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August 5, 2009

Mr. Jason M. Pelton
Project Manager
New York State Department of Environmental Conservation
Division of Environmental Remediation
625 Broadway, 12th Floor
Albany, NY 12233-7013

Re: Modock Road Springs/DLS Sand and Gravel, Inc. Site (HW-35-013)
Feasibility Study Report

Dear Mr. Pelton:

Malcolm Pirnie, Inc., (Malcolm Pirnie) is pleased to present the New York State Department of Environmental Conservation (NYSDEC) with three copies of the enclosed Feasibility Study Report for the Modock Road Springs Site.

Please call me at (518) 250-7358 if you have any questions.

Very truly yours,

MALCOLM PIRNIE, INC.

Daniel C. Lang, P.H.G.
Associate

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Enclosures
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**New York State Department of Environmental Conservation**
625 Broadway • Albany, New York 12233-7011

# Feasibility Study Report

## Modock Road Springs/DLS Sand and Gravel, Inc. Site (HW 8-35-013)
## Victor, New York

August 2009

Report Prepared By:

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# 1. Introduction

## 1.1. Purpose

This Feasibility Study (FS) has been developed to evaluate remedial alternatives for chlorinated volatile organic compounds (CVOCs) in groundwater at the Modock Road Springs/DLS Sand and Gravel, Inc. site in the Town of Victor, New York (Figure 1). This FS describes the screening of potential remedial alternatives for the site (the 169 acre DLS Sand and Gravel, Inc. property located at 1389 Malone Road) and the dissolved-phase CVOC plume which extends from the site approximately 7,500 feet to the north where groundwater discharges to surface water via a series of springs to the south of Modock Road. The purpose of this report is to:

- Identify and screen in-situ dissolved-phase CVOC plume containment/control remedial technologies;
- Identify and screen remedial technologies to address surface water containing CVOCs at concentrations exceeding New York State Department of Environmental Conservation (NYSDEC) Class C Surface Water Standards;
- Evaluate potential remedial alternatives based on seven evaluation criteria; and
- Recommend potential remedial alternatives that could be implemented to meet Remedial Action Objectives (RAOs) and provide site-specific information on performance of the remedial technology.

The remedy for the site will not be selected until this evaluation, and subsequent NYSDEC assessments, have been thoroughly reviewed and presented to the public. This FS was completed in accordance with NYSDEC Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation (DER-10), NYSDEC DER program policy for Presumptive/Proven Remedial Technologies (DER-15), and other appropriate NYSDEC guidance.

## 1.2. Site Description

### 1.2.1. Physical Setting

The Modock Road Springs/DLS Sand and Gravel, Inc. site (site) is located in a rural/suburban area in the Town of Victor, Ontario County, New York (Figure 1). Land use is agricultural and residential adjacent to and north of the DLS Sand and Gravel, Inc. property, in the area of the dissolved-phase CVOC plume. Farther to the north, between

Dryer Road and Modock Road, land use is rural/suburban with some recent home construction. Sand and gravel mines are located to the east and west of the DLS Sand and Gravel, Inc. property.

The topography in the area of the dissolved-phase CVOC plume generally slopes downward to the north, but consists of rolling hills with elevations varying from approximately 620 feet above mean sea level (AMSL) near the Modock Road Springs to approximately 900 feet AMSL near the DLS Sand and Gravel, Inc. property.

### 1.2.2. Hydrogeology

The actual Modock Road Springs, located in the transition zone between the Erie-Ontario Lake Plain and the Appalachian Upland Physiographic Provinces, are situated along the lower slope of a large kame moraine and outwash complex formed by meltwater issuing from a stagnating continental glacier more than 10,000 years ago. Aggregate mining operations (DLS Sand and Gravel, Inc., a second sand and gravel mine located on Malone Road directly west of the site, and a third mine to the east of the site) along the crest of this kame moraine complex have exposed thick sequences of stratified sands, gravels, and occasional silt and clay layers which underlie the hummocky topography. The surficial geology in the central and southern portion of the site consists of lacustrine sand while outwash sand and gravel is present from the northern portion of the site to Dryer Road. Kame deposits are located to the west and southwest of the site and the outwash sand and gravel at the site is most likely related to this kame deposit. Lacustrine sand is present from Dryer Road to the Modock Road Springs and outwash sand and gravel is generally present north of Modock Road.

The permeable soils of this kame moraine complex provide groundwater recharge areas for regional aquifer systems, such as the Irondogenesee Aquifer (incised buried valley of the pre-glacial Genesee River; coincident with present-day Irondequoit Creek). At distinct changes in topography (e.g., toe of slope) and stratigraphy (e.g., clay layers), groundwater may discharge to the surface as springs and wetlands. Small spring-fed streams, which originate at the Modock Road Springs and other springs in the area, form the headwaters of a tributary of Irondequoit Creek, a Class C (T) stream, indicating that it supports fisheries, is suitable for non-contact activities, and may support a trout population.

Groundwater flows from the south near the DLS Sand & Gravel, Inc. property to the north toward the Modock Road Springs (Figure 2). The depth to groundwater varies considerably depending upon location within the hummocky kame deposits. Specifically, at MW-5, the water table is at a depth of approximately 10 feet below ground surface. At MW-10 along Surrey Lane and at MW-14, just north of the DLS Sand & Gravel, Inc. property, groundwater occurs at a depth of approximately 80 feet and 60 feet below ground surface respectively. A low permeability clay layer appears to restrict groundwater contamination to the uppermost, approximately 10- to 50-foot thick zone of saturated sand. Based on information from residential wells, depth to bedrock (Bertie Formation/Onondaga Limestone) varies from roughly 150 to 200 feet below ground surface. Water samples from bedrock residential wells have not shown CVOC contamination.

## 1.3. Site History

Data collected during previous investigations have documented the presence of CVOCs, including trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethene (1,1-DCE), in groundwater and surface water at the Modock Road Springs. Data (analytical sampling results, concentration gradients, groundwater elevations, and hydraulic gradients) indicate that the upgradient portion of the dissolved-phase CVOC plume is located on the DLS Sand and Gravel, Inc. property, which was subsequently listed on the New York State Registry of Inactive Hazardous Waste Disposal Sites as Class 2 in 2001. A site is listed as Class 2 when a consequential quantity of hazardous waste has been confirmed and the presence of such hazardous waste or its components or breakdown products represent a significant threat to the environment or to health as described in 6 NYCRR Part 375-1.4.

The CVOC contamination was initially discovered in February 1990 during a New York State Department of Health (NYSDOH) initiative to sample small community water supplies across New York State. This initiative included the sampling of the Village of Victor community water system which had relied on the Modock Road Springs as a source of supply since approximately 1925. During this community water supply sampling, TCE, 1,1-DCE, and 1,1,1-TCA were detected in the Modock Road Springs. Both TCE and 1,1,1-TCA were detected in the spring water at concentrations (11 and 35 µg/L, respectively) greater than the NYSDOH maximum contaminant level (MCL) of 5 µg/L. As a result, the use of the springs as a public water supply ceased and the Village of Victor connected to the Monroe County Water Authority as a source of drinking water. Earlier sampling of the Modock Road Springs drinking water source in 1980 did not reveal the presence of the solvent contamination. Total CVOC concentrations have decreased from approximately 50 µg/L in samples collected since 1995 from the wetland/stream that originates from the Modock Road Springs to near non-detectable levels within a half mile downstream (north) of the springs.

Detailed sampling of the individual eastern and western springs documented that the contaminants (TCE, 1,1,1-TCA, and 1,1-DCE) were present in the eastern springs and not present in the western springs. A report prepared for the Town of Victor (Engineering-Science,1990) concluded that the solvent contamination does not appear to be migrating from the west. The report concluded that the contamination appeared to be localized and in a direction southeast of the eastern spring collection system.

Following discovery of the CVOC contamination in the Modock Road Springs, the sampling of nearby private water supply wells was immediately started to determine if these domestic water supplies were impacted. The Village of Victor connected to the Monroe County Water Authority municipal water supply, public water lines were expanded, and a series of investigations were completed by the NYSDEC, NYSDOH, and the Town of Victor to identify a source of the contamination. Given the rural/suburban nature of the community upgradient of the springs, there were no obvious suspect source areas.

## 1.4. Previous Investigations

To determine if private water supplies were also impacted by the CVOC contamination, approximately 97 domestic water supply wells in the vicinity of the Modock Road Springs have been sampled since 1990 for laboratory analysis. The sampling showed that contaminants were present in three residential wells at concentrations exceeding standards set for public drinking water supplies. These three homes were subsequently connected to municipal water.

Between 1995 and 2000, the NYSDEC installed monitoring wells to the south and hydraulically upgradient of the Modock Road Springs to delineate the dissolved-phase CVOC plume and determine the potential source of the groundwater contamination. Seven monitoring wells (MW-1 through MW-7 on Figure 2) were installed in 1995 as part of an Immediate Investigation Work Assignment (IIWA) (Parsons Engineering Science, 1995). These wells are located hydraulically upgradient of, and within 1,200 feet to the southeast of, the Modock Road Springs. Except for MW-3, the three CVOCs detected in the Modock Road Springs (TCE, 1,1,1-TCA, and 1,1-DCE) were detected in each of these monitoring wells. The data collected from these wells did not identify a source for the contamination, but suggested that the source was further to the south in an upgradient direction.

To expand on the initial seven wells that were installed, monitoring wells MW-8, MW-9, and MW-11, located on Dryer Road, and MW-10, located on Surrey Lane, were installed in October 1999. The wells on Dryer Road were installed to further evaluate groundwater quality in an upgradient direction and also downgradient of a sand and gravel borrow pit. No CVOCs were detected in the Dryer Road monitoring wells (MW-8, MW-9, and MW-11) and trace levels (3 µg/L) of total CVOCs were detected in MW-10 (Surrey Lane). At approximately the same time that these monitoring wells (MW-8, MW-9, MW-10, and MW-11) were installed and sampled, a shallow domestic water supply well was sampled at the intersection of Hunter's Run and Dryer Road. The groundwater sample collected from the domestic water supply well contained total CVOCs at a concentration of approximately 380 µg/L and suggested that a source for the contaminants existed further to the south. As such, three additional monitoring wells (MW-12, MW-13, and MW-14 on Figure 2) were installed further to the south and just north of the DLS Sand and Gravel, Inc. property in November 2000. Total CVOC concentrations were detected at concentrations of approximately 1,200 and 16,000 µg/L in groundwater samples collected from MW-13 and MW-14, respectively. Based on these groundwater sample results along with groundwater flow directions, the data suggested that the TCE, 1,1,1-TCA, and 1,1-DCE detected in the Modock Road Springs and groundwater upgradient of the springs was originating from the DLS Sand and Gravel, Inc. property.

Based on the NYSDEC's findings, DLS Sand and Gravel, Inc. installed 11 monitoring wells (SS&G MW-1 through SS&G MW-11 on Figure 2) in 2001 (Leader Professional Services, 2002). The majority of these wells were installed on DLS Sand and Gravel, Inc. property. Based on water levels measured from the monitoring wells, an east-west trending groundwater flow divide was identified in the southern portion of the DLS Sand and Gravel, Inc. property between SS&G MW-4 and SS&G MW-7 (Figure 2). The investigation results were summarized in a November 2002 *Groundwater Investigation Summary Report* (Leader Professional Services, 2002). At the request of NYSDEC and related to mining operations, DLS Sand and Gravel, Inc. installed two additional monitoring wells (SS&G MW-15 and SS&G MW-16) in the northwestern corner the site in May 2008 (Figure 2).

A Remedial Investigation Report (Malcolm Pirnie, 2008) summarized the results of a remedial investigation that was conducted in 2007 and 2008. Conclusions of the Remedial Investigation Report include the following:

- Data from passive soil gas, sub-slab vapor, indoor air, groundwater, and soil samples indicate that the dissolved-phase CVOC is comprised of three primary compounds: TCE, 1,1,1-TCA, and 1,1-DCE;
- The results of the investigation activities in the area of highest CVOC groundwater concentrations combined with the groundwater quality data indicate that a source area does not exist in shallow soil. Instead, the data suggests that following release, the contaminants migrated downward to the groundwater table and the remnants of this release are now sorbed onto soil particles or fine grained sand and silt lenses below the water table and represent a continuing and long-term source for the CVOCs in groundwater;
- The approximate dissolved-phase CVOC plume dimensions defined during earlier site investigation activities were confirmed during the RI;
- The highest concentrations of CVOCs in groundwater are located at the northern margin of the DLS Sand and Gravel, Inc. property;

- The dissolved-phase CVOC plume is confined to a narrow path because groundwater flow is controlled by a zone of highly permeable sand and gravel;
- Data suggest that bedrock groundwater quality has not been impacted by the dissolved-phase CVOC plume, which is confined to the uppermost water-table aquifer;
- The dissolved-phase CVOC plume is stable, discharges at the Modock Road Springs, and does not extend to the north of Modock Road;
- Based on spring and surface water samples collected during the RI, the TCE concentrations decrease to below the NYSDEC Class C Surface Water Standard of 40 µg/L within 525 feet of the springs at a surface water sampling point established at Modock Road (Figure 3);
- Based on vapor intrusion sampling completed at 72 locations, NYSDEC and NYSDOH recommended no further action for 44 homes, re-sampling for 14 homes, monitoring for eight (8) homes and mitigation for six (6) locations where sub-slab depressurization systems were installed by the NYSDEC.

## 1.5. Conceptual Site Model

Information obtained during the RI and previous investigations was used to develop a conceptual site model, which summarizes the site-specific geology, the depth and flow of groundwater, and the potential CVOC sources. This model is used herein to facilitate the evaluation of potential CVOC source areas and migration pathways and provide an organizational structure for data collected during multiple investigations. These data include site-specific information on CVOCs in soil, groundwater, soil gas, sub-slab vapor, indoor and outdoor air and the geologic and hydrogeologic characteristics that affect the distribution, fate, and migration of the CVOCs. A summary of the analytical results from samples collected from 2006 through 2008 is provided in Table 1.

Groundwater flows from the south in the vicinity of a groundwater flow divide in the southern portion of the DLS Sand and Gravel, Inc. property to the north toward the Modock Road Springs (Figure 2). The depth to groundwater varies considerably depending upon location within the hummocky lacustrine and outwash deposits. Specifically, at MW-5, which is approximately 300 feet upgradient of the Modock Road Springs, the water table is at a depth of approximately 10 feet below ground surface (bgs). At MW-10 along Surrey Lane and at MW-14, just north of the DLS Sand and Gravel, Inc. property, groundwater occurs at a depth of approximately 80 feet and 60 feet bgs respectively. Analytical data indicate that groundwater in the water-table aquifer contains CVOCs, primarily TCE, 1,1,1-TCA, and 1,1-DCE (Figure 4) and that the dissolved-phase CVOC plume is migrating from the DLS Sand and Gravel, Inc. property and discharging to the Modock Road Springs. As shown on the west to east simplified geologic cross-sections along the tree line at MW-14 and at Dryer Road (Figures 5 and 6), an underlying low permeability clay layer appears to restrict groundwater contamination to the uppermost, approximately 10- to 50-foot thick, zone of saturated sand and gravel. Based on information from residential wells, depth to bedrock (Bertie Formation/Onondaga Limestone) varies from roughly 150 to 200 feet bgs. Water samples from bedrock residential wells have not contained CVOCs.

Sub-slab vapor and indoor air sampling results indicate that CVOC vapors have migrated upward through the vadose zone overlying the dissolved-phase CVOC plume. Consistent with groundwater quality, TCE, 1,1,1-TCA, and 1,1-DCE, were the primary CVOCs present in the sub-slab vapor and indoor air samples. Based on a review of the relevant information and analytical data from the 72 residences where samples were collected, the NYSDEC and NYSDOH recommended mitigation (installation of a sub-slab depressurization system) at 6 homes, which are each located over the dissolved-phase CVOC plume. NYSDEC and NYSDOH also recommended no further action for 44 homes, re-sampling for 14 homes, and monitoring for 8 homes.

A series of investigation activities have been conducted at the DLS Sand and Gravel, Inc. property to identify possible source areas and characterize the overall distribution of contaminants in potential source areas. No NAPL or unsaturated zone CVOC sources have been identified in site soil. NYSDEC has received anecdotal reports of a potential disposal area in the north-central portion of the DLS Sand and Gravel, Inc. property near MW-14 and MW-18. Passive soil gas and MIP screening revealed soil and/or soil gas containing VOCs in this area; however, the lack of VOCs in soil samples collected in this area indicates that the passive soil gas screening analyses may have detected vapor-phase CVOCs emanating from the underlying CVOC plume in groundwater. Additional soil sampling was conducted to further evaluate the presence or absence of CVOCs in unsaturated zone soils in the northeastern portion of the site. Based on the numerous soil samples collected and borings drilled in locations identified as potential disposal areas, and the absence of any significant amounts of CVOCs in these areas, it is likely that a CVOC source is not present in the unsaturated zone at the site. Any solids or liquids containing CVOCs have likely either been excavated or have migrated downward to the groundwater. CVOCs that have sorbed onto soil particles or fine grained sand and silt lenses below the water table are likely acting as a continuing and long-term source of CVOCs to groundwater.

The data suggest that disposal would have occurred in the central/north central part of the DLS Sand and Gravel, Inc. property. Data further suggests that chlorinated solvent disposal did not occur in the western and eastern thirds of the DLS Sand and Gravel, Inc.

property. The overall distribution and concentrations of 1,1,1-TCA, TCE, and 1,1-DCE also suggest that disposal may have occurred at more than one location.

# 2. Identification of RAOs, SCGs, and GRAs

This section outlines the Remedial Action Objectives (RAOs) proposed for the final site remedy. In addition, this section summarizes the standards, criteria, and guidance (SCGs), general response actions (GRAs), and evaluation criteria to be considered in addressing the RAOs. GRAs are medium-specific actions that could be taken to address the RAOs.

## 2.1. Remedial Action Objectives

RAOs are goals set for environmental media, such as soil, groundwater, sediment, surface water, soil vapor, and indoor air, which are intended to provide protection for human health and the environment. RAOs form the basis for the FS by providing overall goals for site remediation. The RAOs are considered during the identification of appropriate remedial technologies and formulation of alternatives for the site, and later during the evaluation of remedial alternatives. RAOs are based on engineering judgment, risk-based information established in the risk assessment, and potentially applicable or relevant and appropriate SCGs. For the purposes of this feasibility study, and based on the results of previous site investigations, the RAOs for the site are to:

- Eliminate, to the extent practicable, exposures to VOCs in groundwater, surface water, and soil vapor;

- Reduce, to the extent practicable, the concentration of site-related contaminants (e.g., TCE, 1,1-DCE, and 1,1,1-TCA) in groundwater downgradient from the DLS Sand and Gravel, Inc. property to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values; and

- Reduce, to the extent practicable, VOC concentrations in surface water downgradient of the Modock Road Springs that exceed NYSDEC Class C Ambient Water Quality Criteria or guidance values.

## 2.2. Standards, Criteria, and Guidance

6 NYSCRR Part 375 requires that SCGs are identified and that remedial actions conform with SCGs unless "good cause exists why conformity should be dispensed with." Standards and Criteria are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, or location. Guidance includes non-promulgated criteria and guidelines

that are not legal requirements; however the site's remedial program should be designed with consideration given to guidance that, based on professional judgment, is determined to be applicable to the site.

The principle SCGs for the site are listed below:

General:

- 6 NYCRR Part 375 – Environmental Remediation Programs, including the Inactive Hazardous Waste Disposal Site Remedial Program
- 6 NYCRR Part 371 – Identification and Listing of Hazardous Wastes

Soil:

- 6 NYCRR Part 375 – Soil Cleanup Objectives
- 6 NYCRR Part 376 – Land Disposal Restrictions
- NYSDEC Division of Solid and Hazardous Materials TAGM 3028 "Contained-in" Criteria for Environmental Media (8/97)

Water:

- 6 NYCRR Part 700-705, Water Quality Regulations for Surface Water and Groundwater
- NYSDEC Division of Water TOGS 1.1.1 – Ambient Water Quality Standards and Groundwater Effluent Limitations

Air:

- NYSDEC Division of Air Resources Policy DAR-1 – Guidelines for Control of Toxic Ambient Air Contaminants
- NYSDOH October 2006 Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York

There are three types of SCGs: chemical-, location-, and action-specific SCGs. Chemical-specific SCGs are health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to the ambient environment. Location-specific SCGs set restrictions on activities based on the characteristics of the site or immediate environs. Action-specific SCGs set controls or restrictions on particular types of remedial actions once the remedial actions have been identified as part of a remedial alternative. The identification of potential SCGs is documented in Table 2.

## 2.3. General Response Actions

NYSDEC Program Policy DER-15: *Presumptive /Proven Remedial Technologies*, provides generally accepted presumptive remedies for various site media which comply with 6 NYCRR section 375-1.8. Presumptive remedies for VOC contaminated site media are presented in Section 4 of the DER#15 Guidance document. The purpose of the presumptive remedy approach is to streamline the remedy selection process by providing remedies which have been proven to be both feasible and cost-effective for specific site types and/or contaminants. In accordance with Section 4.2(a)3 of the NYSDEC Program Policy Draft DER#10: Technical Guidance for Site Investigation and Remediation, the use of presumptive remedies eliminates the need to screen the selected technologies and to proceed directly to the evaluation of the presumptive alternatives.

In accordance with DER#10, Section 4.2(a)3 general response actions (GRAs) have been identified which may be effective remedies for the remediation of soil vapor, groundwater, and/or surface water at the site. The GRAs identified include:

- **No Action** - A no action response, required by the DER for the Feasibility Study (FS) process, provides a baseline for comparison with other alternatives.

- **Institutional Controls** - Institutional controls are applied when active remedial measures do not achieve cleanup limits. Potential human exposure is reduced by limiting public access to site contaminants. Institutional controls such as environmental easements can also apply through an extended remediation period, or to sites where cleanups are completed up to feasible levels but still leave residual contamination greater than background levels.

- **Monitored Natural Attenuation (MNA)** - MNA, also known as intrinsic remediation, bioattenuation, or intrinsic bioremediation, refers to the use of natural processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, as part of overall site remediation. MNA is a non-engineered remedial technique, which involves the degradation of the VOCs in the groundwater by naturally occurring processes (i.e., biodegradation). Such degradation is monitored over time under a long-term monitoring program

- **In-situ Treatment**- In-situ treatment for groundwater uses various technologies including biological, thermal, and reactive materials. In-situ treatment is effective in treating source areas of contamination but can be prohibitively expensive for treatment of large areas of groundwater contamination.

- **Removal Measures-** Removal measures provide for the removal of contaminants or contaminated materials from their existing location for treatment (on-site or off-site) or disposal. Groundwater extraction systems are typically used to remove groundwater and are combined with various ex-situ treatment technologies including UV oxidation, air stripping, and granular activated carbon. The effluent treated water is often returned to the subsurface through injection wells, released to surface water bodies, or released to the local Publicly-Owned Treatment Works (POTW).

- **Containment/Barrier** - Containment for groundwater includes remedial measures that contain or isolate contaminants on-site. Containment prevents migration of contaminants from the site and attempts to prevent direct human and ecological exposure to contaminated media. Examples of containment technologies are grout slurry walls, sheet piling, hydraulic control by pumping, and reactive barriers. Containment technologies are often combined with other treatment technologies to remove contamination.

# 3. Identification and Screening of Technologies

In this section selected technologies are described in general and are screened for their implementability and applicability to the site. Based on this screening, remedial technologies are retained or not retained for further consideration.

Technology types include such general categories as treatment or containment, whereas process options are specific processes within the general technology types (e.g., treatment via chemical oxidation, or containment using a treatment barrier). This section develops a list of potential technology types and process options for treatment and/or containment of groundwater and surface water impacted by VOCs in groundwater at the site. The retained technologies and process options are subsequently evaluated based on the evaluation criteria discussed in Section 4.2.

Remedial strategies/technologies identified for screening include:

- No Further Action
- Monitored Natural Attenuation
- In-situ Chemical Oxidation
- In-Situ Bioremediation
- Permeable Reactive Barriers
- Air Sparging/Soil Vapor Extraction
- Groundwater Extraction
- In-well Air Stripping
- Phytoremediation

Descriptions, evaluations, and screening of each of these potential remedial strategies/technologies are provided below.

## 3.1. No Further Action

The "no further action" option, by definition, involves no further institutional controls, environmental monitoring, or remedial action, and, therefore, includes no technological barriers. The no further action option does not include groundwater or air monitoring to evaluate the effects of any natural attenuation processes at the site. Although the no further action option would be unable to meet the RAO, it will be retained to provide a basis for comparison to other remedial alternatives.

## 3.2. Monitored Natural Attenuation (MNA)

MNA, also known as intrinsic remediation, bioattenuation, or intrinsic bioremediation, refers specifically to the use of natural processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, as part of overall site remediation. MNA is a non-engineered remedial technique, which involves the degradation of the VOCs in the groundwater by naturally occurring processes (i.e., biodegradation). Such degradation is monitored over time under a long-term monitoring program.

Consideration of this option usually requires evaluating contaminant degradation rates and pathways and predicting contaminant concentrations at downgradient receptor points. The primary objective of this evaluation would be to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. Long term monitoring should be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives. A select group of existing monitoring wells would be monitored quarterly for the first year followed by annual sampling as needed.

Natural attenuation is not the same as no further action, although it often is perceived as such. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires evaluation of a no further action alternative but does not require evaluation of natural attenuation. Natural attenuation is considered on a case-by-case basis. In all cases where natural attenuation is being considered, extensive site characterization and monitoring would be required, both before and after any potential implementation of this remedial alternative.

Compared with other remedial technologies, natural attenuation has the following advantages:

- Less generation or transfer of remediation wastes;
- Less intrusive;
- May be applied to all or part of a given site, depending on site conditions and cleanup objectives;

- May be used in conjunction with, or as a follow-up to, other (active) remedial measures; and
- Overall cost will likely be lower than active remediation.

Potential disadvantages of MNA include:

- Data used as input parameters for modeling need to be collected;
- Intermediate degradation products may be more mobile and more toxic than the original contaminant;
- Natural attenuation is not appropriate where imminent site risks are present;
- Contaminants may migrate before they are degraded;
- Institutional controls may be required, and the site may not be available for its highest reuse potential until contaminant levels are reduced;
- It is not meant to address source areas of relatively high contamination;
- There are long term monitoring costs associated with this alternative; and
- Longer time frames would be required to achieve remedial objectives, compared to active remediation.

Analytical data indicates that natural biological degradation of the groundwater contamination is minimally occurring at the site. Despite the long time frame associated with natural attenuation processes, MNA will be considered further.

## 3.3. In-situ Chemical Oxidation

In-situ chemical oxidation (ISCO) has been used since the early 1990s to treat environmental contaminants in groundwater, soil, and sediment. Many of these projects have focused on the treatment of chlorinated solvents (e.g., TCE and PCE), although several projects have also used the process to treat petroleum compounds [(i.e., benzene, toluene, ethylbenzene, and xylene (BTEX) and methyl tertiary-butyl ether (MTBE)] and semi-volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and pesticides (USEPA, 1998 and Siegrist, 2001).

ISCO is defined as the delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants of concern into innocuous end products such as carbon dioxide ($CO_2$), water, and inorganic compounds. A chemical oxidant is injected in areas where a reduction in groundwater contaminant concentration is desired. Injection locations can be either permanently installed wells or temporary injection points installed using direct-push methods. When oxidants come in contact with chlorinated VOCs they are broken down into non-toxic components. However, contact between the oxidant and contaminant required to facilitate the reaction is the most important technical limitation of this technology, as it can be difficult to accomplish.

Accordingly, this remedial approach generally includes several injections over time accompanied by groundwater sampling and analysis. Numerous injections are typically required to remediate the treatment area. Given this and depending on the final contaminant concentration desired, the overall costs are typically medium to high relative to other technologies. Since the reaction with the contaminant and the chemical oxidant generally occurs over a relatively short period, treatment can be more rapid than other in-situ technologies. This technology does not generate large volumes of residual waste material that must be treated and/or disposed.

ISCO can be used to treat localized source areas and dissolved-phase plumes since it is capable of treating high concentrations of contaminants by adding more oxidants. ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration endpoints.

Advantages of ISCO typically include:

- Relatively short remediation times in areas where groundwater flow does not introduce additional contaminants with time (typically one to two years);
- Limited long-term operation, maintenance, and monitoring (OM&M) costs in such settings;
- Treats both dissolved and sorbed contaminants concurrently;
- Treats compounds that are not readily biodegradable; and
- Breakdown of chlorinated VOCs without the generation of potentially more toxic degradation products (although not all chlorinated VOC mass may break down).

Disadvantages of ISCO include:

- Its application to areas with only the highest contaminant concentrations is typically most cost effective;
- The need to inject large volumes of oxidant (especially in areas where groundwater flow introduces additional contaminants over a long period of time from upgradient directions);
- The need for multiple injections;

- The difficulty of contacting oxidants with groundwater contaminants intended for destruction when injecting into low permeability or heterogeneous formations;
- Health and safety issues pertaining to field personnel associated with the handling and injection of oxidants and reagents;
- Relatively high costs per volume treated; and
- Naturally occurring carbon sources increase the oxidant demand in the treatment zone. The presence of carbonates can also add to the oxidant demand for certain ISCO chemicals.

The most common oxidants utilized for ISCO are hydrogen peroxide (Fenton’s reagent), potassium and sodium permanganate, and sodium persulfate. A general summary of each of these oxidants is presented below.

### 3.3.1. Fenton’s Reagent (Hydrogen Peroxide)

Hydrogen peroxide-based in-situ chemical oxidation is driven by the formation of a hydroxyl free radical in the presence of a metal catalyst. This reaction, known as the Haber-Weiss mechanism, was first utilized for the treatment of organic compounds in wastewater in the 1890s by H.J.H Fenton using an iron catalyst (Fenton’s reagent). The hydroxyl free radical is a powerful oxidizer of organic compounds, thus many organic compounds in the subsurface that contact the chemical oxidant are readily degraded to innocuous compounds (e.g., water and carbon dioxide). Any residual hydrogen peroxide remaining after the reaction decomposes to water and oxygen. Soluble iron (ferrous iron), the transition metal catalyst added to the subsurface during injection of the oxidant mixture, is precipitated out of solution during conversion to ferric iron.

Typical hydrogen peroxide concentrations utilized for treatment with Fenton’s reagent range from five to 50 percent by weight, however, concentrations less than 15 percent are utilized at a majority of sites. The hydrogen peroxide concentration used in the injection fluid is based on contaminant concentrations, subsurface characteristics, and treatment volume. Acids are also typically added to the injection solution to lower the pH of the contaminated zone if the natural pH is not low enough to promote the Fenton’s reaction.

Compared to other oxidants, Fenton’s reagent has a relatively short life once injected into the subsurface. Therefore, a larger number of Fenton’s reagent injections would be required to sustain the oxidant in the subsurface compared to injections of other oxidants.

### 3.3.2. Sodium and Potassium Permanganate

Permanganate is an oxidizing agent with a unique affinity for oxidizing organic compounds with carbon-carbon double bonds (e.g., TCE and PCE), aldehyde groups or hydroxyl groups (alcohols). There are two forms of permanganate that are used for

ISCO, potassium permanganate ($KMnO_4$) and sodium permanganate ($NaMnO_4$). Potassium permanganate has been used in drinking water and wastewater treatment for several decades to oxidize raw water contaminants, typically for odor control. Potassium permanganate is available as a dry crystalline material, while sodium permanganate is a liquid. Permanganate turns bright purple when dissolved in water; this purple color is an indicator of unreacted chemical. Reacted permanganate is black or brown, indicating the presence of a manganese dioxide ($MnO_2$) byproduct.

Sodium permanganate has a much higher solubility in water than potassium permanganate, allowing it to be used for ISCO at higher concentrations, compared to two to five percent for potassium permanganate. Since it is supplied in liquid form, the use of sodium permanganate commonly requires no on-site mixing. Permangenate will not be considered further because it is ineffective at treating groundwater containing 1,1,1-TCA.

### 3.3.3. Sodium Persulfate

Sodium persulfate is a strong oxidant that derives its oxidizing potential through the persulfate anion ($S_2O_8^{2-}$). The persulfate anion is capable of oxidizing a wide range of contaminants, including chlorinated ethenes, BTEX, phenols, MTBE, and low molecular weight PAHs. However, when catalyzed in the presence of heat (thermal catalyzation) or transition metals ions (i.e., ferrous iron), the persulfate ion is converted to the sulfate free radical ($SO_4^{2-}\bullet$), which is second only to Fenton's reagent in oxidizing potential. Sodium persulfate is supplied in an aqueous solution at concentrations up to 50 percent by weight. The use of sodium persulfate for the treatment of CVOCs is a relatively new process in the marketplace.

### 3.3.4. RegenOx

RegenOx is a proprietary mixture of oxidants used to treat VOCs in groundwater. A RegenOx application will remove significant amounts of contamination from the subsurface and is typically applied using direct-injection techniques. The application process enables the two part product to be combined, then pressure injected into the zone of contamination and moved out into the aquifer media. Once in the subsurface, RegenOx produces a cascade of efficient oxidation reactions via a number of mechanisms including: surface mediated oxidation, direct oxidation and free radical oxidation. These reactions eliminate contaminants and can be propagated in the presence of RegenOx for periods of up to 30 days on a single injection. RegenOx produces minimal heat and is highly compatible with follow-on enhanced bioremediation applications.

ISCO will not be retained for evaluation as a barrier or plume-wide remedial alternative because of the high cost and large number of injections that would be required to sustain a treatment wall/barrier or treat a large area. Because of the relatively high hydraulic conductivity and gradient downgradient of MW-14 and MW-17S, ISCO vendors expect that ISCO injections would be required every four weeks to maintain an effective barrier. ISCO will be retained for an evaluation of reducing groundwater CVOC concentrations.

## 3.4. Enhanced In-situ Bioremediation

Bioremediation (or enhanced biodegradation) is the controlled management of microbial processes in the subsurface. This differs from monitoring of bioremediation processes under monitored natural attenuation (MNA) by being an active, designed, and managed process. Some microorganisms, such as Dehalococcoides (DHC), break down VOCs to the end products ethane and ethene. Therefore, bioremediation can often be enhanced through biostimulation (substrates injected in-situ to promote microbial activity) or bioaugmentation (increasing of bioremediation by adding microbial cultures). Biostimulation is used to set the proper conditions for increased microbial activity and may be all that is needed for satisfactory remediation. Biostimulation is often focused in areas where microbial populations are marginal and/or under conditions that are insufficient to support practical biodegradation rates. Carbon sources used at anaerobic sites include molasses, edible oils, lactic acid, sodium benzoate, methane, and yeast extract.

The presence of Dehalococcoides bacteria can be quantified to evaluate if bioaugmentation with Dehalococcoides would be necessary to further facilitate chlorinated VOC degradation. If bacteria counts are low, additional cultures can be added to the subsurface to increase populations. However, where dechlorination end products (such as ethene) are already present at the site, it is likely that sufficient reductive dechlorinators are already present and bioaugmentation may not be necessary.

Favorable in-situ conditions must be present to ensure successful bioremediation. Subsurface heterogeneity can complicate the distribution of biostimulants. Chemically, bioremediation of chlorinated compounds works best under highly reducing conditions, with methanogenic conditions being the most favorable. Under sulfate-reducing conditions biodegradation commonly stalls at cis-DCE. Dechlorinators are also limited if the pH is outside the normal range (greater than 8 or less than 5).

Enhanced bioremediation vendors agree that this technology can effectively treat CVOCs, including TCE, 1,1,1-TCA, and 1,1-DCE. Despite this, in-situ bioremediation pilot studies are often conducted to evaluate the applicability, effectiveness, and cost of this remedial technology. Pilot studies provide data to better evaluate remedial alternatives, support the remedial design of a selected alternative, and reduce full-scale implementation cost and performance uncertainties.

A form of in-situ bioremediation is a biological barrier which acts as a passive control to dissolved-phase CVOC plume flow when microorganisms break down VOCs that pass by them in groundwater. Biological barriers have recently been installed using an emulsified edible oil inserted into the soil with the help of chase water and an emulsifying agent (to reduce viscosity). This type of biological barrier does not require excavation; it can be installed by injecting the oil, chase water, and emulsifying agent into the subsurface through temporary injection points or permanent injection wells.

A disadvantage of a biological barrier is the possible increase of DCE and vinyl chloride (VC) downgradient of the treatment area. This is due to the TCE byproduct's (DCE and vinyl chloride) slower reduction rates. Heterogeneity in the soil can disrupt continuity of the wall resulting in gaps that can transmit contaminated water. Increased biofouling can also reduce the permeability of the barrier, potentially causing water to flow around the treatment zone. Additional byproducts of bioremediation may include increased methane and increased concentration of dissolved iron and manganese and occasionally other metals if the local pH is significantly lowered through biological activity.

In the right conditions, chlorinated ethenes can be degraded under anaerobic conditions through reductive dechlorination. Reductive dechlorination is a reaction catalyzed by microorganisms in which a hydrogen atom replaces the chlorine atom on CVOCs such as TCE. The resulting hydrogen is then used by reductive dehalogenators to strip the solvent molecules of their chlorine atoms which allows for further degradation. Though this can occur naturally, it may not happen within an adequate time frame to meet remedial goals. The injection of hydrogen-releasing compounds can be used to enhance dechlorination processes. Anaerobic conditions can be created through the introduction of large amounts of carbon sources, and monitored by measuring dissolved oxygen (DO) to determine if anaerobic conditions have been achieved.

Advantages of anaerobic degradation typically include:

- It can effectively reduce CVOC concentrations under the right conditions;
- CVOCs are degraded in-situ; and
- It is generally less expensive than other remedial technologies.

Disadvantages of anaerobic degradation typically include:

- The presence of DO at levels greater than 1 part-per-million (ppm) limit anaerobic degradation and would require the introduction of a carbon source to reduce DO levels.
- Depending on soil type, degree of heterogeneity, and groundwater depth, this technology may require closely spaced injection sites and can be cost prohibitive.
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient.

There is little evidence that natural degradation of CVOCs is occurring in site groundwater. Degradation products of TCE, 1,1,1-TCA, and 1,1-DCE are not present in site groundwater. However, the presence of 1,1-DCE in site groundwater could be a result of abiotic breakdown of 1,1,1-TCA. Field measurements of dissolved oxygen and reduction oxidation potential indicate that the water-table aquifer is under aerobic conditions (contains oxygen). Under these aerobic conditions, CVOCs degrade at a much slower rate than under anaerobic conditions. Because these conditions could be altered through injection of amendments, bioremediation will be retained for further consideration.

## 3.5. Permeable Reactive Barrier

Permeable Reactive Barriers (PRBs) are vertical zones of material (typically zero-valent iron, mulch, or some other reducing agent) that are installed in the subsurface to passively intercept groundwater flow. PRBs are installed in or down gradient of a dissolved-phase contaminant plume by excavating a trench across the path of a migrating dissolved-phase VOC plume and filling it with the appropriate reactive material (such as a mixture of sand and iron particles), or by injecting the reactive material into the ground as a mobile slurry using direct push technology or injection wells. Groundwater flowing passively under a hydraulic gradient through the PRB is treated as the contaminants in the dissolved-phase plume are broken down into byproducts or immobilized by precipitation or sorption after reacting with the substrate inside the PRB. Although PRBs are a remedial technology that requires no pumping, the rate of groundwater treatment can be accelerated by groundwater withdrawal or injection in the vicinity of the PRB. Groundwater monitoring systems are typically installed to monitor the effectiveness of a PRB (or other remedial technology) over the long term.

PRB systems have been used successfully to treat chlorinated organic compounds, including TCE, 1,1,1-TCA, and 1,1-DCE at numerous full-scale applications. PRBs intended for groundwater containing VOCs are commonly constructed with zero-valent iron. Such PRBs can be constructed as a wall beneath the ground surface either by open trenching or with minimal disturbance to above-ground structures and property using trenchless injection technology. Another emerging PRB method utilizes an electrolysis process to break apart the VOC constituents. Probes are installed into the ground, which generate a current in the subsurface that degrades the VOC constituents. Both methods, in addition to mulch and chitin barriers, are discussed below.

### 3.5.1. Zero-valent Iron

The most common PRB technology utilizes zero-valent iron particles, typically in granular (macro-scale) form, to completely degrade chlorinated VOCs via abiotic reductive dehalogenation. As the iron is oxidized, a chlorine atom is removed from the compound using electrons supplied by the oxidation of iron. As the groundwater containing CVOCs flows through the reactive material, a number of reactions occur that indirectly or directly lead to the reduction of the chlorinated solvents. One mechanism is the reaction of iron filings with oxygen and water, which produces hydroxyl radicals. The hydroxyl radicals in turn oxidize the contaminants. During this process, the chloride in the compound is replaced by hydrogen, resulting in the complete transformation of CVOCs to byproducts (ethene, ethane, and chloride ions). Since degradation rates using the process are several orders of magnitude greater than under natural conditions, any intermediate degradation byproducts formed during treatment (e.g., VC) are also reduced to byproducts in a properly designed treatment zone. The use of zero-valent iron to treat CVOCs has been well documented, and is covered under several patents, depending on the installation method.

PRB longevity using zero-valent iron is dependent on contaminant concentration, groundwater flow velocity, and the geochemical makeup of the groundwater. The oldest full-scale PRB was installed in February 1995 at a site in Sunnyvale, California. This PRB has successfully reduced the concentrations of TCE, DCE, VC, and Freon throughout its 11 years of operation (ETI, 2006). Since the age of the oldest PRB is only approximately 12 years, bench scale studies using reactive iron columns (from both cores obtained from emplaced reactive walls and from virgin reactive iron) have been conducted to evaluate long-term PRB longevity. These tests have shown that, although the reactivity of the iron declines with long-term exposure to groundwater, conditions promoting the dehalogenation of chlorinated solvents are maintained over the long term. Based on these studies, the expected life of a typical reactive wall (where life is defined as the period over which the reactivity of the iron declines by a factor of two) is approximately 30 years (ESTCP, 2003). However, these studies also indicated that groundwater geochemistry, specifically the concentration and resulting flux of natural organic matter (NOM), total dissolved solids (TDS), and carbonate, along with the distribution of VOC concentrations, greatly influences the lifetime of the reactive iron and should be considered in the reactive wall design process (Klausen et al., 2003).

Zero-valent iron PRBs can be installed by direct-injection of iron or iron substrate into a series of injection wells or boreholes along the barrier alignment. The iron particles are injected into the subsurface to form a continuous barrier between the wells/boreholes. During injection, the barrier geometry can be monitored in real-time to ensure fracture coalescence or overlap using resistivity sensors in the subsurface. Once installed, the hydraulic continuity of the PRB can also be verified using hydraulic pulse interference testing. This test involves a cyclic injection of fluid into a source well on one side of the PRB and high precision measurement of the pressure pulse using a receiver transducer in an observation well on the other side of the PRB. The time delay and attenuation of the hydraulic pulse is used to evaluate the hydraulic effectiveness and continuity of the wall. PRBs have been installed to depths exceeding 100 feet below grade and barrier lengths exceeding 1,000 feet. This trenchless method generates almost no waste that would require disposal or treatment.

In contrast, PRB installation using trenching installation technologies are typically physically limited to approximately 60 feet below grade, although a trenched PRB is rarely installed to a depth of more than 30 feet below grade. Also, trenching results in larger volumes of waste in the form of soil that must be disposed of or otherwise treated. Also, trenching technology can create significant disruption to surrounding communities and infrastructure, and is generally limited to areas where underground utilities are not present or, if present, can be disturbed.

Advantages of zero-valent iron PRBs typically include:

- The zero-valent iron PRB is a passive method of treatment and long-term OM&M costs will remain low as long as no adjustments need to be made to the barrier;
- Because it is a barrier technology, PRBs can be an effective method of dissolved-phase plume control; and
- PRB installation using direct injection technology is not constrained by utilities and is typically a relatively low-impact method for PRB installation.

Disadvantages of zero-valent iron PRBs typically include:

- Emplacement of a PRB using conventional trenching methods can be complicated if underground utilities are present;
- Once emplaced the PRB is expensive to adjust, re-locate or remove;
- A high groundwater flow rate would decrease the contact time between CVOCs and zero-valent iron, thereby reducing the PRB effectiveness;
- Changes in groundwater direction or velocity, though unlikely, can reduce the PRB effectiveness; and
- Relatively high capital costs.

Because of its relatively easy implementation using trenchless technology, a PRB using zero-valent iron is retained for evaluation as a potential alternative for remediating the dissolved-phase CVOC plume. Because of the shallow depth to the water table and the top of the clay in the vicinity of the Modock Road Springs, the installation of the PRB using a trench will be considered further for treating the groundwater in this area.

### 3.5.2. Mulch and Chitin Barriers

A form of in-situ bioremediation is a biological barrier which acts as a passive control to dissolved-phase plume flow when microorganisms break down VOCs that pass by them in groundwater. A biological barrier treats VOC containing groundwater biologically, which is different than most PRB technologies where a chemically reactive treatment barrier is utilized. As with chemical barriers, care must be taken to ensure the wall is constructed to the correct thickness so that the dissolved-phase contaminant plume has enough time to biodegrade. Biological barriers can be constructed with a variety of materials including mulch and chitin (though inexpensive, mulch and chitin are limited in the depth to which they can be emplaced) and food waste products such as cheese whey. A mulch or chitin barrier cannot be installed without excavation. Mulch can be used to turn aquifers anaerobic and provide a source of electron donors for reductive dechlorination of CVOCs. Mulch is inexpensive, long-lasting, and is naturally present in the environment. A mulch/chitin barrier will not be considered further for treatment of the majority of the dissolved-phase CVOC plume because of the inability to trench down to or deliver the mulch to the required depths. A mulch/chitin barrier will be considered further as a remedial technology in the vicinity of the Modock Road Springs.

### 3.5.3. Electrically-induced Redox Barrier

Application of this technology involves the insertion of closely spaced permeable electrodes through the groundwater plume. A low voltage direct current drives the oxidation of CVOCs. An electrically-induced redox barrier is an effective method for reduction of CVOCs in groundwater.

Advantages of an electrically-induced redox barrier typically include:

- Like other passive technologies, an electrically induced barrier has low long-term OM&M costs, mostly relating to power usage; and
- The electronic barrier has the potential to control mineral accumulation common on other barriers by periodic reversal of electrode potentials, thereby minimizing potential problems related to decreasing permeability.

Disadvantages of an electrically-induced redox barrier typically include:

- This is a relatively new concept with only limited field testing (conducted by Environmental Security Technology Certification Program and Colorado State University at F.E. Warren Air Force Base);
- A trench and fill system is the only way to initially emplace the barrier making it impractical in deep aquifers or urban/suburban areas; and

- The barrier needs to equilibrate with the dissolved-phase contaminant plume for a few months before implementing the charge.

Although an electrically-induced redox barrier may be feasible for site treatment, it will not be retained for future consideration. This technology is an unproven technology that has had limited field testing at F.E. Warren Air Force Base and would be difficult to implement due to the depth to groundwater.

## 3.6. Air Sparging/Soil Vapor Extraction

Air sparging with soil vapor extraction involves injecting air into groundwater to volatilize contaminants and enhance aerobic biodegradation. A series of injection wells are installed into the saturated zone and soil vapor extraction wells are installed into the vadose zone. After air is injected, air rises in channels through pores in sand and silt with the lowest air-entry pressure (usually the coarser materials) and the contaminants are removed (stripped) from the groundwater and are carried up into the unsaturated zone. A soil vapor extraction system is usually installed to remove vapors from the unsaturated zone.

The system would be designed so that the area of influence of the systems overlap, ensuring that all areas are treated. Pilot tests are often performed to evaluate the most effective distance between injection wells. An injection pump and vacuum extractor would be located above ground. The extracted soil vapor may be treated on-site prior to release to the atmosphere.

Advantages of air sparging with soil vapor extraction typically include:

- Can be installed relatively easily with readily available equipment;
- Can be installed at a relatively low cost.

Disadvantages of air sparging with soil vapor extraction typically include:

- Heterogeneities or stratified soils would cause air flow to not flow uniformly through the subsurface causing some zones to be less treated;
- Ex-situ vapor treatment is commonly required, resulting in the need to properly manage vapor-phase granular activated carbon;
- Surface treatment, vapor extraction, manifold, piping, and injection structures are needed;

- Effective vapor extraction is needed to prevent fugitive vapors; and
- Cannot be used for treating confined aquifers.

Air sparging with soil vapor extraction will be retained for evaluation as a potential remedial alternative for the site.

## 3.7. Groundwater Extraction and Treatment

Groundwater extraction and treatment, also referred to as pump and treat, would involve the removal of contaminant-containing groundwater through the use of pumping wells. The extracted water would be treated and returned to the subsurface, a surface water body, or sewer system. Groundwater pumping systems can also be used to control dissolved-phase plume migration.

Site characteristics, such as hydraulic conductivity, will determine the range of groundwater extraction remedial options possible. Chemical properties of the site and dissolved-phase plume need to be determined to characterize transport of the contaminant and evaluate the feasibility of groundwater pumping. To determine if groundwater extraction is appropriate for the site, the following information is needed to design an effective groundwater pumping strategy:

- Properties of the subsurface; and
- The biological and chemical characteristics of the groundwater.

The advantages of groundwater extraction include:

- Pump and treat is an established and widely proven technique for controlling a large volume of contaminated groundwater;
- Using pumping wells to control groundwater flow and slow or reverse the spread of contaminants can be useful in managing large areas of groundwater contamination;
- Groundwater pumping can create a hydraulic barrier to control the spread of a dissolved-phase plume; and
- The extracted groundwater can be treated with relative ease once it is at the surface.

The following factors may limit the applicability and effectiveness of groundwater pumping as a remedial process and should be evaluated prior to implementation:

- It is possible that a long time may be necessary to achieve the remediation goal;

- Residual saturation of the contaminant in the soil pores cannot be removed by groundwater pumping. Contaminants tend to be sorbed in the soil or rock matrix. Groundwater pumping is not applicable to contaminants with high residual saturation, contaminants with high sorption capabilities, and aquifers with hydraulic conductivity less than 10-5 centimeters per second (cm/sec);

- Bio-fouling of the extraction wells, and associated treatment stream, is a common problem which can severely affect system performance;

- Hydraulic control systems require frequent, long-term maintenance;

- The cost of procuring and operating treatment systems can be high. Additional cost may also be attributed to the disposal of spent carbon and the handling of other treatment residual and wastes;

- Pumping is typically not effective at reducing low contaminant concentrations in the subsurface due to tailing effects; and

- The cost-effectiveness of a groundwater pumping system typically decreases as the concentration in the groundwater decreases.

Surfactant-enhanced recovery may also be used to improve the effectiveness for contaminated sites with LNAPLs and DNAPLs. The following factors may limit the applicability and effectiveness of surfactant-enhanced recovery:

- Subsurface heterogeneities, as with most groundwater remediation technologies, present challenges to the successful implementation of this technology; and

- Off-site migration of contaminants due to the increased solubility achieved with surfactant injection.

Extracted groundwater is generally treated by granular activated carbon, air stripping, or ultraviolet (UV) oxidation. Extracted vapors may also need to be treated. A description of several ex-situ treatments is provided below:

### 3.7.1. Advanced Oxidation Process

Advanced oxidation processes are similar to in-situ chemical oxidation in that oxidants are used to degrade contaminants to carbon dioxide, water, and simple organic and inorganic compounds. The process typically uses ozone, hydrogen peroxide, and ultraviolet light (UV) in some combination to form hydroxyl radicals ($OH^-$). Hydroxyl radicals have the highest oxidation potential and readily breakdown contaminants such as TCE.

Advanced oxidation processes are available in many forms and generally used in treatment systems for groundwater that contain higher concentrations of VOCs. The most widely used products are systems using hydrogen peroxide/UV, ozone/UV, and hydrogen peroxide/ozone. For evaluation purposes, the hydrogen peroxide/ozone system has been selected. This system is effective in treating VOCs and is not significantly affected by turbidity as are processes using UV due to the need to keep UV lamps clean. Ozone is readily mixed with groundwater in the controlled environment of the treatment piping. Oxidation is effective at treating a wide variety of compounds but typically has high costs relative to granular activated carbon and air stripping.

### 3.7.2. Air Stripping/Aeration

Air stripping is a form of aeration, which is a widely used technology used for environmental remediation and in the wastewater treatment industry. Aeration promotes volatilization and biological degradation by increasing the contact between contaminated media and air. Aeration can promote biodegradation in systems where the oxygen-rich air has time to nourish bacteria. Aeration methods include activated sludge, rotating biological contacters, trickling filters, air stripping, air sparging, bioventing, packed towers, diffused aeration, tray aeration, venturi aeration, and spray aeration.

Air stripping involves the mass transfer of VOCs from water to air. In the air stripping process, VOCs are partitioned from extracted groundwater by increasing the surface area of the water containing VOCs exposed to air. Air stripping is most appropriate for VOCs that are easily evaporated from water. Compounds which are highly soluble, such as alcohols and ketones, are difficult to remove with air stripping.

For groundwater remediation, the most widely used air stripping process typically involves use of a packed tower or tray aeration. The typical packed tower air stripper includes a spray nozzle at the top of the tower to distribute water containing VOCs over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect treated water. Packed tower air strippers can be installed as either permanent structures on concrete pads or as temporary structures on a skid or trailer, mainly depending on the volume of water treated. Low-profile air strippers, or tray aerators, include a number of trays in a very small chamber to maximize air-water contact. These systems are easier to install and operate than other air strippers, but have a somewhat larger footprint.

The off-gases may need to be treated if the aerated water contains high concentrations of VOCs. Air strippers commonly use vapor-phase activated carbon systems to capture VOCs in off-gases, especially in early stages of remediation when VOC concentrations are higher. Off-gas treatment is not feasible in some applications of this technology, such as spray irrigation. The effect of, and potential exposures related to, transferring VOCs from water to air must be assessed prior to implementing this technology. Air quality may need to be monitored if this treatment option is implemented.

### 3.7.3. Carbon Adsorption

Carbon adsorption is most appropriate for low concentrations and/or low flow rates of contaminated water. Liquid-phase carbon adsorption typically involves pumping groundwater through one or more vessels in series containing activated carbon to which dissolved VOCs adsorb. When the concentration of contaminants in the effluent from the treatment vessel exceeds a certain level, the carbon is typically removed and regenerated off site or disposed. The most common reactor configuration for carbon adsorption systems involving groundwater is the fixed bed approach with two vessels in series. The fixed-bed configuration is the most widely used for adsorption from liquids. The duration of operation and maintenance (O&M) is dependent upon the contaminant type, concentration, mass treated, other organics or metals that occupy adsorption sites, and the clean-up requirements. It should be noted that several compounds, including vinyl chloride, 1,1,1-TCA, DCA, chloroform, methylene chloride, and alcohols, have a poor affinity for carbon absorption.

Despite the potential drawbacks related to installation, operation, and maintenance, groundwater extraction with ex-situ treatment has the potential to quickly control dissolved-phase plume migration. Although it is effective at treating a wide variety of compounds, oxidation will not be considered further because of its high costs relative to granular activated carbon and air stripping. Groundwater extraction and treatment using granular activated carbon, air stripping, or aeration will be retained for further consideration. Following treatment, the water would be re-injected into the subsurface, released to the atmosphere as a mist, or discharged to a surface water body in accordance with SPDES requirements.

## 3.8. In-well Air Stripping (a.k.a. Groundwater Recirculation)

An in-well air stripping system uses a series of groundwater circulation wells to recapture and re-circulate groundwater within an aquifer. The groundwater circulation well system creates in-situ vertical groundwater circulation cells by drawing groundwater from the aquifer through the lower screen of a double-screened well and discharging it through the upper screen section. No groundwater is removed from the ground. Air is injected into the well, releasing bubbles into the contaminated groundwater, which aerate the water and form an air-lift pumping system (due to an imparted density gradient) that causes groundwater to flow upward in the well.

As the bubbles rise, VOC contamination in the groundwater is transferred from the dissolved state to the vapor state through an air stripping process. The air/water mixture rises in the well until it encounters the dividing device within the inner casing, which is designed to maximize volatilization. The air/water mixture flows from the inner casing to the outer casing through the upper screen. A vacuum is applied to the outer casing, and contaminated vapors are drawn upward through the annular space between the two casings. The partially treated groundwater re-enters the subsurface through the upper screen and infiltrates back to the aquifer and the zone of contamination where it is eventually cycled back through the well, thus allowing groundwater to undergo sequential treatment cycles until the remedial objectives are met. Off gas from the stripping system is collected and treated, typically using granular activated carbon. Pilot testing and field measurements is generally required to determine the exact well and piping configuration.

In-well air stripping has been demonstrated to be effective and has been used or selected as a remedy at numerous sites, particularly in coarse media with little silt or clay lenses. As of January 2006, over 1,300 wells have been installed in more than 75 sites, including federal sites, in 24 states (NYSDEC DER-15). Only a limited number of vendors are available to design and construct an in-well air stripping system.

In general, in-well air strippers are most effective at sites containing high concentrations of dissolved contaminants. The effectiveness of in-well air stripping systems may be limited in shallow aquifers. These systems are typically more cost-effective for remediating groundwater at sites with deep water tables because the groundwater does not need to be brought to the surface. To prevent smearing the contaminants in the area immediately above the water table, this technology should not be used at sites containing non-aqueous phase liquids (NAPLs).

In-well air stripping will not be retained for further evaluation because subsurface heterogeneities can interfere with uniform flow in the aquifer around the well causing incomplete treatment and it would not be as effective as at sites with higher groundwater concentrations.

## 3.9. Phytoremediation

Phytoremediation is a bioremediation process that uses plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. Phytoremediation is used for the remediation of metals, radionuclides, pesticides, explosives, fuels, VOCs and semi-volatile organic compounds (SVOCs). Phytoremediation mechanisms include:

- *Rhizosphere biodegradation* - Natural substances are released through the plant's roots, supplying nutrients to microorganisms in the soil, which enhances biological degradation.

- *Phyto-accumulation* (also called phyto-extraction) - Phyto-accumulation is used primarily for remediation of soil and groundwater containing metals. Contaminant mass is absorbed through the plant roots and stored in the plant's shoots and leaves, which are harvested and either smelted for potential metal recycling/recovery or are disposed of as a hazardous waste.

- *Hydroponic Systems for Treating Water Streams (Rhizofiltration)* - Rhizofiltration is similar to phyto-accumulation, but the plants are grown in greenhouses with their roots in water. This system can be used for ex-situ treatment, where groundwater is pumped to the surface to irrigate these plants. The plants are harvested and disposed of after they become saturated with contaminants.

- *Phyto-stabilization* - Chemical compounds produced by the plant immobilize contaminants, rather than degrade them.

- *Phyto-degradation*. In this process, plants metabolize and destroy contaminants within plant tissues.

- *Phyto-volatilization*. A process where plants absorb contaminants and release them into the atmosphere through their leaves.

- *Hydraulic Control*. In this process, trees indirectly assist with remediation of groundwater by controlling groundwater movement by uptaking water and lowering the water table.

The advantages of phytoremediation include:

- Lower cost than many traditional remedial technologies;

- Vegetation can be easily monitored;

- Potential recovery and re-use of valuable metals (“phytomining”); and

- Uses naturally occurring organisms/vegetation and preserves the natural state of the environment.

The following factors may limit the applicability and effectiveness of phytoremediation:

- The area and depth of the treatment zone is dictated by plant root spread and depth. In most cases, it is limited to shallow soils, streams, and groundwater although deeper groundwater can be treated by pumping it to the surface to irrigate plantations of trees;

- Phytoremediation is generally limited to treatment of lower contaminant concentrations and contamination in shallow soils, streams, and groundwater;

- Climatic factors influence the effectiveness of phytoremediation and its success may be seasonal, depending on location;
- The success of remediation depends in establishing the selected plant community, which may require several seasons of irrigation, potentially increasing the mobilization of contaminants in the soil and groundwater;
- Requires a long-term commitment because of slow growth and low biomass;
- Plant survival is affected by the toxicity and concentrations of the contaminants and the general condition of the soil.
- Plants may not be able to live if contaminant concentrations are too high;
- Phytoremediation may transfer contamination across media (e.g., from soil to air);
- Phytoremediation is not effective for strongly sorbed contaminants such as polychlorinated biphenyls (PCBs); and
- Phytoremediation requires large areas of land.

The following should be considered prior to selecting phytoremediation as a remedy:

- The toxicity and bioavailability of biodegradation products is not always known;
- Degradation by-products may be mobilized in groundwater or bio-accumulated in animals;
- It is unclear whether contaminants that collect in the leaves and wood of trees are released when the leaves fall in the autumn or when the tree is used for firewood or mulch;
- Contaminants may bio-accumulate in plants which then pass into the food chain;
- Plants may contain high levels of heavy metals, making disposal of harvested plants problematic; and
- The ecological impact of introducing new plant species should be evaluated prior to implementation and monitored following implementation.

A phytoremediation system often includes the use of plants suited to conditions at the site to degrade and/or remove contaminants. Vegetation may not need to be imported as native vegetation may be sufficient. The previously existing ecosystem could be altered into a phytoremediation system (such as a constructed wetland) or enhanced to provide the desired treatment design.

To be effective, phytoremediation systems must be properly designed, constructed, operated, and maintained. Once completed, a phytoremediation system requires regular monitoring to ensure proper operation. As with any remedial technology these systems may require enhancements or modifications in addition to routine management to maintain optimum performance.

Because of the depth to groundwater and the uncertainties regarding its effectiveness at the site, phytoremediation will not be retained for further evaluations.

# 4. Remedial Alternatives Overview

Medium-specific remedial alternatives for the protection of human health and the environment were developed based a comparison of the results of the RI to SCGs. Potential remedial alternatives were identified by:

- Developing remedial action objectives that specify the contaminants and media of interest, potential exposure pathways, and remediation goals. The objectives developed were based on contaminant-specific cleanup criteria and SCGs;
- Developing general response actions for each medium of interest that may be taken to satisfy the remedial action objectives for the site;
- Identifying volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the remedial action objectives and the chemical and geological characterization of the site;
- Identifying and screening the technologies applicable to each medium of interest to eliminate those technologies that cannot be implemented technically at the site; and,
- Assembling the selected representative technologies into appropriate alternatives.

By cutting off the continued off-site migration of contaminants in groundwater, the contamination in surface water and soil vapor will likely decrease. As such, remedial alternatives have been developed to address CVOCs in groundwater.

The size of the dissolved-phase CVOC plume makes plume-wide remediation infeasible. As such, alternatives have been developed for remediation of two portions of the dissolved-phase CVOC plume. These remedial alternatives are evaluated in Sections 5 and 6 with the goal of:

- Reducing or eliminating migration of contaminated groundwater past a treatment zone downgradient of MW-14 and MW-17 (Section 5); and
- Reducing groundwater CVOC concentrations in the area of highest CVOC groundwater concentrations (Section 6).

The general location of the proposed treatment area is shown on Figure 7. The area-specific remedial alternatives are evaluated relative to each other in Section 7 and are combined into plume-wide remedial alternatives in Section 8. The plume-wide remedial alternatives include long-term groundwater monitoring (LTM) and either a dissolved-phase CVOC plume alternative (from Section 5) or a highest groundwater CVOC area treatment alternative (from Section 6). An additional plume-wide remedial alternative (discussed in Section 8) was developed to compare restoring the site to pre-disposal conditions versus other remedial alternatives.

Soil vapor intrusion in the vicinity of the dissolved-phase CVOC plume has been addressed by the installation of sub-slab depressurization systems. As such, soil vapor intrusion remedial technologies are not screened or evaluated in this FS. The concentrations of VOCs in soil vapor would be addressed through the implementation of the selected remedial alternative, which would reduce groundwater CVOC concentrations and the mass flux of VOCs into soil vapor.

## 4.1. Common Components of Remedial Alternatives

A Site Management Plan, an environmental easement, a Soil Vapor Intrusion Action Plan, long-term groundwater monitoring, and residential water connections are common elements of the alternatives being evaluated for the site (with the exception of the no further action alternative) and are not discussed in the summary and evaluation of each alternative. The opinion of probable cost for the components common to each remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table 3.

### 4.1.1. Site Management Plan

A Site Management Plan would guide future activities at the site by addressing property and groundwater use restrictions and by developing requirements for periodic site management reviews. The periodic site management reviews would focus on evaluating the site with regard to the continuing protection of human health and the environment as provided by information such as indoor air, soil vapor, sub-slab vapor, and groundwater monitoring results and documentation of field inspections. The site management plan could mandate the ongoing monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. In addition, a site management plan could preclude excavation and construction activities that would expose workers without proper protective equipment to affected groundwater.

### 4.1.2. Environmental Easement

Building/property use restrictions and groundwater use restrictions would be placed on the site property that would require compliance with the approved site management plan. Deed restrictions could be placed on properties located above the dissolved-phase CVOC plume requiring that vapor intrusion mitigation systems would be designed and installed as future buildings are constructed. Costs for an environmental easement were not included in the remedial alternative cost estimates.

### 4.1.3. Soil Vapor Intrusion

A soil vapor intrusion action plan would be developed to address sampling requirements and to monitor, maintain, and further evaluate the effectiveness of the six sub-slab depressurization systems located above the dissolved-phase CVOC plume that were installed by NYSDEC. Soil vapor monitoring points would be installed. The decision to collect soil vapor samples from these monitoring points would be contingent on or triggered by changes in the groundwater chemistry. Follow up air and sub-slab vapor sampling would be completed at residences which fall in the "monitor" category for approximately four consecutive years, at which time the need for additional monitoring will be evaluated.

### 4.1.4. Long-term Groundwater Monitoring

Groundwater samples would be collected periodically for 30 years and analyzed for VOCs. During each of these sampling events, samples would be collected from monitoring wells located up- and down-gradient of the area of highest groundwater CVOC concentrations to evaluate the effectiveness of the selected remedial alternatives and verify the extent of the dissolved-phase CVOC plume. During select sampling events, samples would also be collected from a surface water location.

### 4.1.5. Water Connections

Eleven homes located above the dissolved-phase CVOC plume which currently use well water as their water supply would be connected to public water.

## 4.2. Evaluation Criteria

The remedial alternatives developed in this Feasibility Study were evaluated based on the following seven criteria, as outlined DER#10 Section 4.1(e):

- Overall Protection of Human Health and the Environment;
- Compliance with Standards, Criteria, and Guidance (SCGs);
- Long-term Effectiveness and Permanence;
- Reduction of Toxicity, Mobility, and Volume;
- Short-term Effectiveness;
- Implementability; and
- Cost.

### 4.2.1. Overall Protection of Human Health and the Environment

This criterion serves as a final check to assess whether each alternative meets the requirements that are protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under other evaluation criteria; especially long-term effectiveness and performance, short-term effectiveness, and compliance with SCGs. This evaluation focuses on how a specific alternative achieves protection over time and how site risks and human exposures are reduced. The analysis includes how each source of contamination is to be eliminated, reduced or controlled for each alternative.

### 4.2.2. Compliance with SCGs

This evaluation criterion determines how each alternative complies with SCGs, as discussed and identified in Sections 3 and 4 of this Report. The actual determination of which requirements are applicable or relevant and appropriate is made by NYSDEC and in consultation with NYSDOH. If a SCG is not met, the basis for one of the four waivers allowed under 6 NYCRR Part 375-1.10(c)(i) is discussed. If an alternative does not meet the SCGs and a waiver is not appropriate or justifiable, such an alternative should not be considered further.

### 4.2.3. Short-term Effectiveness

This evaluation criterion assesses the effects of the alternative during the construction and implementation phase. Alternatives are evaluated with respect to the effects on human health and the environment during implementation of the remedial action. The aspects evaluated include: protection of the community and workers during remedial actions, environmental impacts as a result of remedial actions, and time until the remedial response objectives are achieved.

### 4.2.4. Long-term Effectiveness and Permanence

This evaluation criterion addresses the results of a remedial action in terms of its permanence and quantity/nature of waste or residual remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the waste or residual remaining at the site and operating system necessary for the remedy to remain effective. The factors being evaluated include the permanence of the remedial alternative, magnitude of the remaining environmental risks and potential human exposure, adequacy of controls used to manage residual waste, and reliability of controls used to manage residual waste.

### 4.2.5. Reduction of Toxicity, Mobility, and Volume

This evaluation criterion assesses the remedial alternative's use of the technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous wastes as their principal element. The NYSDEC's policy is to give preference to alternatives that eliminate any significant threats at the site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in the contaminants mobility, or reduction of the total volume of contaminated media. This evaluation includes: the amount of the hazardous materials that would be destroyed or treated, the degree of expected reduction in toxicity, mobility, or volume measured as a percentage, the degree in which the treatment would be irreversible, and the type and quantity of treatment residuals that would remain following treatment.

### 4.2.6. Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services, technology, and materials required during its implementation. The evaluation includes:

- Feasibility of construction and operation;
- Ease of undertaking additional remedial action;
- Monitoring considerations;
- Technical aspects of construction, operation, and monitoring;
- Reliability of technology;
- Activities related to coordinating with other offices or agencies and obtaining necessary approvals from government agencies;
- Availability of equipment, services, and materials, including the availability of specialists and the ability to obtain competitive bids; and
- Availability of adequate off-site treatment, storage, and disposal services, if needed.

### 4.2.7. Cost

Cost estimates are prepared and evaluated for each alternative. The cost estimates include capital, OM&M, and future capital costs. A cost analysis is performed which includes the following factors: the effective life of the remedial action, the OM&M costs, the duration of the cleanup, the volume of contaminated material, other design parameters, and the discount rate. Cost estimates developed at the detailed analysis of alternatives phase of a feasibility study generally have an expected accuracy range of –30 to +50 percent (USEPA, 2000).

# 5. Analysis of Dissolved-Phase CVOC Plume Remedial Alternatives

The selection and development of the remedial alternatives was conducted in accordance with New York State NYSDEC Division of Environmental Remediation (DER) policy, DER-15: Presumptive/Proven Remedial Technologies. The presumptive remedy approach is to select remedies that have already been proven to be both feasible and cost effective so as to make the remedy selection quicker. In accordance with Section 1 of DER-15 and with the concurrence of NYSDEC, no further action, long-term groundwater monitoring, MNA, and PRB alternatives are evaluated in this section along with select presumptive remedies for groundwater contaminated with VOCs.

The remedial alternatives selected for evaluation in this Section are consistent with the goals of the groundwater remediation, which is not to remediate the entire dissolved-phase CVOC plume, but to focus on reducing or eliminating migration of contaminated groundwater past the treatment area.

Based on the screening of remedial technologies in Section 3, the groundwater remedial alternatives to be evaluated are:

- No further action;
- MNA;
- Enhanced in-situ bioremediation;
- Permeable reactive barrier;
- Air sparging and soil vapor extraction; and
- Groundwater extraction.

Each alternative (other than the no further action or MNA alternatives) would treat an approximately 35-foot thick by 400-foot wide portion of saturated sand with CVOC-containing groundwater downgradient of MW-14 and MW-17S. This treatment area was selected because the highest CVOC groundwater concentrations in the dissolved-phase CVOC plume have been detected at MW-14 and MW-17S. The opinion of probable costs for these remedial alternatives, with an expected accuracy range of –30 to +50 percent, is presented in Appendix A. The remedial alternatives are described and evaluated below.

## 5.1. No Further Action

A no further action alternative would involve no monitoring or remediation and is considered to be ineffective because groundwater contamination would not be remediated. For this reason, this alterative would not be in compliance with SCGs, effective in the short- or long-term, or protective of human health and the environment. The no action alternative would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume, would require no effort to implement, and would have no costs. This alternative will be retained for comparison to other alternatives.

## 5.2. Monitored Natural Attenuation

The MNA alternative would involve periodic sampling and analysis of site groundwater. No active groundwater remediation is included in this alterative. If this alternative is selected for implementation, the dissolved-phase CVOC plume would not be remediated other than with natural processes (i.e. dilution, dispersion, natural attenuation, etc.). For this reason, the MNA alterative would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume. Even though the MNA alternative does not include groundwater treatment, it would be protective of human health and the environment because groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed. This alternative would require minimal effort to implement and would have significantly lower capital and operation, maintenance, and monitoring (OM&M) costs than the remedial alternatives that include active treatment of the dissolved-phase CVOC plume.

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table A-1. The cost opinion is based on collecting 20 groundwater samples per year for 30 years. Capital costs including the first year of OM&M would be approximately $36,000. Annual OM&M costs are estimated to be $36,000 including two groundwater sampling events and laboratory analysis. The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $580,000.

## 5.3. Enhanced In-situ Bioremediation

Implementation of an in-situ bioremediation treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of in-situ bioremediation treatment and the amount of biostimulant or bacteria required for treatment.

- Implementation and evaluation of a field pilot test to evaluate injection efficacy, distribution, and persistence in the subsurface.
- Injection of biostimulant or bacteria into either temporary direct-push injection points or permanent injection wells.
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

Since in-situ bioremediation relies on direct contact between bacteria and the contaminant, the success of the in-situ bioremediation treatment would be highly dependent on the ability to effectively distribute the biostimulant or bacteria through the treatment area. If such distribution can be achieved, it is anticipated that in-situ bioremediation is capable of meeting the RAO. Biostimulants are typically emulsified oils, lactate, or molasses. The injection of biostimulant or bacteria would be in a linear treatment zone generally perpendicular to groundwater flow downgradient of MW-14 and MW-17S.

Groundwater monitoring both upgradient and downgradient from the treatment area would be required to evaluate the effectiveness of the in-situ bioremediation injections at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase CVOC plume migration. Multiple injections, commonly one to two years apart for emulsified oils or lactate and up to monthly for molasses, are required to sustain anaerobic conditions and microbial populations in the subsurface.

In-situ bioremediation would treat the dissolved-phase CVOC plume as the affected groundwater flows through the treatment area, which would limit migration of the dissolved-phase CVOC plume from the area of highest groundwater CVOC concentrations. There would also be limited downgradient treatment because the bioremediation amendments would flow with groundwater downgradient. However, areas of the dissolved-phase CVOC plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. An in-situ bioremediation pilot study would be conducted to evaluate the implementability, effectiveness, and feasibility of this technology at the site.

### Overall Protection of Human Health and the Environment

This alternative, in the long term, would help reduce contaminant concentrations in groundwater flowing through the treatment area. However, this remedial alternative does not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated. That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed. The six sub-slab depressurization systems that were installed by the NYSDEC to address exposures relating to soil vapor intrusion would continue to be maintained.

#### Compliance with SCGs

If distribution of the biostimulant or bacteria can be achieved, in-situ bioremediation can be used to effectively reduce contaminant concentrations within the treatment area, thus achieving SCGs.

#### Short-term Effectiveness

This alternative is not as effective in the short-term as some other alternatives because it can take years for bioremediation to reduce contaminant concentrations. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

#### Long-term Effectiveness and Permanence

If distribution of the biostimulant or bacteria can be achieved, in-situ bioremediation is considered to be effective in the long-term because groundwater VOC concentrations would be reduced within the treatment area as long as subsurface conditions amenable to bioremediation are maintained. In-situ bioremediation is expected to be effective for at least six months and potentially more than one year before additional injections are required if emulsified oils or lactate are the biostimulant injected.

There is a potential for incomplete degradation of contaminants if the aquifer is not conducive to anaerobic adjustment or the injection frequency and concentration is not sufficient. The potential for incomplete contaminant degradation would be evaluated using available data, including those from pilot studies.

#### Reduction of Toxicity, Mobility, and Volume

In-situ bioremediation is considered to be effective at reducing the toxicity, mobility, or volume of the dissolved-phase CVOC plume because bacteria that are stimulated or added can convert the contaminants to non-toxic byproducts if sufficient distribution can be achieved. Contaminated groundwater downgradient of the proposed injection locations would be addressed with MNA and a separate alternative developed for treatment of groundwater and/or surface water in the vicinity of the Modock Road Springs.

#### Implementability

In-situ bioremediation could be implemented using readily available technologies. There does not appear to be any significant obstacles to implementing this technology at the site. In-situ bioremediation is expected to be effective for at least six months and potentially more than one year before additional injections are required if emulsified oils or lactate are the biostimulant injected.

As the proposed location for the in-situ bioremediation injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the in-situ bioremediation injection locations. It is assumed that access agreements could be obtained from adjacent property owners as necessary. In-situ bioremediation injections do not generate significant waste, so treatment and disposal considerations are negligible.

#### Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table A-2. The cost opinion is based on two injections of a biostimulant each year for 30 years. The capital costs include the installation of 20 injection wells to 100 feet bgs and 6 monitoring wells to 100 feet bgs. Capital costs including the first year of OM&M would be approximately $800,000. Annual OM&M costs are estimated to be $380,000 including two injections of biostimulant and post injection groundwater monitoring and laboratory analysis. The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $6.6 million.

## 5.4. Permeable Reactive Barrier

As discussed in Section 3, a zero-valent iron PRB would be installed by direct-injection in the center of the dissolved-phase CVOC plume. The direct-injection PRB would be constructed using a series of injection wells or boreholes oriented generally perpendicular to groundwater flow downgradient of MW-14 and MW-17S. The PRB would extend vertically from approximately 60 feet bgs (average depth of the water table) to an approximate average depth of 100 feet bgs. Assuming a 400-foot long PRB, the treatment area would contain approximately 350 to 600 tons of iron, depending on the barrier thickness. Groundwater monitoring both upgradient and downgradient of the PRB would be required to evaluate the effectiveness of the PRB at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase CVOC plume migration.

A PRB would treat the dissolved-phase CVOC plume as the affected groundwater flows through the treatment area, which would limit migration of the dissolved-phase CVOC plume from the area of highest groundwater CVOC concentrations. However, areas of the dissolved-phase CVOC plume downgradient and east and west of the PRB would continue to migrate to the north toward the Modock Road Springs.

### Overall Protection of Human Health and the Environment

Zero-valent iron is effective at reducing contaminant concentrations if contact between the iron and contaminated groundwater is attained. The treatment process is in-situ, eliminating treatment process disposal issues and preventing potential contact with contaminated groundwater during the treatment process. PRBs have been shown to be effective at meeting maximum contaminant levels (MCLs) for organic contaminants, and are likely to reduce contaminant concentrations within the treatment area to comply with the applicable MCLs. However, this remedial alternative does not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated. That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed. The six sub-slab depressurization systems that were installed by the NYSDEC to address exposures relating to soil vapor intrusion would continue to be maintained.

### Compliance with SCGs

Assuming that the PRB is properly installed, the RAOs would be met because the mass discharge of the contaminants to downgradient areas would be reduced. It is anticipated that the PRB would effectively treat contaminated groundwater as it flows through the PRB. After treatment of CVOCs, the remaining byproducts (e.g., ethane, ethene, and chloride ions) are less toxic.

### Short-term Effectiveness

A PRB would be effective in the short-term because CVOCs would be completely degraded to ethene and ethane as groundwater passes through the PRB. However, a PRB is ineffective at treating groundwater upgradient and downgradient of the PRB. As with any barrier technology, VOC concentrations downgradient of the PRB would decrease over months to years, which limits the short-term effectiveness. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-term Effectiveness and Permanence

Zero-valent iron longevity is dependent on the contaminant concentration, groundwater flow velocity, and the geochemical makeup of the groundwater. Bench scale studies using reactive iron columns (from both cores obtained from emplaced permeable reactive zero-valent iron walls and from virgin reactive iron) have been conducted to evaluate long-term zero-valent iron longevity. These tests have shown that conditions promoting the dehalogenation of chlorinated solvents are maintained in a permeable reactive zero-valent iron wall over the long term. Based on these studies, the expected life of a typical reactive wall is approximately 30 years (ESTCP, 2003).

The certainty regarding the effectiveness of a PRB is lower and the need for a thicker PRB is greater if it is installed in an area of high groundwater flow rate because there would be less contact time between the CVOCs and zero-valent iron. Though unlikely, the installation of a PRB could alter the groundwater direction or velocity, reducing the PRB's effectiveness.

#### Reduction of Toxicity, Mobility, and Volume

It is anticipated that a PRB would significantly and permanently reduce the toxicity, mobility, and volume of contaminants in groundwater which flows through the PRB. The reduction of CVOCs using zero-valent iron is a proven technology that has been employed at numerous sites throughout the United States. After treatment of CVOCs, the remaining byproducts (e.g., ethane, ethene, and chloride ions) are less toxic. As this alternative involves an in-situ process, there are no other treatment residuals that would require additional handling or disposal.

A PRB would be effective at meeting the RAO for the site by reducing contaminant concentrations and minimizing downgradient migration of contaminated groundwater. A PRB would reduce the mobility of the dissolved-phase CVOC plume by treating the groundwater as it flows through the PRB. Contaminated groundwater downgradient of the proposed PRB location would be addressed with MNA and a separate alternative developed for treatment of groundwater and/or surface water in the vicinity of the Modock Road Springs.

#### Implementability

Trenchless technologies for the installation of PRBs are relatively simple and technically feasible processes for the site. The uncertainties associated with PRB construction consist of minimizing gaps in the barrier and sufficient barrier thickness. These uncertainties could be mitigated using the testing and monitoring procedures discussed in Section 3. The effectiveness of the PRB could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the PRB.

As the proposed location for the PRB may not be owned by the State, an access agreement may need to be obtained from the property owner(s) to allow access to and from the PRB location. As discussed in Section 3, PRB installation using direct injection does not generate significant waste, so treatment and disposal considerations are negligible.

It is anticipated that the necessary specialists and equipment are available to complete the PRB installation. There are a limited number of specialized PRB direct-injection vendors which could potentially limit the ability for competitive bidding. However, when comparing costs and technical feasibility of various PRB technologies, direct-injection is the most applicable and cost-effective method of PRB installation given the site characteristics and proposed PRB location and depth.

### Cost

The PRB alternative has a higher capital cost but lower OM&M cost than all other active treatment alternatives. Over an eight year time period, the PRB alternative would be more expensive than all other alternatives. Over a 30 year time period, the PRB alternative has a similar present net worth to the groundwater extraction and air sparging/SVE alternatives.

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table A-3. This cost opinion is based on the installation of a 400-linear foot PRB along the width of the dissolved-phase CVOC plume. Capital costs include the installation of the PRB, the installation of 6 monitoring wells to 100 feet bgs, and the first year of OM&M. The capital cost for the PRB alternative is approximately $3.0 million. There are annual OM&M costs associated with this alternative. The groundwater sampling and laboratory analysis costs are included as common components of each alternative (Table 3). The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $3.0 million.

## 5.5. Air Sparging/Soil Vapor Extraction

Air sparging wells would be installed using a series of injection wells oriented generally perpendicular to groundwater flow downgradient of MW-14 and MW-17S. Soil vapor extraction wells would be installed in the vadose zone in the vicinity of the air sparging wells. Air would be injected from approximately 60 feet bgs (average depth of the water table) to an approximate average depth of 100 feet bgs, although the majority of air would be injected in the lower 20 feet of this interval. Soil vapor extraction wells would be installed to within 10 feet above the water table. The volume of extracted soil vapor is typically two to three times more than the air injected into the aquifer.

Electrical lines would be run to a treatment shed, which would contain a series of blowers and a control system. The air sparging and soil vapor extraction PVC piping would be buried to prevent freezing during the winter. Periodic on-site monitoring of the system would be conducted to evaluate the system effectiveness and perform system maintenance. Groundwater monitoring both upgradient and downgradient of the air sparging injection area would be required to evaluate the effectiveness of the air sparging at reducing VOC concentrations and from further dissolved-phase CVOC plume migration.

### Overall Protection of Human Health and the Environment

Assuming all zones within the treatment area are treated and the area of influence of the air sparging wells overlap, the implementation of air sparging and SVE would be protective of human health by reducing concentrations of VOCs in groundwater. An air sparging and soil vapor extraction treatment system would be effective at minimizing downgradient migration of contaminated groundwater by removing contaminant mass. The system would achieve the RAOs for the site by minimizing contaminant mass flux past the treatment area. However, this remedial alternative does not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated. That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed. The six sub-slab depressurization systems that were installed by the NYSDEC to address exposures relating to soil vapor intrusion would continue to be maintained.

### Compliance with SCGs

Air sparging and SVE can be used to effectively reduce contaminant concentrations within the treatment area, thus achieving the RAOs while being in compliance with SCGs.

### Short-term Effectiveness

Air sparging and SVE is effective in the short term assuming uniform treatment of the dissolved-phase CVOC plume can be achieved and the system is operated continuously. In general, air sparging is more effective for constituents with greater volatility and lower solubility and for soils with higher permeability. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-term Effectiveness and Permanence

If uniform treatment of the dissolved-phase CVOC plume can be achieved, air sparging and SVE is considered to be effective in the long-term because groundwater VOC concentrations would be reduced within the treatment area as long as the remedial system is continuously operated. There is a potential for incomplete treatment of contaminants if heterogeneities or stratified soils are present or if the area of influence of the air sparging wells do not overlap. Subsurface heterogeneities may cause non-uniform treatment and this would decrease the long-term effectiveness of this technology. The rate at which the contaminant mass would be removed decreases as air sparging operations proceed and concentrations of dissolved constituents are reduced. This effect would be minimized if contaminated groundwater continues to flow into the treatment area.

#### Reduction of Toxicity, Mobility, and Volume

Air sparging and SVE is considered to be effective at reducing the toxicity, mobility, or volume of the dissolved-phase CVOC plume because air sparging can remove contaminants from the groundwater if uniform treatment is achieved. This alternative would be effective at meeting the RAO for the site by reducing contaminant concentrations and minimizing off-site migration of contaminated groundwater.

Air sparging and SVE would reduce the mobility and limit the migration of the dissolved-phase CVOC plume by treating the groundwater as it flows through the treatment area. However, areas of the dissolved-phase CVOC plume downgradient and east and west of the treatment area would continue to migrate to the north toward the Modock Road Springs. The portion of the dissolved-phase CVOC plume downgradient and to the east and west of the treatment area would be addressed with MNA and a separate alternative developed for treatment of groundwater and/or surface water in the vicinity of the Modock Road Springs.

#### Implementability

An air sparging and SVE system could be installed relatively easily with readily available equipment. It is anticipated that the necessary specialists and equipment are available to complete the project. There does not appear to be any significant obstacles to implementing this technology at the site, although the potential effects of silt and silty-sand zones may need to be further investigated. An air sparging and SVE system could be installed with minimal disturbance to the site. However, at a minimum, an injection pump, vacuum extractor and surface treatment structures would need to be located above ground. As the proposed location for the air sparging injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the air sparging and soil vapor extraction well locations.

Although air could be injected at the exact location desired, difficulties associated with air sparging include effective treatment within the air sparging area. Heterogeneities or stratified soils may cause air to not flow uniformly through the subsurface causing some zones to remain untreated. The area of influence of the air sparging wells would need to overlap to maximize the treatment area and effectiveness. The effectiveness of the air sparging system could be monitored using standard monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area. A pilot test would be performed to evaluate an appropriate distance between injection wells.

**Cost**

Capital costs (excluding the first year of OM&M) for air sparging and soil vapor vapor extraction are typically more than for injection technologies but less than PRB installations. However, OM&M costs could be substantial if the system is operated for many years. OM&M costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks. Capital costs would include construction of the treatment shed, running electrical lines to the treatment shed, and installation of the PVC piping, monitoring wells, and injection wells.

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table A-4. The cost opinion assumes that the remedial system will be composed of 20 air sparge wells installed to 100 feet, 20 SVE wells will be installed to 50 feet, and a treatment shed containing the controls and blowers would be designed and constructed. The capital costs include the installation of the remedial system, the installation of eight monitoring wells, and the first year of OM&M. The approximate capital cost is $1.4 million. Approximate annual OM&M costs including the maintenance of the air sparge/SVE system and sampling and laboratory analysis is $80,000. The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $2.6 million.

## 5.6. Groundwater Extraction

A groundwater extraction system would consist of a series of recovery wells piped to an ex-situ treatment system. The extraction wells would be installed in a pattern perpendicular to groundwater flow to provide hydraulic control of the dissolved-phase CVOC plume and limit further downgradient dissolved-phase CVOC plume migration. The extracted water would be pumped to the south approximately 600 feet to the along the northern mine face of the DLS Sand and Gravel, Inc. property where the water would be released to the atmosphere through a misting nozzle. This is a form of spray aeration and involves the mass transfer of CVOCs from water to air. CVOCs are partitioned from extracted groundwater by increasing the surface area of the water containing CVOCs exposed to air. The groundwater extraction system would only be operated approximately nine months of the year, because of issues relating to potential freezing of the extracted groundwater in the pipes or following spraying into the atmosphere.

An aquifer pumping test would be performed to provide additional information for design of the groundwater extraction system. After system installation, a comprehensive OM&M plan would be developed for the system to ensure proper system performance.

**Overall Protection of Human Health and the Environment**

A groundwater extraction and ex-situ treatment system would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass and controlling the dissolved-phase CVOC plume hydraulically. The system could potentially achieve the RAO for the site by minimizing contaminant mass flux from the site. However, this alternative would not be completely effective as a continuous barrier to contaminant transport because the groundwater extraction system may not operate during the winter months. Groundwater quality in areas downgradient of the groundwater extraction wells would be monitored to evaluate the reduction of contaminant levels over time. However, this remedial alternative does not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated. That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed. The six sub-slab depressurization systems that were installed by the NYSDEC to address exposures relating to soil vapor intrusion would continue to be maintained. The spray aeration groundwater treatment is not anticipated to expose the community to site-related contamination because VOCs in the water would likely volatilize prior to reaching the nearest off-site receptor.

#### Compliance with SCGs

When the groundwater extraction system is operating, this alternative would be effective at decreasing the mass flux of VOCs downgradient of the site. CVOC concentrations in groundwater that has flowed through the area of influence of the extraction wells would be in compliance with SCGs. This alternative would not be in compliance with SCGs during winter months when the system is shut down.

#### Short-term Effectiveness

Groundwater extraction systems are typically effective at controlling migration of dissolved-phase contaminant plumes and removing contaminant mass from an aquifer over the short-term. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting dissolved-phase CVOC plume migration within days or weeks of system startup. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. The spray aeration groundwater treatment is not anticipated to expose the community to site-related contamination because VOCs in the water would likely volatilize prior to reaching the nearest off-site receptor. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

#### Long-term Effectiveness and Permanence

Long-term operation of groundwater extraction systems typically result in reduced efficiency, caused by factors such as aquifer heterogeneity and adsorptive partitioning of contaminants between the groundwater and aquifer materials. The result is a decrease in contaminant mass removal, also referred to as tailing or asymptotic reduction. However, the tailing effect would not impact the ability of the groundwater extraction system to limit dissolved-phase CVOC plume migration. Tailing typically limits the ability of the groundwater extraction system to achieve concentration-based remediation goals in a reasonable timeframe. Additionally, as less contaminant is removed from the aquifer, the cost-effectiveness of the treatment system per amount of contaminant treated decreases with time. Therefore, a groundwater extraction system is more effective as an interim corrective measure than a final remedy unless used in conjunction with other remedial technologies. Although potentially less effective than some other remedial technologies, a groundwater extraction system would control the dissolved-phase CVOC plume migration and volume during its operation, thus meeting an RAO for the site.

#### Reduction of Toxicity, Mobility, and Volume

Initially, groundwater extraction systems are typically effective at controlling dissolved-phase CVOC plume migration, reducing the dissolved-phase CVOC plume area, and removing contaminant mass from the aquifer. During initial operation of groundwater extraction systems contaminant mass is most quickly reduced. As operation continues, however, the slow release of contaminants from a residual source such as adsorbed mass can cause tailing of contaminant mass removal. Tailing typically limits the ability of the groundwater extraction system to achieve remediation goals for remediation in a reasonable timeframe without system enhancements via additional remedial technologies. However, the tailing effect would not impact the ability of the groundwater extraction system to limit dissolved-phase CVOC plume migration. The toxicity, mobility, and volume of the dissolved-phase CVOC plume would not be reduced during the winter months when the system is shut down. In addition, the groundwater extraction system would not affect distal portions of the dissolved-phase CVOC plume, and portions of the dissolved-phase CVOC plume downgradient from the wells would continue to migrate toward the Modock Road Springs.

#### Implementability

A groundwater extraction system with ex-situ treatment consists of readily available technologies. Therefore, it is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation.

The implementation of a groundwater extraction and ex-situ treatment system would require significant pre-design studies to finalize design of the system. Installation of a groundwater extraction system may generate secondary waste, including contaminated soils from drill cuttings and contaminated purge water during well development. Waste generated during implementation and initial operation could be managed using generally accepted methods for off-site disposal and/or treatment.

Operation of a groundwater extraction system over a long time period requires significant OM&M activities. The groundwater extraction system and treatment system must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of the treatment system must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment.

#### Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table A-5. The cost opinion is based on the installation of a groundwater extraction system including three 6-inch diameter PVC extraction wells installed to 100 feet bgs, and groundwater treatment through misting nozzles. The capital costs include the costs for the groundwater treatment system components, a shed to house the controls, the extraction wells, and the installation of six 100-foot deep monitoring wells. The total assumed capital costs including the first year of OM&M is approximately $885,000. Annual OM&M cost including maintenance of the groundwater treatment system is estimated to be approximately $74,000. The total present value of this alternative based on a 5% discount rate over a 30-year period is approximately $2.0 million.

# 6. Analysis of Remedial Alternatives for the Area of Highest Groundwater CVOC Concentrations

The remedial alternatives selected for evaluation in this Section are consistent with the goals of the groundwater remediation, which is not to remediate the entire dissolved-phase CVOC plume, but to focus on a one time reduction of groundwater CVOC concentrations in the area of highest CVOC groundwater concentrations.

Based on the screening of remedial technologies in Section 3, the remedial alternatives to be evaluated for reducing groundwater CVOC concentrations in the area of highest CVOC groundwater concentrations are:

- No further action;
- In-situ chemical oxidation;
- Zero-valent iron injections; and
- Groundwater extraction.

There are no OM&M costs associated with these alternatives because their goal is the one time reduction of groundwater CVOC concentrations in the area of highest groundwater CVOC concentrations.  The cost estimates associated with these remedial alternatives and summarized in this section do not include groundwater monitoring beyond the first year. The selected remedial alternative for the area of highest groundwater concentration would be implemented concurrently with a dissolved-phase CVOC plume remedial alternative, which includes costs for ongoing groundwater monitoring.  The opinion of probable costs for these remedial alternatives, with an expected accuracy range of –30 to +50 percent, are presented in Appendix B.

## 6.1. No Further Action

A no further action alternative would involve no monitoring or remediation and is considered to be ineffective because groundwater contamination would not be remediated.  For this reason, this alterative would not be in compliance with SCGs, effective in the short- or long-term, or protective of human health and the environment. The no action alternative would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume, would require no effort to implement, and would have no costs.  This alternative will be retained for comparison to other alternatives.

## 6.2. In-situ Chemical Oxidation

ISCO would be used to treat the area with the highest groundwater CVOC concentrations, over an approximately 400 foot width of the dissolved-phase CVOC plume in the vicinity of MW-13, MW-14, and MW-17S. Although there are several chemical oxidants capable of treating TCE and 1,1-DCE, the most commonly used chemical oxidant for CVOC remediation is permanganate because it is stable in the subsurface and relatively easier and safer to handle than other oxidants. However, since permanganate does not treat 1,1,1-TCA, sodium persulfate and Fenton's reagent will be considered in the following alternative. Implementation of an ISCO treatment program would include the following:

- Bench-scale laboratory testing to evaluate the effectiveness of ISCO treatment and the amount of oxidant required for treatment;
- Injection of oxidant into the subsurface using temporary direct-push injection points; and
- Post-injection groundwater monitoring to evaluate treatment effectiveness.

Since ISCO relies on direct contact between the oxidant solution and the contaminant, the success of the ISCO treatment would be highly dependent on the ability to effectively distribute the oxidant through the treatment area. If such distribution can be achieved, it is anticipated that ISCO treatment is capable of reducing groundwater CVOC concentrations throughout the treatment area. The ISCO injections would be located in the vicinity of MW-14 and MW-17, the area of the highest groundwater CVOC concentrations. Groundwater monitoring within, upgradient, and downgradient of the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations. Although multiple injections are required to sustain the oxidants in the subsurface, only one injection event, using direct-push injection points, are included in this remedial alternative because the goal of this alternative is the one time reduction of groundwater CVOC concentrations. Permanent injection wells would not be installed unless subsurface conditions prohibit the use of direct-push drilling methods.

ISCO would reduce groundwater CVOC concentrations within the treatment area at the time of the injections. Areas of the dissolved-phase CVOC plume outside of the ISCO treatment area would be addressed with the implementation of the selected dissolved-phase CVOC plume remedial alternative.

### Overall Protection of Human Health and the Environment

Assuming the oxidant solution is able to come into contact with the contaminants and the oxidants can be sustained in the subsurface, the implementation of ISCO would be protective of human health by reducing concentrations of CVOCs in groundwater. However, because the goal of this alternative is the one time reduction of groundwater CVOC concentrations within the treatment area the dissolved-phase CVOC plume treatment would be limited in both space and time. The protection of human health and the environment related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by this alternative.

### Compliance with SCGs

Assuming that the oxidant is effectively distributed, the implementation of ISCO would be in compliance with SCGs because there would be a reduction of CVOC concentrations within the treatment area. Because the oxidants cannot be sustained in the subsurface without subsequent injections, compliance with SCGs after the oxidants dissipate will be evaluated as part of the selected dissolved-phase CVOC plume remedial alternative.

### Short-term Effectiveness

ISCO would be effective in the short-term since ISCO treatment oxidizes VOCs almost immediately upon contact. However, ISCO is ineffective at treating groundwater outside of the ISCO treatment area. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-term Effectiveness and Permanence

If distribution of the oxidant can be achieved and sustained in the subsurface, ISCO is considered to be effective in the long-term because groundwater CVOC concentrations would be significantly reduced. The limiting factor to the long-term effectiveness of ISCO is the number of injections necessary to maintain the oxidant in the subsurface. As only one round of injections is included in this remedial alternative, it is not considered effective in the long-term or permanent.

### Reduction of Toxicity, Mobility, and Volume

ISCO is considered to be effective at reducing the toxicity, mobility, or volume of the dissolved-phase CVOC plume because ISCO can convert the VOCs to less toxic byproducts if sufficient distribution can be achieved. However, this is only true within the treatment area and for a limited time unless additional injection events are implemented. This alternative would have a minimal impact on the toxicity, mobility, and volume of the dissolved-phase CVOC plume.

#### Implementability

ISCO treatment could be implemented using readily available technologies and is considered easy to implement. However, the success of the treatment would be dependent on the degree to which the oxidant solution is able to come into contact with the contaminants and the number of injections required.

As the proposed location for the ISCO injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the ISCO injection locations. There would be minimal disruption to site and property owner(s) activities during ISCO injection events because no surface structures are needed, other than injection wells. As discussed in Section 3, ISCO injections do not generate significant waste, so treatment and disposal considerations are negligible.

#### Cost

The material costs for ISCO are greater than the costs for in-situ bioremediation using bioaugmentation and less than the costs for installation of PRBs if only one ISCO injection is required. However, to maintain the oxidant in the treatment zone, ISCO would need to be injected multiple times per year, resulting in greater costs for ISCO than all other remedial alternatives considered. For costing purposes, it is assumed that one injection event would be implemented as part of this remedial alternative. It is also assumed that no pilot tests would be conducted.

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table B-1. The capital costs include one injection event using direct-push injection points. The estimated capital cost including the first year of OM&M is approximately $530,000. As there would be no ISCO injections after the first year, there are no annual OM&M costs associated with this remedial alternative. Groundwater monitoring and laboratory analysis costs beyond the first year are included as common components of each alternative (Table 3).

## 6.3. Zero-valent Iron Injections

Zero-valent iron would be used to treat the highest groundwater CVOC concentration areas, over an approximately 400 foot width of the dissolved-phase CVOC plume in the vicinity of MW-13, MW-14, and MW-17S. It is anticipated that injecting a 2-4 micron zero-valent iron colloidal suspension will reduce the time required to create dechlorinating conditions and may also reduce the time needed to completely dechlorinate CVOCs. In the presence of zero-valent iron, oxidation of the dissolved phased CVOCs will occur while initiating the production of hydrogen for microbial mineralization processes. Zero-valent iron would be used to treat dissolved-phased CVOCs while acting in synergy with anaerobic degradation processes.

As the goal of this alternative is the one time reduction of groundwater CVOC concentrations within the treatment area, one zero-valent iron injection event would be implemented as part of this remedial alternative. Areas of the dissolved-phase CVOC plume outside of the zero-valent iron treatment area would be addressed with the implementation of the selected dissolved-phase CVOC plume remedial alternative. A zero-valent iron pilot study could be conducted to evaluate the implementability, effectiveness, cost, and feasibility of this technology at the site, although a pilot study is not included in the remedial alternative cost estimate.

#### Overall Protection of Human Health and the Environment

Assuming the zero-valent iron is able to come into contact with the contaminants and can be sustained in the subsurface, the implementation of this alternative would be protective of human health by reducing concentrations of CVOCs in groundwater. However, because the goal of this alternative is the one time reduction of groundwater CVOC concentrations within the treatment area the dissolved-phase CVOC plume treatment would be limited in both space and time. The protection of human health and the environment related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by this alternative.

#### Compliance with SCGs

Assuming that the zero-valent iron is effectively distributed and can be sustained in the subsurface, the implementation of this alternative as a remedy would be in compliance with SCGs because there would be a reduction of COC concentrations within the treatment area. Compliance with SCGs after the zero-valent iron dissipates would be evaluated as part of the selected dissolved-phase CVOC plume remedial alternative.

#### Short-term Effectiveness

This alternative would be effective in the short-term since zero-valent iron quickly treats VOCs within the treatment area. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

#### Long-term Effectiveness and Permanence

If distribution of the zero-valent iron can be achieved and sustained in the subsurface, this alternative is considered to be effective in the long-term. The limiting factor to the long-term effectiveness of this alternative is the number of injections necessary to maintain the zero-valent iron in the subsurface. As only one round of injections are included in this remedial alternative, it is not considered effective in the long-term or permanent.

### Reduction of Toxicity, Mobility, and Volume

The zero-valent iron alternative is considered to be effective at reducing the toxicity, mobility, or volume of the dissolved-phase CVOC plume because these technologies can convert the VOCs to less toxic byproducts if sufficient distribution can be achieved. However, this is only true within the treatment area and for a limited time unless additional injection events are implemented. This alternative would have a minimal impact on the toxicity, mobility, and volume of the dissolved-phase CVOC plume.

### Implementability

Zero-valent iron could be implemented using readily available technologies and there does not appear to be any significant obstacles to implementing this technology at the site. However, the success of the treatment would be dependent on the degree to which the zero-valent iron is able to come into contact with the contaminants and the number of injections required.

As the proposed location for the injections is not owned by the State, an access agreement would need to be obtained from the property owner(s) to allow access to and from the injection locations. Injections do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruption to site and property owner(s) activities during the injection events because no surface structures are needed, other than injection wells.

### Cost

This remedial alternative would cost more than using groundwater extraction and ISCO for reduction of CVOC concentrations in the area of highest groundwater CVOC concentrations. Assuming the same number of injection wells and events are implemented, zero-valent iron is more expensive than ISCO. For costing purposes, it is assumed that only one injection event would be implemented as part of this remedial alternative. It is also assumed that no pilot tests would be conducted.

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table B-2. The capital costs include one injection event using direct-push injection points. The estimated capital cost including the first year of OM&M is approximately $990,000. As there would be no zero-valent iron injections after the first year, there are no annual OM&M costs associated with this remedial alternative. Groundwater monitoring and laboratory analysis costs beyond the first year are included as common components of each alternative (Table 3).

## 6.4. Groundwater Extraction

A groundwater extraction system would consist of a series of recovery wells piped to an ex-situ treatment system. The extraction wells would be installed within the area of highest CVOC groundwater concentrations, over an approximately 400 foot width of the plume in the vicinity of MW-13, MW-14 and MW-17S. The extracted water would be pumped to the south approximately 600 feet to the DLS Sand and Gravel, Inc. property mine where the water would be released to the atmosphere through a misting nozzle. This is a form of spray aeration and involves the mass transfer of CVOCs from water to air. CVOCs are partitioned from extracted groundwater by increasing the surface area of the water containing CVOCs exposed to air. The groundwater extraction system would only be operated eight to nine months of the year, because of issues relating to potential freezing of the extracted groundwater in the pipes or following spraying into the atmosphere.

An aquifer pumping test could be performed to provide additional information for design of the groundwater extraction system. Analytical sampling performed during the aquifer test would provide additional information for design of the treatment system.

As the goal of this alternative is a one-time reduction of groundwater CVOC concentrations within the treatment area, the groundwater extraction system would be operated for approximately nine months a year, from late spring to early fall, for five years. After five years of operation, the system would be shut down and its effectiveness and need for continued operation would be evaluated.

### Overall Protection of Human Health and the Environment

A groundwater extraction and ex-situ treatment system would achieve an RAO by reducing CVOC groundwater concentrations by removing contaminant mass. However, because the goal of this alternative is the reduction of groundwater CVOC concentrations within the treatment area by groundwater extraction during a limited time period, the dissolved-phase CVOC plume treatment would be limited in both space and time. The protection of human health and the environment related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by this alternative. The spray aeration groundwater treatment is not anticipated to expose the community to site-related contamination because VOCs in the water would likely volatilize prior to reaching the nearest off-site receptor.

### Compliance with SCGs

Groundwater extraction and ex-situ treatment systems typically have difficulty in achieving MCLs for contaminants in source areas but this will not be an issue as no traditional source areas have been identified at the site and the highest groundwater CVOC concentrations are lower than would be expected at a source. This remedial alternative would be effective at reducing the groundwater CVOC concentrations within the treatment area.

### Short-term Effectiveness

Groundwater extraction systems are typically effective at controlling the migration of dissolved-phase contaminant plumes and removing contaminant mass from an aquifer over the short-term. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting dissolved-phase CVOC plume migration within days or weeks of system startup. The community is not expected to be exposed to site-related contamination during the implementation of this alternative. The spray aeration groundwater treatment is not anticipated to expose the community to site-related contamination because VOCs in the water would likely volatilize prior to reaching the nearest off-site receptor. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-term Effectiveness and Permanence

Long-term operation of groundwater extraction systems typically result in reduced efficiency, caused by factors such as aquifer heterogeneity and adsorptive partitioning of contaminants between the groundwater and aquifer materials. The result is a decrease in contaminant mass removal, also referred to as tailing or asymptotic reduction. However, the tailing effect would not impact the ability of the groundwater extraction system to limit dissolved-phase CVOC plume migration. Tailing typically limits the ability of the groundwater extraction system to achieve remediation goals for remediation in a reasonable timeframe. Additionally, as less contaminant is removed from the aquifer, the cost-effectiveness of the treatment system per amount of contaminant treated decreases with time. Therefore, a groundwater extraction system is more effective as an interim corrective measure than a final remedy unless used in conjunction with other remedial technologies. Although potentially less effective than some other remedial technologies, a groundwater extraction system would control the dissolved-phase CVOC plume migration and volume and reduce groundwater CVOC concentrations, thus meeting an RAO for the site. However, because the groundwater extraction system would only be operated intermittently for five years, this alternative would not be effective in the long-term or permanent.

### Reduction of Toxicity, Mobility, and Volume

Initially, groundwater extraction systems are typically effective at controlling dissolved-phase CVOC plume migration, reducing the dissolved-phase CVOC plume area, and removing contaminant mass from the aquifer. During initial operation of groundwater extraction systems contaminant mass is most quickly reduced. As operation continues, however, the slow release of contaminants from a residual source such as adsorbed mass can cause tailing of contaminant mass removal. Tailing typically limits the ability of the groundwater extraction system to achieve remediation goals in a reasonable timeframe without system enhancements via additional remedial technologies. However, the tailing effect would not impact the ability of the groundwater extraction system to limit dissolved-phase CVOC plume migration. The groundwater extraction system would not affect distal portions of the dissolved-phase CVOC plume, and portions of the dissolved-phase CVOC plume downgradient from the wells would continue to migrate toward the Modock Road Springs. A groundwater extraction system would reduce the toxicity, mobility, and volume of the dissolved-phase CVOC plume, but only within the treatment area and for a limited time unless the system is operated continuously. This alternative would have a minimal impact on the toxicity, mobility, and volume of the dissolved-phase CVOC plume.

#### Implementability

A groundwater extraction system with ex-situ treatment consists of readily available technologies. Therefore, it is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation.

The implementation of a groundwater extraction and ex-situ treatment system would require significant pre-design studies to finalize design of the system. Installation of a groundwater extraction system may generate secondary waste, including contaminated soils from drill cuttings and contaminated purge water during well development. Waste generated during implementation and initial operation could be managed using generally accepted methods for off-site disposal and/or treatment.

Operation of a groundwater extraction system over a long time period requires significant OM&M activities. The groundwater extraction system and treatment system must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of the treatment system must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment and/or granular activated carbon drums. However, because the groundwater extraction system would only be operated for five years the OM&M activities required are somewhat reduced.

#### Cost

The opinion of probable cost for this remedial alternative, with an expected accuracy range of –30 to +50 percent, is presented in Table B-3. The cost opinion is based on the installation of a groundwater extraction system including approximately three 6-inch diameter PVC extraction wells installed to 100 feet bgs. The capital costs include the costs for the groundwater treatment system components, a shed to house the controls, installation of the extraction wells. For costing purposes, it is assumed that no pilot tests would be conducted.

The total assumed capital costs including the first year of OM&M is approximately $680,000. Annual OM&M cost including maintenance of the groundwater treatment system is estimated to be approximately $74,000. Groundwater monitoring and laboratory analysis costs are included as common components of each alternative (Table 3).

# 7. Comparative Evaluation of Alternatives

The remedial alternatives are evaluated in this section relative to the criteria summarized in Section 4.2. A summary of the opinion of probable costs for each of the remedial alternatives is provided in Table 5. A relative ranking evaluation of the remedial alternatives using the seven criteria is summarized in Table 6. This qualitative ranking is based on a reverse scale of 5 to 1, with a rank of 5 representing the lowest value and 1 representing the highest value and for any given criterion. A reverse ranking was used to facilitate sorting for comparison purposes. As such, the lower overall total for any given alternative indicates a relatively more favorable alternative.

## 7.1. Evaluation of Dissolved-Phase CVOC Plume Alternatives

The six remedial alternatives summarized in Section 5 are evaluated below relative to each other and seven criteria. As part of each remedial scenario that involves groundwater treatment (bioremediation, PRB, air sparging/SVE, and groundwater extraction), groundwater will be sampled from locations both upgradient and downgradient of the treatment area to monitor the effectiveness of the remedial alternative at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase CVOC plume migration. The no further action alternative was retained for evaluation to facilitate the comparison of the other remedial alternatives and involves no monitoring, institutional controls, or remediation. The MNA alternative involves periodic groundwater sampling and analysis.

### Overall Protection of Human Health and the Environment

With the exception of the no further action and MNA alternatives, each alternative would be effective at minimizing further off-site migration of contaminated groundwater by removing contaminant mass and controlling migration of the dissolve-phase CVOC plume. The groundwater extraction and air sparging/SVE alternatives physically remove contaminant mass from the groundwater and include components for ex-situ treatment and disposal. In contrast, bioremediation and PRBs are in-situ alternatives that biologically or chemically degrade VOCs to less toxic byproducts (e.g., ethane, ethene, and/or chloride ions). There is less risk for exposure to soil, groundwater, and soil vapor during implementation of the in-situ alternatives and therefore they are slightly more protective of human health and the environment than those with ex-situ components. However, these remedial alternatives do not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated. That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed.

**Compliance with SCGs**

The four groundwater treatment alternatives would reduce the mass discharge of site contaminants to areas downgradient of the treatment area. It is anticipated that each of these alternatives would effectively treat contaminated groundwater as it flows through the treatment area. However, these alternatives will only treat a small percentage of the dissolved-phase CVOC plume, leaving much of the dissolved-phase CVOC plume out of compliance with SCGs. In addition, the groundwater extraction alternative would not be in compliance with SCGs during winter months when the system is shut down. The no further action and MNA alternatives would not actively treat the dissolved-phase CVOC plume and would therefore not be in compliance with SCGs.

**Short-Term Effectiveness**

The no further action and MNA alternatives would have no short-term effects on groundwater concentrations.

Once any of the groundwater treatment remedial alternatives is installed, contaminant concentrations will begin to be reduced as groundwater flows through the treatment area. However, the bioremediation alternative is not as effective in the short-term as some other alternatives because it can take years for bioremediation to reduce contaminant concentrations. With the exception of bioremediation, each of the groundwater treatment alternatives will be effective in the short term assuming sufficient distribution of injected material and uniform treatment is achieved. The short-term effectiveness of each remedial alternative could be monitored using standard groundwater monitoring wells to evaluate upgradient and downgradient (treated) groundwater adjacent to the treatment area.

Groundwater extraction systems are typically effective at controlling the migration of dissolved-phase contaminant plumes and removing contaminant mass from an aquifer over the short-term assuming the system is operated continuously. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting dissolved-phase CVOC plume migration within days or weeks of system startup. Air sparging/SVE systems are effective in the short term assuming uniform treatment of the dissolved-phase CVOC plume can be achieved and the system is operated continuously. A PRB will be effective in the short-term because it would be designed so that VOCs are completely treated by the time groundwater passes through the PRB.

The community is not expected to be exposed to site-related contamination during the implementation of these ex-situ treatment alternatives. Risks to workers, which include potential exposure to contaminated vapor, soils, and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-Term Effectiveness and Permanence

The no further action alternative is not effective in the long-term. The MNA alternative would be effective in the long-term, although it is likely that it would take decades for natural processes to reduce groundwater CVOC concentrations to less than SCGs. Each of the groundwater treatment remedial alternatives are considered to be effective in the long-term because VOC concentrations in groundwater would be reduced within the treatment area.

Biostimulants/bacteria would need to be sustained in the subsurface by developing a periodic injection schedule for the bioremediation alternative to be effective. The bioremediation alternative is only effective as a barrier to dissolved-phase CVOC plume migration if the biostimulant/bacteria are distributed throughout the treatment area. The spacing of the injection wells would need to be designed so as to achieve uniform treatment across the width of the dissolved-phase CVOC plume.

An air sparging/SVE or groundwater extraction system would need to be operated continuously to be effective. There is a potential for incomplete capture and/or treatment of contaminants if heterogeneities or stratified soils are present or if the area of influence of the air sparging or extraction wells do not overlap. The potential for incomplete contaminant degradation would be evaluated using available data, including those from pilot studies.

A groundwater extraction system would also need to be operated continuously to be effective. As discussed in Section 5.6, long-term operation of groundwater extraction systems typically results in reduced efficiency which limits the ability to achieve remediation goals in a reasonable timeframe. Despite this, a groundwater extraction system would control the dissolved-phase CVOC plume migration over the long-term.

The PRB alternative is the most effective and permanent because the integrity of the PRB can be confirmed and a PRB will remain effective longer than other alternatives with no need for additional injections or maintenance of remedial equipment. Bench scale studies indicate that a PRB can remain effective for approximately 30 years. The continuity of the PRB can also be verified using pulse interference testing, as discussed in Section 3.4.

### Reduction of Toxicity, Mobility, or Volume

The four groundwater treatment remedial alternatives would reduce the mobility of the dissolved-phase CVOC plume by treating the groundwater as it flows through the treatment area, thereby minimizing off-site migration of contaminated groundwater. These alternatives will not affect distal portions of the dissolved-phase CVOC plume and portions of the dissolved-phase CVOC plume downgradient from the injection wells would continue to migrate toward the Modock Road Springs. These alternatives would limit dissolved-phase CVOC plume migration and reduce contaminant concentrations in the treatment area, thereby reducing the toxicity, mobility, and volume of the dissolved-phase CVOC plume. During implementation of the groundwater extraction alternative, the toxicity, mobility, and volume of the dissolved-phase CVOC plume would not be reduced during the winter months when the system is shut down. The no further action alternative would not reduce the toxicity, mobility or volume of site contaminants. If the MNA alternative is implemented, the toxicity, mobility or volume of the dissolved-phase CVOC plume would be reduced at a very slow rate as a result of natural processes.

The groundwater extraction and air sparging/SVE alternatives physically remove contaminant mass from the groundwater. In contrast, the biodegradation/enhanced biodegradation and PRB alternatives can biologically or chemically degrade VOCs to less toxic byproducts (e.g., ethane, ethene, and/or chloride ions). The in-situ bioremediation alternative is considered to be effective at reducing the toxicity, mobility, or volume of the dissolved-phase CVOC plume if sufficient distribution can be achieved, sufficient time is provided, and subsurface conditions amenable to bioremediation are maintained.

The amount of reduction of the toxicity, mobility, or volume of the dissolved-phase CVOC plume is dependent on degree to which uniform treatment is achieved within the treatment area. The degree to which uniform treatment is achieved for each alternative, other than the PRB alternative for which the continuity of the barrier can be verified using pulse interference testing, is primarily related to the area of influence and spacing of the injection/extraction wells. Each of the remedial alternatives has uncertainties related to the ability to achieve uniform treatment although the PRB alternative has the least uncertainty because the continuity of the PRB can be verified.

It is anticipated that the PRB alternative is the most likely to significantly and permanently reduce the toxicity, mobility, and volume of contaminants in groundwater which flows through the PRB. After treatment of chlorinated VOCs, the remaining byproducts (e.g., ethane, ethene, and chloride ions) are less toxic.

### Implementability

The no further action alternative requires no effort to implement. The MNA alternative would be easy to implement as it only includes groundwater sampling and creation of a groundwater model. The in-situ bioremediation and PRB alternatives are capable of reducing groundwater CVOC concentrations while eliminating the need for ex-situ treatment facilities and minimizing disposal issues. The air sparging/soil vapor extraction and groundwater extraction alternatives are also capable of meeting an RAO for the site, however, they would require above-ground structures.

There does not appear to be significant obstacles to implementing these remedial technologies at the site, although obtaining access will be necessary for all groundwater treatment alternatives. It is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation of each of the remedial alternatives using readily available technologies. A limited number of vendors are available to design and construct a PRB. Despite this, PRBs have successfully been installed at numerous sites. The air sparging and groundwater extraction alternatives would be relatively more difficult to implement because an above-ground treatment structure and permanent power supply for the remedial equipment would be needed; the other alternatives do not require a sustainable power supply.

The remedial alternatives are all technically feasible and may be affected differently by site-specific geologic and hydrogeologic characteristics. As such, pre-design studies and/or pilot tests are recommended prior to remedy implementation to evaluate the feasibility of the selected remedial alternative and to finalize design of the remedy.

The biodegradation/enhanced biodegradation and PRB alternatives do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruptions to site activities during implementation of the biodegradation/enhanced biodegradation and PRB alternatives because no surface structures, other than possibly injection wells, are needed.

Each of the remedial alternatives that include groundwater treatment would require installation of monitoring and injection wells. The in-situ bioremediation alternative is more flexible than PRBs, air sparging, or groundwater extraction as the results of initial injections may be used to guide, focus, and/or modify subsequent injection strategies. PRB bench scale studies indicate that the barrier would be effective for up to 30 years (ESTCP, 2003); however, a PRB cannot be moved once installed. The MNA and PRB remedial alternatives do not include OM&M costs (excluding groundwater sampling).

Above ground structures, such as an injection pump, vacuum extractor, and/or surface treatment structures would be needed for the operation of groundwater extraction or air sparging/SVE systems. These systems would need to be operated and maintained continuously until it is determined that active dissolved-phase CVOC plume treatment is no longer needed. Operation of these systems over a long time period requires significant OM&M activities. These systems must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of these treatment systems must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment and/or granular activated carbon.

Based on information provided from bioremediation vendors, it is expected that one bioremediation injection would be effective for one to two years. For costing purposes, it is assumed that two bioremediation injections per year would be required. The frequency of injections would be evaluated as part of performance monitoring.

The exact location and design of a dissolved-phase CVOC plume barrier will be influenced by the varying groundwater seepage velocities and hydraulic gradients across the site. The relatively high hydraulic gradient along the tree line near MW-14 and the relatively high groundwater seepage velocity at Dryer Road complicates the effectiveness of injection technologies. Remedy performance monitoring would be used to evaluate the frequency of injections if an injection technology is selected as the remedy for groundwater. The groundwater seepage velocity and hydraulic gradient would have less of an effect on groundwater extraction and air sparging and soil vapor extraction as they would be continuous operations.

#### Cost

A summary of opinion of probable costs for each remedial alternative is provided in Tables A-6 and A-7. A graph of the probable 30-year present value of each of the alternatives is included in Appendix A. The relative order of probable present value for the six alternatives over a 30 year period are, from least to most expensive:

- No further action;
- MNA;
- Air sparging with soil vapor extraction;
- Groundwater extraction and treatment;
- PRB; and
- Bioremediation.

The MNA alternative would be the least expensive alternative to implement (excluding no further action) because the other remedial alternatives include active groundwater treatment in addition to groundwater monitoring. The bioremediation alternative has the lowest capital costs of the four groundwater treatment alternatives, but if this alternative is operated for more than eight years the bioremediation alternative would become more expensive than all other alternatives. OM&M costs for air sparging with soil vapor extraction are significant, but this alternative is less expensive than the other three groundwater treatment alternatives.

Although the PRB alternative would have the highest capital cost, there are no OM&M costs other than groundwater monitoring. The PRB alternative OM&M costs are less than all other alternatives (except MNA). Over a 30 year time period, the PRB alternative is only slightly more expensive than the groundwater extraction and air sparging/SVE alternatives but is significantly less expensive than the bioremediation alternative.

The groundwater extraction and air sparging/SVE alternatives require extensive OM&M efforts. Capital costs for these alternatives are typically more than for injection technologies but less than PRB installations. However, OM&M costs could be substantial if the system is operated for many years. OM&M costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks. Capital costs would include construction of the treatment shed, running electrical and air/water lines to the treatment shed, and installation of the piping, monitoring wells, and injection wells.

### Dissolved-phase CVOC Plume Remedial Alternative Advantages and Disadvantages

The remedial alternatives that are capable of meeting the RAO with a reasonable cost are in-situ bioremediation, air sparging with soil vapor extraction, a PRB, and groundwater extraction. A list of advantages and disadvantages for each of these alternatives is below:

In-situ bioremediation advantages:

- More flexible than PRBs, groundwater extraction, or air sparging as the results of initial injections may be used to guide, focus, and/or modify subsequent injection strategies.

In-situ bioremediation disadvantages:

- Requires multiple injections to maintain the treatment zone;
- Site conditions may dictate the need for closely spaced injection wells;
- Anaerobic degradation could be limited if elevated DO levels are present;
- A carbon source may be required to create anaerobic conditions;
- Bioaugmentation may be necessary if microbial populations are shown to be insufficient.

Air sparging with soil vapor extraction advantages:

- Groundwater seepage velocity and hydraulic gradient would have less of an effect than on other alternatives; and
- Lower capital costs than a PRB.

Air sparging with soil vapor extraction disadvantages:

- Requires significant OM&M costs;
- Requires maintenance of aboveground structures and equipment;
- Requires continuous operation and maintenance until the system is no longer needed;
- Heterogeneities or stratified soils would cause air flow to not flow uniformly through the subsurface causing some zones to be less treated; and
- Effective vapor extraction is needed to prevent fugitive vapors.

PRB advantages:

- Higher confidence of maintaining a complete barrier than other alternatives;
- Does not require multiple injections;
- One-time installation with up to 30-year lifespan;
- No OM&M costs other than groundwater monitoring; and
- Lower long term costs than other alternatives.

PRB disadvantages:

- Once emplaced the PRB is expensive to adjust, re-locate or remove;
- Relatively high groundwater seepage velocity and hydraulic gradient could complicate design and installation; and
- Relatively high capital costs.

Groundwater extraction advantages:

- Groundwater seepage velocity and hydraulic gradient would have less of an effect than on other alternatives; and
- Lower capital costs than a PRB.

Groundwater extraction disadvantages:

- Would not operate during the winter months;
- Requires significant OM&M costs;

- Requires maintenance of aboveground structures and equipment;
- Requires continuous operation and maintenance until the system is no longer needed;
- Heterogeneities or stratified soils could cause causing some zones to be less treated; and
- Extracted groundwater must be disposed of properly.

**Dissolved-phase CVOC Plume Remedial Alternatives Summary**

The no further action and MNA alternatives are the least expensive and easiest to implement but do not include active groundwater treatment.

Assuming each of the groundwater treatment remedial alternatives is designed and installed appropriately, each of these alternatives would be effective at minimizing off-site migration of contaminated groundwater by removing contaminant mass and controlling the dissolved-phase CVOC plume. These alternatives would each be protective of human health and the environment, would be in compliance with SCGs, and would reduce the toxicity, mobility, and volume of the dissolved-phase CVOC plume. As such, the criteria that are considered to be the most important for selecting a remedial alternative are short- and long-term effectiveness, implementability, and cost.

Assuming uniform treatment of the dissolved-phase CVOC plume can be achieved, each of the groundwater treatment remedial alternatives would be effective in the long- and short-term. The implementation of each of the groundwater treatment remedial alternatives would require significant pre-design studies to finalize design of the system. A pilot test could be performed to evaluate the feasibility of the selected remedial alternative at the site and to design the remedy.

The bioremediation alternative can be relatively easily implemented but can be costly as injections may be required as often as twice a year to distribute and sustain biostimulant or bacteria in the subsurface. The groundwater extraction and air sparging/SVE alternatives each require above ground structures and extensive OM&M efforts, especially if the system is operated for many years.

The PRB alternative would be slightly more effective than other alternatives and most likely to produce uniform dissolved-phase CVOC plume treatment, but has a higher capital cost than all other alternatives. The OM&M costs for the PRB alternative are lower than all other alternatives because installation of a PRB is a one-time cost requiring no additional injections and there are no treatment systems to power or maintain. As shown in Table 6, the overall ranking for the PRB alternative is slightly more favorable when considering the seven evaluation criteria; however the difference in the relative rankings is not significant. This indicates that, as a barrier approach for the dissolved-phase CVOC plume, the PRB alternative would be only marginally more effective than the MNA or no further action alternatives. In addition, the overall value of the barrier approach would decrease if a remedial alternative for the area of highest groundwater CVOC concentrations is considered, as discussed below.

## 7.2. Evaluation of Remedial Alternatives for the Area of Highest Groundwater CVOC Concentrations

The four remedial alternatives summarized in Section 6 are evaluated below relative to each other and seven criteria. The no further action alternative was retained for evaluation to facilitate the comparison of the other remedial alternatives and involves no monitoring, institutional controls, or remediation. The ISCO, zero-valent iron, and groundwater extraction alternatives were designed for a one time reduction of groundwater CVOC concentrations. There are no OM&M costs associated with these alternatives. The selected remedial alternative for the area of highest groundwater CVOC concentrations could be implemented concurrently with a dissolved-phase CVOC plume barrier remedial alternative, which includes costs for groundwater monitoring.

### Overall Protection of Human Health and the Environment

The ISCO, zero-valent iron, and groundwater extraction alternatives would only be protective of human health and the environment in that groundwater CVOC concentrations within a small portion of the dissolve-phase CVOC plume would be reduced. The protection of human health and the environment related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by alternative.

### Compliance with Standards, Criteria, and Guidance (SCGs)

The ISCO, zero-valent iron, and groundwater extraction alternatives would each lower concentrations of CVOCs in groundwater within the treatment area. However, the dissolved-phase CVOC plume treatment would be limited in both space and time because the goal of this alternative is the one time reduction of groundwater CVOC concentrations within the treatment area. Compliance with SCGs related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by this alternative.

### Long-term Effectiveness and Permanence

Because the goal of the ISCO, zero-valent iron, and groundwater extraction alternatives is the one time reduction of groundwater CVOC concentrations within the treatment area, it is likely that groundwater CVOC concentrations would rebound once the injected material is no longer sustained or the groundwater extraction system is shut off. Therefore, these alternatives are not effective in the long-term or permanent. However, the ZVI alternative will be more effective than ISCO or groundwater extraction alternatives because ZVI will persist and continue to treat CVOCs for a much longer time period than oxidants or the nine-month operation of the groundwater extraction system.

#### Reduction of Toxicity, Mobility, and Volume

The ISCO, zero-valent iron, and groundwater extraction alternatives would reduce the toxicity, mobility, and volume of the dissolved-phase CVOC plume within the treatment area, but only for a limited time. The toxicity, mobility, and volume of the dissolved-phase CVOC plume related to the dissolved-phase CVOC plume outside of the treatment area is not addressed by this alternative. The toxicity, mobility, and volume of the vast majority of the dissolved-phase CVOC plume would not be impacted if these alternatives are implemented.

#### Short-term Effectiveness

The ISCO, zero-valent iron, and groundwater extraction alternatives would be effective at reducing groundwater CVOC concentrations within the treatment area in the short-term. The community is not expected to be exposed to site-related contamination during the implementation of these alternatives. Risks to workers, which include potential exposure to contaminated soils and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

#### Implementability

There does not appear to be significant obstacles to implementing the ISCO, zero-valent iron, and groundwater extraction remedial alternatives at the site, although obtaining access will be necessary for all groundwater treatment alternatives. It is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation of each of the remedial alternatives using readily available technologies.

The ISCO and zero-valent iron alternatives do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruptions to site activities during implementation of the ISCO and zero-valent iron alternatives because no surface structures, other than possibly injection wells, are needed.

The groundwater extraction alternative would be relatively more difficult to implement because an above-ground treatment structure and power supply for the remedial equipment would be needed; the ISCO and zero-valent iron alternatives do not require a sustainable power supply. Above ground structures, such as an injection pump, vacuum extractor, and/or surface treatment structures would be needed for the operation of groundwater extraction system. This system would need to be operated and maintained continuously and inspected periodically.

**Cost**

A summary of opinion of probable costs for each remedial alternative is provided in Table B-4. The costs estimates associated with these remedial alternatives do not include groundwater monitoring or other OM&M activities as these alternatives were evaluated as a one time reduction of groundwater CVOC concentrations.

The relative order of probable capital costs for the four alternatives are, from least to most expensive:

- No further action;
- ISCO;
- Zero-valent iron injections; and
- Groundwater extraction and treatment.

There are no OM&M costs included in these alternatives. Groundwater monitoring costs are included in the remedial alternatives for the dissolved-phase CVOC plume as summarized in Section 5. There are no costs associated with the no further action alternative. The zero-valent iron injection alternative, which includes one injection event, has the lowest capital costs of the three groundwater treatment alternatives. As developed, the ISCO alternative would involve one injection event. If only one ISCO injection event is implemented, the ISCO alternative would have lower capital costs than the zero-valent iron injection alternative.

The groundwater extraction alternative requires extensive capital costs, which would include construction of the treatment shed, running electrical and air/water lines to the treatment shed, and installation of the piping and injection wells. Operational costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks.

**Remedial Alternative for the Area of Highest Groundwater CVOC Concentrations Advantages and Disadvantages**

The remedial alternatives that are capable of meeting the groundwater CVOC concentration RAO with a reasonable cost are ISCO, zero-valent iron injections, and groundwater extraction. A list of advantages and disadvantages for each of these alternatives is below:

ISCO advantages:

- Less expensive than zero-valent iron injections and groundwater extraction; and
- Groundwater CVOC concentrations will be reduced to non-toxic byproducts upon contact with the oxidant.

ISCO disadvantages:

- Requires multiple injections to maintain the treatment zone; and
- Site conditions may dictate the need for closely spaced injection wells.

Zero-valent iron injection advantages:

- Less expensive than groundwater extraction;
- Zero-valent iron will persist in the subsurface for a longer period to time than an oxidant; and
- Groundwater CVOC concentrations will be reduced to non-toxic byproducts upon contact with the zero-valent iron.

Zero-valent iron injection disadvantages:

- Follow up injection events may be necessary to achieve the RAO; and
- Site conditions may dictate the need for closely spaced injection wells.

Groundwater extraction advantages:

- Groundwater seepage velocity and hydraulic gradient would have less of an effect than on other alternatives; and
- Groundwater extraction is an established and widely proven technique for controlling a large volume of contaminated groundwater and reducing VOC concentrations.

Groundwater extraction disadvantages:

- Requires significant OM&M costs;
- Requires maintenance of aboveground structures and equipment;
- Requires continuous operation and maintenance until the system is no longer needed;

- Heterogeneities or stratified soils could cause causing some zones to be less treated; and

- Extracted groundwater must be disposed of properly.

**Summary of Remedial Alternatives for the Area of Highest Groundwater CVOC Concentrations**

The no further action alternative is the least expensive and easiest to implement but does not include active groundwater treatment.

Assuming each of the groundwater treatment remedial alternatives is designed and installed appropriately, these alternatives would be effective at reducing groundwater CVOC concentrations. These alternatives would each equally be protective of human health and the environment, would be in compliance with SCGs, and would reduce the toxicity, mobility, and volume of the dissolved-phase CVOC plume. As such, the criteria that are considered to be the most important for selecting a remedial alternative are short- and long-term effectiveness, implementability, and cost.

Because groundwater containing CVOCs will continue to flow into the treatment area from upgradient areas, the effectiveness of the remedial alternatives for the area of highest groundwater concentrations is dependent on continued groundwater treatment. Assuming uniform treatment of the dissolved-phase CVOC plume can be achieved, each of the groundwater treatment remedial alternatives would be effective in the short-term. However, because only one ISCO or zero-valent iron injection event is included in these alternatives, they will not be effective in the long-term unless additional injection event is implemented. Similarly, groundwater extraction will only be effective as long as the system is operated continuously. As shown in Table 6, the zero-valent iron alternative would be the most effective because zero-valent iron has the potential to persist in the subsurface for more than several years.

The ISCO and zero-valent iron alternatives can be relatively easily implemented as they include a one-time injection event with no OM&M costs. The groundwater extraction alternative requires above ground structures and OM&M efforts. The implementation of each of the groundwater treatment remedial alternatives would require significant pre-design studies to finalize design of the system. A pilot test could be performed to evaluate the feasibility of the selected remedial alternative at the site and to design the remedy.

# 8. Combined Alternatives Evaluation

Combined remedial alternatives, which are evaluated in this section, are plume-wide remedial alternatives, one of which will be selected as the final remedy for the site. Each of the combined alternatives (except for no further action) include long-term groundwater monitoring (LTM) and either a dissolved-phase CVOC plume alternative (from Section 5) or a remedial alternative for the area of highest groundwater CVOC concentrations (from Section 6). Based on the screening and evaluation of remedial alternatives in Sections 5 through 7, the combined remedial alternatives to be evaluated are:

- No further action
- LTM and ZVI injection in the area of highest groundwater CVOC concentrations (ZVI Alternative)
- LTM and groundwater extraction for five years in the area of highest groundwater CVOC concentrations (Groundwater Extraction Alternative)
- LTM and PRB (PRB Alternative)
- LTM and long-term air sparging and SVE (Air Sparging/SVE Alternative)
- Restoration to Achieve Pre-disposal Conditions with PRBs (Pre-disposal Conditions Alternative)

The MNA, bioremediation, and ISCO injection remedial alternatives evaluated in Sections 5 and 6 were not selected for inclusion in a combined alternative. MNA will not be considered as a component of a combined alternative because analytical data indicate that there is minimal natural biological degradation of the groundwater contamination at the site. Bioremediation injections have not been included in a combined alternative. A bioremediation alternative, which would require numerous injections to maintain anaerobic conditions, would be prohibitively expensive than other technologies. ISCO injections have not been selected for inclusion in a combined alternative because the oxidant will not persist in the subsurface and therefore would not be as effective as alternatives with similar costs.

With the exception of the no further action alternative, each of the above combined alternatives is a combination of LTM and either a dissolved-phase CVOC plume remedial alternative (Section 5) or a remedial alternative for the area of highest groundwater CVOC concentrations (Section 6). The pre-disposal conditions alternative would include installation of four PRBs to reduce groundwater CVOC concentrations to pre-disposal conditions. The combined remedial alternatives are evaluated in this section relative to the criteria summarized in Section 4.2.

It is expected that it would take approximately 1 year to design and implement the PRB, air sparging, ZVI, or groundwater extraction alternatives and up to two years to implement the predisposal conditions alternative. Since the PRB, air sparging, ZVI, or groundwater extraction alternatives focus on treatment within the area of highest groundwater CVOC concentrations and because of the persistent nature of the contaminants and the length of the groundwater plume it is not expected that these alternatives would achieve the groundwater SCGs within the very near future. Groundwater SCGs would likely be achieved after approximately 30 years if the pre-disposal conditions alternative is implemented.

A summary of the opinion of probable costs for each of the remedial alternatives is provided in Table 5. A relative ranking evaluation of the remedial alternatives using the seven criteria is summarized in Table 6. This qualitative ranking is based on a reverse scale of 5 to 1, with a rank of 5 representing the lowest value and 1 representing the highest value and for any given criterion. A reverse ranking was used to facilitate sorting for comparison purposes. As such, the lower overall total for any given alternative indicates a relatively more favorable alternative.

The six combined remedial alternatives listed above are evaluated below relative to each other and seven criteria. As part of each remedial scenario that involves groundwater treatment (all but no further action), groundwater will be sampled from locations both upgradient and downgradient of the treatment area to monitor the effectiveness of the remedial alternative at reducing contaminant concentrations and verify the extent of the dissolved-phase CVOC plume. The no further action alternative was evaluated as a procedural requirement, was retained for evaluation to facilitate the comparison of the other remedial alternatives, and only involves implementation of the common components of each remedial alternative discussed in Section 4.1. The no further action alternative would leave the site in its present condition and would not provide any additional protection to human health or the environment.

The no further action alternative requires minimal costs or effort to implement and would not be protective of human health and the environment, would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase CVOC plume. In contrast, the pre-disposal conditions alternative would have the highest costs, would be protective of human health and the environment, and would be effective in the short- or long-term. Additionally, the pre-disposal conditions alternative would more quickly reach compliance with SCGs and would reduce the toxicity, mobility, and volume of CVOCs in the entire dissolved-phase CVOC plume. Because the no further action alternative would not treat the dissolved-phase CVOC plume and the cost to implement the pre-disposal conditions alternative would make it infeasible, these two alternatives are not evaluated further in this section.

### Overall Protection of Human Health and the Environment

Because the PRB and air sparging alternatives would actively treat the dissolved-phase CVOC plume for 30 years, these alternatives would be more protective of human health and the environment than the ZVI and groundwater extraction alternatives, which would treat CVOCs for up to 5 years.  The groundwater extraction and air sparging alternatives physically remove contaminant mass from the groundwater and include components for ex-situ treatment and disposal.  In contrast, ZVI and PRB alternatives are in-situ alternatives that chemically degrade VOCs to less toxic byproducts (e.g., ethane, ethene, and/or chloride ions).  These remedial alternatives do not provide significant protection of human health and the environment because a small percentage of the total volume of the dissolved-phase CVOC plume would be treated.  That being said, groundwater containing site-related CVOCs is not being used as a water supply and exposures relating to soil vapor intrusion would be addressed.  Implementation of any of the remedial alternatives would not have a negative impact on private drinking water well groundwater quality or water levels.  Water levels would likely only be impacted in the immediate vicinity of the injection or extraction wells.

### Compliance with SCGs

Because the PRB and air sparging alternatives would actively treat the dissolved-phase CVOC plume for 30 years, these alternatives would be more in compliance with SCGs than the ZVI and groundwater extraction alternatives, which would treat CVOCs for up to 5 years.  It is anticipated that each of these alternatives would effectively treat contaminated groundwater as it flows through the treatment area. However, these alternatives will only treat a small percentage of the entire dissolved-phase CVOC plume, leaving much of the groundwater plume with CVOC concentrations that exceed the SCGs.  Since these alternatives focus on treatment within the area of highest groundwater CVOC concentrations and because of the persistent nature of the contaminants and the length of the groundwater plume it is not expected that these alternatives would achieve the groundwater SCGs within the very near future.  Groundwater SCGs would likely be achieved after approximately 30 years if the pre-disposal conditions alternative is implemented.   Unless the pre-disposal conditions alternative is implemented, the surface water downgradient of the Modock Road Springs would not immediately be in compliance with SCGs because the CVOCs in this water would remain untreated.  Over time, the CVOC concentrations in the surface water immediately downgradient of the Modock Road Springs would likely decrease as a result of the upgradient groundwater treatment.

### Short-Term Effectiveness

The groundwater treatment alternatives would be effective in the short-term at reducing groundwater CVOC concentrations within the treatment area but would have very little short-term influence on groundwater CVOC concentrations outside of the treatment area. The short-term effectiveness of each remedial alternative could be monitored using standard groundwater monitoring wells to evaluate upgradient and downgradient (treated) groundwater quality adjacent to the treatment area.

Groundwater extraction systems are typically effective at controlling the migration of a dissolved-phase contaminant plume and removing contaminant mass from an aquifer over the short-term assuming the system is operated continuously. Operation of a groundwater extraction system can typically induce a hydraulic gradient affecting dissolved-phase CVOC plume migration within days or weeks of system startup. Air sparging/SVE systems are effective in the short term assuming uniform treatment of the dissolved-phase CVOC plume can be achieved and the system is operated continuously. A PRB or ZVI injections would be effective in the short-term because the selected alternative would be designed so that VOCs are completely treated by the time groundwater passes through the PRB or treatment area.

The community is not expected to be exposed to site-related contamination during the implementation of the combined alternatives. Risks to workers, which include potential exposure to contaminated vapor, soils, and groundwater during well and equipment installation, are readily controlled using standard work practices and engineering controls.

### Long-Term Effectiveness and Permanence

The ZVI and groundwater extraction alternatives would not be effective in the long term because they involve a one-time injection of ZVI or operation of a groundwater extraction system intermittently for five years. The PRB and air sparging alternatives are considered to be effective in the long-term because VOCs in groundwater would be treated within the PRB or air sparging treatment area over a 30-year period.

An air sparging/SVE system would need to be operated continuously to be effective. There is a potential for incomplete capture and/or treatment of contaminants if heterogeneities or stratified soils are present or if the area of influence of the air sparging wells do not overlap. The potential for incomplete contaminant degradation would be evaluated using available data, including those from pilot studies.

The PRB alternative is more effective and permanent than the air sparging alternative because the integrity of the PRB can be confirmed and a PRB will remain effective longer than other alternatives with no need for additional injections or maintenance of remedial equipment. Bench scale studies indicate that a PRB can remain effective for approximately 30 years. The continuity of the PRB can also be verified using pulse interference testing, as discussed in Section 3.4.

### Reduction of Toxicity, Mobility, or Volume

The toxicity, mobility, and volume of the vast majority of the dissolved-phase CVOC plume would not be impacted if the PRB, air sparging, ZVI, or groundwater extraction alternatives are implemented. If the PRB or air sparging alternatives is implemented, the toxicity, mobility, and volume of the dissolved-phase CVOC plume within the treatment area would be reduced over a 30-year period. The ZVI and groundwater extraction alternatives would reduce the toxicity, mobility, and volume of the dissolved-phase CVOC plume within the treatment area, but only for a limited time. The toxicity, mobility, and volume of the dissolved-phase CVOC plume outside of the treatment area would be reduced at a slow rate as a result of natural processes if the PRB, air sparging, ZVI, or groundwater extraction alternatives are implemented.

The groundwater extraction and air sparging/SVE systems physically remove contaminant mass from the groundwater. In contrast, ZVI and PRBs chemically degrade VOCs to less toxic byproducts (e.g., ethane, ethene, and/or chloride ions).

The amount of reduction of the toxicity, mobility, or volume of the dissolved-phase CVOC plume is dependent on the degree to which uniform treatment is achieved within the treatment area. The degree to which uniform treatment is achieved in the treatment zone is primarily related to the area of influence and spacing of the injection/extraction wells.

### Implementability

It is expected that it would take approximately 1 year to design and implement each of the combined alternatives. The remedial alternatives are all technically feasible and may be affected differently by site-specific geologic and hydrogeologic characteristics. As such, pre-design studies and/or pilot tests are recommended prior to remedy implementation to evaluate the feasibility of the selected remedial alternative and to finalize design of the remedy.

There does not appear to be significant obstacles to implementing these remedial technologies at the site, although obtaining access will be necessary no matter which alternative is selected. It is anticipated that the necessary equipment, personnel, and materials would be available to meet an appropriate schedule for implementation of each of the remedial alternatives using readily available technologies. A limited number of vendors are available to design and construct a PRB. Despite this, PRBs have successfully been installed at numerous sites.

The PRB and ZVI alternatives are capable of reducing groundwater CVOC concentrations while eliminating the need for ex-situ treatment facilities and minimizing disposal issues. The PRB and ZVI alternatives do not generate significant waste, so treatment and disposal considerations are negligible. There would be minimal disruptions to site activities during implementation of the PRB and ZVI alternatives because no surface structures, other than possibly injection wells, are needed.

In contrast to the other alternatives, the air sparging and groundwater extraction alternatives would require above-ground structures, ongoing OM&M of a remediation system, and ex-situ treatment (of extracted groundwater or vapor). As a result of the substantial OM&M efforts required, the air sparging and groundwater extraction alternatives would be more difficult than the PRB or ZVI to implement.

The PRB, ZVI, air sparging, and groundwater extraction alternatives would require installation of monitoring and injection or extraction wells/points. The PRB, ZVI, and groundwater extraction remedial alternatives do not include OM&M costs beyond the first year (excluding groundwater sampling). The air sparging and groundwater extraction alternatives would be relatively more difficult to implement because an above-ground treatment structure and permanent power supply for the remedial equipment would be needed; the other alternatives do not require a sustainable power supply. The groundwater extraction alternative requires extensive capital costs and infrastructure and is relatively difficult to implement considering the extraction system would only be operated intermittently for five years.

Above ground structures, such as an injection pump, vacuum extractor, and/or surface treatment structures would be needed for the operation of groundwater extraction or air sparging/SVE systems. If ongoing groundwater CVOC treatment is desired, these systems would need to be operated and maintained continuously until it is determined that active dissolved-phase CVOC plume treatment is no longer needed. Operation of these systems over a long time period requires significant OM&M activities. These systems must be inspected periodically, with annual reviews to evaluate overall system performance. Unlike in-situ treatment methods, maintenance of these treatment systems must be performed to ensure adequate system performance, including testing and replacement of treatment system equipment.

### Cost

A summary of opinion of probable costs for each remedial alternative is provided in Table 5. The relative order of probable present value for the six alternatives over a 30-year period are, from least to most expensive:

- No further action;

- Groundwater extraction and LTM;
- Zero-valent iron injection and LTM;
- Air sparging with soil vapor extraction and LTM;
- PRB and LTM; and
- Restoration to achieve pre-disposal conditions.

The pre-disposal conditions alternative has the highest capital and OM&M costs but a significantly larger percentage of the dissolved-phase CVOC plume would be remediated if this alternative is implemented compared to any other alternative. The ZVI alternative has a slightly higher probable cost than the groundwater extraction alternative and includes a one-time ZVI injection event with long term groundwater monitoring. The groundwater extraction alternative would be the least expensive alternative to implement (excluding no further action) because the extraction system would only be operated intermittently for five years and there would be no OM&M costs other than groundwater monitoring following the first year of implementation. OM&M costs for air sparging with soil vapor extraction are significant, but this alternative has lower probable costs than the PRB or pre-disposal conditions alternatives.

Although the PRB alternative would have the highest capital cost (other than the pre-disposal conditions alternative), there are no OM&M costs other than long-term groundwater monitoring. Over a 30 year time period, the PRB alternative is only slightly more expensive than the air sparging/SVE alternatives but is significantly less expensive than the pre-disposal conditions alternative.

Groundwater extraction and air sparging/SVE systems require extensive OM&M efforts. Capital costs for these systems are typically more than, or comparable to, injection technologies but less than PRB installations. However, OM&M costs could be substantial if the system is operated for many years. OM&M costs would include electricity, equipment and parts repair/replacement, and periodic system maintenance checks. Capital costs would include construction of the treatment shed, running electrical and air/water lines to the treatment shed, and installation of the piping, monitoring wells, and injection wells.

#### Combined Remedial Alternatives Summary

The no further action alternative is the least expensive and easiest to implement but does not include active groundwater treatment. The pre-disposal conditions alternative would be prohibitively expensive, difficult to implement, and only slightly more protective of human health and the environment than the other combined alternatives. For these reasons, the no further action and pre-disposal conditions alternatives will not be selected for implementation.

Assuming that the ZVI, groundwater extraction, PRB, and air sparging alternatives are designed and installed appropriately, these alternatives would be effective at reducing groundwater CVOC concentrations. The PRB and air-sparging dissolved-phase plume alternatives would be in effect for a longer duration (30 years) than ZVI (3 to 5 years) or groundwater extraction (intermittently for five years), however the overall protection of human health and the environment would not be materially different for these four alternatives. The main reason for this lack of difference is that measures to reduce contact with CVOC-containing groundwater and indoor air (via soil vapor intrusion) are inherent in all of the combined alternatives retained, and none of these would directly treat areas downgradient of the area of highest groundwater CVOC concentrations.

Given these common factors, the selection of the most effective combined alternative would be based on the ability to implement the remedy to rapidly reduce CVOC concentrations while expending the most reasonable cost. The latter criterion is not necessarily the lowest cost, but the best value in terms of reducing CVOC concentrations in the area of highest concentration.

Assuming uniform treatment (or capture in the case of groundwater extraction) of the dissolved-phase CVOC plume can be achieved, each of the groundwater treatment remedial alternatives would be equally effective in the short-term. The groundwater extraction and air sparging alternatives require above ground structures and OM&M efforts and the PRB alternative requires significant capital costs and effort to implement.

The ZVI alternative, which would include a one-time injection event with no OM&M costs (except groundwater monitoring), can be relatively easily implemented compared to the other combined remedial alternatives.

The ZVI and groundwater extraction alternatives are more cost effective than PRB or air sparging and equally effective at rapidly reducing CVOC concentrations in the more concentrated plume area. The ZVI alternative, however, is preferred over groundwater extraction because the latter remedy would be more difficult to implement, would expend considerable capital cost for infrastructure that would only be used for a short duration (up to 9 months because of difficulties with winter-time aeration), would likely result in incomplete treatment of the areas of highest CVOC concentrations, and would not capture or treat CVOCs that migrate into the treatment zone from upgradient areas.

The ZVI alternative, therefore, is the recommended alternative because it is the easiest to implement, would be effective for 3 to 5 years (thus treating CVOC-containing groundwater that, in the short-term, migrates into the treatment zone), and has a lower net present cost than the PRB or air sparging alternatives.

# 9. References


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**New York State Department of Environmental Conservation**
Feasibility Study Report
Modock Road Springs/DLS Sand and Gravel, Inc. Site

# Figures

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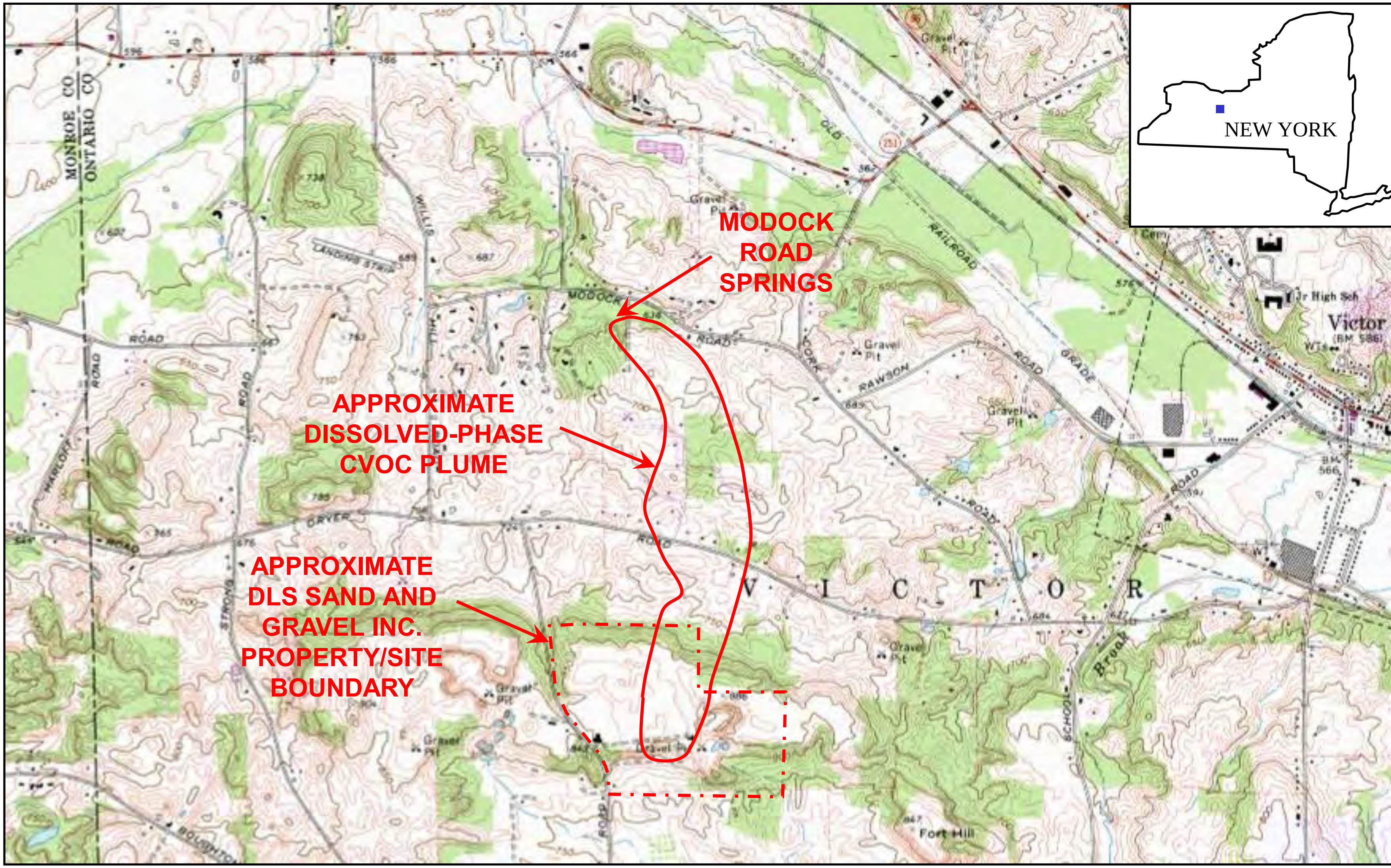
MALCOLM PIRNIE




MAP SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC SERIES, VICTOR QUADRANGLE (PHOTOREVISED 1978)

APPROXIMATE SCALE IN FEET

0 1200 2400 4800

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL REMEDIATION

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

WORK ASSIGNMENT # D-004439 - 9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
VICTOR, NEW YORK

**FIGURE 1**
**SITE MAP**

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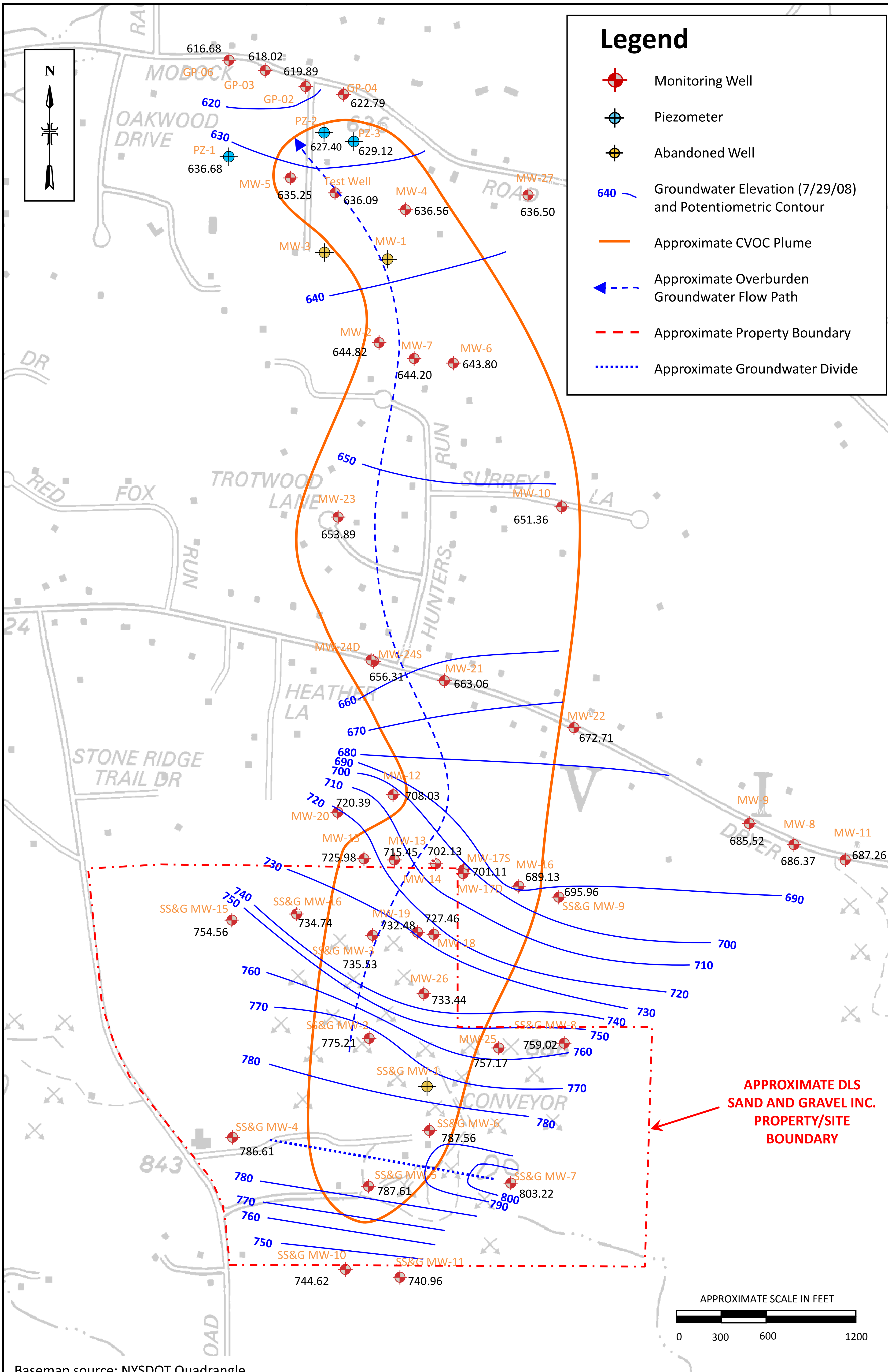


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NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION DIVISION OF ENVIRONMENTAL REMEDIATION

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

WORK ASSIGNMENT # D-004439 - 9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

FIGURE 2

JULY 2008 POTENTIOMETRIC CONTOUR MAP

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| ST-3 | 4/24/97 | 6/6/07 | 6/30/08 |
|---|---|---|---|
| TCE | 1.8 | 1 J | 1 J |
| 1,1,1-TCA | 1.4 | ND | ND |
| 1,1-DCE | ND | ND | ND |

| ST-2 | 4/24/97 | 6/6/07 | 6/30/08 |
|---|---|---|---|
| TCE | 13 | 9 J | 8 J |
| 1,1,1-TCA | 7.3 | 3 J | 3 J |
| 1,1-DCE | ND | ND | ND |

| ST-1 | 4/24/97 | 6/6/07 | 6/30/08 |
|---|---|---|---|
| TCE | 32 | 31 | 25 |
| 1,1,1-TCA | 17 | 12 | 9 J |
| 1,1-DCE | 0.58 | 1 J | 1 J |

| SC-1 | 8/25/95 | 6/6/07 | 6/30/08 |
|---|---|---|---|
| TCE | 110 | 88 | 77 |
| 1,1,1-TCA | 64 | 36 | 31 |
| 1,1-DCE | ND | 4 J | 4 J |

| Spring House | 8/7/90 | 4/24/97 | 11/17/06 |
|---|---|---|---|
| TCE | 15 | 160 | 120 |
| 1,1,1-TCA | 110 | 93 | 41 |
| 1,1-DCE | ND | 3.7 | 6 J |

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WORK ASSIGNMENT # D-004439-9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013) TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

FIGURE 3

Select Surface Water CVOC Analytical Results

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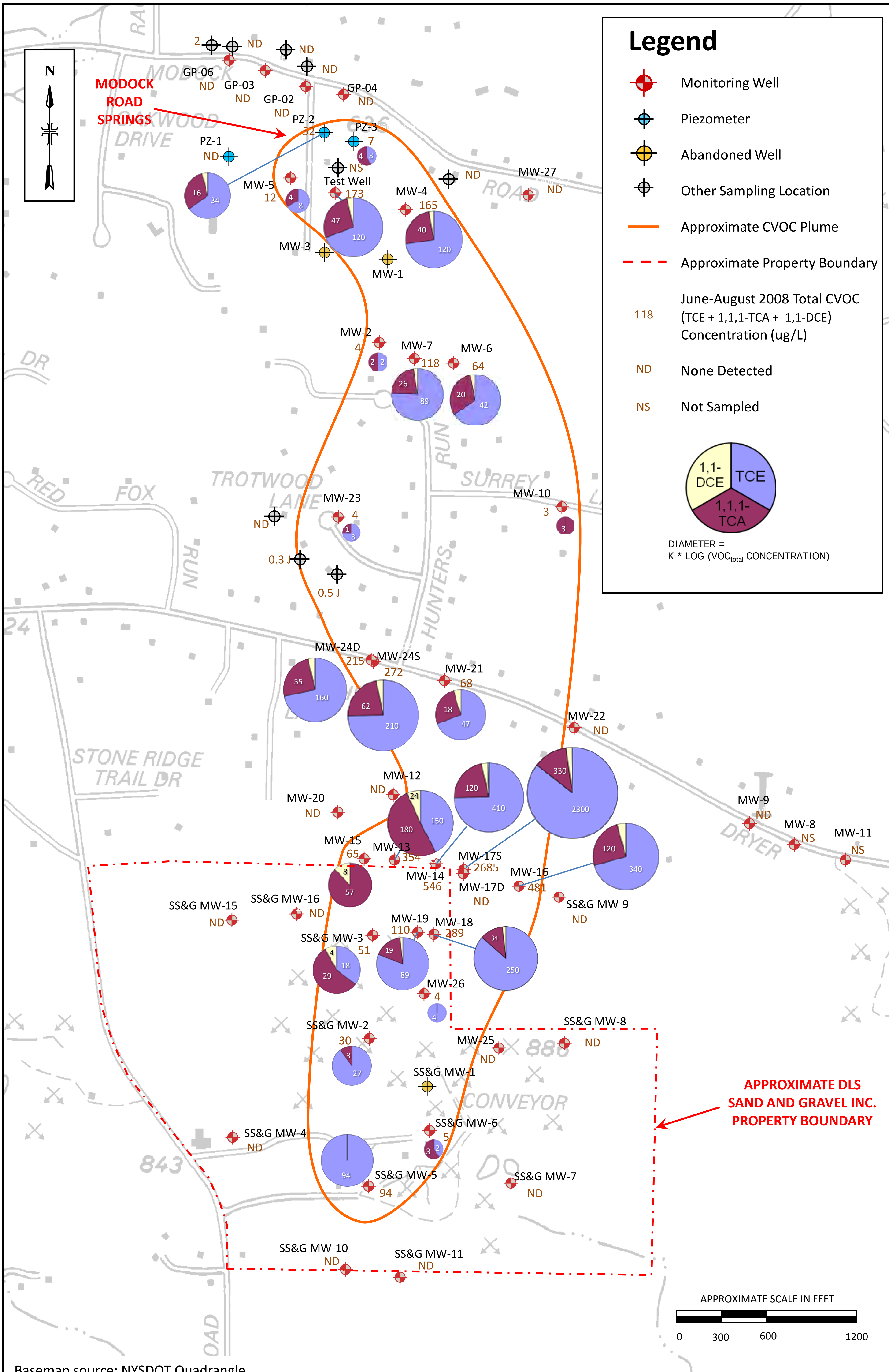


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MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK
FIGURE 4
JUNE-AUGUST 2008 GROUNDWATER TOTAL VOC CONCENTRATIONS

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MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

**FIGURE 5**

**WEST – EAST SIMPLIFIED GEOLOGIC CROSS-SECTION ALONG TREE LINE AT MW-14**

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REMEDIAL INVESTIGATION/FEASIBILITY STUDY

WORK ASSIGNMENT # D-004439 - 9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

**FIGURE 6**

**WEST – EAST SIMPLIFIED GEOLOGIC CROSS-SECTION AT DRYER ROAD**

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DIVISION OF ENVIRONMENTAL REMEDIATION
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
WORK ASSIGNMENT # D-004439-9

MODOCK ROAD SPRINGS/DLS SAND AND GRAVEL, INC. SITE (HW 8-35-013)
TOWN OF VICTOR, ONTARIO COUNTY, NEW YORK

FIGURE 7
REMEDIAL ALTERNATIVE TREATMENT AREA

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**New York State Department of Environmental Conservation**
Feasibility Study Report
Modock Road Springs/DLS Sand and Gravel, Inc. Site

# Tables

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Table 1
NATURE AND EXTENT OF CONTAMINATION
Modock Road Springs/DLS Sand and Gravel, Inc. Site
(NYSDEC HW ID 8-35-013)
Victor, New York

| Medium | | Category | Contaminant of Concern | Concentration Range | Frequency of Samples Exceeding SCGs | SCG |
|---|---|---|---|---|---|---|
| Groundwater | | VOCs | Trichloroethene | ND to 2,300 µg/L | 36 of 91 | 5 µg/L |
| | | | 1,1,1-Trichloroethane | ND to 330 µg/L | 30 of 91 | 5 µg/L |
| | | | 1,1-Dichloroethene | ND to 55 µg/L | 15 of 91 | 5 µg/L |
| Surface Water | | VOCs | Trichloroethene | ND to 110 µg/L | 7 of 21 | 40 µg/L |
| | | | 1,1,1-Trichloroethane | ND to 42 µg/L | - | No SCG |
| | | | 1,1-Dichloroethene | ND to 10 µg/L | - | No SCG |
| Subsurface Soil | All Subsurface Soil (Direct-push, test pit, and subsurface drilling programs) | VOCs | Trichloroethene | ND to 990 µg/kg | 2 of 82 | 470 µg/kg |
| | | | 1,1,1-Trichloroethane | ND to 100 µg/kg | 0 of 82 | 680 µg/kg |
| | | | 1,1-Dichloroethene | ND to 18 µg/kg | 0 of 82 | 330 µg/kg |
| | Direct-push Subsurface Soil from DLS Sand and Gravel, Inc. Property. | VOCs | Trichloroethene | ND to 4.1 µg/kg | 0 of 42 | 470 µg/kg |
| | | | 1,1,1-Trichloroethane | No detections | 0 of 42 | 680 µg/kg |
| | | | 1,1-Dichloroethene | No detections | 0 of 42 | 330 µg/kg |
| | Test Pit Excavation Subsurface Soil | VOCs | Trichloroethene | ND to 4.5 µg/kg | 0 of 17 | 470 µg/kg |
| | | | 1,1,1-Trichloroethane | No detections | 0 of 17 | 680 µg/kg |
| | | | 1,1-Dichloroethene | No detections | 0 of 17 | 330 µg/kg |
| | Drilling Program Subsurface Soil | VOCs | Trichloroethene | ND to 990 µg/kg | 2 of 23 | 470 µg/kg |
| | | | 1,1,1-Trichloroethane | ND to 100 µg/kg | 0 of 23 | 680 µg/kg |
| | | | 1,1-Dichloroethene | ND to 18 µg/kg | 0 of 23 | 330 µg/kg |
| Surface Soil | | VOCs | Trichloroethene | No detections | 0 of 15 | 470 µg/kg |
| | | | 1,1,1-Trichloroethane | No detections | 0 of 15 | 680 µg/kg |
| | | | 1,1-Dichloroethene | No detections | 0 of 15 | 330 µg/kg |
| Indoor Air | | VOCs | Trichloroethene | ND to 12 µg/m$^3$ | 6 of 169 | 5 µg/m$^3$ |
| | | | 1,1,1-Trichloroethane | ND to 74 µg/m$^3$ | - | No SCG |
| | | | 1,1-Dichloroethene | ND to 14 µg/m$^3$ | - | No SCG |
| Sub-slab Vapor | | VOCs | Trichloroethene | ND to 1,700 µg/m$^3$ | - | No SCG |
| | | | 1,1,1-Trichloroethane | ND to 5,900 µg/m$^3$ | - | No SCG |
| | | | 1,1-Dichloroethene | ND to 1,100 µg/m$^3$ | - | No SCG |
| Passive Soil Gas | | VOCs | Trichloroethene | ND to 10,501 nanograms | - | No SCG |
| | | | 1,1,1-Trichloroethane | ND to 12,739 nanograms | - | No SCG |
| | | | 1,1-Dichloroethene | ND to 3,033 nanograms | - | No SCG |

Notes:
ND - Not detected at a concentration greater than the reporting limit.
Only results from samples collected from 2006 through 2008 are included above.

Table 2
EVALUATION OF POTENTIAL SCGs
Modock Road Springs/DLS Sand and Gravel, Inc. Site
(NYSDEC HW ID 8-35-013)
Victor, New York

| Medium/Location/Action | Citation | Requirements | Comments | Potential SCG |
|---|---|---|---|---|
| **Potential chemical-specific SCGs** | | | | |
| Ground water | 6 NYCRR 703 - Class GA ground water quality standards | Promulgated state regulation that requires that fresh ground waters of the state must attain Class GA standards | Potentially applicable to site ground water. | Yes |
| Indoor Air | NYSDOH - Guidance for Evaluating Soil Vapor Intrusion | Guidance that discusses generic levels for monitoring potential exposures, as well as for mitigating current or potential exposures. | Potentially applicable to all occupied structures affected soil vapor intrusion as a result of the dissolve-phase CVOC plume. | Yes |
| Soil | NYSDEC 6 NYCRR Part 375-2 Inactive Hazardous Waste Disposal Site Remedial Program | Regulation that provides guidance for soil cleanup objectives for various property uses. | Not applicable or relevant and appropriate because soil is not a medium of concern for the Site. | No |
| **Potential location-specific SCGs** | | | | |
| Wetlands | 6 NYCRR 633 - Freshwater wetland permit requirements | Actions occurring in a designated freshwater wetland (within 100 ft) must be approved by NYSDEC of its designee. Activities occurring adjacent to freshwater wetlands must: be compatible with preservation, protection, and conservation of wetlands and benefits; result in no more than insubstantial degradation to or loss of any part of the wetland; and be compatible with public health and welfare. | Potentially applicable during surface water remediation activities. | Yes |
| | Executive Order 11990 - Protection of Wetlands | Activities occurring in wetlands must avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction or modification of wetlands. The procedures also require USEPA to avoid direct or indirect support of new construction in wetlands wherever there are practicable alternatives or minimal potential harm to wetlands when there are no practicable alternatives. | Potentially applicable during surface water remediation activities. | Yes |
| 100-year flood plain | 6 NYCRR 373-2.2 - Location standards for hazardous waste treatment, storage, and disposal facilities - 100-yr floodplain | Hazardous waste treatment, storage, or disposal facilities located in a 100-yr floodplain must be designed, constructed, operated and maintained to prevent washout of hazardous waste during a 100-yr flood. | Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain. | No |
| | Executive Order 11988 - Floodplain Management | EPA is required to conduct activities to avoid, to the extent possible, the long- and short- term adverse impacts associated with the occupation or modification of floodplain. The procedures also require EPA to avoid direct or indirect support of floodplain development wherever there are practicable alternatives and minimize potential harm to floodplains when there are no practicable alternatives. | Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain. | No |
| Within 61 meters (200 ft) of a fault displaced in Holocene time | 40 CFR Part 264.18 | New treatment, storage, or disposal of hazardous waste is not allowed. | Not applicable or relevant and appropriate. Site is not located within 200 ft of a fault displaced in Holocene time, as listed in 40 CFR 264 Appendix VI. | No |
| River or stream | 16 USC 661 - Fish and Wildlife Coordination Act | Required protection of fish and wildlife in a stream when performing activities that modify a stream or river. | Potentially applicable during surface water remediation activities. | Yes |
| Habitat of an endangered or threatened species | 6 NYCRR 182 | Provides requirements to minimize damage to habitat of an endangered species. | Potentially applicable during surface water remediation activities due to presence of threatenced species. | Yes |

Table 2
EVALUATION OF POTENTIAL SCGs
Modock Road Springs/DLS Sand and Gravel, Inc. Site
(NYSDEC HW ID 8-35-013)
Victor, New York

| Medium/Location/Action | Citation | Requirements | Comments | Potential SCG |
|---|---|---|---|---|
| Habitat of an endangered or threatened species | Endangered Species Act | Provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction. | Potentially applicable during surface water remediation activities due to presence of threatenced species. | Yes |
| Historical property or district | National Historic Preservation Act | Remedial actions are required to account for the effects of remedial activities on any historic properties included on or eligible for inclusion on the National Register of Historic Places. | Not applicable or relevant and appropriate. Site not identified as a historic property. | No |
| **Potential action-specific SCGs** | | | | |
| Treatment actions | 6 NYCRR 373- Hazardous waste management facilities | Provides requirements for managing hazardous wastes. | Not applicable. No hazardous waste anticipated to be produced. | No |
| Construction | 29 CFR Part 1910 - Occupational Safety and Health Standards - Hazardous Waste Operations and Emergency Response | Remedial activities must be in accordance with applicable OSHA requirements. | Applicable for construction and monitoring phase of remediation. | Yes |
| | 29 CFR Part 1926 - Safety and Health Regulations for Construction | Remedial construction activities must be in accordance with applicable OSHA requirements. | Applicable for construction and monitoring phase of remediation. | Yes |
| Transportation | 6 NYCRR 364 - Waste Transporter Permits | Hazardous waste transport must be conducted by a hauler permitted under 6 NYCRR 364. | Not applicable. Hazardous waste is not anticipated to be generated. | No |
| | 6 NYCRR Part 372- Hazardous Waste Manifest System and Related Standards for Generators, Transporters, and Facilities | Substantive hazardous waste generator and transportation requirements must be met when hazardous waste is generated for disposal. Generator requirements include obtaining an EPA Identification Number and manifesting hazardous waste for disposal. | Not applicable. Hazardous waste is not anticipated to be generated. | No |
| | 49 CFR 172-174 and 177-179 - Department of Transportation Regulations | Hazardous waste transport to offsite disposal facilities must be conducted in accordance with applicable DOT requirements. | Not applicable. Hazardous waste is not anticipated to be generated. | No |
| Generation of air emissions | NYS Air Guide 1 | Provides annual guideline concentrations (AGCs) and short-term guideline concentrations (SGCs) for specific chemicals. These are property boundary limitations that would result in no adverse health effects. | Potentially applicable for treatment residuals. | Yes |
| | NYS TAGM 4031- Dust Suppressing and Particle Monitoring at Inactive Hazardous Waste Disposal Sites | Provides limitations on dust emissions. | Potentially applicable. Dust emissions may be anticipated depending on remedy selected. | Yes |
| Construction storm water management | NYSDEC General permit for storm water discharges associated with construction activities. Pursuant to Article 17 Titles 7 and 8 and Article 70 of the Environmental Conservation Law. | The regulation prohibits discharge of materials other than storm water and all discharges that contain hazardous substance in excess of reportable quantities established by 40 CFR 117.3 or 40 CFR 302.4, unless a separate NPDES permit has been issued to regulate those discharges. A permit must be acquired if activities involve the disturbance of 5 acres or more. If the project is covered under the general permit, the following are required: development and implementation of a monitoring program; all records must be retained for a period of at least 3 years after construction is complete. | Not applicable. Construction disturbances will not exceed the limits. | No |
| Underground Injection | 40 CFR 144 and 146 USEPA Underground Injection Control Regulations | This regulation sets forth minimum requirements for the UIC program promulgated under Part C of the Safe Drinking Water Act and describes the technical standards to follow when implementing the UIC program. | Applicable for the installation of reinjection wells. | Yes |

***Table 3***
**Remedial Alternatives Common Components Opinion of Probable Cost**

**COMPONENTS COMMON TO ALL ALTERNATIVES**

# OPINION OF PROBABLE COST SUMMARY

| | |
|---|---|
| **Site:** | Modock Road Springs |
| **Location:** | Victor, New York |
| **Phase:** | Feasibility Study (-30% to +50%) |
| **Base Year:** | 2009 |
| **Date:** | April 28, 2009 |

**Description:** This spreadsheet includes the costs common to all alternatives. It consists of development of a Site Management Plan, a Soil Vapor Intrusion Action Plan including monitoring and maintaining six sub-slab depressurization systems, 10 residential water connections, and long-term groundwater monitoring for 30 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Report Preparation | | | | | |
| Site Management Plan | 60 | hours | $100.00 | $6,000 | |
| Soil Vapor Intrusion Action Plan | 40 | hours | $100.00 | $4,000 | |
| Site Monitoring | | | | | |
| Groundwater Sampling | 140 | hours | $80.00 | $11,200 | 2 people, 2 events, 35 hours per event per person |
| Passive Diffusion Bags | 20 | bags | $30.00 | $600 | |
| Groundwater Laboratory Analysis | 20 | samples | $100.00 | $2,000 | VOC analysis: 10 samples/event |
| Soil Vapor Monitoring Point Installation | 4 | points | $1,000.00 | $4,000 | |
| Soil Vapor Laboratory Analysis | 4 | samples | $300.00 | $1,200 | TO-15 VOC analysis |
| Air and Sub-slab Vapor Laboratory Analysis | 3 | samples | $300.00 | $900 | TO-15 VOC analysis |
| Data Validation | 7 | samples | $30.00 | $210 | |
| 11 Residential Water Connections | | | | | |
| Excavation and Backfill | 1,600 | Cubic Yards | $12.00 | $19,200 | 3.5 x 5 foot excavation |
| Corporation Stop | 11 | Each | $80.00 | $880 | |
| 1" 200 PSI PVC Water Pipe with fittings | 2,400 | Linear Feet | $2.25 | $5,400 | Piping to 10 residences |
| House Connection | 11 | Each | $2,300.00 | $25,300 | |
| Restoration | 2,667 | Square Yard | $3.00 | $8,000 | Restoration width: 10 feet |
| SUBTOTAL | | | | $88,890 | |
| Contingency | 25% | | | $22,223 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $111,113 | |
| Project Management | 15% | | | $16,667 | Planning, reporting, and administration. |
| Remedial Design | 0% | | | $0 | |
| Construction Management | 0% | | | $0 | |
| **TOTAL CAPITAL COST** | | | | $127,800 | |

**ANNUAL OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 70 | hours | $80.00 | $5,600 | 2 people, 35 hours per event per person |
| Passive Diffusion Bags | 10 | bags | $30.00 | $300 | |
| Groundwater Laboratory Analysis | 10 | samples | $100.00 | $1,000 | VOC analysis: 10 samples/year |
| SUBTOTAL | | | | $6,900 | |
| Contingency | 25% | | | $1,725 | |
| SUBTOTAL | | | | $8,625 | |
| Project Management | 5% | | | $431 | Planning, community relations, and administration. |
| Technical Support | 25% | | | $2,156 | Data evaluation and reporting. |
| **TOTAL ANNUAL O&M COST** | | | | $11,200 | |

**PERIODIC COSTS IN YEARS 2 and 3:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 70 | hours | $80.00 | $5,600 | 2 people, 35 hours per event per person |
| Passive Diffusion Bags | 10 | bags | $30.00 | $300 | |
| Groundwater Laboratory Analysis | 10 | samples | $100.00 | $1,000 | VOC analysis: 10 samples/year |
| SUBTOTAL | | | | $6,900 | |
| Contingency | 25% | | | $1,725 | |
| SUBTOTAL | | | | $8,625 | |
| Project Management | 5% | | | $431 | Planning, community relations, and administration. |
| Technical Support | 25% | | | $2,156 | Data evaluation and reporting. |
| **TOTAL PERIODIC COST** | | | | $11,200 | |

***Table 3***
**Remedial Alternatives Common Components Opinion of Probable Cost**

COMPONENTS COMMON TO ALL ALTERNATIVES

# OPINION OF PROBABLE COST SUMMARY

**PERIODIC COSTS IN YEARS 5, 15, and 25:**

| | | | | | |
|---|---|---|---|---|---|
| Soil Vapor Monitoring | | | | | |
| Soil Vapor Sampling | 4 | samples | $300.00 | $1,200 | |
| Soil Vapor Sampling and Reporting | 20 | hours | $80.00 | $1,600 | |
| SUBTOTAL | | | | $2,800 | |
| Contingency | 25% | | | $700 | |
| SUBTOTAL | | | | $3,500 | |
| Project Management | 5% | | | $175 | Planning, community relations, and administration. |
| Technical Support | 10% | | | $350 | Data evaluation and reporting. |
| **TOTAL PERIODIC COST** | | | | $4,000 | |

**PERIODIC COSTS IN YEARS 10 and 20:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Fan Replacement | | | | | |
| Fan Replacement | 1 | fan | $150.00 | $150 | |
| Subcontractor Installation | 1 | lump sum | $300.00 | $300 | |
| Installation Oversight | 8 | hours | $80.00 | $640 | |
| Soil Vapor Monitoring | | | | | |
| Soil Vapor Sampling | 4 | samples | $300.00 | $1,200 | |
| Soil Vapor Sampling and Reporting | 20 | hours | $80.00 | $1,600 | |
| SUBTOTAL | | | | $3,890 | |
| Contingency | 25% | | | $973 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $4,863 | |
| Project Management | 10% | | | $486 | Planning, reporting, and administration. |
| Remedial Design | 10% | | | $486 | scheduling. |
| Construction Management | 0% | | | $0 | Review of submittals, design modifications, construction oversight. |
| **TOTAL PERIODIC COST FOR ONE FAN REPLACEMENT** | | | | $5,800 | |
| **TOTAL PERIODIC COST FOR SIX FAN REPLACEMENTS** | | | | $34,800 | |

Note:
Expected life of a fan is 5 to 15 years.
Assume fan is replaced every 10 years.
Replace fans in six systems at year 10 and year 20 to get usable fans to year 30.

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $127,800 | $127,800 | 1.00 | $127,800 | |
| Annual O&M | 2-30 | $324,800 | $11,200 | 15.14 | $169,580 | 30 years, 5 % |
| Periodic Cost | 2 | $11,200 | $11,200 | 0.95 | $10,667 | |
| Periodic Cost | 3 | $11,200 | $11,200 | 0.91 | $10,159 | |
| Periodic Cost | 5 | $4,000 | $4,000 | 0.82 | $3,291 | |
| Periodic Cost | 10 | $34,800 | $34,800 | 0.64 | $22,432 | |
| Periodic Cost | 15 | $4,000 | $4,000 | 0.51 | $2,020 | |
| Periodic Cost | 20 | $34,800 | $34,800 | 0.40 | $13,772 | |
| Periodic Cost | 25 | $4,000 | $4,000 | 0.31 | $1,240 | |
| | | $556,600 | | | $360,961 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $361,000 | |

***Table 4***
**Remedial Alternative Opinion of Probable Cost**

**Combined Alternative 6**
**RESTORATION TO ACHIEVE PRE-DISPOSAL CONDITIONS**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description: This a**lternative consists of installing four permeable reactive barriers to treat groundwater throughout the dissolved-phase CVOC plume and restore the site to pre-disposal conditions. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Bench scale and pilot test | 1 | lump sum | $20,000.00 | $20,000 | Hydraulic and geochemical analyses |
| Drilling Mobilization | 1 | lump sum | $11,000.00 | $11,000 | |
| Decon Pad | 1 | lump sum | $500.00 | $500 | |
| Monitoring Well Drilling | 600 | linear feet | $40.00 | $24,000 | Sonic Drilling, 6 wells to 100 feet |
| Monitoring Well Installation | 600 | linear feet | $23.00 | $13,800 | 2" PVC, Schedule 40 |
| Stick-up Monitoring Well Casing | 6 | wells | $235.00 | $1,410 | 6 Monitoring Wells |
| Well Install. & Development Oversight | 400 | hours | $80.00 | $32,000 | |
| Groundwater Laboratory Analysis | 20 | samples | $250.00 | $5,000 | Biological indicators |
| Drums | 40 | Drums | $55.00 | $2,200 | |
| Purge Water and Cuttings Disposal | 40 | Drums | $250.00 | $10,000 | |
| PRB Installations | | | | | |
| Subcontractor and Material Costs | 4,000 | feet | $4,000.00 | $16,000,000 | PRB installed |
| ETI Patent License Fee | 1 | percent | 7% | $1,120,000 | |
| SUBTOTAL | | | | $17,239,910 | |
| Contingency | 25% | | | $4,309,978 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $21,549,888 | |
| Project Management | 5% | | | $1,077,494 | Planning, reporting, and administration. |
| Remedial Design | 6% | | | $1,292,993 | Design analysis, plans, specs, costing, and scheduling. |
| Construction Management | 6% | | | $1,292,993 | Submittal review, design modifications, construction oversight. |
| First year operation and maintenance | 1 | lump sum | | $0 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $25,213,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | 2 people, 1 week, 2 times/year |
| Groundwater Laboratory Analysis | 0 | samples | $100.00 | $0 | VOC analysis: 10 samples/event |
| Data Validation | 0 | samples | $30.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Contingency | 25% | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Project Management | 5% | | | $0 | |
| Technical Support | 10% | | | $0 | |
| **TOTAL ANNUAL O&M COST** | | | | $0 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $25,213,000 | $25,213,000 | 1.00 | $25,213,000 | |
| Annual O&M | 2-5 | $0 | $0 | #DIV/0! | $0 | 5 years, 5 % |
| | | $25,213,000 | | | $25,213,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $25,213,000 | |
| Capital | 1 | $25,213,000 | $25,213,000 | 1.00 | $25,213,000 | |
| Annual O&M | 2-30 | $0 | $0 | #DIV/0! | $0 | 30 years, 5 % |
| | | $25,213,000 | | | $25,213,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $25,213,000 | |

***Table 5***
**Summary of Remedial Alternative Opinion of Probable Costs**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasibility Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

| Alternative | Description | Capital Costs | Annual OM&M Costs | Total Present Value |
|---|---|---|---|---|
| **Common Components of All Remedial Alternatives** | | $127,800 | $11,200 | $361,000 |
| **DISSOLVED-PHASE CVOC PLUME REMEDIAL ALTERNATIVES (DOES NOT INCLUDE COMMON COMPONENT COSTS)** | | | | |
| Alternative 1 | NO FURTHER ACTION | $0 | $0 | $0 |
| Alternative 2 | MONITORED NATURAL ATTENUATION | $36,000 | $36,000 | $581,000 |
| Alternative 3 | IN-SITU BIOREMEDIATION | $798,000 | $381,000 | $6,567,000 |
| Alternative 4 | PERMEABLE REACTIVE BARRIER | $3,027,000 | $0 | $3,027,000 |
| Alternative 5 | AIR SPARGING AND SOIL VAPOR EXTRACTION | $1,385,000 | $78,000 | $2,566,000 |
| Alternative 6 | GROUNDWATER EXTRACTION | $885,000 | $74,000 | $2,005,000 |
| **ALTERNATIVES FOR AREA OF HIGHEST GROUNDWATER CVOC CONCENTRATIONS (DOES NOT INCLUDE COMMON COMPONENT COSTS)** | | | | |
| Alternative 1 | NO FURTHER ACTION | $0 | $0 | $0 |
| Alternative 2 | IN-SITU CHEMICAL OXIDATION | $530,000 | $0 | $530,000 |
| Alternative 3 | ZERO VALENT IRON | $992,000 | $0 | $992,000 |
| Alternative 4 | GROUNDWATER EXTRACTION | $683,000 | $74,000 | $945,000 |
| **COMBINED ALTERNATIVES (INCLUDES COMMON COMPONENT COSTS)** | | | | |
| Alternative 1 | NO FURTHER ACTION | $127,800 | $11,200 | $361,000 |
| Alternative 2 | ZERO-VALENT IRON INJECTION IN THE AREA OF HIGHEST GROUNDWATER CVOC CONCENTRATION AND LTM | $1,119,800 | $11,200 | $1,353,000 |
| Alternative 3 | 5 YEARS OF GROUNDWATER EXTRACTION IN THE AREA OF HIGHEST GROUNDWATER CVOC CONCENTRATION AND | $810,800 | $85,200 | $1,306,000 |
| Alternative 4 | PRB AND LTM | $3,154,800 | $11,200 | $3,388,000 |
| Alternative 5 | AIR SPARGING/SVE AND LTM | $1,512,800 | $89,200 | $2,927,000 |
| Alternative 6 | RESTORATION TO ACHIEVE PRE-DISPOSAL CONDITIONS | $25,340,800 | $11,200 | $25,574,000 |

Notes:
Total Present Value costs assume implementation of each alternative for 30 years.
Periodic costs (non-annual O&M costs) are not listed above but are included in the the Total Present Value costs.

**New York State Department of Environmental Conservation**
Feasibility Study Report
Modock Road Springs/DLS Sand and Gravel, Inc. Site

# Appendix A: Dissolved-Phase CVOC Plume Remedial Alternatives Cost Estimates

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***Table A-1***
**Dissolved-Phase CVOC Plume Remedial Alternative Opinion of Probable Cost**

**Alternative 2**
**MONITORED NATURAL ATTENUATION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 2 consists of monitored natural attenuation with 30 years of groundwater monitoring. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Misc. | 1 | lump sum | $0.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| Contingency | 25% | | | $0 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $0 | |
| Project Management | 10% | | | $0 | |
| Remedial Design | 0% | | | $0 | |
| Construction Management | 0% | | | $0 | |
| First year operation and maintenance | 1 | lump sum | | $36,000 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $36,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 200 | hours | $80.00 | $16,000 | 2 people, 1 week, 2 times/year |
| Groundwater Laboratory Analysis | 20 | samples | $100.00 | $2,000 | VOC analysis: 10 samples/event |
| Groundwater Laboratory Analysis | 20 | samples | $300.00 | $6,000 | Natural Attenuation Parameters |
| Data Validation | 20 | samples | $30.00 | $600 | |
| Grundfos Pump Rental | 2 | weeks | $300.00 | $600 | |
| SUBTOTAL | | | | $25,200 | |
| SUBTOTAL | | | | $25,200 | |
| Contingency | 25% | | | $6,300 | |
| SUBTOTAL | | | | $31,500 | |
| Project Management | 5% | | | $1,575 | |
| Technical Support | 10% | | | $3,150 | |
| **TOTAL ANNUAL O&M COST** | | | | $36,000 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $36,000 | $36,000 | 1.00 | $36,000 | |
| Annual O&M | 2-5 | $144,000 | $36,000 | 3.55 | $127,654 | 5 years, 5 % |
| | | $180,000 | | | $163,654 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $164,000 | |
| Capital | 1 | $36,000 | $36,000 | 1.00 | $36,000 | |
| Annual O&M | 2-30 | $1,044,000 | $36,000 | 15.14 | $545,079 | 30 years, 5 % |
| | | $1,080,000 | | | $581,079 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $581,000 | |

***Table A-2***
**Dissolved-Phase CVOC Plume Remedial Alternative Opinion of Probable Cost**

**Alternative 3**
**IN-SITU BIOREMEDIATION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 3 consists of in-situ bioremediation to treat groundwater in a 400 foot width of the plume. Assuming 2 injections per year for 30 years. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Bench scale and pilot test | 1 | lump sum | $20,000.00 | $20,000 | Hydraulic and geochemical analyses |
| Drilling Mobilization | 1 | lump sum | $11,000.00 | $11,000 | |
| Decon Pad | 1 | lump sum | $500.00 | $500 | |
| Monitoring Well Drilling | 600 | linear feet | $40.00 | $24,000 | Sonic Drilling, 6 wells to 100 feet |
| Monitoring Well Installation | 600 | linear feet | $23.00 | $13,800 | 2" PVC, Schedule 40 |
| Stick-up Monitoring Well Casing | 6 | wells | $235.00 | $1,410 | 6 Monitoring Wells |
| Injection Well Drilling | 2,000 | linear feet | $40.00 | $80,000 | Sonic Drilling, 20 wells to 100 feet |
| Injection Well Installation | 2,000 | linear feet | $23.00 | $46,000 | 2" PVC, Schedule 40 |
| Stick-up Injection Well Casing | 20 | wells | $235.00 | $4,700 | 20 Injection Wells |
| Well Install. & Development Oversight | 400 | hours | $80.00 | $32,000 | |
| Groundwater Laboratory Analysis | 20 | samples | $250.00 | $5,000 | Biological indicators |
| Drums | 40 | Drums | $55.00 | $2,200 | |
| Purge Water and Cuttings Disposal | 40 | Drums | $250.00 | $10,000 | |
| SUBTOTAL | | | | $250,610 | |
| Contingency | 25% | | | $62,653 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $313,263 | |
| Project Management | 8% | | | $25,061 | |
| Remedial Design | 15% | | | $46,989 | |
| Construction Management | 10% | | | $31,326 | |
| First year operation and maintenance | 1 | lump sum | | $381,000 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $798,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Bioremediation Injections | | | | | |
| Injection Materials | 2 | Lump Sum | $110,000.00 | $220,000 | 2 Injections per year over 400 feet |
| Vendor/Subcontractor Field Support | 2 | lump sum | $20,000.00 | $40,000 | |
| Vendor/Subcontractor Reporting | 1 | lump sum | $5,000.00 | $5,000 | |
| SUBTOTAL | | | | $265,000 | |
| SUBTOTAL | | | | $265,000 | |
| Contingency | 25% | | | $66,250 | |
| SUBTOTAL | | | | $331,250 | |
| Project Management | 5% | | | $16,563 | |
| Technical Support | 10% | | | $33,125 | |
| **TOTAL ANNUAL O&M COST** | | | | $381,000 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $798,000 | $798,000 | 1.00 | $798,000 | |
| Annual O&M | 2-5 | $1,524,000 | $381,000 | 3.55 | $1,351,007 | 5 years, 5 % |
| | | $2,322,000 | | | $2,149,007 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $2,149,000 | |
| Capital | 1 | $798,000 | $798,000 | 1.00 | $798,000 | |
| Annual O&M | 2-30 | $11,049,000 | $381,000 | 15.14 | $5,768,749 | 30 years, 5 % |
| | | $11,847,000 | | | $6,566,749 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $6,567,000 | |

***Table A-3***
**Dissolved-Phase CVOC Plume Remedial Alternative Opinion of Probable Cost**

**Alternative 4**
**PERMEABLE REACTIVE BARRIER**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 4 consists of installation of a permeable reactive barrier to treat groundwater in a 400 foot width of the plume . Assumes one time installation based on a quote from Geosierra. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Bench scale test | 1 | lump sum | $20,000.00 | $20,000 | Hydraulic and geochemical analyses |
| Drilling Mobilization | 1 | lump sum | $11,000.00 | $11,000 | |
| Decon Pad | 1 | lump sum | $500.00 | $500 | |
| Monitoring Well Drilling | 600 | linear feet | $40.00 | $24,000 | Sonic Drilling, 6 wells to 100 feet |
| Monitoring Well Installation | 600 | linear feet | $23.00 | $13,800 | 2" PVC, Schedule 40 |
| Stick-up Monitoring Well Casing | 6 | wells | $235.00 | $1,410 | 6 Monitoring Wells |
| Well Install. & Development Oversight | 400 | hours | $80.00 | $32,000 | |
| Drums | 40 | Drums | $55.00 | $2,200 | |
| Purge Water and Cuttings Disposal | 40 | Drums | $250.00 | $10,000 | |
| SUBTOTAL | | | | $114,910 | |
| PRB Installation | | | | | |
| Subcontractor and Material Costs | 400 | feet | $4,500.00 | $1,800,000 | PRB installed |
| ETI Patent License Fee | 1 | lump sum | $120,000.00 | $120,000 | |
| SUBTOTAL | | | | $1,920,000 | |
| SUBTOTAL | | | | $2,034,910 | |
| Contingency | 25% | | | $508,728 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $2,543,638 | |
| Project Management | 5% | | | $127,182 | |
| Remedial Design | 8% | | | $203,491 | |
| Construction Management | 6% | | | $152,618 | |
| First year operation and maintenance | 1 | lump sum | | $0 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $3,027,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Contingency | 25% | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Project Management | 5% | | | $0 | |
| Technical Support | 10% | | | $0 | |
| **TOTAL ANNUAL O&M COST** | | | | $0 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $3,027,000 | $3,027,000 | 1.00 | $3,027,000 | |
| Annual O&M | 2-5 | $0 | $0 | #DIV/0! | $0 | 5 years, 5 % |
| | | $3,027,000 | | | $3,027,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $3,027,000 | |
| Capital | 1 | $3,027,000 | $3,027,000 | 1.00 | $3,027,000 | |
| Annual O&M | 2-30 | $0 | $0 | #DIV/0! | $0 | 30 years, 5 % |
| | | $3,027,000 | | | $3,027,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $3,027,000 | |

***Table A-4***
**Dissolved-Phase CVOC Plume Remedial Alternative Opinion of Probable Cost**

**Alternative 5**
**AIR SPARGING AND SOIL VAPOR EXTRACTION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 5 consists of an Air Sparge and Soil Vapor Extraction Unit over a 400 foot width of the plume. Assuming a 10 ft radius of influence for Air Sparge and Soil Vapor Extraction Wells. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Pilot test | 1 | lump sum | $50,000.00 | $50,000 | 1 inject. well installed; 72-hour test |
| Drilling Mobilization | 1 | lump sum | $11,000.00 | $11,000 | |
| Decon Pad | 1 | lump sum | $500.00 | $500 | |
| Monitoring Well Drilling | 600 | linear feet | $40.00 | $24,000 | Sonic Drilling, 6 wells to 100 feet |
| Monitoring Well Installation | 600 | linear feet | $23.00 | $13,800 | 2" PVC, Schedule 40 |
| Stick-up Monitoring Well Casing | 6 | wells | $235.00 | $1,410 | 6 Monitoring Wells |
| Air Sparge Well Drilling | 2,000 | linear feet | $40.00 | $80,000 | Sonic Drilling, 20 wells to 100 feet |
| Air Sparge Well Installation | 2,000 | linear feet | $23.00 | $46,000 | 2" PVC, Schedule 40 |
| SVE Well Drilling | 1,000 | linear feet | $40.00 | $40,000 | Sonic Drilling, 20 wells to 50 feet |
| SVE Well Installation | 1,000 | linear feet | $23.00 | $23,000 | 2" PVC, Schedule 40 |
| Well Install. & Development Oversight | 400 | hours | $80.00 | $32,000 | |
| Drums | 75 | Drums | $55.00 | $4,125 | |
| Purge Water and Cuttings Disposal | 75 | Drums | $250.00 | $18,750 | |
| SVE/AS Mobilization, Bond, and Insurance | 1 | lump sum | $60,000.00 | $60,000 | |
| Trench for piping | 1 | lump sum | $6,000.00 | $6,000 | |
| Above ground PVC piping | 1 | lump sum | $14,000.00 | $14,000 | |
| Tees, elbows, reducers, and ball valves | 1 | lump sum | $20,000.00 | $20,000 | |
| Valve Vaults | 1 | lump sum | $105,000.00 | $105,000 | 40 Vaults |
| Electrical Service | 1 | lump sum | $60,000.00 | $60,000 | |
| Treatment Shed, Blowers, and Controls | 1 | lump sum | $220,000.00 | $220,000 | |
| SUBTOTAL | | | | $829,585 | |
| Contingency | 25% | | | $207,396 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $1,036,981 | |
| Project Management | 6% | | | $62,219 | |
| Remedial Design | 12% | | | $124,438 | |
| Construction Management | 8% | | | $82,959 | |
| First year operation and maintenance | 1 | lump sum | | $78,000 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $1,385,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| OM&M Inspection | 200 | hours | $80.00 | $16,000 | |
| SUBTOTAL | | | | $16,000 | |
| Misc. | | | | | |
| Electrical | 1 | Lump Sum | $15,000.00 | $15,000 | |
| System effluent sampling | 12 | samples | $300.00 | $3,600 | |
| OM&M Equipment and Materials | 1 | Lump Sum | $20,000.00 | $20,000 | |
| SUBTOTAL | | | | $38,600 | |
| SUBTOTAL | | | | $54,600 | |
| Contingency | 25% | | | $13,650 | |
| SUBTOTAL | | | | $68,250 | |
| Project Management | 5% | | | $3,413 | |
| Technical Support | 10% | | | $6,825 | |
| **TOTAL ANNUAL O&M COST** | | | | $78,000 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $1,385,000 | $1,385,000 | 1.00 | $1,385,000 | |
| Annual O&M | 2-5 | $312,000 | $78,000 | 3.55 | $276,584 | 5 years, 5 % |
| | | $1,697,000 | | | $1,661,584 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $1,662,000 | |
| Capital | 1 | $1,385,000 | $1,385,000 | 1.00 | $1,385,000 | |
| Annual O&M | 2-30 | $2,262,000 | $78,000 | 15.14 | $1,181,004 | 30 years, 5 % |
| | | $3,647,000 | | | $2,566,004 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $2,566,000 | |

***Table A-5***
**Dissolved-Phase CVOC Plume Remedial Alternative Opinion of Probable Cost**

**Alternative 6**
**GROUNDWATER EXTRACTION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 6 consists of a groundwater extraction system to treat groundwater in a 400 foot width of the plume. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Pre-Design and Pilot Studies | | | | | |
| Pilot Test Design and Implementation | 1 | lump sum | $50,000.00 | $50,000 | 1 well installed; 72-hour pumping test |
| Drilling Mobilization | 1 | lump sum | $11,000.00 | $11,000 | |
| Monitoring Well Drilling | 600 | linear feet | $40.00 | $24,000 | Sonic Drilling, 6 borings to 100 feet |
| Monitoring Well Installation | 600 | linear feet | $23.00 | $13,800 | 2" PVC, Schedule 40 |
| Stick-up Monitoring Well Casing | 6 | wells | $235.00 | $1,410 | 6 Monitoring Wells |
| Well Install. & Development Oversight | 400 | hours | $80.00 | $32,000 | |
| Extraction System Installation | | | | | |
| Mobilization, Bond, and Insurance | 1 | lump sum | $100,000.00 | $100,000 | |
| 6-inch Vertical Extraction Wells x 3 (installed) | 300 | LF | $150 | $45,000 | See Note 1 |
| 4" submersible pump, 20-50 gpm, 3 hp | 3 | EA | $5,250 | $15,750 | See Note 2 |
| In-line magnetic flowmeters | 3 | EA | $4,500 | $13,500 | |
| Power and data line conduit | 3800 | LF | $20 | $76,000 | See Note 3 |
| Treatment/controls Shed | 1 | lump sum | $10,000.00 | $10,000 | |
| Controls/SCADA system | 1 | LS | $55,000 | $55,000 | |
| 4" and 6" HDPE, SDR 17 (100 psi) collection pipe w/ testing | 600 | LF | $18 | $10,800 | |
| Exposed 8" HDPE, SDR 17 (100 psi) force main pipe w/ testing | 600 | LF | $25 | $15,000 | |
| 1-2" distribution piping to nozzles | 1500 | LF | $7 | $10,500 | |
| Aeration/misting System | | | | | |
| Misting nozzles | 1 | lump sum | $25,000 | $25,000 | |
| Disposal of Excess Soils | | | | | |
| Drums | 20 | Drums | $55.00 | $1,100 | |
| Purge Water and Cuttings Disposal | 20 | Drums | $250.00 | $5,000 | |
| SUBTOTAL | | | | $514,860 | |
| Contingency | 25% | | | $128,715 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $643,575 | |
| Project Management | 6% | | | $38,615 | |
| Remedial Design | 12% | | | $77,229 | |
| Construction Management | 8% | | | $51,486 | |
| First year operation and maintenance | 1 | lump sum | | $74,000 | See cost breakdown below |
| **TOTAL CAPITAL COST** | | | | $885,000 | |

Notes: Cost data obtained from 2005 RSMeans Environmental Remediation (ER), Building Construction (BC), or Heavy Construction (HC) Cost Data, vendor quotes, and previous Malcolm Pirnie project experience.
1) Assumes 6" diameter PVC wells, 30' screens and 100' average depth. Includes labor & materials.
2) RSM ER 33 23 0528. Includes 1 backup pump for each pump location.
3) Includes 2" diam. rigid galvanized conduit (RSM BC 16120 120 0350) and 600 V armoured #8 cable, 3 conductor solid (RSM BC 16132 240 200).
4) Includes cannisters in series (3 on-line at once)
5) Includes 1 heat exchanger for each on-line canister for humidity removal
6) Includes initial carbon material for new cannisters

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| O&M | | | | | |
| O&M Labor | 250 | hours | $80 | $20,000 | |
| Pipe Maintenance | 1 | ls | $10,000 | $10,000 | |
| Pump Repair and Maintenance | 3 | ea | $425 | $1,275 | |
| Electrical Consumption | 200000 | KWh | 0.1 | $20,000 | |
| SUBTOTAL | | | | $51,275 | |
| Contingency | 25% | | | $12,819 | |
| SUBTOTAL | | | | $64,094 | |
| Project Management | 5% | | | $3,205 | |
| Technical Support | 10% | | | $6,409 | |
| **TOTAL ANNUAL O&M COST** | | | | $74,000 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR (5%) | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $885,000 | $885,000 | 1.00 | $885,000 | |
| Annual O&M | 2-5 | $296,000 | $74,000 | 3.55 | $262,400 | 5 years, 5 % |
| | | $1,181,000 | | | $1,147,400 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $1,147,000 | |
| Capital | 1 | $885,000 | $885,000 | 1.00 | $885,000 | |
| Annual O&M | 2-30 | $2,146,000 | $74,000 | 15.14 | $1,120,439 | 30 years, 5 % |
| | | $3,031,000 | | | $2,005,439 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $2,005,000 | |

***Table A-6***
**Dissolved-Phase CVOC Plume Remedial Alternatives Opinion of Probable Cost**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

| Alternative | Description | Capital Costs | Annual OM&M Costs | Total Present Value |
|---|---|---|---|---|
| Alternative 1 | NO FURTHER ACTION | $0 | $0 | $0 |
| Alternative 2 | MONITORED NATURAL ATTENUATION | $36,000 | $36,000 | |
| | 5 years of monitoring | | | $164,000 |
| | 30 years of monitoring | | | $581,000 |
| Alternative 3 | IN-SITU BIOREMEDIATION | $798,000 | $381,000 | |
| | 2 injections per year for 5 years | | | $2,149,000 |
| | 2 injections per year for 30 years | | | $6,567,000 |
| Alternative 4 | PERMEABLE REACTIVE BARRIER | $3,027,000 | $0 | |
| | 1 time installation, OM&M for 5 years | | | $3,027,000 |
| | 1 time installation, OM&M for 30 years | | | $3,027,000 |
| Alternative 5 | AIR SPARGING AND SOIL VAPOR EXTRACTIC | $1,385,000 | $78,000 | |
| | 1 time installation, OM&M for 5 years | | | $1,662,000 |
| | 1 time installation, OM&M for 30 years | | | $2,566,000 |
| Alternative 6 | GROUNDWATER EXTRACTION | $885,000 | $74,000 | |
| | 1 time installation, OM&M for 5 years | | | $1,147,000 |
| | 1 time installation, OM&M for 30 years | | | $2,005,000 |

***Table A-7***
**Dissolve-Phase CVOC Plume Remedial Alternative 30-Year Cost Summary**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

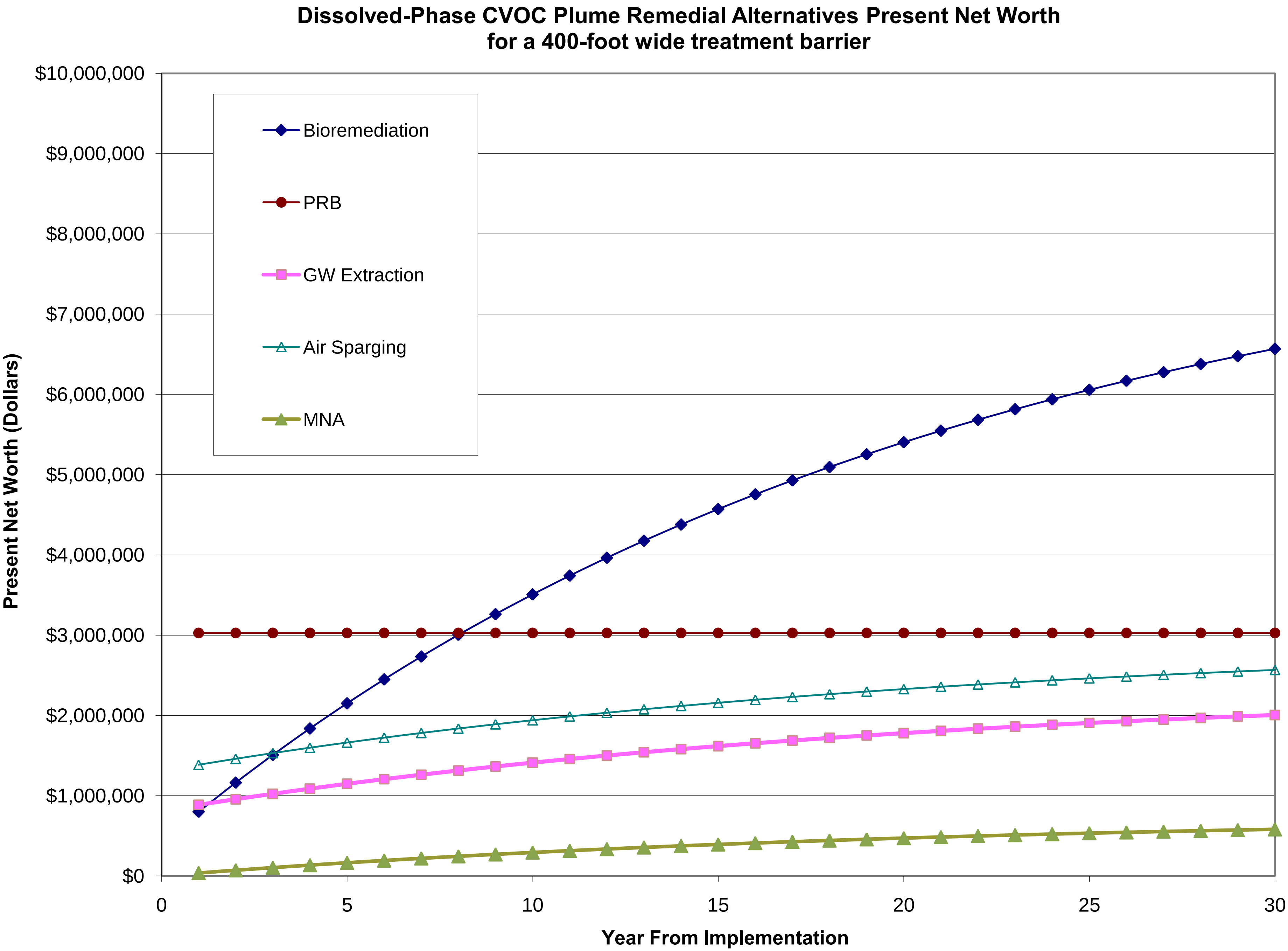
| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Alternative | No Action | MNA | Bio | PRB | Air Sparging | GW Extraction |
| Capital Cost | $0 | $36,000 | $798,000 | $3,027,000 | $1,385,000 | $885,000 |
| Annual O&M | $0 | $36,000 | $381,000 | $0 | $78,000 | $74,000 |
| Year | Present Net Worth | | | | | |
| 1 | $0 | $36,000 | $798,000 | $3,027,000 | $1,385,000 | $885,000 |
| 2 | $0 | $70,286 | $1,160,857 | $3,027,000 | $1,459,286 | $955,476 |
| 3 | $0 | $102,939 | $1,506,435 | $3,027,000 | $1,530,034 | $1,022,596 |
| 4 | $0 | $134,037 | $1,835,557 | $3,027,000 | $1,597,413 | $1,086,520 |
| 5 | $0 | $163,654 | $2,149,007 | $3,027,000 | $1,661,584 | $1,147,400 |
| 6 | $0 | $191,861 | $2,447,531 | $3,027,000 | $1,722,699 | $1,205,381 |
| 7 | $0 | $218,725 | $2,731,839 | $3,027,000 | $1,780,904 | $1,260,601 |
| 8 | $0 | $244,309 | $3,002,608 | $3,027,000 | $1,836,337 | $1,313,192 |
| 9 | $0 | $268,676 | $3,260,484 | $3,027,000 | $1,889,131 | $1,363,278 |
| 10 | $0 | $291,882 | $3,506,080 | $3,027,000 | $1,939,410 | $1,410,979 |
| 11 | $0 | $313,982 | $3,739,981 | $3,027,000 | $1,987,295 | $1,456,408 |
| 12 | $0 | $335,031 | $3,962,744 | $3,027,000 | $2,032,900 | $1,499,675 |
| 13 | $0 | $355,077 | $4,174,899 | $3,027,000 | $2,076,334 | $1,540,881 |
| 14 | $0 | $374,169 | $4,376,951 | $3,027,000 | $2,117,699 | $1,580,124 |
| 15 | $0 | $392,351 | $4,569,382 | $3,027,000 | $2,157,094 | $1,617,499 |
| 16 | $0 | $409,668 | $4,752,650 | $3,027,000 | $2,194,613 | $1,653,095 |
| 17 | $0 | $426,160 | $4,927,190 | $3,027,000 | $2,230,346 | $1,686,995 |
| 18 | $0 | $441,866 | $5,093,419 | $3,027,000 | $2,264,377 | $1,719,281 |
| 19 | $0 | $456,825 | $5,251,733 | $3,027,000 | $2,296,788 | $1,750,029 |
| 20 | $0 | $471,072 | $5,402,507 | $3,027,000 | $2,327,655 | $1,779,314 |
| 21 | $0 | $484,640 | $5,546,102 | $3,027,000 | $2,357,052 | $1,807,204 |
| 22 | $0 | $497,561 | $5,682,859 | $3,027,000 | $2,385,050 | $1,833,765 |
| 23 | $0 | $509,868 | $5,813,104 | $3,027,000 | $2,411,714 | $1,859,062 |
| 24 | $0 | $521,589 | $5,937,147 | $3,027,000 | $2,437,109 | $1,883,154 |
| 25 | $0 | $532,751 | $6,055,283 | $3,027,000 | $2,461,294 | $1,906,099 |
| 26 | $0 | $543,382 | $6,167,793 | $3,027,000 | $2,484,328 | $1,927,952 |
| 27 | $0 | $553,507 | $6,274,946 | $3,027,000 | $2,506,264 | $1,948,764 |
| 28 | $0 | $563,149 | $6,376,996 | $3,027,000 | $2,527,157 | $1,968,584 |
| 29 | $0 | $572,333 | $6,474,186 | $3,027,000 | $2,547,054 | $1,987,461 |
| 30 | $0 | $581,079 | $6,566,749 | $3,027,000 | $2,566,004 | $2,005,439 |

**Notes:**

**Present Net Worth is based on a 5% discount rate.**

**Capital costs, which include the first year of O&M, occur in year 1.**

**Assumes O&M costs incurred at the end of each year.**


Dissolved-Phase CVOC Plume Remedial Alternatives Present Net Worth
for a 400-foot wide treatment barrier
Bioremediation
PRB
GW Extraction
Air Sparging
MNA
$10,000,000
$9,000,000
$8,000,000
$7,000,000
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
Present Net Worth (Dollars)
0
5
10
15
20
25
30
Year From Implementation

**New York State Department of Environmental Conservation**
Feasibility Study Report
Modock Road Springs/DLS Sand and Gravel, Inc. Site

# Appendix B: Area of Highest Groundwater CVOC Concentrations Remedial Alternatives Cost Estimates

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MALCOLM PIRNIE

***Table B-1***
**Area of Highest Groundwater CVOC Concentrations Remedial Alternative Opinion of Probable Cost**

**Alternative 2**
**IN-SITU CHEMICAL OXIDATION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 2 consists of in-situ chemical oxidation to treat the area of the plume with the highest concentrations. Assumes injection of RegenOx during three applications over an 400 foot width of the plume. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | |
| Passive Diffusion Bags | 0 | bags | $30.00 | $0 | |
| Groundwater Laboratory Analysis | 0 | samples | $100.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| ISCO Injections | | | | | |
| Mobilization/Demobilization and Shipping | 1 | lump sum | $10,000.00 | $10,000 | |
| Vendor support | 3 | days | $1,200.00 | $3,600 | |
| Injection Materials | 1 | lump sum | $140,000.00 | $140,000 | |
| Vendor/Subcontractor Field Support/Drilling | 40 | days | $4,000.00 | $160,000 | 40 injection points |
| Vendor/Subcontractor Reporting | 1 | lump sum | $5,000.00 | $5,000 | |
| SUBTOTAL | | | | $318,600 | |
| SUBTOTAL | | | | $318,600 | |
| Contingency | 25% | | | $79,650 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $398,250 | |
| Project Management | 8% | | | $31,860 | |
| Remedial Design | 15% | | | $59,738 | |
| Construction Management | 10% | | | $39,825 | |
| **TOTAL CAPITAL COST** | | | | $530,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| Contingency | 25% | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Project Management | 5% | | | $0 | |
| Technical Support | 10% | | | $0 | |
| **TOTAL ANNUAL O&M COST** | | | | $0 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $530,000 | $530,000 | 1.00 | $530,000 | |
| Annual O&M | 2-30 | $0 | $0 | #DIV/0! | $0 | 30 years, 5 % |
| | | $530,000 | | | $530,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $530,000 | |

***Table B-2***
**Area of Highest Groundwater CVOC Concentrations Remedial Alternative Opinion of Probable Cost**

**Alternative 3**
**ZERO VALENT IRON**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 3 consists of 1 injection of zero valent iron to treat the area of the plume with the highest concentrations. Assumes injection of zero-valent iron during one event over an 400 foot width of the plume. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-30.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Work | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | |
| Passive Diffusion Bags | 0 | bags | $30.00 | $0 | |
| Groundwater Laboratory Analysis | 0 | samples | $100.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| Zero-valent Iron Injections | | | | | |
| Project Planning, Design and Coordination, and HASP | 1 | lump sum | $24,000.00 | $24,000 | |
| Mobilization/Demobilization and Shipping | 1 | lump sum | $14,000.00 | $14,000 | |
| Injection Materials | 1 | lump sum | $125,000.00 | $125,000 | 1 Injection event over a 400 foot width of the plume |
| Vendor/Subcontractor Field Support/Drilling | 23 | days | $20,000.00 | $460,000 | |
| Vendor/Subcontractor Reporting | 1 | lump sum | $6,000.00 | $6,000 | |
| ETI License Fee | 1 | percent | 15% | $89,850 | 15% of mobe, material, and drilling costs |
| SUBTOTAL | | | | $718,850 | |
| SUBTOTAL | | | | $718,850 | |
| Contingency | 15% | | | $107,828 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $826,678 | |
| Project Management | 6% | | | $49,601 | |
| Remedial Design | 6% | | | $49,601 | |
| Construction Management | 8% | | | $66,134 | |
| **TOTAL CAPITAL COST** | | | | $992,000 | |

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Site Monitoring | | | | | |
| Groundwater Sampling | 0 | hours | $80.00 | $0 | |
| SUBTOTAL | | | | $0 | |
| Contingency | 25% | | | $0 | |
| SUBTOTAL | | | | $0 | |
| Project Management | 5% | | | $0 | |
| Technical Support | 10% | | | $0 | |
| **TOTAL ANNUAL O&M COST** | | | | $0 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $992,000 | $992,000 | 1.00 | $992,000 | |
| Annual O&M | 2-30 | $0 | $0 | #DIV/0! | $0 | 30 years, 5 % |
| | | $992,000 | | | $992,000 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR THIRTY YEARS** | | | | | $992,000 | |

***Table B-3***
**Area of Highest Groundwater CVOC Concentrations Remedial Alternative Opinion of Probable Cost**

**Alternative 4**
**GROUNDWATER EXTRACTION**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

**Description:** Alternative 4 consists of a groundwater extraction system to treat the area of the plume with the highest concentrations. Assumes five years of groundwater extraction over an 400 foot width of the plume. Capital costs and first year O&M costs occur in Year 1. Annual O&M costs occur in Years 1-5.

**CAPITAL COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| Extraction System Installation | | | | | |
| Mobilization, Bond, and Insurance | 1 | lump sum | $100,000.00 | $100,000 | |
| 6-inch Vertical Extraction Wells x 3 (installed) | 300 | LF | $150 | $45,000 | See Note 1 |
| 4" submersible pump, 20-50 gpm, 3 hp | 3 | EA | $5,250 | $15,750 | See Note 2 |
| In-line magnetic flowmeters | 3 | EA | $4,500 | $13,500 | |
| Power and data line conduit | 3800 | LF | $20 | $76,000 | See Note 3 |
| Treatment/controls Shed | 1 | lump sum | $10,000.00 | $10,000 | |
| Controls/SCADA system | 1 | LS | $55,000 | $55,000 | |
| 6" and 8" HDPE, SDR 17 (100 psi) collection pipe w/ testing | 600 | LF | $18 | $10,800 | |
| Exposed 12" HDPE, SDR 17 (100 psi) force main pipe w/ testing | 600 | LF | $25 | $15,000 | |
| 1-2" distribution piping to nozzles | 1500 | LF | $7 | $10,500 | |
| Aeration/misting System | | | | | |
| Misting nozzles | 1 | lump sum | $25,000 | $25,000 | |
| Disposal of Excess Soils | | | | | |
| Drums | 20 | Drums | $55.00 | $1,100 | |
| Purge Water and Cuttings Disposal | 20 | Drums | $250.00 | $5,000 | |
| O&M | | | | | |
| O&M Labor | 250 | hours | $80 | $20,000 | |
| Pipe Maintenance | 1 | lump sum | $10,000 | $10,000 | |
| Pump Repair and Maintenance | 3 | ea | $425 | $1,275 | |
| Electrical Consumption | 200000 | KWh | 0.1 | $20,000 | |
| SUBTOTAL | | | | $433,925 | |
| Contingency | 25% | | | $108,481 | 10% scope + 15% Bid |
| SUBTOTAL | | | | $542,406 | |
| Project Management | 6% | | | $32,544 | |
| Remedial Design | 12% | | | $65,089 | |
| Construction Management | 8% | | | $43,393 | |
| **TOTAL CAPITAL COST** | | | | $683,000 | |

Notes: Cost data obtained from 2005 RSMeans Environmental Remediation (ER), Building Construction (BC), or Heavy Construction (HC) Cost Data, vendor quotes, and previous Malcolm Pirnie project experience.
1) Assumes 6" diameter PVC wells, 30' screens and 100' average depth. Includes labor & materials.
2) RSM ER 33 23 0528. Includes 1 backup pump for each pump location.
3) Includes 2" diam. rigid galvanized conduit (RSM BC 16120 120 0350) and 600 V armoured #8 cable, 3 conductor solid (RSM BC 16132 240 200).
4) Includes cannisters in series (3 on-line at once)
5) Includes 1 heat exchanger for each on-line canister for humidity removal
6) Includes initial carbon material for new cannisters

**OPERATION & MAINTENANCE COSTS:**

| DESCRIPTION | QTY | UNIT | UNIT COST | TOTAL | NOTES |
|---|---|---|---|---|---|
| O&M | | | | | |
| O&M Labor | 250 | hours | $80 | $20,000 | |
| Pipe Maintenance | 1 | ls | $10,000 | $10,000 | |
| Pump Repair and Maintenance | 3 | ea | $425 | $1,275 | |
| Electrical Consumption | 200000 | KWh | 0.1 | $20,000 | |
| SUBTOTAL | | | | $51,275 | |
| Contingency | 25% | | | $12,819 | |
| SUBTOTAL | | | | $64,094 | |
| Project Management | 5% | | | $3,205 | |
| Technical Support | 10% | | | $6,409 | |
| **TOTAL ANNUAL O&M COST** | | | | $74,000 | |

**PRESENT VALUE ANALYSIS:**

| COST TYPE | YEAR | TOTAL COST | TOTAL COST PER YEAR | DISCOUNT FACTOR (5%) | PRESENT VALUE | NOTES |
|---|---|---|---|---|---|---|
| Capital | 1 | $683,000 | $683,000 | 1.00 | $683,000 | |
| Annual O&M | 2-5 | $296,000 | $74,000 | 3.55 | $262,400 | 5 years, 5 % |
| | | $979,000 | | | $945,400 | |
| **TOTAL PRESENT VALUE OF ALTERNATIVE FOR FIVE YEARS** | | | | | $945,000 | |

***Table B-4***
**Area of Highest Groundwater CVOC Concentrations Remedial Alternative Opinion of Probable Cost**

# OPINION OF PROBABLE COST SUMMARY

**Site:** Modock Road Springs
**Location:** Victor, New York
**Phase:** Feasability Study (-30% to +50%)
**Base Year:** 2009
**Date:** April 28, 2009

| Alternative | Description | Capital Costs | Annual OM&M Costs | Total Present Value |
|---|---|---|---|---|
| Alternative 1 | NO FURTHER ACTION | $0 | $0 | $0 |
| Alternative 2 | IN-SITU CHEMICAL OXIDATION | $530,000 | $0 | $530,000 |
| Alternative 3 | ZERO VALENT IRON | $992,000 | $0 | $992,000 |
| Alternative 4 | GROUNDWATER EXTRACTION (FIVE YEARS OF OPERATION) | $683,000 | $74,000 | $945,000 |