REMEDIAL INVESTIGATION/FEASIBILTY STUDY

FEASIBILITY STUDY REPORT

WORK ASSIGNMENT D004433-23.1

315 N. MEADOW ST.
ITHACA (C)

SITE NO. 7-55-014
TOMPKINS COUNTY, NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Alexander B. Grannis, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

URS Corporation
77 Goodell Street
Buffalo, New York 14203

Final
April 2010

FEASIBILITY STUDY REPORT

315 N. MEADOW ST. PROPERTY SITE
SITE #7-55-014
ITHACA, NEW YORK

Prepared For:

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL REMEDIATION
WORK ASSIGNMENT D004433-23.1

Prepared By:

URS CORPORATION
77 GOODELL STREET
BUFFALO, NEW YORK 14203

FINAL

APRIL 2010

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
CPCs	chemicals of potential concern
DER	Division of Environmental Remediation
DCE	dichloroethene
EVO	emulsified vegetable oil
ERH	electrical resistance heating
FS	Feasibility Study
gpm	gallons per minute
HHEA	Human Health Exposure Assessment
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mV	millivolts
NOD	natural oxidant demand
NYCRR	New York Code Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OM&M	operation, maintenance and monitoring
PCE	tetrachloroethene
PSA	Preliminary Site Assessment
RAOs	remedial action objectives
RI	Remedial Investigation
SCGs	standards, criteria, and guidance
SCO	soil cleanup objectives
sf	square feet
Site	315 N. Meadow Property Site
SMP	Site Management Plan
SSD	subslab depressurization
SVE	soil vapor extraction
TCE	trichloroethene
TMV	toxicity, mobility or volume
TOGS	Technical and Operational Guidance Series
µg/L	micrograms per liter
UIC	underground injection control
URS	URS Corporation
UST	underground storage tank
VC	vinyl chloride
VOCs	volatile organic compounds
ZVI	zero-valent ion

EXECUTIVE SUMMARY

This Feasibility Study (FS) report was prepared by URS Corporation (URS) for the 315 N. Meadow Street property ("the site"), located in the City of Ithaca, Tompkins County, New York. The site was historically used for a dry cleaning service and still is presently. There are indications that the site was previously used as a gas station. Tetrachloroethene (PCE) was previously used in dry cleaning operations as a cleaning solvent but is not currently used at the site. No other facilities or businesses situated immediately adjacent to the site historically are known to have used PCE. Results of the Remedial Investigation (RI) prepared by URS (May 2009) and previous investigations indicated the presence of PCE and related degradation products in soil vapor and groundwater at the site. The horizontal extent of volatile organic compounds (VOCs) in soil has been delineated.

Based on investigations performed to date, the horizontal extent of groundwater contamination in the upper portion of the aquifer has been delineated. PCE and its degradation products (e.g., trichloroethene [TCE], *cis*-1,2-dichloroethene [*cis*-1,2-DCE], *trans*-1,2-dichloroethene [*trans*-1,2-DCE], and vinyl chloride [VC]) have migrated offsite via groundwater. There is strong evidence that reductive dechlorination is occurring at the site. VOC contamination has exceeded applicable standards, criteria, and guidance (SCGs) in both soil and groundwater. Although VOC contamination has migrated offsite to a limited extent, the vast majority of contamination is present on the site.

The remedial goal for the site is to eliminate or mitigate all significant threats to public health and the environment presented by the contaminants disposed at the site. Numerical cleanup goals for the site are based on Part 375 criteria for unrestricted future use. To meet the remedial goal for the site, the following RAOs were established for soil, groundwater and soil vapor/indoor air:

- Prevent ingestion of groundwater with contaminant levels exceeding drinking water quality standards.
- Prevent contact with VOCs from contaminated groundwater during future construction activities.
- Restore groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable.
- Prevent direct contact exposure to soil containing VOCs above Part 375 unrestricted use criteria.
- Reduce the potential for soil vapor intrusion to occur in buildings.

In order to meet the remedial goal and remedial action objectives for the site, the following remedial alternatives were developed:

- Alternative 1 – No Further Action.
- Alternative 2 – Institutional Controls.
- Alternative 3 – In Situ Reduction with Limited Source Excavation.
- Alternative 4 – In Situ Chemical Oxidation with Limited Source Excavation.
- Alternative 5 – Air Sparging.
- Alternative 6 – Building Demolition, Soil Excavation and Groundwater Treatment

These alternatives were evaluated against the New York State Department of Environmental Conservation (NYSDEC) criteria: Overall Protection of Public Health and the Environment; Compliance with Standards; Criteria and Guidance; Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility and Volume with Treatment; Short-term Effectiveness; Implementability; Land Use; and Cost. Based on the evaluation, Alternative 3 – In Situ Reduction with Limited Source Excavation is the recommended remedy for the site with a total present worth cost of about $675,000. It includes the following components.

- The treatment reagent is applied to the subsurface through the rods of a direct push rig during two injection events. Typically, the rods are driven to the deepest treatment point, and then withdrawn in stages as reagent is applied through the depth of contamination. A pilot study would be conducted to select the appropriate treatment reagent. Treatment reagent should be applied in a regular grid pattern to effectively achieve subsurface distribution and reach the contamination present in the aquifer. Assuming a 15-foot radius of influence, a possible injection pattern would include 21 injection points, including a few within the southern portion of the building (which should be accessible using a direct push rig).
- Each injection point would apply reagent throughout a depth interval of about 5 to 20 feet bgs. There are many approaches to determining the appropriate electron donor dosage, including mass per cubic yard, stoichiometric ratios (based on amount of hydrogen released and hydrogen required by electron acceptors), and volume required by pore volume or soil adsorption targets. Evaluating these various estimation techniques, about 10,000 to 20,000 pounds of emulsion is recommended for injection across the 21 injection points. The EVO material would be diluted for injection for a total of approximately 40,000 to 100,000

gallons of solution. It is anticipated that two injection events would be required. Onsite performance sampling and analysis will be performed during this time period.

- The injection of the EVO will lower the redox potential further and create even better conditions for anaerobic bacterial growth. Should bacterial levels remain low following the initial injection, bioaugmentation would be an appropriate component of the second injection to expedite the remediation process.
- This alternative includes excavation of approximately 370 cubic yards of soil near the southeast corner of the building. The excavated area would be backfilled with clean soil and repaved.
- The UST within the soil excavation area, and any contents, would be excavated and disposed of offsite.
- An onsite direct read and sampling and analysis program would be performed during the estimated two year implementation period.
- A five year period of monitoring is included to assess the effectiveness of remediation.

1.0 INTRODUCTION

1.1 Contract Authority

URS Corporation (URS) prepared this Feasibility Study (FS) report for the 315 N. Meadow Property site located in the City of Ithaca, Tompkins County, New York. The report was prepared for the New York State Department of Environmental Conservation (NYSDEC) under the State Superfund Standby Contract, Work Assignment D004433-23.1.

1.2 Scope of Feasibility Study

This FS report evaluates the remedial action for the contaminants found to be present at and in the vicinity of the site. This FS was developed to meet the requirements set forth in the New York State Code Rules and Regulations (NYCRR) 6 NYCRR 375, and NYSDEC Department of Environmental Remediation (DER) Draft DER-10 Technical Guidance for Site Investigation and Remediation. This FS specifies the remedial goal and remedial action objectives, identifies potential remedial technologies feasible for use at this site, and develops remedial alternatives that meet the remedial action objectives. Remedial alternatives will be evaluated in sufficient detail such that the NYSDEC can prepare a Proposed Remedial Action Plan and issue a Record of Decision.

1.3 Report Organization

This document has been organized consistent with NYSDEC Draft DER-10 and includes the following sections:

- Executive Summary.
- Introduction.
- Site Description and History.
- Remedial Goal and Remedial Action Objectives.
- Identification and Screening of Remedial Technologies.
- Development and Description of Alternatives.
- Detailed Analysis of Alternatives and Recommended Remedy.

2.0 SITE DESCRIPTION AND HISTORY

This section presents a site description and a summary of site conditions and site history.

2.1 Site Description

The 315 N. Meadow Property site (#7-55-014) is located at the intersection of N. Meadow Street and W. Court Street in the City of Ithaca, Tompkins County, New York (Figure 2-1). There is currently a single-story concrete building on the site. The building is a slab-on-grade structure with approximately 2,700 square feet (sf) of the space used for dry cleaning service activities. A small single-story addition (approximately 400 sf) on the north end of the building currently is a barber shop. Asphalt and/or concrete paved parking surfaces surround the building on the north and west. A gravel parking area is located south of the building. Surrounding land uses include commercial (banking, restaurants, offices), parking and housing. The north-flowing Cayuga Inlet, a NYSDEC Class C (T) stream, is approximately 1,000 feet west of the site. The best usage of the Cayuga Inlet is for fishing (the T designates it as trout water). The grade at the site is generally flat with an elevation of approximately 386 feet above mean sea level (amsl).

2.2 Site History

The 315 N. Meadow Street property ("the site") has historically been used for a dry cleaning service and still is presently. Based upon layout and construction of the building it appears that the site was previously used as a gas station. Tetrachloroethene (PCE) was previously used in dry cleaning operations as a cleaning solvent but is not currently used at the site. No other facilities or businesses situated immediately adjacent to the site historically are known to have used PCE.

2.3 Site Geology

The site is located at the southern end of Cayuga Lake in the Allegheny Plateau Physiographic Province of New York State. Cayuga Lake is one of the Finger Lakes formed during the Pleistocene Epoch as huge ice sheets advanced across New York State. The ice widened and deepened former river valleys to make the Finger Lake troughs. The ice scoured the Seneca and Cayuga Lake valleys so deeply that their bedrock floors are currently below sea level. Once Cayuga Lake attained its present surface elevation of 382 feet amsl, streams discharging into the south end of the Lake began building a vast delta. Floodplain deposits later covered the delta deposits and it is upon these that the main section of Ithaca developed. It is estimated that the maximum sediment thickness beneath Ithaca is on the order of 545 feet.

Information from the RI and previously installed borings and monitoring wells was used to develop localized site geology and hydrogeology. The locations of these borings and wells are shown in Figure 2-2. Using the stratigraphic information gathered during the installation of these borings, two subsurface cross section interpretations were developed, and are presented in Figures 2-3 and 2-4. These figures show a surficial fill layer ranging from 2 to 4 feet in thickness across the area. The fill material consists primarily of clayey silt mixed with some ash, wood, cinder, and gravel.

The fill material overlies a 7 to 19-foot thick clayey silt to silty clay unit containing thin and discontinuous sand and silt layers. Groundwater at the site is first encountered within the sand and silt layers of the silty clay to clayey silt unit.

Beneath the site, the clayey silt to silty clay unit is thinnest (approximately 7 feet thick), and overlies a unit consisting of fine to coarse sand that grades into a silty fine sand before transitioning to clayey silt. The sand unit is approximately 10 feet bgs and 15 feet thick below the site.

North and west of the site (north of W. Court St. and west of N. Meadow St.), the sand layer is much thinner or nonexistent. Consequently, the silty clay is significantly thicker (approximately 19 feet thick), extending to approximately 21 feet bgs. The medium-to-coarser sands found beneath the site within the 16 to 22 foot bgs interval are not present here.

Beneath the entire study area, a fine silty sand (approximately 8 feet thick) is located at an average depth interval of 20 to 28 feet bgs. Beneath the fine silty sand at a depth of approximately 26 feet bgs, lies a silt unit with a clay content of approximately 11 percent. This unit is properly described as a silt with some clay. These two units appear to extend laterally across the entire area investigated as part of this RI.

2.4 Site Hydrogeology

The Cayuga Inlet is the major surface water body in the area. Unconfined groundwater in the region flows toward this stream and eventually north towards Cayuga Lake.

Depth to water in the overburden was measured during the RI and ranged from approximately 3 to 5 feet bgs. Groundwater elevation contours for water levels measured in the shallow monitoring wells indicate groundwater flow direction towards the west-northwest. Groundwater within the deeper portions of the unconfined aquifer flows in a similar direction to the shallow groundwater (i.e., west-northwest).

A large diameter (20 inch) sewer main runs south to north beneath N. Meadow Street. The sewer line is located at approximately the same depth as the shallow groundwater table. The presence of the sewer line and associated higher permeability bedding material increases the heterogeneity of the subsurface and may create localized variability in the direction of groundwater flow. The sewer line is tied into a pumping station located nearby the northwest corner of N. Meadow Street and W. Buffalo Street, south of the site.

2.5 Previous Investigations

Several investigations were performed prior to the RI and are summarized below.

2.5.1 2005 Subsurface Investigation of 313 N. Meadow Street

In June 2005, Buck Engineering conducted a Phase II investigation as part of a property transaction involving 313 N. Meadow Street. This property is located directly adjacent to and south of the site. The investigation, summarized in a report dated June 30, 2005, indicated that elevated levels of PCE and trichloroethene (TCE) were detected in groundwater samples from the property. The investigation included the advancement of four Geoprobe® borings for the purpose of collecting groundwater samples for volatile organic compounds (VOCs) analysis. No soil samples were analyzed. PCE was detected in all four groundwater samples at concentrations ranging from 130 to 1,700 micrograms per liter (μg/L). TCE was detected at one location at a concentration of 56 μg/L. All detections of PCE and TCE were above their respective class GA groundwater quality criteria as listed in NYSDEC Technical and Operational Guidance Series (TOGS) 1.1.1, April 2000.

2.5.2 2005 PSA Investigation

URS conducted a Preliminary Site Assessment (PSA) investigation between August and November 2005 that confirmed the continued presence of VOC contamination associated with the former dry cleaning operations. The investigation activities included the following work tasks:

- Advancement of 10 Geoprobe® borings.
- Collection of 10 soil samples from the Geoprobe® borings.
- Collection of 10 groundwater samples from the Geoprobe® borings.
- Sampling of one soil vapor implant.
- Sampling soil vapor below the slab of the on-site building.
- Collection of air sampling from seven buildings surrounding the site.

Results of the PSA indicated that PCE was detected above NYSDEC Standards, Criteria, and Guidance (SCGs) in both soil and groundwater within the property boundary of the site. There were no exceedances outside of the property boundary. PCE was also detected at greatest concentrations in soil vapor directly beneath the building located on the site and the property immediately to the south of the 315 N. Meadow Street property. Based on elevated concentrations of PCE detected in a sub-slab vapor sample, a subslab depressurization systems was installed at one building located south of the site. Additional air sampling was recommended at two buildings. The sampling results of the remaining buildings were typical of levels usually found in the indoor air of buildings and no additional sampling was recommended.

2.5.3 2006 Structure Sampling

As a follow-up to the PSA, URS collected air samples from seven new structures surrounding the site. Buildings were selected by New York State to complement and expand upon environmental testing that was being completed as part of the PSA. Based on the air sampling results, the State installed a SSD system on one commercial building and recommended additional sampling at one commercial building. The air results of the remaining buildings were typical of levels usually found in the indoor air of buildings and no additional sampling was recommended.

2.6 Potentially Applicable Standards, Criteria, and Guidance

Potentially applicable standards, criteria, and guidance (SCGs) for the site consist of Part 375: Remedial Program Soil Cleanup Objectives (SCOs) that were used as the basis for evaluating remedial alternatives in this FS. There are seven categories of SCOs in Part 375. These categories include the following: unrestricted use, residential use, restricted residential use, commercial use, industrial use, protection of ecological resources, and protection of groundwater. Unrestricted use criteria are considered the most appropriate for the site and these SCOs were used to develop and evaluate alternatives in this FS.

Groundwater standards are set by the Class GA standards presented in NYSDEC TOGS 1.1.1, April 2000.

There are no applicable regulatory criteria for soil vapor contamination. However, because PCE and TCE are common soil and groundwater contaminants, the New York State Department of Health (NYSDOH) has established air guidelines for indoor air concentrations of these compounds to assist in determining whether actions should be taken to reduce potential exposures to contaminants from soil vapor intrusion.

2.7 Nature and Extent of Contamination

The nature and extent of contamination was delineated in the RI Report prepared by URS in May 2009. A summary of the RI findings is presented in this section.

2.7.1 Soil

Figure 2-5 shows the location of soil samples collected during the RI and presents results where soil SCGs were exceeded. The highest chlorinated VOC concentrations were detected in soil samples collected from locations east and south of the dry cleaning building. Lower concentrations of PCE, its breakdown products, and/or other VOCs were detected in other soil samples collected during the RI. The horizontal extent of VOCs in soil has been delineated and consists primarily of chlorinated hydrocarbons, which are attributable to former site use. The area of impact is primarily within the southern and southeastern portions of the site property (near the presumed original spill location), but the impact extends off of the property slightly toward the south and approximately 30 feet east of the site property. Although chlorinated VOCs are the primary contaminant at this site, benzene, toluene, ethylbenzene and xylene (BTEX) concentrations exceeded SCOs, and acetone was also detected west and northwest of the site building at concentrations exceeding the SCO.

2.7.2 Groundwater

Figure 2-6 shows the locations of groundwater samples (both grab and monitoring well samples) collected during the RI and the results that exceed the groundwater SCGs. The main source area for PCE lies within the soil near the southeast corner of the building. Dissolved PCE and its breakdown products in groundwater migrate primarily west and north-northwest in the general direction of groundwater flow. The overall horizontal extent of PCE contamination extends from the southeast corner to the northwest corner of the site property. PCE does not appear to have migrated in any significant concentrations beyond the west side of N. Meadow Street or beyond the north side of W. Court Street.

The RI found that the concentration distribution of various chlorinated hydrocarbons indicated that reductive dechlorination has taken place and/or is ongoing within the saturated overburden. As degradation occurs, the original compound released into the environment is converted sequentially to its degradation products, where chloride atoms are successively removed and replaced with hydrogen. For this site, PCE would be degraded to TCE, then to *cis*- or *trans*-1,2-DCE, then to VC, and finally to ethene. There is strong evidence that anaerobic reductive dechlorination is occurring at this site. The evidence includes: 1) favorable geochemical conditions - low or no dissolved oxygen and reduced oxidation reduction potential (ORP) and; 2) the presence of PCE breakdown products including TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and VC. DCE is present in several groundwater samples and VC is present at elevated levels downgradient and southeast of the site.

The distribution of the PCE breakdown products (i.e., TCE, *cis*-1,2-DCE, and VC) reflects that as dissolved PCE is transported with groundwater toward the north-northwest, total PCE concentrations decrease and a corresponding increase in breakdown products occurs. The greatest concentrations of the breakdown products were observed near the northwest corner of the property (specifically NM-MW-04D) as shown in Figure 2-6.

The dissolved phase chlorinated solvents appear to be migrating to the fine to coarse sand layer located up to 19 feet bgs. Groundwater samples collected from the deeper fine silty sand layer and the silt (with some clay) unit did not show any significant contamination.

Benzene concentrations exceeded the Class GA SCG at locations NM-GS-04, NM-GS-06, NM-GS-07, and NM-MW-04S. All of these locations are located north of the site building and are likely related to the building's historical use as a gas station.

2.7.3 Structure Sampling

From 2005 to 2008, air samples were collected from eighteen residential and/or commercial buildings surrounding the site, plus the site building itself in order to determine whether actions were necessary to address potential soil vapor intrusion from occurring in buildings. Figure 2-7 shows the general locations of the buildings sampled. Based on the air sampling results, the State installed subslab depressurization (SSD) systems at two commercial buildings and one residential building. In addition, the site owner installed an SSD system in the site building. Subsequent soil vapor intrusion sampling results following SSD installation documented effective mitigation.

2.8 Summary of Qualitative Human Health Exposure Assessment

A Qualitative Human Health Exposure Assessment (HHEA) was presented in the RI. The HHEA provided a summary of potential exposure pathways and potentially toxicological effects that may result from exposure to contaminants attributable to former site activities under current and potential future site conditions. The HHEA used data and information collected from the RI, together with data collected as part of previous investigations, to assess human health exposure in the immediate and surrounding areas. The HHEA identified twelve chemicals of potential concern (CPCs) for the mediums of potential concern at this site. A medium of potential concern is identified when one or more contaminants are detected at concentrations exceeding SCGs. Results indicated that:

- Concentrations of site-related contaminants exceeded SCGs in groundwater samples collected during the RI and/or previous site investigations. Consequently, groundwater is considered a medium of concern.

- Concentrations of site-related contaminants in subsurface soil exceeded SCGs in samples collected during the RI. Consequently, subsurface soil is considered a medium of concern.

- Concentrations of site-related contaminants in subslab vapor and indoor air resulted in mitigation activity in accordance with State guidance. Consequently, soil vapor and indoor air are considered to be mediums of concern.

- Concentrations of site-related contaminants in outdoor air samples were generally consistent with levels commonly found in outdoor air. Consequently, outdoor air was not considered to be a medium of concern at the time of the RI.

In summary, CPCs for the mediums of concern are:

1,1-dichloroethene	groundwater
trans-1,2-DCE	groundwater
cis-1,2-DCE	groundwater
PCE	groundwater, soil, soil vapor/indoor air
TCE	groundwater, soil, soil vapor/indoor air
VC	groundwater
1,2,4-trichlorobenzene	groundwater
benzene	groundwater
ethylbenzene	groundwater, soil
xylene	groundwater, soil
isopropylbenzene	groundwater
acetone	soil.

2.8.1 Potentially Exposed Receptors

The previous and current use of the site is commercial. The area immediately surrounding the site is mixed-use commercial/residential. Other than residential fencing on the adjacent properties to the west and south of the site, access to the site is not restricted. The future use of the site and the surrounding area is anticipated to be the same as the current use.

Currently, there are no known potable wells within the immediate vicinity of the site. The City of Ithaca supplies potable water to residences in this area from a reservoir in Six Mile Creek located approximately 3.5 miles southeast of the site. An ice cream manufacturer is located approximately 1,000 feet away and has onsite wells. These have been tested by the Tompkins County Health Department and found to be non-detect for VOCs. However, the company has been advised to use this water, if necessary, for non-contact cooling purposes only. This business is also served by municipal water.

Under both the current and future use scenarios, potentially exposed receptors include commercial workers in buildings located at and near the site, nearby residents, other workers (e.g., construction) at and in the vicinity of the site, and trespassers.

The potential future use includes continued commercial use of the property, including possible future construction activities. Thus, construction workers have also been identified as potential receptors if construction occurs at the property in the future. Residents or site workers could be exposed through groundwater ingestion if wells were installed near the site and the water was used for human contact and/or consumption.

2.8.2 Exposure Pathways

Under the current use scenario, exposure to site-related contaminants via indoor air was identified as a completed exposure pathway for some receptors. While direct exposure to contaminated soil or groundwater is not considered to be a completed exposure pathway under the current use scenario, these media contribute to the contaminated soil vapor.

Under the future use scenario, exposure to site-related contaminants via groundwater, subsurface soil, and indoor air are identified as potentially completed exposure pathways for some potential receptors. Groundwater may be used for either non-potable or potable purposes, assuming there are no restrictions on the installation of private wells. Exposure may also occur during potential commercial or residential construction efforts on the site or at nearby residences. Ingestion, dermal absorption, and inhalation of VOCs are potential exposure pathways if contaminated media are exposed. Indoor air contamination directly caused by soil and groundwater contamination would continue to pose an inhalation exposure threat in the absence of continued operation of the mitigation systems currently in place in structures north and south of the site.

3.0 REMEDIAL GOAL AND REMEDIAL ACTION OBJECTIVES

The approach of this FS is in accordance with NYSDEC's "*Draft DER-10 Technical Guidance for Site Investigation and Remediation*" prepared by the NYSDEC, dated December 2002. The development of remedial alternatives includes the following elements:

- Statement of the Remedial Goal.
- Development of Remedial Action Objectives.
- Development of General Response Actions.
- Identification of Areas and/or Volumes of Media to be Addressed.
- Identification of Technologies.
- Assembly of Remedial Alternatives.
- Evaluation of Remedial Alternatives.
- Recommendation of Remedy.

3.1 Remedial Goal

In accordance with DER-10, the remedial goal for site remediation is as follows:

- The remedy will eliminate or mitigate all significant threats to public health and the environment presented by the contaminants disposed at the site.

3.2 Remedial Action Objectives

In order to meet the remedial goal, remedial action objectives (RAOs) were developed to protect public health and the environment and provide the basis for selecting technologies and developing alternatives. In order to develop site-specific RAOs, the generic RAOs presented in DER-10 were considered for the potential mediums of concern (groundwater, soil, soil vapor/indoor air). Table 3-1 presents a summary of the generic RAOs and the rationale for site-specific RAO selection.

Groundwater: As shown in Figure 2-6, some groundwater samples exhibited VOC contamination above Class GA SCGs. The RAOs for groundwater are:

- Prevent ingestion of groundwater with contaminant levels exceeding drinking water quality standards.
- Prevent contact with VOCs from contaminated groundwater during future construction activities.
- Restore groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable.

Soil: Numerical soil cleanup goals for the site are based on Part 375 soil cleanup objectives (SCOs) for unrestricted use. As shown in Figure 2-5, detected soil contaminant concentrations exceeded SCOs for unrestricted use. The RAOs for soil are:

- Prevent direct contact exposure to soil containing VOCs above Part 375 unrestricted use criteria.

Soil Vapor/Indoor Air: Sampling has identified some structures that contained VOC vapors in or below structures at levels that resulted in actions being taken to reduce potential exposures to contaminants through soil vapor intrusion. The RAO for soil vapor/indoor air is:

- Reduce the potential for soil vapor intrusion to occur in buildings.

3.3 Areas of Contamination Addressed

Based on the RI results summarized in Section 2 and the RAOs presented in the previous sections, the areas and depth (as appropriate) of contamination addressed by this FS are described in the following sections.

3.3.1 Groundwater

Groundwater contamination addressed by this FS is limited to the site property itself, with some limited contamination present north of the site. No VOC contamination above SCGs has been observed outside of the site property, with the exception of VC in NM-MW-12D about 100 feet north of the northwest corner of the site. At this location, much higher VOC levels were detected in a grab groundwater sample collected prior to well installation. Groundwater contamination extends from the top of the water table, at approximately 5 to 6 feet bgs, to approximately 19 feet bgs.

3.3.2 Soil

Soil contamination is limited to the site itself. The one soil sample exceeding SCGs beyond the site property was collected near the surface during the installation of NM-MW-08S, where acetone, a non-site-related contaminant, was found at 70 µg/kg. Soil contamination onsite is characterized by high chlorinated VOC concentrations in the southeastern portion of the site (near the presumed original spill location) and is limited to BTEX compounds in the western/northwestern portion. Soil contamination is limited to the near-surface soils, primarily above the water table in the south/southwestern portion of the site. The soil near the southeast corner of the building contains the highest levels of PCE detected in soil, as high as 220,000 µg/kg at a 2 to 4-foot depth. Above-water table soil contamination (though at lower concentrations) extends to the west (towards N. Meadow St.) and to the north (in the backyard of the adjacent 619 W. Court St. property). The extent of contaminated soil is roughly defined by the area shown in Figure 3-1, which is approximately 2,000 sf. Assuming a depth of 5 feet (to the water table), soil remediation would encompass an in-place volume of approximately 370 cubic yards (cy). For the purposes of this FS, it is assumed that due to the high concentrations of PCE detected in several soil samples, half of this volume would require offsite incineration and half would require offsite disposal without treatment.

An underground storage tank (UST) was encountered by URS personnel during RI boring activities in the vicinity of GP-10. Three attempts at installing the boring were met by shallow (approximately 1 to 2’ depths) refusals. Neither the size nor the contents of the UST were determined during the RI. The approximate UST location is shown in Figure 3-1.

3.3.3 Soil Vapor/Indoor Air

Vapor intrusion monitoring was detected in subslab samples as far south as Buffalo Street (Figure 2-7). To the east of the site, only one structure has been impacted, and no impacts were present north, west and northwest of the site. Subslab depressurization (SSD) systems were installed at the onsite building and structures immediately east and south. Air sampling in 2008 resulted in no additional actions being required for structures located near the 315 N. Meadow St. site

3.4 General Response Actions

General response actions are broad response categories capable of satisfying the remedial action objectives for the site.

No Further Action: A no further action response provides a baseline for comparison with other alternatives and includes the ongoing vapor intrusion mitigation program.

Institutional Controls: Institutional controls, such as environmental easements and Site Management Plans, are measures to provide protection to human health and then environment by identifying contamination and reducing exposure.

Exposure Point Mitigation: Remedial measures may be implemented at the point of exposure to mitigate exposure to contaminated material and provide adequate protection to human health and the environment.

Containment: Containment measures are those remedial actions whose purpose is to contain and/or isolate contaminants. These measures prevent migration from, or direct human exposure to, contaminated media without treating, disturbing or removing the contamination.

Removal: Removal measures remove contamination from the subsurface for subsequent treatment and/or disposal.

Treatment: Treatment and disposal measures include technologies whose purpose is to reduce the toxicity, mobility, or volume of contaminants by directly altering, isolating, or destroying those contaminants.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section consists of identifying specific remedial technologies for soil, groundwater and soil vapor/indoor air and evaluating them with respect to their technical implementability in meeting the RAOs for this site. Appropriate technologies will be carried forward into the development of alternatives.

4.1 Identification of Technologies for Groundwater

This section identifies remedial technologies for groundwater at the site. Technologies are identified according to the general response actions presented in Section 3.4.

4.1.1 Institutional Controls

No remedial actions have been performed for groundwater. Institutional controls would provide no action towards remediating groundwater contamination, but would include an environmental easement and a Site Management Plan which may be used in conjunction with, or in the absence of, remedial measures. Currently, groundwater onsite and near the site is not utilized for potable purposes. Potable water is provided to all residents and commercial establishments in the area by the City of Ithaca. However, private wells may be installed in the future. Institutional controls would:

- Require compliance with the approved Site Management Plan.
- Limit the use and development of the property to specific uses (e.g., unrestricted use, commercial use).
- The use of groundwater underlying the site is prohibited without treatment rendering it safe for intended purpose and approval by NYSDOH.
- Include requirements to complete and submit to the NYSDEC periodic certification with long-term monitoring results.
- Identify procedures for characterization, handling, and the health and safety of workers and the community who come into contact with the low levels of contaminated groundwater in the event of intrusive subsurface activity at the site and/or offsite locations where contamination has migrated.

Effectiveness: Institutional controls with an SMP and an environmental easement would be effective in meeting the RAOs of preventing ingestion of groundwater with contaminant levels exceeding drinking water standards, and preventing contact with groundwater contaminated with VOCs during future construction activities, but would not be effective in meeting the RAO of restoring the aquifer to pre-disposal/pre-release conditions.

Implementablity: Institutional controls would not be difficult to implement considering that potable water is provided by the City of Ithaca.

Cost: The cost for institutional controls would be relatively low.

Conclusion: Institutional controls are retained for use at the site.

4.1.2 Exposure Point Mitigation

Because groundwater is not used for personal consumption in the vicinity of the site, Exposure Point Mitigation technologies are not applicable.

4.1.3 Containment

Groundwater containment technologies aim to limit the migration of contaminated groundwater. Containment can be accomplished through physical isolation or hydraulic control. Primary physical containment technologies are the installation of sheet piling or slurry walls. These technologies are particularly effective on small source areas that have not migrated significantly. Hydraulic containment comprises extraction well(s) to reverse natural hydraulic gradients to prevent plume migration. Extracted groundwater typically requires treatment prior to discharge.

Effectiveness: Contamination has not migrated far from the source at the site. However, it has migrated sufficiently far to have impacted adjacent residences through the vapor intrusion exposure pathway. Therefore, containment would not be effective in mitigating the impacts from this plume. Although it may prevent the further spread of contamination from the site, it would not provide a significant exposure reduction.

Hydraulic containment would also be of limited effectiveness because of the relatively low permeability of the soil. Although groundwater in the immediate vicinity of the source area (southeast corner of the building) could be hydraulically contained, the rest of the plume could not be hydraulically contained without the installation of multiple extraction wells.

Implementability: It would be difficult to construct and maintain containment measures over a long time period due to infrastructure in the vicinity of the site including buildings, parking lots, roadways, and subsurface utilities.

Cost: Containment construction costs are low to moderate.

Conclusion: Containment technologies will not be retained for consideration.

4.1.4 Removal

Groundwater contamination can be removed either as a liquid (groundwater removal) or by being volatilized and removed as a vapor through air sparging or electrical resistance heating.

4.1.4.1 Groundwater Removal

Extraction via pumping wells is the typical method for groundwater removal as a liquid. Collection trenches installed perpendicular to the plume flow direction have also been used for groundwater removal. Removed groundwater would have to be treated prior to discharge.

Effectiveness: Groundwater extraction would be of limited effectiveness at this site because of the stratigraphic heterogeneity. Groundwater would be preferentially extracted from the higher permeable sandy units, leaving residual contamination in the less permeable silt and clay units.

Implementability: Groundwater extraction through wells is technically implementable. Removal via collection trenches would be difficult to implement because of the broad distribution of the plume. Additionally, the urban nature of the site and the presumed presence of subsurface utilities would make a trench difficult to install, as it would have to be installed across both W. Court St. and N. Meadow St. to capture the entire plume.

Cost: Groundwater removal through extraction wells has low to moderate capital cost, but would have to operate for a very long time (decades) and thus would incur significant operating costs.

Conclusion: Groundwater removal through an extraction well(s) will be retained for consideration.

4.1.4.2 Air Sparging

Air sparging removes VOCs from groundwater by injecting air into the aquifer, transferring the VOCs into the air, and then collecting the air with a vapor extraction system. The air would be sparged into the lower portion of the sand units (i.e., 20 feet bgs) and collected using horizontal vapor extraction manifolds installed in the vadose zone.

Effectiveness: Contaminants at the site are amenable to removal via air sparging. The highest levels of contamination are primarily found in the sand zones beneath the site. The sand zones are amenable to an even distribution of sparged air and subsequent uniform treatment. However, there is significant heterogeneity in the soil beneath the site, possibly more than is discernable through interpretation of boring logs. Heterogeneity increases near the surface where the shallower zone is more contaminated. This heterogeneity would lead to preferential air flow pathways, and possible non-uniform treatment.

Implementability: Air sparging requires a tight, regular pattern of injection points, including within the building footprint. Therefore access within the building would be required. However, access would only be needed on a temporary basis during system installation, impacting the business operation for a relatively short time (e.g., a matter of days). The air supply to the sparge points could be provided by dedicated air lines installed in trenches in the floor slab.

Installation of the vapor extraction system would pose a greater implementability challenge. Horizontal extraction wells would be required because the vadose zone is shallow. The horizontal wells would have to be installed below the existing building, either by cutting trenches in the existing slab or by horizontally drilling beneath the structure.

For both the air injection and vapor extraction systems, the blowers, condensers, off-gas treatment units, and other ancillary equipment could be located outside the building so impacts to the business operation would occur only during the initial installation.

Cost: The cost for air sparging would be moderate.

Conclusion: Treatment via air sparging will be retained for consideration.

4.1.4.3 Electrical Resistance Heating

Electrical Resistance Heating (ERH) transfers VOCs in groundwater into the vapor phase through heating rather than sparging. Steel electrodes are installed into the subsurface to the maximum depth of contamination in a regular pattern. Electricity is passed from electrode to electrode, using the saturated zone as a conductor. Because the saturated zone is merely an adequate conductor, it provides sufficient electrical resistance. Power in the electrical current is dissipated as heat. This heat causes the groundwater to boil, stripping out the more volatile contaminants. The VOCs and steam are collected by a vapor recovery system similar to, but larger in scope (to accommodate the steam), than that which would be employed with air sparging.

Effectiveness: ERH is more effective than air sparging as it is not dependent on uniform flow of sparged air. Volatilization occurs as a result of heat transfer, which is not affected by soil permeability. The contaminants present at the site are amenable to volatilization via ERH.

Implementability: ERH requires a relatively tight, very regular pattern of injection points, including within the building footprint. Therefore access within the building would be required. Unlike with air sparging, building use would have to be curtailed during treatment as workers and the public would have to be kept away from the high current electrical lines for safety reasons. This would significantly impact the business operation.

Hundreds of kilowatts of power are required to implement ERH. Such capacity may not be available from the local grid.

A vapor recovery system constructed to capture vapor phase VOCs released during the ERH process would be difficult to effectively construct beneath the building.

Cost: The cost of ERH with a vapor recovery system is moderate to high.

Conclusion: ERH will not be retained for further consideration because of the implementability limitations.

4.1.5 Treatment

Treatment technologies destroy contaminants, converting them to less toxic end products. Organic contaminants at the site can be converted through oxidation or reduction processes.

4.1.5.1 In Situ Chemical Oxidation

In situ chemical oxidation (ISCO) uses oxidants delivered into the saturated zone to oxidize the contaminants to innocuous compounds such as water, carbon dioxide, and chloride ions. The three principal oxidants used in environmental remediation are Fenton's reagent, permanganate, and activated persulfate. Within these chemical approaches there are proprietary oxidants such as RegenOx™, Klozur®, and Cool-Ox™ .

Effectiveness: All ISCO approaches are dependent upon aqueous phase contact between the delivered oxidant materials and the contaminant. Therefore, the ability to achieve adequate subsurface distribution closely determines the effectiveness of the approach. In the shallow zone of contamination soils, are less permeable which may lead to uneven reagent distribution.

Methods for increasing subsurface distribution within lower permeability aquifers include hydraulic or pneumatic fracturing, jet grouting, soil mixing, low-pressure injection, and infiltration or gravity feed delivery. The lower permeability soil located near the surface increases the difficulty in using hydraulic or pneumatic fracturing methods for increased amendment distribution. Low-pressure (e.g., less than 50 pounds per square inch gauge [psig]) via permanent injection wells is anticipated to be the most effective delivery method to achieve adequate subsurface distribution.

Fenton's reagent, permanganate, and activated persulfate are effective in oxidizing the contaminants at the site; all have the ability to treat the BTEX compounds present. Permanganate has been observed to be less effective in treating benzene, but has a documented ability to treat the other compounds. Permanganate presents some advantages over Fenton's reagent and persulfate. Although a relatively weaker oxidant than the other two options, it is strong enough for oxidizing the contaminant concentrations present at the site. In contrast, permanganate is a longer-lasting oxidant. It has the potential to remain active in the subsurface for months, allowing it to diffuse and otherwise travel into the lower permeability zones more effectively.

Implementability: Injection of ISCO reagents using low-pressure injection techniques requires a tight, regular pattern of injection points, including within the building footprint. Therefore access within the building would be required. However, access would only be needed on a temporary basis, impacting the business operation for a relatively short time (e.g., a matter of days). Oxidant materials could be delivered by dedicated lines installed in trenches in the floor slab.

Multiple events would be required with limited site access for each event. Temporary equipment would be mobilized to the site and could be located outside to reduce impacts to business operations during each event.

Cost: The costs for ISCO are moderate.

Conclusion: Treatment via ISCO will be retained for consideration. For the development and analysis of remedial alternatives, oxidation by permanganate will be selected as the process option considered for the analysis since it is effective and longer lasting. Low-pressure injection methods will be considered in this option as the delivery method.

4.1.5.2 In Situ Reduction

In situ reduction can be implemented using biological and/or non-biological mechanisms. Both include the sequential dechlorination of target compounds where one chlorine atom is removed at a time, from the starting compound to innocuous end products. Amendment materials used to implement in situ reduction include the following, alone or in combination:

- Biostimulants (e.g., electron donor materials use to create suitable anaerobic aquifer conditions and provide microbial food) such as emulsified vegetable oil (EVO), soluble plant carbon, and sodium lactate-based materials;
- Chemical reducing agents (e.g., where reduction occurs on the contact of the material and may also be used to establish reducing aquifer conditions) such as zero-valent iron materials; and
- Microbial culture (e.g., introduction of laboratory grown bacteria known to degrade target contaminants) such as *Dehalococcoides* (DHC), which is typically only introduced following aquifer conditioning to anaerobic conditions.

For aquifer conditioning and biostimulation, EVO products include: EOS® from EOS remediation, SRS™ from Terra Systems, Inc., and Newman Zone® from Remediation and Natural Attenuation Services, Inc. Each of these products consists principally of a vegetable oil mixture that has been emulsified to serve as a long-term carbon source (acting as an electron donor) and small amounts of sodium lactate for short-term biostimulation, and a variety of other additives and vitamins.

Products in the sodium lactate electron donor category include HRC® products from Regenesis and WilCLEAR® by JRW Bioremediation. The HRC® products typically have increased longevity within the subsurface (months to years); whereas WilCLEAR® is a quickly dissolving lactate solution that is typically consumed very rapidly (weeks to months).

Chemical reducing materials include zero-valent iron (ZVI), a granular or powdered material proven to degrade target compounds such as PCE and TCE via reductive dechlorination. Surface contact is required between the target contaminant and the ZVI material surface. Products such as BOS 100 from Remediation Products, Inc. utilize granular activated carbon (e.g., non-soluble carbon for contaminant adsorption) with iron precipitates on the carbon surface to facilitate abiotic reduction. Treatment using ZVI with abiotic dechlorination alone requires substantial subsurface distribution for contact between the contaminant and the ZVI materials. Therefore, this would typically be implemented using a permeable reactive barrier or very tight spacing across the target treatment area.

Additionally, ZVI can be used for aquifer conditioning, primarily in the ability of ZVI to create reducing conditions (e.g., ORP of less than –200 millivolts [mV]). Several products combine ZVI with an electron donor to support both abiotic and biological dechlorination processes. These combination products include EHC® (e.g., soluble plant carbon and ZVI) from Adventus Americas, Inc. and EZVI (nano-scale ZVI suspended in emulsified oil) from TEA, Inc.

Following biostimulation or aquifer conditioning activities, bioaugmentation, using laboratory grown culture, may be necessary to meet SCGs and/or remedial action objectives. Microbial cultures for reductive dechlorination are commercially available from several vendors including KB-1® from SiREM and Bio-Dechlor INOCULUM® from Regenesis. Microbial cultures are typically introduced once suitable aquifer conditions have been established (e.g., ORP of less than –100 mV and pH between 6 and 8).

The majority of in situ reduction materials presented above rely on microbiological activity to perform complete dechlorination. Dechlorinating bacteria have been found at many sites naturally, even where aquifer conditions may not be suitable for complete degradation to occur. Dechlorination has been observed to be naturally occurring at the site, and therefore, it is likely that some necessary dechlorinating bacteria are present. Bioaugmentation may not be required.

Effectiveness: In situ reduction materials presented above are effective in dechlorinating the chlorinated contaminants present at the site, provided adequate subsurface distribution is achieved. Distribution may be more challenging and less consistent within the shallow zone of contamination where the soils are less permeable. However, many electron donors have longevity of months to years. Bacteria predominantly reside on soil particles and self-distribute (i.e., bloom) as aquifer conditions become suitable. At other sites, this has allowed greater distribution over time within low permeability zones, increasing treatment effectiveness. Dechlorination process appears to be occurring naturally at the site indicating that the site is likely amenable to biostimulation. As with ISCO, low-pressure injection methods are anticipated to be the most suitable delivery method.

Implementability: Injection of in situ reduction reagents requires a tight, regular pattern of injection points, including within the building footprint. Therefore access within the building would be required. However, access would only be needed on a temporary basis, impacting the business operation for a relatively short period of time (e.g., a matter of days). Electron donor and/or microbial culture materials are suitable for low-pressure injection. Materials could be delivered via dedicated lines installed in trenches in the floor slab. Multiple events may be required with limited site access for each event. Temporary equipment would be mobilized to the site and could be located outside to reduce impacts to local business operations during each event.

Materials containing ZVI may require moderate injection pressures to deliver powdered or granular materials. These types of materials would require use of temporary hoses rather than dedicated lines installed within trenches (e.g., powdered or granular material would likely clog dedicated lines). This would require increased access to buildings during injection events, but could still be implemented with limited impacts.

Cost: The costs of in situ reduction are moderate.

Conclusion: Treatment via in situ reduction will be retained for consideration. For the development and analysis of remedial alternatives, biostimulation using an EVO will be selected as the process option considered for the analysis. Bioaugmentation may be included with this option. Low-pressure injection will be included as the delivery method.

4.1.5.3 Natural Reductive Dechlorination

As discussed in Sections 2.7.3 and 5.2.3, there is evidence that anaerobic reductive dechlorination is occurring at this site and may be effective in degrading the site-related chlorinated VOCs to meet remedial action objectives. Although the primary type of contamination is chlorinated ethenes, there is also BTEX contamination, presumably from the site's previous use as a service station. The BTEX compounds can serve as an effective electron donor source, and along with other organic compounds in the soil, promote the natural reduction process.

Effectiveness: Natural processes at the site, including reductive dechlorination in particular, have been shown to be effective in reducing the concentrations of PCE and its degradation products to innocuous compounds.

Implementability: This technology is easy to implement. Natural processes have shown to be effective and do not require additional intrusive activities. A groundwater monitoring program utilizing existing monitoring wells could be implemented to document effectiveness.

Cost: There is no cost associated with natural reductive dechlorination other than continued monitoring.

Conclusion: Since natural reductive dechlorination is occurring at the site, it will not be considered a remedial technology.

4.2 Identification of Technologies for Soil

This section identifies the remedial technologies for soil at the site. Technologies are identified according to the general response actions identified in Section 3.4.

4.2.1 Institutional Controls

To date, no remedial actions have been performed for soil. Institutional controls would provide no action towards remediating soil contamination, but would include an environmental easement and a SMP, which may be used in conjunction with, or in the absence of, remedial measures. Currently, contaminated soil is completely covered at the site by the building and surrounding pavement/gravel. However, future excavation activities at the site could provide an exposure pathway to the VOCs present. Institutional controls would:

- Require compliance with the approved Site Management Plan.
- Limit the use and development of the property to specific uses (e.g., unrestricted use, commercial use).
- Identify procedures for characterization, handling, and the health and safety of workers and the community who come into contact with the contaminated soil in the event of intrusive subsurface activity at the site and/or offsite locations where contamination has migrated.
- Require future assessment of contamination in soils below the building should the building be demolished in the future.

Effectiveness: While institutional controls would be effective in limiting exposure to receptors, they would not meet soil SCGs.

Implementability: There are no difficulties with implementing this option.

Cost: There is a low cost associated with this option.

Conclusion: Institutional controls will be retained as an option that may be combined with other technologies to meet RAOs.

4.2.2 Exposure Point Mitigation

The RAO for soil is to prevent direct contact exposure to soil containing VOCs above Part 375 unrestricted use criteria. Since contaminated soil is completely covered at the site by the building and surrounding pavement/gravel, there are no existing direct contact exposures to the contaminated soil at the site. Exposure point mitigation technologies are therefore not applicable.

4.2.3 Containment

Containment technologies provide a physical barrier between contaminated soil and potential receptors. Because contaminated soil is currently beneath the building and/or pavement/gravel, and there are no plans for the removal of the building or parking lots, the containment approaches would be identical to the no additional action option.

4.2.4 Removal

For contaminated soil there are two removal technologies: soil excavation followed by offsite treatment and/or disposal; and, removal of VOCs through soil vapor extraction.

4.2.5 Excavation

Excavation removes contaminated soil and the UST from the site followed by transportation offsite for disposal or treatment. Depending on the level of contamination present, soil, the UST, and the contents of the UST, may be disposed and/or treated as hazardous or nonhazardous waste. Although PCE itself is a hazardous waste if disposed, soil contaminated with PCE is handled on a "contained-in" basis, rather than as a mixture of waste. If the contaminants in soil are above levels specified in TAGM 3028 "*Contained In" Criteria for Environmental Media: Soil Action Levels*, then the soil would have to be classified as a hazardous waste and may require treatment prior to disposal.

Effectiveness: Excavation with offsite treatment/disposal is effective in removing contamination, but only to the extent that the contaminated soil can be accessed. Although no soil samples were collected from beneath the site building, the highest levels of PCE in soil were detected near the southeast corner of the building (220,000 µg/kg between 2 to 4 feet bgs at location NM-MW-05S), suggesting that PCE soil contamination continues under the building as well. Soil under the buildings would not be accessible for excavation.

Implementability: Excavation of soil and the UST outside the building are readily implementable. Excavation of soil from underneath the building is not implementable.

Cost: Although the cost of excavation is relatively low, subsequent offsite treatment and/or disposal of soil classified as hazardous is high. The cost of nonhazardous soil disposal would be moderate. The cost of disposal of the UST and any contents is low.

Conclusion: Limited soil excavation (i.e., source area) may be retained as an option to be used as a component of remedial alternatives. Excavation and offsite disposal of the UST, and contents if appropriate, will be retained.

4.2.6 Soil Vapor Extraction

Soil Vapor Extraction (SVE) removes VOCs as vapors from the vadose zone by applying a vacuum to the soil, causing fresh air to be drawn past the contaminants adsorbed to soil particles. As fresh air passes by the contaminated soil, VOC mass is transferred to the air in an effort to re-establish equilibrium between the sorbed phase and the vapor phase. As the air is recovered by the SVE system, the VOCs in the air are captured and treated.

Effectivness: SVE would be of limited effectiveness at this site because the vadose zone contains low permeability soil. It is difficult to draw air through low permeability soils, and the air that is extracted would pass through preferential pathways, leaving zones untreated, resulting in limiting effectiveness. SVE is not effective in the saturated zone.

Implementability: The vadose zone is relatively shallow at the site, posing an implementability challenge. Horizontal extraction wells would be required. The horizontal wells would have to be installed below the existing building, either by cutting trenches in the existing slab or by horizontally drilling beneath the structure.

Cost: The cost of this technology is mainly driven by the amount of off-gas treatment required. Because of the limited effectiveness of the technology in only the vadose zone, off-gas treatment requirements would not be great and thus costs would be low.

Conclusion: This technology will not be retained for soil.

4.2.7 Treatment

Treatment technologies destroy contamination by converting contaminants to less toxic forms. As with groundwater, organic contamination in soil can be converted either through oxidation or reduction. However, reduction chemistry requires anaerobic conditions which are not present in the vadose zone. Thus, treatment is limited to chemical oxidation technologies.

4.2.7.1 In Situ Chemical Oxidation

The three ISCO reagents, Fenton’s reagent, permanganate, and activated persulfate, presented for groundwater treatment in Section 4.1.5.1, would be effective in varying degrees in the vadose zone as well. Because the reaction occurs in the aqueous phase, enough moisture has to be present to allow for adequate mixing of the oxidant solution and dissolved contaminant mass. Typically, ISCO applications in the vadose zone are referred to as chemical flooding.

Effectiveness: All three ISCO reagents are effective in oxidizing the contaminants present at the site. In the shallow zone, soils are less permeable which may lead to uneven reagent distribution. All ISCO approaches depend upon aqueous phase contact between the delivered oxidant materials and the contaminant. Therefore, the ability to achieve adequate subsurface distribution closely determines effectiveness. All have the ability to treat the BTEX present at the site, with some reservation for permanganate. Permanganate has been observed to be less effective in treating benzene, but has a documented ability to treat the other compounds.

Implementability: Injection of ISCO reagents requires a tight, regular pattern of injection points, including within the building footprint. Therefore access within the building would be required. However, access would only be needed on a temporary basis, impacting the business operation for a matter of days.

Cost: The costs for ISCO are moderate.

Conclusion: Treatment via ISCO will be retained for consideration. Oxidation by permanganate is the process option retained for the development and analysis of alternatives.

4.3 Identification of Technologies for Soil Vapor/Indoor Air

This section identifies the remedial technologies for soil vapor/indoor air at the site.

4.3.1 No Further Action

Subslab depressurization (SSD) systems have been installed at the onsite building and structures immediately east and south of the site. Air sampling in 2008 resulted in no additional actions being required for structures located near the site.

Effectiveness: The installation of SSD systems and analytical results from air monitoring to date show that measures already implemented are effective in meeting the air RAO of reducing the potential for soil vapor intrusion to occur in buildings.

Implementablity: SSD systems were installed at the building and the structures located immediately north and south of the site. Air monitoring has been conducted and analytical results evaluated in accordance with State guidance.

Cost: There is no cost associated with No Further Action.

Conclusion: No Further Action is retained for use at the site.

4.3.2 SSD System Inspection and Maintenance

In accordance with State guidance, long-term inspection and maintenance of existing SSD systems, including those installed immediately north and south of the site, could be conducted. Requirements for continued inspection and maintenance would be outlined in the SMP which would require annual re-certification of the operation of the SSD systems.

Effectiveness: The installation of SSD systems and analytical results from air monitoring to date show that measures already implemented are effective in meeting the soil vapor/indoor air RAO of reducing the potential for soil vapor intrusion to occur in buildings.

Implementablity: SSD systems have already been installed at the onsite building and the structures immediately north and south of the site. Continued inspection and maintenance in structures where existing access agreements are in place would be implementable.

Cost: The cost for SSD inspection and maintenance would be low.

Conclusion: SSD inspection and maintenance is retained for use at the site.

4.4 Summary of Remedial Technologies

Remedial technologies retained for use in the development of alternatives include:

- No Further Action.
- Institutional Controls.
- SSD System Inspection and Maintenance.
- Air Sparging.
- In Situ Chemical Oxidation.
- In Situ Reduction.
- Limited Source Excavation.
- Groundwater Extraction and Treatment.

5.0 DEVELOPMENT AND DESCRIPTION OF ALTERNATIVES

This section combines the remedial technologies considered feasible into remedial alternatives for the site. The alternatives are then described.

5.1 Development of Alternatives

In order to meet the remedial goal and remedial action objectives for the site, the following remedial alternatives were developed. They include a comprehensive range of options in a manner which progressively attains RAOs with increasing complexity.

Alternative 1 – No Further Action.
Alternative 2 – Institutional Controls.
Alternative 3 – In Situ Reduction with Limited Source Excavation.
Alternative 4 – In Situ Chemical Oxidation with Limited Source Excavation.
Alternative 5 – Air Sparging.
Alternative 6 – Building Demolition, Soil Excavation and Groundwater Treatment.

5.2 Description of Alternatives

Alternatives are described in accordance with DER-10, with regard to: size and configuration, time for remediation, spatial requirements, options for disposal, permitting requirements, limitations, and ecological impacts.

5.2.1 Alternative 1 - No Further Action

Under this alternative, soil contaminants would remain above the SCGs for unrestricted use and contaminants present in groundwater would attenuate over time by natural processes which have been shown to be effective on site contaminants. The RAOs for soil and groundwater would not be met. The RAO for air would be met as the installed SSD systems and analytical results from air monitoring to date show that measures already implemented are effective in reducing the potential for soil vapor intrusion to occur in buildings.

Size and Configuration

- No remedial construction would take place.

Time for Remediation

- No active remedial measures for soil or groundwater are included.
- Analytical results from structures installed with SSD systems indicate that measures are effective in reducing the potential for soil vapor intrusion to occur in buildings.

Spatial Requirements

- There are no spatial requirements.

Options for Disposal

- There are no materials requiring disposal.

Permit Requirements

- No permits would be required for this alternative.

Limitations

- This alternative does not meet unrestricted use criteria for soil or SCGs for groundwater.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.2 Alternative 2 – Institutional Controls

Under this alternative, institutional controls would be developed to minimize future exposures to contaminants at the site. This alternative includes long-term groundwater monitoring to assess the degree to which natural processes are effective. Restrictions on groundwater use as a source of potable or process water would be enforced.

The SSD systems are installed and analytical results from air monitoring indicate that indoor air contamination mitigation measures already implemented are effective in reducing the potential for soil vapor intrusion to occur in buildings. In order to provide continued compliance with State guidance, long-term inspection and maintenance of existing SSD systems, including those installed onsite and at structures east and south of the site, would be conducted.

Size and Configuration

- No remedial construction would take place.
- Fifteen existing groundwater monitoring wells shown in Figure 5-1 would be sampled annually and analyzed for VOCs and indicator parameters.
- The four existing SSD systems installed at the onsite building and the two structures east and south of the site would be included in the annual inspection and maintenance program.

Time for Remediation

- Monitoring and provisions of the SMP will be in place over the long term while natural processes continue to reduce contaminant concentrations.

Spatial Requirements

- There are no spatial requirements.

Options for Disposal

- There are minimal materials (i.e., groundwater samples) requiring disposal.

Permit Requirements

- No permits will be required for this alternative; however, a continuance of the access agreements would be required for inspection and maintenance purposes.

Limitations

- This alternative does not meet unrestricted use criteria for soil or SCGs for groundwater.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.3 Alternative 3 - In Situ Reduction with Limited Source Excavation

This alternative comprises injection of an electron donor into the aquifer to promote anaerobic dechlorination of chlorinated VOC contamination. For the purposes of this FS it is assumed that emulsified vegetable oil will be used as the electron donor. As discussed in Section 4.1.5.2, there are other reductive dechlorination reagents, including those based on the release of lactate and those that incorporate ZVI, for example. The final choice of amendment would be made during the design phase of the project.

The distribution of chlorinated ethene species in groundwater makes it clear that reductive dechlorination is occurring naturally. The shallow well near the source area (NM-MW-05S) shows primarily the presence of PCE. Much lower TCE, *cis*-1,2-DCE, and VC concentrations are present at the downgradient end of the site (e.g., well NM-MW-4D). Contamination has primarily shifted to *cis*-1,2-DCE, with some VC present and only residual concentrations of PCE and TCE. This suggests that bacterial populations exist that are suitable for performing reductive dechlorination, but that may be held back due to an insufficient supply of electron donors.

URS collected data on the aquifer chemical/physical parameters of pH, ORP, DO, and conductivity as well as the inorganic parameters of iron, manganese, alkalinity, nitrate, and sulfate. These data are presented in Table 5-1. (Measurements of pH, DO, ORP, and conductivity were obtained once every five minutes during purging. Values in the table are the last of the measurements taken prior to sampling under stable conditions.) These parameters are useful in evaluating whether conditions are suitable for reductive dechlorination. Ideally, DO and ORP would be low to promote anaerobic growth. In general, DO was low, but ORP was not consistently recorded below zero millivolts. However, both these parameters are difficult to accurately measure in water collected during purging; pH measurements were varied. During the phase 1 sampling, the pH measurements were uniform and within the ideal range of 6.5 to 7. During phase 2 sampling, they varied from 4 to 9. (pH should be between 6 and 8 to support bacterial growth.) Phase 2 sampling measurements are suspect as they significantly vary from measurements taken during phase 1. Alkalinity, which buffers the pH, was high in the 200 – 400 milligram per liter (mg/L) range. This indicates buffering capacity against such wide swings in pH, and would assist in buffering the aquifer as volatile fatty acids are produced during the biological reductive dechlorination process. Iron, manganese, sulfate, and nitrate can compete as electron acceptors. Sulfate concentrations are moderately high (100 – 200 mg/L) in some wells, but lower in wells such as NM-MW-04S and NM-MW-02D where significant degradation products are observed. The metals levels are not very high.

Overall, the indicator parameters suggest that the site is amenable for anaerobic reductive dechlorination, but sufficient organic material will be required to lower the ORP and overcome sulfate competition to enable more complete dechlorination.

To address contaminated soil in the vadose zone where anaerobic conditions cannot be established, and therefore where soil (source) contamination cannot be treated by the in situ reduction reagent, soil will be excavated where accessible. Excavated soil would be sent offsite for disposal and/or treatment.

The installed SSD systems and analytical results from air monitoring to date show that indoor air contamination mitigation measures already implemented are effective in reducing the potential for soil vapor intrusion to occur in buildings. In order to provide continued compliance with State guidance, long-term inspection and maintenance of existing SSD systems would be conducted. The existing SSD systems installed on the structures east and south of the site would be included.

Size and Configuration

- The treatment reagent is applied to the subsurface through the rods of a direct push rig during two injection events. Typically, the rods are driven to the deepest treatment point, and then withdrawn in stages as reagent is applied through the depth of contamination. A pilot study would be conducted to select the appropriate treatment reagent. Treatment reagent should be applied in a regular grid pattern to effectively achieve subsurface distribution and reach contamination present in the aquifer. Assuming a 15-foot radius of influence (ROI), a possible injection pattern is shown in Figure 5-2 which includes 21 injection points, including a few within the southern portion of the building (which should be accessible using a direct push rig).
- Each injection point would apply reagent throughout a depth interval of about 5 to 20 feet bgs. There are many approaches to determining the appropriate electron donor dosage, including mass per cubic yard, stoichiometric ratios (based on amount of hydrogen released and hydrogen required by electron acceptors), and volume required by pore volume or soil adsorption targets. According to several EVO

vendors, a mass-to-volume-based dosage estimate should fall between 0.5 and 2.5 pounds of EVO material per cubic yard of media is recommended. However, this is the least site-specific approach. To be more site specific, the dosage can be based stoichiometrically from the contaminant and sulfate concentrations, or from the percentage of pore volume displaced and/or the amount that would be adsorbed onto the soil medium. Rough calculations of EVO requirements using these more site-specific approaches are presented in Appendix B. These calculations include dose calculations for two of the products on the market, Newman Zone from RNAS and EOS from EOS Remediation. These calculations evaluate possible EVO requirements based both on the highest contaminant levels detected in the dissolved phase, the average sulfate level of ~60 mg/L at this site and a target pore displacement percentage of 20% (Newman Zone) or the amount of adsorption to the soil (EOS). The target pore displacement/soil adsorption needs are higher than stoichiometric requirements, and thus drive the dosage estimate of EVO estimate for this site to approximately 10,000 to 20,000 pounds across the 21 injection points. The EVO material would be diluted for injection for a total of approximately 40,000 - 100,000 gallons of solution. It is anticipated that two injection events would be required.

- The injection of the EVO will lower the redox potential further and create even better conditions for anaerobic bacterial growth. Should bacterial levels remain low following the initial injection, bioaugmentation would be an appropriate component of the second injection to expedite the remediation process.
- This alternative includes excavation of an in place volume of approximately 370 cy of soil near the southeast corner of the building. The excavated area would be backfilled with clean soil and repaved.
- The UST within the soil excavation area, and any contents, would be excavated and disposed of offsite.
- An onsite direct read and sampling and analysis program would be performed during the estimated two year implementation period.
- A five year period of monitoring is included to assess the effectiveness of remediation.

Time for Remediation

- This alternative could be implemented in a matter of months. Each of the two injection events could be completed in approximately four weeks for mobilization, staging of the reagent, and injection activities assuming operation of one injection at a time. Time could be decreased by using a multi-point manifold system. Excavation and backfill could be completed within a matter of weeks.

- Although the site activity could be completed in a timely fashion, the reductive dechlorination process may require one to two years for maximum treatment effectiveness. This time period would be reduced when bioaugmentation is used. Both a two-year onsite direct read and sampling and analysis program, and a five year onsite and offsite monitoring period are included to assess effectiveness.

Spatial Requirements

- No permanent access to the site would be required for this alternative. However, during injection events, nearly full access to the site would be required. Although only one injection location at a time may be serviced, the contractor would shift from one point to another over several days. To gain access to injection locations, some equipment and garment storage areas would have to be moved.

- Treatment reagents would be staged onsite for a matter of weeks during reagent application. This would include storage tanks, mixing skids, and secondary containment.

- During excavation, the side parcel of the site property and the backyard of the 619 W. Court St. property would be inaccessible. This would be a temporary spatial limitation.

Options for Disposal

- Excavated soil and the UST would be transported offsite for disposal/treatment. For the purposes of this FS, it is assumed that contaminant concentrations of 10% of the excavated soil are high enough to require offsite treatment (incineration). The remaining soil should not require offsite treatment prior to disposal.

Permit Requirements

- No permits would be required for injection of treatment reagent. Injection wells incidental to aquifer remediation and experimental technologies are distinguished from hazardous waste injection wells and are designated as Class V under the Underground Injection Control (UIC) program. Class V wells covered by the Federal UIC program are authorized by rule and do not require a separate UIC permit.
- Permitted waste haulers and disposal facilities would be utilized for excavated soil.

Limitations

- The presence of the building provides some limitations to this alternative. Although nearly full coverage of the subsurface can be obtained assuming a 15-foot radius of influence of each injection point, difficult access in the northern portion of the building may leave one small area without direct treatment. However, the permeable nature of the saturated zone below this portion of the site should allow the treatment reagents to treat most of the contaminants in this area.
- The presence of the building provides a limitation to the excavation component of the alternative. Although no soil samples were taken from below the building footprint, it is presumed that spills occurring near the southeast corner of the building may have extended to beneath the building as well.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.4 Alternative 4 - In Situ Oxidation with Limited Source Excavation

Alternative 4 is similar to Alternative 3, but instead of in situ reduction technologies, Alternative 4 uses chemical oxidation reagents to destroy VOC contamination via oxidation. For the purposes of the FS, permanganate oxidation was selected as the ISCO process option that is considered in this alternative. Although the treatment reaction with permanganate (and other oxidants) is different from the reduction technologies, the injection process is similar. Just as with Alternative 3, reagent injection would be through direct push injection. Assuming a 15-foot injection ROI, the injection points would be in a similar pattern as shown in Figure 5-3.

The amount of permanganate required for treatment is typically determined by the natural oxidant demand (NOD) of the aquifer material. No site-specific NOD analyses were performed on soils from the site; however, typical NOD values for this type of soil are 1 milligram per kilogram (mg/kg). Based on this assumed NOD, calculations presented in Appendix C show approximately 14,500 kg of permanganate would be required (assuming injection reaches 60% of pore volumes). Potassium permanganate is less expensive and is delivered as a solid. However, potassium permanganate needs to be mixed into solution onsite, and is limited to a maximum injection concentration of about 4%. This would require up to 40,000 gallons of 4% potassium permanganate solution to be injected. Sodium permanganate is received onsite as a concentrated liquid. Although dilution may be required prior to injection, no solid/liquid mixing is required. Additionally, sodium permanganate may be injected at concentrations up to 20%, requiring less water to be injected into the aquifer, thus reducing the extent of contaminant displacement. Sodium permanganate is selected as the oxidant for this alternative for these reasons. However, while sodium permanganate is simpler to prepare, additional safety and material compatibility issues would need to be considered in the design and implementation.

In contrast to the reductive dechlorination approach, ISCO also works in the vadose zone, albeit less effectively. The aerobic conditions in the vadose zone do not inhibit the oxidation chemical reaction. However, the oxidant is applied as a solution, and thus the vadose zone may not become entirely saturated. There is a therefore a greater chance that portions of the soil remain untreated. It is assumed that permanganate will be applied to the vadose zone under the building as well as the saturated zone.

Size and Configuration

- The size and configuration of the oxidant injection system would be similar in scope to that described above for reductive chlorination in Alternative 3.

- Oxidant would arrive in a tanker truck and be transferred to storage and dilution tanks, and from there dispensed to the injection points.

- At a 20% solution, 8,000 gallons of sodium permanganate solution would be injected into the aquifer. The solution would be injected equally among the approximately 21 injection points shown in a typical arrangement in Figure 5-3. In contrast to Alternative 3, the oxidant reagents are not as long lasting. Therefore, not all the oxidant would be injected at once. The oxidant solution would be injected in three phases, with 50% of the volume injected in the first phase, 25% in the second phase, and 25% in the third phase. This allows contamination levels to be successively polished, potentially reaching lower end concentrations.

- Similar to Alternative 3, this alternative includes excavation of approximately 370 cy of soil near the southeast corner of the building. The excavated area would be backfilled with clean soil and repaved.
- The UST within the soil excavation area, and any contents, would be excavated and disposed of offsite.
- An onsite direct read and sampling and analysis program would be performed during the estimated one year implementation period.
- A five year period of monitoring is included to assess the effectiveness of remediation.

Time for Remediation

- ISCO results in a fast acting chemical reaction. Although the chemical reaction is nearly instantaneous, the rate of treatment is governed by the rate of convective and diffusive transport of the oxidant within the aquifer. Typically, months are allowed to pass between injections to allow for a maximum extent of oxidant migration prior to reinjection of subsequent rounds. Therefore, the overall duration of ISCO treatment would be on the order of up to one year. Both a one-year onsite direct read and sampling and analysis program, and a five year onsite and offsite monitoring period are included to assess effectiveness.

Spatial Requirements

- The spatial requirements would be similar to those described for Alternative 3.

Options for Disposal

- Soil and UST disposal requirements would be the same as those described for Alternative 3.

Permit Requirements

- Permit requirements would be similar to those described for Alternative 3. Because the oxidants, unlike EVO and other electron donors, are considered hazardous material, more extensive storage control requirements would apply.
- Permitted waste haulers and disposal facilities would be utilized for excavated soil.

Limitations

- The presence of the building presents similar limitations as those described for Alternative 3. However, the oxidant would be more effective for treating vadose zone soil under the building.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.5 Alternative 5 - Air Sparging

This alternative uses a single approach to removing VOCs from both the saturated and vadose zones, capturing VOCs using activated carbon followed by offsite destruction. This technology would entail construction of a treatment building housing a blower, a vacuum pump, and carbon canisters for vapor recovery. The blower would deliver air to the subsurface through an array of air injection wells, while the vacuum pump would draw a vacuum through horizontal pipes in the vadose zone to collect injected air and stripped-out VOCs.

Size and Configuration

- Because of the heterogeneity of the subsurface, the spacing of the air injection wells would have to be relatively tight. Since injected air flows more quickly through the saturated zone than the aqueous treatment reagents considered in Alternatives 3 and 4, the confounding issue of preferential flow pathways is greater with this technology. A tighter air injection well spacing of 20 feet (10 foot ROI) may be required, and is assumed for this evaluation. A possible air injection well arrangement using 30 wells is shown in Figure 5-4. A pilot study would be conducted to select the appropriate spacing.

- A treatment building would be constructed onsite within the parking lot to house the blower, vacuum pump, carbon treatment, and other required equipment. Dedicated air lines would be installed below grade from the treatment building to each of the sparge wells.
- Due to the shallow nature of the vadose zone, the vapor recovery component of the air sparge system would consist of horizontal wells. These wells would be installed by trenching to a depth of 2 to 3 feet and placing slotted PVC pipe in gravel bedding. The trenches would be backfilled with clean soil and repaved. The horizontal wells would be installed at a spacing of roughly 15 feet, corresponding to the distances between the rows of injection wells installed (to the extent practical).
- To minimize the amount of air drawn from the surface, existing pavement at the site would have to be patched and/or repaired to provide a relatively air-tight surface. Where the system extends into the neighboring 619 W. Court St. back yard, a temporary surface membrane barrier would be installed to minimize short circuiting.
- Extracted air would be passed through activated carbon to remove VOCs prior to discharge to the atmosphere. Two carbon units would be placed in series, with the leading unit removed from service (and sent offsite for disposal/regeneration) once breakthrough was observed.
- An onsite direct read and sampling and analysis program would be performed during the estimated two year implementation period.
- The UST, and any contents, would be excavated and disposed of offsite.
- A five year period of monitoring is included to assess the effectiveness of remediation

Time for Remediation

- Air sparging systems have the greatest rate of contaminant removal upon start up, and asymptotically trend towards *de minimis* removal rates. The decision of when to shut down the system is made by professional judgment through an evaluation of monitoring results and the rate of VOC removal. For the purposes of this evaluation, it is assumed that the air sparging system would operate continuously for two years.

Both a two-year onsite direct read and sampling and analysis program, and a five year onsite and offsite monitoring period are included to assess effectiveness.

Spatial Requirements

- The air injection and vapor recovery wells would be located below grade. However, a treatment building housing the blower, vacuum pump, carbon treatment, and other equipment would be required, and would take up a portion of the parking lot.

Options for Disposal

- The air extracted by the vapor recovery system would be passed through activated carbon upon which the contaminants adsorb. When breakthrough occurs on a canister, the carbon from that canister would be sent offsite for treatment. The carbon would likely contain sufficiently high levels of chlorinated ethenes to be considered hazardous, and would thus require incineration for disposal.
- Collected liquid would be containerized and periodically disposed offsite.
- The UST and any contents would be disposed offsite.

Permit Requirements

- Although no permits would be required because the remediation would be part of a State Superfund cleanup, the requirements for an air permit would have to be met.

Limitations

- The lower permeability soils within the shallow vadose zone may make it difficult to effectively capture air and vapors from this area.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.6 Alternative 6 - Building Demolition, Soil Excavation and Groundwater Treatment

Under this alternative, the building would be partially demolished so that contaminated soil could be excavated. Groundwater would be extracted and treated. The highest concentration of PCE in the soil (220,000 µg/kg) is located immediately adjacent to the southeast corner of the building. PCE levels above SCGs extend greater than 50 feet in the northeast and southwest direction. Considering the high levels of PCE in subslab gas under the site building (as high as 630,000 µg/m^3), it is reasonable to assume that PCE extends to a similar extent in the northwest direction, under the southern portion of the building. Therefore, a portion of the building will have to be demolished to reach the contaminated soil. Based upon visual inspection, the building appears to be two separate, connected buildings and is presumed to be a former gasoline/service station. The northern portion of the building houses offices and a service desk for the current tenants, and sits on a slab of higher elevation than the southern section. The southern section of the building houses the actual dry cleaning operations and appears to be the former automobile service garage. Because of the segmented nature of the building, only the southern portion of the building is assumed to require demolition in order to reach the contaminated soil. This alternative would therefore include demolition of the southern portion, disposal of the demolition debris, and construction of a new wall to enclose the remaining portion of the building.

Size and Configuration

- Following demolition of the building, the area to be excavated would be as depicted on Figure 5-5. This area assumes that contamination extends 40 to 50 feet into the interior of the building, commensurate with the approximate spread observed outside the building and the distribution of high subslab PCE measurements in this portion of the building.
- The depth of excavation would be approximately 5 feet corresponding to the top of the water table.
- Groundwater would be extracted from two wells. The first would be located near the southeast corner of the building, near the existing well NM-MW-05S, which has registered the highest levels of VOC contamination at the site. This well would be screened at an interval of 8 to 18 feet bgs that encompasses the screened interval of NM-MW-05S and also the sand zone below it which is contaminated as measured by NM-MW-2D. The second well would be located at the northwest corner of the property near the intersection of N. Meadow and W. Court St. This location is near the locations of wells NM-MW-04S and NM-MW-04D. This well would be screened at a depth of interval of 9 to 19 feet corresponding to the depths of these wells. These wells would be pumped at a total rate of 3 gallons per minute (gpm),

which is estimated to be sufficient to induce a radius of influence covering the entire site.

- Extracted groundwater would be treated onsite through air stripping. A trailer-mounted air stripping system, complete with a shallow tray stripper, required surge capacity, and control equipment would be installed in the southern portion of the site. The treated groundwater would be discharged to the storm sewer running under N. Meadow St. The offgas from the treatment system would be treated with carbon adsorption.
- A ten year period of groundwater monitoring is included to assess the effectiveness of remediation.

Time for Remediation

- The demolition and excavation component of the remedy could be implemented in a matter of months.
- The installation of the groundwater extraction and treatment system could be accomplished in a matter of months. The system would have to operate for an estimated ten years until the contaminants are reduced to groundwater standards.

Spatial Requirements

- This alternative would require a treatment building housing the stripper, controls, tanks, vapor phase carbon, and other equipment, and would take up a portion of the parking lot.

Options for Disposal

- Soil and UST disposal requirements would be the same as those described for Alternative 3.

Permit Requirements

- A permit or permit equivalent would be required for discharge of treated water to the storm sewer.

Limitations

- The rate of contaminant removal from the groundwater would be limited by the rate of desorption from the saturated zone aquifer material. It may take a decade or more to reduce groundwater concentrations to standards using extraction.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

6.0 DETAILED ANALYSIS OF ALTERNATIVES AND RECOMMENDED REMEDY

6.1 Description of Evaluation Criteria

Each of the alternatives is subjected to a detailed evaluation with respect to the criteria outlined in 6 NYCRR Part 375. A description of each of the evaluation criteria is provided below. This evaluation aids in the selection process for remedial actions in New York State.

Overall Protection of Public Health and the Environment

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

Compliance with Standards, Criteria, and Guidance

This criterion determines whether or not each alternative and the proposed remedial technologies comply with applicable environmental laws and SCGs pertaining to the chemicals detected in contaminated media and the location of the site.

Long-term Effectiveness and Permanence

This criterion addresses the performance of a remedial action in terms of its permanence and the quantity/nature of waste or residuals remaining at the site after implementation. An evaluation is made on the extent and effectiveness of controls required to manage residuals remaining at the site and the operation and maintenance systems necessary for the remedy to remain effective. The factors that are evaluated include permanence of the remedial alternative, magnitude of the remaining risk, adequacy and reliability of controls used to manage residual contamination.

Reduction of Toxicity, Mobility or Volume with Treatment

This criterion assesses the remedial alternative's use of technologies that permanently and significantly reduce toxicity, mobility, or volume (TMV) of the contamination as their principal element. Preference is given to remedies that permanently and significantly reduce the toxicity, mobility, or volume of the contaminants at the site.

Short-term Effectiveness

This criterion assesses the effects of the alternative during the construction and implementation phase with respect to the effect on human health and the environment. The factors that are assessed include protection of the workers and the community during remedial activities, environmental impacts that result from remediation, and the time required until the remedial action objectives are achieved.

Implementability

This criterion addresses the technical and administrative feasibility of implementing the alternative and the availability of various services and materials required during implementation. The evaluation includes the feasibility of construction and operation, the reliability of the technology, the ease of undertaking additional remedial action, monitoring considerations, activities needed to coordinate with regulatory agencies, availability of adequate equipment, services and materials, offsite treatment, and storage and disposal services.

Land Use

This criterion addresses the current, intended, and reasonably anticipated future land use of the site and surroundings. The current and continued use of the site is as a dry cleaning business. While this constitutes a commercial use of the property, Part 375-6 Remedial Program Soil Cleanup Objectives for unrestricted use were utilized since the site is in a mixed residential and commercial area.

Cost

Capital costs and operation, maintenance, and monitoring costs (OM&M) are estimated for each alternative and presented as present worth using a 5% discount rate for duration of future activities.

Community and State Acceptance

Concerns of the State and the Community will be addressed separately in accordance with the public participation program developed for this site.

6.2 Alternative 1 – No Further Action

Under this alternative, contaminated soil and groundwater would remain onsite above SCGs. The installed SSD systems and analytical results from air monitoring to date show that measures already implemented are effective in reducing the potential for soil vapor intrusion to occur in buildings. No construction would be required.

6.2.1 Overall Protection of Public Health and the Environment

This alternative is not protective of public health and the environment. Although there are no current completed exposure pathways (existing SSD systems in the onsite and nearby structures address the vapor intrusion pathway), contamination would remain in groundwater and soil at concentrations that could pose a health threat in the future should site use change and/or subsurface construction activities be conducted.

6.2.2 Compliance with SCGs

This alternative does not meet soil or groundwater SCGs.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.2.3 Long-Term Effectiveness and Permanence

This alternative is not effective in the long term.

6.2.4 Reduction of Toxicity, Mobility and Volume with Treatment

Natural processes which are currently active in soil and groundwater would continue to reduce contaminant levels. However, the existing natural processes would not destroy the majority of the contamination within the foreseeable future.

6.2.5 Short-Term Effectiveness

As there is no construction associated with this alternative, there would be no short-term impacts to workers or the community.

6.2.6 Implementability

This alternative would be difficult to implement due to administrative issues, especially State and local approvals. The RAOs would not be met. The site would not meet the SCGs for unrestricted use, and groundwater contamination would remain above SCGs.

6.2.7 Land Use

This alternative would not allow unrestricted site use, but with the in-place SSD systems, existing uses could be continued.

6.2.8 Cost

There is no remediation cost associated with this alternative.

6.3 Alternative 2 – Institutional Controls

Under this alternative, contaminated soil and groundwater would remain onsite above SCGs. Institutional controls would include long-term groundwater monitoring and during this time period, an environmental easement restricting groundwater use as a source of potable or process water would be enforced. These controls along with long-term inspection and maintenance of the existing SSD systems would provide protection to public health. No construction is included.

6.3.1 Overall Protection of Public Health and the Environment

This alternative is protective of public health and the environment through institutional controls limiting exposure to contaminated soil and groundwater, and inspection and maintenance of existing SSD systems. Long-term groundwater monitoring would evaluate the effectiveness of this alternative in providing continued protection to public health and the environment. Existing SSD systems would remain operational to protect against the vapor intrusion exposure pathway.

6.3.2 Compliance with SCGs

This alternative does not meet soil or groundwater SCGs.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.3.3 Long-Term Effectiveness and Permanence

This alternative is not effective in the long term. Although institutional controls would restrict exposure to contamination and natural processes are reducing contaminant concentrations, residual contamination would remain.

6.3.4 Reduction of Toxicity, Mobility and Volume with Treatment

Natural processes which are currently active in soil and groundwater would continue to reduce contaminant concentrations. However, existing natural processes will not destroy the majority of contamination within the foreseeable future.

6.3.5 Short-Term Effectiveness

As there is no construction associated with this alternative, there would be no short-term impacts to workers or the community.

6.3.6 Implementability

This alternative would be difficult to implement due to administrative issues, especially State and local approvals. The RAOs would not be met. The site would not meet the SCGs for unrestricted use, and groundwater contamination would remain above SCGs.

6.3.7 Land Use

This alternative would not allow unrestricted site use, but with the in-place SSD systems, existing uses could be continued.

6.3.8 Cost

Estimated capital and OM&M costs for Alternative 2 are presented in Table 6-1. The total capital cost is $13,000; annual OM&M costs are $17,900; and the total present worth of Alternative 2 is $289,000.

6.4 Alternative 3 - In Situ Reduction with Limited Source Excavation

Under this alternative, much of the contaminated vadose zone soil would be removed from the site and the saturated zone would be treated with electron donor compounds to promote reductive dechlorination, destroying the VOC contamination. Soil SCGs would be met over the majority of the site following excavation from the (presumed) original spill location. These technologies, along with long-term inspection and maintenance of the existing SSD systems would provide protection to public health.

6.4.1 Overall Protection of Public Health and the Environment

This alternative is protective of public health and the environment through removal (and offsite disposal/treatment) of contaminants in the more-accessible portions of the vadose zone soil and through in situ destruction of VOC contamination in the saturated zone. Existing SSD systems will remain operational to protect against the vapor intrusion exposure pathway.

6.4.2 Compliance with SCGs

This alternative would meet soil SCGs over the majority of the site. It is presumed that some soil contamination in the vadose zone exists below the building, and this would remain. Groundwater SCGs would be met following in situ treatment and natural processes.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.4.3 Long-Term Effectiveness and Permanence

The chemistry and biology of reductive dechlorination is well documented and effective in destroying chlorinated ethenes. The effectiveness of reductive dechlorination at this site will be determined primarily by: the ability to adequately distribute treatment reagent and promote contact between the reagent and the full extent of contamination (in order for the dechlorination reaction to take place); and, the ability of the injected reagent to reduce the ORP to sufficient levels (low enough) such that complete dechlorination can be achieved.

An advantage of biologically-mediated reductive dechlorination, such as provided by EVO, is that the process is slow, yet long lasting. Bacteria can continue to grow and spread both through ongoing growth as well as diffusive and convective transport. This allows the bacteria and the injected reagent to travel into the lower permeability zones, achieve good contact, and treat contaminants present. The use of bioaugmentation following the second injection event would further promote remediation processes.

Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination may remain.

The observation that vinyl chloride is not accumulating in the aquifer suggests that either dechlorination is proceeding all the way to production of ethene, or that any vinyl chloride that is produced is subsequently aerobically oxidized. Alternatively, dechlorination may be stalling somewhat at the cis-1,2,-DCE stage due to inadequate reducing power and subsequent higher ORP. In this later case, bioaugmentation would introduce bacteria known to degrade chlorinated ethenes to ethane.

6.4.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 3 includes excavation of soil exceeding unrestricted use SCGs in the southeastern portion of the site in the presumed spill source area, significantly reducing the volume of onsite soil contamination. In situ treatment included in Alternative 3 would reduce the toxicity of contaminants through degradation to innocuous compounds. The existing SSD systems control the mobility of soil vapor contaminants to eliminate human exposure.

6.4.5 Short-Term Effectiveness

No permanent access to the site would be required for this alternative. However, during construction and injection events, nearly full access to the site would be required impacting dry cleaning workers. During excavation, there would be impacts to adjacent property owners, the community, and the environment which would have to be mitigated through agreements and controls. RAOs would be met for the most part following soil excavation and groundwater treatment.

6.4.6 Implementability

The presence of an active business presents implementability issues during mobilization and injection events. The proposed locations of the injection points are such that relatively few (approximately two) points would have to be located within the more inaccessible portions of the site. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

6.4.7 Land Use

Remediation at the site will not meet unrestricted use criteria due to the presence of contaminated soil beneath the site building; however, existing site use could be continued with in situ treatment and the in-place SSD systems.

6.4.8 Cost

Estimated capital and OM&M costs for Alternative 3 are presented in Table 6-1. The total capital cost is $629,600; annual OM&M costs are $14,900; and the total present worth of Alternative 3 is $675,000.

6.5 Alternative 4 - In Situ Oxidation with Limited Source Excavation

Under this alternative, much of the contaminated vadose zone soil would be removed from the site and both the vadose and saturated zones would be treated through chemical oxidation destroying the VOC contamination. Soil SCGs would be met over the majority of the site following excavation from the (presumed) original spill location. These technologies, along with long-term inspection and maintenance of the existing SSD systems would provide protection to public health.

6.5.1 Overall Protection of Public Health and the Environment

This alternative is protective of public health and the environment through removal (and offsite disposal/treatment) of contaminants in the more-accessible portions of the vadose zone soil and through in situ oxidation of VOC contamination in the remaining vadose and saturated zones. Existing SSD systems will remain operational to protect against the vapor intrusion exposure pathway.

6.5.2 Compliance with SCGs

This alternative would meet soil SCGs over the majority of the site. It is presumed that some soil contamination in the vadose zone exists below the building, and this would be treated using ISCO. Groundwater SCGs would be met following in situ treatment and natural processes.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.5.3 Long-Term Effectiveness and Permanence

Soil excavation and in situ chemical oxidation have been shown to be effective on the contaminants present at the site. Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination may remain.

6.5.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 4 includes excavation of soil exceeding unrestricted use SCGs in the southeastern portion of the site in the presumed spill source area, significantly reducing the volume of onsite soil contamination. Groundwater across the site would be treated by ISCO over one year to achieve degradation of groundwater contaminants through oxidation. The existing SSD systems control the mobility of soil vapor contaminants to eliminate human exposure.

6.5.5 Short-Term Effectiveness

No permanent access to the site would be required for this alternative. However, during construction and injection events, nearly full access to the site would be required impacting dry cleaning workers. During excavation, there would be impacts to adjacent property owners, the community, and the environment which would have to be mitigated through agreements and controls. RAOs would be met for the most part following soil excavation and groundwater treatment.

6.5.6 Implementability

The presence of an active business presents implementability issues during mobilization and injection events. The proposed locations of the injection points are such that relatively few (approximately two) points would have to be located within the more inaccessible portions of the site. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

6.5.7 Land Use

Remediation at the site will not meet unrestricted use criteria; however, existing site use could be continued with in situ treatment and the in-place SSD systems.

6.5.8 Cost

Estimated capital and OM&M costs for Alternative 4 are presented in Table 6-1. The total capital cost is $625,400; annual OM&M costs are $14,900; and the total present worth of Alternative 4 is $663,000.

6.6 Alternative 5 - Air Sparging

Under this alternative, contaminated soil in both the vadose and saturated zones would be treated through air sparging. Collected VOCs (in the carbon canisters), in all likelihood, would be destroyed offsite. Soil and groundwater SCGs would not be met over the majority of the site in the foreseeable future. These technologies, along with long-term inspection and maintenance of the existing SSD systems would provide limited protection to public health.

6.6.1 Overall Protection of Public Health and the Environment

This alternative is protective of public health and the environment through removal of VOCs from soil in the vadose and saturated zones. Existing SSD systems will remain operational to protect against the vapor intrusion exposure pathway.

6.6.2 Compliance with SCGs

Contaminant concentrations in soil will be reduced following air sparging and natural processes. Groundwater SCGs would be met following in situ treatment and natural processes.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.6.3 Long-Term Effectiveness and Permanence

Air sparging has been shown to be effective on the contaminants present at the site; however, at this site, construction issues within the active businesses will make it difficult to construct an effective system across the entire site. Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination may remain.

6.6.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 5 includes treatment of soil in the vadose and saturated zones across the site, including under the building, for one year to collect (and destroy offsite) VOCs. The existing SSD systems control the mobility of soil vapor contaminants to eliminate human exposure.

6.6.5 Short-Term Effectiveness

No permanent access to the site would be required for this alternative. However, during construction, nearly full access to the site would be required impacting dry cleaning workers. During excavation, there would be impacts to adjacent property owners, the community, and the environment which would have to be mitigated through agreements and controls. RAOs would be met for the most part over the long term following treatment.

6.6.6 Implementability

The lower permeability soils within the shallow vadose zone may make is difficult to effectively capture the air and vapors and more wells would be required for this alternative than for other treatment alternatives. The presence of active businesses presents implementability issues during mobilization and injection events. The proposed locations of the injection points and the collection pipes are within the more inaccessible portions of the site. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

6.6.7 Land Use

Remediation at the site may meet unrestricted use criteria depending on the effectiveness of the SVE system in the shallow vadose zone. There may be portions of the vadose zone that remain above the 1,300 μg/kg PCE unrestricted use criterion. The existing site use could be continued with in situ treatment and the in-place SSD systems.

6.6.8 Cost

Estimated capital and OM&M costs for Alternative 5 are presented in Table 6-1. The total capital cost is $770,800; annual OM&M costs are $14,900; and the total present worth of Alternative 5 is $836,000.

6.7 Alternative 6 - Building Demolition, Soil Excavation and Groundwater Treatment

Under this alternative, most or all of the contaminated vadose zone soil would be removed from the site and the saturated zone would be treated by groundwater extraction. Soil SCGs would be met over the majority of the site following excavation from the (presumed) original spill location. These technologies, along with long-term inspection and maintenance of the existing SSD systems would provide protection to public health.

6.7.1 Overall Protection of Public Health and the Environment

This alternative is protective of public health and the environment through removal (and offsite disposal/treatment) of contaminants in the vadose zone soil and through extraction of VOC contamination from the saturated zone. Existing SSD systems (with the exception of the portion of the system located in the portion of the site building that would be demolished) will remain operational to protect against the vapor intrusion exposure pathway.

6.7.2 Compliance with SCGs

This alternative would meet soil SCGs in the vadose zone. Groundwater SCGs would eventually be met. However, groundwater extraction and treatment in heterogeneous stratigraphy present at this site may preferentially treat the higher permeability zones, leaving contamination above SCGs in lower permeability zones.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met.

6.7.3 Long-Term Effectiveness and Permanence

The excavation of the soil represents a permanent remedy for the vadose zone contamination.

Institutional controls would restrict exposure to contamination while the groundwater extraction component is operating. Monitoring over a ten year period is included to assess the effectiveness of proposed remedial measures. Residual contamination may remain.

6.7.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 6 includes excavation of soil exceeding unrestricted use SCGs in the southeastern portion of the site in the presumed spill source area, significantly reducing the volume of onsite soil contamination. Some of the soil will have PCE levels sufficiently high to require incineration prior to offsite disposal. Incineration will permanently reduce the toxicity of these soils.

The extraction and treatment system reduces the mobility and volume of the contaminants through removing them from the aquifer, and transferring them to the carbon used to treat the air stripper off gas.

6.7.5 Short-Term Effectiveness

During construction and injection events, nearly full access to the site would be required impacting dry cleaning workers. The demolition of parts of the building would have a significant impact on the operation of the dry cleaning operation.

During excavation, there would be impacts to adjacent property owners, the community, and the environment which would have to be mitigated through agreements and controls.

6.7.6 Implementability

The presence of an active business presents significant implementability limitations on this alternative. Although only a portion of the building would be demolished under this alternative, it is unlikely that the business could continue operating, even if the business elected to construct a new addition following remediation.

6.7.7 Land Use

Through partial removal of the site building, this alternative would be able to directly address all of the vadose zone contamination above unrestricted use criteria. Groundwater contamination would remain for years, however, which would limit the unrestricted use of the site until the extraction and treatment system reduced the plume to below SCGs.

6.7.8 Cost

Estimated capital and OM&M costs for Alternative 6 are presented in Table 6-1. The total capital cost is $715,400; annual OM&M costs are $69,400; and the total present worth of Alternative 6 is $1,252,000.

6.8 Comparative Analysis of Alternatives

6.8.1 Overall Protection of Public Health and the Environment

Alternatives 3 and 4 are protective of public health and the environment through removal (excavation and offsite disposal/treatment) of contaminants in the more-accessible portions of the vadose zone soil and through in situ treatment of VOC contamination in the remaining vadose (Alternative 4) and saturated zones (Alternatives 3 and 4). Alternative 6 goes further by also excavating the soil under the existing building. Alternative 5 does not include soil excavation, but it is effective and protective, albeit to a lesser extent, through air sparging in the vadose and saturated zones. Existing SSD systems will remain operational to protect against the vapor intrusion exposure pathway for all alternatives, including Alternatives 1 and 2.

6.8.2 Compliance with SCGs

Installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met equally for all alternatives including Alternatives 1 and 2.

Soil SCGs over the majority of the site would be met for Alternatives 3 and 4 following excavation in the presumed original spill location in the southwestern portion of the site. Alternative 6 meets soil SCGs over a larger area by also excavating the soil under the existing building. Alternatives 4 and 5 also include treatment of vadose zone soil under the building using ISCO and air sparging, respectively.

Groundwater SCGs would be met to a greater degree following treatment included in Alternatives 3, 4, 5, and 6. Of these three alternatives, Alternative 3 would likely meet groundwater SCGs in the shortest time frame since it includes reductive dechlorination supplemented with bioaugmentation and Alternative 6 would take the longest, relying on partition of contaminants into groundwater and collection by extraction.

6.8.3 Long-Term Effectiveness and Permanence

The excavation of soil in Alternatives 3, 4, and 6 would provide a permanent solution to the vadose zone contamination. Alternative 6 would provide a great degree of permanent remediation through excavating over a larger area.

The proposed saturated zone treatment systems proposed for Alternatives 3, 4, and 5 have been shown to be effective on the contaminants present at the site. Because of the slow release of electron donors from injected EVO and continued contaminant destruction ability from continuously growing anaerobic bacteria, Alternative 3 would likely provide more thorough destruction of the contamination resulting in better long term effectiveness compared to Alternative 4, which may be more susceptible to rebounds in contaminant concentrations. Alternative 6 would be effective in constraining the spread of the plume and eventually would permanently remediate the groundwater. For all saturated zone treatment technologies, some residual contamination may remain in low permeability zones.

6.8.4 Reduction of Toxicity, Mobility and Volume with Treatment

Natural processes which are currently active at the site would continue to reduce the levels of contaminants at the site for all alternatives including Alternatives 1 and 2. Soil excavation included in Alternatives 3, 4, and 6 would reduce the volume of the contamination present in soil, reducing its toxicity. Alternative 5 would destroy contamination by first extracting it and reducing its volume by transferring it to carbon, and than ultimately destroying it when the carbon is regenerated. The existing SSD systems control the mobility of soil vapor contaminants to eliminate human exposure for all alternatives.

6.8.5 Short-Term Effectiveness

During construction and injection events, nearly full access to the site would be required impacting dry cleaning workers for Alternatives 3, 4, 5 and especially 6. Limited access would be required during sampling for Alternative 2. During excavation, included with Alternatives 3 and 4, there would be impacts to adjacent property owners, the community, and the environment which would have to be mitigated through agreements and controls.

Construction issues presented by Alternatives 5 and 6 within the active business would make these difficult to effectively construct and present short-term effectiveness limitations.

Institutional controls would restrict exposure to contamination while remediation and natural processes reduce contaminant concentrations.

6.8.6 Implementability

The presence of active businesses presents implementability issues during mobilization and treatment included in Alternatives 3, 4, 5, and 6. The proposed locations of the injection points and/or the collection pipes are located within the building, some in areas of limited accessibility. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas. Alternative 5 presents more implementation issues, due to the greater number of injection wells and collection piping required, than Alternatives 3 and 4. Alternative 6 presents the greatest implementation issues as it would require demolition of an entire portion of the building. This would significantly impact the operation of the business.

6.8.7 Land Use

Remediation at the site will not meet unrestricted use criteria except for Alternative 6 which relies on the partial demolition of the site building in order to gain access to contaminated soil northwest of the apparent PCE release point at the southeast corner of the building. Existing site use could be continued for all alternatives with the in-place SSD systems.

6.8.8 Cost

A review of costs for each alternative that Alternatives 5 and 6 have the highest capital cost followed in descending order by Alternatives 3 and 4 (which have essentially the same costs), 2 and 1 (which has no cost). Alternative 1 has no annual OM&M. Alternatives 3, 4 and 5 have similar annual OM&M costs. Alternative 6 has the highest annual OM&M cost.

In ascending order, the alternative which poses the lowest total present worth is Alternative 1 followed by Alternatives 2, 4, 3, 5, and 6 which has the highest total present worth.

6.9 Recommended Remedy

Natural processes currently active at the site would continue to reduce the levels of contaminants for all alternatives including Alternatives 1 and 2; however, Alternative 1 is not protective of human health or the environment. Alternative 2, which does not provide active remedial measures, fully relies on institutional controls for protection. Alternatives 3 and 4 are protective of public health and the environment through removal (excavation and offsite disposal/treatment) of contaminants in the more-accessible portions of the vadose zone soil, and through in situ treatment of VOC contamination in the saturated zone (Alternative 3) and the remaining vadose and saturated zones (Alternative 4). Alternative 5 does not include soil excavation but is protective through air sparging in both the vadose and saturated zones. Alternative 6 includes the greatest amount of contaminated vadose zone excavation, providing a greater measure of protectiveness. Alternatives 3, 4, 5, and 6 are similar in their removal of the UST and any contents. Alternatives 3, 4, 5, and 6 all include technologies that treat groundwater.

The presence of active businesses presents implementability issues during mobilization and treatment included in Alternatives 3, 4, 5, and especially 6. The proposed locations of the injection points and/or the collection pipes are within the more inaccessible portions of the site. Measures would have to be taken to reduce the disruption of business operations both onsite and in the surrounding areas. Alternative 5 presents more implementation issues, due to the greater number of injection wells and collection piping required, than Alternatives 3 and 4. The severe implementability issues posed by Alternative 6 (demolition, which would severely impact the business operation), keep this alternative from being preferred.

Existing installed SSD systems and air monitoring analytical results indicate that air SCGs in affected buildings have been met equally for all alternatives. Soil SCGs over the majority of the site would be met for Alternatives 3, 4, and 6 following excavation in the presumed original spill source area in the southwestern portion of the site. Groundwater SCGs would be met to a greater degree following treatment included in Alternatives 3, 4, 5, and 6. Of these three alternatives, Alternative 3 is expected to provide the largest zone of groundwater meeting SCGs. This is because the biological activity inherent in in situ reduction technologies continues for a longer duration compared to in situ oxidation as the bacteria continue to grow. The effects of in situ reduction can extend farther into low permeability zones during this extended period of operation.

Alternative 3 is the recommended remedy for the site as it is protective of human health and the environment in a cost-effective manner. Alternative 3 meets SCGs for soil vapor/indoor air and for soil over the majority of the site, and would likely meet groundwater SCGs in the over the greatest proportion of the plume compared to the other alternatives. It is effective on the contaminants present at the site by reducing the volume of contaminants in soil and reducing the toxicity of contaminants in groundwater through degradation to less innocuous compounds.

Alternative 3 is implementable at the site and existing site use could be continued with in situ treatment and the in-place SSD systems. The components of the recommended remedy are described in Section 5.2.3.

7.0 REFERENCES

New York State Department of Environmental Conservation. 2002. Draft DER-10, Technical Guidance for Site Investigation and Remediation. December.

NYSDEC. 2006. Subpart 375-6 Remedial Program Soil Cleanup Objectives. December.

URS Corporation, Final Remedial Investigation Report for 315 N. Meadow Property, City of Ithaca, Tompkins County, NY. September, 2009.

TABLES

TABLE 3-1

DEVELOPMENT OF SITE-SPECIFIC REMEDIAL ACTION OBJECTIVES

MEDIUM	REMEDIAL ACTION OBJECTIVE	RATIONALE	SITE RAO
Groundwater	Prevent ingestion of groundwater with contaminant levels exceeding drinking water standards.	Potable water is provided to all residents and commercial establishments in the area by the City of Ithaca. However, private wells may be installed in the future.	Yes
Groundwater	Prevent contact with, or inhalation of, volatiles from contaminated groundwater.	Dermal contact with contaminated groundwater is a potential completed pathway in the event of future intrusive subsurface (construction) activity at the site.	Yes, direct contact
Groundwater	Restore groundwater aquifer to pre-disposal / pre-release conditions, to the extent practicable.	A plume of dissolved contamination consisting of chlorinated hydrocarbons and limited in horizontal and vertical extent is present at the site.	Yes
Groundwater	Prevent the discharge of contaminants to surface water.	Limits of dissolved phase groundwater plume are limited horizontally and vertically and do not extend to nearest surface water body.	No
Groundwater	Remove the source of ground or surface water contamination.	The original source of contamination is unknown but the presumed original spill location is in the southeastern portion of the site.	No
Soil	Prevent ingestion/direct contact with contaminated soil.	Concentrations exceed soil cleanup objectives for unrestricted use.	Yes
Soil	Prevent inhalation of or exposure from contaminants volatilizing from contaminants in soil.	At this site the majority of the property and adjacent areas are covered by pavement and buildings and SSD systems have been installed.	No
Soil	Prevent migration of contaminants that would result in groundwater or surface water contamination.	The majority of soil contamination is present in near surface soils in the vadose (unsaturated) zone. The presence of pavement and buildings significantly reduces infiltration resulting in limited potential for contaminant migration through surface water erosion or to the groundwater system.	No

MEDIUM	REMEDIAL ACTION OBJECTIVE	RATIONALE	SITE RAO
Soil	Prevent impacts to biota from ingestion/direct contact with soil causing toxicity or impacts from bioaccumulation through terrestrial food chain.	At this site the majority of the property and adjacent areas are covered by pavement and buildings.	No
Air	Mitigate impacts to public health resulting from the potential for soil vapor intrusion into buildings.	Structure sampling has identified some structures that contained VOC vapors in or below the structure at levels that resulted in actions being taken to reduce potential exposures to contaminants through soil vapor intrusion.	Yes

TABLE 5-1
IRON, MANGANESE, SULFATE, SULFIDE, NITRATE-NITROGEN, PH, ORP AND DO RESULTS
315 NORTH MEADOW STREET SITE REMEDIAL INVESTIGATION

Monitoring Well	NM-01S	NM-02S	NM-02D	NM-03S	NM-03D	NM-04S	NM-04D	NM-05S	NM-06S	NM-07S	NM-08S	NM-09D	NM-10D	NM-11S	NM-11D	NM-12D
Sample Date: March 2009																
Parameter																
Alkalinity, total (as CaCO3)	390	NT	290	340	350	380	310	270	220	240	480	260	340	250	310	460
Iron	0.086	21	15	4.9	14	20	14	1.5	0.56	0.44	4.1	9.6	7.6	16	4.9	13
Manganese	0.014	7.7	1.2	1.4	0.69	2	1.1	0.24	1.4	0.26	3.8	1	0.64	1.2	0.56	2.5
Nitrate-nitrogen	6.9	NT	1.3	ND	0.21	ND	ND	4.8	ND	0.26	0.14	ND	ND	0.13	ND	ND
Sulfate (as SO4)	53	NT	32	140	3.4	17	20	110	150	78	110	58	ND	36	ND	32
Sulfide, total	ND	NT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH	4.42	9.26	8.82	7.42	9.19	8.98	9.78	4.28	5.86	6.99	7.95	8.65	9.73	8.97	9.29	9.04
ORP	125	-118	-121	-32	-137	-110	-111	136	36	-12	-53	-113	-124	-81	-115	-110
DO	0	7.8	0	0	0	4.81	4.63	0	5.6	0	0	0	5.72	6.15	5.1	0
Sample Date: March 2009																
Parameter																
pH	6.77	6.72	6.63	6.47	6.83	6.58	NS	6.66	6.49	6.59	6.58	NS	NS	NS	NS	NS
ORP	82	28	-93	77	-118	-102	NS	67	63	95	132	NS	NS	NS	NS	NS
DO	2.1	0.044	0.32	0.08	0.18	0.19	NS	1.7	1.27	1.25	0.05	NS	NS	NS	NS	NS
Sample Date: Sept.2007																
Parameter																
pH	6.51	6.43	6.65	6.36	6.74	6.66	NS	6.37	6.24	6.43	6.37	NS	NS	NS	NS	NS
ORP	118	-25	-88	21	-53	-111	NS	95	65	70	52	NS	NS	NS	NS	NS
DO	0.61	0	0	0	0	0	NS	0.95	0	0	0	NS	NS	NS	NS	NS

Notes:
ND = Not detected.
NT = Not tested for due to insufficient sample (well went dry).
NS = Not sampled. Well not yet installed.

TABLE 6-1

REMEDIAL ALTERNATIVE COST ESTIMATES
315 N. MEADOW STREET

Cost Component	Alternative 1 No Further Action	Alternative 2 Institutional Controls	Alternative 3 In Situ Reduction with Limited Source Excavation	Alternative 4 In Situ Chemical Oxidation with Limited Source Excavation	Alternative 5 Air Sparging	Alternative 6 Partial Demolition with Limited Source Excavation and Groundwater Treatment
Total Capital Costs	$0	$13,000	$629,600	$625,400	$770,800	$715,400
Annual OM&M Costs	$0	$17,900	$14,900	$14,900	$14,900	$69,400
Present Worth OM&M Costs	$0	$275,200	$44,700	$36,900	$64,600	$535,900
Years of Monitoring	0	30	5	5	5	10
Total Cost*	**$0**	**$289,000**	**$675,000**	**$663,000**	**$836,000**	**$1,252,000**

* Rounded up to nearest $1,000

FIGURES

SOURCE:
USGS Topographic 7.5 Minute Quadrangles
Ithaca West, New York
Ithaca East, New York

2,000 0 2,000
Feet

URS

315 NORTH MEADOW STREET
SITE LOCATION MAP

FIGURE 2-1

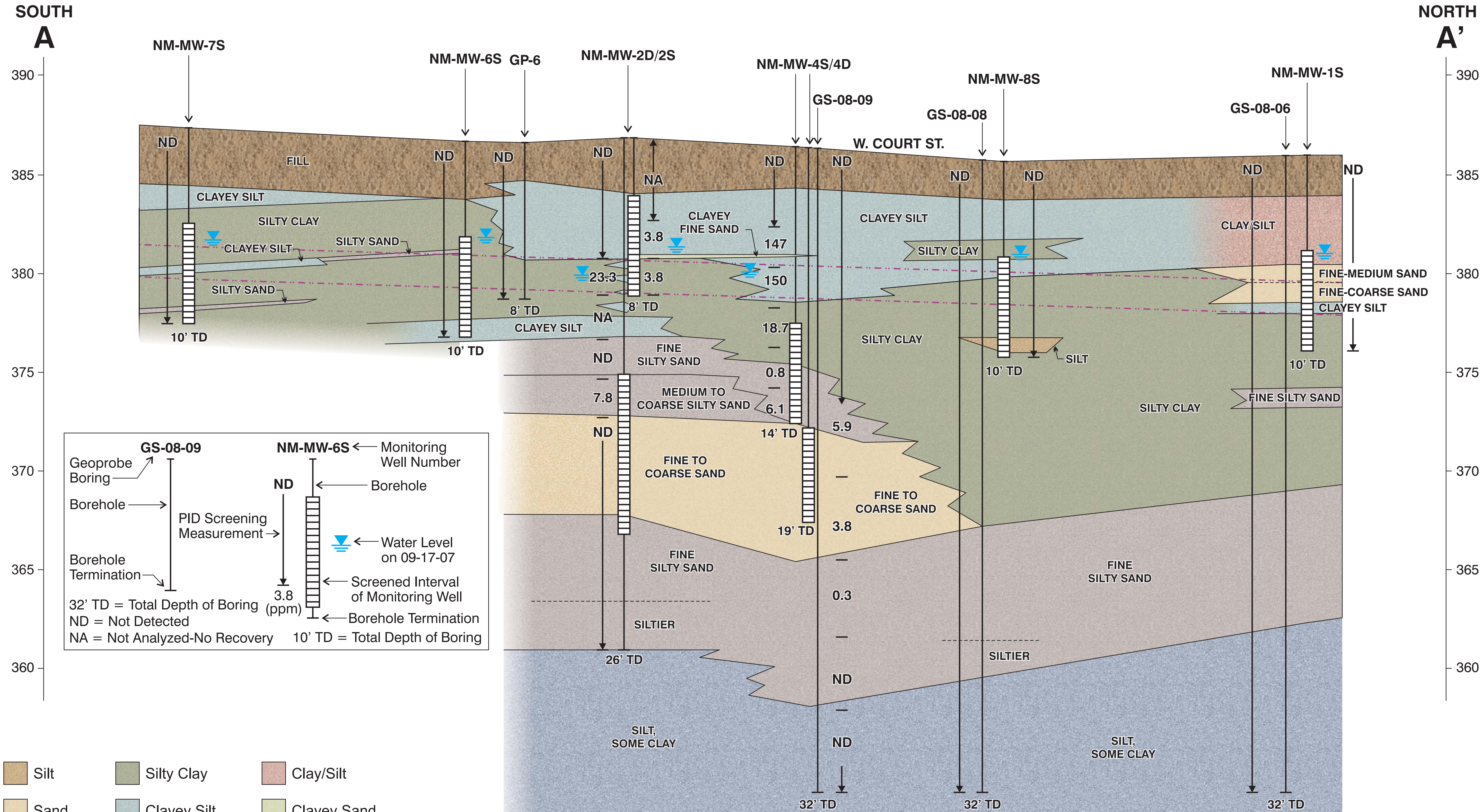
N:\11174365.00000\DB\GIS\FS_figures\FIG 2-1 Site Location.mxd 10/5/2009 BJF

URS

315 NORTH MEADOW STREET
MONITORING WELL AND
GEOPROBE BORING LOCATIONS

FIGURE 2-2

N:\11174365.00000\DB\GIS\FS_figures\FIG 2-2 MW Boring locations.mxd 10/5/2009 BJF



Silt | Silty Clay | Clay/Silt
Sand | Clayey Silt | Clayey Sand
Silty Sand | Silt, Some Clay | Fill

NOTES:
1. Geologic conditions shown are representative of conditions encountered at each boring location to the depth drilled. Extrapolations between borings have been interpreted using standardly accepted geologic practices and principles. Actual conditions may vary between borings from those shown.
2. Elevations based on North American Vertical Datum, 1988.
3. Refer to Figure 2-2 for Cross Section Location.

Approximate depth of 20" sewer line present in North Meadow Street (projected)

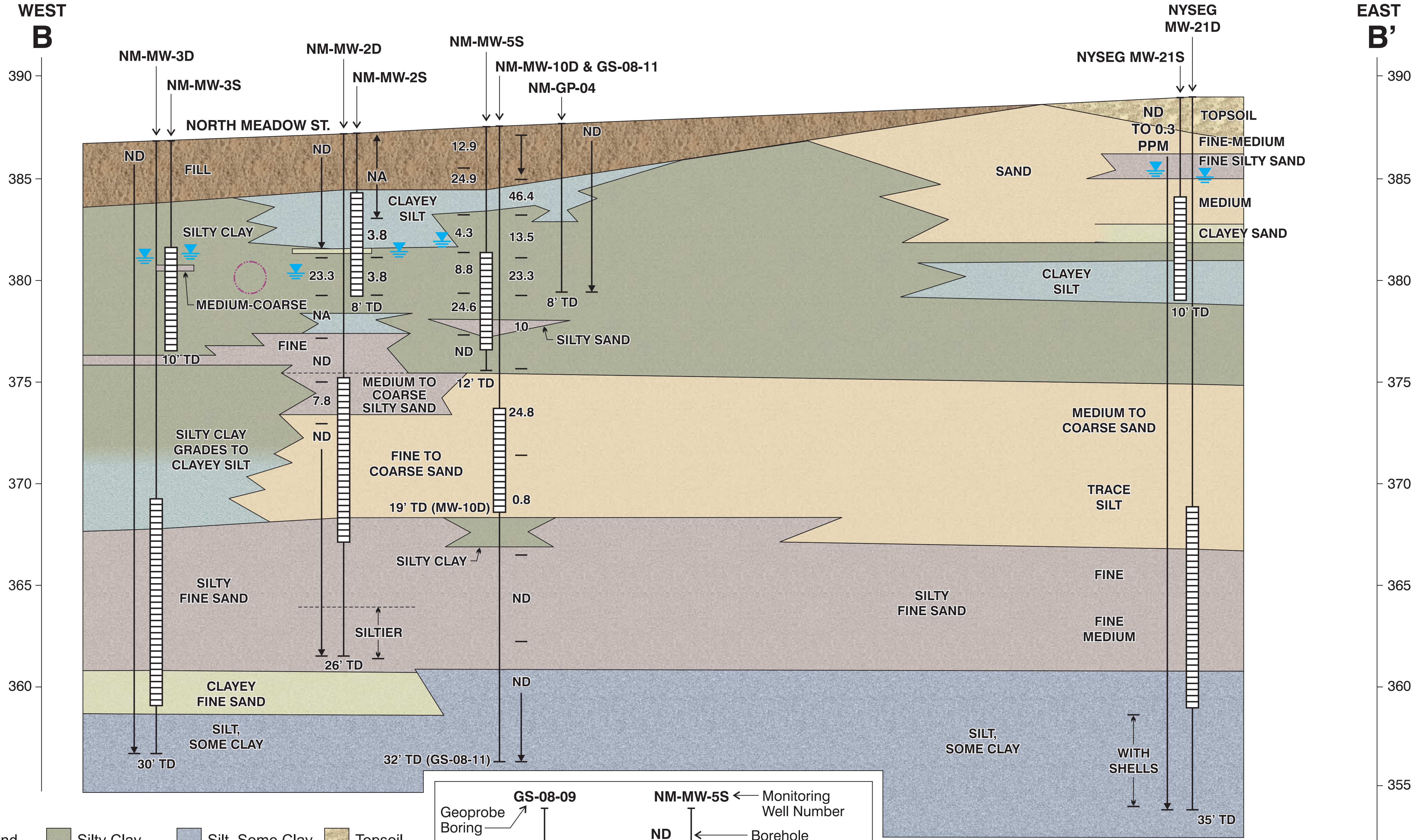
Horizontal Scale: 1" = 50'
Vertical Scale: 1" = 5'
10x Vertical Exaggeration

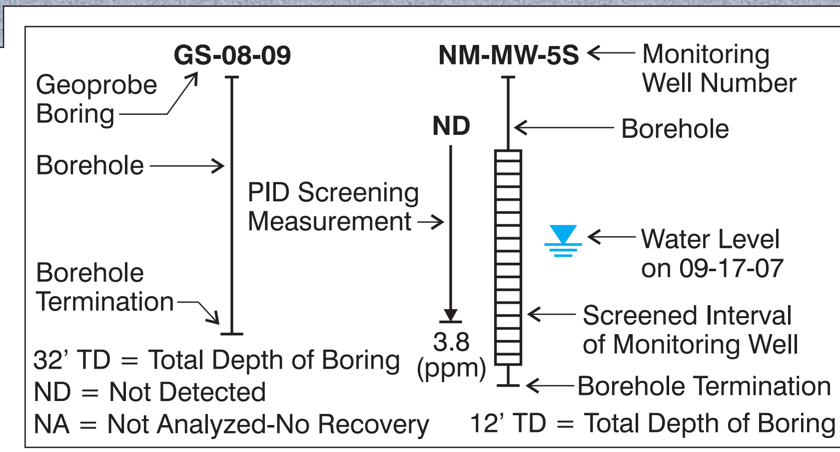
315 NORTH MEADOW STREET
ITHACA, NEW YORK
GEOLOGIC CROSS SECTION A - A'

URS

FIGURE 2-3

AG199308-11175769-100609-GCM





Silty Sand | Silty Clay | Silt, Some Clay | Topsoil
Sand | Clayey Silt | Clayey Sand | Fill

NOTES:
1. Geologic conditions shown are representative of conditions encountered at each boring location to the depth drilled. Extrapolations between borings have been interpreted using standardly accepted geologic practices and principles. Actual conditions may vary between borings from those shown.
2. Elevations based on North American Vertical Datum, 1988.
3. Refer to Figure 2-2 for Cross Section Location.

Approximate depth of 20" sewer line present in North Meadow Street

Horizontal Scale: 1" = 50'
Vertical Scale: 1" = 5'
10x Vertical Exaggeration

315 NORTH MEADOW STREET
ITHACA, NEW YORK
GEOLOGIC CROSS SECTION B - B'

URS

FIGURE 2-4

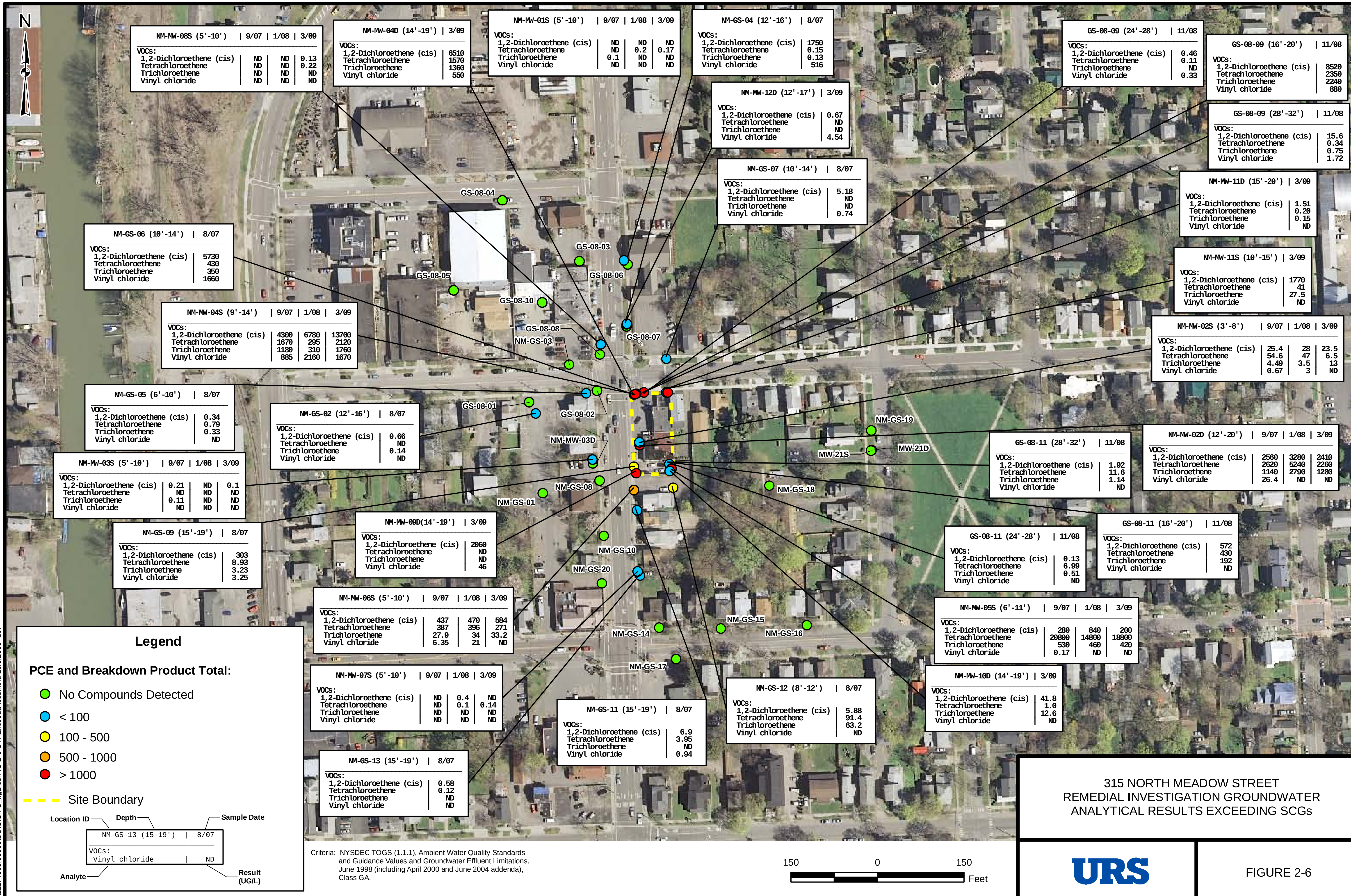
AG19931B-11175769-100609-GCM

URS

315 NORTH MEADOW STREET
REMEDIAL INVESTIGATION SOIL ANALYTICAL RESULTS - EXCEEDING SOIL CRITERIA

FIGURE 2-5

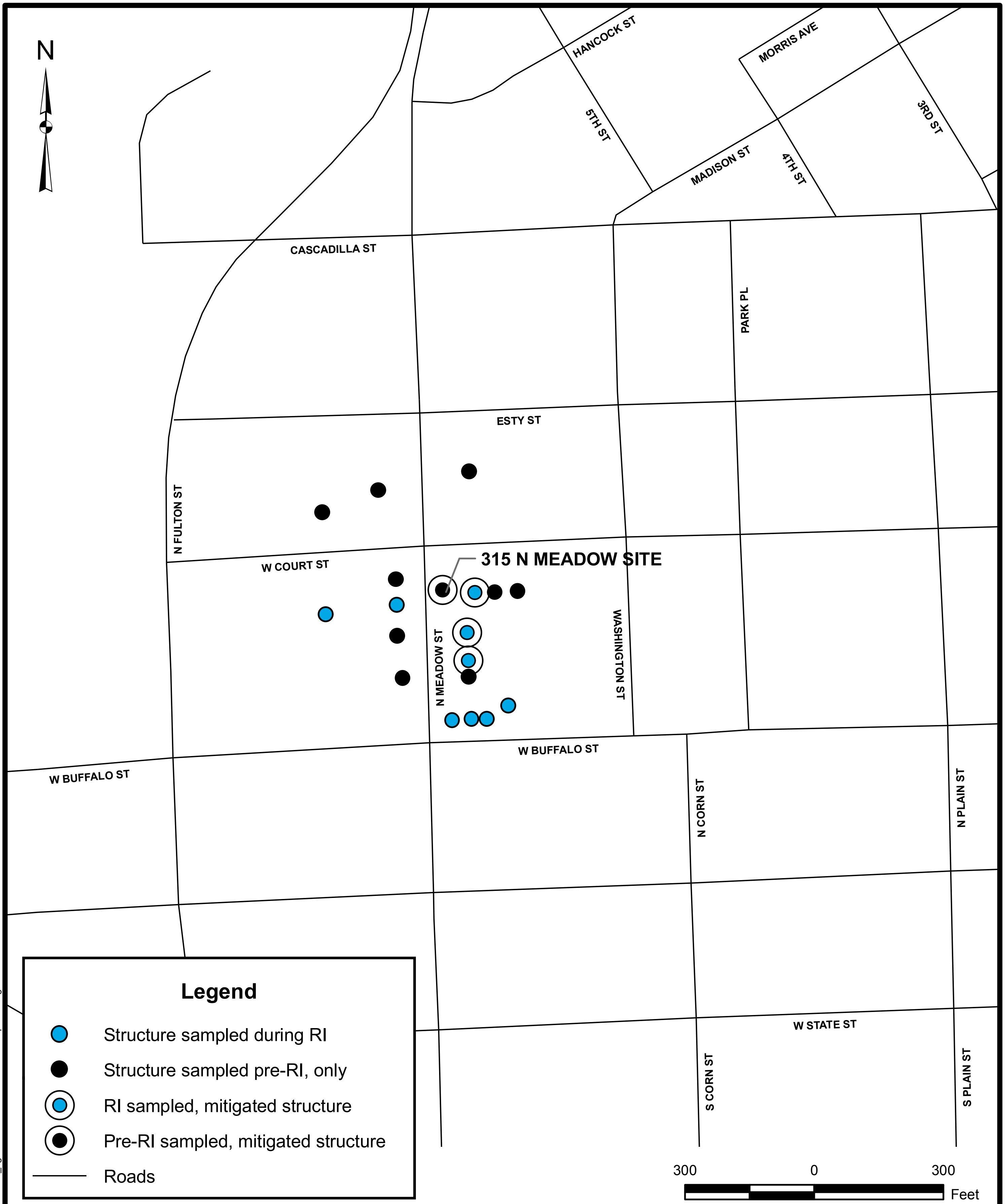
N:\11174365.00000\DB\GIS\FS_figures\FIG 2-5 Soil Exceedances.mxd 10/5/2009 BJF



315 NORTH MEADOW STREET
REMEDIAL INVESTIGATION GROUNDWATER
ANALYTICAL RESULTS EXCEEDING SCGs

URS

FIGURE 2-6

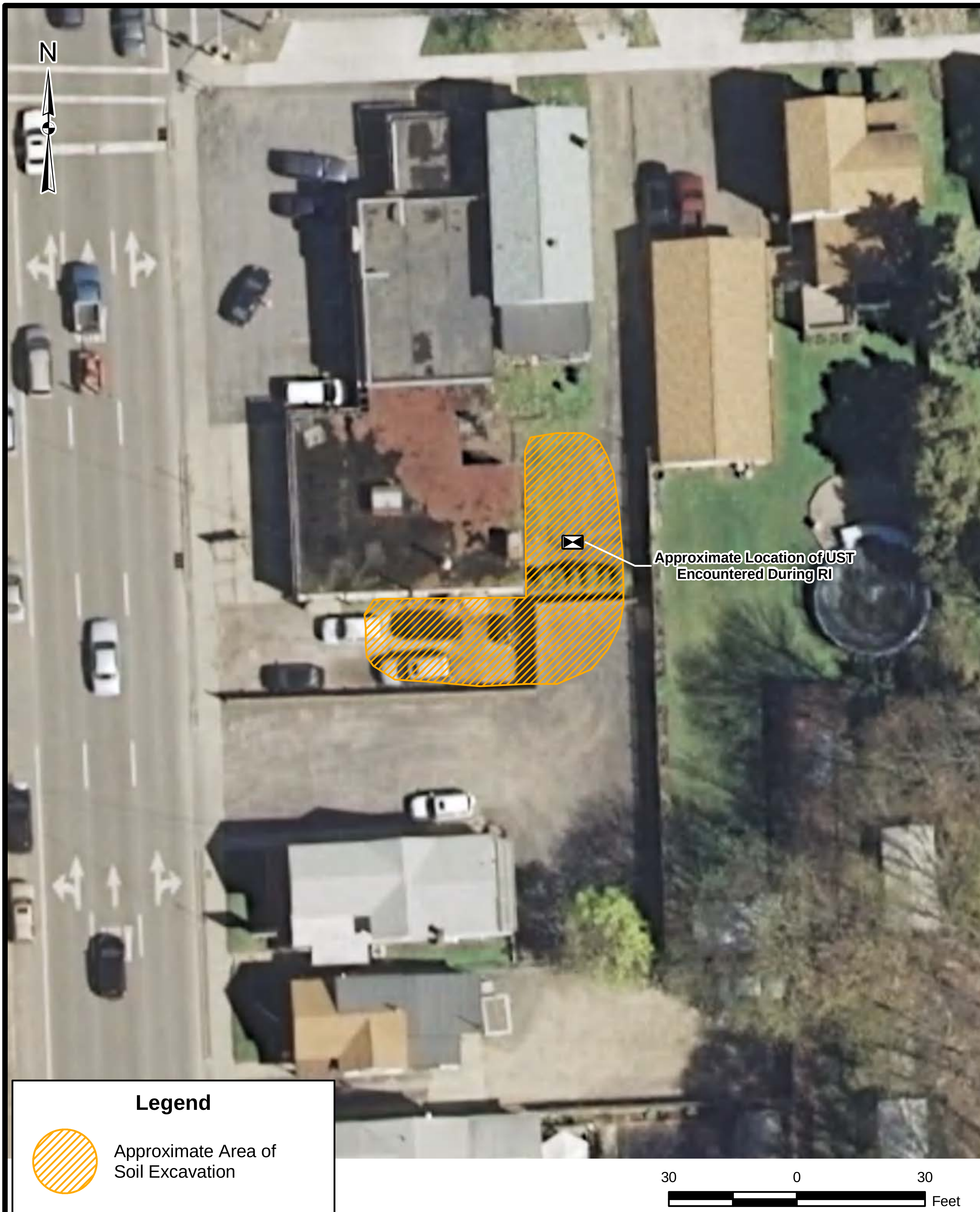


URS

315 NORTH MEADOW STREET
STRUCTURES SAMPLED AND MITIGATED BY SSD

FIGURE 2-7

N:\11174365.00000\DB\GIS\FS_figures\FIG 2-7 Structures Sampled Mitigated.mxd 10/5/2009 BJF

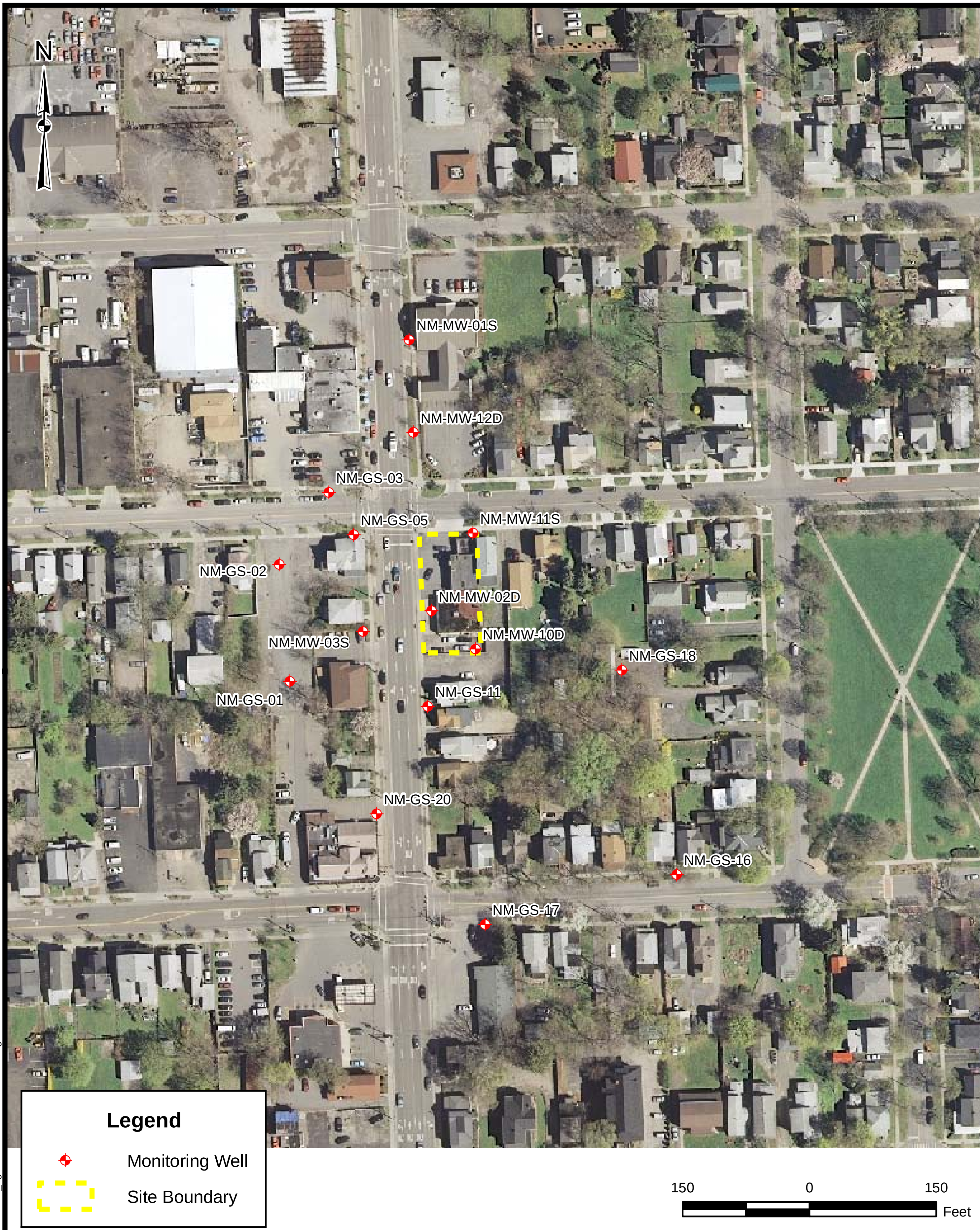


URS

315 NORTH MEADOW STREET
FEASIBILITY STUDY
SOIL REMEDIATION AREA

FIGURE 3-1

N:\11174365.00000\DB\GIS\FS_figures\FIG 3-1 Soil Remediation Area.mxd 10/23/2009 MDL

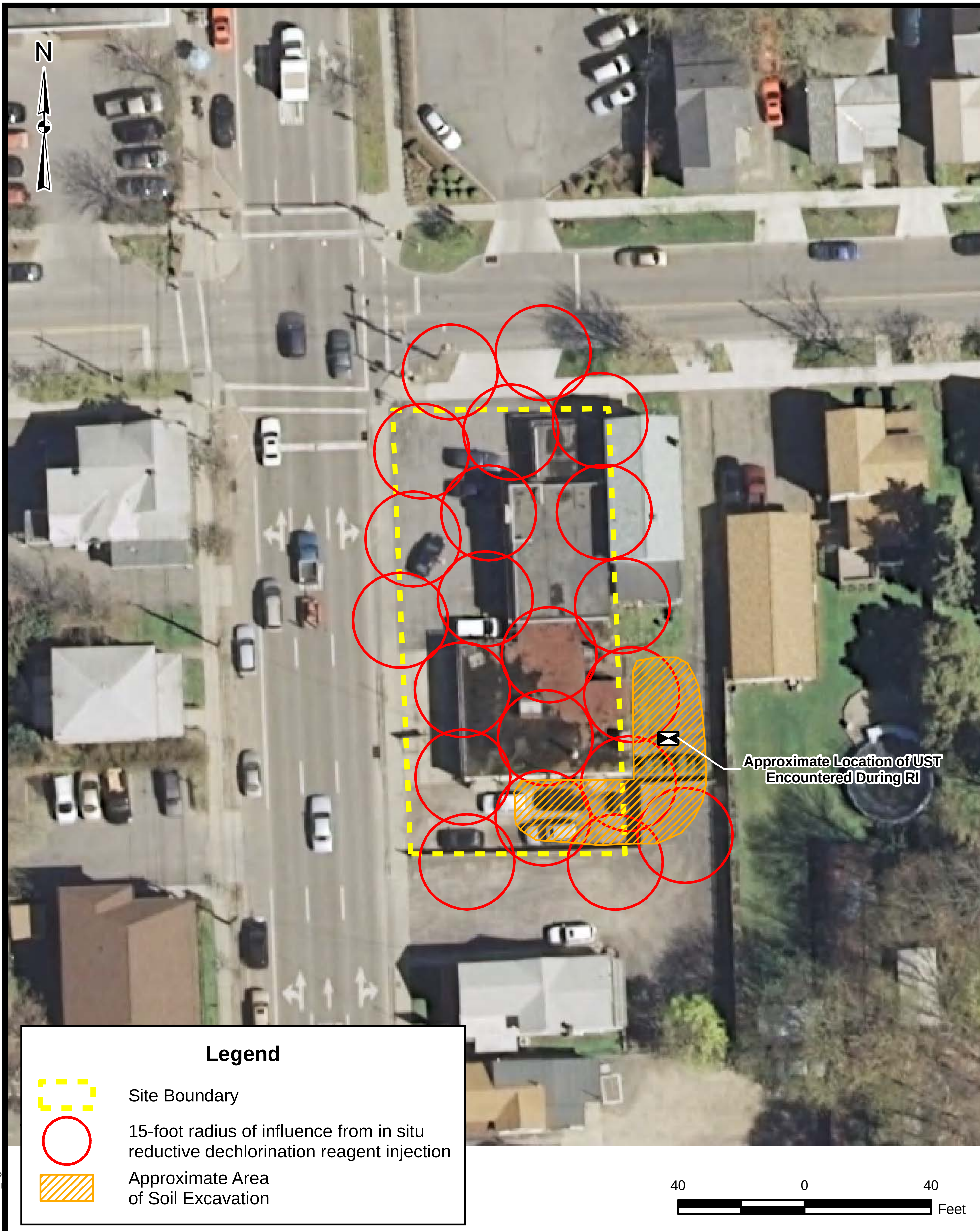


URS

315 NORTH MEADOW STREET
GROUNDWATER MONITORING LOCATIONS

FIGURE 5-1

N:\11174365.00000\DB\GIS\FS_figures\FIG 5-1 GW Monitoring.mxd 10/5/2009 BJF

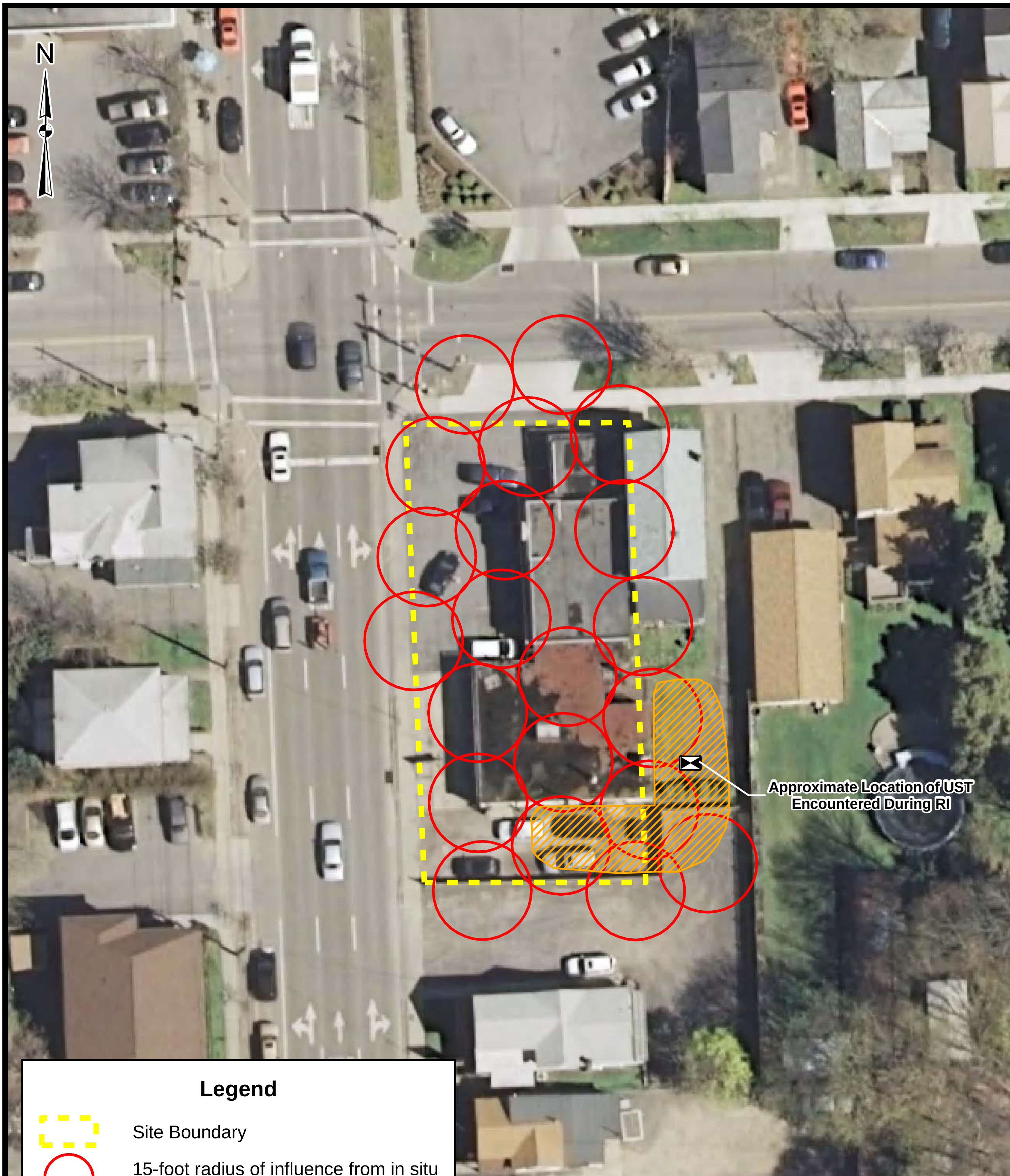


URS

315 NORTH MEADOW STREET
CONCEPTUAL LAYOUT FOR ALTERNATIVE 3

FIGURE 5-2

N:\11174365.00000\DB\GIS\FS_figures\FIG 5-2 ALT 3.mxd 10/23/2009 MDL



Legend

- Site Boundary
- 15-foot radius of influence from in situ chemical oxidation reagent injection
- Approximate Area of Soil Excavation

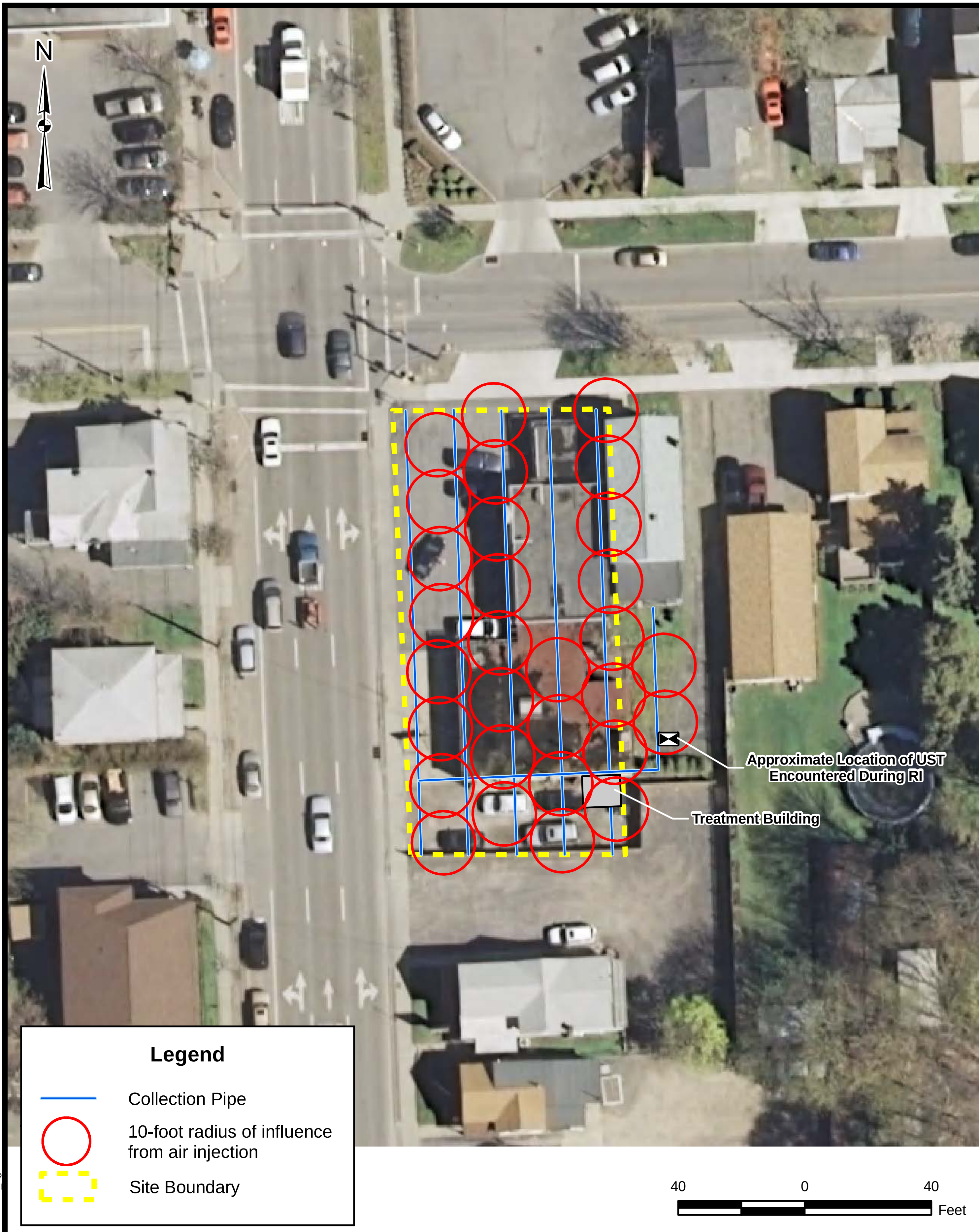
40 0 40
Feet

URS

315 NORTH MEADOW STREET
CONCEPTUAL LAYOUT FOR ALTERNATIVE 4

FIGURE 5-3

N:\11174365.00000\DB\GIS\FS_figures\FIG 5-3 ALT 4.mxd 10/23/2009 MDL

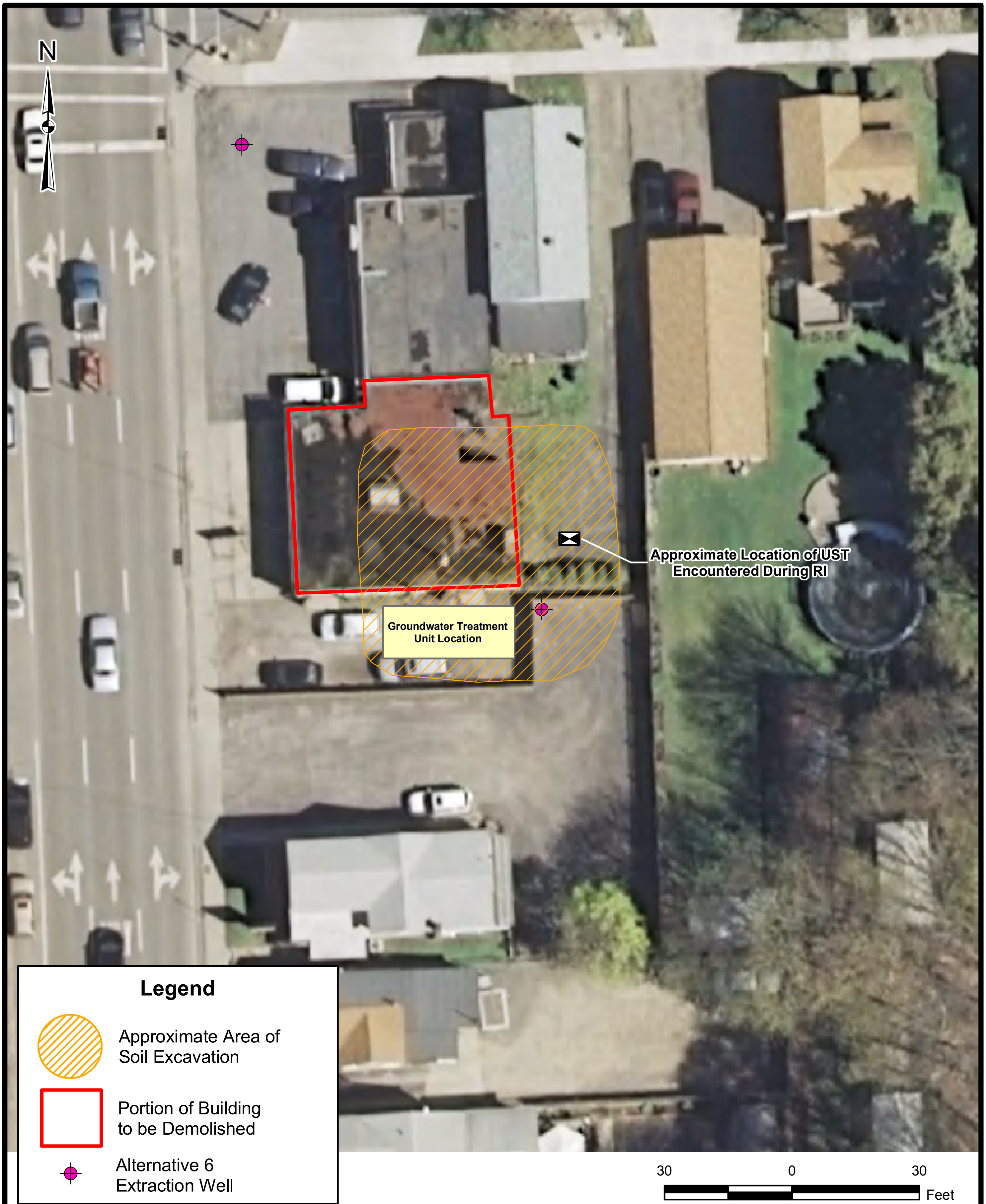


URS

315 NORTH MEADOW STREET
CONCEPTUAL LAYOUT FOR ALTERNATIVE 5

FIGURE 5-4

N:\11174365.00000\DB\GIS\FS_figures\FIG 5-4 ALT 5.mxd 10/23/2009 MDL

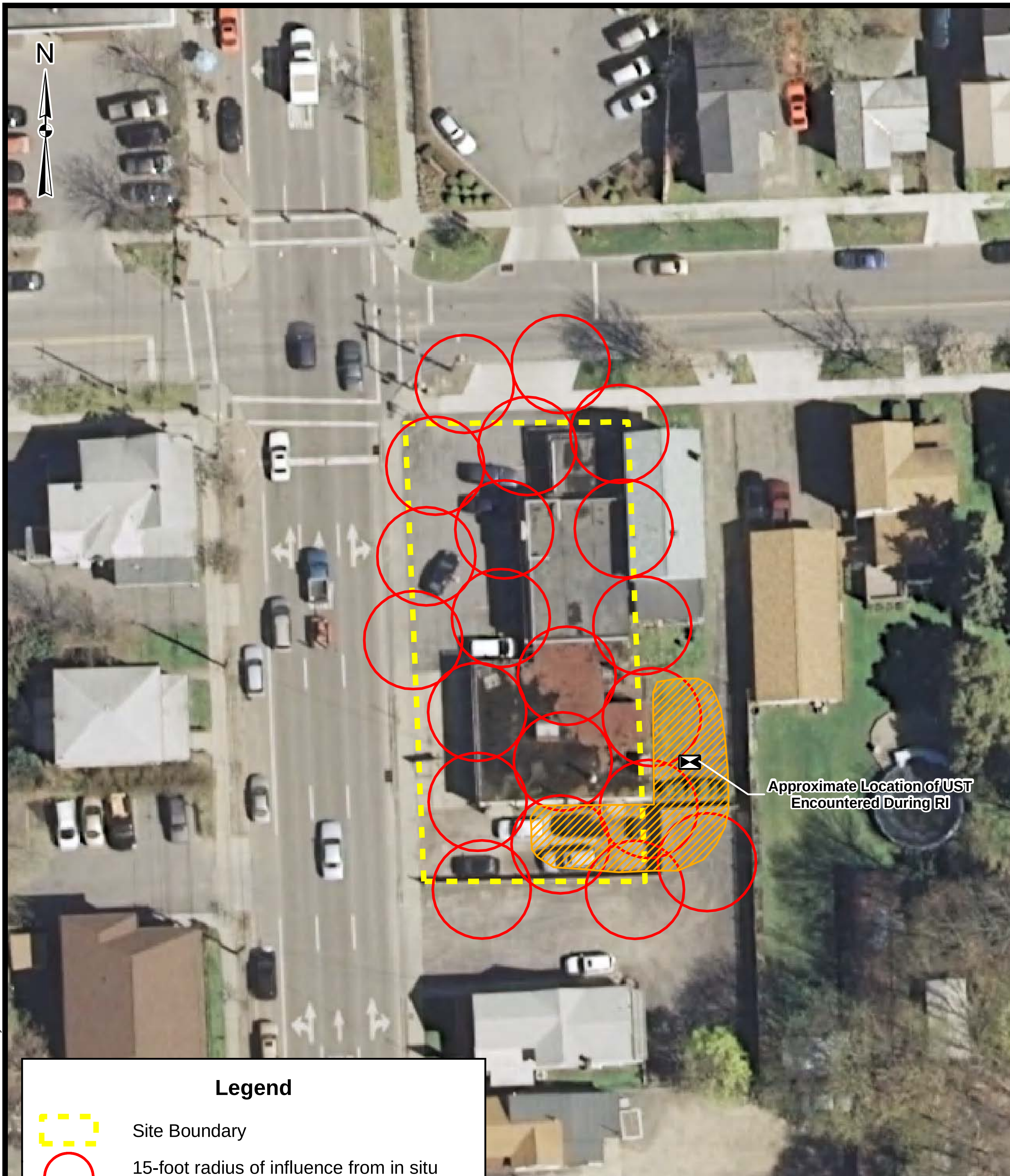


URS

315 NORTH MEADOW STREET
CONCEPTUAL LAYOUT FOR ALTERNATIVE 6

FIGURE 5-5

N:\11174365.00000\DB\GIS\FS_figures\FIG 5-5 ALT 6.mxd 4/13/2010 BJF



Legend

- Site Boundary
- 15-foot radius of influence from in situ reductive dechlorination reagent injection
- Approximate Area of Soil Excavation

40 0 40
Feet

URS

315 NORTH MEADOW STREET
CONCEPTUAL LAYOUT FOR RECOMMENDED REMEDY

FIGURE 6-1

N:\11174365.00000\DB\GIS\FS_figures\FIG 6-1 Recommended Remedy.mxd MDL

APPENDIX A

REMEDIAL ALTERNATIVE COST ESTIMATES

NYSDEC
315 N. MEADOW ST. SITE
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 1 - No Further Action	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
There is zero cost associated with this Alternative	

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit	**20.00%**	
SUBTOTAL - CONSTRUCTION COSTS		
Contingency	**30.00%**	
TOTAL		
TOTAL CAPITAL COST		

NYSDEC
315 N. MEADOW ST. SITE
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 2 - Institutional Controls	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
Site Management Plan	**$8,000**
SUBTOTAL	**$8,000**

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit	**25.00%**	**$2,000**
	SUBTOTAL	**$10,000**
Contingency	**30.00%**	**$3,000**
SUBTOTAL CONSTRUCTION COSTS		**$13,000**
Engineering Design		
TOTAL CAPITAL COST		**$13,000**
OPERATIONS AND MAINTENANCE COST (30 years)		**$275,200**
ALTERNATIVE 2 - TOTAL COST		**$289,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 2 Institutional Controls	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1					
2	Site Management Plan	1	ls	$8,000.00	$8,000
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$8,000**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 2 - Annual Sampling, Analysis and Reporting (30 year period)	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Monitoring Well Sampling - 15 wells - Labor: 4 wells / day @ 20 mhr	75	man hour	$60.00	$4,500
2	Sample Analysis: Annually				
3	Reports	1	each	$2,500.00	$2,500
4	Annual Inspection and Maintenance @ existing SSD Systems	8	man hour	$60.00	$480
5	Sample Analysis: Annually				
6	Analytical Cost Detail				
7	Direct read pH, ORP, Conductivity Meter	1	week	$320.00	$320
8	Direct Read DO Meter	1	week	$105.00	$105
9	Lab Analysis, NYSDEC Contract Rates				
10	Iron	15	each	35.00	$525
11	Manganese	15	each	35.00	$525
12	Alkalinity	15	each	15.00	$225
13	Nitrate	15	each	15.00	$225
14	Sulfate	15	each	25.00	$375
15	VOC's (full TCLP)	15	each	100.00	$1,500
16	Sample Shipping	5	each	50.00	$250
17					
18				**Subtotal**	**$11,530**
19	**Contractor's Overhead and Profit 25%**				$2,883
20	**Contingency 30%**				$3,459
21	**Total Annual OM&M**				**$17,900**
22					
23					
24					
25					
26					
27					
28	**Present Worth (30 yr. @ 5% Discount)**			**15.373**	**$275,177**
29					
	TOTAL COST:				**$275,200**

NYSDEC
315 N. Meadow Street Site
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 3 - In Situ Reduction With Limited Source Excavation	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
Mobilization and Demobilization	**$35,200**
In Situ Chemical Reduction	**$156,300**
Limited Source Excavation	**$134,400**
SUBTOTAL	**$325,900**

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit 25.00%	**$81,475**
SUBTOTAL	**$407,375**
Contingency 30.00%	**$122,213**
SUBTOTAL CONSTRUCTION COSTS	**$529,588**
Engineering Design	**$100,000**
TOTAL CAPITAL COST	**$629,600**
OPERATIONS AND MAINTENANCE COST (5 years)	**$44,700**
ALTERNATIVE 3 - TOTAL COST	**$675,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 3 Mobilization/Demobilization	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Submittals				
2	Health and Safety Plan	1	ls	$2,500.00	$2,500
3	Shop drawings	1	ls	$2,500.00	$2,500
4	Schedules	1	ls	$3,000.00	$3,000
5	Record drawings	1	ls	$2,500.00	$2,500
6	Survey	2	day	$1,186.00	$2,372
7	Permits and easements - Allowance	1	ls	$5,000.00	$5,000
8	Portable toilet	4	mo	$206.00	$824
9	Direct Push rig mobe/demobe	2	each	$3,250.00	$6,500
10	Reagent Storage Infrastructure	1	ls	$10,000.00	$10,000
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$35,200**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 3 - In Situ Chemical Reduction	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Pilot Study** - Allow	1	ls	$20,000.00	$20,000
2					
3	**First Event**				
4	Geoprobe with 2 man crew	10	day	$1,250.00	$12,500
5	Injection Pump equipment	1	event	$2,500.00	$2,500
6	Injection Charge	21	each	$10.00	$210
7	Concrete Core Drill and generator	1	day	$250.00	$250
8	Water Supply and Tank	1	ls	$2,000.00	$2,000
9	**Total Estimated Cost - First Event**				**$37,460**
10	**Second Event**				
11	Geoprobe with 2 man crew	10	day	$1,250.00	$12,500
12	Injection Pump equipment	1	event	$2,500.00	$2,500
13	Injection Charge	21	each	$10.00	$210
14	Concrete Core Drill and generator	1	day	$250.00	$250
15	Water Supply and Tank	1	ls	$2,000.00	$2,000
16	**Total Estimated Cost - Second Event**				**$17,460**
17					
18	**Emulsified Vegetable Oil Reagent**	2	events	$20,500.00	**$41,000**
19					
20	**Bioaugmentation (@ 2nd reduction event)**	1	event	$5,000.00	**$5,000**
21					
22	**Contractor's Progressive Oversight (quarterly over first two years)**				
23	Direct read pH, ORP, Conductivity Meter	24	day	$80.00	**$1,920**
24	Direct Read DO Meter	24	day	$26.00	**$624**
25	Monitoring Well Sampling - 10 wells - Labor: 4 wells / day @ 20 mhr	400	man hour	$60.00	**$24,000**
26	Lab Analysis, NYSDEC Contract Rates				
27	Full TCLP VOC's	80	each	$100.00	**$8,000**
28	Sample Shipping	16	each	$50.00	**$800**
29	Progress Results Analysis and Reports (quarterly)	8	each	$2,500.00	**$20,000**
30					
31					
32					
33					
	TOTAL COST:				**$156,300**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client: NYSDEC	Project Number: 11174365		
Project: 315 N. Meadow St. Site	Calculated By: Patrick Baker	Date:	27-Feb-10
Title: Alternative 3 - Limited Source Excavation	Checked By: Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Excavate and segregate contaminated /non-contaminated soils	370	cy	$20.00	$7,400
2	Soil Characterization - Allow 4 samples @ each roll-off box	120	each	$75.00	$9,000
3	Transport / Dispose Contaminated Soil - Hazardous (incineration)	56	ton	$880.00	$49,280
4	Transport / Dispose Contaminated Soil - Non-Hazardous (landfill)	500	ton	$55.00	$27,500
5	Backfill and compact excavation - common fill	444	cy	$15.00	$6,660
6	Pavement restoration (asphalt)	225	sy	$30.00	$6,750
7					
8	UST Removal	1	ls	$25,000.00	$25,000
9					
10					
11	Confirmation Sampling and Analysis (sidewalls and bottom of excavation)	1	ls	$2,800.00	$2,800
12					
13					
14					
15					
16					
17					
18	**Note: Assume 90% of contaminated soil is non-hazardous (333 cy)**				
19	**and 10% of contaminated soil is hazardous (37 cy).**				
20	**Assume cy to ton conversion factor is 1.5.**				
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
	TOTAL COST:				**$134,400**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 3 - Annual Sampling, Analysis and Reporting - years 3, 4, and 5	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Monitoring Well Sampling - 15 wells - Labor: 4 wells / day @ 20 mhr	75	man hour	$60.00	$4,500
2	Sample Analysis: Annually				
3	Reports	1	each	$2,500.00	$2,500
4	Annual Inspection and Maintenance @ existing SSD Systems	8	man hour	$60.00	$480
5	Sample Analysis: Annually				
6	Direct read pH, ORP, Conductivity Meter	1	week	$320.00	$320
7	Direct Read DO Meter	1	week	$104.00	$104
8	Lab Analysis, NYSDEC Contract Rates				
9	Full TCLP VOC's	15	each	$100.00	$1,500
10	Sample Shipping	4	each	$50.00	$200
11					
12				**Subtotal**	**$9,604**
13	**Contractor's Overhead and Profit 25%**				$2,401
14	**Contingency 30%**				$2,881
15	**Total Annual OM&M Cost**				**$14,900**
16					
17					
18					
19					
20					
21					
22					
23	**Present Worth (5 yr. @ 5% discount)**			**4.330**	**$44,700**
24					
	TOTAL COST:				**$44,700**

NYSDEC
315 N. Meadow Street Site
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 4 - In Situ Chemical Oxidation With Limited Source Excavation	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
Mobilization and Demobilization	**$34,200**
In Situ Chemical Treatment	**$154,700**
Limited Source Excavation	**$134,400**
SUBTOTAL	**$323,300**

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit	**25.00%**	**$80,825**
	SUBTOTAL	**$404,125**
Contingency	**30.00%**	**$121,238**
SUBTOTAL CONSTRUCTION COSTS		**$525,363**
Engineering Design		**$100,000**
TOTAL CAPITAL COST		**$625,400**
OPERATIONS AND MAINTENANCE COST (5 years)		**$36,900**
ALTERNATIVE 4 - TOTAL COST		**$663,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 4 Mobilization/Demobilization	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Submittals				
2	Health and Safety Plan	1	ls	$2,500.00	$2,500
3	Shop drawings	1	ls	$2,500.00	$2,500
4	Schedules	1	ls	$3,000.00	$3,000
5	Record drawings	1	ls	$2,500.00	$2,500
6	Survey	2	day	$1,186.00	$2,372
7	Permits and easements - Allowance	1	ls	$5,000.00	$5,000
8	Portable toilet	4	mo	$206.00	$824
9	Direct Push rig mobe/demobe	1	ls	$5,500.00	$5,500
10	Reagent Storage/Mixing Infrastructure	1	ls	$10,000.00	$10,000
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$34,200**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 4 - In Situ Chemical Oxidation	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**First Event**				
2	Geoprobe with 2 man crew	5	day	$1,250.00	$6,250
3	Injection Pump equipment	1	event	$1,000.00	$1,000
4	Injection Charge	21	each	$10.00	$210
5	Concrete Core Drill and generator	1	day	$250.00	$250
6	Water Supply and Tank	1	ls	$2,000.00	$2,000
7	**Total Estimated Cost - First Event**				**$9,710**
8	**Second Event**				
9	Geoprobe with 2 man crew	4	day	$1,250.00	$5,000
10	Injection Pump equipment	1	event	$1,000.00	$1,000
11	Injection Charge	21	each	$10.00	$210
12	Concrete Core Drill and generator	1	day	$250.00	$250
13	Water Supply and Tank	1	ls	$2,000.00	$2,000
14	**Total Estimated Cost - Second Event**				**$8,460**
15	**Third Event**				
16	Geoprobe with 2 man crew	4	day	$1,250.00	$5,000
17	Injection Pump equipment	1	event	$1,000.00	$1,000
18	Injection Charge	21	each	$10.00	$210
19	Concrete Core Drill and generator	1	day	$250.00	$250
20	Water Supply and Tank	1	ls	$2,000.00	$2,000
21	**Total Estimated Cost - Third Event**				**$8,460**
22					
23	Sodium Permanganate	14,445	lb	$5.03	$72,658
24					
25	**Contractor's Progressive Oversight (quarterly over first two years)**				
26	Direct read pH, ORP, Conductivity Meter	24	day	$80.00	$1,920
27	Direct Read DO Meter	24	day	$26.00	$624
28	Monitoring Well Sampling - 10 wells - Labor: 4 wells / day @ 20 mhr	400	man hour	$60.00	$24,000
29	Lab Analysis, NYSDEC Contract Rates				
30	Full TCLP VOC's	80	each	$100.00	$8,000
31	Sample Shipping	16	each	$50.00	$800
32	Progress Results Analysis and Reports (quarterly)	8	each	$2,500.00	$20,000
33					
	TOTAL COST:				**$154,700**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 4 - Limited Source Excavation	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Excavate and segregate contaminated /non-contaminated soils	370	cy	$20.00	$7,400
2	Soil Characterization - Allow 4 samples @ each roll-off box	120	each	$75.00	$9,000
3	Transport / Dispose Contaminated Soil - Hazardous (incineration)	56	ton	$880.00	$49,280
4	Transport / Dispose Contaminated Soil - Non-Hazardous (landfill)	500	ton	$55.00	$27,500
5	Backfill and compact excavation - common fill	444	cy	$15.00	$6,660
6	Pavement restoration (asphalt)	225	sy	$30.00	$6,750
7					
8	UST Removal	1	ls	$25,000.00	$25,000
9					
10					
11	Confirmation Sampling and Analysis (sidewalls and bottom of excavation)	1	ls	$2,800.00	$2,800
12					
13					
14					
15					
16					
17					
18	**Note: Assume 90% of contaminated soil is non-hazardous (333 cy)**				
19	**and 10% of contaminated soil is hazardous (37 cy).**				
20	**Assume cy to ton conversion factor is 1.5.**				
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$134,400**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 4- Annual Sampling, Analysis and Reporting - Years 3, 4, and 5	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Monitoring Well Sampling - 15 wells - Labor: 4 wells / day @ 20 mhr	75	man hour	$60.00	$4,500
2	Sample Analysis: Annually				
3	Reports	1	each	$2,500.00	$2,500
4	Annual Inspection and Maintenance @ existing SSD System	8	man hour	$60.00	$480
5	Sample Analysis: Annually				
6	Direct read pH, ORP, Conductivity Meter	1	week	$320.00	$320
7	Direct Read DO Meter	1	week	$104.00	$104
8	Lab Analysis, NYSDEC Contract Rates				
9	Full TCLP VOC's	15	each	$100.00	$1,500
10	Sample Shipping	4	each	50.00	$200
11				**Subtotal**	**$9,604**
12	**Contractor's Overhead and Profit 25%**				$2,401
13	**Contingency 30%**				$2,881
14	**Total Annual OM&M Cost**				**$14,900**
15					
16					
17					
18					
19					
20					
21					
22					
23	**Present Worth (years 3, 4, and 5 @ 5% discount)**				**$36,804**
24					
	TOTAL COST:				**$36,900**

NYSDEC
315 N. Meadow Street Site
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 5 - Air Sparging	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
Mobilization and Demobilization	**$21,600**
Air sparging	**$391,200**
SUBTOTAL	**$412,800**

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit 25.00%	**$103,200**
SUBTOTAL	**$516,000**
Contingency 30.00%	**$154,800**
SUBTOTAL CONSTRUCTION COSTS	**$670,800**
Engineering Design	**$100,000**
TOTAL CAPITAL COST	**$770,800**
OPERATIONS AND MAINTENANCE COST (5 years)	**$64,600**
ALTERNATIVE 5 - TOTAL COST	**$836,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 5 Mobilization/Demobilization	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Submittals				
2	Health and Safety Plan	1	ls	$2,500.00	$2,500
3	Shop drawings	1	ls	$2,500.00	$2,500
4	Schedules	1	ls	$3,000.00	$3,000
5	Record drawings	1	ls	$2,500.00	$2,500
6	Survey	2	day	$1,186.00	$2,372
7	Permits and easements - Allowance	1	ls	$5,000.00	$5,000
8	Portable toilet	1	mo	$206.00	$206
9	Construction Equipment	1	ls	$3,500.00	$3,500
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$21,600**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client: NYSDEC	Project Number: 11174365		
Project: 315 N. Meadow St. Site	Calculated By: Patrick Baker	Date:	27-Feb-10
Title: Alternative 5 Air Sparging	Checked By: Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Air Sparging System Installation**				
2	Treatment Building - Concrete Slab on Grade	3	cy	$350.00	$1,050
3	Treatment Building - Wood Frame Construction (12' X 20')	260	sf	$75.00	$19,500
4	271 CFM Blower with Motor (11.8 HP)	1	each	$5,000.00	$5,000
5	615 CFM Blower (vacuum) with Motor	1	each	$9,500.00	$9,500
6	Moisture Knockout tank	1	each	$500.00	$500
7	Holding Tank (250 gal.)	1	each	$600.00	$600
8	Vapor Phase Carbon Canisters (300 lb/each)	2	each	$1,500.00	$3,000
9	Pumps - centrifugal	2	each	$3,800.00	$7,600
10	PVC Pipe - 4" slotted	1300	lf	$8.20	$10,660
11	PVC Pipe Fittings	30	each	$11.30	$339
12	Valves	8	each	$350.00	$2,800
13	Instrumentation and Controls	1	ls	$10,000.00	$10,000
14	Saw Cut Pavement	2500	lf	$2.75	$6,875
15	Concrete Pavement demolition	18	cy	$75.00	$1,350
16	Trench Excavation (hand and machine)	385	cy	$25.00	$9,625
17	Pipe Bedding Stone	150	cy	$29.00	$4,350
18	Backfill and Compaction	135	cy	$15.00	$2,025
19	Pavement Restoration	1	ls	$10,000.00	$10,000
20	Synthetic Cap (HDPE - 60' x 25')	1500	sf	$6.50	$9,750
21	Equipment Installation	120	man hr	$60.00	$7,200
22	Startup and Testing	80	man hr	$60.00	$4,800
23	T&D Non-Hazardous concrete and soil (350 cy)	525	ton	$55.00	$28,875
24	T&D Hazardous Soil (40 cy)	60	ton	$880.00	$52,800
25	Air Sparge Well Point Installation	30	each	$2,500.00	$75,000
26	Dismantle/Remove System at Treatment Completion/Restoration	480	man hr.	$60.00	$28,800
27	Restoration Materials - Allow	1	ls	$8,500.00	$8,500
28	**UST Removal**	1	ls	$25,000.00	$25,000
29	Air Sparging System Operation (2 years)				
30	Operation/Maintenance of Air Sparge System (3 days per month)	72	day	$480.00	$34,560
31	Miscellaneous Supplies	24	month	$100.00	$2,400
32	Carbon Changes (2 x 300 lb. per change x 2 changes per year)	2400	lb	$3.00	$7,200
33	Water Disposal	1000	gallon	$1.50	$1,500
	TOTAL COST:				**$391,200**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 5- Annual Sampling, Analysis and Reporting - 5 Year Period	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Monitoring Well Sampling - 15 wells - Labor: 4 wells / day @ 20 mhr	75	man hour	$60.00	$4,500
2	Sample Analysis: Annually				
3	Reports	1	each	$2,500.00	$2,500
4	Annual Inspection and Maintenance @ existing SSD System	8	man hour	$60.00	$480
5	Sample Analysis: Annually				
6	Direct read pH, ORP, Conductivity Meter	1	week	$320.00	$320
7	Direct Read DO Meter	1	week	$104.00	$104
8	Lab Analysis, NYSDEC Contract Rates				
9	Full TCLP VOC's	15	each	$100.00	$1,500
10	Sample Shipping	4	each	50.00	$200
11				**Subtotal**	**$9,604**
12					
13					
14					
15					
16					
17					
18					**$9,604**
19	**Contractor's Overhead and Profit 25%**				$2,401
20	**Contingency 30%**				$2,881
21	**Total Annual OM&M Cost**				**$14,900**
22					
23					
24	**Present Worth (5 yr. @ 5% discount)**			**4.330**	**$64,600**
25					
	TOTAL COST:				**$64,600**

NYSDEC
315 N. Meadow Street Site
FEASIBILITY STUDY
ENGINEER'S COST ESTIMATE

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Description:	Alternative 6 - Demolition (partial), Limited Excavation and GW Treatment	Checked By:	Jon Sundquist	Date:	1-Mar-10

SUMMARY

DESCRIPTION	ESTIMATED COST
Mobilization and Demobilization	**$21,600**
Demolition	**$57,900**
Limited Source Excavation	**$205,600**
Groundwater Treatment System Installation	**$93,550**
SUBTOTAL	**$378,650**

STANDARD SUPPLEMENTAL PROJECT COSTS

Overhead and Profit 25.00%	**$94,663**
SUBTOTAL	**$473,313**
Contingency 30.00%	**$141,994**
SUBTOTAL CONSTRUCTION COSTS	**$615,306**
Engineering Design	**$100,000**
TOTAL CAPITAL COST	**$715,400**
OPERATIONS AND MAINTENANCE COST (10 years)	**$535,900**
ALTERNATIVE 6- TOTAL COST	**$1,252,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 6 Mobilization/Demobilization	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Submittals				
2	Health and Safety Plan	1	ls	$2,500.00	$2,500
3	Shop drawings	1	ls	$2,500.00	$2,500
4	Schedules	1	ls	$3,000.00	$3,000
5	Record drawings	1	ls	$2,500.00	$2,500
6	Survey	2	day	$1,186.00	$2,372
7	Permits and easements - Allowance	1	ls	$5,000.00	$5,000
8	Portable toilet	1	mo	$206.00	$206
9	Construction Equipment	1	ls	$3,500.00	$3,500
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$21,600**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 6 Demolition	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Partial Building Demolition**				
2	Electrical Disconnection and Reconfiguration	1	ls	$8,900.00	$8,900
3	Water / Sewer Disconnection and Reconfiguration	1	ls	$5,800.00	$5,800
4	Labor - 3 men	120	man hr	$60.00	$7,200
5	Equipment - track excavator with thumb	1	week	$9,500.00	$9,500
6	Saw Cut Pavement	2500	lf	$2.75	$6,875
7	Concrete Slab Demolition	18	cy	$75.00	$1,350
8	Rubble Transport and Disposal (Non-Hazardous/Non-contaminated)	225	cy	$55.00	$12,375
9	Concrete Block in-fill at Exposed Wall (Remaining Structure)	1000	sf	$5.00	$5,000
10	Barricades and Barriers - allow	1	ls	$850.00	$850
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
	TOTAL COST:				**$57,900**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client: NYSDEC | Project Number: 11174365
Project: 315 N. Meadow St. Site | Calculated By: Patrick Baker | Date: 27-Feb-10
Title: Alternative 6 - Limited Source Excavation | Checked By: Jon Sundquist | Date: 1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Excavate and segregate contaminated /non-contaminated soils	761	cy	$20.00	$15,220
2	Soil Characterization - Allow 4 samples @ each roll-off box	120	each	$75.00	$9,000
3	Transport / Dispose Contaminated Soil - Hazardous (incineration)	114	ton	$880.00	$100,320
4	Transport / Dispose Contaminated Soil - Non-Hazardous (landfill)	1027	ton	$55.00	$56,485
5	Backfill and compact excavation - common fill	914	cy	$15.00	$13,710
6	Pavement restoration (asphalt)	267	sy	$30.00	$8,010
7					
8					
9					
10					
11	Confirmation Sampling and Analysis (sidewalls and bottom of excavation)	1	ls	$2,800.00	$2,800
12					
13					
14					
15					
16					
17					
18	**Note: Assume 90% of contaminated soil is non-hazardous (333 cy)**				
19	**and 10% of contaminated soil is hazardous (37 cy).**				
20	**Assume cy to ton conversion factor is 1.5.**				
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
	TOTAL COST:				**$205,600**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 6 Groundwater Treatment System	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Extraction Well Installation 2 each x 4" dia. 26' deep	2	each	$4,500.00	$9,000
2	Trench Excavation (hand and machine)	60	cy	$25.00	$1,500
3	Piping and valves	250	lf	$22.00	$5,500
4	Well Pumps	2	each	$5,800.00	$11,600
5	Electrical Installation	1	ls	$16,000.00	$16,000
6	Treatment Building - Concrete Slab on Grade	3	cy	$350.00	$1,050
7	Treatment Building - Wood Frame Construction (12' X 20')	260	sf	$75.00	$19,500
8	Shallow Tray Air Stripper - 1 to 5 GPM - Allow	1	each	$18,000	$18,000
9	Vapor Phase Carbon Vessels - 1,000lb. each	2	each	$3,200.00	$6,400
10	Blower and piping	1	ls	$5,000.00	$5,000
11	Instrumentation and Controls	1	ls	$14,500.00	$14,500
12	System startup 2 men x 8 days	128	man hrs	$60.00	$7,680
13				**Subtotal**	**$93,550**
14					
15					
16					
17					
17					
19					
20					
	TOTAL COST:				**$93,550**

URS CORPORATION
ENGINEER'S COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11174365		
Project:	315 N. Meadow St. Site	Calculated By:	Patrick Baker	Date:	27-Feb-10
Title:	Alternative 6- Annual Sampling, Analysis and Reporting: GWT System Operation - 10 Year Period	Checked By:	Jon Sundquist	Date:	1-Mar-10

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Monitoring Well Sampling - 15 wells - Labor: 4 wells / day @ 20 mhr	75	man hour	$60.00	$4,500
2	Sample Analysis: Annually				
3	Reports	1	each	$2,500.00	$2,500
4	Annual Inspection and Maintenance @ existing SSD System	8	man hour	$60.00	$480
5	Sample Analysis: Annually				
6	Direct read pH, ORP, Conductivity Meter	1	week	$320.00	$320
7	Direct Read DO Meter	1	week	$104.00	$104
8	Lab Analysis, NYSDEC Contract Rates				
9	Full TCLP VOC's	15	each	$100.00	$1,500
10	Sample Shipping	4	each	50.00	$200
11					
	GWT Operation (Annual)				
12	Carbon Change-outs every 3 months = 4 x 2,000 lb	8,000	lb	$1.75	$14,000
13	WT - Operation - Labor 3 day/month x 12 months x 8 hrs	192	hr	$60.00	$11,520
14	Electrical Power - Allow $500/month x 12	12	month	$500.00	$6,000
	Sanitary sewer Discharge - Allow - 12 Months x $300	12	month	$300.00	$3,600
15				**Subtotal**	**$44,724**
16					
17					
18					
19	**Contractor's Overhead and Profit 25%**				$11,181
20	**Contingency 30%**				$13,417
21	**Total Annual OM&M Cost**				**$69,400**
22					
23					
24	**Present Worth (10 yr. @ 5% discount)**			**7.722**	**$535,900**
25					
	TOTAL COST:				**$535,900**

APPENDIX B

VEGETABLE OIL INJECTION CALCULATION

1.0 Purpose

This calculation estimates the amount of emulsified vegetable oil (EVO) to inject at a chlorinated hydrocarbon plume in groundwater at the 315 N. Meadow St. site in Ithaca, New York. There are a variety of EVO reagents available on the market, and this Feasibility Study (FS) does not select one in particular for evaluating the in situ reduction alternative. For the purposes of estimating the amount of reagent and its cost, this calculation uses estimating approaches for two brands of EVO, Newman Zone and EOS. For comparison, a vendor quotation for addition of an iron/oil mixture, EHC, is also included.

2.0 Data and Assumptions

2.1 Data

- Target compounds are Tetrachloroethene, Trichloroethene, cis-1,2 Dichloroethene, trans-1,2 Dichloroethene, and Vinyl Chloride. Contaminant concentrations are based on the highest concentrations detected on site (Ref. 1).
- Sulfate concentrations are based on the average concentrations detected in the treatment area (Ref. 2).
- Contaminated groundwater exists in the soil at depths from 5 to 20 feet below ground surface (bgs) (Ref. 1).
- Groundwater flow direction appears to be northwest at a gradient of approximately 0.005 ft/ft (Ref. 1).

2.2 Assumptions

- The treatment would be conducted within an area of approximately 15,000 ft^2. The reagent would be injected using twenty-one injection direct push injection points, at depths approximately 5 feet bgs to 20 feet bgs. The injection points will be spaced using a nominal radius of influence of 15 feet, (Figure 1).
- The total and effective porosity of the soil is estimated in the range of 28% - 30%.
- For Newman Zone, assume a target minimum pore displacement volume of 30%.

3.0 Calculations

The amount of EVO be injected in the treatment area is determined using the estimated mass of dissolved levels of contamination and other electron acceptors.

3.1 Newman Zone Amount and Application Rate

The amount of Newman Zone is calculated using a stoichiometric relationship between the sulfate concentration and the amount of vegetable oil. This calculation assumes that EVO would be needed at a mass ratio of 8.2 to sulfate.

The Newman Zone calculation is provided on Page 4. Results are summarized below.

Newman Zone required:

24,688 lbs (approximately 3,028 gals).

144 gal/injection point, or 4,806 gal/point when diluted 33:1 (water:emulsion)

Total (diluted) volume injected = 100,938 gals.

3.2 EOS™ Amount and Application Rate

The amount of EOS™ is calculated using EOS Source Area & DNAPL design software.

The EOS™ calculation is provided on Pages 5-6. Results are summarized below.

EOS™ calculated = 13,400 lbs (approximately 32 55-gal drums or 1,760 gals)

84 gal/injection point, or 2,800 gal/point when diluted 33:1 (water:EOS)

Total (diluted) volume injected =58,700 gals.

3.3 Material Costs

Estimated material costs are provided below.

Substrate	Quantity	Cost Estimate	Reference
Newman	24,688 lbs	$41,147	Phone quotations received for recent projects (Ref 3)
EOS™	13,400 lbs	$41,000	Phone quotations received for recent projects (Ref 3)

4.0 VENDOR QUOTATION FOR EHC

URS also solicited a quotation from Adventus Americas, Inc. for their proprietary mixture of zero valent iron and electron donor reagent. A copy of the relevant pages of the quotation is provided in Reference 4. Adventus estimated that for the site specific application at 315 N. Meadow St., an estimated mass of 60,400 lbs of their EHC reagent would be required. ERC reagent cost plus transportation was estimated at $151,960

5.0 CONCLUSIONS

The amount of reagent needed for remediation of the site can vary from vendor to vendor, and varies depending on the value of the assumptions made for certain parameters. For purposes of the FS, assume that EVO costs in the range of $41,000 would be required. The higher EHC quotation is based upon a more complex reagent.

6.0 REFERENCES

1. URS Corporation. 2009. *Remedial Investigation Report, 315 N. Meadow St. Site, Buffalo, New York. Final.*. Buffalo, New York.

2. URS Corporation. No Date. Table 5-1 of the draft Feasibility Study report.

3. URS Corporation. No Date. Summary of telephone vendor quotations.

4. Adventus Americas, Inc. July 2009 quotation

Target Treatment Area based on groundwater concentrations and surface access limitations

Estimated Treatment Area	15,000	square feet (sqft)		
Target Treatment Thickness	15	ft		
Target Treatment Volume	225,000	cubic feet (cuft)		
Assumed porosity	30%			
Volume of Groundwater (~1 pore volume)	67,500	cuft		
Conversion: 1 cubic feet (cuft) = 28.3 liter (L)	1,910,250	L		
Conversion: 1 L = 0.264 gallons (gal)	504,306	gal		
Bulk density assumed for the site (dry)	107	pounds per cubic foot (lbs/cuft)		
Mass of soil within Target Treatment Volume	24,075,000	lbs		
Conversion: 1 lb = 0.454 kilogram (kg)	10,930,050	kg		

Total Oxidant Demand (TOD) = Contaminant Demand + Natural Oxidant Demand

Quantity based on Contaminant Demand (Stoichiometry)				
Primary VOC: PCE in groundwater	20.0	mg/L	Highest detected PCE concentration	
	84	lbs	estimated dissolved contaminant mass (PCE) present	
Stoichiometry: 1.14 kg NaMnO4 per kg PCE	96	lbs NaMnO4	For PCE alone; subsurface distribution not included	

>> small amount of oxidant required to treat contaminant mass directly

Quantity based on Natural Oxidant Demand				
Assuming **X**% subsurface distribution	100%		**60%**	
1 g NaMnO4/kg soil	24,075	lbs	$\boxed{\textbf{14,445}}$	lbs NaMnO4
Assumed subsurface distribution =	60%			
Estimated NaMnO4 =	14,445	lbs		
Estimated Cost	**$ 72,586**	rough cost estimate	$5.03	per pound NaMnO4

Estimated Oxidant Mass Delivery

Assm'd injection flow rate =	8	gallons per minute (gpm)	
NaMnO4 Solution =	1.8	lbs NaMnO4 per gallon (20 % by weight solution)	
Target Injection Volume - NaMnO4 =	8,025	gallons	
Total Injection Time =	17	hours	
Total Number of Injection Locations =	21	locations	*assuming equal volumes per location*
Injection Volume per Location =	382	gallons per location	
Total Number of Events (or site visits) =	3	events	*4,815 lbs NaMnO4 per event*
			229 lbs NaMnO4 per location per event
Injection Volume per Location per Event =	127	gallons per location per event	
Injection Time per Location per Event =	0.27	hours (hrs)	
Total Injection Time per Event =	5.57	hrs	
Injection Hours per Day =	5.00	hrs per 8-hour (hr) shift	
=>	1.1	8-hr days, 1 location at a time	
=>	0.3	8- hr days, 4 locations at a time	

4

5

EOS® SOURCE AREA & DNAPL DESIGN WORKSHEET

U.S. Version 2.1f, Rev. Date: June 18, 2008
www.EOSRemediation.com

Site Name:	315 N. Meadow St.
Location:	Ithaca, NY
Project No.:	11175059

Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list): EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here

Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Source Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	150	ft	45.7	m
Width of treatment area perpendicular to groundwater flow, "y"	100	ft	30.5	m
Minimum depth to contamination	5	ft	1.5	m
Maximum depth of contamination	20	ft	6.1	m
Treatment thickness, "z"	15	ft	4.6	m
Treatment zone cross-sectional area, A = y * z	1,500	ft^2	139.4	m^2

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter n)	0.28	(decimal)		
Effective Porosity (accept default or enter n_e)	0.17	(decimal)		
Soil bulk density: (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.91	g/cc	119	lbs / ft^3
Fraction of organic carbon: foc	0.0050	range: 0.0001 to 0.01		

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter K)	1	ft/day	3.5E-04	cm/sec
Hydraulic Gradient (accept default or enter i)	0.005	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter $-i$ in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	0.03	ft/day	0.009	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$	56.10	gallons/day	212.38	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)	100	typical values 60 to 120 days, see comment		
Calculated Contact Length (x) = $\tau * V_x$ — Suggested Minimum	5.0	ft	1.6	m
Treatment zone volume	225,000	ft^3	6,371	m^3
Treatment zone groundwater volume (volume * porosity)	471,240	gallons	1,783,961	L

Section D: Design Lifespan For One Application

Design Lifespan For One Application	5	year(s)	typical values 5 to 10 years	
Estimated total groundwater volume treated over design life	573,623	gallons	2,171,548	L

Section E: Electron Acceptors

Dissolved Phase Electron Donor Demand

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e- equiv./ mole	Stoichiometry *Contaminant/ H_2 (wt/wt H_2)*	Hydrogen Demand *(g H_2)*
Dissolved Oxygen (DO)	0 to 5	0.05	32.0	4	7.94	13.67990927
Nitrate Nitrogen (NO_3^- - N)	1 to 10	1.246	62.0	5	12.30	219.9120103
Sulfate (SO_4^{2-})	10 to 500	60.42857143	96.1	8	11.91	11015.07595
Tetrachloroethene (PCE), C_2Cl_4		20.8	165.8	8	20.57	2196.173561
Trichloroethene (TCE), C_2HCl_3		2.8	131.4	6	21.73	279.8578661
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		6.54	96.9	4	24.05	590.6151919
Vinyl Chloride (VC), C_2H_3Cl		2.1	62.5	2	31.00	147.0839281
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_3CHCl_2			99.0	4	24.55	
Chloroethane, C_2H_5Cl			64.9	2	32.18	
Perchlorate, ClO_4			99.4	8	12.33	
Hexavalent Chromium, Cr(VI)			52.0	3	17.20	
User added						
User added						
User added						

Sorbed Phase Electron Donor Demand

The concentration of the sorbed contaminant can be estimated by:

Where K_{oc} is partition coefficient with respect to organic carbon.
f_{oc} (fraction organic carbon) is the mass of organic matter in soil divided by the total mass of soil
C_{WATER} is the concentration of the contaminant in the groundwater

Default values for Koc taken from: US EPA, Superfund Section, APPENDIX K, Soil Organic Carbon (Koc) / Water (Kow) Partition Coefficients (Average Value Used)

Inputs Adjust Koc as necessary to provide site specific estimates or enter sediment concentration (C_{SOIL})	K_{oc} (L/kg)	C_{SOIL} (mg/Kg)	Mass (g)	Hydrogen Demand ($g\,H_2$)
Tetrachloroethene (PCE), C_2Cl_4	272	28.29	343881.28	16720.24
Trichloroethene (TCE), C_2HCl_3	97	1.36	18508.44	759.83
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$	38	1.24	15105.59	628.20
Vinyl Chloride (VC), C_2H_3Cl	241	2.53	30761.86	992.18
Carbon tetrachloride, CCl_4	158			
Chloroform, $CHCl_3$	53			
sym-tetrachloroethane, $C_2H_2Cl_4$	79			
1,1,1-Trichloroethane (TCA), CH_3CCl_3	139			
1,1-Dichloroethane (DCA), CH_3CHCl_2	54			
User added				
User added				
User added				

Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant / H_2*	Hydrogen Demand ($g\,H_2$)	DOC Released *(moles)*
Estimated Amount of Fe^{2+} Formed	10 to 100	50	55.8	1	55.41	1959.623425	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	398.3951734	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	10914.45728	
Target Amount of DOC to Release	[illegible]	100	12.0				18079.66

Design Safety Factor: 2.0 typical values: 1 to 3

Calculations assume:
1.) all reactions go to completion during passage through emulsified edible oil treated zone, and,
2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand 206.3 pounds
DOC Released 2,064.4 pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

3,005 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e," (typically less than 10%) 0.25
For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated 6,700,081 lbs

Adsorptive Capacity of Soil (accept default or enter site specific value) 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]
- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1] Default values provided based on laboratory studies completed by NCSU
For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

13,400 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project 32 drums

†Exclusive license agreement with Solutions-IES under U.S. Patent # 6,398,960, E.U. Patent # EP 1 315 675 and several other pending international patents.
††EOS® is a registered trademark of EOS Remediation, LLC

Reference 1

8

REMEDIAL INVESTIGATION/FEASIBILTY STUDY

REMEDIAL INVESTIGATION REPORT

WORK ASSIGNMENT D004433-23.1

315 N. MEADOW ST.
ITHACA (C)

SITE NO. 7-55-014
TOMPKINS COUNTY, NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Alexander B. Grannis, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

URS Corporation
77 Goodell Street
Buffalo, New York 14203

Draft Final
May 2009

N:\11174365.00000\WORD\DRAFT\RI Cover.doc water table surface. Depth to water in these wells measured on September 17, 2007, January 17-18, 2008 and on March 10, 2009. Depths to water in these shallow wells ranged from approximately 4 to 5 feet below ground surface (Figures 3-3, 3-4 and 3-5, Table 2.1). The deep wells (NM-MW-02D, NM-MW-03D, NM-MW-04D, NM-MW-10D and NYSEG's MW-21D) are screened in the silty sand underlying the clayey silt to silty clay. Depths to water in these deep wells also ranged from approximately 4 to 5 feet below ground surface (Figure 3-6, Table 2.1)

When water levels were measured on September 17, 2007, January 17-18 and again on March 10, 2009, the elevations in each paired well were similar (Table 2-1), indicating no consistent upward or downward gradient. It should be noted that the NYSEG wells (MW-21S and MW-21D) were not measured in March of 2009.

Stratigraphically, the silty clay unit contains discontinuous seams of silty sand and sand lenses that most likely increase the vertical hydraulic conductivity throughout the unit. Based on the water level information and stratigraphy, the units monitored by the shallow and deep wells appear to be hydraulically connected and the upper 28 feet of overburden, above the clayey silt unit, most likely represents one hydrostratigraphic unit.

Figures 3-3, 3-4 and 3-5 show the groundwater elevation contours for water levels measured in the shallow monitoring wells on September 17, 2007, January 17-18, 2008 and March 10, 2009, respectively. The data shows the groundwater flow direction to be generally to the west-northwest with a gradient of approximately 0.004 ft/ft to 0.009 ft/ft. A large diameter (20 inch) sewer main runs south to north beneath N. Meadow Street. The sewer line is located at approximately the same depth as the shallow groundwater table. High permeability bedding along the sewer line may provide a preferential flow pathway for groundwater, inducing a northerly component to the groundwater flow direction. Figure 3-6 shows the groundwater elevation contours for water levels measured in seven deep wells screened in the silty sand unit as measured on March 20, 2009 (prior to the Phase 2 RI there were insufficient wells to develop deep well groundwater contours). Groundwater flow direction is generally to the west-northwest.

The groundwater contamination does not appear to have migrated to the west side of N. Meadow Street. Some component of dissolved phase contamination may be intercepted and possibly redirected (i.e., more north-northwest) along the axis of the sewer lines and other utilities beneath N. Meadow Street. A large diameter (20 inch) sewer main runs south to north beneath N. Meadow Street; the approximate location and depth of the sewer line has been depicted on the cross-sections (Figure 3-1 and 3-2). The sewer line is located at approximately the same depth as the shallow groundwater table. High permeability bedding along the sewer line may provide a preferential flow pathway for groundwater.

The entire study area is underlain by a silty fine sand layer located greater than 18 - 20 feet bgs. With the exception of upgradient NYSEG well MW-21D, and side-gradient well NM-MW-3D, this zone is not monitored by the current set of wells. One might expect contamination in the 10 – 20 ft bgs sandier zones (e.g. as monitored by NM-MW-02D and NM-MW-04D) to have migrated down into the lower silty fine sand layer. Two grab groundwater samples were collected from this lower silty fine sand layer at on-site locations GS-08-11 (southeast corner of site) and GS-08-09 (northwest corner of site). At the southeast corner (source area), the contamination has not significantly migrated vertically below the water table, and is still found primarily as undegraded PCE. At GS-08-11, very little PCE was detected in any of the grab groundwater samples collected from the lower portion of the fine silty sand layer (24' – 28' bgs). At the northwest corner, the grab groundwater sample at the interval 24' – 28' bgs was taken from the heart of the fine silty sand layer. While the interval above this (16' – 20' bgs, subsequently monitored by NM-MW-04D) was highly contaminated, the fine silty sand grab groundwater sample was not contaminated (though the next deeper interval, 28' – 32' had traces of cis-1,2-DCE). This suggests that contamination has not significantly migrated into the fine silty sand layer.

4.3 Structure Sample Results

The results of the soil vapor intrusion sampling are presented on Table 4-7. The identities of the structures sampled are not presented in this report to protect the privacy of the

TABLE 4-4
STATISTICAL SUMMARY OF DETECTED ANALYTES - PHASE 1 GROUNDWATER SAMPLES
315 NORTH MEADOW SITE REMEDIAL INVESTIGATION

Parameter	Units	No. of Samples	No. of Detections	Range of Detections			Location of Max Value
				Min	Max	Avg	
Volatile Organic Compounds							
1,1-Dichloroethene	UG/L	44	9	0.550	13.40	5.30	NM-GS-06
1,2-Dichloroethene (cis)	UG/L	44	21	0.210	6,540	1,268	NM-MW-04S
1,2-Dichloroethene (trans)	UG/L	44	12	0.100	56.00	16.91	NM-MW-04S
1,4-Dichlorobenzene	UG/L	44	4	0.120	0.360	0.193	NM-MW-05S
Acetone	UG/L	32	15	1.25	24.20	6.01	NM-MW-02S
Benzene	UG/L	44	9	0.160	153.5	47.05	NM-MW-04S
Carbon disulfide	UG/L	44	5	0.140	3.86	1.18	NM-MW-08S
Chlorobenzene	UG/L	44	4	0.120	0.345	0.266	NM-MW-04S
Chloroform	UG/L	44	8	0.100	5.52	1.17	NM-MW-05S
Cyclohexane	UG/L	44	6	0.650	58.50	25.28	NM-MW-04S
Ethylbenzene	UG/L	44	5	3.57	53.50	25.05	NM-MW-04S
Isopropylbenzene (Cumene)	UG/L	44	6	0.250	85.00	29.83	NM-MW-04S
Methyl ethyl ketone (2-Butanone)	UG/L	32	2	1.99	4.71	3.35	NM-GS-09
Methyl tert-butyl ether	UG/L	44	6	0.290	1.28	0.598	NM-GS-20
Methylcyclohexane	UG/L	44	7	0.260	18.00	7.72	NM-MW-02S
Tetrachloroethene	UG/L	44	19	0.100	2.08E+04	2,462	NM-MW-05S
Toluene	UG/L	44	24	0.100	1.77	0.403	NM-GS-06
Trichloroethene	UG/L	44	18	0.100	2,790	380.0	NM-MW-02D

Only Detected Results Reported.

Advanced Selection: PHASE1GWSTAT
N:\11174365.00000\DB\Program\Stat.mde
Printed: 5/12/2009 8:31:02 AM
WHERE [LOGDATE] >= #3/26/2007# AND [LOGDATE] < #11/18/2008# AND [MATRIX] = 'WG' AND ([SACODE] = 'N' OR [SACODE] = 'FD');

TABLE 4-4
STATISTICAL SUMMARY OF DETECTED ANALYTES - PHASE 1 GROUNDWATER SAMPLES
315 NORTH MEADOW SITE REMEDIAL INVESTIGATION

Parameter	Units	No. of Samples	No. of Detections	Range of Detections			Location of Max Value
				Min	Max	Avg	
Volatile Organic Compounds							
Vinyl chloride	UG/L	44	13	0.170	2,110	405.4	NM-MW-04S
Xylene (total)	UG/L	44	11	0.100	234.0	34.01	NM-MW-02S

Only Detected Results Reported.

Advanced Selection: PHASE1GWSTAT
N:\11174365.00000\DB\Program\Stat.mde
Printed: 5/12/2009 8:31:02 AM
WHERE [LOGDATE] >= #3/26/2007# AND [LOGDATE] < #11/18/2008# AND [MATRIX] = 'WG' AND ([SACODE] = 'N' OR [SACODE] = 'FD');

12

Reference 2

TABLE 5-1
IRON, MANGANESE, SULFATE, SULFIDE, NITRATE-NITROGEN, PH, ORP AND DO RESULTS
315 NORTH MEADOW STREET SITE REMEDIAL INVESTIGATION

Monitoring Well	NM-01S	NM-02S	NM-02D	NM-03S	NM-03D	NM-04S	NM-04D	NM-05S	NM-06S	NM-07S	NM-08S	NM-09D	NM-10D	NM-11S	NM-11D	NM-12D
Sample Date: March 2009																
Parameter																
Alkalinity, total (as CaCO3)	390	NT	290	340	350	380	310	270	220	240	480	260	340	250	310	460
Iron	0.086	21	15	4.9	14	20	14	1.5	0.56	0.44	4.1	9.6	7.6	16	4.9	13
Manganese	0.014	7.7	1.2	1.4	0.69	2	1.1	0.24	1.4	0.26	3.8	1	0.64	1.2	0.56	2.5
Nitrate-nitrogen	6.9	NT	1.3	ND	0.21	ND	ND	4.8	ND	0.26	0.14	ND	ND	0.13	ND	ND
Sulfate (as SO4)	53	NT	32	140	3.4	17	20	110	150	78	110	58	ND	36	ND	32
Sulfide, total	ND	NT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH	4.42	9.26	8.82	7.42	9.19	8.98	9.78	4.28	5.86	6.99	7.95	8.65	9.73	8.97	9.29	9.04
ORP	125	-118	-121	-32	-137	-110	-111	136	36	-12	-53	-113	-124	-81	-115	-110
DO	0	7.8	0	0	0	4.81	4.63	0	5.6	0	0	0	5.72	6.15	5.1	0
Sample Date: March 2009																
Parameter																
pH	6.77	6.72	6.63	6.47	6.83	6.58	NS	6.66	6.49	6.59	6.58	NS	NS	NS	NS	NS
ORP	82	28	-93	77	-118	-102	NS	67	63	95	132	NS	NS	NS	NS	NS
DO	2.1	0.044	0.32	0.08	0.18	0.19	NS	1.7	1.27	1.25	0.05	NS	NS	NS	NS	NS
Sample Date: Sept.2007																
Parameter																
pH	6.51	6.43	6.65	6.36	6.74	6.66	NS	6.37	6.24	6.43	6.37	NS	NS	NS	NS	NS
ORP	118	-25	-88	21	-53	-111	NS	95	65	70	52	NS	NS	NS	NS	NS
DO	0.61	0	0	0	0	0	NS	0.95	0	0	0	NS	NS	NS	NS	NS

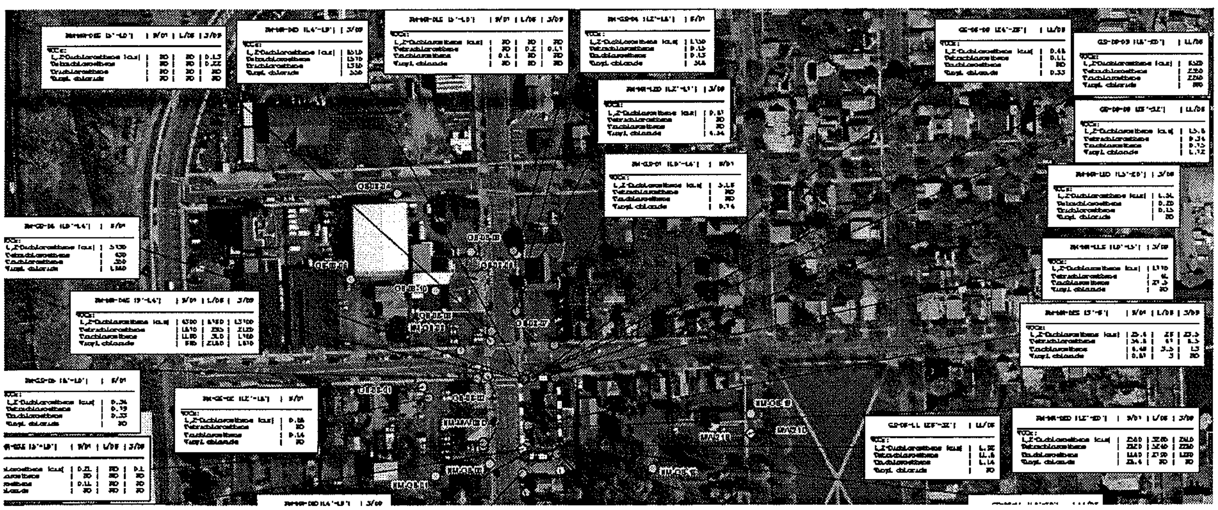
Notes:
ND = Not detected.
NT = Not tested for due to insufficient sample (well went dry).
NS = Not sampled. Well not yet installed.

Reference 3

UNDERSTANDING SITE CONDITIONS AND GOALS

The site is a former dry cleaner facility located in the town of Ithaca, NY. Static groundwater at the site is encountered at about 5 ft bgs and flows to the north/northwest through a sandy gravel aquifer at a linear velocity of 0.5 ft/day. Contaminant concentrations range from the 20,000 ug/L range of mostly PCE in the source area (upgradient/southeast) to a mixture of daughter products (cis-1,2-DCE highest) totaling ~18,000 ug/L in the downgradient (northwest corner). The area of the property, which corresponds roughly to the area needing remediation, is roughly 15,000 ft^2. Contamination is present from the water table (5 ft bgs) to depths of about 20 ft bgs. Laterally, concentrations are lower, away from this southeast-to-northwest axis (**Figure 5**). Current redox conditions appear to be moderately oxic, with an ORP ranging from -100 to +0 mV. The aquifer is neutral in term of pH which ranges from 6 to 8 based on sampling events from 2007.

Figure 5: PCE concentrations measured in groundwater (ug/L).

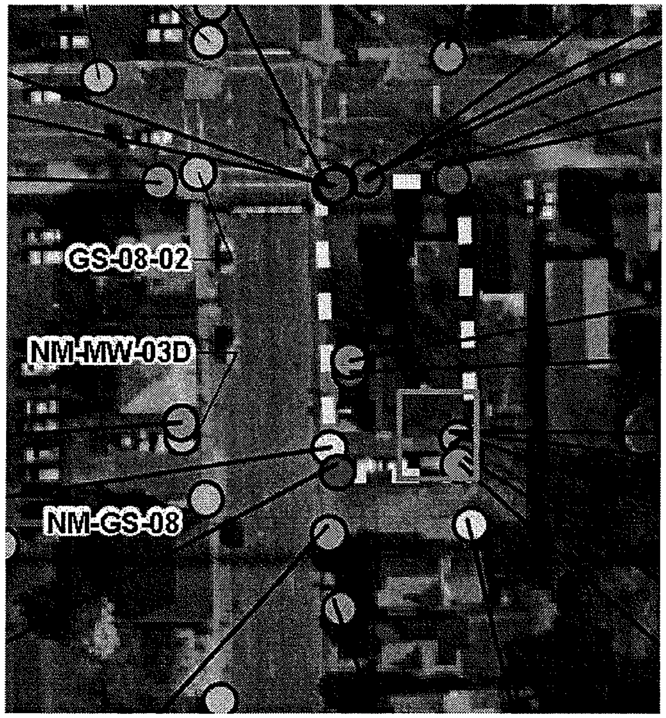


CONCEPTUAL DESIGN

The project goal is to reduce the concentration of PCE in groundwater to < 5 ppb. The proposed remedial design accomplishes this through *in situ* chemical reduction (ISCR) uniquely induced via the use of the EHC. As shown in **Figure 6** and outlined below, material cost estimates have been provided for:

i) <u>**Grid area injections within and downgradient of the source**</u>: this will reduce CVOC mass without the accumulation of potentially problematic catabolites such as DCE or VC (predictable occurrences with the use of oils and other carbon-only sources). Mass removal and source reduction will prevent additional CVOCs from entering the aquifer and significantly reduce the length of time ultimately required for site remediation and closure.

Figure 6: Conceptual Remedial Designs for Source Area Treatment (Blue Square) and downgradient area (Yellow Square)



EHC will be injected in a grid pattern throughout the targeted area measuring about 100 feet wide x 150 ft long x 15 feet deep (from 5 to 20 ft bgs). The target area has been divided into two sections (source and downgradient area) and addressed separately. EHC will be applied at an average loading rate of 0.4% to soil mass in the source area and 0.2% in the remaining area. The EHC will be provided in 50-lb bags as a dry powder and mixed with water on site into aqueous slurry containing *ca.* 30% solids. **Table 1** provides the EHC-O requirements and injection details.

Table 1: EHC mass requirements, injection details and estimated cost.

	Source area	Downgradient Area	Unit
Treatment Area Dimensions:			
Length of treatment zone	50	125	ft
Width of treatment zone	50	100	ft
Depth to top of treatment zone	5	5	ft
Depth to bottom of treatment zone	20	20	ft
Treatment zone thickness	15	15	ft
Treatment zone volume	37,500	187,500	ft3
Mass of soil in treatment zone	2,156	10,781	U.S. tons
Estimated porosity	30%	30%	

Volume pore space	11,433	57,165	ft3
EHC mass calculations:			
Percentage EHC by soil mass	0.40%	0.2%	
Mass of EHC required	17,250	43,150	lbs
Preparation of EHC Slurry:			
Percent solids in slurry (can be altered)	29%	29%	
Volume water required	5,178	12,952	U.S. gallons
Slurry volume to inject	6,292	15,738	U.S. gallons
Injection details:			
Injection spacing	10	15	ft
Number of injection points	25	56	points
Mass EHC per point	690	771	lbs
Water volume per point	207	231	U.S. gallons
Slurry volume per point	252	281	U.S. gallons
Application rates for reference:			
Slurry volume to pore space volume	7.4%	3.7%	
EHC concentration in groundwater	1.5	0.8	lbs/ft3

PLEASE NOTE that the construction estimates presented can be readily modified in the field as required (for example, the density of the slurry can be changed to modify the total injection volume or the injection layout/number of injection points could be altered depending on recommendations from the contractor and technology employed).

DISTRIBUTION OF RESPONSIBILITIES

For field scale work at the Site, Adventus will provide environmental biotechnology and design support. It is our intention and understanding that URS will be responsible for remedial construction, permitting, performance monitoring and reporting. The distribution of responsibilities envisioned is as follows:

1. Adventus will provide and arrange delivery of EHC to the Site.
2. URS will be responsible for remedial construction contracting.
3. It is highly recommended that Adventus personnel be on site during project start-up to support URS's field staff.
4. Adventus will provide data interpretation to URS upon request.
5. Adventus will provide technical writing support to URS, upon request.
6. URS will provide manpower for receiving shipments, monitoring treatment performance and collecting samples.
7. URS will maintain overall project responsibility, and will maintain all client contact and control of the Site.

8. URS will be responsible for all health and safety, permitting and approvals, sampling and analytical costs along with all data management and reporting costs.

ESTIMATED COST

AAI's material and delivery costs for the proposed treatment are presented below (**Table 2**). These costs include EHC and estimated delivery to the Site. Adventus oversight, labor and travel are presented as highly recommended options. These costs do not include the remedial construction or services assigned to URS. This pricing is valid for 45 days.

Table 2: Conceptual Design Cost Estimate (USD)

Parameter	Source Area	Downgradient Area
EHC Mass	17,250	43,150
EHC Unit Price*	$2.40/lb	
EHC Cost	$41,400	$103,560
Small Order Handling Fee**	N.A.	N.A.
Delivery to the Site (estimated)***	$10,000	
Adventus Field Support and Travel (2 to 3 days on site estimated) OPTIONAL****	($3,000)	
TOTAL ADVENTUS COST	**$154,960**	

* Volume discounts applied where applicable. Any applicable taxes not included.

**Warehousing and additional handling fee billed at 5% of material orders <5,000 lbs.

***Shipping billed at actual cost plus 8%. Transportation quotes assume 5 to 7 day delivery time via truck, no lift gate, no pallet jack.

****Field oversight is presented as a recommended option and not included in the total cost. The Adventus performance warranty (below) is predicated on our oversight to verify material emplacement conditions. If additional field oversight If additional field oversight is desired, it can be provided on a time and expense basis.

Adventus will provide copies of our patents and written, full indemnification backed by insurance coverage to URS and the end-user / client from any lawsuits purporting patent infringement or other technology violations.

Adventus warrants the performance of its technology. In the event that the prescribed EHC injections do not yield at least 80% reduction in overall CVOC groundwater concentrations within the treatment zone within 9 to 12 months, then we will provide an equivalent amount of EHC at 50% of the listed price (plus delivery costs). Adventus' field installation oversight would also be provided at no cost. This performance guarantee requires that a representative from Adventus is on site for the initiation of the project and that the injections are conducted according with Adventus' recommendations.

Reference 4

F.E. Warren Air Force Base, Wyoming

Spill Site 7 - Downgradient of PRB

Price and Dosage Comparison Between Amendments

Product	Vendor	Recommended Dosage (lb/cy)	Product Price ($/lb)	Quote Source
Newman Zone	RNAS, Inc.	0.23	1.50	URS Calculations according to phone conversations and quote
EOS 450 (EVO)	EOS Remediation, LLC	2.57	2.40	Dosage from EOS Tool and pricing from EOS
EOS 598	EOS Remediation, LLC	1.96	3.06	Dosage from EOS Tool and pricing from EOS
SRS EVO	Terra Systems, Inc.	0.52	2.45	Terra Systems proprietary model given URS inputs

21

Figure 1

URS	315 NORTH MEADOW STREET FEASIBILITY STUDY CONCEPTUAL ARRANGEMENT OF INJECTION POINTS	FIGURE ~~5-1~~ 1

N:\11174365.00000\DB\GIS\FS-Figure-5-1.mxd 7/1/2009

APPENDIX C

PERMANGANATE INJECTION CALCULATION

1.0 Purpose

This calculation estimates the amount of sodium permanganate to inject at a chlorinated hydrocarbon plume in groundwater at the 315 N. Meadow St. site in Ithaca, New York.

2.0 Data and Assumptions

2.1 Data

- Target compounds are Tetrachloroethene, Trichloroethene, cis-1,2 Dichloroethene, trans-1,2 Dichloroethene, and Vinyl Chloride. Contaminant concentrations are based on the highest concentrations detected on site (Ref. 1).
- Contaminated groundwater exists in the soil at depths from 5 to 20 feet below ground surface (bgs) (Ref. 1).

2.2 Assumptions

- The treatment would be conducted within an area of approximately 15,000 ft^2. The reagent would be injected using twenty-one injection direct push injection points, at depths approximately 5 feet bgs to 200 feet bgs. The injection points will be spaced at a nominal distance of 15 feet, as shown on Figure 1.
- The total and effective porosity of the soil is estimated in the range of 28% - 30%.
- Natural Oxidant Demand is assumed to be 1 mg/kg.

3.0 Calculations

The amount of sodium permanganate to be injected in the treatment area is determined using the estimated mass of dissolved levels of contamination and the assumed oxidant demand.

The amount of pemangante is calculated both using a stoichiometric relationship between the PCE concentration as well as the amount of soil oxidant demand. This calculation is provided on Page 2. An estimated 14,445 lbs would be required. The amount of permanganate required is driven by the assumed soil oxidant demand.

5.0 REFERENCES

1. URS Corporation. 2009. *Remedial Investigation Report, 315 N. Meadow St. Site, Buffalo, New York. Final.*. Buffalo, New York.

Target Treatment Area based on groundwater concentrations and surface access limitations

Estimated Treatment Area	15,000	square feet (sqft)		
Target Treatment Thickness	15	ft		
Target Treatment Volume	225,000	cubic feet (cuft)		
Assumed porosity	30%			
Volume of Groundwater (~1 pore volume)	67,500	cuft		
Conversion: 1 cubic feet (cuft) = 28.3 liter (L)	1,910,250	L		
Conversion: 1 L = 0.264 gallons (gal)	504,306	gal		
Bulk density assumed for the site (dry)	107	pounds per cubic foot (lbs/cuft)		
Mass of soil within Target Treatment Volume	24,075,000	lbs		
Conversion: 1 lb = 0.454 kilogram (kg)	10,930,050	kg		

Total Oxidant Demand (TOD) = Contaminant Demand + Soil Oxidant Demand

Quantity based on Contaminant Demand (Stoichiometry)

Primary VOC: PCE in groundwater	20.0	mg/L	Highest detected PCE concentration
	84	lbs	estimated dissolved contaminant mass (PCE) present
Stoichiometry: 1.14 kg NaMnO4 per kg PCE	96	lbs NaMnO4	For PCE alone; subsurface distribution not included

>> small amount of oxidant required to treat contaminant mass directly

Quantity based on Soil Oxidant Demand

Assuming **X%** subsurface distribution	100%		**60%**	
1 g NaMnO4/kg soil	24,075	lbs	$\boxed{\textbf{14,445}}$	lbs NaMnO4
Assumed subsurface distribution =	60%			
Estimated NaMnO4 =	14,445	lbs		
Estimated Cost	$ **72,586**	rough cost estimate	$5.03	per pound NaMnO4

Estimated Oxidant Mass Delivery

Assm'd injection flow rate =	8	gallons per minute (gpm)	
NaMnO4 Solution =	1.8	lbs NaMnO4 per gallon (20 % by weight solution)	
Target Injection Volume - NaMnO4 =	8,025	gallons	
Total Injection Time =	17	hours	
Total Number of Injection Locations =	21	locations	*assuming equal volumes per location*
Injection Volume per Location =	382	gallons per location	
Total Number of Events (or site visits) =	3	events	*4,815 lbs NaMnO4 per event*
			229 lbs NaMnO4 per location per event
Injection Volume per Location per Event =	127	gallons per location per event	
Injection Time per Location per Event =	0.27	hours (hrs)	
Total Injection Time per Event =	5.57	hrs	
Injection Hours per Day =	5.00	hrs per 8-hour (hr) shift	
=>	1.1	8-hr days, 1 location at a time	
=>	0.3	8- hr days, 4 locations at a time	

Reference 1

48

REMEDIAL INVESTIGATION/FEASIBILTY STUDY

REMEDIAL INVESTIGATION REPORT

WORK ASSIGNMENT D004433-23.1

315 N. MEADOW ST.
ITHACA (C)

SITE NO. 7-55-014
TOMPKINS COUNTY, NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Alexander B. Grannis, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

URS Corporation
77 Goodell Street
Buffalo, New York 14203

Draft Final
May 2009

N:\11174365.00000\WORD\DRAFT\RI Cover.doc

85

water table surface. Depth to water in these wells measured on September 17, 2007, January 17-18, 2008 and on March 10, 2009. Depths to water in these shallow wells ranged from approximately 4 to 5 feet below ground surface (Figures 3-3, 3-4 and 3-5, Table 2.1). The deep wells (NM-MW-02D, NM-MW-03D, NM-MW-04D, NM-MW-10D and NYSEG's MW-21D) are screened in the silty sand underlying the clayey silt to silty clay. Depths to water in these deep wells also ranged from approximately 4 to 5 feet below ground surface (Figure 3-6, Table 2.1)

When water levels were measured on September 17, 2007, January 17-18 and again on March 10, 2009, the elevations in each paired well were similar (Table 2-1), indicating no consistent upward or downward gradient. It should be noted that the NYSEG wells (MW-21S and MW-21D) were not measured in March of 2009.

Stratigraphically, the silty clay unit contains discontinuous seams of silty sand and sand lenses that most likely increase the vertical hydraulic conductivity throughout the unit. Based on the water level information and stratigraphy, the units monitored by the shallow and deep wells appear to be hydraulically connected and the upper 28 feet of overburden, above the clayey silt unit, most likely represents one hydrostratigraphic unit.

Figures 3-3, 3-4 and 3-5 show the groundwater elevation contours for water levels measured in the shallow monitoring wells on September 17, 2007, January 17-18, 2008 and March 10, 2009, respectively. The data shows the groundwater flow direction to be generally to the west-northwest with a gradient of approximately 0.004 ft/ft to 0.009 ft/ft. A large diameter (20 inch) sewer main runs south to north beneath N. Meadow Street. The sewer line is located at approximately the same depth as the shallow groundwater table. High permeability bedding along the sewer line may provide a preferential flow pathway for groundwater, inducing a northerly component to the groundwater flow direction. Figure 3-6 shows the groundwater elevation contours for water levels measured in seven deep wells screened in the silty sand unit as measured on March 20, 2009 (prior to the Phase 2 RI there were insufficient wells to develop deep well groundwater contours). Groundwater flow direction is generally to the west-northwest.

Ø6

The groundwater contamination does not appear to have migrated to the west side of N. Meadow Street. Some component of dissolved phase contamination may be intercepted and possibly redirected (i.e., more north-northwest) along the axis of the sewer lines and other utilities beneath N. Meadow Street. A large diameter (20 inch) sewer main runs south to north beneath N. Meadow Street; the approximate location and depth of the sewer line has been depicted on the cross-sections (Figure 3-1 and 3-2). The sewer line is located at approximately the same depth as the shallow groundwater table. High permeability bedding along the sewer line may provide a preferential flow pathway for groundwater.

The entire study area is underlain by a silty fine sand layer located greater than 18 - 20 feet bgs. With the exception of upgradient NYSEG well MW-21D, and side-gradient well NM-MW-3D, this zone is not monitored by the current set of wells. One might expect contamination in the 10 – 20 ft bgs sandier zones (e.g. as monitored by NM-MW-02D and NM-MW-04D) to have migrated down into the lower silty fine sand layer. Two grab groundwater samples were collected from this lower silty fine sand layer at on-site locations GS-08-11 (southeast corner of site) and GS-08-09 (northwest corner of site). At the southeast corner (source area), the contamination has not significantly migrated vertically below the water table, and is still found primarily as undegraded PCE. At GS-08-11, very little PCE was detected in any of the grab groundwater samples collected from the lower portion of the fine silty sand layer (24' – 28' bgs). At the northwest corner, the grab groundwater sample at the interval 24' – 28' bgs was taken from the heart of the fine silty sand layer. While the interval above this (16' – 20' bgs, subsequently monitored by NM-MW-04D) was highly contaminated, the fine silty sand grab groundwater sample was not contaminated (though the next deeper interval, 28' – 32' had traces of cis-1,2-DCE). This suggests that contamination has not significantly migrated into the fine silty sand layer.

4.3 Structure Sample Results

The results of the soil vapor intrusion sampling are presented on Table 4-7. The identities of the structures sampled are not presented in this report to protect the privacy of the

TABLE 4-4
STATISTICAL SUMMARY OF DETECTED ANALYTES - PHASE 1 GROUNDWATER SAMPLES
315 NORTH MEADOW SITE REMEDIAL INVESTIGATION

Parameter	Units	No. of Samples	No. of Detections	Range of Detections			Location of Max Value
				Min	Max	Avg	
Volatile Organic Compounds							
1,1-Dichloroethene	UG/L	44	9	0.550	13.40	5.30	NM-GS-06
1,2-Dichloroethene (cis)	UG/L	44	21	0.210	6,540	1,268	NM-MW-04S
1,2-Dichloroethene (trans)	UG/L	44	12	0.100	56.00	16.91	NM-MW-04S
1,4-Dichlorobenzene	UG/L	44	4	0.120	0.360	0.193	NM-MW-05S
Acetone	UG/L	32	15	1.25	24.20	6.01	NM-MW-02S
Benzene	UG/L	44	9	0.160	153.5	47.05	NM-MW-04S
Carbon disulfide	UG/L	44	5	0.140	3.86	1.18	NM-MW-08S
Chlorobenzene	UG/L	44	4	0.120	0.345	0.266	NM-MW-04S
Chloroform	UG/L	44	8	0.100	5.52	1.17	NM-MW-05S
Cyclohexane	UG/L	44	6	0.650	58.50	25.28	NM-MW-04S
Ethylbenzene	UG/L	44	5	3.57	53.50	25.05	NM-MW-04S
Isopropylbenzene (Cumene)	UG/L	44	6	0.250	85.00	29.83	NM-MW-04S
Methyl ethyl ketone (2-Butanone)	UG/L	32	2	1.99	4.71	3.35	NM-GS-09
Methyl tert-butyl ether	UG/L	44	6	0.290	1.28	0.598	NM-GS-20
Methylcyclohexane	UG/L	44	7	0.260	18.00	7.72	NM-MW-02S
Tetrachloroethene	UG/L	44	19	0.100	2.08E+04	2,462	NM-MW-05S
Toluene	UG/L	44	24	0.100	1.77	0.403	NM-GS-06
Trichloroethene	UG/L	44	18	0.100	2,790	380.0	NM-MW-02D

Only Detected Results Reported.

Advanced Selection: PHASE1GWSTAT
N:\11174385.00000\DB\Program\Stat.mde
Printed: 5/12/2009 8:31:02 AM
WHERE [LOGDATE] >= #3/26/2007# AND [LOGDATE] < #11/18/2008# AND [MATRIX] = 'WG' AND ([SACODE] = 'N' OR [SACODE] = 'FD');

7

TABLE 4-4
STATISTICAL SUMMARY OF DETECTED ANALYTES - PHASE 1 GROUNDWATER SAMPLES
315 NORTH MEADOW SITE REMEDIAL INVESTIGATION

Parameter	Units	No. of Samples	No. of Detections	Range of Detections			Location of Max Value
				Min	Max	Avg	
Volatile Organic Compounds							
Vinyl chloride	UG/L	44	13	0.170	2,110	405.4	NM-MW-04S
Xylene (total)	UG/L	44	11	0.100	234.0	34.01	NM-MW-02S

Only Detected Results Reported.

Advanced Selection: PHASE1GWSTAT
N:\11174365.00000\DB\Program\Stat.mde
Printed: 5/12/2009 8:31:02 AM
WHERE [LOGDATE] >= #3/26/2007# AND [LOGDATE] < #11/18/2008# AND [MATRIX] = 'WG' AND ([SACODE] = 'N' OR [SACODE] = 'FD');

8

Figure 1

URS

315 NORTH MEADOW STREET
FEASIBILITY STUDY
CONCEPTUAL ARRANGEMENT OF INJECTION POINTS

FIGURE 5-1

N:\11174355.00000\DB\GIS\FS-Figure-5-1.mxd 7/1/2009