.2	6-3	Table 6-2	The natural organic carbon fraction must be determined during the installation of the pump and treat system.	Samples of soil to determine the fraction of natural organic carbon will be collected during installation of bioventing wells and monitoring points.
10	6.2	6-4	Figure 6-1	Figure 6-1 presents the removal action conceptual design at Site OT-29 and depicts the concentrations of TPH detected in each monitoring well and the TPH isoconcentration contour. The isoconcentration contour may not be accurate since additional samples are needed east of monitoring wells MW-TOW-01, MW-TOW-05, and MW-TOW-06 and along the west bank of the unnamed creek in the apparent direction in which the groundwater contamination plume is flowing. In addition, since the horizontal extent of groundwater contamination is not adequately defined, the present proposed location/length of the trench to capture groundwater may not be adequate. Once the extent of groundwater contamination is fully defined, it may be necessary to reposition/lengthen the trench so that the groundwater contamination plume will be adequately captured. This is another example of how the work to be done may need reevaluation and the field team must remain flexible.	The isoconcentration contours are accurate within the limits of the data. None of the contours are closed to the east or to the south where no samples of groundwater have been collected. Additional groundwater samples can be collected by the HydroPunch® method in bioventing wells and monitoring point locations to define the extent of contamination on the east. If the data from the additional samples are obtained before final design of the extraction trench, the trench may be lengthened to the southeast to assure capture of the plume.
11	6.2	6-4	Figure 6-1	Figure 6-1 makes it obvious that the effectiveness of the capture trench cannot be fully evaluated without monitoring both in the stream and in groundwater on the west side of the stream. Additional monitoring well(s) must be installed on the west side of the stream.	Monitoring of surface water in the stream and shallow groundwater on the west side of the stream could be accomplished without a permanent monitoring well. Stream grab samples and direct push or hand auger groundwater samples would provide data on the effectiveness of the capture trench.

SPECIFIC COMMENTS TO THE DRAFT SITE-SPECIFIC ACTION MEMORANDUM (SSAM) FOR THE TOWER ROAD SITE (OT-29) (Continued)

Comment #	Section	Draft Page	Draft Paragraph	Comment	Response
12	8.0	8-1	Paragraph 2, Bullet 2	The text states that "collection of additional hydrogeological data and groundwater treatment data is recommended to aid in the design of an effective and efficient extraction system and treatment system." However, the text does not specify the type of hydrogeological and groundwater treatment data which are recommended. Please clarify.	Text has been added to specify the data that should be collected.

APPENDIX A

ARARs

APPENDIX A

Potential Applicable or Relevant and Appropriate Requirements and "To Be Considered" Requirements

1.0 PURPOSE

The purpose of this appendix is to identify potential chemical- and location-specific applicable or relevant and appropriate requirements (ARARs) and "to be considered" requirements (TBCs) that may apply to Air Force sites. Detailed ARAR evaluations will be included in individual feasibility study or engineering evaluation/cost analysis reports, so that regulatory requirements can be considered when evaluating the feasibility of alternatives. The detailed evaluations will also include action-specific ARARs, which only come into play once alternatives for remediation are being considered.

The potential ARARs identified in this appendix are those that could affect the selection of remediation actions. The United States Environmental Protection Agency (U.S. EPA) and relevant state agencies must approve the application of ARARs to all sites being remediated. Following negotiation of final ARARs, documentation of agreed-upon ARARs is included in any Interim Records of Decision (IRODs). The purpose of this appendix is to present the universe of ARARs that may apply, not to present the process of selecting among these ARARs, which is left to the individual site remediation documents.

1.1 ARARs and the CERCLA Process

The Superfund process is often represented as being serial, with site discovery leading to the remedial investigation and feasibility study (RI/FS), and then to the record of decision (ROD) and remedial actions. This serial representation is, in general, an oversimplification and has led to slow, inefficient progress at sites. Recent efforts to streamline the Superfund process have recognized that it is more complex, with many interrelated processes that are parallel and interdependent. Whether the process for any given site is serial or a complex interrelation of parallel activities, U.S. EPA's mandate through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) is to protect human health and the environment.

One of the first steps in the Superfund process is to define the problem at a site and determine that the action (or no action) taken in response to the problem protects human health and the environment. Along with risk assessment, one of the tools used to define and solve a site problem is evaluation of environmental laws and regulations called ARARs (defined below).

Defining the problem at a site and evaluating the remedial alternatives for solving it require evaluating site data to determine:

- Is remedial action necessary (does a problem exist now or is there a threat of a problem)?
- What is the areal extent of the action (how big is the problem)?
- What are the performance requirements of the action (what activities occur during the remedial action)?
- What is the endpoint, or duration, of the action (when is remediation completed)?

The ARAR analysis is an important part of answering these questions. The need to meet ARARs can be one factor that determines how a remedial action is to be implemented.

1.2 Definition of ARARs and the CERCLA Process

Congress mandated in Section 121(d) of the 1986 Superfund Amendments and Reauthorization Act (SARA) that site cleanups conducted under CERCLA must comply with the requirements of federal laws, and duly promulgated state environmental laws that are stricter than federal laws that are applicable or relevant and appropriate to the remedial actions. These laws are known in the Superfund program as ARARs.

Once a requirement has been determined to be an ARAR, the remedial action chosen by U.S. EPA must comply with that requirement (unless a waiver, as defined by SARA, can be invoked). Potential ARARs are identified in the RI/FS, and then the final list of ARARs that the remedy must meet is established in the ROD.

The ARARs must be identified on a site-specific basis involving a two-part analysis: first, a determination of whether a given requirement is applicable, then, if it is not applicable, a determination of whether it is both relevant *and* appropriate.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly apply and specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. A promulgated requirement is one that is legally enforceable and of general applicability. "Legally enforceable" means that

the law or standard must be issued in accordance with state or federal procedural requirements and contain specific enforcement provisions.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not specifically "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Determining that a requirement is relevant and appropriate generally involves comparing a number of site-specific factors, including the characteristics of the remedial action, the hazardous substances present at the site, and the physical characteristics of the site, with the factors addressed in the statutory or regulatory requirement. If the requirement is not both relevant *and* appropriate, it is not considered an ARAR for the site. It is possible for portions of a requirement to be considered both relevant and appropriate while the rest may be dismissed as irrelevant or inappropriate. If a requirement is determined to be both relevant and appropriate, the requirement must be complied with to the same degree as if it were applicable.

Five criteria must be met for a regulation to be considered a state ARAR:

1. Promulgated standard, requirement, criterion, or limitation;

2. More stringent than federal standards, requirements, criteria, or limitations;

3. Identified to U.S. EPA by the state in a timely manner;

4. Structured so that it does not result in a statewide prohibition on land disposal; and

5. Consistently applied statewide.

If a state standard is determined to be "applicable" while a more stringent federal standard is "relevant and appropriate," the more stringent federal standard will govern.

State and federal ARARs can be divided into three categories: ambient or chemical-specific requirements; location-specific requirements; and performance, design, or other action-specific requirements. They are defined as follows:

- **Chemical-Specific ARARs** include those laws and requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limitations for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should generally be applied.

- **Location-Specific ARARs** are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the type of remedial actions that can be implemented and may impose additional constraints on the cleanup action.

- **Action-Specific ARARs** are requirements that define acceptable treatment and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the remedial activities that are selected to accomplish a remedy. Because there are usually several alternative actions for any remedial site, different requirements can come into play. The action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate the performance requirements that a selected alternative must achieve. These will be evaluated in individual feasibility studies.

According to CERCLA 121(e), a remedial response action that takes place entirely on site may proceed without obtaining permits. This exemption allows the remedial action to progress in a timely manner without the lengthy delays of approval from administrative bodies. Although the administrative requirements do not need to be met, the remedial action must still comply with the substantive requirements of the ARAR. Therefore, if an environmental law imposes a certain limit that is an ARAR while also requiring a permit, the Air Force need meet only the limit (substantive) and would not have to acquire the permit (administrative) before taking the remedial action.

1.3 Definition of TBCs and the CERCLA Process

A requirement may not meet the definition of ARAR as defined above, but may still be useful in determining whether to take action at a site or to what degree action is necessary. This can apply, for example, when there are no ARARs for a site.

Such requirements are called TBCs. The TBC requirements are nonpromulgated advisories or guidance issued by federal or state government that are not legally binding but may provide useful information or recommended procedures for remedial action. Although TBCs do not have the status of ARARs, they are considered along with ARARs as part of the site risk assessment to establish the required level of cleanup for protection of health or the environment.

The critical difference between a TBC and an ARAR is that the Air Force is not legally bound to comply with or meet a TBC when deciding on a remedial action. However, should the Air Force establish a TBC as a cleanup standard in the ROD, then the TBC effectively functions as an ARAR.

The ARARs and TBCs are identified at various points throughout the Superfund process. These criteria are identified on a site-specific basis, and as additional information is developed for the site, including special features of the site location, the specific chemicals at the site, and the actions that are being considered as remedies, more ARARs will be identified and the list of potential ARARs will be further refined. Figure A-1 is a summary of which ARARs or actions are identified and communicated at each stage of the Superfund process. This appendix identifies only potential chemical and location-specific ARARs and TBCs.

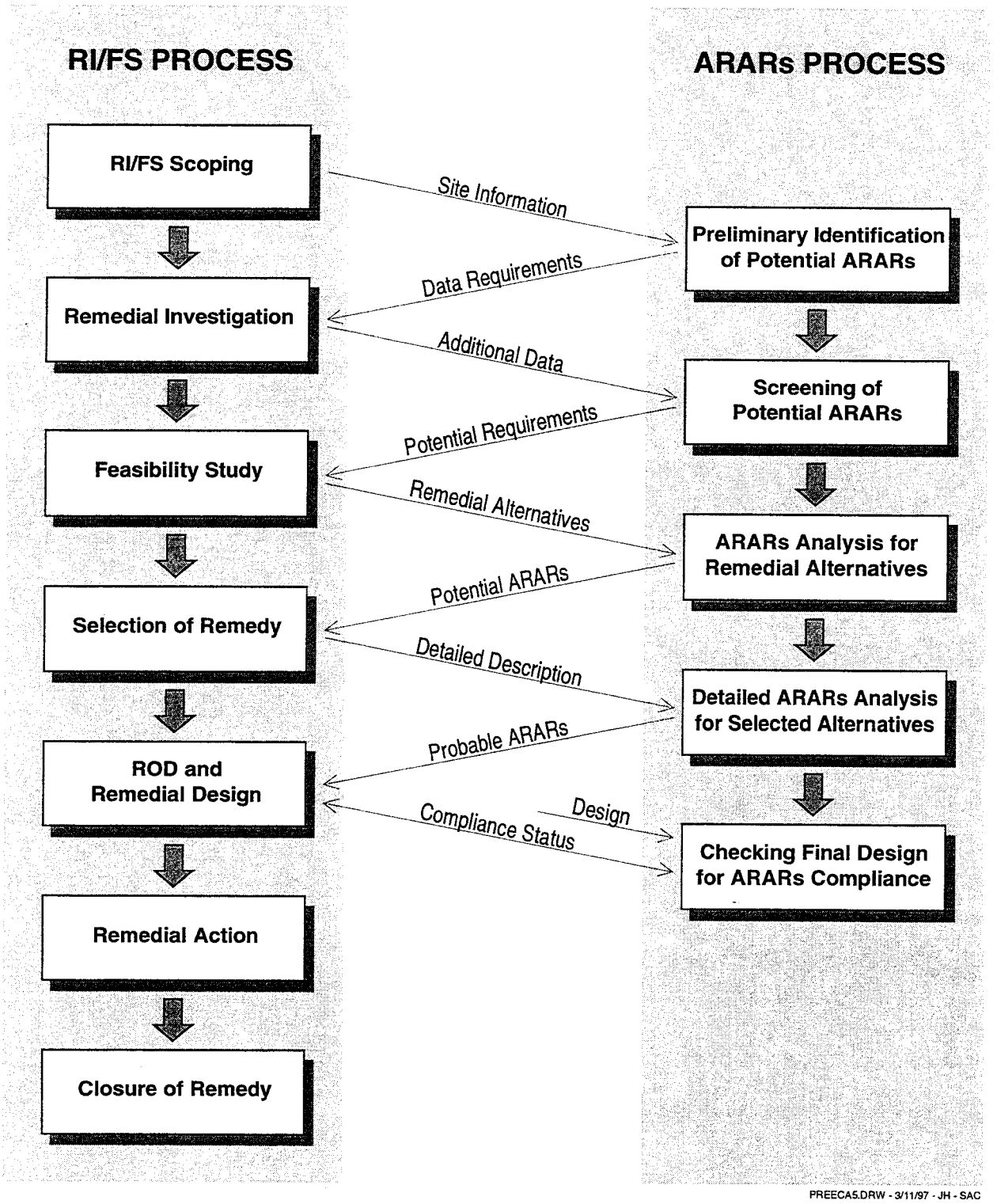
1.4 Waivers

Section 121 in CERCLA provides that, under certain circumstances, an otherwise applicable or relevant and appropriate requirement may be waived. These waivers apply only to the attainment of the ARAR; other statutory requirements, such as that remedies be protective of human health and the environment, cannot be waived. The waivers provided by CERCLA Section 121(d)(4) are listed below:

1. **Interim-Remedy**—The remedial action selected is only part of a total remedial action that will attain such a level or standard of control when completed.

2. **Greater Risk to Human Health or the Environment**—Compliance with the requirement at the site will result in greater risk to human health and the environment than alternative options.

3. **Technical Impracticability—Compliance with the requirement is technically impracticable from an engineering perspective.**



Source: CH2M HILL

Figure A-1. Interaction of the ARARs Process and the RI/FS Process

4. **Equivalent Standard of Performance**—The remedial action selected will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, criterion, or limitation through use of another method or approach.

5. **Inconsistent Application of State Requirements**—With respect to a state standard, requirement, criterion, or limitation, the state has not consistently applied (or demonstrated the intention to apply consistently) the standard, requirement, criterion, or limitation in similar circumstances at other remedial actions.

6. **Fund Balancing**—In the case of a remedial action to be undertaken solely under Section 104 using the fund, selection of a remedial action that attains the level or standard of control in the requirement will not provide a balance between the need for protection of public health and welfare and the environment at the site under consideration, and the availability of amounts from the fund to respond to other sites that present or may present a threat to public health or welfare or the environment, taking into consideration the relative immediacy of such threats. The fund balancing waiver is not applicable to THE AIR FORCE because remedial actions at the base are not fund actions.

ARAR waivers are considered throughout the ARAR identification process and documented in an appendix to each FS document. The ROD documents the rationale for any selected ARAR waivers.

2.0 POTENTIAL CHEMICAL-SPECIFIC ARARS AND TBCS

Chemical-specific ARARs and TBCs are typically health-based or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values, in turn, establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment (soil, groundwater, surface water, or air) as a result of the final remedial action(s) selected. Potential chemical-specific ARARs are presented below. These ARARs and TBCs are organized by medium (groundwater, surface water, soil, and soil gas), and are further subdivided into federal and state requirements. Table A-1 lists the chemical-specific ARARs and TBCs included in this appendix. The section of this appendix that provides additional discussion of each of the ARARs or TBCs listed in Table A-1 is listed after each ARAR/TBC title.

Table A-1. Potential Chemical-Specific ARARs And TBCs

ARAR/TBC	ARAR or TBC	Federal or State Requirement	Potential Applicability to Remedial Action
Federal Drinking Water Standards (Section 2.1.1)	ARAR	Federal	Cleanup levels for groundwater
Region IX Preliminary Remediation Goals (PRGs) (Sections 2.1.2 and 2.5.4)	TBC	Federal	Action and cleanup levels for soil, air, and groundwater
Federal Health Advisories (Section 2.1.3)	TBC	Federal	Cleanup levels for groundwater
Federal Water Quality Standards (40 CFR 131) (Section 2.3.1)	ARAR	Federal	Requirements for discharge of material into surface water
National Pollutant Discharge Elimination System (40 CFR 122-125) (Section 2.4.1)	ARAR	Federal/State Administered	Wastewater discharge requirements to storm drains and wastewater treatment plants.
RCRA Proposed Corrective Action Media Action Levels (Section 2.5.1)	TBC	Federal	Cleanup levels for soil
Resource Conservation and Recovery Act (Section 2.5.2)	ARAR	Federal/State Administered	Standards for storage or treatment of hazardous wastes
Toxic Substances Control Act (Section 2.5.3)	ARAR	Federal	Standards for storage, handling, transportation, and cleanup of PCB-contaminated soil
Guidance on Remedial Actions for Superfund Sites with PCB Contamination (Section 2.5.3)	TBC	Federal	Cleanup levels for soils contaminated with PCBs

2.1 Federal Groundwater ARARs and TBCs

2.1.1 Federal Drinking Water Standards

Federal drinking water standards (40 CFR Part 141) have been established and must be considered during development of remediation strategies. Pursuant to 40 CFR 300.430(e)(2)(i)(B), maximum contaminant levels (MCLs) are relevant and appropriate as in situ aquifer standards for groundwater. The National Primary Drinking Water Regulations establish MCLs that are enforceable standards under the Safe Drinking Water Act for specific contaminants in public water supplies. The MCLs are "applicable" to public water systems serving water directly to 25 or more people or to 15 or more service connections. In this instance, the MCLs are applied at the tap. Federal secondary MCLs are not enforceable and are therefore TBCs but not ARARs.

Maximum contaminant level goals (MCLGs) are strictly health-based standards from which MCLs are derived. Where relevant and appropriate to the circumstances of a release, MCLGs set at levels above zero must be followed. The corresponding MCL must be followed where the MCLG is determined not to be relevant and appropriate (see 40 CFR 300.430 (e)(2)(i)(B)).

Table A-2 presents the federal MCLs, national secondary drinking water standards, and national MCLGs for the constituents regulated by the federal Safe Drinking Water Act. As noted in the footnotes to the table, the federal MCL and MCLG list includes a number of revisions that were

adopted by the U.S. EPA in 1991 and 1992 but only became effective on January 17, 1994.

Table A-2. Federal Drinking Water Standards

Contaminants	National Primary MCLs[a] (mg/L)	National Secondary MCLs[b] (mg/L)	National MCLGs[c] (mg/L)
ORGANICS			
Atrazine	0.003	—	0.003
Bentazone	—	—	—
Benzene	0.005	—	zero
Carbofuran	0.04	—	0.04
Carbon tetrachloride	0.005	—	zero
Chlordane	0.002	—	—
Chloroform	0.1	—	—
Chlorophenoxys/2,4-d	0.07	—	0.07
Chlorophenoxys/2,4,5-TP Silvex	0.05	—	0.05
1,2-Dibromo-3-chloropropane	0.0002	—	zero
Di(2-ethylhexyl)phthalate	0.006[s]	—	zero[d]
1,4-Dichlorobenzene	0.075	0.005	0.075
1,1-Dichloroethane	—	—	—
1,2-Dichloroethane	0.005	—	zero
cis-1,2-Dichloroethene	0.07	—	0.07
trans-1,2-Dichloroethene	0.10	—	0.10
1,1-Dichloroethylene	0.007	—	0.007
1,2-Dichloropropane	0.005	—	zero
1,3-Dichloropropene	—	—	—
Di(2-ethylhexyl)phthalate	—	—	—
Endrin	0.002	—	0.002
Ethylbenzene	0.7	—	0.7
Ethylene dibromide	0.00005	—	zero
Glyphosate	0.70	—	0.70
Heptachlor	0.0004	—	zero
Heptachlor epoxide	0.0002	—	zero
Lindane	0.0002	—	0.0002
Methyoxychlor	0.04	—	0.04
Molinate	—	—	—
Monochlorobenzene	0.10	—	0.10
Simazine	0.04	—	0.04
1,1,2,2-Tetrachloroethane	—	—	—
Tetrachloroethylene	0.005	—	zero
Thiobencarb	—	—	—
Toluene	1	—	1
Toxaphene	0.003	—	zero
1,1,1-Trichloroethane	0.2	—	0.20
1,1,2-Trichloroethane	0.005[e]	—	0.003[f]
Trichloroethylene	0.005	—	zero
Trichlororfluoromethane	—	—	—
1,1,2-Trichloro-1,2,2-Trifluoroethane	0.002	—	zero
Vinyl chloride	—	—	—
Xylenes (total)	10	0.020	10
INORGANICS			
Aluminum	—	0.05 TO 0.2	—
Antimony	0.006[c]	—	0.006[d]
Arsenic	0.05[d]	—	—
Asbestos	7 million fibers/liter	—	—
Barium	2.0	—	2.0

Table A-2. Federal Drinking Water Standards			
Contaminants	National Primary MCLs[a] (mg/L)	National Secondary MCLs[b] (mg/L)	National MCLGs[c] (mg/L)
Beryllium	0.004[c]	—	0.004[c]
Cadmium	0.005	—	0.005
Chloride	—	250	—
Chromium	0.1	—	0.1
Copper	1.3[d]	1.0	1.3
Cyanide (as free cyanide)	0.2[e]	—	0.2[e]
Fluoride	4.0	2.0	4.0
Iron	—	0.3	—
Lead	0.015[d]	—	zero
Manganese	—	0.05	—
Mercury	0.002	—	0.002
Nickel	0.1[c]	—	0.1[c]
Nitrate (as NO_3)	10	—	10
Nitrite (as nitrogen)	1	—	1
Total nitrate and nitrile (as nitrogen)	10	—	10
Selenium	0.05	—	0.05
Silver	—	0.1	—
Sulfate	400–500	250	400–500
TDS (total dissolved solids)	—	500	—
Thallium	0.002[c]	—	0.0005[d]
Zinc	—	5	—
PHYSICAL PROPERTIES			
pH	—	6.5–8.5 S.U.	—
SEMIVOLATILE ORGANIC COMPOUNDS			
Benzo(a)pyrene	0.0002[c]	—	zero
ORGANOCHLORINE PESTICIDES AND PCBs			
PCB 1260	0.0005	—	zero
PCB 1254	0.0005	—	zero
PCB 1248	0.0005	—	zero
PCB 1242	0.0005	—	zero

[a] From 40 CFR, Section 141.61 for organics and Section 141.62 for inorganics (effective 30 July 1992, unless otherwise noted).
[b] From 40 CFR, Section 143.3 (effective 30 July 1992, unless otherwise noted).
[c] From 40 CFR, Section 141.50 for organics and Section 141.51 for inorganics (effective 30 July 1992, unless otherwise noted).

— MCL or MCLG not specified.

2.1.2 U.S. EPA Preliminary Remediation Goals

U.S. EPA Region IX has drafted Preliminary Remediation Goals (PRGs) for soil, air, and tap water, which were issued in April 1993 and updated on February 1, 1994. PRGs are health-based concentrations that can be used as triggers for further investigation or as initial cleanup goals if applicable. A site-specific risk assessment will generally supersede PRGs, because a site-specific

risk assessment applies to local receptor populations and exposure pathways. These draft remediation goals are currently under revision and are not considered ARARs. They are, however, TBC criteria in the absence of ARARs or where ARARs are not sufficiently protective.

2.1.3 Federal Health Advisories

Federal health advisories are criteria published by U.S. EPA's Office of Drinking Water, founded on the National Academy of Science's Suggested Non-Adverse Response Levels (SNARLS) at which no known or anticipated adverse human health effects would occur, given an adequate margin of safety. Health advisories are draft documents that are subject to change as new information becomes available. The SNARL health advisories are TBC criteria.

2.2 Federal Surface Water ARARs and TBCs

2.2.1 Federal Water Quality Standards

Sources of federal water quality standards include 40 CFR 131 and U.S. EPA *Quality Criteria for Water 1991* (U.S. EPA 440/5-86-001, May 1991). These water quality standards apply only to surface waters, not to groundwater. A water quality standard defines the water quality goals of a water body by designating the use or uses to be made of the water and by setting criteria as necessary to protect the uses. Water quality standards serve to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. The U.S. EPA also has developed ambient surface water quality criteria (SWQC) for the protection of aquatic life, which are found in *Quality Criteria for Water 1991*, and are presented in Table A-3. These federal SWQC establish acceptable instream concentrations of pollutants for the protection of aquatic life.

Table A-3. Federal Surface Water Quality Criteria				
	Freshwater SWQC			
Chemical	Acute (mg/L)		Chronic (mg/L)	
METALS				
Aluminum	2	750	5	87
Antimony	2	88	5	30
Arsenic	2	360	5	190
Barium	2	NA	5	NA
Beryllium	2	130 [a]	5	5.3[a]
Cadmium	2	1.4	5	0.55
Calcium	2	NA	5	NA
Carbon disulfide		ND		ND
Chromium (total)	2	1,700+[b]	5	210+[b]
Cobalt	2	NA	5	NA
Copper	2	7.5	5	5.4
Iron	2	NA	5	NA
Lead	2	25	5	0.99
Magnesium	2	NA	5	NA
Manganese	2	NA	5	NA
Mercury	2	2.4	5	0.012
Molybdenum	2	NA	5	NA
Nickel	2	653	5	73
Potassium	2	NA	5	NA
Selenium	2	20	5	5
Silver	2	0.84	5	0.12
Sodium	2	NA	5	NA
Thallium	2	1,400[a,b]	5	40[a,b]
Tin	2	--	5	--
Vanadium	2	NA	5	NA
Zinc	2	54	5	49
ORGANOCHLORINE PESTICIDES AND PCBs				
alpha-BHC		100		NA
delta-BHC		100		NA
4,4'-DDD	4	0.6		NA
4,4'-DDE	4	1,050		NA
4,4'-DDT	1	1.1	6	0.001
PCB 1260	4	2	3	0.014
PCB 1254	4	2	3	0.014
PCB 1248	4	2	3	0.014
PCB 1242	4	2	3	0.014

Table A-3. Federal Surface Water Quality Criteria				
	Freshwater SWQC			
Chemical		Acute (mg/L)		Chronic (mg/L)
VOLATILE ORGANICS COMPOUNDS				
Acetone		NA		NA
Benzene	4	5,300[a]		NA
Bromodichloromethane	4	11,000[a]		NA
Carbon tetrachloride	4	35,200[a]		NA
Chlorobenzene	4	250[a]		50[a]
Chloroform	4	28,900[a]	7	1,240[a]
1,2-Dichloroethane	4	118,000[a]	7	20,000[a]
1,1-Dichloroethane		NA		NA
1,2-Dichloroethene		11,600		NA
trans-1,2-Dichloroethene	4	11,600[a]		NA
Ethyl benzene	4	32,000[a]		NA
4-Methyl-2-pentanone		NA		NA
Methylene chloride	4	11,000[a]		NA
1,1,1,2-Tetrachloroethane		NA		NA
1,1,2,2-Tetrachloroethane	4	9,320	7	2,400[a]
Tetrachloroethene	4	5,280		NA
Toluene	4	17,000		NA
1,1,1-Trichloroethane	4	18,000[a]		NA
1,1,2-Trichloroethane	4	18,000[a]		9,400[a]
Trichloroethene	4	45,000[a]		21,900[a]
Trichlorofluoromethane	4	11,000[a]		NA
Xylenes (total)		NA		NA
SEMIVOLATILE ORGANICS COMPOUNDS				
Acenaphthene	4	1,700		[c]
Anthracene		NA		NA
Benzo(a)anthracene		NA		NA
Benzo(a)pyrene		NA		NA
Benzo(b)fluoranthene		NA		NA
Benzo(k)fluoranthene		NA		NA
Butylbenzylphthalate	4	940[a]		3[a]
Chrysene		NA		NA
Di-n-butylphthalate	4	940[a]		3[a]
Dibenz(a,h)anthracene		NA		NA
Dibenzofuran		NA		NA
bis(2-Ethylhexyl)phthalate		400		360
Fluoranthene	4	3980		NA
2-Hexanone		NA		NA

Table A-3. Federal Surface Water Quality Criteria				
	Freshwater SWQC			
Chemical	Acute (mg/L)		Chronic (mg/L)	
2-Methylnaphthalene	--		--	
2-Methylphenol	--		--	
Naphthalene	4	2300		620
Phenanthrene	5	30	2	6.3
Phenol	4	10200[a]	7	2560[a]
Pyrene		NA		NA
GENERAL				
Cyanide	5	22	2	5.2
Total organic carbon		--		--

[a] Lowest effect concentration, criteria not available.

[b] U.S. Environmental Protection Agency (EPA). "Amendments to The Water Quality Standards Regulation to Establish the Numeric Criteria for Priority Toxic Pollutants Necessary to Bring All States into Compliance with Section 303(c)(2)(B); Final Rule. *Federal Register* 60848, Tuesday, December 22, 1992.

[c] (Total NH_3) pH and temperature dependent.

HBL = Health-Based Level
NA = Indicates the absence of criteria recommendations.
U = Under review.
-- = Not available.
+ = Hardness dependent criteria (100 mg/l used).

Source: *USEPA Quality Criteria for Water*, May 1991, unless otherwise noted, and "A Compilation of Water Quality Goals," California Central Valley RWQCB (Marshack, May 1993).

(1) Acute used Maximum-Instantaneous
(2) Acute used Maximum-1 hour average
(3) Acute used Maximum 24-hour average
(4) Acute used additional toxicity information
(5) Chronic used 4-day
(6) Chronic used 24 hours
(7) Chronic used additional toxicity

2.3 Federal Soil ARARs and TBCs

2.3.1 U.S. EPA RCRA Proposed Corrective Action Media Action Levels

The proposed Resource Conservation and Recovery Act (RCRA) corrective action Subpart S regulations 40 CFR Part 264, Subpart S, Section 264.521 (proposed July 27, 1990, 55 *Federal Register* 30798 *et seq.*), contain methodology and criteria for calculating action levels for contaminants in soil, water, and air. Action levels are not cleanup standards; rather, an exceedance of a solid waste management unit (SWMU) level potentially triggers the need for a corrective measures study (CMS) of a solid waste. Appendix A of the proposed rule presents example action levels that are to be updated as new data on hazardous constituents are developed (preamble, 55 *Federal Register* 30798 at Section VI.E.2.b). Action levels under the proposed Subpart S regulations are to be considered as points of departure for setting cleanup standards.

The RCRA corrective action cleanup standards (media protection standards) (discussed in Section 2.3.1) are established at the CMS stage and may be less stringent than the action levels, depending on the site conditions.

Media cleanup standards are contaminant concentrations that must be achieved by the remedial action under the proposed RCRA corrective action program. Media cleanup standards must ensure protection of human health and the environment, be set for each medium of concern during the remedy selection process, and be met at the "point of compliance" specified in Section 264.525(e) of Subpart S. The U.S. EPA is proposing to set media cleanup standards within the overall context of the remedy selection process.

2.3.2 Federal Hazardous Waste Management Regulations, Resource Conservation and Recovery Act

The RCRA regulates the treatment, storage, and disposal of hazardous wastes. The act contains nine sections (subtitles) that deal with specific waste management activities. Subtitle C 40 CFR Part 261 through 40 CFR Part 268 govern the management of hazardous waste. If RCRA hazardous wastes are present and the RCRA jurisdictional requirements are met, RCRA requirements will apply to CERCLA activities. In the event the RCRA jurisdictional prerequisites are not met, the RCRA requirements may be "relevant and appropriate."

2.3.3 Federal Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) specifies requirements for polychlorinated biphenyls (PCBs). The specific regulations of importance to Superfund actions are found in 40 CFR 761.60-761.79. These regulations specify treatment, storage, and disposal requirements for PCBs based on their form and concentration. The regulations define categories of PCB waste (e.g., liquid PCB, PCB articles, PCB containers, PCB-contaminated electrical equipment, nonliquids, and dredged materials), each of which has specified remediation options dependent on concentration levels.

Although the TSCA requirements do not apply to PCBs at concentrations less than 50 ppm, PCBs cannot be diluted to escape TSCA requirements. For example, if PCB transformers leaked oil containing PCBs at greater than 500 ppm, the soil contaminated by the oil would have to be remediated according to TSCA regulations as if all of the PCB-contaminated soil contained PCBs at greater than 500 ppm.

To address cleanup of sites with PCB contamination, a key U.S. EPA document is *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, OSWER Directive 93554-01, August 1990. Although this document is a TBC, it provides guidance on recommended cleanup levels and remediation strategies for sites with PCB contamination. This document was used in the Operable Unit (OU) B1 remediation project as the key rationale for determining PCB cleanup levels for OU B1. The document specifies that, for soils, the preliminary remediation goals should generally be 1 ppm for sites in or expected to be in residential areas. Higher starting point values (10 to 25 ppm) are suggested for sites where nonresidential land use is anticipated. These concentrations are based on levels above which unrestricted exposure may result in risks exceeding protective levels. The remediation goals for PCBs in groundwater that is potentially drinkable is stated to be the MCL of 0.5 ppb.

2.3.4 U.S. EPA Region IX Preliminary Remediation Goals

U.S. EPA Region IX has drafted PRGs for soil, air, and tap water, which were issued in April 1993 and are updated biannually. These draft remediation goals are not considered ARARs. They are, however, TBC criteria. The text in the following paragraphs is edited from the February 1, 1994 U.S. EPA PRG document.

The Region IX PRG reference tables combine U.S. EPA toxicity values (updated biannually) with health-protective exposure assumptions to estimate "safe" contaminant levels in environmental media (e.g., soil, air, and water). When applicable, Region IX PRGs can be used as a rapid reference for screening concentrations in environmental media, as "triggers" for further investigation at CERCLA sites, and as initial cleanup goals. Chemical concentrations above the levels in the table suggest a need for additional risk analysis.

Before applying the PRGs as initial cleanup goals at a site, it should be considered whether the exposure pathways are fully accounted for in the PRG calculation. Region IX PRGs are based on direct exposures (i.e., ingestion, dermal contact, and inhalation) for specific land-use assumptions. To determine the appropriateness of Region IX PRGs, the U.S. EPA recommends that the following questions be asked:

- Are there potential ecological concerns?
- Is there potential for land use other than uses covered by the PRGs (i.e., residential and industrial)?

- Are there other likely human exposure pathways that were not considered in development of the PRGs (e.g., impact to groundwater; local fish consumption; raising beef, dairy, or other livestock)?

- Are there unusual site conditions (e.g., large areas of contamination, high fugitive dust levels)?

If any of these four conditions exist, the PRG may need to be modified to reflect this new information. In general, PRGs are refined in the site conceptual model developed as part of a site-specific risk assessment.

The U.S. EPA has specifically stated that PRGs are not intended to be used as a (1) stand-alone decision-making tool, (2) substitute for U.S. EPA guidance for preparing baseline risk assessments, (3) source of site-specific cleanup levels, or (4) rule to determine if a waste is hazardous under RCRA. A site-specific risk assessment will generally supersede PRGs because a site-specific risk assessment applies local receptor populations and exposure pathways.

3.0 LOCATION-SPECIFIC ARARS

Location-specific ARARs are requirements that affect the management of hazardous constituents due to the location of the site. They might be triggered, for example, if groundwater remediation were selected as the remedy that required the construction of new surface wastewater treatment units. Examples of sensitive locations for such units include wetlands, floodplains, historic areas, and wildlife refuges. Potential federal location-specific ARARs are set forth in Table A-4.

Table A-4. Potential Federal Location-Specific ARARs

Requirements/Prerequisite	Citation	Comment
Treatment, storage, and disposal for hazardous wastes must be constructed to avoid washouts if located in a 100-year flood plain.	40 CFR 264.18(b)	If a RCRA facility is located in a 100-year flood plain, it must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood.
Relates to actions that will occur in a flood plain, i.e., lowlands and relatively flat areas adjoining inland and coastal waters and other flood-prone areas. Actions must be taken to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Executive Order 11988, Protection of Flood Plains 40 CFR 6, §6.302(b)	Federal agencies are directed to ensure that planning programs and budget requests reflect consideration of flood-plain management, including the restoration and preservation of such land as natural undeveloped flood plains. If newly constructed facilities are to be located in a flood plain, accepted flood-proofing and other flood control measures shall be undertaken to achieve flood protection. Whenever practical, structures shall be elevated above the base flood level rather than fill land. As part of any federal plan or action, the potential for restoring and preserving flood plains so their natural beneficial values can be realized must be considered.
Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data. Construction on previously undisturbed land would require an archaeological survey of the area.	National Archaeological Resources Protection and Historical Preservation Acts (16 USC Sections 469 and 470); 36 CFR Part 65	Since there is always a possibility that buried historic or prehistoric remains could be discovered during a remedial action, mitigation measures to protect an area would be required if such a discovery were uncovered.
Provides for the preservation of historical and archaeological data.		
If property is included in or eligible for the National Register of Historic Places, actions must be taken to preserve historic properties; planning of action to minimize harm to National Historic Landmarks.	National Historic Preservation Action, as amended (16 USC 470 *et seq.*); 36 CFR Part 800.	Determine whether the property is proposed for listing as a National Historic Landmark.
Requires action to conserve endangered species or threatened species, including consultation with the Department of the Interior, Fish and Wildlife Service.	Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 CFR Part 200, 50 CFR Part 402	A complete ecological assessment will have to be conducted at McClellan AFB to confirm the presence of protected bird species.
Lists species of birds protected by four treaties between the U.S. and Canada, Mexico, Japan, and Russia	Migratory Bird Treaty Act (16 USC 703-712) with list of protected birds in 50 CFR 10.13	

Table A-4. (Continued)

Requirements/Prerequisite	Citation	Comment
Wetlands are defined by Executive Order 11990, Section 7. Requires action to minimize the destruction, loss, or degradation of wetlands. Action to prohibit discharge of dredged or fill material into wetlands without permit.	Executive Order 11990, Protection of Wetlands (40 CFR 6, §6.302(a)	If wetlands are located within the area of proposed federal activities, the agency must conduct a wetlands assessment to identify wetlands and potential means of minimizing impacts. If there is no practical alternative to locating in or affecting the wetland, the Agency shall act to minimize potential harm to the wetland.
	Clean Water Act Section 404; 40 CFR Parts 230, 231	The Clean Water Act prohibits discharge of dredged or fill material into wetlands without a permit.
Proposed discharges of dredged or fill material into waters of the U.S. are evaluated with respect to impacts on the aquatic ecosystem.	CWA Section 404 40 CFR 230	
Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife will require actions to protect fish or wildlife.	Fish and Wildlife Coordination Act (16 USCC 661 *et seq.*); 40 CFR 6.302	
Protection of aquifer through federal assistance funding. Applies to aquifers that are sole or principal drinking water sources and if contamination would present a significant hazard to public health. Prohibits injection of waste.	SDWA 42 USC Section 300n; 40 CFR Section 146.4	
Actions to limit worker exposure to hazardous wastes or hazardous substances, including training or monitoring.	20 CFR 1910.120	

4.0 REFERENCES

U.S. Environmental Protection Agency, 1988. CERCLA *Compliance with Other Laws Manual.* Interim Final. August.

U.S. Environmental Protection Agency, 1989. CERCLA Compliance with Other Laws Manual: Part 2--Clean Air Act and Other Environmental Statutes and State Requirements. August.

U.S. Environmental Protection Agency, 1990. *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, OSWER Directive 93554-01, August 1990.

U.S. Environmental Protection Agency, 1991. *Quality Criteria for Water 1991.* EPA 440/5-86-001, May.

U.S. Environmental Protection Agency, Region IX, 1992. *Drinking Water Standards and Health Advisories Table.* December.

U.S. Environmental Protection Agency, 1992. *Drinking Water Regulations and Health Advisories.* December.

U.S. Environmental Protection Agency, Region IX, 1993. Memorandum from Stanford J. Smucker, Ph.D., Regional Toxicologist, to PRG Table Mailing List, re "Region IX Preliminary Remediation Goals (PRGs) First Half 1994. February 1.

ATTACHMENT 1

Guidance for Remediation and Closure (Capping) of Landfills

APPENDIX A

Potential Applicable or Relevant and Appropriate Requirements and "To Be Considered" Requirements

1.0 PURPOSE

The purpose of this appendix is to identify potential chemical- and location-specific applicable or relevant and appropriate requirements (ARARs) and "to be considered" requirements (TBCs) that may apply to Air Force sites. Detailed ARAR evaluations will be included in individual feasibility study or engineering evaluation/cost analysis reports, so that regulatory requirements can be considered when evaluating the feasibility of alternatives. The detailed evaluations will also include action-specific ARARs, which only come into play once alternatives for remediation are being considered.

The potential ARARs identified in this appendix are those that could affect the selection of remediation actions. The United States Environmental Protection Agency (U.S. EPA) and relevant state agencies must approve the application of ARARs to all sites being remediated. Following negotiation of final ARARs, documentation of agreed-upon ARARs is included in any Interim Records of Decision (IRODs). The purpose of this appendix is to present the universe of ARARs that may apply, not to present the process of selecting among these ARARs, which is left to the individual site remediation documents.

1.1 ARARs and the CERCLA Process

The Superfund process is often represented as being serial, with site discovery leading to the remedial investigation and feasibility study (RI/FS), and then to the record of decision (ROD) and remedial actions. This serial representation is, in general, an oversimplification and has led to slow, inefficient progress at sites. Recent efforts to streamline the Superfund process have recognized that it is more complex, with many interrelated processes that are parallel and interdependent. Whether the process for any given site is serial or a complex interrelation of parallel activities, U.S. EPA's mandate through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) is to protect human health and the environment.

One of the first steps in the Superfund process is to define the problem at a site and determine that the action (or no action) taken in response to the problem protects human health and the environment. Along with risk assessment, one of the tools used to define and solve a site problem is evaluation of environmental laws and regulations called ARARs (defined below).

Defining the problem at a site and evaluating the remedial alternatives for solving it require evaluating site data to determine:

- Is remedial action necessary (does a problem exist now or is there a threat of a problem)?
- What is the areal extent of the action (how big is the problem)?
- What are the performance requirements of the action (what activities occur during the remedial action)?
- What is the endpoint, or duration, of the action (when is remediation completed)?

The ARAR analysis is an important part of answering these questions. The need to meet ARARs can be one factor that determines how a remedial action is to be implemented.

1.2 Definition of ARARs and the CERCLA Process

Congress mandated in Section 121(d) of the 1986 Superfund Amendments and Reauthorization Act (SARA) that site cleanups conducted under CERCLA must comply with the requirements of federal laws, and duly promulgated state environmental laws that are stricter than federal laws that are applicable or relevant and appropriate to the remedial actions. These laws are known in the Superfund program as ARARs.

Once a requirement has been determined to be an ARAR, the remedial action chosen by U.S. EPA must comply with that requirement (unless a waiver, as defined by SARA, can be invoked). Potential ARARs are identified in the RI/FS, and then the final list of ARARs that the remedy must meet is established in the ROD.

The ARARs must be identified on a site-specific basis involving a two-part analysis: first, a determination of whether a given requirement is applicable, then, if it is not applicable, a determination of whether it is both relevant *and* appropriate.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly apply and specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. A promulgated requirement is one that is legally enforceable and of general applicability. "Legally enforceable" means that

the law or standard must be issued in accordance with state or federal procedural requirements and contain specific enforcement provisions.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not specifically "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Determining that a requirement is relevant and appropriate generally involves comparing a number of site-specific factors, including the characteristics of the remedial action, the hazardous substances present at the site, and the physical characteristics of the site, with the factors addressed in the statutory or regulatory requirement. If the requirement is not both relevant *and* appropriate, it is not considered an ARAR for the site. It is possible for portions of a requirement to be considered both relevant and appropriate while the rest may be dismissed as irrelevant or inappropriate. If a requirement is determined to be both relevant and appropriate, the requirement must be complied with to the same degree as if it were applicable.

Five criteria must be met for a regulation to be considered a state ARAR:

1. Promulgated standard, requirement, criterion, or limitation;

2. More stringent than federal standards, requirements, criteria, or limitations;

3. Identified to U.S. EPA by the state in a timely manner;

4. Structured so that it does not result in a statewide prohibition on land disposal; and

5. Consistently applied statewide.

If a state standard is determined to be "applicable" while a more stringent federal standard is "relevant and appropriate," the more stringent federal standard will govern.

State and federal ARARs can be divided into three categories: ambient or chemical-specific requirements; location-specific requirements; and performance, design, or other action-specific requirements. They are defined as follows:

- **Chemical-Specific ARARs** include those laws and requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limitations for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should generally be applied.

- **Location-Specific ARARs** are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the type of remedial actions that can be implemented and may impose additional constraints on the cleanup action.

- **Action-Specific ARARs** are requirements that define acceptable treatment and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the remedial activities that are selected to accomplish a remedy. Because there are usually several alternative actions for any remedial site, different requirements can come into play. The action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate the performance requirements that a selected alternative must achieve. These will be evaluated in individual feasibility studies.

According to CERCLA 121(e), a remedial response action that takes place entirely on site may proceed without obtaining permits. This exemption allows the remedial action to progress in a timely manner without the lengthy delays of approval from administrative bodies. Although the administrative requirements do not need to be met, the remedial action must still comply with the substantive requirements of the ARAR. Therefore, if an environmental law imposes a certain limit that is an ARAR while also requiring a permit, the Air Force need meet only the limit (substantive) and would not have to acquire the permit (administrative) before taking the remedial action.

1.3 Definition of TBCs and the CERCLA Process

A requirement may not meet the definition of ARAR as defined above, but may still be useful in determining whether to take action at a site or to what degree action is necessary. This can apply, for example, when there are no ARARs for a site.

Such requirements are called TBCs. The TBC requirements are nonpromulgated advisories or guidance issued by federal or state government that are not legally binding but may provide useful information or recommended procedures for remedial action. Although TBCs do not have the status of ARARs, they are considered along with ARARs as part of the site risk assessment to establish the required level of cleanup for protection of health or the environment.

The critical difference between a TBC and an ARAR is that the Air Force is not legally bound to comply with or meet a TBC when deciding on a remedial action. However, should the Air Force establish a TBC as a cleanup standard in the ROD, then the TBC effectively functions as an ARAR.

The ARARs and TBCs are identified at various points throughout the Superfund process. These criteria are identified on a site-specific basis, and as additional information is developed for the site, including special features of the site location, the specific chemicals at the site, and the actions that are being considered as remedies, more ARARs will be identified and the list of potential ARARs will be further refined. Figure A-1 is a summary of which ARARs or actions are identified and communicated at each stage of the Superfund process. This appendix identifies only potential chemical and location-specific ARARs and TBCs.

1.4 Waivers

Section 121 in CERCLA provides that, under certain circumstances, an otherwise applicable or relevant and appropriate requirement may be waived. These waivers apply only to the attainment of the ARAR; other statutory requirements, such as that remedies be protective of human health and the environment, cannot be waived. The waivers provided by CERCLA Section 121(d)(4) are listed below:

1. **Interim-Remedy**—The remedial action selected is only part of a total remedial action that will attain such a level or standard of control when completed.

2. **Greater Risk to Human Health or the Environment**—Compliance with the requirement at the site will result in greater risk to human health and the environment than alternative options.

3. **Technical Impracticability—Compliance with the requirement is technically impracticable from an engineering perspective.**

Figure A-1. Interaction of the ARARs Process and the RI/FS Process

4. **Equivalent Standard of Performance**—The remedial action selected will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, criterion, or limitation through use of another method or approach.

5. **Inconsistent Application of State Requirements**—With respect to a state standard, requirement, criterion, or limitation, the state has not consistently applied (or demonstrated the intention to apply consistently) the standard, requirement, criterion, or limitation in similar circumstances at other remedial actions.

6. **Fund Balancing**—In the case of a remedial action to be undertaken solely under Section 104 using the fund, selection of a remedial action that attains the level or standard of control in the requirement will not provide a balance between the need for protection of public health and welfare and the environment at the site under consideration, and the availability of amounts from the fund to respond to other sites that present or may present a threat to public health or welfare or the environment, taking into consideration the relative immediacy of such threats. The fund balancing waiver is not applicable to THE AIR FORCE because remedial actions at the base are not fund actions.

ARAR waivers are considered throughout the ARAR identification process and documented in an appendix to each FS document. The ROD documents the rationale for any selected ARAR waivers.

2.0 POTENTIAL CHEMICAL-SPECIFIC ARARS AND TBCS

Chemical-specific ARARs and TBCs are typically health-based or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values, in turn, establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment (soil, groundwater, surface water, or air) as a result of the final remedial action(s) selected. Potential chemical-specific ARARs are presented below. These ARARs and TBCs are organized by medium (groundwater, surface water, soil, and soil gas), and are further subdivided into federal and state requirements. Table A-1 lists the chemical-specific ARARs and TBCs included in this appendix. The section of this appendix that provides additional discussion of each of the ARARs or TBCs listed in Table A-1 is listed after each ARAR/TBC title.

Table A-1. Potential Chemical-Specific ARARs And TBCs

ARAR/TBC	ARAR or TBC	Federal or State Requirement	Potential Applicability to Remedial Action
Federal Drinking Water Standards (Section 2.1.1)	ARAR	Federal	Cleanup levels for groundwater
Region IX Preliminary Remediation Goals (PRGs) (Sections 2.1.2 and 2.5.4)	TBC	Federal	Action and cleanup levels for soil, air, and groundwater
Federal Health Advisories (Section 2.1.3)	TBC	Federal	Cleanup levels for groundwater
Federal Water Quality Standards (40 CFR 131) (Section 2.3.1)	ARAR	Federal	Requirements for discharge of material into surface water
National Pollutant Discharge Elimination System (40 CFR 122-125) (Section 2.4.1)	ARAR	Federal/State Administered	Wastewater discharge requirements to storm drains and wastewater treatment plants.
RCRA Proposed Corrective Action Media Action Levels (Section 2.5.1)	TBC	Federal	Cleanup levels for soil
Resource Conservation and Recovery Act (Section 2.5.2)	ARAR	Federal/State Administered	Standards for storage or treatment of hazardous wastes
Toxic Substances Control Act (Section 2.5.3)	ARAR	Federal	Standards for storage, handling, transportation, and cleanup of PCB-contaminated soil
Guidance on Remedial Actions for Superfund Sites with PCB Contamination (Section 2.5.3)	TBC	Federal	Cleanup levels for soils contaminated with PCBs

2.1 Federal Groundwater ARARs and TBCs

2.1.1 Federal Drinking Water Standards

Federal drinking water standards (40 CFR Part 141) have been established and must be considered during development of remediation strategies. Pursuant to 40 CFR 300.430(e)(2)(i)(B), maximum contaminant levels (MCLs) are relevant and appropriate as in situ aquifer standards for groundwater. The National Primary Drinking Water Regulations establish MCLs that are enforceable standards under the Safe Drinking Water Act for specific contaminants in public water supplies. The MCLs are "applicable" to public water systems serving water directly to 25 or more people or to 15 or more service connections. In this instance, the MCLs are applied at the tap. Federal secondary MCLs are not enforceable and are therefore TBCs but not ARARs.

Maximum contaminant level goals (MCLGs) are strictly health-based standards from which MCLs are derived. Where relevant and appropriate to the circumstances of a release, MCLGs set at levels above zero must be followed. The corresponding MCL must be followed where the MCLG is determined not to be relevant and appropriate (see 40 CFR 300.430 (e)(2)(i)(B)).

Table A-2 presents the federal MCLs, national secondary drinking water standards, and national MCLGs for the constituents regulated by the federal Safe Drinking Water Act. As noted in the footnotes to the table, the federal MCL and MCLG list includes a number of revisions that were

adopted by the U.S. EPA in 1991 and 1992 but only became effective on January 17, 1994.

Table A-2. Federal Drinking Water Standards

Contaminants	National Primary MCLs[a] (mg/L)	National Secondary MCLs[b] (mg/L)	National MCLGs[c] (mg/L)
ORGANICS			
Atrazine	0.003	—	0.003
Bentazone	—	—	—
Benzene	0.005	—	zero
Carbofuran	0.04	—	0.04
Carbon tetrachloride	0.005	—	zero
Chlordane	0.002	—	—
Chloroform	0.1	—	—
Chlorophenoxys/2,4-d	0.07	—	0.07
Chlorophenoxys/2,4,5-TP Silvex	0.05	—	0.05
1,2-Dibromo-3-chloropropane	0.0002	—	zero
Di(2-ethylhexyl)phthalate	0.006[s]	—	zero[d]
1,4-Dichlorobenzene	0.075	0.005	0.075
1,1-Dichloroethane	—	—	—
1,2-Dichloroethane	0.005	—	zero
cis-1,2-Dichloroethene	0.07	—	0.07
trans-1,2-Dichloroethene	0.10	—	0.10
1,1-Dichloroethylene	0.007	—	0.007
1,2-Dichloropropane	0.005	—	zero
1,3-Dichloropropene	—	—	—
Di(2-ethylhexyl)phthalate	—	—	—
Endrin	0.002	—	0.002
Ethylbenzene	0.7	—	0.7
Ethylene dibromide	0.00005	—	zero
Glyphosate	0.70	—	0.70
Heptachlor	0.0004	—	zero
Heptachlor epoxide	0.0002	—	zero
Lindane	0.0002	—	0.0002
Methyoxychlor	0.04	—	0.04
Molinate	—	—	—
Monochlorobenzene	0.10	—	0.10
Simazine	0.04	—	0.04
1,1,2,2-Tetrachloroethane	—	—	—
Tetrachloroethylene	0.005	—	zero
Thiobencarb	—	—	—
Toluene	1	—	1
Toxaphene	0.003	—	zero
1,1,1-Trichloroethane	0.2	—	0.20
1,1,2-Trichloroethane	0.005[e]	—	0.003[f]
Trichloroethylene	0.005	—	zero
Trichlororfluoromethane	—	—	—
1,1,2-Trichloro-1,2,2-Trifluoroethane	0.002	—	zero
Vinyl chloride	—	—	—
Xylenes (total)	10	0.020	10
INORGANICS			
Aluminum	—	0.05 TO 0.2	—
Antimony	0.006[c]	—	0.006[d]
Arsenic	0.05[d]	—	—
Asbestos	7 million fibers/liter	—	—
Barium	2.0	—	2.0

Table A-2. Federal Drinking Water Standards			
Contaminants	National Primary MCLs[a] (mg/L)	National Secondary MCLs[b] (mg/L)	National MCLGs[c] (mg/L)
Beryllium	0.004[c]	—	0.004[c]
Cadmium	0.005	—	0.005
Chloride	—	250	—
Chromium	0.1	—	0.1
Copper	1.3[d]	1.0	1.3
Cyanide (as free cyanide)	0.2[e]	—	0.2[e]
Fluoride	4.0	2.0	4.0
Iron	—	0.3	—
Lead	0.015[d]	—	zero
Manganese	—	0.05	—
Mercury	0.002	—	0.002
Nickel	0.1[c]	—	0.1[c]
Nitrate (as NO_3)	10	—	10
Nitrite (as nitrogen)	1	—	1
Total nitrate and nitrile (as nitrogen)	10	—	10
Selenium	0.05	—	0.05
Silver	—	0.1	—
Sulfate	400–500	250	400–500
TDS (total dissolved solids)	—	500	—
Thallium	0.002[c]	—	0.0005[d]
Zinc	—	5	—
PHYSICAL PROPERTIES			
pH	—	6.5–8.5 S.U.	—
SEMIVOLATILE ORGANIC COMPOUNDS			
Benzo(a)pyrene	0.0002[c]	—	zero
ORGANOCHLORINE PESTICIDES AND PCBs			
PCB 1260	0.0005	—	zero
PCB 1254	0.0005	—	zero
PCB 1248	0.0005	—	zero
PCB 1242	0.0005	—	zero

[a] From 40 CFR, Section 141.61 for organics and Section 141.62 for inorganics (effective 30 July 1992, unless otherwise noted).
[b] From 40 CFR, Section 143.3 (effective 30 July 1992, unless otherwise noted).
[c] From 40 CFR, Section 141.50 for organics and Section 141.51 for inorganics (effective 30 July 1992, unless otherwise noted).

— MCL or MCLG not specified.

2.1.2 U.S. EPA Preliminary Remediation Goals

U.S. EPA Region IX has drafted Preliminary Remediation Goals (PRGs) for soil, air, and tap water, which were issued in April 1993 and updated on February 1, 1994. PRGs are health-based concentrations that can be used as triggers for further investigation or as initial cleanup goals if applicable. A site-specific risk assessment will generally supersede PRGs, because a site-specific

risk assessment applies to local receptor populations and exposure pathways. These draft remediation goals are currently under revision and are not considered ARARs. They are, however, TBC criteria in the absence of ARARs or where ARARs are not sufficiently protective.

2.1.3 Federal Health Advisories

Federal health advisories are criteria published by U.S. EPA's Office of Drinking Water, founded on the National Academy of Science's Suggested Non-Adverse Response Levels (SNARLS) at which no known or anticipated adverse human health effects would occur, given an adequate margin of safety. Health advisories are draft documents that are subject to change as new information becomes available. The SNARL health advisories are TBC criteria.

2.2 Federal Surface Water ARARs and TBCs

2.2.1 Federal Water Quality Standards

Sources of federal water quality standards include 40 CFR 131 and U.S. EPA *Quality Criteria for Water 1991* (U.S. EPA 440/5-86-001, May 1991). These water quality standards apply only to surface waters, not to groundwater. A water quality standard defines the water quality goals of a water body by designating the use or uses to be made of the water and by setting criteria as necessary to protect the uses. Water quality standards serve to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. The U.S. EPA also has developed ambient surface water quality criteria (SWQC) for the protection of aquatic life, which are found in *Quality Criteria for Water 1991*, and are presented in Table A-3. These federal SWQC establish acceptable instream concentrations of pollutants for the protection of aquatic life.

Table A-3. Federal Surface Water Quality Criteria				
	Freshwater SWQC			
Chemical	Acute (mg/L)		Chronic (mg/L)	
METALS				
Aluminum	2	750	5	87
Antimony	2	88	5	30
Arsenic	2	360	5	190
Barium	2	NA	5	NA
Beryllium	2	130 [a]	5	5.3[a]
Cadmium	2	1.4	5	0.55
Calcium	2	NA	5	NA
Carbon disulfide		ND		ND
Chromium (total)	2	1,700+[b]	5	210+[b]
Cobalt	2	NA	5	NA
Copper	2	7.5	5	5.4
Iron	2	NA	5	NA
Lead	2	25	5	0.99
Magnesium	2	NA	5	NA
Manganese	2	NA	5	NA
Mercury	2	2.4	5	0.012
Molybdenum	2	NA	5	NA
Nickel	2	653	5	73
Potassium	2	NA	5	NA
Selenium	2	20	5	5
Silver	2	0.84	5	0.12
Sodium	2	NA	5	NA
Thallium	2	1,400[a,b]	5	40[a,b]
Tin	2	--	5	--
Vanadium	2	NA	5	NA
Zinc	2	54	5	49
ORGANOCHLORINE PESTICIDES AND PCBs				
alpha-BHC		100		NA
delta-BHC		100		NA
4,4'-DDD	4	0.6		NA
4,4'-DDE	4	1,050		NA
4,4'-DDT	1	1.1	6	0.001
PCB 1260	4	2	3	0.014
PCB 1254	4	2	3	0.014
PCB 1248	4	2	3	0.014
PCB 1242	4	2	3	0.014

Table A-3. Federal Surface Water Quality Criteria				
		Freshwater SWQC		
Chemical		Acute (mg/L)		Chronic (mg/L)
VOLATILE ORGANICS COMPOUNDS				
Acetone		NA		NA
Benzene	4	5,300[a]		NA
Bromodichloromethane	4	11,000[a]		NA
Carbon tetrachloride	4	35,200[a]		NA
Chlorobenzene	4	250[a]		50[a]
Chloroform	4	28,900[a]	7	1,240[a]
1,2-Dichloroethane	4	118,000[a]	7	20,000[a]
1,1-Dichloroethane		NA		NA
1,2-Dichloroethene		11,600		NA
trans-1,2-Dichloroethene	4	11,600[a]		NA
Ethyl benzene	4	32,000[a]		NA
4-Methyl-2-pentanone		NA		NA
Methylene chloride	4	11,000[a]		NA
1,1,1,2-Tetrachloroethane		NA		NA
1,1,2,2-Tetrachloroethane	4	9,320	7	2,400[a]
Tetrachloroethene	4	5,280		NA
Toluene	4	17,000		NA
1,1,1-Trichloroethane	4	18,000[a]		NA
1,1,2-Trichloroethane	4	18,000[a]		9,400[a]
Trichloroethene	4	45,000[a]		21,900[a]
Trichlorofluoromethane	4	11,000[a]		NA
Xylenes (total)		NA		NA
SEMIVOLATILE ORGANICS COMPOUNDS				
Acenaphthene	4	1,700		[c]
Anthracene		NA		NA
Benzo(a)anthracene		NA		NA
Benzo(a)pyrene		NA		NA
Benzo(b)fluoranthene		NA		NA
Benzo(k)fluoranthene		NA		NA
Butylbenzylphthalate	4	940[a]		3[a]
Chrysene		NA		NA
Di-n-butylphthalate	4	940[a]		3[a]
Dibenz(a,h)anthracene		NA		NA
Dibenzofuran		NA		NA
bis(2-Ethylhexyl)phthalate		400		360
Fluoranthene	4	3980		NA
2-Hexanone		NA		NA

Table A-3. Federal Surface Water Quality Criteria				
	Freshwater SWQC			
Chemical	Acute (mg/L)		Chronic (mg/L)	
2-Methylnaphthalene		--		--
2-Methylphenol		--		--
Naphthalene	4	2300		620
Phenanthrene	5	30	2	6.3
Phenol	4	10200[a]	7	2560[a]
Pyrene		NA		NA
GENERAL				
Cyanide	5	22	2	5.2
Total organic carbon		--		--

[a] Lowest effect concentration, criteria not available.

[b] U.S. Environmental Protection Agency (EPA). "Amendments to The Water Quality Standards Regulation to Establish the Numeric Criteria for Priority Toxic Pollutants Necessary to Bring All States into Compliance with Section 303(c)(2)(B); Final Rule. *Federal Register* 60848. Tuesday, December 22, 1992.

[c] (Total NH_3) pH and temperature dependent.

HBL	=	Health-Based Level
NA	=	Indicates the absence of criteria recommendations.
U	=	Under review.
--	=	Not available.
+	=	Hardness dependent criteria (100 mg/l used).

Source: *USEPA Quality Criteria for Water*, May 1991, unless otherwise noted, and "A Compilation of Water Quality Goals," California Central Valley RWQCB (Marshack, May 1993).

(1) Acute used Maximum-Instantaneous
(2) Acute used Maximum-1 hour average
(3) Acute used Maximum 24-hour average
(4) Acute used additional toxicity information
(5) Chronic used 4-day
(6) Chronic used 24 hours
(7) Chronic used additional toxicity

2.3 Federal Soil ARARs and TBCs

2.3.1 U.S. EPA RCRA Proposed Corrective Action Media Action Levels

The proposed Resource Conservation and Recovery Act (RCRA) corrective action Subpart S regulations 40 CFR Part 264, Subpart S, Section 264.521 (proposed July 27, 1990, 55 *Federal Register* 30798 *et seq.*), contain methodology and criteria for calculating action levels for contaminants in soil, water, and air. Action levels are not cleanup standards; rather, an exceedance of a solid waste management unit (SWMU) level potentially triggers the need for a corrective measures study (CMS) of a solid waste. Appendix A of the proposed rule presents example action levels that are to be updated as new data on hazardous constituents are developed (preamble, 55 *Federal Register* 30798 at Section VI.E.2.b). Action levels under the proposed Subpart S regulations are to be considered as points of departure for setting cleanup standards.

The RCRA corrective action cleanup standards (media protection standards) (discussed in Section 2.3.1) are established at the CMS stage and may be less stringent than the action levels, depending on the site conditions.

Media cleanup standards are contaminant concentrations that must be achieved by the remedial action under the proposed RCRA corrective action program. Media cleanup standards must ensure protection of human health and the environment, be set for each medium of concern during the remedy selection process, and be met at the "point of compliance" specified in Section 264.525(e) of Subpart S. The U.S. EPA is proposing to set media cleanup standards within the overall context of the remedy selection process.

2.3.2 Federal Hazardous Waste Management Regulations, Resource Conservation and Recovery Act

The RCRA regulates the treatment, storage, and disposal of hazardous wastes. The act contains nine sections (subtitles) that deal with specific waste management activities. Subtitle C 40 CFR Part 261 through 40 CFR Part 268 govern the management of hazardous waste. If RCRA hazardous wastes are present and the RCRA jurisdictional requirements are met, RCRA requirements will apply to CERCLA activities. In the event the RCRA jurisdictional prerequisites are not met, the RCRA requirements may be "relevant and appropriate."

2.3.3 Federal Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) specifies requirements for polychlorinated biphenyls (PCBs). The specific regulations of importance to Superfund actions are found in 40 CFR 761.60-761.79. These regulations specify treatment, storage, and disposal requirements for PCBs based on their form and concentration. The regulations define categories of PCB waste (e.g., liquid PCB, PCB articles, PCB containers, PCB-contaminated electrical equipment, nonliquids, and dredged materials), each of which has specified remediation options dependent on concentration levels.

Although the TSCA requirements do not apply to PCBs at concentrations less than 50 ppm, PCBs cannot be diluted to escape TSCA requirements. For example, if PCB transformers leaked oil containing PCBs at greater than 500 ppm, the soil contaminated by the oil would have to be remediated according to TSCA regulations as if all of the PCB-contaminated soil contained PCBs at greater than 500 ppm.

To address cleanup of sites with PCB contamination, a key U.S. EPA document is *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, OSWER Directive 93554-01, August 1990. Although this document is a TBC, it provides guidance on recommended cleanup levels and remediation strategies for sites with PCB contamination. This document was used in the Operable Unit (OU) B1 remediation project as the key rationale for determining PCB cleanup levels for OU B1. The document specifies that, for soils, the preliminary remediation goals should generally be 1 ppm for sites in or expected to be in residential areas. Higher starting point values (10 to 25 ppm) are suggested for sites where nonresidential land use is anticipated. These concentrations are based on levels above which unrestricted exposure may result in risks exceeding protective levels. The remediation goals for PCBs in groundwater that is potentially drinkable is stated to be the MCL of 0.5 ppb.

2.3.4 U.S. EPA Region IX Preliminary Remediation Goals

U.S. EPA Region IX has drafted PRGs for soil, air, and tap water, which were issued in April 1993 and are updated biannually. These draft remediation goals are not considered ARARs. They are, however, TBC criteria. The text in the following paragraphs is edited from the February 1, 1994 U.S. EPA PRG document.

The Region IX PRG reference tables combine U.S. EPA toxicity values (updated biannually) with health-protective exposure assumptions to estimate "safe" contaminant levels in environmental media (e.g., soil, air, and water). When applicable, Region IX PRGs can be used as a rapid reference for screening concentrations in environmental media, as "triggers" for further investigation at CERCLA sites, and as initial cleanup goals. Chemical concentrations above the levels in the table suggest a need for additional risk analysis.

Before applying the PRGs as initial cleanup goals at a site, it should be considered whether the exposure pathways are fully accounted for in the PRG calculation. Region IX PRGs are based on direct exposures (i.e., ingestion, dermal contact, and inhalation) for specific land-use assumptions. To determine the appropriateness of Region IX PRGs, the U.S. EPA recommends that the following questions be asked:

- Are there potential ecological concerns?
- Is there potential for land use other than uses covered by the PRGs (i.e., residential and industrial)?

- Are there other likely human exposure pathways that were not considered in development of the PRGs (e.g., impact to groundwater; local fish consumption; raising beef, dairy, or other livestock)?

- Are there unusual site conditions (e.g., large areas of contamination, high fugitive dust levels)?

If any of these four conditions exist, the PRG may need to be modified to reflect this new information. In general, PRGs are refined in the site conceptual model developed as part of a site-specific risk assessment.

The U.S. EPA has specifically stated that PRGs are not intended to be used as a (1) stand-alone decision-making tool, (2) substitute for U.S. EPA guidance for preparing baseline risk assessments, (3) source of site-specific cleanup levels, or (4) rule to determine if a waste is hazardous under RCRA. A site-specific risk assessment will generally supersede PRGs because a site-specific risk assessment applies local receptor populations and exposure pathways.

3.0 LOCATION-SPECIFIC ARARS

Location-specific ARARs are requirements that affect the management of hazardous constituents due to the location of the site. They might be triggered, for example, if groundwater remediation were selected as the remedy that required the construction of new surface wastewater treatment units. Examples of sensitive locations for such units include wetlands, floodplains, historic areas, and wildlife refuges. Potential federal location-specific ARARs are set forth in Table A-4.

Table A-4. Potential Federal Location-Specific ARARs

Requirements/Prerequisite	Citation	Comment
Treatment, storage, and disposal for hazardous wastes must be constructed to avoid washouts if located in a 100-year flood plain.	40 CFR 264.18(b)	If a RCRA facility is located in a 100-year flood plain, it must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood.
Relates to actions that will occur in a flood plain, i.e., lowlands and relatively flat areas adjoining inland and coastal waters and other flood-prone areas. Actions must be taken to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Executive Order 11988, Protection of Flood Plains 40 CFR 6, §6.302(b)	Federal agencies are directed to ensure that planning programs and budget requests reflect consideration of flood-plain management, including the restoration and preservation of such land as natural undeveloped flood plains. If newly constructed facilities are to be located in a flood plain, accepted flood-proofing and other flood control measures shall be undertaken to achieve flood protection. Whenever practical, structures shall be elevated above the base flood level rather than fill land. As part of any federal plan or action, the potential for restoring and preserving flood plains so their natural beneficial values can be realized must be considered.
Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data. Construction on previously undisturbed land would require an archaeological survey of the area.	National Archaeological Resources Protection and Historical Preservation Acts (16 USC Sections 469 and 470); 36 CFR Part 65	Since there is always a possibility that buried historic or prehistoric remains could be discovered during a remedial action, mitigation measures to protect an area would be required if such a discovery were uncovered.
Provides for the preservation of historical and archaeological data.		
If property is included in or eligible for the National Register of Historic Places, actions must be taken to preserve historic properties; planning of action to minimize harm to National Historic Landmarks.	National Historic Preservation Action, as amended (16 USC 470 *et seq.*); 36 CFR Part 800.	Determine whether the property is proposed for listing as a National Historic Landmark.
Requires action to conserve endangered species or threatened species, including consultation with the Department of the Interior, Fish and Wildlife Service.	Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 CFR Part 200, 50 CFR Part 402	A complete ecological assessment will have to be conducted at McClellan AFB to confirm the presence of protected bird species.
Lists species of birds protected by four treaties between the U.S. and Canada, Mexico, Japan, and Russia	Migratory Bird Treaty Act (16 USC 703-712) with list of protected birds in 50 CFR 10.13	

Table A-4. (Continued)

Requirements/Prerequisite	Citation	Comment
Wetlands are defined by Executive Order 11990, Section 7. Requires action to minimize the destruction, loss, or degradation of wetlands. Action to prohibit discharge of dredged or fill material into wetlands without permit.	Executive Order 11990, Protection of Wetlands (40 CFR 6, §6.302(a)	If wetlands are located within the area of proposed federal activities, the agency must conduct a wetlands assessment to identify wetlands and potential means of minimizing impacts. If there is no practical alternative to locating in or affecting the wetland, the Agency shall act to minimize potential harm to the wetland.
	Clean Water Act Section 404; 40 CFR Parts 230, 231	The Clean Water Act prohibits discharge of dredged or fill material into wetlands without a permit.
Proposed discharges of dredged or fill material into waters of the U.S. are evaluated with respect to impacts on the aquatic ecosystem.	CWA Section 404 40 CFR 230	
Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife will require actions to protect fish or wildlife.	Fish and Wildlife Coordination Act (16 USCC 661 *et seq.*); 40 CFR 6.302	
Protection of aquifer through federal assistance funding. Applies to aquifers that are sole or principal drinking water sources and if contamination would present a significant hazard to public health. Prohibits injection of waste.	SDWA 42 USC Section 300n; 40 CFR Section 146.4	
Actions to limit worker exposure to hazardous wastes or hazardous substances, including training or monitoring.	20 CFR 1910.120	

4.0 REFERENCES

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