SRSNE Site Group

Remedial Design Work Plan Attachment L

Monitored Natural Attenuation Plan

Solvents Recovery Service of New England, Inc.
(SRSNE) Superfund Site
Southington, Connecticut

November 2010

ARCADIS

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New England, Inc. (SRSNE)
Superfund Site
Southington, Connecticut

Prepared for:

SRSNE Site Group

Prepared by:

ARCADIS
1687 Cole Blvd.
Suite 200
Lakewood
Colorado 80401
Tel 303.231.9115
Fax 303.231.9571

Our Ref.:

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Date:

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Executive Summary

This *Monitored Natural Attenuation Plan* (MNA Plan) has been prepared to address certain requirements of the Statement of Work (SOW) for the Remedial Design/Remedial Action (RD/RA) activities at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut. It sets forth the procedures for collection and evaluation of data in support of MNA as a remedy for groundwater that contains Site-related constituents of concern (COCs) at concentrations exceeding acceptable risk levels or regulatory limits. MNA is a component of the overall remedial strategy for groundwater as set forth for the Site in the United States Environmental Protection Agency's (USEPA's) 2005 Record of Decision for the Site.

This MNA Plan fulfills the requirement set forth in Section VII.A.1 of the SOW for submittal of an MNA Plan as part of the Remedial Design Work Plan (RDWP) and includes the following components:

- Evaluation of existing Site data to establish the Site Conceptual Model (SCM) for the natural attenuation of chemical constituents in Site groundwater Inclusion of the SCM also addresses the requirement of SOW Section V.C.1.I.

- Presentation of the evaluation and decision-making process that led to the selection of MNA as a remedy for COCs in Site groundwater, data gaps, and performance objectives and standards.

- Summary of the sampling and analysis requirements for groundwater monitoring in support of the MNA remedy, including performance monitoring objectives, performance standards, and performance monitoring program (monitoring network locations, monitoring parameters and analytical methods, monitoring frequency, and data quality objectives).

- Detailed description of how monitoring data will be interpreted and presented in subsequent annual monitoring reports, including the data quality assessment process, data interpretation approach, statistical procedures and changes in environmental conditions that may reduce the efficacy of NA processes

- Presentation of the reporting and schedule information related to the MNA program.

1. Introduction

1.1 Purpose

This *Monitored Natural Attenuation Plan* (MNA Plan) has been prepared on behalf of the SRSNE Site Group, an unincorporated association of Settling Defendants to a Consent Decree (CD) and Statement of Work (SOW) for the Remedial Design/Remedial Action (RD/RA) at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut (Site) (Figure L-1). The CD was lodged on October 30, 2008 with the United States District Court for the District of Connecticut in connection with Civil Actions No. 3:08cv1509 (SRU) and No. 3:08cv1504 (WWE). The CD was entered by the Court on March 26, 2009.

This MNA Plan sets forth the procedures for collection and evaluation of data in support of MNA as a remedy for groundwater that contains Site-related constituents of concern (COCs) at concentrations exceeding acceptable risk levels or regulatory limits. MNA is a component of the overall remedial strategy set forth for the Site in the Record of Decision (ROD) (United States Environmental Protection Agency [USEPA] 2005), which requires:

> "*the in-situ treatment of subsurface source material (non-aqueous phase liquid or NAPL) in the overburden aquifer; capping surface source material (contaminated soil and wetland soil); capturing groundwater that exceeds federal drinking water standards and other risk-based cleanup levels; institutional controls; and monitored natural attenuation of NAPL in the deep subsurface (bedrock) and contaminated groundwater throughout the plume including outside the capture zone, until cleanup levels are achieved across the entire Site.*"

This plan fulfills the requirement set forth in Section VII.A.1 of the SOW for submittal of an MNA Plan as part of the Remedial Design Work Plan (RDWP). That section of the SOW indicates that the MNA Plan:

> "*shall include all monitoring and analysis necessary to complete the delineation of the groundwater plume(s) in three dimensions; evaluate the effectiveness of institutional controls; assess temporal and spatial variations in plume chemistry and geometry; and assess progress in meeting the long-term remedial goal of groundwater restoration throughout the Site to its natural quality.*"

A portion of this requirement – to include monitoring and analysis to support plume delineation – is addressed, along with other MNA-related objectives, as part of the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). The needs and objectives of the MNA Plan were considered in developing the well network and sampling approach described in that document.

This MNA Plan, by way of the MNA Site Conceptual Model (SCM) provided in Section 2 of this MNA Plan, also addresses SOW Section V.C.1.I, which requires further development of

> "*a site-specific conceptual model for MNA, based on the conceptual model and other information developed during the Remedial Investigation and Feasibility Study (RI/FS) that was the basis for selection of MNA, and incorporating all new data collected since the RI/FS.*"

To meet requirements of SOW Section V.C.1.I, the MNA SCM includes an evaluation of existing Site data to establish the SCM for the natural attenuation of COCs in groundwater. The MNA SCM combines available Site information into a comprehensive picture of the nature and extent of the COCs and the processes controlling transport and fate of COCs in the environment.

1.2 Scope

This MNA Plan was developed to describe the components of the MNA remedy for COCs in groundwater at the Site. The MNA remedy applies to the groundwater and residual NAPL underlying the Site and addresses the following areas of the Site, in accordance with the SOW:

- Groundwater and saturated glacial deposits (gravel, sand, silt, and clay) in the "Overburden Groundwater" aquifer that contain COC concentrations exceeding acceptable risk levels or regulatory criteria

- Groundwater and fractured rock in the "Bedrock Groundwater" aquifer that contain COC concentrations exceeding acceptable risk levels or regulatory criteria

MNA refers to the reliance on natural attenuation (NA) processes, within the context of a carefully controlled and monitored site cleanup approach, to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. When properly employed, MNA provides an effective knowledge-based remedy, where a thorough analysis provides significant information toward understanding, monitoring, predicting, and documenting COC transport and natural attenuation processes. An MNA remedy requires a strong scientific basis supported by appropriate research and site-specific monitoring. NA is the reduction in mass or concentration of COCs in groundwater over time or distance from the source of the impact due to naturally occurring processes. Attenuation processes include nondestructive physical processes (e.g., advection, dilution, dispersion, volatilization, dissolution, and sorption) and destructive chemical and biological processes (e.g., abiotic chemical reactions and biological degradation [aerobic oxidation and reductive dechlorination]).

As part of the MNA remedy, concentrations of COCs in groundwater in the overburden and bedrock aquifers underlying the Site, and NAPL in the bedrock aquifer underlying the Site and overburden aquifer outside the Overburden NAPL Area will be monitored. In addition to monitoring COC concentrations, this MNA Plan includes long-term monitoring of a suite of geochemical parameters (“MNA parameters”) to confirm geochemical evidence of NA and to verify biochemical processes continue to occur in Site groundwater. COCs in Site groundwater include chlorinated solvents, alcohols, 1,4-dioxane, target analyte list (TAL) metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). MNA parameters include anions (sulfate, sulfide, chloride, nitrate, nitrite), total organic carbon, iron (ferric, ferrous), divalent manganese, light hydrocarbons (methane, ethane, ethene), dissolved oxygen, oxidation/reduction potential, pH, alkalinity and temperature.

To meet requirements of SOW Sections VII.A.1 and V.C.1.I, this MNA Plan includes the following components:

- Evaluation of existing Site data to establish the SCM for the natural attenuation of chemical constituents in Site groundwater

- Summary of the sampling and analysis requirements for groundwater monitoring in support of the MNA remedy

- Detailed description of how monitoring data will be interpreted and presented in subsequent annual monitoring reports

- Well maintenance program that contains provisions for inspection, continued maintenance, repair and prompt and proper abandonment, if necessary

This MNA Plan has been prepared based on USEPA guidance, directives and other publications including, but not limited to the following:

- *Use of Monitored Natural Attenuation at Superfund, Resource Conservation and Recovery Act (RCRA) Corrective Action, and Underground Storage Tank Sites* (USEPA 1999)

- *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (USEPA 2000)

- *Performance Monitoring of MNA Remedies for Volatile Organic Compounds (VOCs) in Ground Water* (USEPA 2004)

1.3 Document Organization

The remainder of this MNA Plan is organized into the following six sections:

- **Section 2 – Site Conceptual Model:** describes available Site information and present this information as a comprehensive picture of the nature and extent of the COCs and the processes controlling transport and fate of COCs in the environment

- **Section 3 – Selection of MNA Remedy:** describes the evaluation and decision-making process that led to the selection of MNA as a remedy for COCs in Site groundwater. In addition, Section 2 identifies data gaps and presents performance objectives and standards.

- **Section 4 – Performance Monitoring:** presents the MNA performance monitoring objectives, performance standards, and performance monitoring program, including the monitoring network locations, monitoring parameters and analytical methods, monitoring frequency, and data quality objectives.

- **Section 5 – Analysis of Performance Monitoring Data:** discusses the analysis of performance monitoring data, including the data quality assessment process, data interpretation approach, statistical procedures and changes in environmental conditions that may reduce the efficacy of NA processes.

- **Section 6 – Reporting and Schedule:** presents reporting and schedule information related to the MNA program.

- **Section 7 – References:** lists the references that are cited within this MNA Plan.

Several supporting tables and figures are also attached and referenced as appropriate throughout the text. Finally, reference is made to other RD documentation that directly supports this MNA Plan, including the RDWP, *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP), and *Remedial Design Project Operations Plan* (RD POP).

2. Site Conceptual Model

For any MNA remedy to be successful, it is important to understand the SCM for the Site. The SCM combines available Site information into a comprehensive picture of the nature and extent of the COCs and the processes controlling transport and fate of COCs in the environment. The level of site characterization necessary to support a comprehensive evaluation of MNA can be more detailed than that needed to support active remediation. Characterization of the following factors is typically required to develop a SCM for MNA evaluation:

- Quantitative understanding of source mass and distribution;
    - Location, nature, phase distribution, and extent of COC source
    - Location, nature, concentration of plume and potential impact on receptors
- Site hydrogeology, including potential for flow along preferential pathways;
    - Aquifer hydraulics, recharge and discharge areas, and aquifer geochemical properties
- COC phase distribution and partitioning between soil, groundwater, and soil gas;
    - Contributions of sorption, dilution, volatilization, and diffusion
- Biological and non-biological transformation;
    - Distribution of nutrients and electron donors and acceptors present in groundwater
    - Concentrations of co-metabolites and metabolic by-products
    - Specific analyses to identify microbial populations present
- An understanding of how all of these factors may vary with time.

Information regarding the Site operational history, regulatory status, Site setting including geology, hydrogeology, and surface water hydrology, and the distribution and mass of COCs in Site groundwater including delineation of NAPL zones and dissolved phase groundwater plume, and VOC mass estimates are provided in Section 2 of the RDWP*.* The following sections present additional site-specific information used in developing the SCM for COCs in Site-related groundwater including natural attenuation processes, historic MNA evaluations, and an update to historic MNA evaluations. The area of interest for the SCM includes the entire Study Area (Figures L-2 and L-3)

2.1 Physical, Chemical, and Biological Natural Attenuation Processes for Site COCs

COCs in Site groundwater can be naturally attenuated via physical, chemical, and biological processes. Physical attenuation processes include sorption, volatilization, dilution, and diffusion and do not result in destruction of the COC. Chemical and biological processes, such as hydrolysis, oxidation, and reduction, result in degradation or destruction of COCs. Each of the major physical, chemical, and biological natural attenuation processes are described in the following sections. The following discussions build upon information provided in the RI (Blasland, Bouck & Lee [BBL] 1998) and FS (BBL and USEPA 2005; Geosyntec 2005a and 2005b *in* BBL and USEPA 2005) and references provided therein.

2.1.1 Physical Attenuation Mechanisms (COC Mass Transfer)

2.1.1.1 Sorption

Sorption refers to the chemical transport process whereby chemicals – such as organic compounds dissolved in groundwater – partition preferentially to solid phase aquifer materials. The quantity of chemicals that can partition to solid phase materials is directly proportional to the affinity of the dissolved chemical to sorb to the solid phase material. For metals, this affinity is described by the soil-water partition coefficient, K_d. Non-polar, hydrophobic chemicals, such as chlorinated solvent compounds dissolved in groundwater, partition preferentially to solid organic matter present within soils. The K_d for non-polar compounds is described by the product $K_{oc} \times f_{oc}$ where K_{oc} is the chemical-specific organic carbon partition coefficient and f_{oc} is the fraction of solid organic carbon in the soil.

The result of this process is that some quantity of the chemical mass is removed from groundwater during transport, and the rate of COC migration in groundwater can be less than the average linear groundwater velocity. Sorption is, therefore, a process which results in the COC plume velocity being retarded relative to the average linear groundwater velocity.

Sorption of COCs in the overburden aquifer is an important process attenuating COC transport in groundwater within the Study Area. For example, the estimated mass of VOCs sorbed to overburden materials is 9,300 kilograms (kg) while the estimated dissolved phase mass of VOCs is 1,900 kg (BBL and USEPA 2005). Therefore, the sorbed mass of VOCs is approximately 83% of the estimated total mass of VOCs in overburden groundwater outside of the NAPL area.

2.1.1.2 Volatilization

Volatilization is the transfer of mass from the solid or liquid phases to the vapor phase. Factors affecting volatilization of COCs from groundwater into soil gas include COC concentration, change in COC concentration with depth, Henry's law constant, and diffusion coefficient of COC, mass transport coefficients for the COC in water and soil gas, sorption, and the temperature of the water. Partitioning of a chemical between the liquid phase and the gaseous phase is governed by Henry's law which states that the concentration of a chemical in the gaseous phase is directly proportional to the concentration of the chemical in the liquid phase and is a constant characteristic of the chemical. The Henry's law constant, H, describes the tendency of a chemical to volatilize from groundwater into soil gas.

Generally, volatilization can be ignored as a major attenuation process for VOCs in groundwater when evaluating natural attenuation via biological degradation (Wiedemeier et al. 1999). However, volatilization may play an important role in causing unacceptable levels of VOCs in soil vapor gas, especially in locations with elevated groundwater concentrations of VOCs and shallow depths to groundwater. A separate study of the potential for vapor intrusion is being conducted. Institutional and/or engineering controls will be maintained to prevent exposure to soil vapor gas potentially impacted with VOCs.

2.1.1.3 Dilution

Dilution of COCs in groundwater occurs due to the addition of clean water through recharge of precipitation, infiltration of water from the surface (e.g., streams and lakes), and migration of groundwater from upgradient areas. Recharge from infiltrating precipitation and surface water is the result of a complex series of processes in the unsaturated zone that result in the downward transport of water, chemicals, and nutrients to the water table. Addition of nutrients, such as nitrogen and phosphorus, and addition of electron acceptors, such as oxygen and sulfate, in infiltrating water and groundwater migrating from upgradient areas, can be important for supporting natural attenuation of COCs in groundwater.

The upper portion of the shallow overburden groundwater plume is the portion of the Site COC plume most likely to be affected by infiltrating water. Introduction of oxygen to groundwater via water recharging from the surface may be beneficial for degradation of ketones and aromatic hydrocarbons, but may make conditions less favorable for reductive dechlorination of chlorinated solvents. However, as described in more detail in Section 6, groundwater geochemistry rapidly shifts to reducing conditions when upgradient groundwater interacts with source COCs.

Much of the Study Area is located within the 100 year flood plain of the Quinnipiac River, including portions of the former Cianci property closest to the river, and portions of the Connecticut Light & Power (CL&P) Easement, and the Town Well Field Property (Federal Emergency Management Agency [FEMA] 2009). Inundation of low lying areas of the Site may result in dilution of shallow overburden groundwater. The 100-year flood plain for the Study Area is generally defined to be located at an elevation of 156 feet (BBL 1998). Extensive areas of wetlands have been mapped within the Study Area. These wetland areas are generally defined to be present at locations with elevations less than 150 feet (BBL 1998). The primary wetland within the Study Area is a riparian wetlands habitat canopied by a deciduous forest community interspersed with scrub and shrub and herbaceous communities. These wetland areas are generally groundwater discharge zones (BBL 1998).

Periodic flooding of low laying areas of the Site may result in additional dilution of COCs in Site groundwater. Historic stage and discharge data for the Quinnipiac River United States Geological Survey (USGS) gaging station 01195490 at Southington, CT (USGS 2009) were reviewed to estimate the probable frequency that flooding occurs in the Study Area. The Southington Quinnipiac River gage is located approximately ½-mile downstream from the Site. Based on flood stage data provided by the National Weather Service (NWS 2009), flooding begins at a stage elevation of 145.47 feet. This stage elevation corresponds to a USGS gage height of 7 feet. At this gage height, minor flooding develops and the primary impact is for lowland flooding along the river. The NWS categorizes additional flood stages of moderate flooding at gage height above 8.5 feet and major flooding at gage height above 10.5 feet. At moderate flooding gage heights, road flooding begins and some structures become flooded along the river, with greater inundation of low laying areas. At major flood gage heights, widespread inundation of areas along the river occurs, more roads are flooded, and evacuations occur.

Review of available USGS gage height data for the entire period of record (April 12, 1996 through March 20, 2009) indicates that the Quinnipiac River gage height has exceeded minor flooding gage height of 7.0 feet eight times during this time. Of these eight flooding events, five events had gage heights that exceeded 8.5 feet, indicating moderate flooding and probable inundation of low laying areas of the Study Area. Based on these results, minor flooding events at the Site have a return period of about 1.6 years and moderate flooding events have a return period of about 2.6 years. Gage heights greater than the major flooding gage height of 10.5 feet were not reported for the period of record. These results indicate that additional dilution of COC-impacted groundwater may occur relatively frequently.

2.1.1.4 Hydrodynamic Dispersion

Hydrodynamic dispersion is a combination of mechanical mixing and molecular diffusion, and results in COC plumes spreading slightly laterally outward from the main direction of groundwater flow along a flow path. Molecular diffusion is described in the following section. Because groundwater flow can exhibit a high degree of heterogeneity due to the natural variability of soil texture and structure, groundwater flow paths can be highly tortuous resulting in mechanical mixing of COC-impacted groundwater with unimpacted groundwater. Mechanical mixing during advective groundwater flow thus leads to lowering of COC concentrations with time and distance along a given flow path. With time, chemical plumes in groundwater may disperse a small distance longitudinally, horizontally, and vertically as different portions of the mass are transported at different velocities. Hydrodynamic dispersion may result in slight decreases in COC concentrations with time within the severed plume (defined as the COC-impacted groundwater plume located downgradient of the capture zone associated with the groundwater extraction and treatment system).

2.1.1.5 Molecular Diffusion

Molecular diffusion occurs when concentration gradients cause solutes to migrate from zones of higher concentration to zones of lower concentration. The molecular diffusion of a solute in groundwater is described by Fick's law;

$$F = -D\, dC/dx$$

Where F is the mass flux of solute per unit area of time, D is the diffusion coefficient, and dC/dx is the concentration gradient of the COC. The effective diffusion coefficient for the transport of a COC in groundwater is typically 1×10^{-9} to 2×10^{-9} m^2/s. Molecular diffusion generally is important only at low groundwater velocities and is considered negligible during advective transport in granular soils.

Given the generally coarse-grained nature of the overburden material, molecular diffusion may have a limited affect on COC transport in overburden groundwater, although diffusion from higher permeability zones to low-permeability lenses and strata contributes to the overall retardation of the plume (Gorelick et al. 1993).

Molecular diffusion in fine-grained soil and bedrock settings can have a strong effect on migration of COCs in groundwater. Calculations were performed during the RI and the FS using Site-derived physical parameters for bedrock and literature-reported degradation half-lives and site-specific retardation factors for the groundwater COCs (Kueper 1997; Kueper and West 2004). Calculated retardation factors for COCs in bedrock groundwater indicate that molecular diffusion of COCs into the unfractured bedrock matrix has a particularly important role in plume migration in bedrock groundwater. The arkoses that underlie the Site are a relatively porous rock type and this bedrock matrix porosity represents a significant storage capacity for VOCs. VOCs diffuse from impacted groundwater or NAPL in bedrock fractures into the rock matrix.

The mean bedrock matrix porosity is approximately 1,100 times larger than the mean fracture porosity, indicating that the matrix represents the predominant zone in which VOC mass would be stored in the saturated bedrock (BBL 1998). However, the low permeability of the bedrock matrix suggests that VOC movement into or out of the bedrock matrix is generally controlled by molecular diffusion, or "matrix diffusion" (BBL 1998). This diffusion into the rock matrix was confirmed by bedrock matrix VOC analysis performed during the RI. The COCs diffuse slowly back out of the rock pores in the presence of groundwater with relatively lower concentrations of COCs. This process is slow and cleanup of bedrock groundwater was estimated to require approximately 225 years (Kueper and West 2004).

2.1.2 Chemical and Biological Attenuation Mechanisms (COC destruction)

Chemical and biological attenuation mechanisms result in the degradation or destruction of COC mass. The major chemical and biological attenuation processes are described in the following sections. A summary of specific degradation processes relevant to COCs in Site groundwater is provided in Table L-1 and Figures L-4 through L-7.

2.1.2.1 Abiotic Degradation

Many chlorinated organic compounds can undergo degradation by abiotic (non-microbially mediated) reactions such as hydrolysis and dehydrohalogenation. Hydrolysis is a substitution reaction in which a compound reacts with water and a halogen substituent (e.g., Cl^- or Br^-) is replaced with a hydroxyl (OH^-) group (Wiedemeier et al. 1999). Hydrolysis of organic compounds frequently results in the formation of alcohols and alkenes; reaction products that may be more susceptible to biodegradation than the parent material. Dehydrohalogenation is an elimination reaction involving halogenated alkanes in which a halogen is removed from one carbon atom, followed by subsequent removal of a hydrogen atom from an adjacent carbon atom (Wiedemeier et al. 1999). In this two-step reaction, an alkene is produced. For example, 1,1,1-trichloroethane (1,1,1-TCA) can undergo dehydrohalogenation to form 1,1- dichloroethene (1,1-DCE) or hydrolysis to form acetate:

$$\text{1,1,1-TCA} \rightarrow \text{1,1-DCE or acetate}$$

As shown on Table L-1 and Figures L-5 through L-7, 1,2-dichloroethane (1,2-DCA), chloroethane (CA), carbon tetrachloride (CT), and dichloromethane (DCM) can also abiotically degrade via hydrolysis or dehydrohaologenation.

The likelihood that a halogenated solvent will undergo hydrolysis depends in part on the number of halogen substituents; for compounds with a greater number of halogenated substituents, there is a lesser chance that hydrolysis will occur. Compounds with bromine substituents are more susceptible to hydrolysis than compounds with chlorine substituents. 1,1,1-TCA is the only major chlorinated solvent that can be transformed chemically through hydrolysis. Chlorinated ethenes, such as tetrachloroethene (PCE) and trichloroethene (TCE), do not undergo significant hydrolysis reactions in natural environments. Unlike the degradation patterns observed for hydrolysis, the likelihood that dehydrohalogenation will occur increases with the number of halogen substituents (Wiedemeier et al. 1999).

Based on the presence of 1,1-DCE in groundwater, abiotic degradation of 1,1,1-TCA via dehydrohalogenation likely is occurring. Based on the presence of acetic acid (the acid form of the acetate anion) in groundwater, degradation of 1,1,1-TCA via hydrolysis may be occurring.

2.1.2.2 General Biological Attenuation Mechanisms (COC Destruction)

Organic chemicals can undergo biological degradation (biodegradation) through two major mechanisms; direct oxidation and cometabolism. Direct oxidation involves the direct use of the target substrate as an electron donor, coupled to the reduction of an electron acceptor such as oxygen (in aerobic environments) or nitrate, iron, sulfate or carbon dioxide (CO_2) (in anaerobic environments). Depending on the electron acceptor used, the process is termed aerobic oxidation or anaerobic oxidation. Energy availability based on electron acceptors typically follows the following order from greater energy availability to lesser energy availability: oxygen, nitrate, manganese oxides, iron oxides, sulfate, and carbon dioxide (methanogenesis).

The relative importance of the various electron acceptors utilized during aerobic and anaerobic oxidation processes can be evaluated by assessing changes in concentrations of electron acceptors and their reduced counterparts along a flow path. Aerobic degradation and nitrate reduction will result in declines in groundwater dissolved oxygen and nitrate concentrations relative to background concentrations. Reduction of iron and manganese oxides will result in increased concentrations of dissolved iron and manganese concentrations in groundwater. Reduction of sulfate will result in declines in sulfate concentrations relative to background and may lead to detectable concentrations of sulfide in groundwater. Low concentrations of sulfide in groundwater with active sulfate reduction processes may occur due to the presence of geochemical reactions in which sulfide reacts with dissolved iron to form pyrite. Alternatively, sulfide may react with organic compounds (e.g., carbon tetrachloride and chloroform) to form carbon disulfide. For example, carbon disulfide was not detected in association with NAPL at the Site, but was detected in some groundwater samples. Methanogenesis will result in increased concentrations of methane in groundwater.

Cometabolism involves the metabolism of a primary substrate other than the target COC as an electron donor, with coincident degradation of the target COC. In the case of aerobic cometabolism (generally termed co-oxidation), bacteria oxidize a primary substrate such as methane or toluene, and fortuitously co-oxidize other substrates such as chlorinated solvents. In the case of anaerobic cometabolism (generally termed reductive dechlorination), bacteria use an organic co-substrate or hydrogen (H_2) as an electron donor and chlorinated compounds as electron acceptors, reducing these compounds.

The following sections provide descriptions of the main biodegradation mechanisms for organic compounds, including the key groups of microorganisms involved in aerobic oxidation, aerobic cometabolism, anaerobic oxidation, and reductive dechlorination. Generalized pathways for the degradation of chlorinated ethenes, ethanes, and methanes are shown on Figures L-4 through L-7. A summary of specific degradation processes relevant to COCs in Site groundwater is provided in Table L-1. Additional detail regarding specific degradation processes for COCs in Site groundwater is provided in Appendix H of the FS (Geosyntec 2005b in BBL and USEPA 2005).

2.1.2.3 Aerobic Oxidation

The oxidation of organic compounds results from the transfer of electrons from an organic compound (i.e., the electron donor or primary substrate) to an electron acceptor. Under aerobic conditions, oxygen serves as the electron acceptor and is reduced as the primary substrate (i.e., COC) is oxidized. The oxidation of the primary substrate results in its mineralization to harmless by-products (i.e., CO_2 and water). In many cases, the primary substrate can serve as both a carbon source and an energy source for microbial populations. This means that the substrate being oxidized provides both carbon atoms for molecular processes and energy for cellular processes. Many common groundwater COCs (e.g., petroleum hydrocarbons) can serve as both energy and carbon sources for microorganisms. The microorganisms use enzymes (proteins which promote specific reactions) to break down the substrates to carbon and energy sources. In aerobic oxidation, the enzymes that mediate the oxidation of organic material are called oxygenases. There are two kinds of oxygenases: dioxygenases, that catalyze the incorporation of both atoms of oxygen (O_2) into the molecule; and monoxygenases, that catalyze the transfer of only one of the two O_2 atoms to an organic compound. In monoxygenase systems, the O_2 molecule is split with one oxygen atom forming a hydroxyl radical (OH^-), which is then incorporated into the organic compound; and the other oxygen atom combines with hydrogen to form water (H_2O). Geochemical evidence of this activity is a depletion of oxygen coinciding with a decrease of the target chemical, and increase in CO_2 (rise in alkalinity).

The bacteria involved in aerobic oxidation can be divided into three groups, the obligate aerobes (those that require O_2), the facultative aerobes (those that do not require O_2 but grow better in the presence of O_2), and microaerophillic bacteria (those that require O_2 at levels that are lower than atmospheric). Obligate aerobes require oxygen mainly for respiration and as a terminal electron acceptor whereby oxygen is reduced to H_2O.

Site-specific COCs that are known to be degraded via aerobic oxidation include the 1- and 2-chlorine substituted ethenes, ethanes, and methanes (e.g., dichloroethenes, 1,2-dicholoethane, CA, DCM, and chloromethane) (Figures L-4 through L-7), aromatic compounds, and ketones (Table L-1). Aerobic oxidation of Site-specific COCs may be occurring within shallow overburden groundwater in the Non-Time-Critical Removal Action (NTCRA) 2 capture zone and the severed plume where oxygen may be replenished to the plume via infiltration of oxygenated precipitation.

2.1.2.4 Aerobic Cometabolism (Co-oxidation)

A wide variety of organic compounds can be fortuitously oxidized to CO_2 and water (and chloride for chlorinated constituents) by non-specific microbial oxygenase enzymes produced by a variety of aerobic microorganisms. These enzymes are produced to metabolize specific compounds (e.g., methane, propane, toluene, phenol, ammonia and ethene) termed cometabolites that serve as the primary substrate (electron donor) for these microorganisms. Various other organic compounds (e.g., chlorinated ethenes, ethanes, and methanes) can fortuitously react with these enzymes, producing unstable intermediates (e.g., epoxides) that spontaneously decompose to CO_2, water, and chloride.

The microorganisms that produce the oxygenase enzymes and mediate the cometabolic biodegradation reactions rarely derive benefit from degradation of these organic constituents. In fact, the epoxide intermediates produced by some solvents can adversely impact cellular intermediates. In subsurface environments, the active zone where cometabolic biodegradation reactions occur tends to be located at the fringes of the plumes where reduction-oxidation (redox) conditions transition from anaerobic to aerobic. For cometabolic reactions to occur, the primary substrate (referred to as the cometabolite), O_2, and the target organic chemical must be present in relatively balanced proportions. In groundwater environments, a variety of cometabolites (e.g., methane, ammonia and ethene) can be produced through the metabolic activities of indigenous microorganisms within anaerobic redox zones (e.g., source areas). At some sites, the cometabolite is present in the groundwater as a result of co-release (e.g., for toluene, phenol). At these sites, cometabolic biodegradation of organic constituents can occur naturally where the correct ratios of cometabolite, oxygen, and COC exist.

Methanotrophic and aromatic/alkane oxidizing bacteria are widely distributed in the environment. These bacteria produce the various oxygenase enzymes responsible for co-metabolic reactions. Methanotrophic, aromatic, and alkane oxidizers use methane, BTEX (benzene, toluene, ethylbenzene and xylenes), or natural gases and alkanes (propane/propene and n-alkanes up to C16), respectively, as a source of carbon and energy and are oxidized to CO_2 or incorporated into biomass. Because these oxidizers are capable of cometabolic oxidation of chlorinated compounds such as TCE and other persistent chemicals, they have a particular potential for natural attenuation and bioremediation.

Site-specific COCs that are known to be degraded via aerobic cometabolism include most chlorinated ethenes, ethanes, and methanes (Figures L-4 through L-7), 1,4-dioxane, naphthalene, and tetrahydrofuran (Table L-1). Similar to aerobic oxidation, aerobic cometabolism of Site-specific COCs may be occurring within shallow overburden groundwater in the NTCRA 2 capture zone and the severed plume where oxygen may be replenished to the plume via infiltration of oxygenated precipitation.

2.1.2.5 Anaerobic Oxidation

The anaerobic oxidation of organic compounds results from the transfer of electrons from an organic compound (the electron donor or primary substrate) to an electron acceptor. Under anaerobic conditions, an inorganic compound that contains oxygen acts as the electron acceptor and becomes reduced as the primary substrate (e.g., COC) is oxidized. The oxidation of the primary substrate results in its mineralization to harmless by-products (i.e., CO_2 and water). The oxygen atom can be provided from various sources such as water (H_2O), ferrous hydroxides ($Fe(OH)_3$), manganese oxides, sulfate, and even carbonates. Anaerobic oxidation results in a large amount of electron acceptor being reduced. The reduced electron acceptor (e.g., nitrite (NO_2^-), sulfide, and methane) is often excreted from the cells, resulting in geochemical changes in the environment. These gross geochemical changes can be used as indicators of biological activity in assessing the nature, rate, and extent of biodegradation.

The key bacteria involved in anaerobic oxidation are the denitrifying, sulfate, and iron reducing bacteria, which are widely distributed in the natural environment. Denitrifying, sulfate, and iron bacteria use nitrate (NO_3^-), sulfate (SO_4^{2-}), and oxidized iron and manganese as their electron acceptors, and subsequently reduce them to nitrogen gas (N_2) or ammonia (NH_4^+), hydrogen sulfide (H_2S), and dissolved (ferrous) iron, respectively.

Site-specific COCs that are known to be degraded via anaerobic oxidation include select chlorinated compounds (e.g., cis-1,2-dichloroethene [cDCE], vinyl chloride [VC], carbon tetrachloride and DCM) (Figures L-4 and L-7), ketones, and most aromatic compounds with the exception of 1,4-dioxane (Table L-1). Given the presence of high concentrations of VC and CO_2, and decreased concentrations of electron acceptors (e.g., sulfate) and/or increased concentrations of reduced species (e.g., ferric iron, sulfide, and methane) relative to background concentrations, anaerobic oxidation of cDCE, and VC likely is occurring.

2.1.2.6 Reductive Dechlorination

Reductive dechlorination involves the sequential replacement of chlorine atoms on the organic molecule by hydrogen atoms. The reaction occurs primarily under anaerobic and reducing redox conditions that typically favor methanogenesis, although reductive dechlorination has been observed in bulk aerobic aquifers where it occurs within anaerobic micro-habitats. The chlorinated volatile organic compounds (CVOCs) serve as electron acceptors for the halorespiring bacteria that carry out these degradation reactions; simple organic carbon compounds (e.g., alcohols, fatty acids, sugars, petroleum hydrocarbons, and natural organic carbon substances such as humic/fulvic acids) can serve as electron donors. Reductive dechlorination is one of the most common mechanisms for biodegradation of most highly chlorinated compounds such as PCE, TCE, 1,1,1-TCA, and CT.

Although reductive dechlorination is caused by halorespiring bacteria, these bacteria appear to be present in environments that are associated with methanogenesis. In these environments, various anaerobic bacteria interact to completely decompose organic compounds to methane, and in the process produce hydrogen as an intermediate. Hydrogen is used by the halorespiring bacteria to reduce CVOCs. There is some indication that halorespiring bacteria also derive other trace nutrients from bacteria that are active in methanogenic environments, such as the acetogenic bacteria that produce acetate.

Site-specific COCs that are known to be degraded via reductive dechlorination include all chlorinated ethenes, ethanes, and methanes (Table L-1 and Figures L-4 through L-7). Based on detected concentrations of cDCE, VC, 1,1-DCA, 1,2-DCA, CA, ethane, ethane, and chloride, reductive dechlorination is a major degradation mechanism for chlorinated ethane and ethanes in Site groundwater.

2.2 Summary of Historic MNA Evaluations

This section describes the history of MNA evaluations for the Site with particular emphasis on the methods, results, and conclusions of these previous MNA evaluations that lead to the selection of MNA as a component of the Site remedy in the ROD (USEPA 2005). The following discussions build upon information provided in the RI (BBL 1998) and FS (BBL and USEPA 2005; Geosyntec 2005a and 2005b *in* BBL and USEPA 2005) and references provided therein.

2.2.1 Technical MNA Evaluation in the RI

During sampling activities performed as part of the RI activities completed in 1996, BBL measured biologic and geochemical parameters of groundwater at several wells located along the general groundwater flow path from upgradient of the Operations Area, eastward through the Overburden NAPL Area and NTCRA 1 containment area, and southward into the Town Well Field Property (Figures L-2 and L-3). These data were evaluated to determine the effects of biodegradation in reducing VOC concentrations within the affected groundwater area. An evaluation of natural attenuation processes, indicator parameters, and products was performed and presented in detail in the RI Report (BBL 1998). A summary is provided below.

The results of the RI MNA evaluation indicated that natural attenuation processes were robust within the Site-related groundwater plume, and particularly in and immediately downgradient of the NAPL zones. Groundwater analytical data obtained at the Site indicated that dissolved VOCs were being degraded to CO_2 and methane (CH_4) due to the presence of naturally occurring, biologically mediated redox reactions, and that dissolved chlorinated VOCs were being dechlorinated in situ due to the anaerobic conditions resulting from biodegradation of aromatic VOCs (e.g., toluene, ethylbenzene, and xylenes). The data showed that dissolved chlorinated solvent compounds, such as PCE, TCE, and TCA, were undergoing complete dechlorination with byproducts consisting of ethene, ethane, and chloride. It was likely that, in addition to dechlorination, the more highly chlorinated VOCs were also cometabolically degraded during biodegradation of the ketones, alcohols, semi-volatile organic compounds (SVOCs), and aromatic VOCs. Furthermore, lesser chlorinated VOCs, such as dichloroethene (DCE) (combined 1,1-DCE and 1,2-DCE isomers) and vinyl chloride, were also likely being cometabolically degraded.

The available data at the time of the RI also demonstrated that robust degradation processes were occurring within the NAPL zone, as supported by biologic data described below. This is important because the rate of biologically-assisted NAPL dissolution has been found to be 3- to 6.5-times higher than the rate of abiotic dissolution (Carr *et al.* 2000; Yang and McCarty 2000). Thus, robust degradation within the NAPL zone can decrease the overall remediation timeframe.

Geochemical conditions of groundwater were evaluated to determine which geochemical processes were occurring in groundwater at the Site (BBL 1998). Upgradient groundwater in overburden and bedrock deposits contain a relatively high concentration of dissolved oxygen, an abundance of alternate electron acceptors, a minor amount of naturally occurring organic carbon, and sufficient nutrients and environmental conditions for a variety of oxidation/reduction processes to occur in situ. Groundwater geochemistry at the Site changes within the NAPL zone and dissolved VOC plume, as observed with depleted DO concentrations (anoxic conditions), negative oxidation-reduction potential (ORP) readings, and the presence of dissolved methane, indicating anaerobic bacteria have been stimulated due to the introduction of VOCs into the groundwater system. Specific redox reactions occurring in groundwater at the Site were inferred based on the presence and distribution of electron acceptors and metabolic byproducts in groundwater near and downgradient of the NAPL zone and within the dissolved COC plume. Inferred redox reactions included nitrate reduction, iron and manganese reduction, sulfate reduction, and methanogenesis. These reducing conditions are conducive for the reductive dechlorination of chlorinated ethenes and ethanes.

The presence, type, and status of indigenous subsurface microorganisms in Site groundwater were evaluated by analyzing groundwater samples from 16 overburden and bedrock monitoring wells for phospholipid fatty acids (PLFA). Wells selected for the PLFA analyses were situated along an apparent groundwater flow path originating within the Operations Area upgradient of the probable NAPL zone, and extending across the former Cianci property and through the Town Well Field Property. Phospholipids are part of intact cell membranes and, therefore, identification and quantification of PLFA in groundwater samples provides information related to biomass, community structure, and metabolic status of indigenous microbial populations.

The maximum biomass concentrations in overburden and bedrock groundwater were detected at locations situated within the overburden and bedrock NAPL zones. A spatial correlation was observed between the location of maximum biomass and the maximum groundwater VOC concentrations that strongly suggested the population of groundwater microorganisms in overburden and bedrock had grown in response to inputs of anthropogenic organic carbon associated with operations at the Site. This correlation was supported by the nature of the microbial community structure, availability of nutrients in groundwater, and the presence of VOC and metabolic byproducts, as described in more detail in the RI (BBL 1998).

In summary, the RI concluded that there was strong evidence for natural attenuation of chlorinated VOCs in groundwater at the Site due to in situ biodegradation processes.

2.2.2 Technical MNA Evaluation in the FS

In June 2003, 31 monitoring wells at the Site were sampled for a range of bioremediation assessment parameters (e.g., dissolved hydrocarbon gases, volatile fatty acids, anions, dissolved metals, alkalinity and other key natural attenuation parameters). Using these data, an MNA evaluation was performed for groundwater inside the NTCRA 1 containment area and NTCRA 2 capture zone, including the NAPL zones. This work also evaluated the feasibility of using enhanced in situ bioremediation (EISB) as a process option for treating overburden and bedrock groundwater in the NAPL zones at the Site. Results and conclusions of this evaluation are summarized as follows:

- The portion of the plume downgradient of the NTCRA 2 capture zone has already attenuated to COC concentrations that are less than drinking water standards.

- Geochemical and biological conditions in Site groundwater are appropriate to support anaerobic degradation of COCs within the NTCRA 1 containment area and NTCRA 2 capture zone.

    - Field parameter data indicate that anaerobic conditions, as indicated by low dissolved oxygen readings and negative oxidation-reduction potential measurements, which are required for reductive dechlorination, have been established in the NTCRA 1 containment area and NTCRA 2 capture zone.

    - There are a number of electron donors present in groundwater at the Site including: alcohols (e.g., isopropanol); toluene, ethylbenzene, and xylenes (TEX); and ketones (e.g., 4-methyl-2-pentanone [MIBK], acetone) that support reductive dechlorination of chlorinated VOCs.

  - As described in more detail below, geochemical conditions indicate presence of nitrate reducing, iron and manganese reducing, and sulfate reducing conditions. Methane concentrations increase downgradient of the containment system, suggesting methanogenesis is occurring outside of the dense non-aqueous phase liquid (DNAPL) area. Biological degradation processes, such as reductive dechlorination, may be enhanced under methanogenic conditions.

  - Screening for dehalococcoides microorganisms (DHC) and DHC-like organisms using polymerase chain reaction (PCR) was conducted to assess the presence and relative abundance of these organisms at the Site. This species has been documented to facilitate the reductive dechlorination of PCE and TCE (Hendrickson et al. 2002). The DHC PCR results indicate that there is abundant DHC present in the groundwater sampled from the NTCRA 1 containment area.

- MNA is effective at decreasing mass and concentration of COCs in groundwater.

  - Reductive dechlorination is a prominent removal mechanism in operation at the Site as evidenced by the production of cDCE, VC, ethene, and chloride, which are dechlorination products of PCE and TCE. The data also indicated that any continued dissolution of PCE and TCE from NAPL was being rapidly degraded through reductive dechlorination to cDCE, VC, and ethene within the NTCRA 1 containment area. Although the NTCRA 1 system maintains hydraulic control of COC-impacted groundwater, reductive dechlorination reactions would continue to result in complete destruction of chlorinated ethenes, ethanes, and methanes whether or not the system was present.

  - Anaerobic oxidation reactions remove cDCE, VC, and ethene by oxidation to CO_2. The groundwater samples contained more chloride than would be expected from chlorinated VOC data used to estimate the extent of reductive dechlorination of the parent compounds, supporting the hypothesis that anaerobic oxidation processes are active in the NTCRA 1 containment area.

- In situ biodegradation processes are removing approximately 30- to 72-times more TCE mass equivalent compared with dissolved phase extraction within the NTCRA 1 containment area.

    - Mass removal via dissolution of COCs from NAPL with subsequent extraction from the NTCRA 1 containment system resulted in a cumulative mass removal of 12,128 pounds (lbs) (5,512 kg) of total VOCs during the period from July 26, 1995 to February 28, 2005, an average total VOC mass removal rate of approximately 580 kg/year. This mass represents the total mass flux of dissolved phase COCs that would have migrated from NTCRA 1 had it not been captured and treated. However, given the robust biodegradation that is occurring in groundwater throughout the Site, it is likely that complete attenuation of these VOCs would have occurred at some point along the groundwater flow path.

    - COC mass destruction was estimated based on groundwater chloride concentrations and the relationship that each dechlorination step of TCE releases one mole of chloride. Using this relation, the total amount of TCE equivalents was estimated using the NTCRA 1 monitoring and recovery well chemistry data. Using this approach, the total amount of TCE and degradation products being biodegraded in situ ranges from approximately 61,800 to 149,300 kg over eight years. In contrast, the amount of dissolved phase TCE and its degradation products extracted via groundwater pumping within NTCRA 1 is approximately 2,100 kg over the same time period.

    - Biological processes are enhancing mass transfer from the DNAPL surface. Degradation of COCs decreases their concentrations in the dissolved phase which increases the concentration gradient, and thus mass transfer, between groundwater and the NAPL.

2.2.3 Geochemical Evaluation

Concentrations and distributions of electron acceptors, electron donors, and byproducts of microbially mediated reactions were evaluated to establish the types of geochemical and biodegradation processes active in Site groundwater. Groundwater geochemical data collected during the June 2003 interim monitoring and sampling (IMS) event are provided in Table L-2 and are summarized below.

Oxygen is present in upgradient groundwater and ORP readings are positive. Within the NTCRA 1 containment area and the NTCRA 2 capture zone, DO in groundwater is depleted relative to background concentrations and negative ORP readings are prevalent. These results are consistent with an anoxic and reducing groundwater environment that is conducive to supporting reductive dechlorination of CVOCs and other anaerobic degradation processes.

Background concentrations of nitrate in groundwater were below the reporting limit of 0.5 milligrams per liter (mg/L) and 6.3 mg/L for overburden and bedrock groundwater, respectively (Table L-2). Concentrations of nitrate in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone were generally below the detection limit. The lack of nitrate in groundwater across the Site indicates that nitrate has been preferentially consumed as an electron acceptor for microbial respiration, and that groundwater conditions are anaerobic and at least mildly reducing. Given the generally limited presence of nitrate in Site groundwater, nitrate reduction processes are not expected to contribute significantly to COC degradation.

Dissolved manganese concentrations are generally elevated above background concentrations in Site groundwater, indicating that manganese reduction processes are occurring (Table L-2). Elevated detection limits for ferrous iron hampered the interpretation of data to support the presence of iron reducing conditions in Site groundwater above background levels. As shown in the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP) (Attachments B and C, respectively, to the RD POP), detection limits for future analysis of groundwater concentrations of iron will be sufficiently low to facilitate interpretation of iron reduction processes in Site groundwater.

Concentrations of sulfate in upgradient groundwater were 13 mg/L and 210 mg/L for overburden and bedrock groundwater, respectively (Table L-2). Sulfate concentrations in overburden and bedrock groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone were generally less than the respective background concentrations, indicating that sulfate reduction is occurring in overburden groundwater (Table L-2). Detections of sulfide in most groundwater samples support the interpretation of the occurrence of sulfate reduction in Site groundwater. Reduction of sulfate indicates a strongly reducing groundwater environment, favorable for reductive dechlorination processes.

Bedrock groundwater sulfate concentrations were elevated above overburden groundwater sulfate concentration, indicating a source of sulfate within the arkose bedrock. This bedrock sulfate source likely is gypsum that would be contained in evaporite deposits present in arkose bedrock. Since the overburden material is ultimately derived from the local bedrock, overburden material is likely to contain some gypsum. This gypsum may provide an additional source of sulfate to support additional sulfate reduction in overburden groundwater contained within the NTCRA 1 containment area and the NTCRA 2 capture zone.

Concentrations of methane in upgradient groundwater were 0.19 micrograms per liter (ug/L) and 0.24 ug/L for overburden and bedrock groundwater, respectively (Table L-2). Methane concentrations in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone were substantially higher than background. For example, methane concentrations greater than 10,000 ug/L were measured at CPZ-6, CPZ-6A, MW-07, MW-502, and MW-121B. Elevated concentrations of methane in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone indicate that groundwater conditions are highly reducing and methanogenic. These strongly reducing conditions are especially favorable for complete reductive dechlorination of chlorinated ethenes, ethanes, and methanes. In addition, methane is a degradation product of reductive dechlorination of chlorinated methanes and likely indicates that complete destruction of these compounds is occurring in Site groundwater.

As described in Section 2.1.2 and shown on Figures L-4 through L-7, CO_2 is a final degradation product from the destruction of many of the organic compounds present in Site groundwater. Addition of CO_2 to groundwater via degradation of organic compounds results in increased alkalinity due to the transformation of CO_2 to bicarbonate (HCO_3^-). As shown in Table L-2 and on Figures L-8 and L-9, alkalinity increases in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone relative to background concentrations. Elevated alkalinity in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone, indicate that complete destruction of COCs is occurring in Site groundwater.

Chloride ions enter solution during biodegradation of CVOCs; therefore, chloride concentrations in groundwater are expected to increase above background concentrations in areas where biodegradation of CVOCs is occurring. As shown in Table L-2 and on Figures L-8 and L-9, concentrations of chloride in groundwater increase within the NTCRA 1 containment area and NTCRA 2 capture zone relative to background concentrations. The elevated concentrations of chloride in groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone, indicate that reductive dechlorination of CVOCs is occurring in Site groundwater. As described in Section 2.2.2, concentrations of chloride in groundwater within the NTCRA 1 containment area were used to estimate destruction of an equivalent mass of TCE. This estimate only considers chlorinated solvent destruction and does not include degradation of other non-chlorinated VOCs. Using this approach, the total amount of TCE and degradation products being biodegraded in situ ranges from approximately 7,700 to 18,700 kg/year.

Ethene and ethane are degradation products of the reductive dechlorination of chlorinated ethenes and ethanes. Concentrations of ethene and ethane in groundwater are expected to increase above background concentrations in areas where biodegradation of chlorinated ethenes and ethanes is occurring. The ethene and ethane concentrations measured in groundwater at upgradient wells were 24 nanograms per liter (ng/L) and less than the reporting limit of 5 ng/L for overburden and bedrock groundwater, respectively (Table L-2). As shown on Figures L-10 and L-11, concentrations of ethene and ethane in groundwater the NTCRA 1 containment area and NTCRA 2 capture zone were substantially elevated above background concentrations in both overburden and bedrock groundwater. These results indicate that substantial reductive dechlorination and complete destruction of CVOCs is occurring in Site groundwater.

Concentrations of TOC measured in Site overburden and bedrock groundwater were generally greater elevated above background concentrations and were generally greater than 20 mg/L (Table L-2). Concentrations of TOC in excess of 20 mg/L are desirable in facilitating biological dechlorination reactions (Wiedemeier et al. 1999). These results indicate that sufficient carbon is available in Site groundwater to support biological degradation processes.

Overall, the observed trends in groundwater geochemistry along an inferred groundwater flow path, from upgradient of the Operations Area and through the NTCRA 1 containment and NTCRA 2 hydraulic control areas, indicate that groundwater geochemical conditions at the Site are conducive to supporting degradation of Site COCs. Concentrations of chloride, ethane, ethane, and methane, and increases in alkalinity indicate that complete destruction of chlorinated ethenes, ethanes, and methanes in Site groundwater is occurring.

2.3 Update of MNA Evaluations and Site Data

Data collected during IMS events indicate an overall decline in groundwater concentrations, supporting the selection of MNA as a remedial measure for COCs in groundwater at the Site. This section builds upon results of the previous MNA evaluations discussed in Section 6, incorporating data that have been collected since completion of the FS MNA evaluation. Included in this section are current concentration trends for total VOCs in groundwater at select monitoring locations, an estimate of bulk attenuation rates for total VOCs in groundwater, comparison of COC concentrations to regulatory limits, and presentation of NTCRA 1 and NTCRA 2 COC mass flux with time.

2.3.1 Trend Analysis

The final IMS Report (BBL 2005) compared groundwater VOC concentrations reported in the RI with concentrations measured at 25 IMS locations during the April 2005 (final) IMS event. IMS sampling locations were located within the NTCRA 2 capture zone and the severed plume portions of the Site. At 18 monitoring locations, the April 2005 samples had lower total VOC concentrations than total VOC concentrations measured at the same locations during the RI. Trend analyses were conducted using total VOC concentration data from the RI and IMS monitoring events for the 25 IMS monitoring locations to determine whether the observed decreases in total VOC concentrations were statistically significant. The combined RI and IMS monitoring data provided sufficient data for a statistically robust interpretation of concentrations trends with time.

Total VOC concentrations were plotted versus time for the five different groundwater depth intervals and are shown on Figures L-12 through L-16 for shallow overburden, middle overburden, deep overburden, shallow bedrock, and deep bedrock, respectively. Sample points with no detected VOCs were set to a value of 0.1 ug/L. As shown, total VOC concentrations are generally declining or stable for all wells at all depth intervals.

To evaluate the statistical significance of the observed decreasing concentration trends, trend analyses were conducted using Mann-Kendall (non-parametric) and linear regression (parametric) trend analyses. Trend analyses were conducted for all sampling locations that had detected total VOC concentrations for more than 50% of the sampling events.

The Mann-Kendall trend test evaluates trends based on ranked data, rather than actual concentrations. Mann-Kendall trend tests were conducted to evaluate total VOC concentration trends without the potential confounding effects of large variations in total VOC concentrations with time at a given location. Linear regression analyses were conducted using natural-log-normalized concentration data to estimate trend direction and total VOC concentration bulk attenuation rates (Weidemeier et al. 1999).

For both trend tests, the confidence level is reported at a 90% confidence interval with a corresponding p-value less than or equal to 0.10. Mann-Kendall and linear trend results with p-values greater than 0.10 are not considered to be significant. The trend direction was defined as decreasing if total VOC concentrations decreased with time, and increasing if total VOC concentrations increased with time; however, the trend was not considered significant unless the relationship for the test was significant at the 0.10 (90%) level. For the linear regression analysis, the correlation coefficient, or R^2, is a measure of how well the linear regression fits the data. Values close to 1.0 are considered to be a good fit, while R^2 values close to 0 are considered to be a poor fit. Concentrations were considered to be stable with time if the trend result was not significant.

2.3.1.1 Trend Analyses Results

Results of both the linear regression analysis and the Mann-Kendall trend analysis indicate that 18 monitoring locations had statistically significant decreasing concentration trends and three monitoring locations had no trend (Table L-3). For the three monitoring locations with no trend, two monitoring locations (MW-127B and CW-4-75) had generally low concentrations of VOCs, while monitoring location MW-706DR had elevated concentrations that potentially indicate the presence of DNAPL in the vicinity of this deep bedrock monitoring location. No monitoring locations had increasing concentration trends (Table L-3). Four monitoring locations had insufficient numbers of detected VOCs to run trend analyses. Results for the different groundwater depth intervals are provided in more detail in the following bullets.

- Three shallow overburden monitoring locations (MWL-312, P-13, and P-101C) were evaluated for trends (Table L-3 and Figure L-12).

Concentrations of VOCs were below reporting limits at monitoring location MWL-312 for 13 of 16 monitoring events, therefore, no trend analyses were run for this location. Monitoring locations P-13 and P-101C had decreasing concentrations of total VOCs.

- Six middle overburden monitoring locations (CW-B-77, MW-03, MW-127B, MW-205B, MW-501B, and P-101B) were evaluated for trends (Table L-3 and Figure L-13). With the exception of monitoring location MW-127B, all monitoring locations had decreasing concentrations of total VOCs. Monitoring location MW-127B had no trend in total VOC concentrations; however, VOC concentrations at this location are quite low.

- Six deep overburden monitoring locations (CW-4-75, MW-04, MW-204B, MW-502, MW-704D, and MW-707D) were evaluated for trends (Table L-3 and Figure L-14). Concentrations of VOCs were below reporting limits at monitoring location MW-707D for nine of 15 monitoring events; therefore, no trend analyses were run for this location. With the exception of monitoring location CW-4-75, all other monitoring locations had decreasing concentrations of total VOCs. Monitoring location CW-4-75 had no trend in total VOC concentrations; VOC concentrations at this location are generally low and no VOCs were detected during the last two monitoring events.

- Six shallow bedrock monitoring locations (MW-127C, MW-128, MW-204A, MW-205A, MW-501A, and P-11A) were evaluated for trends (Table L-3 and Figure L-15). All six shallow bedrock monitoring locations had decreasing concentrations of total VOCs.

- Four deep bedrock monitoring locations (MW-703 DR, MW-704DR, MW-706DR, and MW-707DR) were evaluated for trend analyses (Table L-3 and Figure L-16). Due to limited numbers of detected VOC concentrations, trend analyses were not run for MW-703DR and MW-707DR. Monitoring location MW-704DR had decreasing concentrations of total VOCs. Monitoring location MW-706DR had no trend in total VOC concentrations. Concentrations of VOCs in groundwater at MW-706DR are sufficiently high to suggest the potential presence of NAPL in the vicinity of this sampling location.

2.3.1.2 Trend Analyses Summary

Both the linear regression and the Mann-Kendall trend analyses indicate that VOC concentrations are, with few exceptions, decreasing within the NTCRA 2 capture zone and severed plume portions of the Site at groundwater monitoring locations monitored during the IMS program (BBL 2005). These results indicate that concentrations of COCs in groundwater at the Site are attenuating. However, as noted in Section 3, additional data must be collected to demonstrate the on-going effectiveness of MNA.

2.3.2 Bulk Attenuation Rate

Results from the linear regression analyses were used to estimate bulk attenuation rates for total VOCs in groundwater at the Site. Calculation of bulk attenuation rates was performed in accordance with a USEPA guidance document on determining first-order attenuation rate constants for MNA studies (USEPA 1998). Following this guidance, the natural log of COC groundwater concentration versus time was used and a best-fit regression line was generated for total VOC concentrations for each monitoring location that had a statistically significant decreasing total VOC concentration trend. The slope of the regression line provides an estimate of the total VOC bulk attenuation rate constant (k_{point}) in groundwater at the respective monitoring locations.

$$k_{point} = [\text{slope of best-fit regression line}]$$

The natural groundwater remediation total VOC half-life ($t_{1/2}$) was estimated from the equation:

$$t_{1/2} = 0.693 / k_{point}$$

> where: 0.693 is the negative of the natural log of 0.5 (half of the starting total VOC concentration).

The estimated half-life for attenuation of total VOCs at the Interim Monitoring and Sampling locations ranged from 2.9 to 9.1 years with an average half-life of 4.6 years (Table L-3). These estimated half-life values for total VOC concentrations compare well with literature values of attenuation rates presented for individual compounds in Appendix H of the FS (BBL and USEPA 2005) and indicate that COC concentrations in groundwater are attenuating within the Hydraulic Containment and Treatment System (HCTS) capture zone and severed plume portions of the Site.

2.3.3 Estimate of COC Mass Flux in Groundwater

As part of the compliance monitoring program, COC mass extraction rates and cumulative mass removal are monitored for the NTCRA 1 containment system and NTCRA 2 groundwater capture system. With the exception of the severed plume and limited discharge to surface water, the HCTS captures the entire dissolved phase groundwater COC plume at the Site. Therefore, the HCTS COC mass extraction rates and cumulative mass extraction data represent the total mass flux for the dissolved phase COC groundwater plume and can be used to monitor changes in groundwater total dissolved-phase COC mass flux with time.

Total VOC mass extraction rates and cumulative mass extraction for the NTCRA 1 containment systems and NTCRA 2 groundwater capture system were plotted for the July 1995 through December 2008 time period are Figure L-17. Mass extraction rates are expressed in units of pounds mass per day and the cumulative mass extraction is expressed in units of pounds. Mass extraction rates range between about 0.1 to 10 pounds per day and appear to be generally declining with time. The observed slight flattening of the cumulative mass extraction curve supports an interpretation of declining mass extraction rates. These results are consistent with results from the trend analyses that indicated generally declining groundwater VOC concentrations with time. These data will continue to be collected as part of the HCTS compliance monitoring program and will be periodically evaluated as part of the MNA performance monitoring program.

2.3.4 Summary

This section presented an update to the evaluation of the effectiveness of MNA as a remedial measure for COCs in groundwater in the Site and included evaluations of current concentration trends for total VOCs in groundwater at select monitoring locations, estimates of bulk attenuation rates for total VOCs in groundwater, and presentation of NTCRA 1 and NTCRA 2 COC mass flux with time. Results of these evaluations indicated:

- Groundwater VOC concentrations are generally declining with time throughout the NTCRA 2 capture zone and the severed plume.

- Estimated bulk VOC attenuation rates were comparable to attenuation rates for individual COCs presented in the FS (BBL and USEPA 2005).

- Compliance monitoring data from the NTCRA 1 and NTCRA 2 containment systems are useful for evaluating changes in plume COC mass flux with time.

These results favorably support the use of MNA as a remedy for COCs in Site groundwater.

2.4 Summary of Current Understanding of Site Conceptual Model

The MNA conceptual model for the Site may be described in terms of source condition, dissolved plume stability, and MNA processes, and for the Site is summarized as follows:

<u>Source Condition</u>: The source of impacts was thoroughly characterized during RI and FS activities, and consists of delineated zones of NAPL in overburden soils and bedrock. The NAPL is a complex mixture of chlorinated solvents. The NAPL zones in overburden soils and bedrock contain mixtures of dissolved NAPL-related chlorinated ethenes, ethanes, and methanes, as well as aromatic hydrocarbons, ketones, phthalates, ethers, and alcohols. These NAPL zones are currently being hydraulically contained by a physical barrier (vertical cutoff wall) and pump-and-treat systems. The NAPL zones have formed a dissolved phase chemical plume that has been severed by the hydraulic containment system. The Overburden NAPL zone contains the majority of the Site VOCs, and will be treated with in-situ thermal remediation to remove the vast majority of those VOCs, resulting in a greatly diminished source zone upgradient of the NTCRA 1 sheet-pile wall. Upon entry of the CD, the NTCRA systems became known as the "Hydraulic Containment and Treatment System (HCTS)."

<u>Dissolved Plume Stability</u>: The dissolved chemical plumes in overburden and bedrock groundwater within the source area are stable and likely shrinking in time due to the combination of hydraulic containment and active in situ biodegradation processes in groundwater within the capture zone of the pump-and-treat system. In situ biodegradation processes within the capture zone of the NTCRA 1 and NTCRA 2 systems (now the HCTS) were correctly characterized as "robust" in the FS (BBL and USEPA 2005). The dissolved chemical plumes in overburden and bedrock groundwater in the severed

portion of the plume beyond the capture zone of the pump-and-treat system are shrinking with time, also due to the combination of hydraulic containment and natural attenuation processes. Evaluations of trends in total dissolved-phase VOC concentrations in groundwater within the NTCRA 2 capture zone and the severed plume indicated statistically significantly decreasing concentration trends.

<u>NA Processes</u>: NA processes active within the dissolved chemical plumes in overburden and bedrock groundwater that have contributed to plume stabilization and shrinkage include in situ abiotic and biodegradation reactions, sorption to aquifer sediments, dispersion due to flow path mixing, and matrix diffusion. Reductive dechlorination is a prominent removal mechanism that continues to operate at the Site as evidenced by the production of cDCE, VC, DCA, VC, ethene, ethane, and chloride, which are dechlorination products of PCE and TCE. There are also anaerobic oxidation reactions occurring that remove cDCE, VC, and ethene by oxidation to CO_2.

3. Selection of MNA Remedy

This section summarizes the evaluation and decision-making process that led to the selection of MNA as a remedy for COCs in Site groundwater. In addition, this section identifies data gaps and presents performance objectives and standards. Site background information, including history, setting, source mass and distribution, COC transformation processes, and previous and updated MNA evaluations, with particular emphasis on the MNA SCM and conclusions of previous MNA evaluations that led to the selection of the MNA remedy, are provided in Section 2.

3.1 Selection of MNA Remedy

Based on the demonstrated efficacy of NA for treating COCs in Site groundwater, MNA was included as a component of several remedial alternatives evaluated in the FS (BBL and USEPA 2005). Based on evaluations presented in the FS, the USEPA selected MNA as a component of the remedial approach for the Site.

The ROD for the Site was issued by the USEPA in September 2005. The selected remedy consists of MNA of the groundwater plume, including:

- groundwater outside the capture zone of the HCTS until groundwater cleanup levels are achieved
- groundwater within the capture zone of the HCTS until groundwater cleanup levels are achieved
- groundwater in the NAPL area of the overburden and bedrock aquifers, until groundwater cleanup levels are achieved

The ROD provides the following description of the MNA remedy component:

> *"The goal of this remedial action is to restore groundwater throughout the Site to its natural quality. Aquifer restoration of the entire plume is expected to take longer than 225 years which is the estimated time frame for the entire plume to meet federal drinking water standards and risk based levels. Restoration of groundwater to natural quality will be achieved by reliance on naturally-occurring biological, physical and chemical*

> *attenuation processes in the subsurface and groundwater (which is expected to be enhanced by all of the other components of the remedial action, including in-situ thermal treatment of the Overburden NAPL Area). These naturally-occurring processes are collectively referred to as "natural attenuation". Monitoring the result of these processes throughout the plume(s) is an integral part of this remedial technology, known as monitored natural attenuation (MNA).*
>
> *Monitoring will be used to:*
>
> > *Delineate the plume(s) in three dimensions;*
> >
> > *Evaluate the effectiveness of institutional controls (e.g., evaluate whether any activities at or near the Site are adversely affecting the plume);*
> >
> > *Assess temporal and special [sic] variations in plume chemistry and geometry; and*
> >
> > *Assess progress in meeting the long-term remedial objective(s)."*

Based on previous evaluations of the efficacy of MNA for remediation of COCs in Site groundwater, and evaluation of MNA against other remedial during the FS, MNA was selected as a remedy component for the long-term treatment of COCs in Site groundwater.

3.2 Identified Data Gaps

The SOW identifies two data gaps associated with implementing the MNA remedy component at the Site. The identified data gaps and the strategy to address them are as follows:

- *Incomplete plume delineation in the* severed *plume.* This data gap is being addressed by installing and sampling additional groundwater monitoring wells near the eastern edge of the severed plume, east of the Quinnipiac River and in the CL&P Easement. Locations of proposed plume delineation monitoring wells are presented in detail in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). Well installation, development and sampling procedures are described in the Sampling and Analysis Plan (SAP) (Attachments B and C to the RD POP).

- *Long-term monitoring data demonstrating the effectiveness of MNA as a remedy component.* This data gap is being addressed through the preparation, submittal and eventual approval of this MNA Plan, which will trigger additional data collection in support of MNA.

3.3 Objectives of MNA Performance Monitoring

This MNA Plan, in conjunction with the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP), describes the monitoring and analysis steps required to meet the following objectives of MNA performance monitoring:

- Complete the delineation of COCs in groundwater in three dimensions

- Assess temporal and spatial variations in groundwater chemistry and geochemistry

- Assess progress in meeting the long-term remedial goal of groundwater restoration throughout the Site to its natural quality

- Evaluate the effectiveness of institutional controls

In accordance with the SOW, this MNA Plan includes the following components:

- Detailed description of how field data will be interpreted and presented in subsequent annual monitoring reports including, but not limited to, statistical methods, iso-concentration contour plots and groundwater potentiometric surface maps

- Well maintenance program, which contain provisions for inspection, continued maintenance, repair and prompt and proper abandonment, if necessary

- Evaluation of contingency measures if progress in meeting long-term groundwater restoration goals is inadequate, as determined by the USEPA

Based on the results of MNA performance monitoring, decisions related to the MNA program may include:

- Continuation of the performance monitoring program without change.

- Continuation of the performance monitoring program with action. Recommendations for action may include changes in monitoring locations, frequencies, methods and analyses, with a rationale for changes. Recommended actions may also include remedy modifications, implementation of contingency or alternative remedies, advancement to verification monitoring, or termination of performance monitoring based on achievement of Site remedial goals.

- Modification of the institutional controls. Any observed or pending changes in land or resource uses or ownership (e.g., property ownership change, housing developments, and well installations) will be evaluated in view of their current and possible future impact on the effectiveness of the controls and the performance monitoring operations.

3.4 Performance Standards

The Remedial Action will be implemented in compliance with applicable or relevant and appropriate requirements (ARARs) identified in the ROD. These requirements include compliance with Performance Standards for the contaminated groundwater, soil and wetland soil, and for NAPL that is present in the subsurface in the overburden and bedrock aquifers. The following subsections discuss Performance Standards applicable to MNA, and the means for demonstrating compliance with these standards.

3.4.1 MNA-Related Performance Standards

Performance Standards pertaining to MNA at the Site, as set forth in the SOW, are described in the following paragraphs.

Groundwater

Interim cleanup levels for groundwater are specified by the USEPA in Table L-1 of the ROD. While the interim cleanup levels in Table L-1 of the ROD are consistent with ARARs, the levels are considered interim cleanup levels because the cumulative risk posed by these COCs, after attainment of the interim cleanup levels, may still exceed the USEPA's risk management standard.

Site groundwater will be remediated until the concentration of each groundwater COC complies with the interim cleanup level for the COC at every well that is part of the groundwater containment, MNA and compliance monitoring system within the Site, and at any well that the USEPA requires to be installed for adequate verification that interim cleanup levels and Performance Standards have been achieved.

Because waste is left in place, the point of compliance for groundwater is the edge of the waste management unit (defined as the area that will be located under the multilayer (“RCRA C”) cap after completing thermal treatment in the Overburden NAPL Area). Groundwater cleanup levels will be met throughout the Site (except for under the cap), including throughout the severed plume.

NAPL outside the Overburden NAPL Area

NAPL in bedrock and those portions of the overburden not treated with in-situ thermal remediation will be addressed using MNA and will be reduced to levels that attain the cleanup levels for groundwater. Design and operation of the in-situ thermal treatment system will be conducted to minimize expansion of COCs in groundwater at the Site due to further NAPL migration.

Severed Plume

In addition to meeting the Performance Standard for groundwater, federal and state drinking water standards must be met throughout the severed plume at all times following the filing of the CD. The groundwater quality in the severed plume has shown a trend of decreasing COC concentrations since the pre-ROD construction of the NTCRA 1 and NTCRA 2 systems (i.e., HCTS). The SOW-specified Performance Standard requires that the groundwater quality of this area not be adversely impacted by changes in Site conditions, decline in equipment performance and/or moving of components of the HCTS.

If the Southington Water Department (SWD) activates production wells in the Curtiss Street Well Field, the risks in the severed plume beyond the supplemental containment system must remain within the USEPA's risk management standard for carcinogens and non-carcinogens.

An environmental monitoring program will be implemented to evaluate the performance of the HCTS, and the overall effectiveness of the remedy including the MNA component. Performance monitoring throughout the COC-impacted groundwater in three dimensions will be conducted to ensure the proper operation of the remedy and to satisfy Connecticut Remediation Standard Regulations (RSRs) monitoring requirements. Performance monitoring will include periodic monitoring and necessary maintenance of the capped areas and monitoring of HCTS influent and effluent flows.

Institutional controls in the form of Environmental Land Use Restrictions (ELURs) pursuant to the RSRs, or in some other form, will be implemented to prevent uses of the Site that may pose a potential risk to human health or have an adverse impact on the remedy. Once implemented, the institutional controls will be maintained, monitored and enforced.

The environmental monitoring program is described in more detail in Section 3.

3.4.2 Demonstration of Compliance Report

Demonstration of compliance with cleanup levels will be achieved according to evaluation procedures defined in 40 C.F.R. Section 264.97. Using these procedures, a Demonstration of Compliance Report, demonstrating that groundwater COC concentrations have not exceeded interim cleanup levels for three consecutive years, will be submitted in accordance with Section VIII.F of the SOW. If the USEPA, after reasonable opportunity for review and comment by the Connecticut Department of Environmental Protection (CTDEP), approves the Demonstration of Compliance Report and agrees that the interim cleanup levels have been achieved, a risk assessment of residual groundwater contamination will be performed.

The risk assessment of residual groundwater contamination will assess the cumulative risks for carcinogens and non-carcinogens posed by consumption of Site groundwater. If the USEPA determines, and after reasonable opportunity for review and comment by the CTDEP, that the risks are within the USEPA's risk management standard for carcinogens and non-carcinogens, the residual groundwater concentrations will constitute the final cleanup levels for the Site groundwater and will be considered Performance Standards for any Remedial Action regarding Site groundwater. If the USEPA determines, after reasonable opportunity for review and comment by the CTDEP, that the cumulative risks are not within USEPA's risk management standard for carcinogens and non-carcinogens, the USEPA will establish modified cleanup levels and remedial actions will be continued until the modified cleanup levels established by the USEPA are achieved, or until the remedy is otherwise deemed protective by the USEPA. These modified cleanup levels will constitute the final cleanup levels for Site groundwater and will be considered Performance Standards for any remedial action regarding Site groundwater.

4. Performance Monitoring

4.1 Introduction

This section of the MNA Plan presents the performance monitoring program for Site groundwater in support of the MNA component of the remedy. The performance monitoring program for MNA was developed in conjunction with the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). Section IV.B.5 of the SOW sets forth requirements for an environmental monitoring program to be implemented to evaluate the performance of the HCTS and the overall effectiveness of the remedy, including the MNA component. Groundwater monitoring requirements are as follows:

- An initial comprehensive sampling event across the entire plume. This event will be conducted in the first or second year after filing of the Consent Decree. Groundwater will be analyzed for VOCs, alcohols, 1,4-dioxane, TAL metals, PAHs, PCBs and MNA parameters. A portion of these samples can be proposed for analysis of MNA parameters.

- Subsequent comprehensive sampling events across the entire plume for five-year reviews. Groundwater will be analyzed for VOCs, 1,4-dioxane,TAL metals and MNA parameters. Sampling for five-year reviews will be conducted in the year prior to the five-year review, with the exception of the first five-year review. Data collected for the initial comprehensive sampling event can be used for the first five-year review, on the condition that the data is no more than two years old. A portion of these samples can be proposed for analysis of MNA parameters.

- Sampling of a select subset of monitoring wells in the overburden aquifer and the bedrock aquifer in the area between the railroad tracks and the NTCRA 1 sheet pile wall with the following frequency: every other year until the start of the in-situ thermal treatment; annually during performance of in-situ thermal treatment; three times each year after in-situ thermal treatment is complete until equilibrium is restored, as determined by the USEPA; and annually thereafter. Groundwater will be analyzed for VOCs and MNA parameters, except during long-term annual sampling (which begins after equilibrium is restored), when MNA parameters can be reduced to every other year.

- Annual monitoring of VOCs and biennial monitoring of MNA parameters of a select subset of wells in the overburden and bedrock aquifers in the area outside the NTCRA 1 sheet pile wall.

Sections 3.2 through 3.6 describe the monitoring locations, monitoring frequency, monitoring parameters, analytical methods and data quality objectives (DQOs) designed to meet the environmental monitoring program requirements set forth in Section IV.B.5 of the SOW. Groundwater monitoring will be conducted to monitor changes in groundwater COC concentrations, changes in plume size and shape, and the effectiveness of NA processes at reducing concentrations of COCs in groundwater. The following documents were used for guidance in establishing the MNA portion of the overall Site monitoring plan:

- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (USEPA 1999)

- *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (USEPA 2000)

- *Performance Monitoring of MNA Remedies for VOCs in Ground Water* (USEPA 2004)

- RD POP, including the FSP and the QAPP (Attachments B and C, respectively, to the RD POP)

4.2 Groundwater Performance Monitoring Locations

Groundwater performance monitoring locations were chosen to provide robust, three-dimensional coverage of COCs in overburden and bedrock groundwater at the Site. All proposed monitoring locations are identified in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). This includes monitoring well cluster locations, which are well groupings that provide vertical assessment of COC concentrations and groundwater geochemistry for overburden and bedrock groundwater in a specific location. Monitoring well cluster locations are specifically indicated in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP).

In accordance with the SOW, selected MNA monitoring locations include upgradient (background) sampling locations, in-plume sampling locations (HCTS capture zones and severed plume), sidegradient sampling locations outside of plume areas and downgradient locations. Monitoring locations are designated by well groups to define the purpose of each sampling location and are provided in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). Well group designations specified in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* and that are relevant to MNA monitoring include:

- Background Metals and MNA Parameters (“M” designation) – These are monitoring wells located upgradient from the source area. Monitoring parameters include TAL metals and MNA parameters for establishing background concentrations.

- NTCRA 1 Area (“N” designation) – These are monitoring wells located within the NTCRA 1 containment area between the railroad tracks and the sheet pile wall. Monitoring parameters include COCs and MNA parameters for monitoring the efficacy of thermal treatment in the Overburden NAPL Area.

- Routine Plume Monitoring (“R” designation) – These are monitoring wells located downgradient from the NTCRA 1 containment area. Monitoring parameters include COCs and MNA parameters for monitoring the efficacy of NA in overburden and bedrock groundwater.

- Comprehensive Rounds Only (“C” designation) – These are monitoring wells located downgradient from the NTCRA 1 containment area that are to be monitored as part of comprehensive sampling rounds (i.e., every five years). Monitoring parameters include COCs for monitoring the efficacy of NA in overburden and bedrock groundwater.

Monitoring well locations, well construction information and corresponding well group designations are summarized in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). In addition to the groundwater monitoring locations identified in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP), additional monitoring wells may be installed in the future, if necessary, as determined by the USEPA, to adequately monitor the plume as

Site conditions change. Any new monitoring wells installed within areas where NAPL is known to be present, or may be present, will be installed to minimize the potential for migration of NAPL.

4.3 MNA Monitoring Parameters

The primary classes of data included in the MNA monitoring program are Site-specific groundwater COCs, groundwater MNA parameters, groundwater hydraulic information and HCTS COC mass removal estimates. Each of these primary data classes are described below.

Site-specific COCs are chemical constituents that were identified during Site investigations and risk assessment that are required to be addressed by the response actions set forth in the remedy decision documents (ROD [USEPA 2005]). COCs were initially identified from groundwater and soil monitoring data, COC source histories, and evaluation of COCs that potentially may be formed or mobilized as a result of NA processes or changes in the geochemical environment. Site-specific COCs for groundwater include VOCs, 1,4-dioxane, TAL metals, alcohols, PAHs and PCBs. Analytical methods, sample volume, container type, preservation methods and hold times are provided in the FSP and QAPP (Attachments B and C, respectively to the RD POP).

MNA parameters were selected to confirm dominant biotransformation processes, evaluate the potential for continued transformation of COCs, and identify zones of dominant geochemical conditions. MNA parameters include: temperature, iron (ferric and ferrous), divalent manganese, light hydrocarbons (methane, ethane, ethane), alkalinity, chloride, nitrate–N, nitrite–N, pH, sulfate, sulfide and TOC. In addition to laboratory-based MNA parameters, the following MNA parameters will be collected as field measurements: pH, dissolved oxygen (DO), oxidation-reduction potential (ORP) and temperature. Divalent manganese and ferric iron will be determined by measuring the dissolved concentrations of iron and manganese in groundwater samples, defined as the concentration of manganese and iron in samples passed through a 0.45 micron pore-size filter and measured using methods defined in the FSP and QAPP (Attachments B and C, respectively to the RD POP).

The hydraulic parameter of interest is the elevation of groundwater at monitoring well locations, which will be determined by measuring the depth to groundwater from a set measurement point, then converting to groundwater elevation. Groundwater elevations will be characterized in all five groundwater depth zones, including both horizontal and vertical components of hydraulic gradients that control three-dimensional migration of COCs. Hydraulic gradients, along with hydraulic conductivity and COC-specific partition coefficient information, may be used to estimate potential groundwater velocities and COC velocities within the severed plume to evaluate whether COCs in groundwater are attenuating at rates that are greater than groundwater COC transport velocities. Groundwater and COC velocities within the HCTS are less important because the HCTS captures COC-impacted groundwater within the NTCRA 1 containment area and NTCRA 2 capture zone.

Estimates of the COC mass flux removal from the HCTS are provided in Section 2 of this MNA Plan. These data were used to evaluate potential trends in COC mass removal from the HCTS and can be used to evaluate future efficacy of groundwater remedies, including MNA. Future estimates of groundwater COC mass removal from the HCTS will be obtained as part of the compliance monitoring program for the HCTS operations.

4.4 Monitoring Frequency

Monitoring frequencies were designed to meet requirements of the environmental monitoring program set forth in Section IV.B.5 of the SOW and summarized in Section 3 of this MNA Plan. Detailed monitoring frequency information is provided in the *Monitoring Well Network Evaluation and Groundwater Monitoring Program* (Attachment N to the RDWP). All sampling and analysis will be conducted in accordance with the QAPP (Attachment C to the RD POP).

Once in-situ thermal treatment is complete and equilibrium is restored, a reduction in frequency of long-term annual monitoring may be proposed. Any proposal will be supported by a demonstration that such a reduction is protective and meets the Performance Standards established in the SOW. Any proposed changes to the long-term monitoring program will be submitted as part of the Annual State of Compliance Report(s).

4.5 MNA Monitoring Objectives

The monitoring frequencies set forth in this MNA Plan will be adequate to evaluate the MNA monitoring objectives presented below (USEPA 1999; USEPA 2004).

Provide Timely Warning of Potential Impact to Receptors

Prevention of unacceptable impacts to receptors includes continuing verification of plume stability and the reliability of institutional controls. Annual monitoring of VOC concentrations at “R”-designated monitoring wells will provide continuing verification of plume stability. Annual monitoring of institutional controls will provide continuing verification of the reliability of institutional controls.

Detect Changes in Plume Size/Concentration

Performance monitoring data will be obtained using a three-dimensional monitoring network to assess hydrogeological changes, to monitor temporal variability in the lateral and vertical extent of the plume, and to determine the effective boundary for demonstrating compliance with the objective of no further expansion of the plume.

Determine Temporal Variability of Data

Temporal trends in the concentrations of COCs measured in groundwater samples are essential indicators of plume stability and progress toward COC reduction objectives. Temporal trends in COC concentrations will be assessed at a minimum frequency of every five years to be included in the five-year reviews. Temporal trends in groundwater at an individual well may be used to estimate the potential lifetime of the plume at that location. However, COC concentration trends at monitoring points located throughout the plume will be monitored to adequately interpret progress toward COC reduction goals.

Detect Changes in Geochemistry That Warn of Potential Changes in COC Attenuation

Routine monitoring parameters for these determinations are primarily geochemical indicators of the COC transformation reactions that may occur within the aquifer (i.e., MNA parameters), and groundwater elevations in wells that are used to estimate hydraulic gradients in each hydrogeologic zone. These data will be used to monitor and evaluate the effects of other remedial actions (pump and treat, and in-situ thermal treatment) that will occur at the Site. These remedial actions could change hydrogeologic and/or geochemical conditions, potentially adversely affecting the MNA remedy. Continued monitoring of MNA parameters and groundwater elevations will provide sufficient data for these assessments.

Yield Data Necessary to Reliably Evaluate Progress Toward COC Reduction Objectives

Data analyses useful in evaluating progress toward COC reduction objectives include evaluation of temporal trends in COC concentrations or mass, comparisons of observed COC distributions with predictions or required milestones, and (in some cases) comparison of calculated attenuation rates with the range of rates required to meet remedial objectives within the required time frame. Data to support these evaluations will be available from the planned monitoring events.

4.6 Data Quality Objectives

The DQO process is a systematic planning tool based on the scientific method that is used to establish criteria for data quality and to develop data collection designs. The primary purpose of the DQO process is to: 1) clarify the study objective, 2) define the most appropriate type of data to collect, 3) determine the most appropriate conditions from which to collect the data, and 4) specify tolerable limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision (USEPA 1994). The DQOs for data addressed in this MNA Plan are provided in the QAPP (Attachment C to the RD POP).

4.7 Well Maintenance and Inspection Program

A complete Well Maintenance and Inspection Plan is provided in the FSP (Attachment B to the RD POP).

4.8 Monitoring of Institutional Controls

As described in Section 2, institutional controls that will be implemented at the Site include:

- Restrictions on property uses to prevent human exposure to contaminated groundwater, NAPL and COCs
- Prohibition of activities that might harm the cap
- Prohibition of construction above that portion of the groundwater plume that exceeds the state's volatilization criteria, if remedial design studies confirm the need for such restrictions

The *Institutional Controls Plan*, which is a future remedial design submittal required by Section V.B.7 of the SOW, will describe the scope and monitoring program associated with institutional controls to be implemented at the Site.

5. Analysis of Performance Monitoring Data

5.1 Introduction

This section describes how the MNA performance monitoring data collected in accordance with this MNA Plan will be analyzed, interpreted and reported during implementation of the MNA component of the Site remedy. Data analysis, interpretation and reporting methods will be completed in accordance with the following regulatory guidance documents:

- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (USEPA 1999)
- *Performance Monitoring of MNA Remedies for VOCs in Ground Water* (USEPA 2004)

In general, data interpretation will involve:

- Placing the MNA performance monitoring data in the context of time, location, sampling and analytical methods
- Performing preliminary assessments of the MNA performance monitoring data using basic statistical measures, such as means and ranges
- Applying appropriate statistical tests to detect changes and trends in COC concentrations, and attainment of remedial objectives

These data interpretation methods are further described below.

5.2 Data Quality Assessment Process

The data quality assessment (DQA) process outlined in USEPA (2000) and USEPA (2004) provides the basis for evaluating and interpreting the MNA performance monitoring data collected in accordance with this MNA Plan. The DQA process is described below.

The sampling design, performance monitoring data and DQOs are reviewed periodically to determine if the data meet the DQOs. The purpose of this activity is to verify that the data are of the correct type, quality and quantity for evaluating remedial effectiveness.

Preliminary evaluations of recently collected monitoring data are performed, which may include calculating means, ranges or other basic statistical analyses of the data, generating data graphs or contouring data on maps. The purpose of this activity is to help identify data anomalies.

Data analysis methods such as statistical tests and graphing techniques used to evaluate the monitoring data are periodically verified. The purpose of this activity is to support decision-making and sampling design.

The performance monitoring data are evaluated periodically to ensure that the data are in accordance with assumptions of the statistical tests used, and also to evaluate whether any changes in data analysis methods may be warranted.

The results of the statistical tests and other data analysis methods are used to interpret and draw conclusions regarding remedial progress. As part of this step, the sampling design may be evaluated to determine if any programmatic changes are needed.

The performance monitoring data and results of statistical tests and other data analysis methods are used to update the SCM.

5.3 Data Interpretation Approach

The purpose of interpreting the Site MNA data is to monitor remedial progress and provide the ability to detect trends, changes, anomalies and outliers in the data. Data interpretation methods that will be used to evaluate the Site data include:

- Preliminary presentation (e.g., tabulation and graphing) and evaluation of data
- Data comparisons
- Statistical analysis
- Evaluations of:

- changes in environmental conditions that may reduce the efficiency of MNA
- potentially toxic and/or mobile transformation products
- plume stability
- no unacceptable impacts to downgradient receptors
- new releases of COCs
- institutional controls
- reductions in mass flux

Each of these methods is described in more detail in the following subsections.

5.3.1 Preliminary Presentation and Evaluation of the Data

Initial evaluation and review of the data will be performed by evaluating trends for COC concentrations and MNA parameter values, graphing the performance monitoring data, and/or contouring some of the data on Site maps or hydrogeologic cross-sections. Examples include data summary tables, graphs of chemical concentrations through time and groundwater elevation or concentration contour maps.

5.3.2 Data Comparisons

The following data comparison methods will be performed:

- Comparison of chemical concentrations within and outside the plume for COCs and geochemical parameters.
- Trend analysis including comparisons of chemical concentrations with time and distance.
- Comparisons of Site biogeochemical data with existing literature and laboratory studies.

- Comparison of COC concentrations with applicable drinking water criteria and Interim Cleanup Levels.

5.3.3 Statistical Analysis

Quantitative statistical tests will be used to test hypotheses regarding trends, changes, anomalies and outliers in the Site monitoring data, and to support decision-making as necessary. In the event that a sample is suspected to be an outlier, the USEPA and CTDEP will be notified and an appropriate response (e.g., resampling) or action (e.g., adding a flag/qualifier to the result) will be recommended. The notification and recommendation will be via email or the monthly progress report immediately following the identification of the potential outlier. Examples of statistical tests that may be used include:

- Moving averages

- Regression analysis

- Mann-Whitney, Mann-Kendall and Sen’s test for trends

- Chi-squared test for outliers

- Tests to determine lognormal and normal data distributions

Other parametric or nonparametric statistical tests may be used if needed. Selection of the appropriate statistical test will depend on, among other things, the nature of the hypothesis that needs to be tested, and the type, quantity and distribution assumptions of the available data. The nature and quantity of censored data, such as non-detects in the Site monitoring datasets, will also be considered when selecting quantitative statistical tests.

Linear regression and Mann-Kendall trend tests were performed using historical Site groundwater VOC data collected during the FS and interim monitoring and sampling (BBL 1998; BBL 2005). Details on conducting the trend tests and results of the tests are provided in Section 2 of this MNA Plan. In summary, both the linear regression and the Mann-Kendall trend analyses indicates that total VOC concentrations at 18 of the 25 IMS monitoring locations had statistically significant decreasing trends. Sampling locations with decreasing total VOC concentration trends were located within the NTCRA 2 capture zone and severed plume portions of the Study Area. Three locations had no trend in total VOC concentrations with time. However, only one of these three locations had groundwater VOC concentrations that were persistently high. Four of the monitoring locations had an insufficient number of detections to perform the trend analyses. None of the 25 monitoring locations had a statistically significant increasing total VOC concentration trend. These results indicate that concentrations of COCs in groundwater at the Site are attenuating.

5.3.4 Evaluation of Changes in Environmental Conditions that May Reduce Efficiency of MNA

The MNA parameter data will be used to evaluate potential changes in environmental conditions that may reduce the efficiency of MNA. The only anticipated environmental changes are within the capture zone of the Site NTCRA 1 groundwater containment system due to the addition of heat and removal of electron donors during in-situ thermal treatment of the Overburden NAPL Area. Thermal treatment will temporarily destroy most of the naturally occurring subsurface microorganisms within the treatment volume, and will also remove some electron donors due to volatilization and degradation. Fortunately, this will occur within the capture zone; therefore, it will not influence plume stability outside of the NTCRA 1 containment area, especially in the severed plume portion of the Site. Evaluation methods may include data comparison, graphical and statistical methods.

5.3.5 Evaluation of Potentially Toxic and/or Mobile Transformation Products

To evaluate potentially toxic transformation products, select groundwater samples will be analyzed for concentrations of regulated chemical intermediates (such as VC) and regulated transition metals (such as manganese). The list of sampling locations, sampling frequencies and analytes is provided in Tables L-1 and L-2. The acquired data will be compared with ARARs. If the concentration of a potentially toxic transformation product exceeds ARARs, then the data may be subject to further evaluation and interpretation, including data comparison, graphical and statistical methods. Potentially mobile transformation products (such as rust particles) are not anticipated to be mobile in overburden or bedrock groundwater under current or future anticipated hydraulic gradients at the Site.

5.3.6 Evaluation of Plume Stability

In terms of plume stability, a dissolved-phase chemical plume in groundwater may be characterized as a:

- Shrinking plume, in which the plume volume decreases through time
- Stable plume, in which the plume volume does not change through time
- Growing plume, in which the plume volume increases through time

In general, shrinking plumes are indicated by decreasing chemical concentrations through time, growing plumes may be indicated by increasing or stable chemical concentrations through time, and stable plumes are indicated by plume volume estimates that do not change significantly through time.

The stability of the dissolved-phase plumes in overburden and bedrock groundwater at the Site will be evaluated using graphical and statistical methods. Primarily, plume stability will be evaluated using graphical plots of COC concentrations measured in groundwater samples through time. Statistical tests, including the trend tests listed above, may be performed to test hypotheses regarding the COC concentration datasets. Chemical concentration contour maps may also be developed to evaluate plume stability.

5.3.7 Evaluation of No Unacceptable Impacts to Downgradient Receptors

Potential downgradient receptors, including water supply wells at the Town Well Field Property and surface water in the Quinnipiac River, will be evaluated by periodically sampling and analyzing water at these locations and comparing current analytical results to historical analytical results and ARARs. Sampling locations, sampling frequency and analytes are listed in Tables L-2 and L-3. If the concentration of COCs exceeds ARARs in these samples, then the data may be subject to further evaluation and interpretation, including data comparison, graphical and statistical methods. A response to ARAR exceedances may also include re-sampling of the well(s).

5.3.8 Evaluation of New Releases of COCs

Evaluation of new releases of COCs is not needed because potential sources of new releases have been removed from the Site, the former source area is located within the capture zone of the HCTS, and the Overburden NAPL Area (also within the capture zone) is to be remediated via in-situ thermal remediation. The potential for DNAPL to be mobilized during in-situ thermal treatment is a potential cause for concern, and it is being addressed separately in the NAPL Mobilization Contingency Plan as part of the in-situ thermal treatment program.

5.3.9 Evaluation of Institutional Controls

None of the planned institutional controls (Section 3.8) will impact the efficiency of MNA in groundwater. Therefore, ongoing evaluation of the continued effectiveness of institutional controls is not pertinent to assessing the long-term effectiveness of MNA.

5.3.10 COC Mass Flux / Mass Reduction

COC mass flux and mass reduction will be evaluated by monitoring changes in groundwater COC mass recovery from the HCTS. With the exception of the severed plume and de minimis discharges to surface water immediately adjacent to the river, the entire Site groundwater plume is contained within the HCTS capture zone. As a result, the groundwater extracted from via the HCTS represents the entire mass flux of COCs within the plume. Groundwater extraction rate and COC concentration information collected periodically during system operation, maintenance and monitoring (OMM) activities as part of the compliance monitoring program for the HCTS will be used to evaluate changes in COC mass flux with time. An initial compilation of VOC mass extraction rates is described in Section 2 and is shown on Figure L-17.

5.4 Contingency Measures

An evaluation of contingency measures will be performed if progress in meeting long-term groundwater restoration goals is inadequate, as determined by the USEPA. While the specific measures to be undertaken may depend on several factors (e.g., the nature, location, apparent source, or timeframe at which the inadequacy is identified), examples of possible contingency measures may include:

- Detailed assessment of groundwater data to identify possible underlying factors that may be adversely affecting the continued effectiveness of NA, as well as potential measures for addressing those factors.

- Additional specialized monitoring to further assess geochemical and biological processes affecting COC concentrations in Site groundwater. Additional specialized monitoring may include analyses such as compound-specific isotope analysis of individual COCs in Site groundwater or polymerase chain reaction (PCR) and DNA/RNA analysis to identify specific microbial species that may be present in Site groundwater.

- Installation of additional wells to expand the monitoring network and monitor and evaluate potential plume migration.

- Installation of additional extraction wells to further control plume migration. New extraction wells will be strategically placed to enhance plume capture.

- A change in the remedy, following USEPA's issuance of a ROD Amendment. Such a change would result from a Focused Feasibility Study and determination of the feasibility, implementability and costs associated with potential new remedial alternatives.

Any contingency measure considered will first be approved by USEPA, in consultation with CTDEP, prior to implementation.

6. Reporting and Schedule

In accordance with the SOW (VII.A.2), the initial MNA Report will be submitted to the USEPA within 120 days after installation of any new monitoring wells provided for, or that become necessary to complete, the delineation process described in the RDWP. Thereafter, MNA Reports will be submitted to the USEPA and the CTDEP annually until approval or modifications by the USEPA, after reasonable opportunity for review and comment by the CTDEP, as part of the Annual State of Compliance Reports, as specified in Section VIII.B of the SOW. All MNA Reports will be prepared in accordance with the USEPA's MNA Guidance (USEPA 1999; USEPA 2004).

All MNA reports are subject to USEPA approval or modification, and will include, at a minimum, the following:

- Background and site description
- Evaluation of new data and summary of data interpretation
- Update of the MNA conceptual model
- Assessment of progress in meeting long-term groundwater restoration goals
- Recommendations for action that include, but are not limited to, changes in monitoring locations and frequencies, and sampling methods

At the direction of the USEPA, but no less frequently than as part of the five-year reviews, the MNA Plan will be evaluated to assess progress in meeting the Performance Standards. The MNA Plan will also be reviewed as part of the five-year reviews to incorporate new detection limits for COC or MNA parameters. In addition, the MNA Plan will be reviewed as part of the five-year reviews to incorporate newly promulgated ARARs and modified ARARs that might call into question the protectiveness of the remedy.

7. References

BBL. June 1998. Remedial Investigation Report, Solvents Recovery Service of New England, Inc., Superfund Site, Southington, Connecticut.

BBL and USEPA. May 2005. Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut.

BBL. June 2005. SRSNE Site – Southington Connecticut, Interim Monitoring and Sampling Report No. 14.

Carr, C.S., S. Garg, and J.B. Hughes. 2000. Effect of dechlorinating bacteria on the longevity and composition of PCE-containing non-aqueous phase liquids under equilibrium dissolution conditions. Environmental Science and Technology, 34(6): 1088-1094.

FEMA. 2009. http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcome View?storeId=10001&catalogId=10001&langId=-1. Accessed March 20, 2009.

Geosyntec. 2005a. Appendix G Site Specific Assessment and Evaluation of Enhanced In Situ Bioremediation as a Remedial Technology, *in* BBL and USEPA. 2005. Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut. May 2005.

Geosyntec. 2005b. Appendix H Evaluation of Biodegradation Mechanisms for Site Chemicals, *in* BBL and USEPA. 2005. Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut. May 2005.

Gorelick S. M., Freeze, R. A., Donohue, D., and Keely, J. F. 1993. Groundwater Contamination: Optimal Capture and Containment. Lewis Publishers, Boca Raton, Florida.

Hendrickson, E.R., J.A. Payne, R.M. Young, M.G. Starr, M.P. Perry, J.A. Payne, and L.W. Buonamici. 2002. Molecular analysis of *Dhc* 16s ribosomal DNA from chloroethene-contaminated sites throughout North America and Europe. Applied and Environmental Microbiology, 68: 485-495.

Kueper, B.H. 1997 Impact of Matrix diffusion on Contaminant Fate and Transport in Fractured Bedrock at the SRSNE Superfund Site. *In* BBL. 1998.

Remedial Investigation Report, Solvents Recovery Service of New England, Inc., Superfund Site, Southington, Connecticut. June 1998.

Kueper, B.H. and M.R. West. 2004. Simulation of Plume Migration in Fractured Bedrock Subject to Aqueous Phase Decay and Source Zone Decay. *In* BBL and USEPA. 2005. Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut. May 2005.

NWS. 2009. http://newweb.erh.noaa.gov/ahps2/river.php?wfo=okx&wfoid=18739&riverid=204908&view=0%2C1%2C1%2C1&toggles=&pt%5B%5D=145614&allpoints=145614&data%5B%5D=all&submit=Make+my+River+Page%21. Accessed March 20, 2009.

USEPA. 1994. Guidance for the Data Quality Objectives Process. EPA/600/R-96/055 September 1994.

USEPA. 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, EPA/600/R-98/128.

USEPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. USEPA OSWER Directive 9200.4-17P. April 1999.

USEPA. 2000. Guidance for Data Quality Assessment: Practical Methods for Data Analysis. EPA/600/R-96/084.

USEPA. 2004. Performance of Monitoring of MNA Remedies for VOCs in Ground Water. EPAI600R-041027, April 2004.

USEPA. 2005. EPA Superfund Record of Decision: Solvents Recovery Service Of New England, Southington, CT. EPA/ROD/R01-05/008, EPA ID: CTD009717604. September.

USGS. 2009. http://waterdata.usgs.gov/nwis/dv/?site_no=01195490&referred_module=sw. Accessed March 20, 2009.

Wiedemeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson. 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley & Sons, New York.

Yang, Y., and P.L. McCarty. 2000. Biologically enhanced dissolution of tetrachloroethene DNAPL. Environmental Science and Technology, 34(14): 2979-2984.

Tables

Table L-1.
Summary of Degradation Processes for COCs in Site Groundwater
SRSNE Superfund Site, Southington, CT

Class		Aerobic*		Anaerobic*		Abiotic
	Compound	Oxidation	Co-metabolism	Oxidation[1]	Reduction	Hydrolysis[2]
Chlorinated ethenes	Tetrachloroethene	X	√	X	√	√
	Trichloroethene	X	√	X	√	X
	trans/cis-1,2-Dichloroethene	√	√	√	√	
	1,1-Dichloroethene	√	√		√	X
	Vinyl chloride	√	√	√	√	X
Chlorinated ethanes	1,1,2-Trichloroethane	X	√		√	√
	1,1,1-Trichloroethane		√		√	√
	1,2-Dichloroethane	√	√		√	√
	1,1-Dichloroethane		√		√	
	Chloroethane	√			√	√
Chlorinated methanes	Carbon tetrachloride	X	X	√	√	√
	Chloroform		√		√	X
	Chloromethane	√	√		√	
	Dichloromethane (Methylene chloride)	√	√	√	√	√
Aromatics	1,4-Dioxane	√	√	X		
	4-Methyphenol	√				
	Benzene	√		√		X
	Chlorobenzene	√				X
	Ethylbenzene	√		√		X
	Naphthalene	√	√	√		X
	Phenol	√		√		X
	Tetrahydrofuran	√	√			
	Toluene	√		√		
	Xylenes (all isomers)	√		√		
Ketones	4-Methyl-2-Pentanone (MIBK)	√		√		X
	2-Butanone (MEK)	√		√		X
	Acetone	√		denitrification		X

Notes:
√ - literature indicates that degradation occurs through the specified mechanism
x - literature indicates that degradation does not occur through the specified mechanism
* - a blank cell implies that degradation through the specified mechanism is unknown or uncertain
1. Oxidation under iron, manganese, nitrate or sulfate reducing conditions
2. Those compounds having large half-lives (ie. >100 years) are considered not subject to hydrolysis in groundwater

Table L-2.
Concentrations of Geochemical Parameters in Groundwater
SRSNE Superfund Site, Southington, CT

		Background		Within NTCRA 1 Containment Area												NTCRA 1 Recovery Wells			
Location ID: Date Collected:	**Units**	**P-8B M 06/09/03**	**MW-702DR DR 06/09/03**	**P-16 S 06/11/03**	**P-1B M 06/12/03**	**MWL-307 S 06/11/03**	**CPZ-9 OB 06/10/03**	**MWD-601 D 06/11/03**	**TW-08A M 06/11/03**	**MW-413 D 06/11/03**	**MW-415 M 06/11/03**	**MW-409 M 06/11/03**	**CPZ-7R R 06/12/03**	**CPZ-9R R 06/11/03**	**MW-408 R 06/10/03**	**RW-9 OB 06/12/03**	**RW-10 OB 06/10/03**	**RW-3 OB 06/10/03**	**RW-5 OB 06/10/03**
Geochemical Parameters																			
Wet Chemistry																			
Alkalinity, Carbonate	mg/L	6.3	110	100	150	99	100	160	170	200	130	140	92	110	100	200	210	97	44
Chloride	mg/L	4.3	9.4	9	27	29	14	54	69	100	52	41	120	51	10	32	38	21	18
Nitrate - Nitrogen	mg/L	0.5 U	6.3	0.5 U	0.5 U	0.5 U	8.9	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.1	0.5 U	0.5 U	0.5 U	0.5 U
Nitrite - Nitrogen	mg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfate	mg/L	13	210	9.4	7.3	5	13	9	6.4	1 U	1 U	4.3	52	89	140	4.7	5	9.9	16
Sulfide	mg/L	0.98	1.6	2.3	0.98	0.98	0.65	2 U	2 U	0.65	1.6	2 U	1.6	0.98	1.6	1.3	0.65	2.9	2 U
Total Organic Carbon	mg/L	5 U	5 U	6.6	22	26	1.5	3.7	47	93	84	47	23	23	1.4	22	26	18	3.1
Metals																			
Ferric Iron	mg/L	1 U	0.58	0.81	1 U	1 U	2	1 U	0.8	0.89	1 U	1 U	1 U	1 U	1.7	1 U	1	23	0.75
Divalent Manganese	mg/L	1 U	1 U	3.6	5.6	3.8	1 U	2.3	6.9	9	5.7	4.1	1.1	1 U	1 U	4.1	4.1	3	0.08
Dissolved Hydrocarbon Gases																			
Ethane	ng/L	5 U	13	120,000	40,000	47,000	32	5,500	45,000	24,000	18,000	9,700	7,700	1,600	2,100	60,000	94,000	9,600	130
Ethene	ng/L	24	5 U	13,000	430,000	300,000	340	9,300	220,000	230,000	120,000	90,000	190,000	22,000	3,500	490,000	240,000	43,000	46
Methane	ug/L	0.19	0.24	1,500	1,500	1,000	3.6	10	530	640	290	180	880	260	79	900	970	130	5.3
Organic Acids																			
Acetic Acid	mg/L	1 U	1 U	1 U	23	22	1 U	1 U	21	110	100	52	1 U	1 U	1 U	3.9	1 U	1 U	1 U
Butyric acid	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Lactic Acid	mg/L	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Propionic acid	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2.2	3.1	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Pyruvic acid	mg/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Biota																			
Dehalococcoides	%	0 U	NA	NA	125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	101	NA	NA
Constituents of Concern																			
Total VOCs	ug/L	U	82	1,557	379,000	155,610	162	221,800	239,300	404,700	358,600	223,200	2,819,000	3,428,000	3,380	64,370	45,752	39,360	92

Table L-2.
Concentrations of Geochemical Parameters in Groundwater
SRSNE Superfund Site, Southington, CT

		Upgradient of NTCRA 1 Within NTCRA 2			Immediately Downgradient of NTCRA 1 Within NTCRA 2				Further Downgradient of NTCRA 1 Within NTCRA 2					NTCRA 2 Recovery Well
Location ID:		**MW-705R**	**MW-705DR**	**MW-706DR**	**CPZ-6A**	**CPZ-6**	**MW-502**	**MW-125C**	**MW-07**	**SRS-5**	**MW-121B**	**MW-704M**	**MW-704D**	**RW-13**
		R	**DR**	**DR**	**OB**	**OB**	**D**	**R**	**M**	**M**	**D**	**M**	**D**	**OB**
Date Collected:	**Units**	**06/09/03**	**06/12/03**	**06/11/03**	**06/12/03**	**06/10/03**	**06/11/03**	**06/11/03**	**06/10/03**	**06/10/03**	**06/10/03**	**06/09/03**	**06/09/03**	**06/09/03**
Geochemical Parameters														
Wet Chemistry														
Alkalinity, Carbonate	mg/L	57	150	17	780	470	600	330	360	120	350	150	120	180
Chloride	mg/L	14	25	14	250	87	260	170	120	22	100	20	10	29
Nitrate - Nitrogen	mg/L	0.5 U	0.49	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Nitrite - Nitrogen	mg/L	0.5 U	0.48	0.5 U	0.5 U	0.5 U	0.5 U	0.42	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfate	mg/L	19	130	680	4.2	6	1 U	4.4	1 U	8.9	1 U	8.8	14	9.8
Sulfide	mg/L	0.65	1.6	0.98	1.3	2.9	2.9	0.65	0.65	1.3	2 U	2 U	1.6	1.6
Total Organic Carbon	mg/L	1.3	97	5 U	34	7.9	66	110	10	3.9	11	2.9	1.8	23
Metals														
Ferric Iron	mg/L	1 U	1 U	1 U	1 U	2.7	0.66	1 U	1 U	0.76	1 U	1 U	1 U	70
Divalent Manganese	mg/L	1 U	1 U	1 U	2.2	4.6	3	1 U	4	1.7	4.4	2.2	1.7	3.9
Dissolved Hydrocarbon Gases														
Ethane	ng/L	150	9,200	260	450,000	640,000	200,000	110,000	650,000	71,000	100,000	71,000	12,000	74
Ethene	ng/L	230	27,000	280	1,600	18,000	3,500	920,000	430	60	470	200	870	5 U
Methane	ug/L	6.4	140	20	18,000	19,000	23,000	2,500	24,000	4,300	23,000	3,300	300	1.8
Organic Acids														
Acetic Acid	mg/L	1 U	7.3	1 U	1 U	1.5	7.8	200	2.9	1 U	1.9	1 U	1 U	1 U
Butyric acid	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Lactic Acid	mg/L	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Propionic acid	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	16	1 U	1 U	1 U	1 U	1 U	1 U
Pyruvic acid	mg/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Biota														
Dehalococcoides	%	NA	NA	NA	95	NA	NA	NA	NA	NA	NA	44	NA	NA
Constituents of Concern														
Total VOCs	ug/L	13,220	958,200	11,170	22,030	3,400	86,780	6,595	5,010	884	3,632	92	34	200

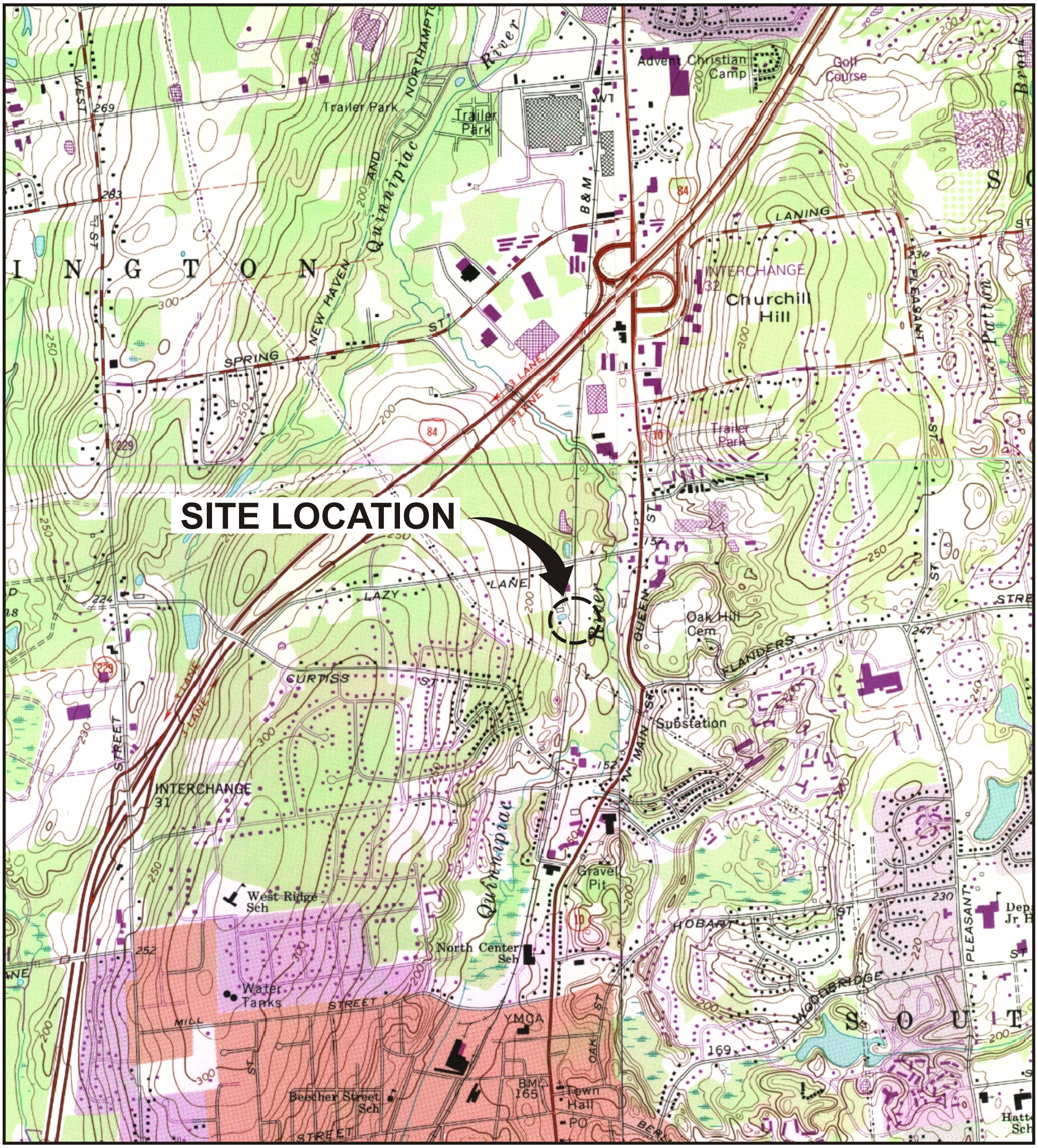
Notes:
mg/L - milligram per Liter
ug/L - microgram per Liter
ng/L - nanogram per Liter
% - percent
OB - Overburden
S - Shallow Overburden
M - Middle Overburden
D - Deep Overburden
R - Shallow Bedrock
DR - Deep Bedrock

Table L-3.
Statistical Summary of Groundwater Total VOC Concentration Trends
SRSNE Superfund Site, Southington, CT

Well	Mann-Kendall Trend	M-K p-value	Regression Trend	Regression R^2	Regression p-value	Bulk Attenuation Half-Life (years)
Shallow Overburden Wells						
MWL-312	--	--	--	--	--	NA
P-13	decreasing	0.001	decreasing	0.42	0.003	5.2
P-101C	decreasing	0.002	decreasing	0.54	0.001	4.6
Middle Overburden Wells						
CW-B-77	decreasing	0.046	decreasing	0.32	0.029	4.0
MW-03	decreasing	0.018	decreasing	0.48	0.004	3.8
MW-127B	no trend	0.114	no trend	0.09	0.241	NA
MW-205B	decreasing	0.019	decreasing	0.25	0.05	4.7
MW-501B	decreasing	0.006	decreasing	0.41	0.008	5.2
P-101B	decreasing	<0.001	decreasing	0.6	<0.001	2.9
Deep Overburden Wells						
CW-4-75	no trend	0.12	no trend	0.1	0.25	NA
MW-04	decreasing	<0.001	decreasing	0.61	<0.001	3.6
MW-204B	decreasing	0.001	decreasing	0.42	0.005	4.6
MW-502	decreasing	0.058	decreasing	0.21	0.078	9.1
MW-704D	decreasing	0.023	decreasing	0.31	0.024	3.4
MW-707DR	--	--	--	--	--	NA
Shallow Bedrock Wells						
MW-127C	decreasing	0.053	decreasing	0.37	0.012	5.1
MW-128	decreasing	<0.001	decreasing	0.61	<0.001	5.9
MW-204A	decreasing	<0.001	decreasing	0.36	0.011	3.2
MW-205A	decreasing	0.004	decreasing	0.41	0.008	4.0
MW-501A	decreasing	<0.001	decreasing	0.73	<0.001	5.4
P-11A	decreasing	0.002	decreasing	0.45	0.003	3.4
Deep Bedrock Wells						
MW-703DR	--	--	--	--	--	NA
MW-704DR	decreasing	0.057	decreasing	0.36	0.018	4.5
MW-706DR	no trend	0.461	no trend	0.005	0.77	NA
MW-707DR	--	--	--	--	--	NA

Notes:
No Trend - no trend in Mann-Kendall analysis at 90% confidence interval
< - less than
-- indicates more than 50% of the sampling dates had total VOC concentrations below the detection limit, thus trends were not evaluated
NA - indicates bulk attenuation rates were not evaluated for sampling locations that had no trend or trend was not evaluated

Figures



REFERENCE: SOUTHINGTON, CONN. USGS QUAD. 1968 PR 1992, MERIDEN, CONN. USGS QUAD. 1966 PR 1984, NEW BRITAIN, CONN. USGS QUAD. 1966 PR 1984, & BRISTOL, CONN. USGS QUAD 1967 PR 1984.

2000' 0 2000'

Approximate Scale: 1" = 2000'

Area Location

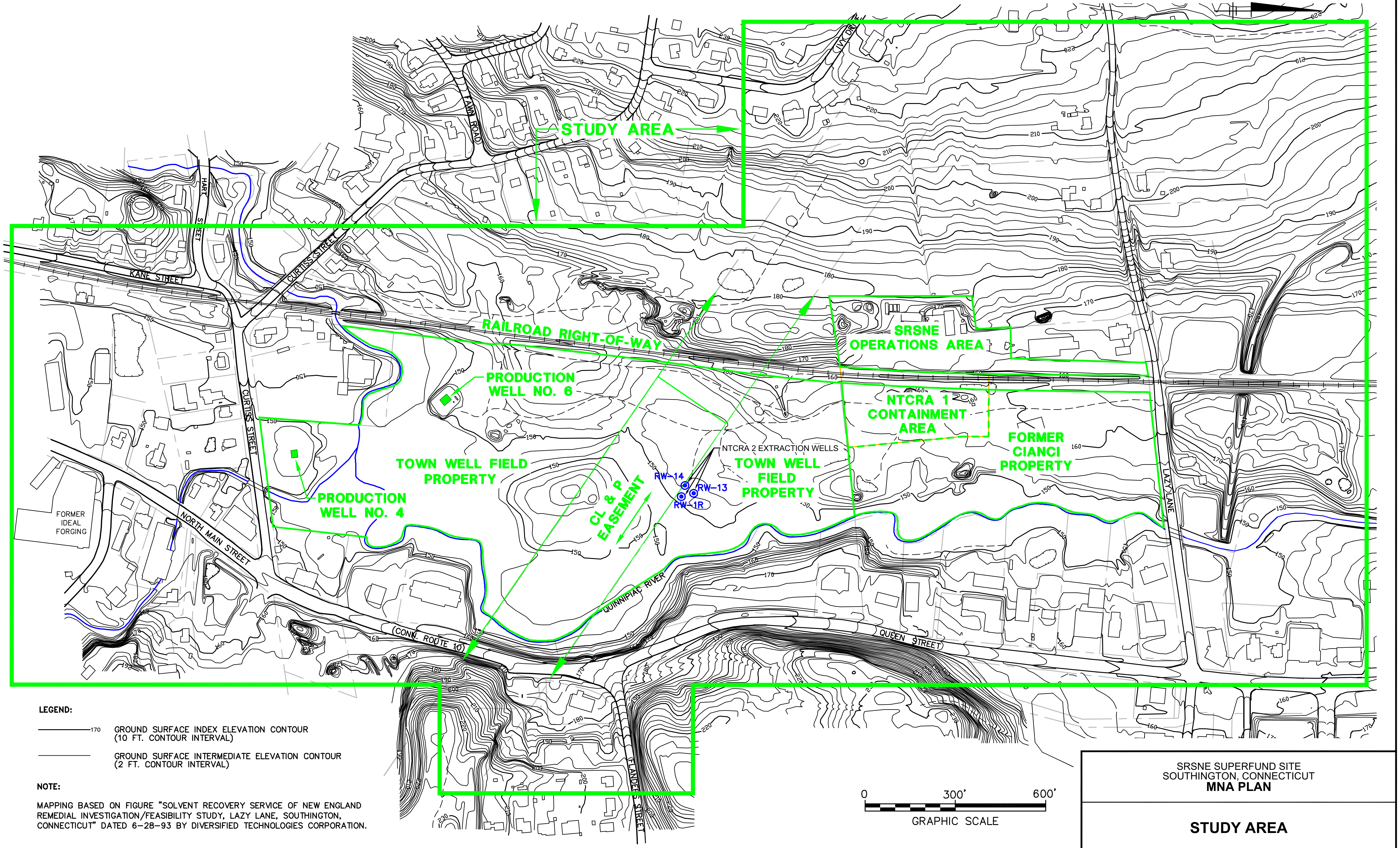
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
MNA PLAN

SITE LOCATION MAP

ARCADIS

FIGURE
L-1

02/24/09 SYRACUSE, NY-ENV/CAD-DJH
B0054634/0000/00800/CDR/54634N01.CDR



LEGEND:

——170	GROUND SURFACE INDEX ELEVATION CONTOUR (10 FT. CONTOUR INTERVAL)
——	GROUND SURFACE INTERMEDIATE ELEVATION CONTOUR (2 FT. CONTOUR INTERVAL)

NOTE:

MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

0 300' 600'
GRAPHIC SCALE

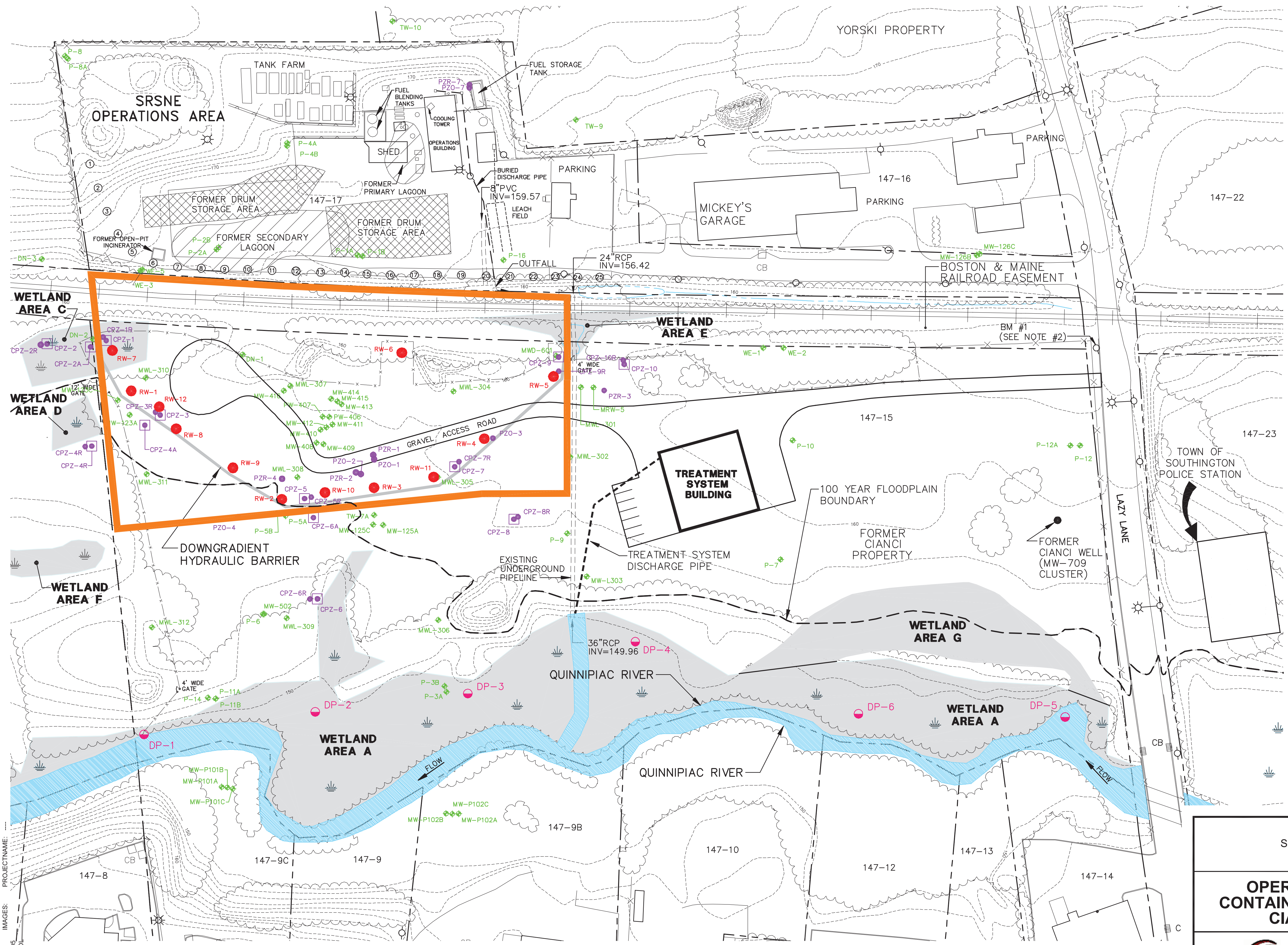
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
MNA PLAN

STUDY AREA

ARCADIS

FIGURE
L-2

CITY: SYRACUSE, NY GROUP: ENV/CAD DB: P. LISTER, R.BASSETT, P. LISTER PM: M. GEFELL TR: R. STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\SYRACUSE\ACT\B0054634\0000\00800\DWG\MNA\54634B03.DWG LAYOUT: L-2 SAVED: 3/26/2009 3:27 PM ACADVER: 17.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 3/26/2009 3:28 PM BY: LISTER, PAUL
XREFS: 54634X01 IMAGES: PROJECTNAME: ----



LEGEND:

— — —	PROPERTY LINE
— — —	100-YEAR FLOOD LIMIT
— — —	WATER
▨	RIVER
▨	WETLAND
▭	NTCRA 1 CONTAINMENT AREA
	EXISTING STRUCTURE
	VEGETATION
- - - -	EXISTING CONTOUR
—X—X—	FENCE
P-10	PREVIOUSLY INSTALLED MONITORING WELL
● PZR-3	NTCRA 1 PIEZOMETER
CPZ-10	NTCRA 1 COMPLIANCE PIEZOMETER
● RW-1	NTRCA 1 OVERBURDEN EXTRACTION WELL
DP-5	WETLAND DRIVE POINT
147-12	LOT NUMBER
□ ○	ABOVE-GROUND TANK
⑫	FORMER ON-SITE INTERCEPTOR SYSTEM EXTRACTION WELL
	UTILITY POLE
	LIGHT POLE

NOTES:

1. SITE PLAN TAKEN FROM DIVERSIFIED TECHNOLOGIES CORP., 556 WASHINGTON AVE., NORTH HAVEN, CT, DATED 6/93. TOPOGRAPHY REPORTED TO HAVE BEEN DIGITIZED FROM TOWN OF SOUTHINGTON TOPOGRAPH MAPS G-7, G-8, G-9; PHOTOGRAPHY DATED NOV. 1978, SCALE: 1"=100'. PROPERTY LINES REPORTED TO HAVE BEEN DIGITIZED AND LOT NUMBERS TAKEN FROM "PROPERTY MAP, TOWN OF SOUTHINGTON" MAPS 134 & 147, SCALE: 1"=100' BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. BENCHMARK #1 IS AT ELEVATION 164.03. PK NAIL; S'LY SIDE; POLE #9049.
3. THE 100-YEAR FLOOD LIMIT AND WETLAND AREAS WERE TAKEN FROM THE FINAL REMEDIAL INVESTIGATION REPORT (HNUS, MAY 1994). THE 100-YEAR FLOOD LIMIT WAS REVISED TO FOLLOW THE ELEVATION 156 CONTOUR BASED ON INFORMATION PROVIDED BY THE SOUTHINGTON TOWN ENGINEER.
4. THE LOCATIONS OF EXISTING DRIVE POINTS, WELLS AND PIEZOMETERS ARE APPROXIMATE ONLY.

0 50' 100'
GRAPHIC SCALE

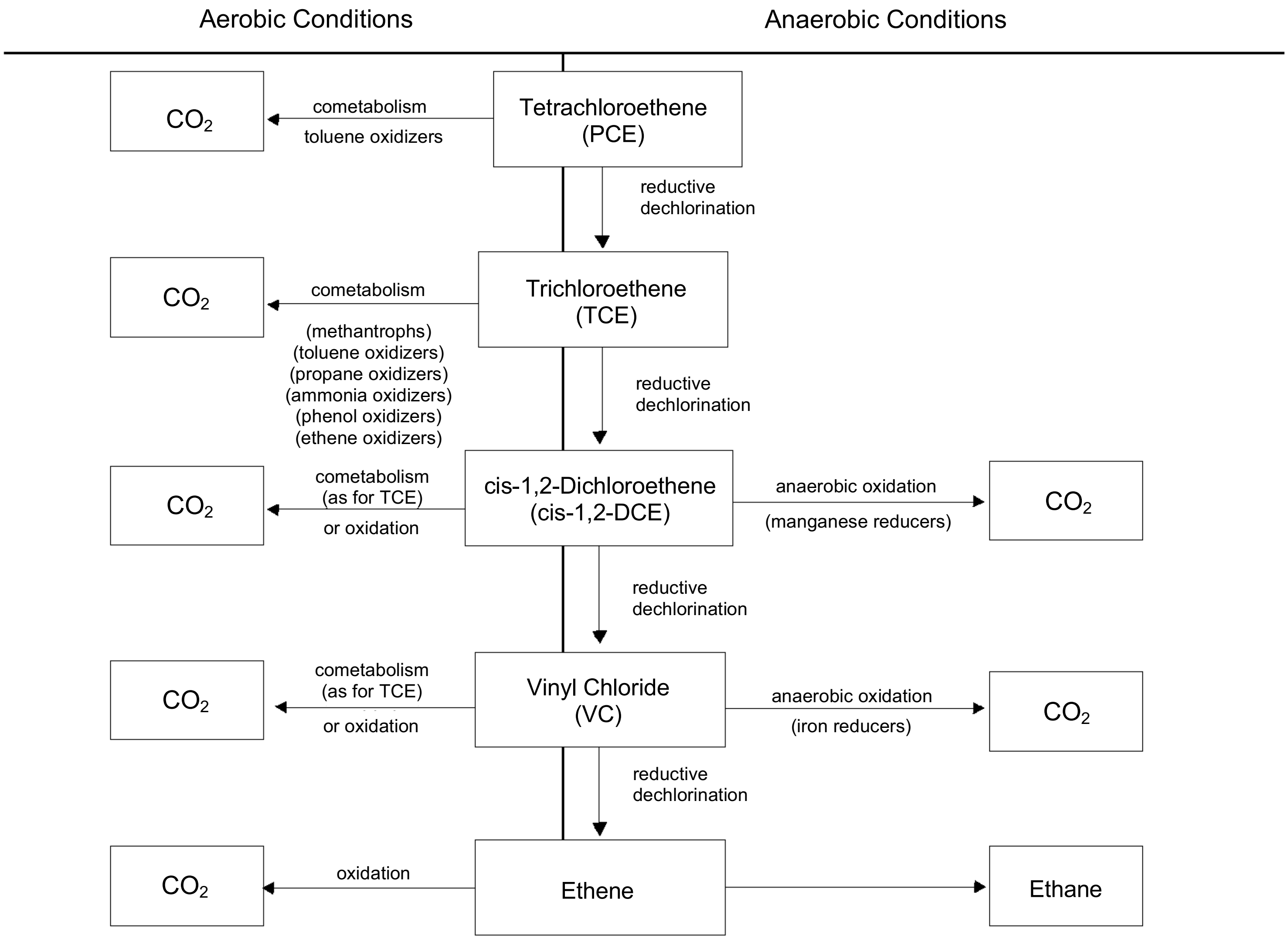
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
MNA PLAN

OPERATIONS AREA, NTCRA 1 CONTAINMENT AREA, AND FORMER CIANCI PROPERTY MAP

ARCADIS

FIGURE
L-3

CITY: SYRACUSE, NY GROUP: ENVCAD DB: P. LISTER PM: J. HOLDEN TR: J. SUEKER LYR: ON=*;OFF=REF (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0054634\0000\00800\DWG\MNA\54634B98.DWG LAYOUT: L-3 SAVED: 3/9/2009 4:18 PM ACADVER: 17.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 3/9/2009 4:19 PM BY: ALLEN, ROYCE
XREFS: 54634X05 54634XDL IMAGES: PROJECTNAME: ---



Source:

Blasland, Bouck & Lee, Inc. (BBL) and United States Environmental Protection Agency (USEPA), May 2005.
Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNETICUT

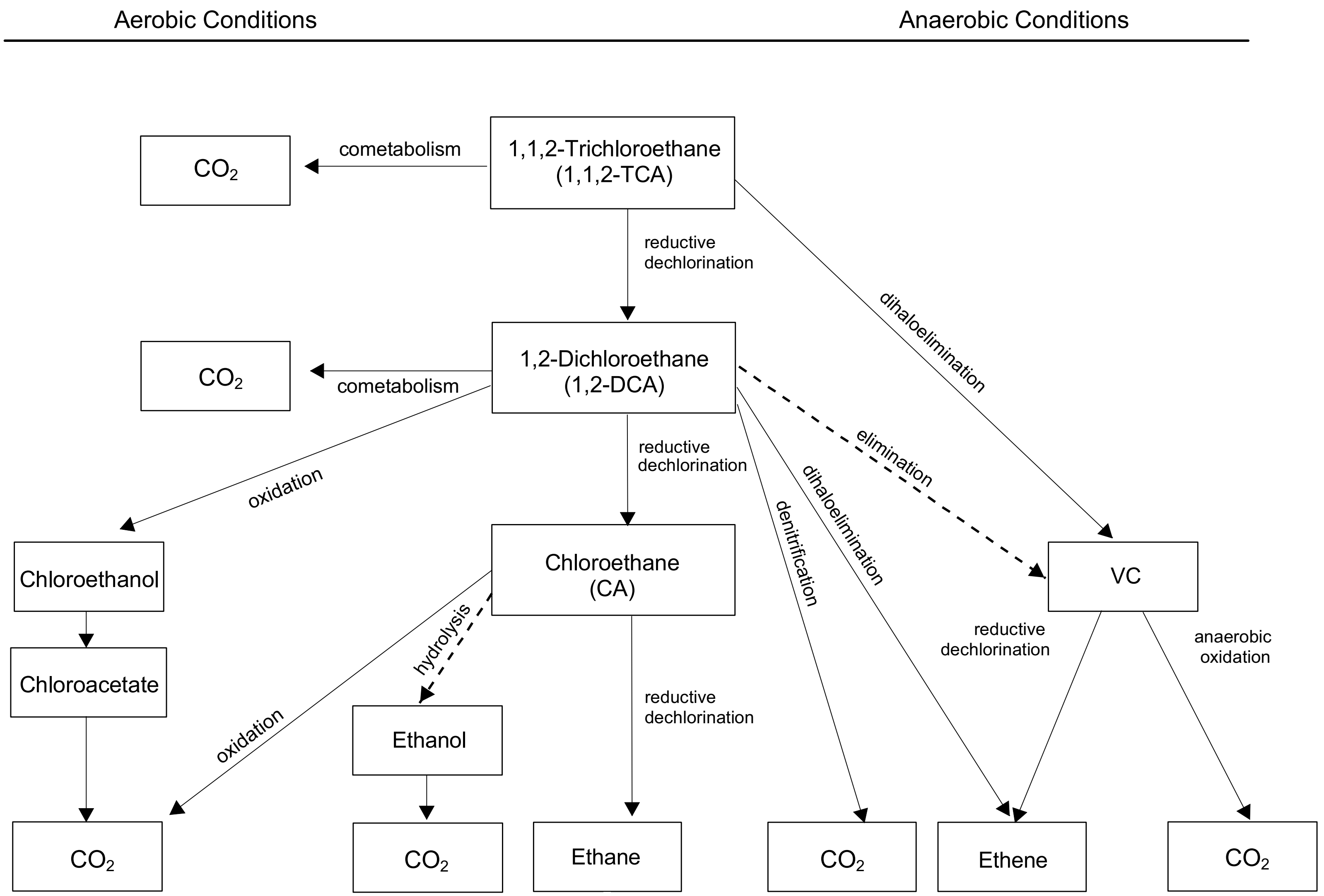
MNA PLAN

PATHWAYS FOR THE DEGRADATION OF CHLORINATED ETHENES

ARCADIS

FIGURE
L-4

I:\SRSNE\GIS\ArcMap_MXD\DegPth_112TCA_112DCA.mxd - 3/25/2009 @ 5:23:08 PM



——▶ biological reaction

- - - -▶ abiotic reaction

Source:

Blasland, Bouck & Lee, Inc. (BBL) and United States Environmental Protection Agency (USEPA), May 2005.
Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNETICUT

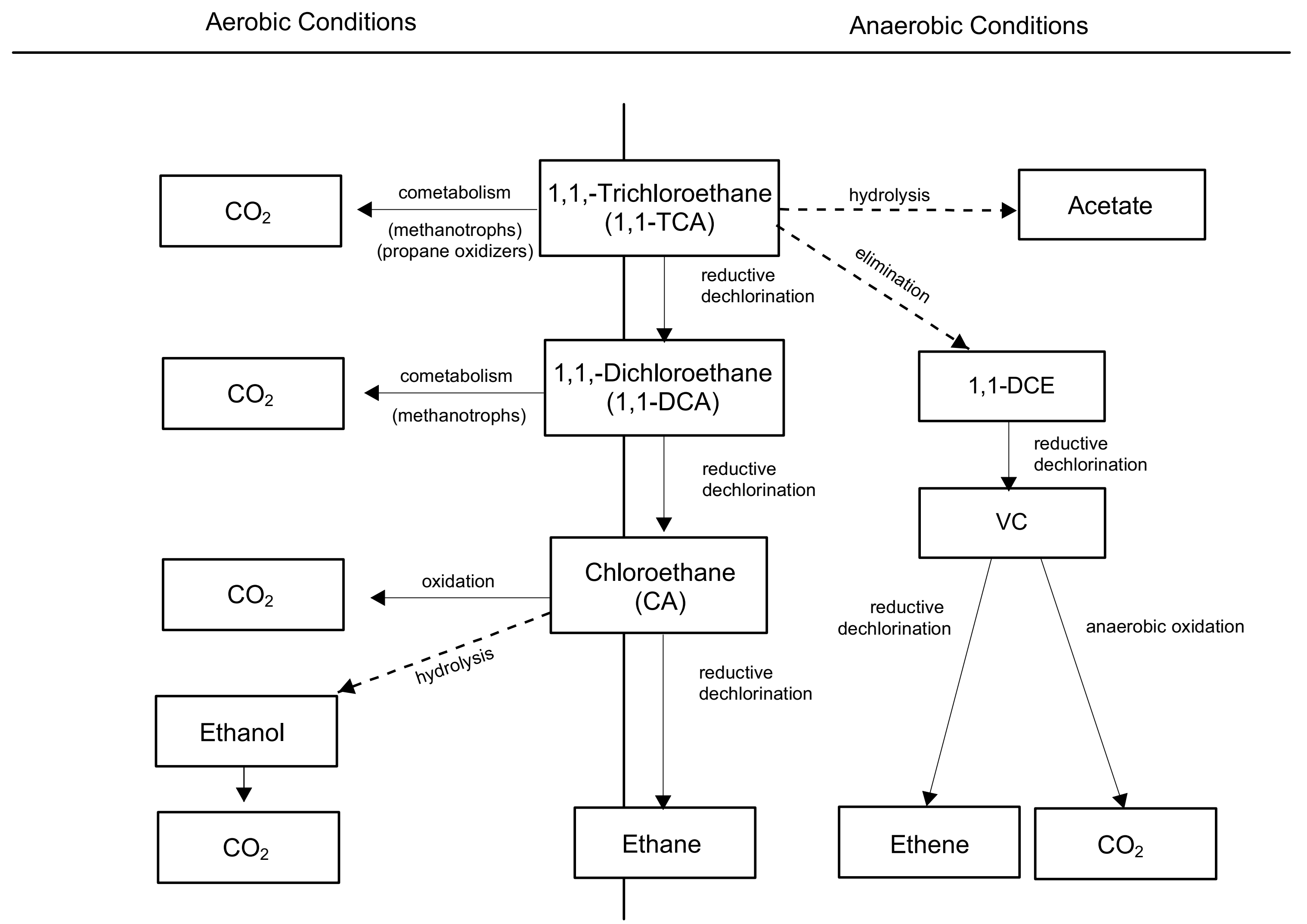
MNA PLAN

PATHWAYS FOR THE DEGRADATION OF 1,1,2-TRICHLOROETHANE AND 1,2-DICHLOROETHANE

ARCADIS

FIGURE
L-5

I:\SRSNE\GIS\ArcMap_MXD\DegPth_111TCA.mxd - 3/25/2009 @ 5:23:40 PM



→ biological reaction

⇢ abiotic reaction

Source:

Blasland, Bouck & Lee, Inc. (BBL) and United States Environmental Protection Agency (USEPA), May 2005.
Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNETICUT

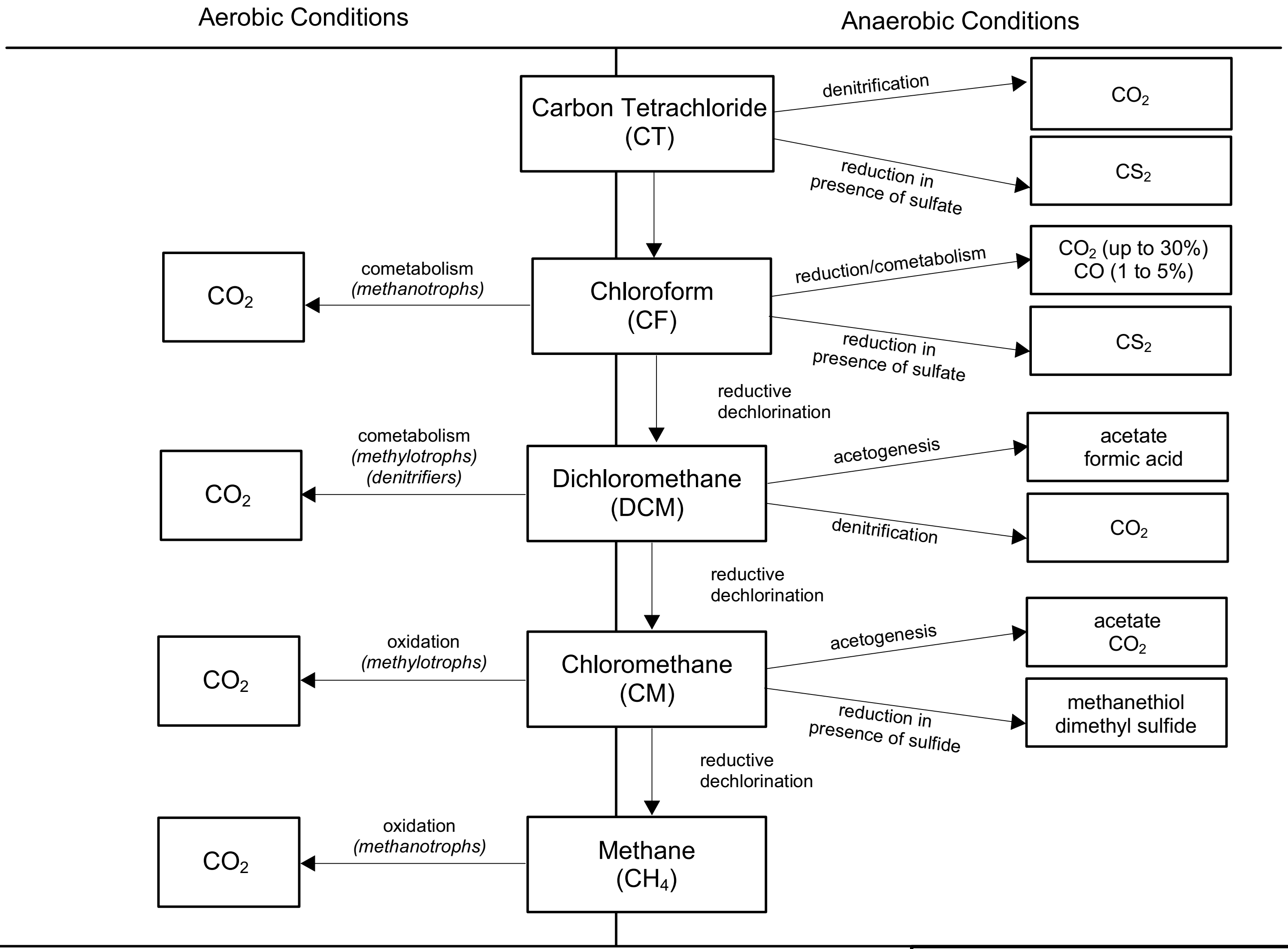
MNA PLAN

PATHWAYS FOR THE DEGRADATION OF 1,1,1-TRICHLOROETHANE

ARCADIS

FIGURE
L-6

I:\SRSNE\GIS\ArcMap_MXD\DegPth_ChlorMethanes.mxd - 3/25/2009 @ 5:21:46 PM



Source:

Blasland, Bouck & Lee, Inc. (BBL) and United States Environmental Protection Agency (USEPA), May 2005.
Draft Feasibility Study, Solvents Recovery Service of New England, Inc., Southington, Connecticut.

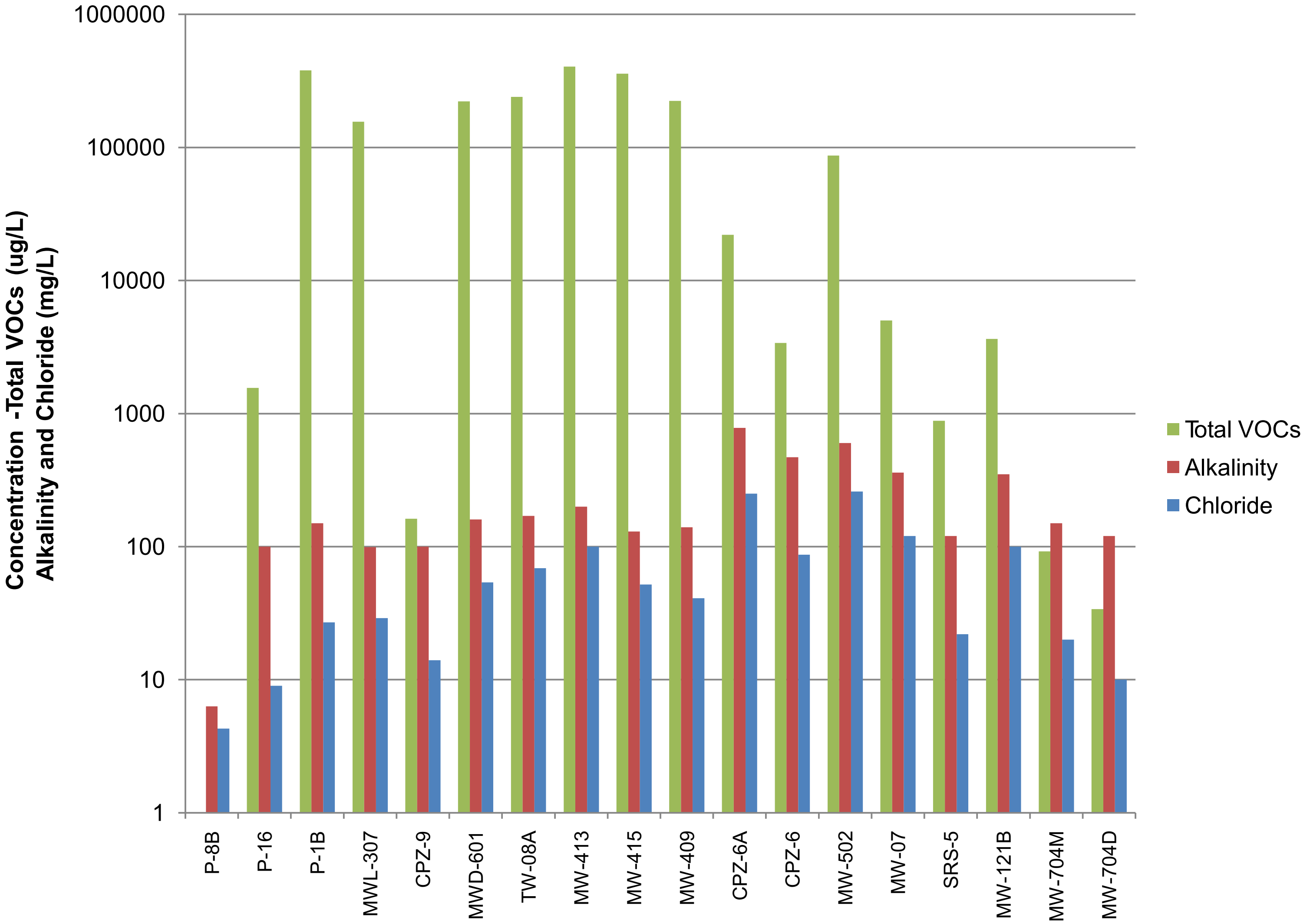
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNETICUT

MNA PLAN

PATHWAYS FOR THE DEGRADATION OF CHLORINATED METHANES

ARCADIS

FIGURE
L-7



Note:
1. Data from June 2003 Interim Monitoring and Sampling event.

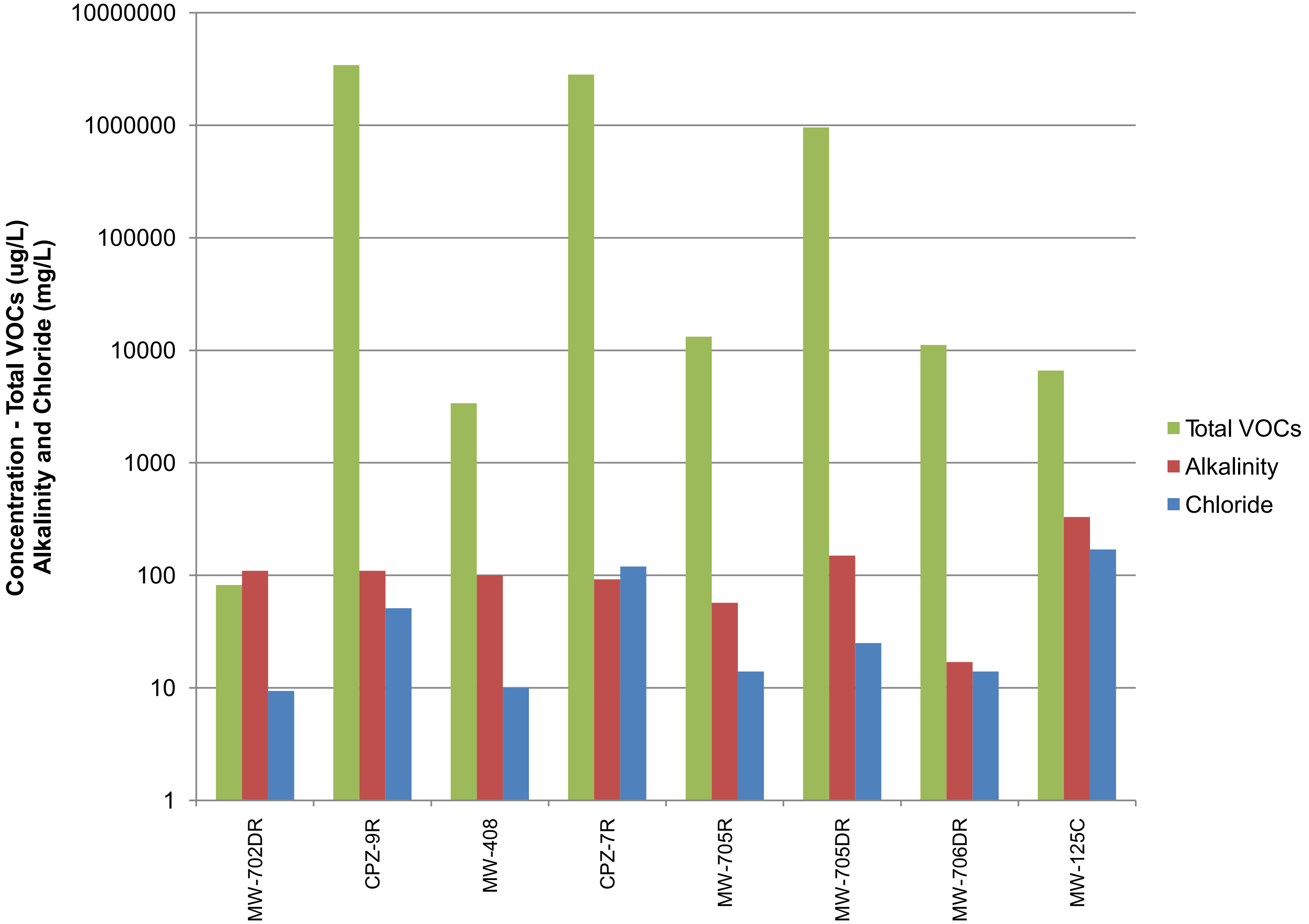
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOCS, ALKALINITY, AND CHLORIDE CONCENTRATIONS ALONG AN OVERBURDEN GROUNDWATER TRANSECT

ARCADIS

FIGURE
L-8



Note:
1. Data from June 2003 Interim Monitoring and Sampling event.

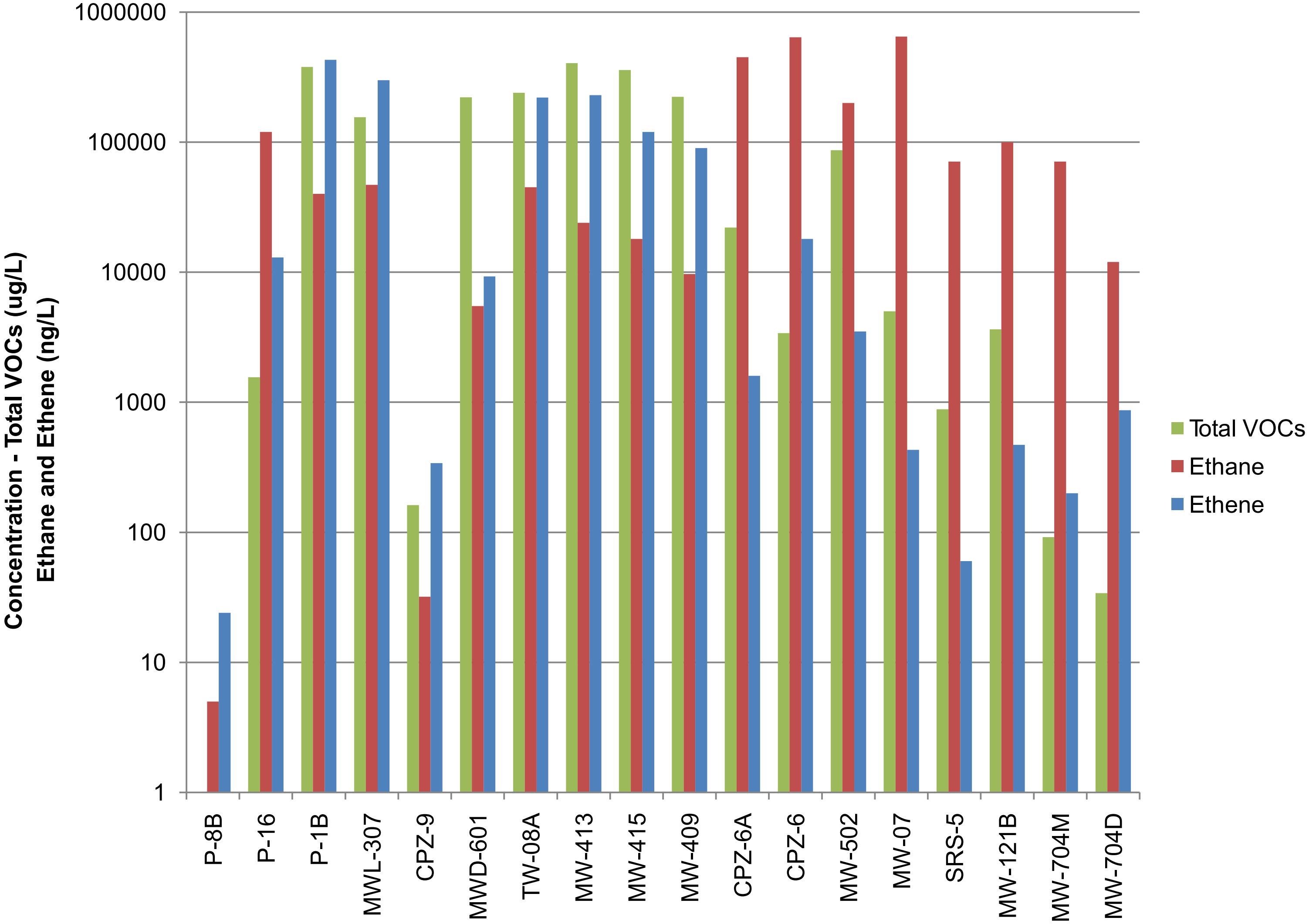
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOCS, ALKALINITY, AND CHLORIDE CONCENTRATIONS ALONG A BEDROCK GROUNDWATER TRANSECT

ARCADIS

FIGURE
L-9



Note:
1. Data from June 2003 Interim Monitoring and Sampling event.

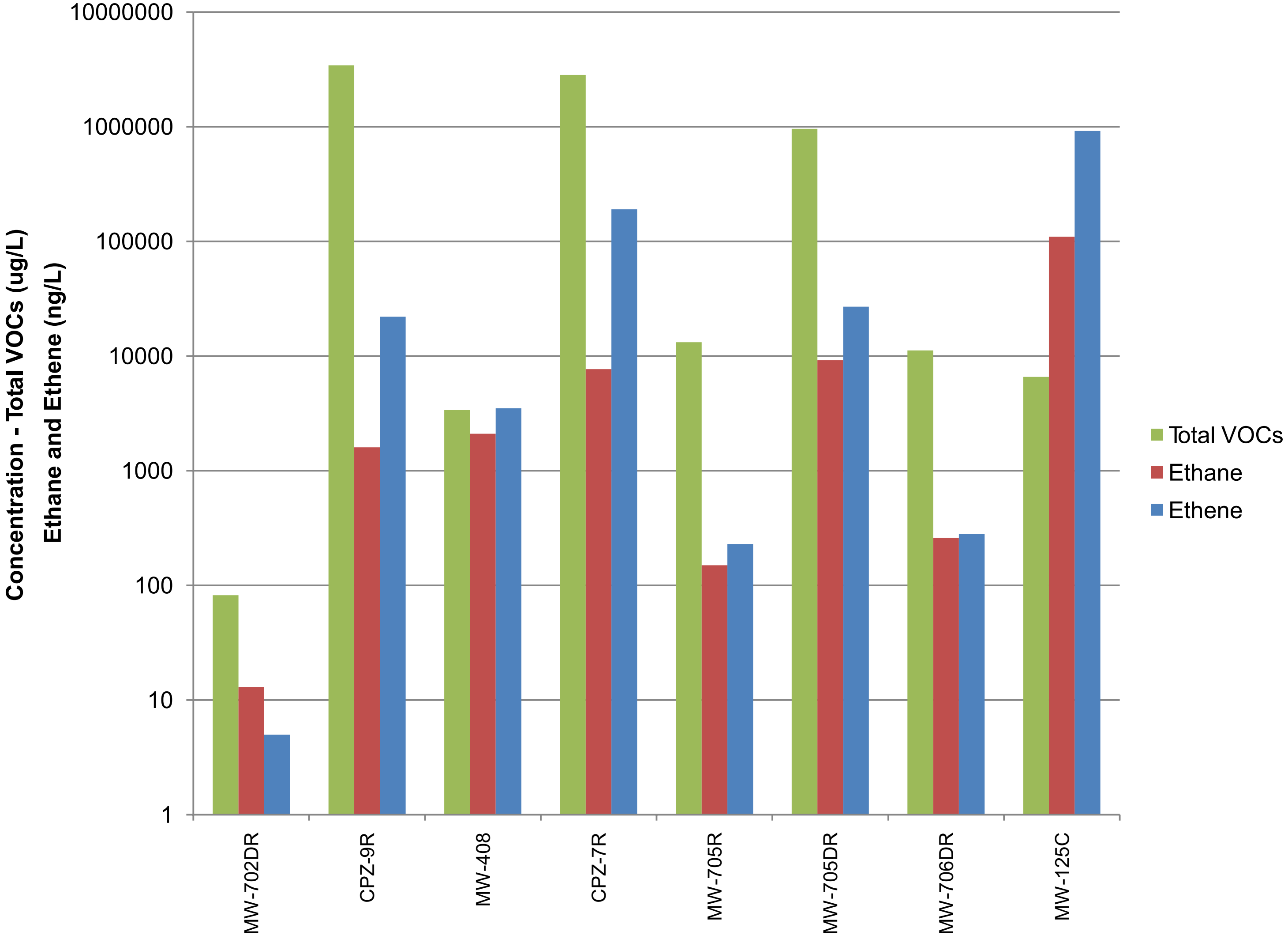
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOCS, ETHANE, AND ETHENE CONCENTRATIONS ALONG AN OVERBURDEN GROUNDWATER TRANSECT

ARCADIS

FIGURE
L-10



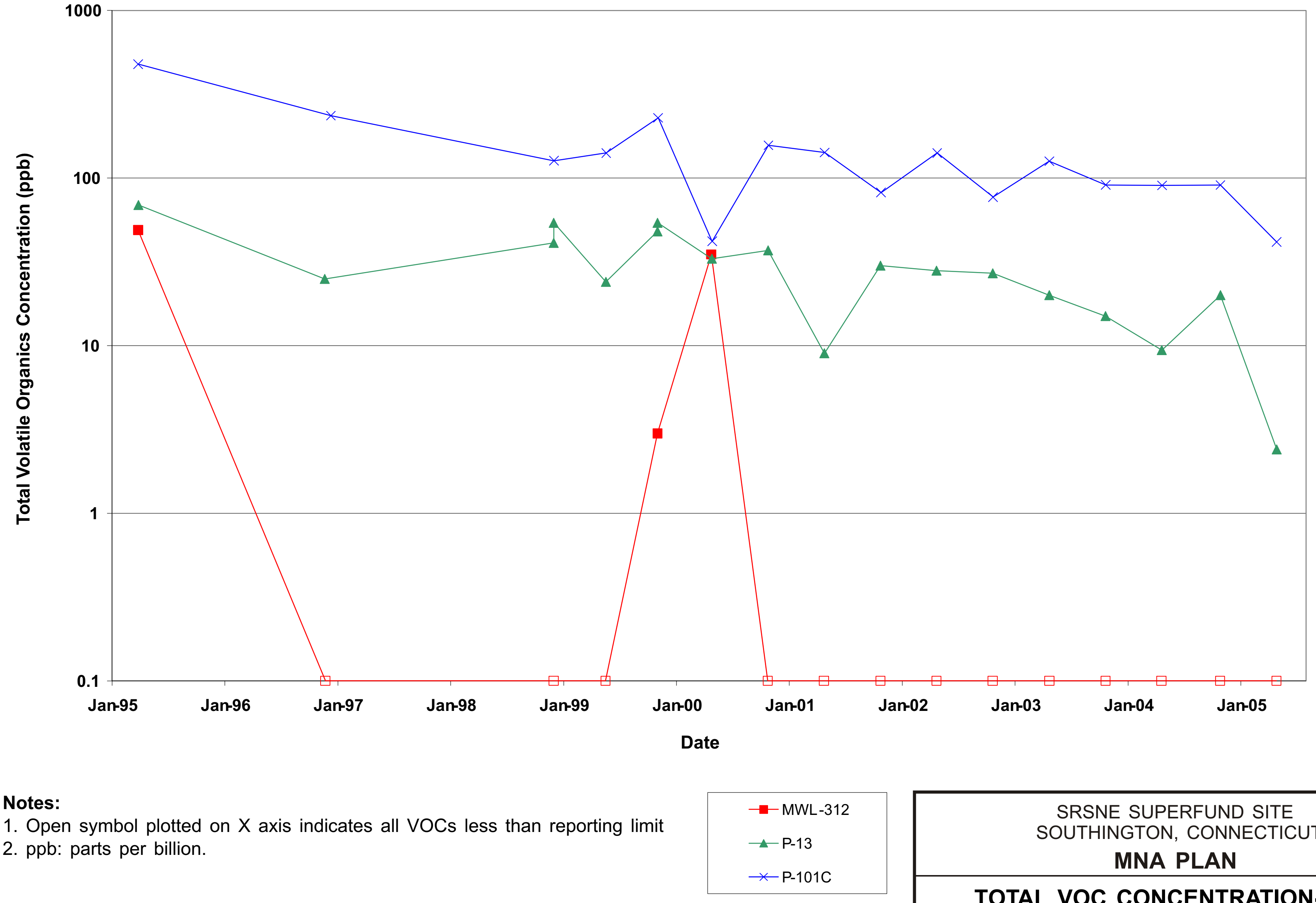
Note:
1. Data from June 2003 Interim Monitoring and Sampling event.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
MNA PLAN

TOTAL VOCS, ETHANE, AND ETHENE CONCENTRATIONS ALONG A BEDROCK GROUNDWATER TRANSECT

ARCADIS

FIGURE
L-11



Notes:

1. Open symbol plotted on X axis indicates all VOCs less than reporting limit
2. ppb: parts per billion.

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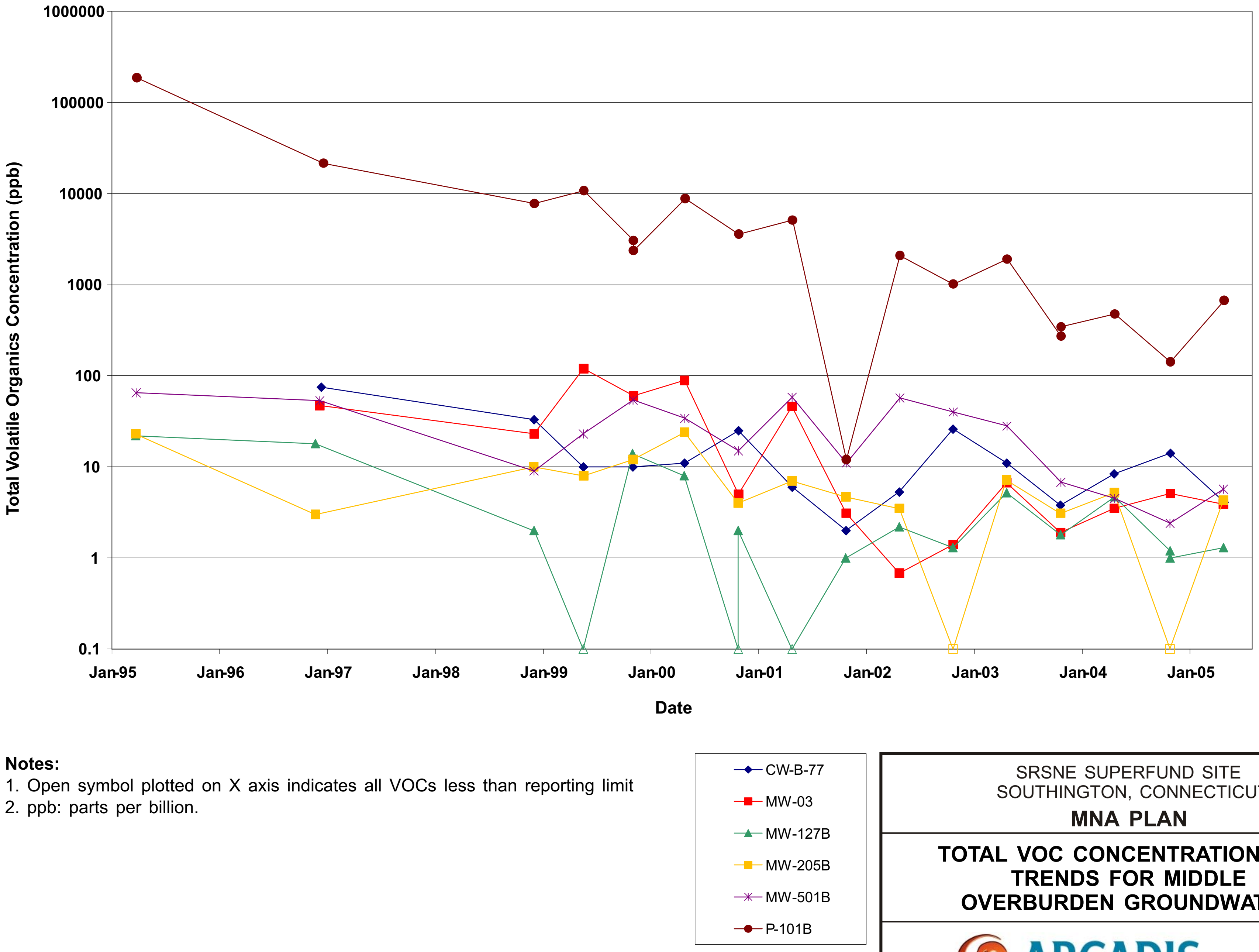
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOC CONCENTRATION-TIME TRENDS FOR SHALLOW OVERBURDEN GROUNDWATER

ARCADIS

FIGURE
L-12



Notes:
1. Open symbol plotted on X axis indicates all VOCs less than reporting limit
2. ppb: parts per billion.

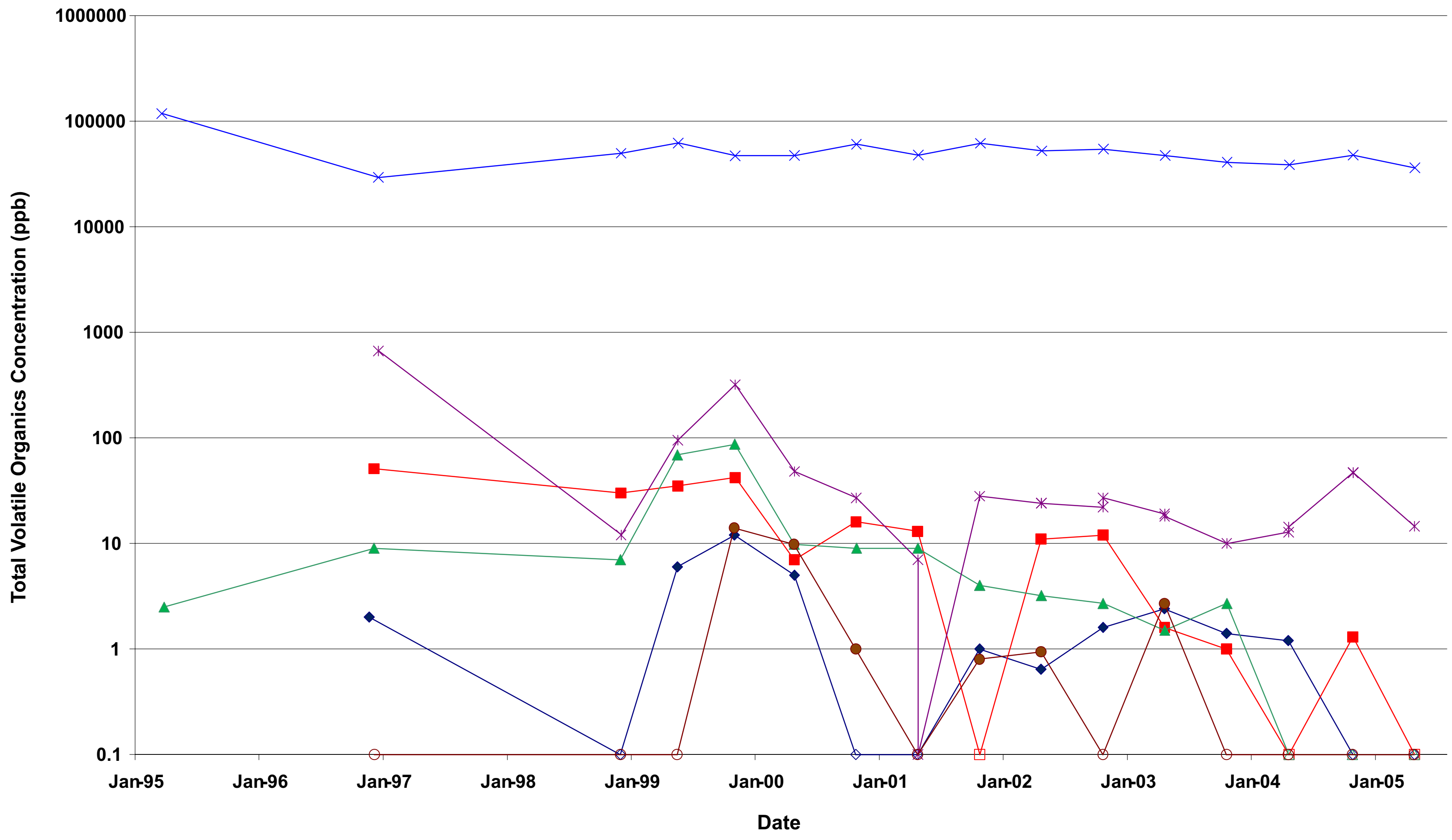
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOC CONCENTRATION-TIME TRENDS FOR MIDDLE OVERBURDEN GROUNDWATER

ARCADIS

FIGURE
L-13



Notes:

1. Open symbol plotted on X axis indicates all VOCs less than reporting limit
2. ppb: parts per billion.

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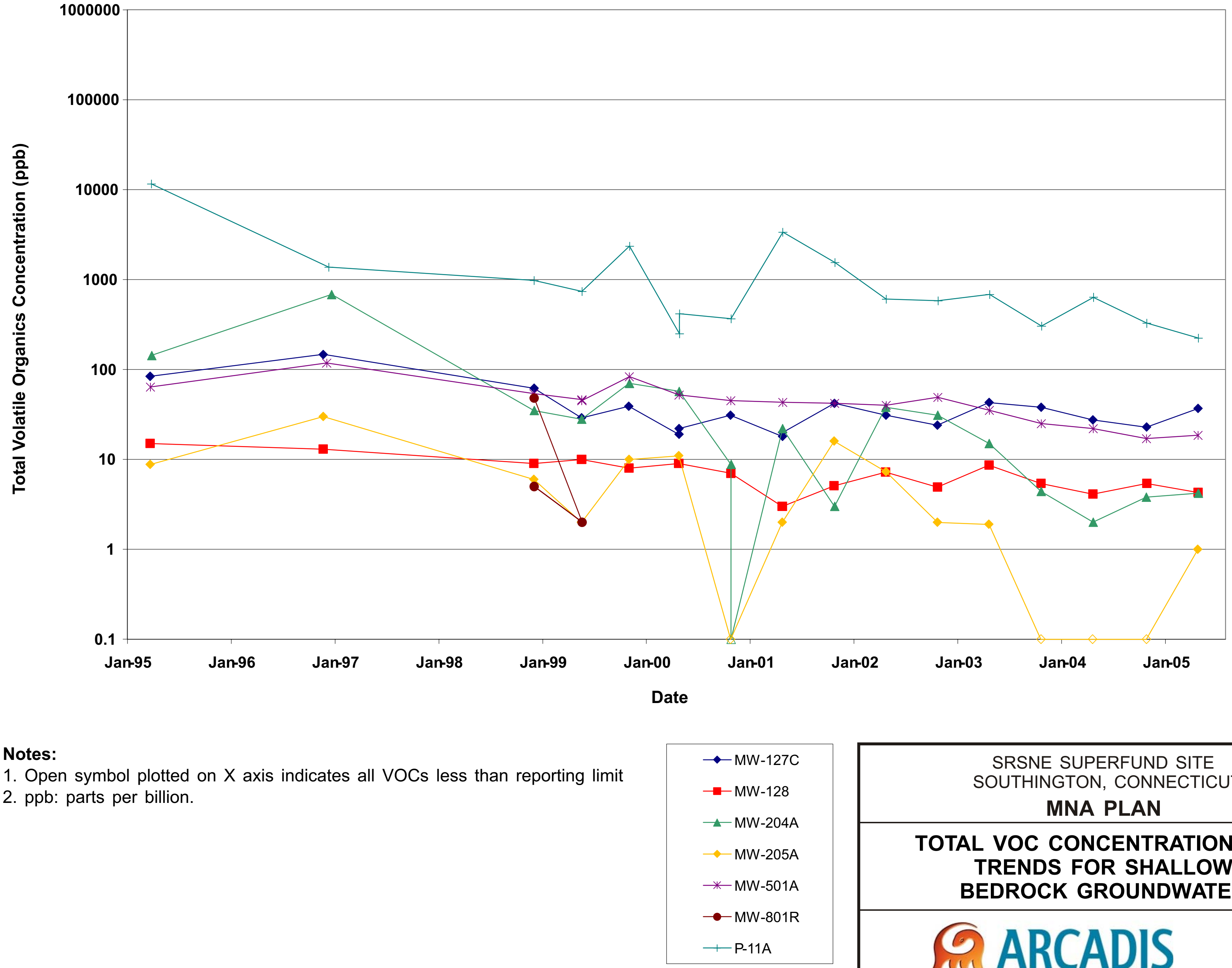
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOC CONCENTRATION-TIME TRENDS FOR DEEP OVERBURDEN GROUNDWATER

ARCADIS

FIGURE
L-14



Notes:

1. Open symbol plotted on X axis indicates all VOCs less than reporting limit
2. ppb: parts per billion.

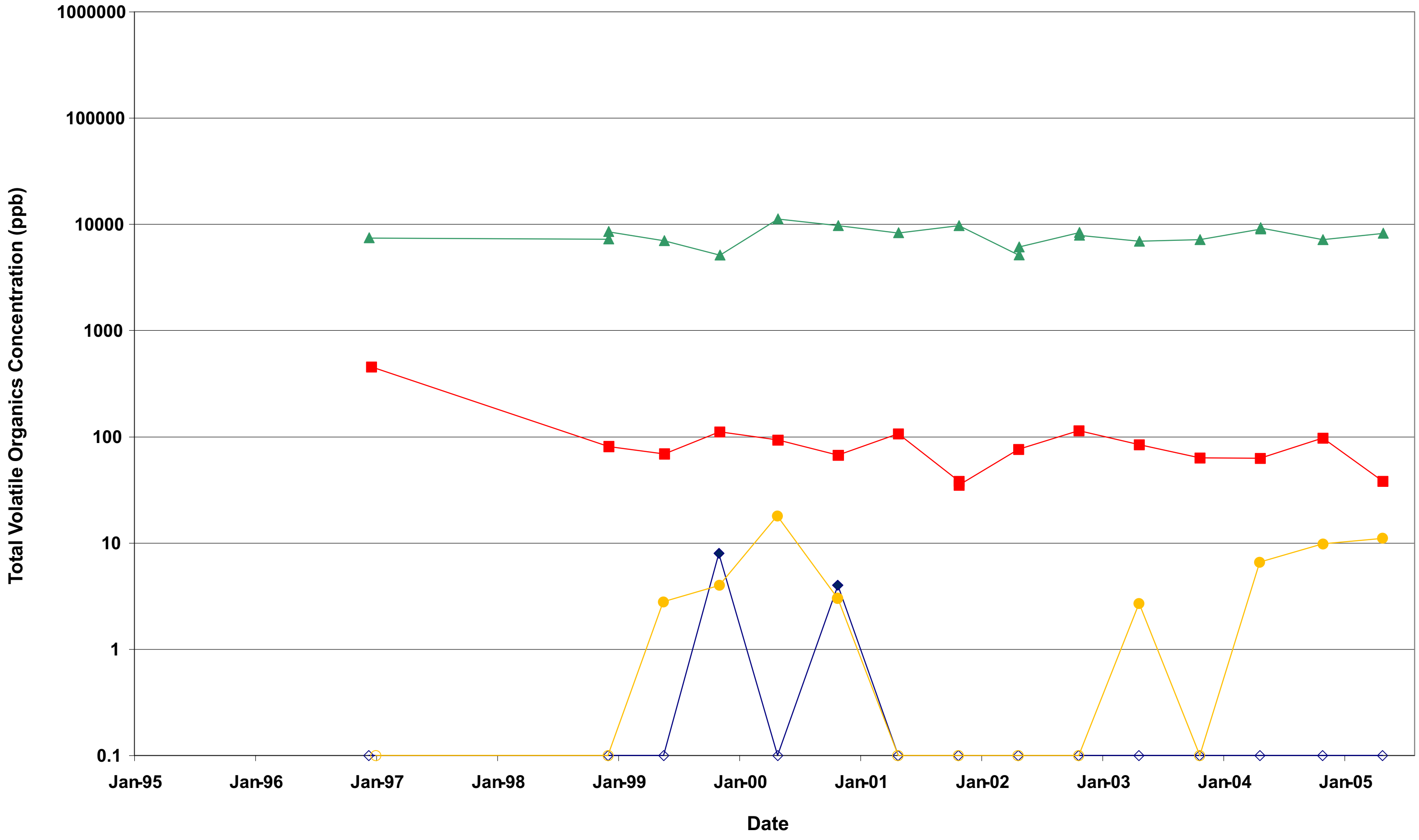
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

**TOTAL VOC CONCENTRATION-TIME
TRENDS FOR SHALLOW
BEDROCK GROUNDWATER**

ARCADIS

FIGURE
L-15



Notes:
1. Open symbol plotted on X axis indicates all VOCs less than reporting limit
2. ppb: parts per billion.

◆ MW-703DR
■ MW-704DR
▲ MW-706DR
● MW-707DR

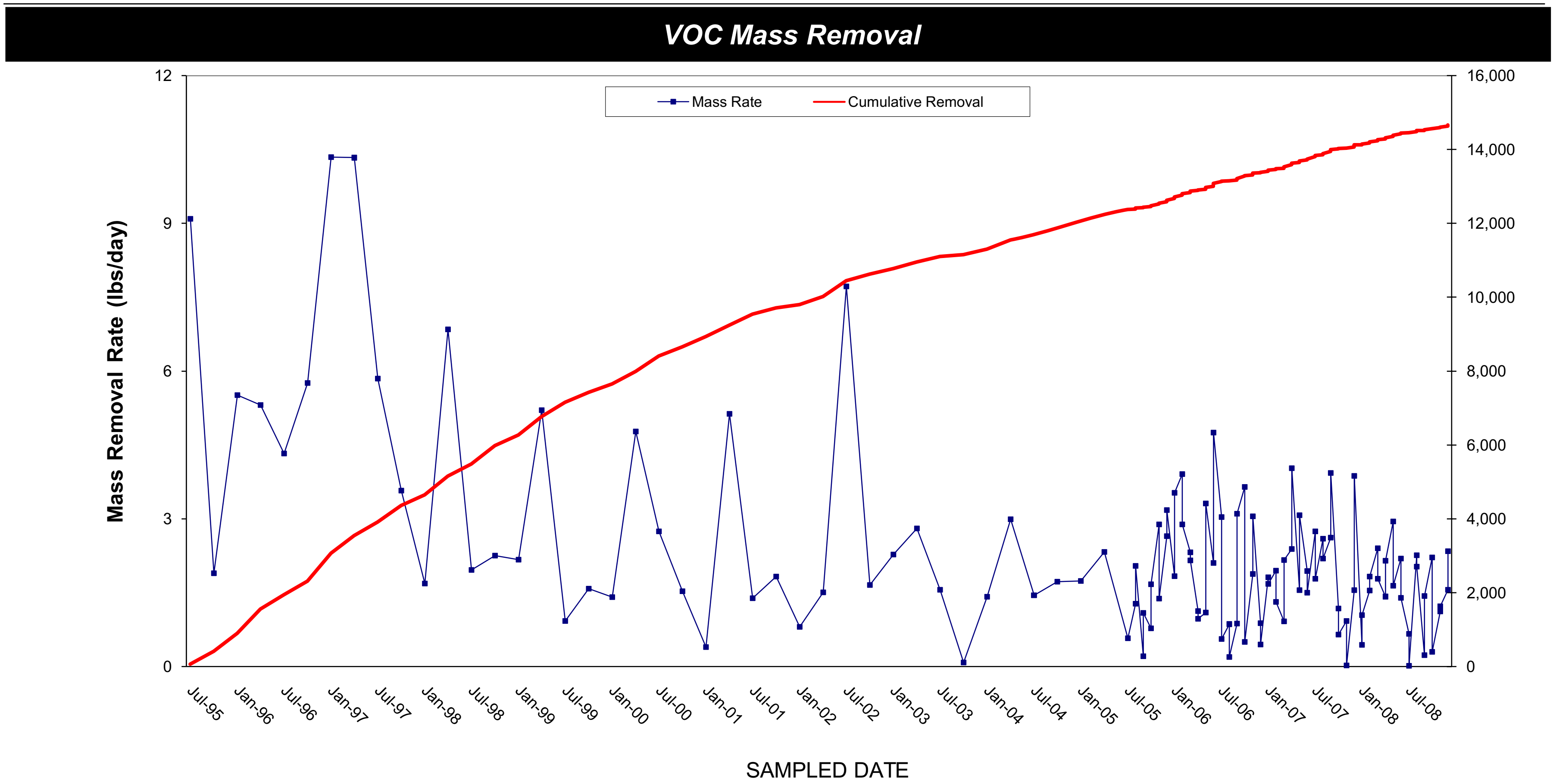
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL VOC CONCENTRATION-TIME TRENDS FOR DEEP BEDROCK GROUNDWATER

ARCADIS

FIGURE
L-16



SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT

MNA PLAN

TOTAL MASS OF VOCS REMOVED BY NTCRA 1 AND NTCRA 2 GROUNDWATER EXTRACTION WELLS

ARCADIS

FIGURE
L-17