1-1-2014

Petroleum Releases from Underground Storage Tanks in Northwest Indiana: Successful Remediation Techniques and Implications of Cost Effectiveness

Richard Jason Lenz

Petroleum releases from underground storage tanks in northwest Indiana: Successful remediation techniques and implications of cost effectiveness

By

Richard Jason Lenz

A Dissertation
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in Earth and Atmospheric Science
in the Department of Geosciences

Mississippi State, Mississippi

December 2014

Petroleum releases from underground storage tanks in northwest Indiana: Successful remediation techniques and implications of cost effectiveness

By

Richard Jason Lenz

Approved:

Darrel W. Schmitz
(Major Professor)

Shrinidhi S. Ambinakudige
(Committee Member)

Renee M. Clary
(Committee Member)

John E. Mylroie
(Committee Member)

Michael E. Brown
(Graduate Coordinator)

R. Gregory Dunaway
Professor and Dean
College of Arts & Sciences

Name: Richard Jason Lenz

Date of Degree: December 13, 2014

Institution: Mississippi State University

Major Field: Earth and Atmospheric Science

Major Professor: Darrell W. Schmitz

Title of Study: Petroleum releases from underground storage tanks in northwest Indiana: Successful remediation techniques and implications of cost effectiveness

Pages in Study: 115

Candidate for Degree of Doctor of Philosophy

Prior to the passage of the 1976 Resource Conservation and Recovery Act (RCRA) 1.6 million bare steel Underground Storage Tanks (UST) were in use in the United States. Many of them were leaking. In Indiana approximately 13,000 UST remain but have been upgraded to meet current industry and regulatory standards. Cleaning up the petroleum releases from leaking UST has continued since it became evident that bare steel underground tanks leaked. In Northwest Indiana glacial moraine and outwash deposits from the Wisconsin Ice Age that retreated 10,000 years ago left 200 feet of glacial till above the underlying bedrock. Soil Vapor Extraction (SVE) and Air Sparging (AS) have proven to be effective and provide significant cost savings for remediation in the glacial deposits in Northwest Indiana. Indiana also has the Excess Liability Trust Fund (ELTF) to help pay for and to expedite clean-up of releases from registered UST. Cleaning up petroleum releases requires the appropriate technology for the localized geology, adequate funding, and appropriate guidance from state and federal regulations.

This study discusses these issues at three sites in Northwest Indiana to demonstrate how technology, funding, and regulatory compliance must collaborate to work in the field.

KEY WORDS: Air Sparging, Excess Liability Trust Fund, Glacial End Moraines, Glacial Outwash Deposits, Indiana, Regulatory Compliance, Soil Vapor Extraction, Underground Storage Tanks

DEDICATION

I would like to dedicate this publication to my wife Joni. She has supported my efforts over the last 30 years, including my academic pursuits. I would also like to dedicate this publication to the memory of my mother Fay Lenz, and my sister Lisa Lenz (Fritz), who both passed away in 2014.

ACKNOWLEDGEMENTS

I would like to acknowledge the contributions of Dr. Darrel Schmitz and his wife Donna. Without their faith, patience, friendship, and trust, this document would not have been possible. Guidance from friends and mentors Larry Maddox and Steve Myers were greatly appreciated.

TABLE OF CONTENTS

DEDICATION ii

ACKNOWLEDGEMENTS iii

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

I. INTRODUCTION 1

Background 1
Objectives and Goals 3
Site Characterization 4
Literature/Background Review 6
Corrective Action Plan 6
Corrective Action Progress Reports 7
Funding 8
Closure 11
Treatment Options 13
Study Areas 20
DeMotte, Indiana 21
Michigan City, Indiana 24
Westville, Indiana 26

II. LITERATURE REVIEW 29

Underground Storage Tanks 29
Leaking Underground Storage Tanks 31
Resource Conservation and Recovery Act, 1976 33
Comprehensive Environmental Response, Compensation and Liability Act, 1980. 34
Superfund Amendments and Reauthorization Act, 1986 35
Indiana Regulations 36
Indiana Department of Environmental Management 38
Excess Liability Trust Fund 42
Types of UST Petroleum Remediation in Indiana 44
Ex Situ Remediation Technology, Over-Excavation 46

In Situ Technologies - Air Sparging 48
In Situ Technologies – Soil Vapor Extraction 53
In Situ Technologies – Bioremediation....................53
In Situ Remediation Technologies - Dual Phase Extraction....................54
In Situ Technologies – Enhanced Fluid Recovery....................54
In Situ Remediation Technologies – Monitored Natural Attenuation....................55
In Situ Remediation Technology – Groundwater Pump and Treat....................56
Northwest Indiana Glacial Advance and Geology....................56
Study Areas....................58
DeMotte, Indiana 59
Michigan City, Indiana 59
Westville, Indiana 60

III. METHODOLOGY 62

Sites Chosen....................62
Excess Liability Trust Fund....................62
Clean-Up Objectives in Groundwater....................64
Clean-Up Objectives in Soil 65
Active Releases in Indiana....................66
Soil Vapor Extraction and Air Sparging....................66
Introduction....................70
DeMotte, Indiana 72
Background....................72
Release 73
Impact 77
Long-Term Remediation....................77
Michigan City, Indiana 79
Background....................79
Release 80
Impact 83
Long-Term Remediation....................83
Westville, Indiana 85
Background....................85
Release 85
Impact 89
Long-Term Remediation....................90

IV. REMEDIATION TECHNOLOGIES, APPLICATION AND EFFECTIVENESS....................93

Introduction....................93
DeMotte, Indiana 96
Michigan City, Indiana 99
Westville, Indiana 101

V. CONCLUSION....104

REFERENCES....106

APPENDIX

A. FIGURES....111

B. NO FURTHER ACTION SITES....113

LIST OF TABLES

1 Applicable Federal Regulations 1

2 Applicable Indiana Regulations 2

3 Industry Guidance Documents 4

4 Applicable State Guidance Documents 5

5 Excess Liability Trust Fund Labor Rates 9

6 Graph of Totals Spent Broken Down by Remedial Strategy 98

LIST OF FIGURES

1 Diagram of Leaking USTs. 2

2 Leaking Underground Storage Tank. 3

3 Fund Revenue Sources. 10

4 Map of Indiana Showing 3 Sites Investigated. 21

5 DeMotte, Indiana Location. 22

6 DeMotte, Indiana Facility. 22

7 Michigan City Location. 25

8 Michigan City Facility. 25

9 Westville, Indiana Location. 27

10 Westville, Indiana Facility. 27

11 Excavated Steel Tank. 30

12 Typical Boring Log. 50

13 Typical Monitoring Well Construction Diagram. 51

14 Typical Chain of Custody Record. 52

15 Hydrogeologic Atlas of Aquifers in Indiana. 57

16 Aquifer Types – Hydrogeologic Sections. 58

17 Typical Soil Vapor Extraction/Air Sparging (SVE/AS) System Conceptual Design. 67

18 Typical Dual Phase Extraction (DPE) System Layout. 68

19 Typical Air Sparging (AS) System Layout. 68

20 UST Open Releases. 71

21 GW Flow Directions – Demotte.....75

22 GW Impact Levels – Demotte.....76

23 Graph of Analytical Data – Demotte.....79

24 Groundwater Flow Direction – Michigan City. 81

25 Groundwater Impact Levels – Michigan City.....82

26 Graph of Analytical Data – Michigan City. 84

27 Groundwater Flow Direction – Wentville.....88

28 Groundwater Impact Levels – Wentville. 89

29 Graph of Analytical Data – Westville.....92

30 Abandoned UST Location.....112

31 Abandoned UST Location.....112

CHAPTER I

INTRODUCTION

Background

It is estimated that 1.6 million Underground Storage Tanks (USTs) existed prior to the passage of the 1976 Resource Conservation and Recovery Act (RCRA) (Rawson, 2003). The RCRA was followed by the 1980 Comprehensive Emergency Response and Liability Act (CERLA), and the 1986 Superfund Re-Authorization Act (SARA). It was suddenly evident that USTs may have leaked and could be affecting our drinking water supply (Liberti, 1993). Figure 1 shows how contamination can occur. The passage of these federal mandates provided states with the regulations for UST management and the power to manage and enforce these new requirements (Table 1).

Table 1 Applicable Federal Regulations

Resource Conservation & Recovery Act (RCRA)	1976
Comprehensive Emergency Response & Liability Act (CERLA)	1980
Super Fund Re-Authorization Act (SARA)	1986

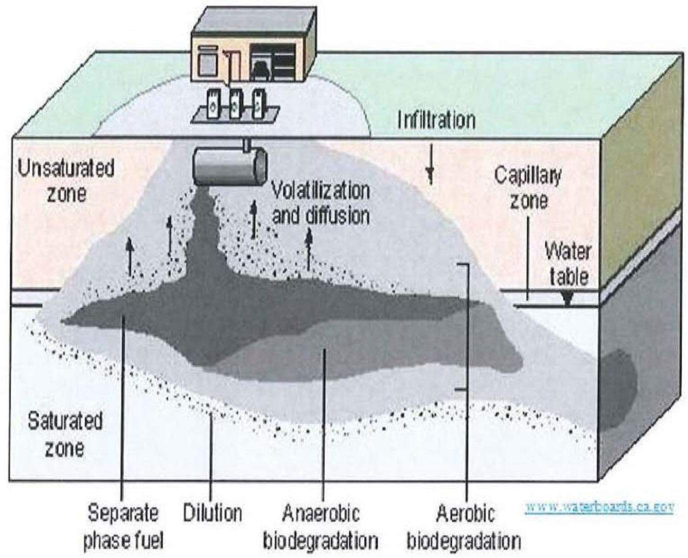


Figure 1 Diagram of Leaking USTs.

The Indiana Department of Environmental Management (IDEM) currently tracks more than 50,000 registered or formerly registered USTs. Of these, 37,000 are no longer in use. Many of the 37,000 USTs were Leaking Underground Storage Tanks (LUSTs) (Table 2). The number of USTs removed from the ground prior to the effective dates of federal regulations is unknown.

Table 2 Applicable Indiana Regulations

Title 328 Indiana Administrative Code (IAC)	1989
Indiana Code (IC) Title 13, Article 23 (IC 13-23)	1988

Undocumented and unknown USTs, many of them leaking, are still being discovered beneath sidewalks, during utility upgrades, in parking lots, and during surveys and assessments completed for real estate transactions and estate settlements (Figure 2). They are former private heating oil tanks, used oil tanks, and tanks no longer in use at service stations. These USTs, such as ones formerly located in Mt. Etna, were abandoned and/or replaced when they were no longer needed (Creek Run, SRC Mt. Etna, 2010). In most cases, these USTs require mitigation. Different types of LUST mitigation technologies, both *ex situ* and *in situ*, have been developed and perfected since the late 1980s. Each technological option offers distinct advantages and disadvantages depending upon the local geology, facility use, and long term mitigation objectives.

Figure 2 Leaking Underground Storage Tank.

Objectives and Goals

The primary objectives of this study are to illustrate and discuss the impact LUSTs can have on the environment, to include the cost of remediation versus anticipated results for a remediation model for northwest Indiana. Resource

Conservation & Recovery Act (RCRA) mandates all UST owners and operators to meet strict requirements regarding inventory control, leak protection, secondary containment, and installation protocols that can substantially reduce the risk of using USTs (Simon and O'Neill, 1988). Prior to 1988, USTs were predominately constructed of bare, unprotected steel, which often leaked and had relatively short life expectancies (Buehlman, et al, 1998). The goals of this project are to (1) determine how state and federal regulations have played a key role in preventing petroleum hydrocarbon releases into the groundwater, (2) determine an effective model for funding environmental remediation in Indiana, and (3) illustrate that Air Sparging (AS) and Soil Vapor Extraction (SVE) are appropriate remediation technologies in northwest Indiana.

Site Characterization

Within 24 hours of discovery of a UST leak, known as a *release*, the owner of the UST must report it to the Indiana Department of Environmental Management (IDEM). Disputes occurred in the past over how and when LUST systems are discovered and who reports the discovery. Tables 3 and 4 contain various state and industry guidance documents. The owner/operator bears legal responsibility for the report.

Table 3 Industry Guidance Documents

American Petroleum Institute (APIRP) 1615 - Underground Storage Tank Installations
American Petroleum Institute (APIRP) 1604 - Underground Storage Tank Removals
American Petroleum Institute (APIRP) 1632 - Cathodic Protection
National Association of Corrosion Engineers (NACE) Recommended Practices (RP) 0285 - 85 External Corrosion, 1985
National Institute for Occupational Safety & Health (NIOSH)/Occupational Safety & Health Association (OSHA) - Pocket Guide to Hazardous Chemicals, 1987

Table 4 Applicable State Guidance Documents

Indian Department of Environmental Management Financial Assurance Board (FAB) meeting minutes
Indiana Department of Environmental Management (IDEM), Non-Rule Policy (NP), Waste 0063, Non-Rule Policy Document (NPD), 2013
Indiana Department of Environmental Management (IDEM), Underground Storage Tank (UST) Branch Guidance Manual, 2004

UST leaks can be discovered in a number of ways: (1) examination of inventory control records, (2) system alarm and electronic monitoring indicators, (3) presence of visible liquid phase hydrocarbons in the sewer system, monitoring wells or in spill containment areas, and (4) presence of petroleum hydrocarbon vapors in existing on-site or off-site structures. In Indiana, the Excess Liability Trust Fund (ELTF) may reimburse eligible owners and operators for costs incurred in minimization, containment, elimination, mitigation, and clean-up of petroleum releases resulting from eligible LUSTs. The Excess Liability Trust Fund (ELTF) provides a mechanism for the reimbursement of money spent by underground storage tank owners and operators on the cleanup of petroleum released from underground storage tanks. It also provides the federally mandated financial assurance for owners and operators of underground petroleum storage tanks and a source of money for the indemnification of third parties. Eligibility requirements for ELTF funds include the proper and timely report of the release to appropriate local and state regulators. In Indiana, state regulators require the tank owner or operator to report the discovery of a release with 24 hours of discovery (Title 328 IAC, 1989).

Following the report of a release, IDEM may require the owner or operator to perform an Initial Site Characterization (ISC) which defines the full nature and extent of soil and groundwater contamination caused by the release. IDEM dictates activities pursuant to the release after it is reported (Title 328 IAC, 1989). In regulating these activities IDEM establishes completion deadlines for specific remediation activities and associated documentation. The Excess Liability Trust Fund (ELTF) reimburses qualifying owner/operators for eligible costs incurred during the investigation, less a predetermined deductible amount. Reimbursement funds can be disbursed to anyone by the owner/operator including 1) contractors, 2) consultants, 3) lenders, 3) and other financial stakeholders. As a result the owner/operator may forfeit some project oversight and management, which can affect the efficient completion of the project (White 1996).

Literature/Background Review

Corrective Action Plan

In a Corrective Action Plan (CAP), the owner/operator recommends to Indiana Department of Environmental Management (IDEM) the best remediation technology for mitigation of a particular release based on findings reported in the ISC. The CAP includes the evaluation of available remediation strategies with respect to cost, effectiveness, and time required for each strategy. Common strategies include, but are not limited to, excavation, pump and treat, natural attenuation, and less invasive *in situ* technologies. Natural attenuation is the natural occurring remediation that takes place due to microbiological breakdown of petroleum hydrocarbons. Certain site-specific conditions such as local geology and pilot test results influence selection of the recommended strategy. For example, excavation of petroleum-impacted soils would not address the impacted groundwater. Monitored natural attenuation (MNA), a remedial approach described later in this document, would not be recommended if off-site areas are impacted, or in environmentally sensitive areas (White, 1996).

Following CAP approval by employees of IDEM, that include staff geologist and project managers, implementation of the CAP commences. Implementation may be extremely time consuming and usually includes the procurement of local and state permits, on-site inspections, preparation of bid documents, solicitation and review of bids, award of contracts, negotiations with contractors, and on-site implementation activities. IDEM requires the procurement of at least three bids for remediation activities prior to the hire of an outside contractor (IDEM, Non-Rule Policy, 2013). Bids must comply with specifications in the bid request documents.

Corrective Action Progress Reports

Beginning at the approval of the ISC, IDEM may require a Corrective Action Progress Report (CAPR) at the end of each completed calendar quarter. The CAPRs are designed to document all remediation activities at the site during the previous quarter. Remediation activities include at least one groundwater sample collection event from the monitoring well network for the three-month period documented in the report. The sampling event completed from the monitoring network is normally completed by the consultant. The network is a system of monitoring wells installed to define the contaminant plume. Each release site in Indiana must have a monitoring well network (Title 328, IAC, 1989). The network includes all groundwater sampling wells installed as part of the ISC. Some monitoring wells are installed within the contaminant plume of the release and some are installed outside the plume to monitor plume migration. The CAPR will document the progress of the cleanup process, including (1) treatment system run time, (2) hydrocarbons removed, (3) groundwater removed, treated and disposed of, and/or re-injected, and (4) all other site activities.

The CAPR documents all cleanup activity. Consultants use the CAPR to track remediation progress and adjust remediation techniques as needed (Cole, 1994). Waiting for IDEM to request changes to the system will result in untimely delays and excessive expense that may not be reimbursable under ELTF. The average petroleum hydrocarbon remediation project in Indiana costs $ 480,000 USD and takes three to five years of system operation and an additional year of monitoring before closure is granted (Braun, 2013). Many projects will take more time and in some cases much more money to complete. IDEM has determined that remediation is more likely to take place when a managed and solvent ELTF fund exists. The numbers above are based on estimates by ELTF. (IDEM, Non Rule Policy, 2013)

The primary objective of this study is to illustrate and discuss the impact that LUSTs can have on the environment and provide an effective remediation model for northwest Indiana.

Funding

ELTF reimburses approximately 50% of eligible costs submitted (IDEM, Non Rule Policy, 2013). Some companies will receive up to 100 % of eligible cost. According to the most recent meetings of the Financial Assistance Board (FAB), $76 million USD are available to registered UST owners to pay for properly reported and documented LUSTs. The FAB controls the funds available to ELTF. FAB is a nine member board, members include environmental consultants working in the private sector, UST owners or operators, and IDEM staff members. Funds dispersed for reimbursement are determined by the IDEM project manager following the protocols of Title 328 IAC 1989, IC 13-23, and IDEM Non-Rule Policy Waste 0063 – NPD (Tables 2 and 4). The board meets quarterly in a public meeting and all data including funds available are published. Minutes of the meeting are available and published. When a release is properly reported IDEM assigns it a unique reference number known as an incident number, and an IDEM project manager. ELTF requires the IDEM project manager to review reimbursement requests for compliance with labor rates for specific activities, regardless of the title of the person doing the work. Labor rates are included for Principals, Senior Project Managers, Project Managers, Staff and Field Geologists, Draftsmen, Toxicologists, and Administrative Support (Title 328 IAC, 1989). Labor rates follow industry standards. Table 5 contains ELTF rates from June 1, 2014 through May 31, 2015. A properly completed ELTF claim would be paid out at 100 %. When ineligible costs are requested or when reimbursement costs requested do not comply with the lowest bid, then funding will be denied.

Table 5 Excess Liability Trust Fund Labor Rates

Principal	$142.00
Senior Project Manager	$131.75
Project Manager	$108.25
Staff Project Person	$91.00
Field Tech	$62.25
Drafting Person	$53.25
Word Processor/Clerical	$36.75
Toxicologist	$162.25

ELTF pays out $4 million USD per month for LUST mitigation, while collecting $8 million USD per month in UST fees, interest, and a retail fuel tax (IDEM, Non Rule

Policy, 2013). The one cent USD per gallon gasoline and diesel tax makes up the majority of all funds collected. The diesel tax has only been in place since 2006 (Figure 3). This system is unique to Indiana. The maximum reimbursement per incident is $2 million USD, disbursed at a maximum rate of $1 million USD per year per incident. A maximum of $3 million USD per year is disbursed to any one person or entity, regardless of the number of sites or claims submitted for the year by that person or entity (IDEM FAB Board Meeting Minutes, 2013).

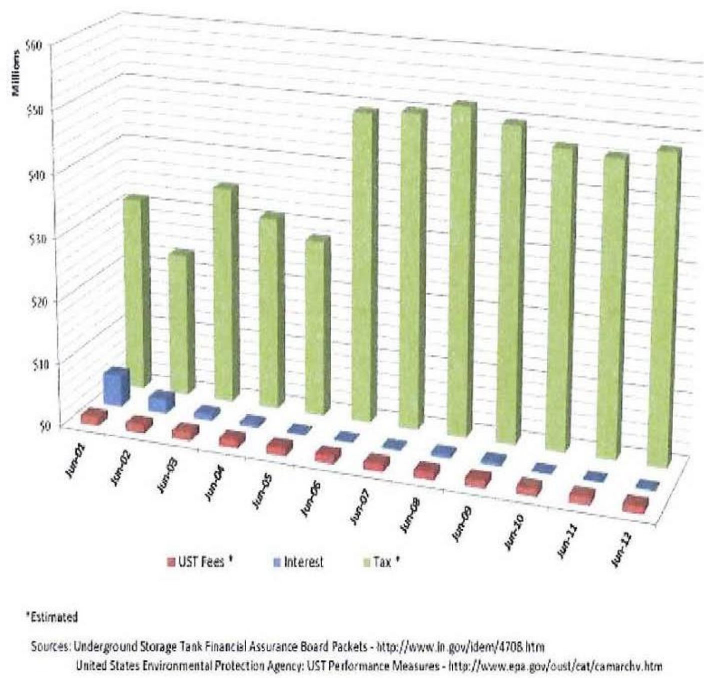


Figure 3 Fund Revenue Sources.

In Ohio the Bureau of Underground Storage Tank Regulations (BUSTR) collects tank fees from tank owners but does not have a gasoline or diesel tax to help fund remediation project costs. The program, managed by the Ohio Department of

Commerce, reimburses only high priority projects or only those where groundwater is impacted, and takes 16 to 18 months to disburse funds. In Indiana payment can be expected in four months. In Michigan the UST program is insolvent and has not disbursed any funds for environmental remediation in more than a decade (Creek Run, CSA Coldwater, Michigan, 1997). In Kentucky all remediation activities are backed by insurance and bonds funded entirely by UST owners or operators, environmental consultants, and environmental contractors. Kentucky requires the owner or operator to provide bonds to offset reimbursement costs (Creek Run, SCR Lexington, Kentucky, 2006). South Carolina and Minnesota have programs that mirror Indiana in many ways, in that their programs are funded not only by tank fees but also a tax on the retail sale of gasoline and diesel fuel. Therefore, individuals who buy gasoline and diesel help pay for the cost associated with environmental remediation (Huber, 2009).

Matt Huber believed that more states should mirror these types of state-sponsored programs in order to help pay for the destruction of the environment caused by the use of automobiles (Huber, 2009). “If we are going to prioritize the rewards,” stated Huber, “we should not socialize the cost.”

Closure

Once acceptable closure levels have been met and data from the CAPRs have documented the success of the remediation, the owner/operator may request incident closure, also known as site closure, from IDEM. IDEM will generally ask for remediation system shutdown and continuation of the quarterly CAPRs for an additional year. Remediation activities will cease while quarterly sampling continues to check for rebound of contaminant levels. Hydrocarbons trapped, attached to, or absorbed by the soil can reenter the groundwater. Although infrequent, this can happen in the capillary zone or in the zone of water table fluctuation (Cole, 1994).

The goal is to achieve closure at acceptable levels. At the beginning of a remediation project it is difficult to discuss its end results (Nyer, 1992). Evan G. Nyer declared that consultants need to spend as much time and money at the beginning of the project addressing its end results as they do in determining which technical approaches will remediate its environmental impacts. Closure will involve the risk assessment of any contaminants left in place. Contaminant migration pathways, federal drinking water standards, human exposure, human consumption, desired long term property usage, property location, owner desires, and fund holders' desires will all need to be considered (Nyer, 1992).

All remediation systems have an effective period and will reach a point of asymptote (Nyer, 1992), that is, the point at which the remediation system is no longer effective. Once the system is shut down, the contamination levels may rebound and contaminants may migrate from the soil into the aquifer. Nyer argued that this is why regulators must always allow for the determination of contaminant rebound and acceptable contaminant closure levels at the beginning of the project. Sometimes acceptable closure levels may be arbitrary contaminant concentrations that are decided well in advance of closure (Nyer, 1992).

The CAP should state acceptable closure levels. The acceptable closure levels will depend in part on the location of the site. For example, a site next to an elementary school with a shallow drinking water well in a residential neighborhood will have a very low benzene cleanup level, and a very low methyl tertiary butyl ether (MTBE) cleanup level (Creek Run, CAP DeMotte, 2012). Residential closure levels for benzene in water in Indiana are 5 parts per billion (ppb) (5µg/L). For example, a site in an industrial area served by public utilities will have higher closure levels (Creek Run, CAPR Michigan City, 2013). Industrial closure levels for water in Indiana are 52 ppb (52µg/L). For example, Simon James questioned the definition of “clean”, and asked what is meant if contaminants are left in the ground (James, 2013) James researched the meaning of nature and how we can find nature and the meaning of nature in almost anything, even at the mall, or a gas station, or a closed gas station, even a closed gas station that has environmental impacts that are being addressed. He questioned why we would address these impacts to achieve a closure level that is simply a number. He asked what meanings we find in numbers when we talk about closure of environmentally impacted sites. However, the goal of the environmental consultant working in Indiana is to achieve closure, based on numerical values.

The ELTF has been criticized in recent years on many number issues including the average payout of only 50 % of a claim (IDEM Non-Rule Policy, 2013). Reasons for the low payout, according to IDEM, include the lack of three compliant bids, failure to justify costs, failure to meet industry standards, and submission of costs for activities at higher billing rates than the activity is allowed. IDEM also pointed out in the Non-Rule Policy that many consultants exceed the 50 % average and are at or close to 100%.

Treatment Options

Treatment options include *ex situ* and *in situ*. *Ex situ* treatment options include over excavation, land farming and Monitoring Natural Attenuation (MNA). *In situ* include Air Sparging (AS) Soil Vapor Extraction (SVE), Ozone Sparging, Enhanced

Fluid Extraction (EFR), bio-remediation, pump and treat, and Dual Phase Extraction (DPE).

The *ex situ* treatment option, including excavation and removal of contaminated soil, is not a desirable option. For example 20 to 25 years ago it generally was the only affordable option and therefore viewed as the only option available (Jim Allen Maintenance, 1992). Owner/operators were removing LUSTs from the ground in order to replace them, following the new applicable regulations. All the new fiberglass-reinforced plastic (FRP) tanks were longer and wider. A new 10,000 gallon (37,854 L) FRP tank would be 32 feet (9.14 m) long and 8 feet (9.14 m) wide. All new FRP tanks must be installed by licensed contractors in all 50 states, including Indiana. New tanks must be installed in accordance with requirements of the manufacture and Comprehensive Emergency Response & Liability Act (CERCLA). One of the requirements is the use of imported backfill materials around new FRP tanks, rather than the native soil excavated on site. Installation of steel USTs had none of these requirements. Installation procedures rarely followed any state or other guidelines because there were none before RCRA or CERLA. Soil had to be removed to allow for a larger excavation to accommodate the new UST. If the soil was impacted with petroleum, the thought process was that the soil had to be removed simply to accommodate the new tanks. In most cases, remediation was only an afterthought by tank owner/operators who were merely removing their old USTs in order to comply with new regulations. For example if the old UST leaked, then this was a problem that was only addressed as the excavations were made larger. It was an afterthought, and in many cases no planning was done prior to removal of the LUST. The owner/operator merely wanted his new tanks installed so he could reopen his store as soon as possible (Rawson, 2003). What occurred in many cases was that it became a convenient option to remove impacted material only because it had to be removed off-site. It was extremely expensive, but very convenient. Convenience in environmental remediation can become expensive (Nyer and Skladany, 1992).

In situ treatment options include Air Sparging (AS), which promotes volatilization and biodegradation by introducing air into the aquifer, and In-Well Aeration, which introduces air into the well to create a vacuum. Air is introduced into the water table through a well that is screened below the water table. It is under pressure to force flow into the aquifer, and must be hydraulically isolated from the vadose zone. The injected air will then migrate up through the aquifer material to the vadose zone or the unsaturated zone. This process works much like a fish tank or farm pond aeration system that is designed to oxygenate the groundwater. Bubbles are created with very distinct flow patterns that should be captured. Volatilization evaporates and then extracts the contaminants in the process. Robert Johnson argued that the flow patterns are not distinct and therefore, although volatilization occurs, it is not possible to capture all the volatilized vapors. This is in contrast to what Robert Hinchee stated. The vapors in a petroleum remediation setting must be captured for Air Introduction to be the most successful (Creek Run, IIR Westville, 2008).

It is possible to use In-Well Aeration and Air Injection at the same time in a remediation project. In some cases a network of nested wells, in which multiple well screens and their casings are installed in single vertical boreholes or horizontal bores, provide the most effective remediation. Nested wells allow for access to any of a number of individual well screens at a discreet borehole location. Horizontal drilling can allow nested monitoring wells at a single location. These horizontal installations can reach off-site contaminants, but are drilled on site. They extend underneath buildings, allow for access underneath utilities, and public rights of way (Ryan, 2013). If a monitoring well is converted for use as a remediation well it can no longer be used for the collection of quarterly groundwater samples (IDEM, Guidance Branch Manual, 2004). It has been determined that since this is point where remediation would be the most enhanced, then sampling from this point would not yield a sample representative of the plume of contamination that was defined in the ISC (Hinchee, 1994).

Multiple nested wells can be placed in within a contamination plume depending upon the radius of influence and the size of the defined plume. The radius of influence is calculated by determining the differential vacuum in adjacent wells. It is an attempt to determine the radius of influence based upon the monitoring well network (Nyer, 1992).

Another technique researched by Evan Nyer is Ozone Sparging. Ozone Sparging has not proven effective over long periods. I have only seen it used once, at a site I will describe later, with less than conclusive results. The premise of Ozone Sparging technique is that ozone, an oxidizing agent, can effectively treat hydrocarbons. Fifteen years ago ozone was considered effective in the remediation of petroleum-impacted soil and groundwater. Ozone Sparging has proven ineffective (Nyer, 1992). The extraction of volatiles from porous soils by Soil Vapor Extraction (SVE) can be efficient and rapid. In heavy, non-porous soils and clays SVE is slow and inefficient, and, in some cases, ineffective. It is necessary to establish the value of the soil porosity at the beginning of the project, before a remediation technology is selected (Johnson, 1994). According to

Robert Johnson, other considerations for a successful SVE remediation project include soil moisture content, depth to the water table, and other factors that would affect the flow of volatile contaminants. Many in the industry consider SVE a successful remediation technology when combined with other treatment technologies, including AS.

Bio-Remediation is expensive to monitor because it requires a relatively long time, in some cases decades, to produce measurable remediation results (Nyer, 1992). Land farming is considered an *ex situ* remediation technology because contaminated soil is excavated and spread on the surface in thin layers to allow bioremediation to take place.

In land farming, excavated contaminated soil is spread in a thin [less than 12 inches (0.3 m)] layer to allow atmospheric oxygen to contact the soil. Waterproof membranes placed under and around the edges of the spread soil prevent erosion. Although some contaminant degradation results from microbial activity, most of the volatile contaminants enter the atmosphere untreated. Land farming requires relatively large areas of space. The contaminated soil is excavated, transported to the land farm location, and spread over the waterproof membrane by agricultural equipment. The contaminated soil must be contained to prevent water runoff, but should remain relatively dry. Fences or similar barriers prevent unauthorized access to the land farm. IDEM does not approve off-site land farm locations (IDEM, UST Guidance Branch Manual, 2004).

Dual Phase Extraction (DPE) has been demonstrated to be an effective, stand-alone technology for the remediation of petroleum-impacted unsaturated soil, saturated soil, and groundwater. Site hydrogeology and the efficiency of the DPE system determine the time required to remediate petroleum vapors and impacted groundwater and achieve cleanup goals. As Ryan (2013) discussed, the same factors affect the time required for other treatment technologies. Short-term costs associated with DPE pilot testing, system design, and system installation are relatively high compared to other system technologies, such as SVE. For example, DPE requires new extraction wells dedicated to the purpose. Existing monitoring wells may not be converted to extraction wells. Extraction wells must be strategically placed within the most highly impacted areas. They are generally deeper and larger in diameter than the 2 inch (50.8 mm) monitoring wells. Long-term costs for system operation and maintenance (O&M) and groundwater quarterly monitoring can be significant. Trenching is required for the installation of DPE collection piping. Short term disruption to business operations is unavoidable. Once DPE system installation is complete, disruption to business operations is minimal (Ryan, 2013).

DPE is generally considered the most expensive treatment technology. Recovery and treatment of large quantities of goundwater from coarse-grained aquifers require extensive operation and maintenance (O&M), especially in the extreme weather conditions of northern Indiana.

Enhanced Fluid Recovery (EFR) events remove contaminated groundwater by applying vacuum to selected monitoring wells or extraction wells for an extended period of time, generally six to eight hours. A truck equipped with an integral vacuum pump and water storage tank removes groundwater from the aquifer via the well. The truck-mounted storage tank is usually 3,000 gallon (11,356 L) capacity. Recovered fluids are transported off-site to a permitted non-hazardous wastewater treatment and disposal facility. Recovered vapors are discharged to the atmosphere in accordance with applicable state air emissions standards and regulations.

The primary advantages of EFR events are their relatively low cost and minimal site activity disruption. EFR can remove several thousand gallons of the most heavily impacted groundwater and hydrocarbon vapors from the contaminated area. Effectiveness is dependent on the duration and number of events. The relatively brief EFR events do not provide positive hydraulic control of a contaminant plume in groundwater and do not provide continual recovery of vapors from the vadose zone. Many times EFR events are implemented in conjunction with other treatment methods (Johnson, 1994).

Monitored Natural Attenuation (MNA) may become a viable alternative to active remediation technologies once contaminant levels have been reduced. MNA documents the progress of contaminant reduction by the action of naturally-occurring microorganisms. In most cases MNA is implemented following completion of an active remediation technology.

In certain circumstances the pump and treat approach provides effective remediation. Pump and treat remediation consists of the continuous removal of contaminated ground water by the use of pumps which discharge to a ground water treatment system. The treatment system discharges the treated water to a sanitary sewer or storm drain. Pump and treat prevents migration of contaminants by establishing hydraulic control of the contaminant plume. Additional advantages of pump and treat are the ability to lower the water level, which exposes saturated soil to air movement, and the availability of relatively simple and reliable equipment (Nyer, 1992). The disadvantages of pump and treat are (1) relatively high equipment installation costs, (2) significant O&M costs associated with water treatment, (3) space requirements for a pump and treat system, (4) significant disruptions to site operations, and in many cases, the cessation of site operations (Creek Run, CAP Middletown, 2004), (5) the amount of time required to achieve cleanup objectives, and (6) the inability of the technology to reach acceptable cleanup goals in hydrogeologic settings characterized by fine-grained materials that produce little water, such as silt and clay.

Study Areas

In northwest Indiana, perched water is very close to the surface, that is, within a few feet/meters in all three cases investigated, and within the contact area of the original excavation for USTs (Wayne, 2013). West has written extensively about the aggregate mining of these glacial till deposits and how such mining affects groundwater flow and recharge (West and Cho, 2006). The preferred treatment technology at each location in northwest Indiana is Soil Vapor Extraction (SVE) and Air Sparging (AS). Figure 4 shows locations of the three sites investigated: DeMotte, Michigan City and Westville, IN)

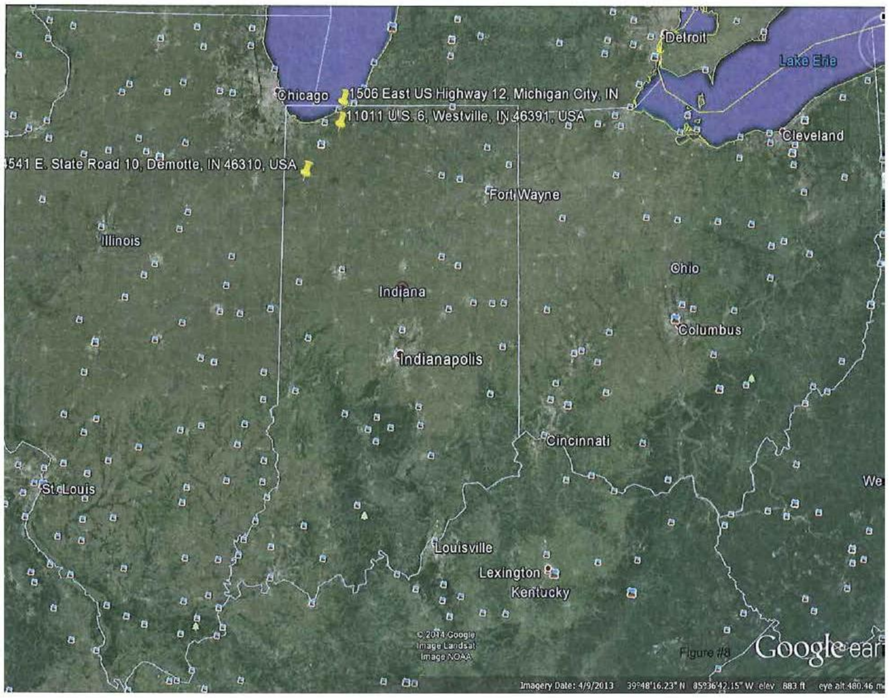


Figure 4 Map of Indiana Showing 3 Sites Investigated.

DeMotte, Indiana

The DeMotte, Indiana site is a retail and bulk fuel facility with a convenience store and office located on the property. Previous land use was agricultural. The site is bordered by agricultural land to the south and by residential property to the west and east, and by a state highway (a two-lane blacktop road) to the north. There are nine USTs located and in use on this site. All USTs are catholically protected steel tanks (API RP 1632, 1992). The site has a documented historical release. IDEM has received no report of a petroleum release from the USTs. Figure 5 shows the site on Google Earth. Figure 6 shows the facility at the site.

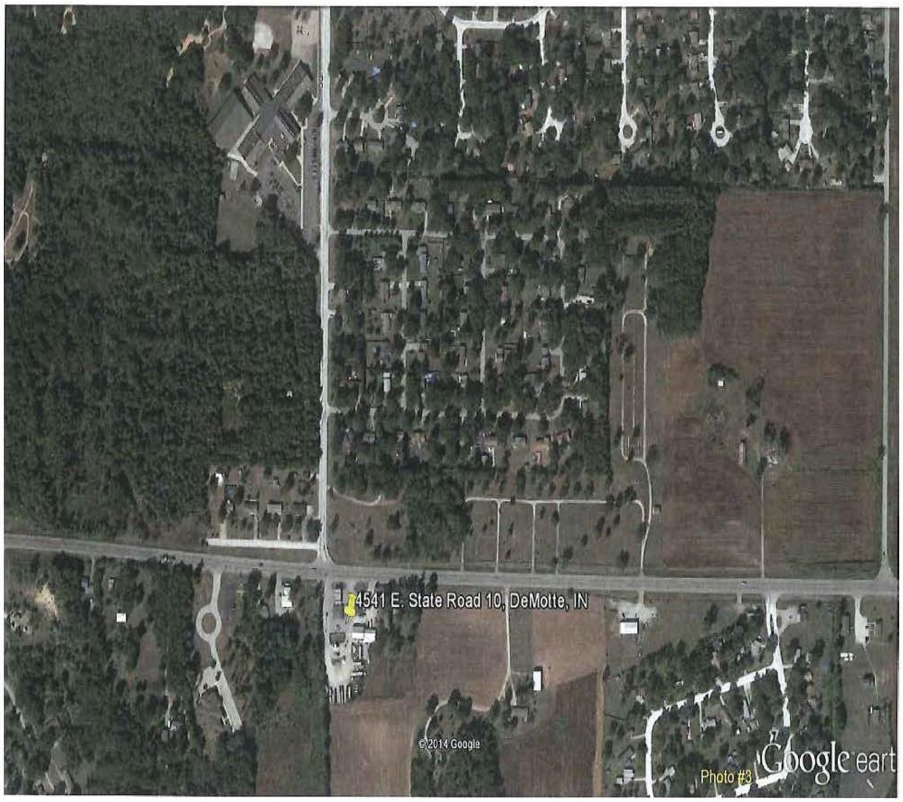


Figure 5 DeMotte, Indiana Location.

Figure 6 DeMotte, Indiana Facility.

In February 2002, a county health department employee detected an apparent petroleum odor from water in the restroom of the existing building and verbally reported a petroleum release to IDEM (Mundell and Associates, DeMotte, 2002). An initial site characterization (ISC) was completed in August 2002 by Mundell and Associates (Mundell) of Indianapolis, Indiana. The ISC and the subsequent Further Site Investigation (FSI), completed in December 2002, reported areas of unsaturated soil and groundwater beneath the site impacted by benzene, toluene, ethlybenzene and total xylenes (BTEX), and methyl tertiary butyl ether (MTBE). A dissolved contaminant plume extended off site to the north and northwest. MTBE dissolves easily in groundwater and travels very quickly.

Off-site impacts extended laterally more than 400 feet (metric) to the north, beneath the state highway and one residential property, impacting a private drinking water well and the drinking water well for Lincoln Elementary School in DeMotte, Indiana. Temporary emergency response measures included the addition of activated carbon to the drinking water supplies of the site, the private residence, and the elementary school to ensure safe drinking water for those affected. Many of these temporary emergency response measures remained in place for ten years. Ozone Sparging and a limited off-site pump and treat system were remediation technologies selected by the consultant and approved by IDEM. These had little effect on contaminant levels and cost the ELTF fund and insurance carriers more than $ 3.5 million USD. (Creek Run, CAPA, 2012). The Ozone Sparging was discontinued and AS and SVE were installed. The limited pump and treat approach was expanded, and the on-site drinking water well was replaced. The new well was placed outside the contaminant plume. Closure of this site and receipt of a notice of No Further Action (NFA) status from IDEM is anticipated in early 2015 (Creek Run, CAPA 2012).

Michigan City, Indiana

The Knoll Brothers site in Michigan City, Indiana has its own set of unique circumstances. The site is eligible for ELTF funding even though the UST on site operated for a short time following the enactment of 328 Indiana Administrative Code (IAC). In 2010, Knoll Brothers' insurance carrier assumed direct oversight of remediation efforts in a process termed "reservation of rights," which permits the insurance carrier to assume management of the remediation activities conducted by the tank owner/operator and the former environmental consultant (Dorsey, 2013). In January 2011, a different environmental consultant was retained by the insurance carrier as the consultant of record. It appears that petroleum releases in the form of surface spills of small quantities of petroleum fuel occur daily. These releases occur from the bulk fuel off-loading area near the above ground storage tanks (ASTs) that remain in use and at the loading rack where fuel is dispensed from the ASTs. Since 2010, at least one major release, a 2,000 gallon (7,570 L) surface spill, has occurred. The consultant of record was not informed of the release until after the tank owner/operator attempted to mitigate the release without submitting a timely report to IDEM. Figure 7 shows the Google Earth location. Figure 8 shows the facility at the site.

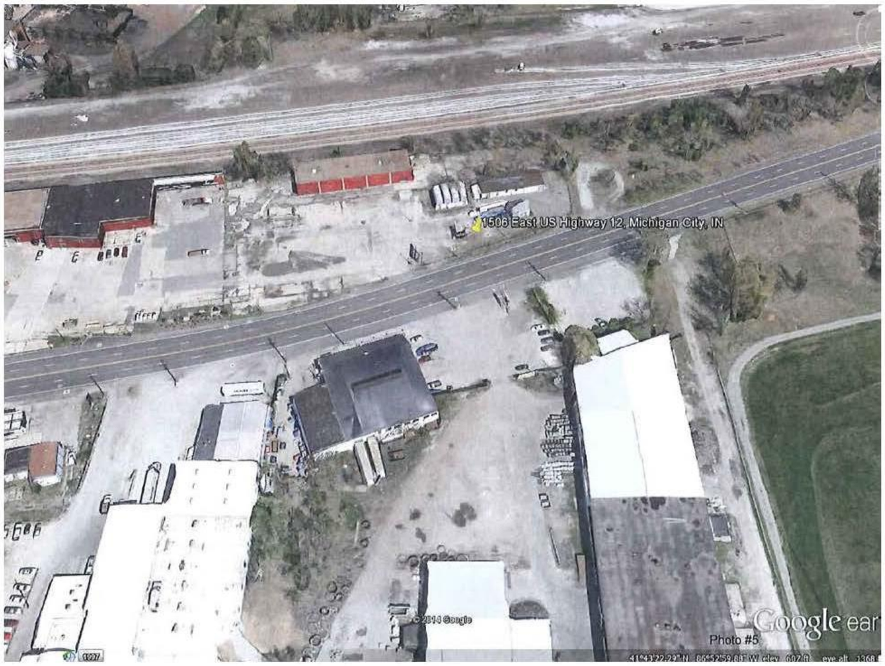


Figure 7 Michigan City Location.

Figure 8 Michigan City Facility.

Environmental petroleum contamination extends to an adjoining property to the west. Emergency response activities to control plume migration have continued into 2014, a corrective action plan (CAP) was approved by IDEM. Cap approval allows implementation of long term remediation activities. IDEM approved a combined AS and SVE system, with limited use of DPE. Efforts to remediate soil and groundwater contamination are hampered by the ongoing spills and releases that remain uncorrected. These spills and releases will delay clean-up efforts and add to the cost of remediation This site is not expected to achieve a No Further Action (NFA) status by IDEM until 2016 (Creek Run, RWP 2013).

Westville, Indiana

In 2007, IDEM assigned incident number 200711506 to Family Express, a fuel station and convenience store located in Westville, Indiana. SESCO Environmental, an environmental consultant retained by Prassus Brothers, the owner of an adjoining property, requested permission to collect soil and groundwater samples on the Family Express site. Family Express granted permission to Prassus Brothers' consultant and impacted soil and groundwater were encountered. IDEM, which had formerly assigned an incident number to the Prassus Brothers location, assigned this incident number to Family Express. This decision was based on the groundwater flow direction and the fact that Family Express may be contributing to the hydrocarbon plume being addressed by Prassus Brothers (Satkus, 2009). Figure 9 shows the Google Earth location. Figure 10 shows the facility at the site.

Figure 9 Westville, Indiana Location.

Figure 10 Westville, Indiana Facility.

The issue was complicated by the fact that different consultants were working on each site and that locations directly south were also impacted with hydrocarbons but there were no investigation or remedial activities taking place at those locations. The investigation was completed on the Family Express property and a CAP was approved in July 2010 (Creek Run, IIR Westville, 2008). The CAP addressed the issues on the Family Express property and in the right of way directly off site to the south and to the southeast. The system was an Air Sparge (AS) and Soil Vapor Extraction (SVE) system with the ability to use DPE technology with up-gradient reinjection points. SESCO Environmental proposed and installed AS only, which proved ineffective (SESCO, CAP, 2008). At this writing, lawsuits to resolve the issue continue. Projected closure for the Family Express site is expected in early 2015. No time table exists for an NFA at the Prassus Brothers location and the issue is unlikely to be resolved without further litigation. SESCO Environmental has exhausted funds available for the Prassus Brothers project and has been unsuccessful in achieving site closure. It is likely litigation will stall activities at the adjacent location (Satkus, 2011). It appears that the AS system was not sufficient to remediate the hydrocarbon plume, and failure to act with additional technology in a timely manner has cost too much time and money (Creek Run, IIR Westville, 2008).

CHAPTER II

LITERATURE REVIEW

Underground Storage Tanks

Underground Storage Tanks (USTs) for the storage and retail sale of petroleum have been in place since the beginning of petroleum retail use and they have been used extensively since the end of World War II. Until the late 1980s and early 1990s almost all of these USTs and piping systems were constructed of bare unprotected steel. It is estimated that 85 % of all USTs installed before 1988 were bare unprotected steel tanks (IDEM, UST Branch Guidance, 2004). Huber defined (1) the need for cheap oil and gasoline, (2) the necessity of the UST fuel storage system, (3) USTs, and (4) how they applied to the long term growth period following World War II called Fordism (Huber, 2009). Steel storage tanks provided a mechanism for petroleum fuel distribution. These tanks were installed under few or no regulations. Native soil was used as backfill in many cases, without regard to traffic patterns, surface drainage conditions, or environmentally sensitive areas (Huber, 2009). Cole documented that no regulatory authority existed at the federal or state level until the mid-1970s, when federal authorities noticed that bare unprotected steel USTs leak and can have negative impacts on our environment, drinking water, and health (Cole, 1994). Prior to the mid-1970s, no one seriously considered that bare unprotected steel tanks might leak. Another decade passed before many states had the authority and the personnel to implement regulations that would allow, and ultimately enforce, the removal of these USTs (IC 13-23). Figure 11 shows an excavated steel tank.

Figure 11 Excavated Steel Tank.

Despite the 1984 passage of IC 13-23, Underground Storage Tank Regulations, Indiana state authorities, like those in many states, had little or no authority to determine that (1) existing USTs did not leak and (2) new and/or upgraded USTs were installed according to current technology (IDEM, UST Branch Guidance, 2004). Leaking USTs were abandoned in place and other USTs were installed next to or near the leaking USTs. As properties were sold, abandoned, or repurposed, these now "orphaned" USTs were left to be discovered by others who then incurred the financial burden of their removal (Lenz, 2012). In a small town in north central Indiana, an abandoned gas station with two known USTs was owned by an estate. After a site investigation was completed and during a UST removal project seven USTs were discovered and removed (Creek Run, CSCR Mt. Etna UST Removal, 2010). The financial burden fell upon the property owner who had never used any of the USTs.

Leaking Underground Storage Tanks

This research focuses on Leaking Underground Storage Tanks (LUST) in Indiana. However, it is estimated by IDEM that 1.6 million USTs exist in the United States. Most states have similar regulations regarding USTs and LUSTs. In Indiana, the regulatory authority is the Indiana Department of Environmental Management (IDEM). IC 13-23 and the UST Guidance Branch Manual, adopted from Title 40 Code of Federal Regulations (CFR) 280 under the Resource Conservation and Recovery Act (RCRA, 1976), direct how IDEM regulates USTs and LUSTs. IDEM is managed by the Office of Homeland Security, formerly the State Fire Marshal's Office. Their office has reported 40,000 LUST incidents from the more than 50,000 USTs that are or were in in place in Indiana and were known and regulated. Only approximately 13,000 USTs remain that are registered and regulated by IDEM. Many identified exempt USTs exist. Rawson (2004) discussed how unregistered, unregulated and exempted USTs may pose a bigger threat to our water supply system than registered and regulated USTs. Figures 12 and 13 are examples of such locations. The reason is that most of these USTs are unknown and therefore in unknown condition. Farm tanks, less than 1,100 gallons (4,164 L) capacity, would be an example of an exempt UST. Other examples would be heating oil tanks, septic tanks, used oil tanks, and flow-through processing tanks (Rawson, 2003).

LUSTs pose a threat to our water supply and account for 90 % of all of the remedial sites in the United States (Simon and O'Neill, 1988). Clean-up technologies (Simon and O'Neill 1988) varied over the last 25 years. As regulations went into effect to identify, register, and regulate USTs and remove and upgrade them, LUSTs were removed. New upgraded USTs were simply installed on another part of the property and no remediation took place from the now-removed, abandoned and undocumented USTs that could have been leaking for decades and were left in place (Creek Run, IIR Westville, 2008). In other cases, minimal investigations were completed on sites during UST upgrades. Some excavation took place but water contamination was not addressed (Creek Run, DeMotte, CAPA, 2012). In the 1990s it was not uncommon to excavate contaminated soil as new USTs replaced LUSTs. Generally the new tanks were larger and simply required larger excavations. In these cases petroleum-contaminated native soil was removed to accommodate the longer and wider new USTs. This petroleum-impacted material was removed from the ground to allow for the larger excavation and to meet the regulatory requirements for UST removals (IDEM UST Branch Guidance, 2004). Impacted groundwater, or even the presence of groundwater itself, was an inconvenience dealt with for the short term prior to new UST installation. Groundwater was forgotten once the new USTs were installed and surface restoration completed. If a petroleum release was reported it could be years before IDEM contacted the responsible party (Creek Run, Montpelier, 2013).

Steel USTs leak because bare steel placed in the ground will encounter soil and moisture conditions that combine to produce an underground electrical current (API RP 1632, 1992). This current over time causes corrosion which destroys the steel. These bare steel tanks displayed severe pitting in the ends of each tank when removed from the ground. The pitting was caused by the electrical charge passing through the tank (API RP 1632, 1992). It is estimated that a buried steel tank has a maximum life expectancy of

25 to 30 years (NACE RP-0285-85, 1985). All or most USTs installed shortly after World War II were past their estimated life expectancy when the first rules and regulations went into effect in Indiana to govern USTs in 1988. Ryan reported that almost all USTs installed before 1990 were bare steel (Ryan, 2013). By 1999, when all new UST regulations took effect and bare steel regulated USTs were disallowed, more than 370,000 LUSTs had already been identified in the United States; approximately $70 million USD would be required to clean up the petroleum impacted sites (Ryan, 2013). By 2013, Ryan estimated 21,000 LUST sites had been remediated. Not only had the USTs leaked, but also their connected bare steel piping. Steel pipe fittings can, over time, leak more petroleum than the tanks themselves because of improperly tightened or loosened (Creek Run, DeMotte CAPR, 2013).

New regulations for new USTs did not adequately address the existing LUST sites. The unaddressed LUST problems include (1) how these sites would be remediated, (2) who would be financially responsible for remediation costs, and (3) how public agencies could ensure that the remediation was properly performed (Webb, 1990).

Resource Conservation and Recovery Act, 1976

The Resource Conservation and Recovery Act (RCRA) was enacted by the United States Congress in 1976. It was estimated that 90% of all hazardous waste in 1976 was improperly disposed (Cole, 1994). Although RCRA largely ignored LUSTs, it specifically excluded them as a hazardous waste (Title 40 CFR Part 280, 1976). Weber(1989) developed the premise that although RCRA ignored LUSTs, its enactment did lead to regulatory structure that would ultimately require the regulatory compliance of all USTs. Shortly after the Love Canal, New York incident in 1976, which did not involve LUSTs but rather the illegal dumping of hazardous waste in 55 gallon (208 L) drums, Nightline and then 60 Minutes (CBS) reported on two LUST locations, one in Denver, Colorado and the other in New York, New York. In each incident, gasoline leaked from LUSTs into nearby basements (Weber, 1989). Weber wrote that these high-profile incidents led to the passage of additional regulations. For the first time, USTs were identified as a major unaddressed source of groundwater contamination in all areas of the United States (Beck, 1979). It was also established that not only were USTs a major source of unaddressed contamination, no one, including the US Environmental Protection Agency (EPA), had any data on how many USTs existed, how many leaked, or how the contamination would be addressed (Webb, 1990).

Comprehensive Environmental Response, Compensation and Liability Act, 1980.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERLA) exempts petroleum from the definition of hazardous substances but it does not exempt petroleum contaminated sites. This enabled the environmental remediation of petroleum impacted sites (Weber, 1989). In 1980, The Environmental Protection Agency was in its infancy. Evacuations at Love Canal began to take place on a limited basis in 1978. By 1980 Love Canal was not a landmark event of national concern, but only a neighborhood in Niagara Falls, NY where people were struggling to ensure they would have clean groundwater to drink (Beck, 1979). Beck documented how Love Canal was neither the first nor was it the worst impacted location discovered, but it was a landmark event because it involved a residential neighborhood. Martha Fowlkes and Patricia Miller documented the tragedy from a place of hope to a place a terror.

When children begin to die of cancer people take notice (Fowlkes and Miller, 1982). Beck (1979) stated that Love Canal led to the implementation of CERLA.

CERLA's chief aim was to establish not only who is responsible for the remediation of contaminated locations, but also who is responsible for the cost of remediation. CERLA delineated who is ultimately responsible for remediation, and included not only the owner/operator of the facility but also the contaminant generator and the transporter. All were identified as Potentially Responsible Parties (PRP). Before CERLA, determining who was the responsible party and why was difficult. Responsibility often fell only upon the property's deed holder. CERLA identified three components of liability: strict, joint and several, and retroactive (Weber, 1989). Strict liability means that the site must be cleaned up regardless of who is responsible. Joint and several means that all PRPs are responsible, and all or any PRPs can and will be held responsible for both the cleanup and the cost associated with that cleanup. Retroactive means that those responsible are held accountable for impacts that took place before CERLA was passed (Cole, 1994).

Superfund Amendments and Reauthorization Act, 1986

CERLA was reauthorized in 1986 and extended by the Superfund Amendments and Reauthorization Act (SARA). SARA primarily deals with the sudden release of hazardous materials including petroleum. It established reportable quantity amounts and other major documentation requirements. SARA also established a federal taxation program that would help pay for some of these cleanup projects. This superfund, as it has become known, is not available to private UST tank owners (Amendments, SARA, 1986).

SARA also requires all states to devise systems to regulate all USTs within their boundaries. States are required to (1) establish regulations and determine how they will be implemented, (2) build a data base of all USTs, (3) determine how RCRA regulations affecting tank owner/operators will be implemented, and (4) determine who will oversee this process (Amendments, SARA, 1986). In other words, determine when bare steel USTs will be removed and how the soil and groundwater contamination found during the UST removals and upgrades will be cleaned up. Federal regulations under SARA mandate that all steel tank removals under RCRA include a strict analysis of the surrounding soil, and later the groundwater, to determine if soil or groundwater contamination exists. These documented closure reports must follow a strict protocol to ensure that the PRP is identified and is held responsible for the USTs he or she owns. All states must enact regulations equal to or exceeded the RCRA requirements. This included the removal of all bare steel USTs in place on or before December 22, 1998.

Indiana Regulations

Indiana adopted, as required, all federal guidelines for USTs under RCRA with the implementation IC 13-23 Underground Storage Tanks in 1984. IC stands for Indiana Code and 13 stands for all applicable environmental regulations within the state. The number 23 represents all applicable USTs regulations. The most recent significant changes took place in 1996 with the passage of the UST licensing programs for individuals to work on or around, install, or remove USTs. However, Indiana has implemented minor annual revisions, up to and including 2012.

As of 1984 Indiana is required to follow federal UST federal regulation. This represents a significant shift within the industry. Prior to 1984, few, if any, regulations were in effect and property owners could install and operate a UST without a permit. No data base of USTs, owner/operators, or of UST locations existed. The data base was not built until 1988. At that time owners and operators were required to report or register with the state all USTs that were in place and in use (CERLA, 1986).

With the new mandates, tanks installed after 1984 are required to follow certain rules. The main impacts of these rules are (1) a ban on new bare steel unprotected USTs and (2) the requirement to remove all existing bare steel unprotected USTs by December 22, 1998. This allowed owners and operators more than ten years to comply (API RP 1604, 1987). The new regulations require all new tanks to be something other than bare unprotected steel. Alternatives include Fiberglass Reinforced Plastic (FRP) USTs, or catholically protected steel tanks. Catholically protected steel tanks may have anodes attached to the tank, or an engineering alternative designed to neutralize the electrical charge (API RP 1632, 1992). One last alternative that became very popular, for a different reason, was installation of a fiberglass lining within the bare steel USTs. This alternative did not force the owner/operator to remove the USTs from the ground. Therefore no tank removal document was required (API RP 1604, 1987). The benefits of fiberglass lining are the prevention of releases from a deteriorated steel UST, and the attainment of compliance without UST removal and its related costs of construction, investigation, possible remediation, and documentation. Therefore, many owner/operators of UST systems who knew soil and ground water contamination would likely be encountered opted to have their existing USTs fiberglass-lined rather than removed and replaced with new USTs. Although the result was a cost savings for the owner/operator, lined USTs which had leaked in the past could have historical contamination that would remain unnoticed, unreported, and undocumented (NACE RP-0285-85, 1985).

Lining of USTs was permitted if the tanks were found to be "structurally sound" a term which meant very little to most tank lining contractors; their job was to line the tank. Owner/Operators of bare steel USTs had few alternatives to the use of tank linings (Nyer and Bittner, 1992). Lining was only a temporary measure, permitted until December 22, 1998. IDEM required inspections of lined USTs every five years. Between 1988 and 1998, many UST upgrades took place where soil and groundwater contamination went unreported. These historical releases would become evident at a later date (Simon and O'Neill, 1988). Many large remediation projects taking place in Indiana and other states today result from reports of historical releases (Ryan, 2013).

Indiana Department of Environmental Management

IC 13-23 established the Indiana Department of Environmental (IDEM) in 1984. IDEM is composed of many departments but UST regulations became the primary driver in the establishment of IDEM. In 1986, IDEM directed all UST owner/operators to register their USTs in 1987. These registrations were used to establish a 1988 data base, at a time when most UST owners did not fully understand the new regulations under RCRA and CERLA. It was estimated that only 75 % of all regulated, in-use USTs were registered in a timely manner, or about 30,000 of the estimated 40,000 USTs. In 1986, IDEM estimated 40,000 USTs were in place in Indiana. Today IDEM tracks approximately 50,000 USTs, with an estimated 13,000 still in use and in compliance with current regulations. The others have been removed, replaced, upgraded, or are no longer in use and are unaccounted for, such as in the case of unknown ownership. This is exactly what CERLA was trying to avoid (IDEM FAB, 2013).

IDEM is a large government operation with approximately two hundred employees in the UST and LUST sections. IDEM staff track UST compliance and removal documents, enforce release reporting requirements, and make periodic inspections. In IDEM's infancy, state employees documented the removal of thousands of USTs.

In 1988, IDEM advised all owner/operators who had registered USTs of the RCRA and CERLA requirements. Owner/operators were allowed one year to remove their now registered USTs or begin paying an annual tank registration fee. The fee requirement remains in force today and is currently $270 USD per year per tank (IDEM FAB, 2013). The one-year UST removal grace period was unique to Indiana. Indiana allowed UST owner/operators to remove their USTs with no questions asked during that year, regardless of the presence of soil and/or groundwater contamination. Owner/Operators could remove the USTs without regard to state or federal regulations regarding the UST contamination. Owner/operators were not required to follow the IDEM Guidance Branch protocol first published in 1988, and last updated in 2004. USTs could be removed by any method and could be performed without regard to loss of contents or historical releases that remained undocumented (IDEM, Guidance Branch Manual, 2004).

In the small town of Brookston, Indiana a site with a documented historical release from USTs removed during the one-year grace period in 1988 is under investigation with input from IDEM. Now a restaurant, this former UST location has not been in use since 1988. Evidence exists that USTs did in fact operate on this location. Historical documents clearly show the presence of USTs (Creek Run, IIR Brookston, 2008). The soil and groundwater contamination left in the ground from this release has migrated off-site onto a neighboring property that is an existing gas station. It was found during routine work while excavating new utility trenches to upgrade electrical service and add new sidewalks. The incident was initially reported as a release with the property owner as the responsible party. Subsequent soil and water investigations determined the source of contamination was off-site at the former gas station. It is difficult to obtain the cooperation of all affected persons. Off-site access problems persist. For example, the neighboring property owner did not want their property investigated. IDEM allowed the UST removal 25 years ago without an investigation. IDEM has requested access to the property for purposes of an investigation, but the owner has declined. IDEM appears unwilling to demand the access. As a result, we have a historical release that impacts a neighboring property and an unwilling property owner who does not want to spend money to investigate something that may cost more money. Brookston town officials are now involved in attempts to obtain access, but it appears unlikely that progress toward a resolution will occur without court intervention (Creek Run, IIR Brookston, 2008).

The number of USTs removed in Indiana, whether leaking or intact, during the 1988 to 1989 one-year grace period is unknown. Hundreds, if not thousands, may have leaked (Lenz, 2012). It seems likely that these locations were profitable for the owner/operators, such as those gas stations which were unique and not part of a retail chain. Owners may have been sole operators and may have lived nearby. Many small towns in Indiana and across the country have such sites. Experience in the industry indicates most of these sites are no longer gas stations. Some are vacant and many are no longer registered. Ryan researched this topic and stated that most of the sites that are currently undergoing remediation have some co-mingled contaminant plumes from undocumented historical releases (Ryan, 2013).

In compliance with IDEM regulations, USTs may be temporarily closed. Within 90 days of the cessation of use of the UST, the owner/operator may request a one-time temporary closure for a period of up to one year. Provided certain on-site requirements are met, a UST in temporary closure is considered to be in compliance with UST regulations. These requirements include removal of the tank contents, maintenance of a tank vent to atmosphere, locked fill ports, and locked, disabled, or removed dispensers. Failure to request temporary closure within 90 days of cessation of use of the UST is a violation and the UST is then not compliance. In addition, temporary closure status is not granted if a UST is out of compliance at the time of the request. The goal is to leave the UST empty as well as safe. If contents remain in the UST, the UST is considered in use. For example, a UST would be put in temporary closure if the gas station closed but planned to re-open at a later date, again as a gas station. Many times USTs are put in temporary closure to avoid excavation and removal, which could reveal a reportable release. Inappropriate use of temporary closure can affect ELTF cost reimbursement and deductible levels, which will be discussed later. If a UST is deemed out of compliance for any reason IDEM may impose fines and penalties, and future ELTF reimbursements may be reduced (IDEM UST Branch Guidance, 2004). Annual tank fee payments must continue while a UST is temporarily closed.

But if an owner/operator keeps a UST in use in Indiana after 1988, the owner/operator is required to pay the tank fee and collect and pay a one cent per gallon tax on all gasoline sold to help fund future environmental remediation efforts. Also, owner/operators had until December 22, 1998 to put their USTs in compliance with the new federal requirements. That included the proper documentation of all UST removals. No longer could the owner/operator ignore soil and groundwater contamination. CERLA required the clean-up of petroleum-impacted sites and multiple persons were held responsible. UST upgrade and replacement regulations forced owners to collect and analyze soil samples from the bottom and sides of the excavation and from the excavated soil at the time of the closure. If groundwater was encountered during closure activities then groundwater sample collection and analysis also was required. If a UST was over 20 feet (6 m) in length, regulations required one additional soil sample per UST. One excavation bottom sample was required for every 10 linear feet (3 m) of tank excavation sidewall. IDEM established parameters for sample collection, analysis, and handling (IDEM UST Branch Guidance, 2004). IDEM required the upgrade of every registered UST in service in Indiana before December 22, 1998. In most cases the upgrade required replacement and in almost every case these unprotected steel USTs and piping leaked, and a reportable incident under CERLA and IDEM was discovered during UST replacement activities. Thousands of UST sites, each unique and with its own set of site-specific remediation and financial issues, required identification (Stilglitz, 1976).

Excess Liability Trust Fund

The Excess Liability Trust Fund (ELTF) is a state program in Indiana which collects a one cent (USD) per gallon tax on the retail sale of gasoline and diesel fuel.

Revenues from this tax help fund environmental investigation and environmental remediation of impacts of LUSTs and their piping systems in Indiana. Title 328-IAC of 1989 enforces the program and describes corrective actions to minimize, contain, eliminate, remediate, mitigate, or clean up a release caused by an accident, equipment failure, or similar Fund Qualifying Occurrence as described below. The key provision of 328 IAC is that the release must come from a regulatory-compliant UST. The USTs must be properly registered with the state of Indiana, tank fees must be paid current, and the UST must be properly equipped and maintained. Bare steel unprotected steel USTs are not compliant. The UST must have leak detection equipment, current inventory records, and spill containment equipment in operation. The incident must result from a Fund Qualifying Occurrence (occurrence), causing a release from a registered UST system and dispensing components, except the hose and nozzle. The incident must be directly attributable to a registered UST system, and must have an IDEM-assigned incident number. The owner/operator must report the incident to IDEM within 24 hours for the assignment of an incident number. ELTF does not fund incidents that occurred prior to April 1, 1988.

Failure to give proper notice within 24 hours results in the denial of ELTF benefits. The definition of the time at which the 24-hour period begins has raised significant questions (Creek Run, RWP Rushville, 2009). In some cases the owner/operator may not know when the 24-hour period begins or how to give the notice. In other cases the owner/operator may get advice from an attorney who may wish to review the report with the consultant before he advises his client. According to research compiled by White, the consultant is paid to advise his client to make decisions based upon data from the analysis of samples collected from the site (White, 1996). In some cases the owner/operator may refuse the consultant's advice, or wait for the advice of another party, such as an attorney. Still, failure to comply with the 24-hour reporting period will result in the denial of ELTF funds. This is significant and in some cases can cause severe hardship on the owner/operator and on the environmental remediation project. At the beginning of the project the primary concern is cost minimization. The simple reporting process is a huge step and will cost money, and in some cases clients do not wish to make that step (Spirm, 1996). Educating all involved persons on how the ELTF works is important and this fund should not be taken for granted.

The ELTF has a fund-deductible amount for all eligible sites. The deductible is either $30,000 or $35,000 USD, depending upon when the site came in compliance with the 1980 CERLA regulations. If a site achieves regulatory compliance between 1988 and December 22, 1998, the deductible is $35,000. If the site achieves compliance prior to or during 1988, deductible is $30,000 USD (Title 328, IAC, 1989). The lower deductible amount was intended to encourage early compliance.

Types of UST Petroleum Remediation in Indiana

Petroleum in Latin means "Rock Oil" (White, 1996). It is composed primarily of hydrocarbons and is considered the most important source of energy today (Huber, 2009). Most petroleum is used for the production of fuel oil, gasoline, and diesel fuels. Since the mid 1950's petroleum is the world's most important source of energy (Huber, 2009). It has a high energy density level, it is relatively easy to transport, and is abundant. Matt Huber argued that we have enough petroleum to last for hundreds of years. In 2009, 65%

of all petroleum was consumed in gasoline automobiles, all of which was stored in USTs as part of the distribution system (Huber, 2009).

Petroleum consists of a mixture of hydrocarbons, comprised of hydrogen and carbon. Depending on how the carbon atoms are structured they can produce numerous types of petroleum. Petroleum is formed in slowly subsiding sedimentary basins with high surface biological productivity and restricted oxygenation of stagnant bottom waters. Under reduced oxygen conditions an insoluble matter is formed called "kerogen" (Roy, 2010). As the sediments undergo deep burial over time and the temperature increases because of the deep burial, kerogen begins to form into oil and gas. Petroleum system refers to the process of generation, migration, accumulation, and preservation of petroleum in a trap (Roy, 2010). Once stored in a trap of sedimentary rocks, it may undergo some alteration processes that could reduce its commercial value, including degradation, which is essentially over-cooking. Based upon the stored temperature, kerogen may be transformed into natural gases such as butane (Roy, 2010)).

Gasoline*:* *A mixture of volatile hydrocarbons suitable for use in internal combustion engines. The major chemical components are branched chain paraffins (branched chain alkanes) cycloparaffins (cycloalkanes), and aromatics.*

Diesel*:* *Composed primarily of unbranched paraffins (straight chain alkanes) with a flash point between 110 degrees and 190 degrees F.*

Fuel Oil*:* *Chemical mixtures having flash point greater than 100 degrees F. Fuels oils can be distilled fractions of* *petroleum, residuum from refinery operations, crude petroleum, or a mixture of any of these materials.*

Under RCRA all products derived from petroleum are regulated, but are not hazardous. Therefore, petroleum impacted soil from a LUST site is a regulated special waste, not a hazardous waste. As explained by Mark Buehlman et al. (1998), because LUST sites are not hazardous their remediation can be relatively easy and less expensive than other types of contaminated sites. Remediation projects may range from less than 1 year to 10 years. Their corresponding costs may range from $50,000 USD (Creek Run, CAI Crown Point, 2013) to millions of dollars (Creek Run, CAPR DeMotte, 2013). Petroleum products are less dense than water and have limited solubility, but can be relatively easy to remediate. It is estimated by Buehlman et al. (1998) that 1.5 million USTs exist in the United States. Prior to 1988 almost all of these, 95%, were bare unprotected steel, and we may assume that all of them leaked their contents at one time (Buehlman, et al, 1998).

***Ex Situ* Remediation Technology, Over-Excavation**

Ex situ treatment is defined as treatment of petroleum-impacted soil and groundwater by removal, and therefore does not occur in place. In *Ex situ* soil remediation, soil is excavated and transported to a landfill for disposal (Creek Run, RWP Rushville, 2009). Disposal is not treatment. It can, under the right circumstances, achieve site clean-up goals, but it does not clean up the soil.

In 2013 soil excavation and disposal was an undesirable clean-up practice. It is not remediation. Therefore, it is not implemented if other viable alternatives for the site in question exist. For example, if groundwater is not impacted, the soil contaminants are relatively shallow, and the release is recent, *in situ* methods are considered more appropriate. A recent release at a site with a deep groundwater table generally does not result in significant groundwater impacts. When a prompt response is required, then excavation is not only convenient but will allow for relatively short project duration. Excavation is not a viable remediation option if groundwater impacts exist (Buehlman et al, 1998). Excavation is a viable alternative only if the contaminant plume is located entirely on the original site owned or controlled by the owner/operator. Legal and technical issues preclude excavation as a quick response on third-party-owned property. (Rawson, 2003). A site undergoing permanent closure, such as a gas station where all obstructions can be removed along with all impacted soil, would be a candidate for over-excavation, removal, and disposal. Over-excavation is the removal of contaminated soil that exists outside the area of the original UST installation. A site with features such as buildings and utilities which must remain in place, where soil contamination extends to areas adjacent to or below these features, is not a candidate for this *ex situ* method. Impacted clays, difficult to treat by any other manner due to their poor porosity and low permeability, may require excavation. Heavier petroleum distillates with high molecular hydrocarbons such as used oil or heating oils also have few treatment options except for *ex situ* treatment and disposal (Liberti, 1993).

Other limiting conditions for over-excavation include the use of heavy equipment, sometimes in very tight spaces. Excavations sometimes require groundwater removal, shoring of sidewalls, and other dangerous conditions for on-site workers, which may require Occupational Safety and Health (OSHA) training (Creek Run, CR Huntington, 2006). Since regulated contaminants are brought to the surface and handled by on-site personnel, protective measures must be included in the project Health and Safety Plan (HASP). Landfill disposal requires permits and payment of expensive fees for disposal and transportation. Travel from an excavation site to a distant approved landfill location in a tri-axle dump truck can take hours, extending the project duration at significant cost (Creek Run, RWP Rushville, 2009).

Over-excavation for *ex situ* remediation was once a viable alternative for most owner/operators during UST removal and replacement operations. It was commonly regarded as a necessity. However, it was often ineffective in that groundwater issues were not addressed, not all impacted soils were removed, and historical releases remained unaddressed until the extent of contamination was addressed (Creek Run, SCR Angola, 1997).

Thermal stripping, or thermal treatment, of excavated materials is an alternative to landfill disposal or land farming. In thermal stripping, excavated material is heated to a temperature at which contaminants volatilize. In some cases, excavated material can be incinerated completely, leaving ash for disposal. These options generally are not applicable due to the high cost of treatment for large quantities of material. Thermal stripping was a desirable treatment option before bioremediation and biodegradation became financially feasible. It is rarely used today and Nyer refutes any benefit, arguing that all one is left with is a pile of ashes (Nyer, 1992).

***In Situ* Technologies - Air Sparging**

Air Sparging (AS) is the introduction of air below the water table to promote site remediation. The two methods are In-Well Aeration and Air Introduction. In In-Well aeration, air is introduced into an environmental well at an elevation below the well's static water level. An environmental well at a remediation site may have a number of uses. Typically it is installed as a probe point for the collection of soil samples. A one inch (2.54 mm)-diameter soil sampling probe is driven to pre-determined depth and continuous soil samples collected for field examination. The examination process will generally include measurements to define the depths of environmental contaminants, saturation, and soil classification. Collected soil samples may be analyzed for contaminants, including gasoline constituents such as benzene, ethyl benzene, toluene, and xylenes (BTEX). Figure 12 shows a typical boring log documenting these characteristics. A temporary well screen and casing may be placed into the bore hole to allow for the collection of a water sample for laboratory analysis. Permanent monitoring wells are then installed at the location of the temporary well. Figure 13 shows a diagram of a typical monitoring well. Permanent monitoring wells are usually two inches in diameter, installed in a bore hole drilled with an 8 inch (203 mm)-diameter hollow stem auger truck-mounted drilling rig. Monitoring wells are installed to a depth below the water table but must be screened to an elevation above the water table. In the cases examined in this research, the typical monitoring well depth is less than 30 feet (9.1 m) and well screens extend from the bottom of the well to a depth of 10 feet (3 m) Below Grade Surface (bgs). These wells comprise the monitoring well network and are used to collect water samples at three-month intervals to document changes in groundwater elevations and contaminant concentrations. Figure 14 shows a typical chain of custody for samples for chemical analysis.

BORING LOG

BORING NO: B-38

CLIENT:	Family Express	**DATE DRILLED:**	6-28-11
PROJECT NAME:	Family Express #16	**DRILL RIG:**	Diedrich D-120
ADDRESS:	11011 West US Hwy. 6	**BORING DIAMETER:**	2 Inches
CITY:	Westville **STATE:** IN	**BORING DEPTH:**	26 Feet
FIELD SUPERVISOR:	Stephanie Bragg	**DEPTH TO WATER:**	12.5 Feet
DRILLER:	Josh Lolmaugh #2274 (SCS)	**GROUND ELEVATION:**	Feet

USCS Symbol	Lithologic Description	Depth	Sample	Soil Recovery Percentage	Headspace (ppm)	Lab Results	Well Completion Diagram
	Asphalt (SM) Silty sand, little clay, brown (10YR 5/3) mottles with light brownish gray (10YR 6/2), moist less clay			100	0.7		
				100	0.5		
	(SW) Sand, fine-medium grained, brown (10YR 5/3), moist	5		100	2.0		
	little clay			80	3.9		
	becomes medium-coarse grained			80	3.5		
	(SC) Clayey sand, silty, brown (10YR 5/3), moist (SW) Sand, medium-coarse grained, light brownish gray (10YR 6/2), moist becomes clayey	10		100	5.3		
	becomes coarse grained, saturated			100	2.2		
	has gravel, silty, yellowish brown (10YR 5/4) no gravel, silt, becomes fine-coarse grained, gray (10YR 5/1)	15		100	2.6		
				100	3.3		
	becomes fine-medium grained			100	2.3		
		20		100	3.3		
				100	2.0		
		25		100	1.8		

NOTES:	Air knifed from 0-5' below grade RI-2

Figure 12 Typical Boring Log.

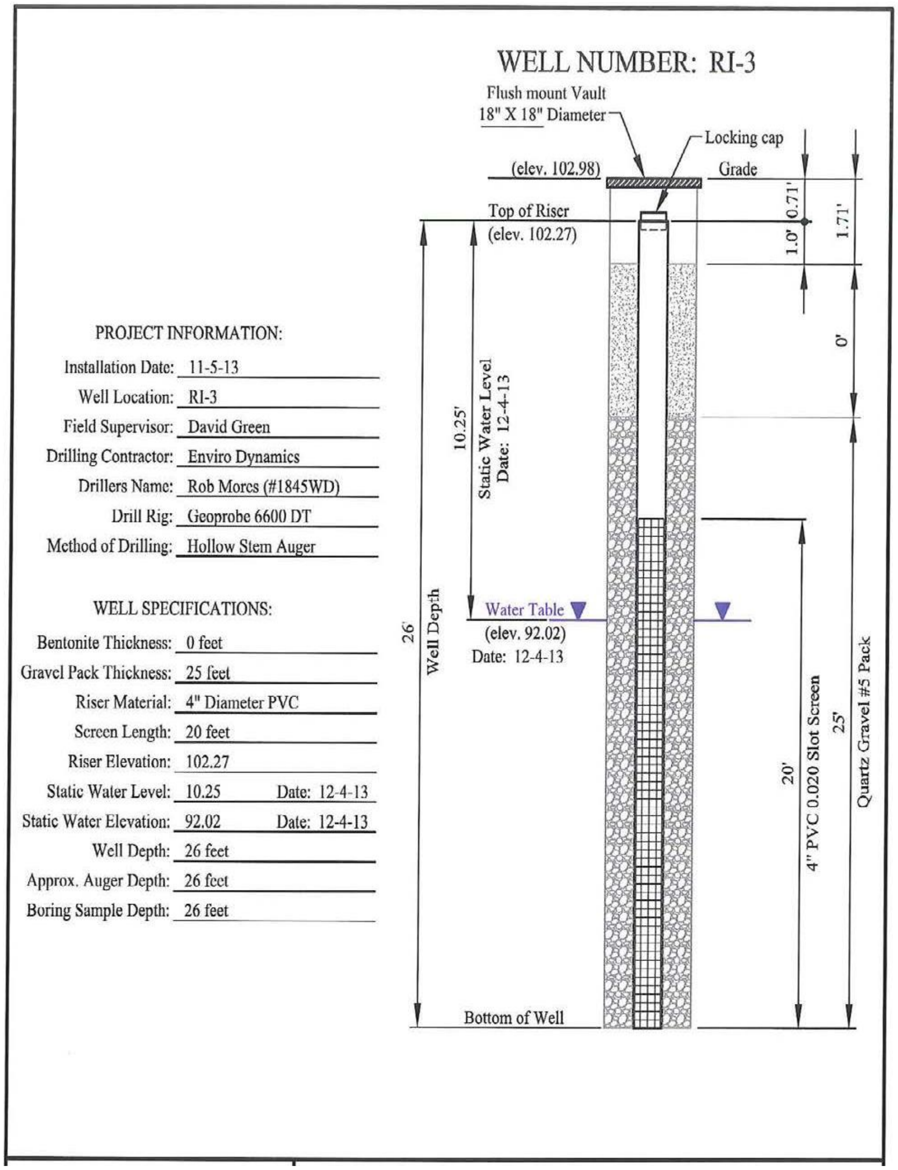
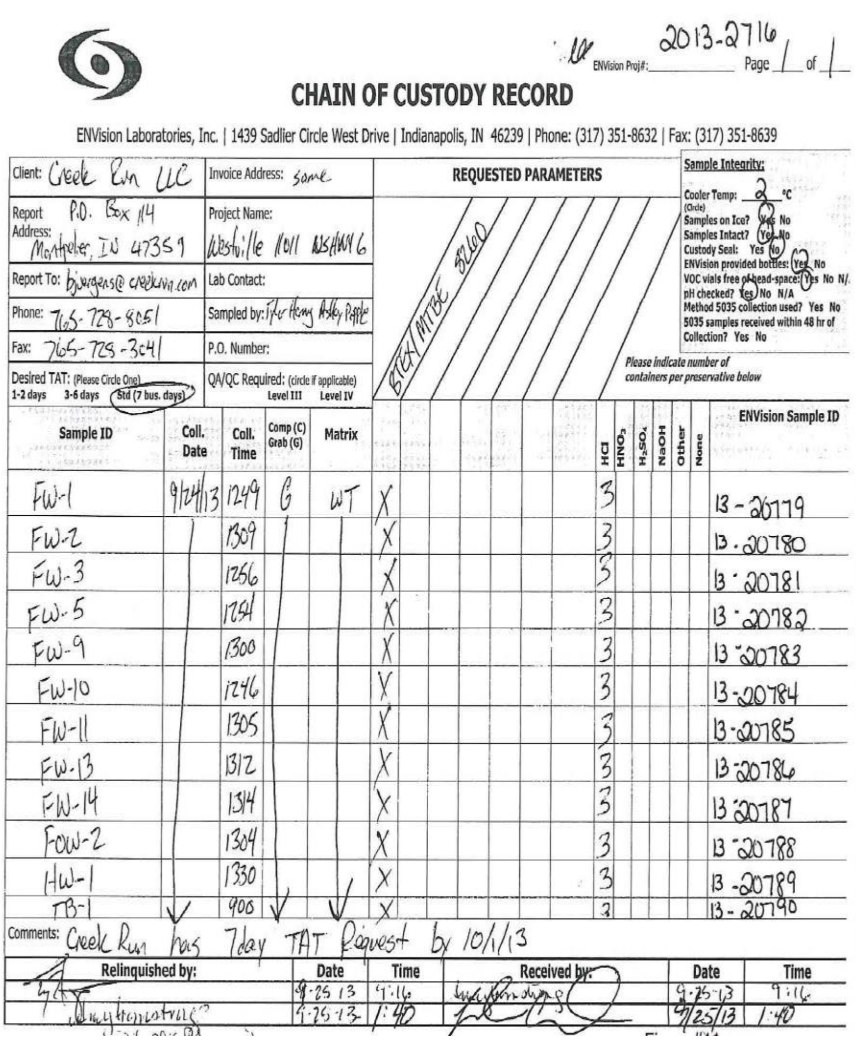


Figure 13 Typical Monitoring Well Construction Diagram.



2013-2716 ENVision Proj#: Page 1 of 1

CHAIN OF CUSTODY RECORD

ENVision Laboratories, Inc. | 1439 Sadlier Circle West Drive | Indianapolis, IN 46239 | Phone: (317) 351-8632 | Fax: (317) 351-8639

Client: Creek Run LLC
Invoice Address: same
Report Address: P.O. Box 114 Montpelier, IN 47359
Project Name: Westville Moll ASHWY 6
Report To: bjuergens@creekrun.com
Lab Contact:
Phone: 765-728-8051
Sampled by:
Fax: 765-728-3041
P.O. Number:
Desired TAT: (Please Circle One) 1-2 days 3-6 days Std (7 bus. days)
QA/QC Required: (circle if applicable) Level III Level IV

REQUESTED PARAMETERS: BTEX/MTBE 8260

Sample Integrity: Cooler Temp: 2 °C; Samples on Ice? Yes No; Samples Intact? Yes No; Custody Seal: Yes No; ENVision provided bottles: Yes No; VOC vials free of head-space: Yes No N/A; pH checked? Yes No N/A; Method 5035 collection used? Yes No; 5035 samples received within 48 hr of Collection? Yes No

Please indicate number of containers per preservative below

Sample ID	Coll. Date	Coll. Time	Comp (C) Grab (G)	Matrix	BTEX/MTBE 8260	HCl	ENVision Sample ID
FW-1	9/24/13	1249	G	WT	X	3	13-20779
FW-2		1309			X	3	13-20780
FW-3		1256			X	3	13-20781
FW-5		1254			X	3	13-20782
FW-9		1300			X	3	13-20783
FW-10		1246			X	3	13-20784
FW-11		1305			X	3	13-20785
FW-13		1312			X	3	13-20786
FW-14		1314			X	3	13-20787
FOW-2		1304			X	3	13-20788
HW-1		1330			X	3	13-20789
TB-1		900			X	2	13-20790

Comments: Creek Run has 7day TAT Request by 10/1/13

Relinquished by:	Date	Time	Received by:	Date	Time
[illegible]	9-25-13	9:16	[illegible]	9-25-13	9:16
[illegible]	9-25-13	1:40	[illegible]	9/25/13	1:40

Figure 14 Typical Chain of Custody Record.

In some cases, some of the monitoring wells on a site are used for AS remediation. An air compressor or blower at the surface introduces air through tubing into the bottom of the well. The introduced air rises back up the well, carrying volatiles to the atmosphere and aerating the water. Robert Hinchee reported that the first use of this technology was in the mid-1970s (Hinchee, 1994). The principle is relatively straight forward. Air is used to strip and/or oxygenate the water, serving as an In-Well pump and treat system. It establishes a circulation pattern within the aquifer that works as a pump and treats system without removing the water from the aquifer to surface equipment. The method allows for minimal site disruption compared with most pump and treat systems. It allows not only for volatilization but also biodegradation because of the introduction of air into the saturated zone surrounding the well screen. Heavily oxygenated water will promote biodegradation (Johnson, 1994).

In Situ **Technologies – Soil Vapor Extraction**

Soil Vapor Extraction (SVE), or volatilization, is a proven technology that has been in use since the 1960s to remediate a variety of different contaminants (Cole, 1994). Volatilization means the removal of volatile hydrocarbons from subsurface soil, specifically from the vadose zone, and more specifically from the interstitial spaces within the vadose zone. Hydrocarbon vapors are entrained in a flow of extracted air and removed from the pore spaces of the contaminated soil.

In Situ **Technologies – Bioremediation**

Bioremediation is the phrase linked to a multitude of *in situ* treatment options including biodegradation, biorestoration, and the *ex situ* method land farming. The idea is to allow locally-occurring microorganisms to break down and/or volatilize petroleum contaminants (Simon and O'Neill, 1988). Bioremediation is expensive to monitor and it is rarely possible to reach cleanup objectives in an acceptable period of time. Nyer (1992) implied that many individuals and regulators prefer this process because it appears less disruptive, less costly, and is easily implemented. He explained that those advantages do not exist. Bioremediation and/or biodegradation can have some effect on lighter hydrocarbons but will rarely work in a practical manner on heavier constituents (Cole, 1994).

***In Situ* Remediation Technologies - Dual Phase Extraction**

High Vacuum Dual Phase Extraction (DPE) is a remediation technology that employs a high vacuum pump to simultaneously remove liquid-phase, vapor phase, and dissolved-phase hydrocarbons from extraction wells. Hydrocarbons are removed from a network of vertical extraction wells, piped to a centralized equipment area, separated into vapor and liquid phases, and treated as necessary to comply with applicable air and water discharge requirements. DPE is an aggressive remedial technology especially well-suited for lower permeability soil. Impacted, unsaturated material is treated by moving air through pore spaces, fractures, and bedding planes in a manner similar to SVE methods, providing oxygen to naturally-occurring bacteria. Sufficient vacuum is applied to DPE wells to recover impacted groundwater and volatile contaminants. By de-watering the upper portion of the unsaturated zone, DPE is also capable of treating the heavily impacted soil below the water table, referred to as the smear zone, by exposing previously saturated materials, now de-watered. This allows air movement through those materials, promoting volatilization (Simon and O'Neill, 1988).

***In Situ* Technologies – Enhanced Fluid Recovery**

Enhanced Fluid Recovery (EFR) employs a truck-mounted vacuum pump operating at a high vacuum to dewater the soil and extract petroleum vapors and impacted groundwater. EFR remediates by several mechanisms: (1) it directly extracts free product. The equipment can be adjusted as needed to maximize product recovery verses water recovery. (2) EFR can induce air flow in the subsurface, remediating contaminated soils above the water table, similar to a SVE system. (3) The high vacuum and air flow of EFR will volatilize "smeared product" and exposed residual hydrocarbons within the well's cone of depression or radius of influence (Nyer, 1992). Concurrently, fresh air is drawn in into the contaminated soil area. The increased oxygen content enhances aerobic biodegradation. Most of the hydrocarbons recovered from the ground, including free liquid petroleum, are volatilized in the air flow and are emitted through the stack of the vacuum truck into the atmosphere. Liquids, primarily water, are collected in a liquid knock-out tank, or holding tank. A single EFR treatment is scheduled to last one day, or six to eight hours. Multiple treatments are generally scheduled at weekly or monthly intervals (Johnson, 1994).

***In Situ* Remediation Technologies – Monitored Natural Attenuation**

Monitored Natural Attenuation (MNA) is the passive remediation of hydrocarbons in groundwater by natural processes. The primary advantages of MNA are low initial cost and minimal site disruption. Disadvantages include the long time period needed to achieve cleanup goals and variable regulatory acceptance. MNA is different from bioremediation and biodegradation in that little evidence is provided that MNA will achieve clean-up goals within a specific time period, or reach those goals at all. Site closure then becomes dependent whether existing contaminant concentrations are acceptable for closure. As specified in IDEM Non-rule Policy Document (NPD) W0054, MNA is a viable remedial approach once groundwater benzene concentrations decrease to less than 300 ppb (300µg/L) in on-site monitoring wells, 15 ppb (15µg/L) benzene in off-site monitoring wells, and 45 ppb average (45µg/L) MTBE in all wells.

In Situ Remediation Technology – Groundwater Pump and Treat

Groundwater Pump and Treat technology involves the removal of impacted groundwater from pumping wells using electric or pneumatic submersible pumps. Nyer argued that ground water pump and treat is an under-used *in situ* remediation technology that seems to have lost favor with federal and state regulators. Pump and treat consists of the removal of groundwater for treatment in an on-site treatment system comprised of aeration strippers and/or carbon adsorption units for contaminant removal. The treated groundwater is discharged to a sanitary disposal system or re-injected up gradient from the groundwater plume (Nyer, 1992). Re-injection is the preferred alternative because the addition of cleaned, highly oxygenated water back into the aquifer contributes to the efficiency of the treatment, making groundwater pump and treat a very effective *in situ* treatment alternative.

Northwest Indiana Glacial Advance and Geology

More than two-thirds of the state of Indiana owes its landscape to the activity of glacial advances. The last retreating glacier occurred 12,000 years ago. It reached present day I-70, which bisects the center of the state, east to west, from Richmond to Terre Haute (Wilson, 1988). Wilson researched the glacial geology of Indiana and proposed that we could be in an interglacial period. Each of the previous four glacial advances is known for the state in which their presence is most evident: Nebraskan, Kansan, Illinoisan, and Wisconsinian. The Wisconsinian began about 70,000 years ago and ended about 12,000 years ago. The Michigan lobe of the Wisconsin glacier entered into northwest Indiana (Figure 15). The ice at this point was 3 miles (4.8 km) thick. Glacial till and drift were deposited by melt water and directly by the ice itself. Glacial till in northwest Indiana is 165 feet (50 m) thick in some places along the southern shore of Lake Michigan (Figure 16). Many northwest Indiana lakes were formed by large ice sheets breaking off, or calving. These kettle lakes as they have become known include Lake Wawasee and Hamilton Lake (Wilson, 2008). All three study areas are located in the area of deep glacial till deposits, including the Kankakee Outwash Plain, and the former shoreline of Lake Chicago in the Valparaiso Moraine (Wilson, 2008). Much of the drinking water in Northwest Indiana comes from the water stored in the pore spaces of the deep glacial till left by the Wisconsin glacial advance (Wilson 2008).

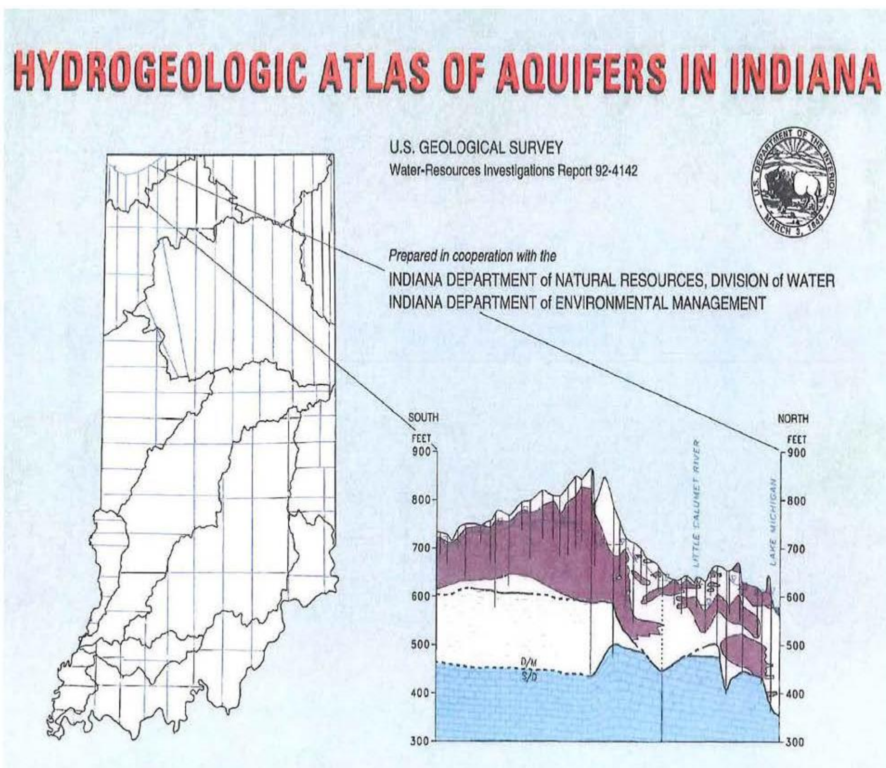
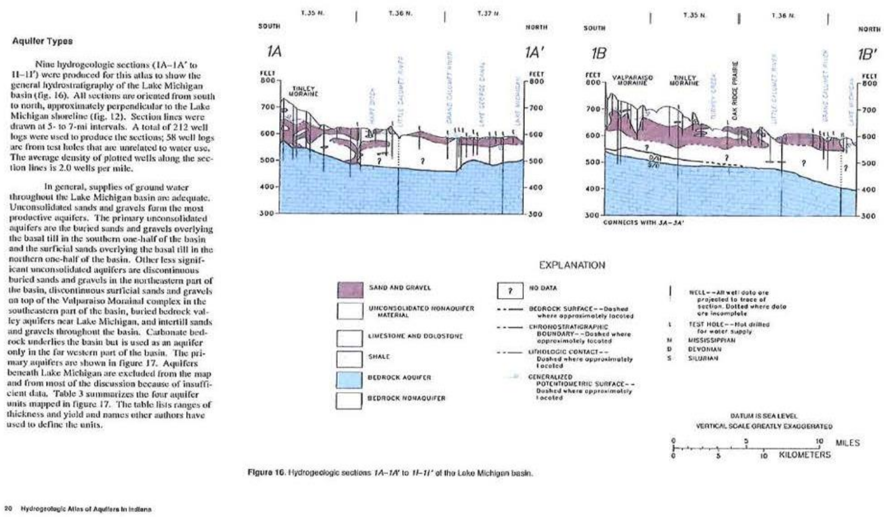


Figure 15 Hydrogeologic Atlas of Aquifers in Indiana.



Aquifer Types

Nine hydrogeologic sections (1A–1A' to 1I–1I') were produced for this atlas to show the general hydrostratigraphy of the Lake Michigan basin (fig. 16). All sections are oriented from south to north, approximately perpendicular to the Lake Michigan shoreline (fig. 12). Section lines were drawn at 5- to 7-mi intervals. A total of 212 well logs were used to produce the sections; 58 well logs are from test holes that are unrelated to water use. The average density of plotted wells along the section lines is 2.0 wells per mile.

In general, supplies of ground water throughout the Lake Michigan basin are adequate. Unconsolidated sands and gravels form the most productive aquifers. The primary unconsolidated aquifers are the buried sands and gravels overlying the basal till in the southern one-half of the basin and the surficial sands overlying the basal till in the northern one-half of the basin. Other less significant unconsolidated aquifers are discontinuous buried sands and gravels in the northeastern part of the basin, discontinuous surficial sands and gravels on top of the Valparaiso Morainal complex in the southeastern part of the basin, buried bedrock valley aquifers near Lake Michigan, and intertill sands and gravels throughout the basin. Carbonate bedrock underlies the basin but is used as an aquifer only in the far western part of the basin. The primary aquifers are shown in figure 17. Aquifers beneath Lake Michigan are excluded from the map and from most of the discussion because of insufficient data. Table 3 summarizes the four aquifer units mapped in figure 17. The table lists ranges of thickness and yield and names other authors have used to define the units.

Figure 16. Hydrogeologic sections 1A–1A' to 1I–1I' of the Lake Michigan basin.

20 Hydrogeologic Atlas of Aquifers in Indiana

Figure 16 Aquifer Types – Hydrogeologic Sections.

Study Areas

Three sites in northwest Indiana (Figure 4) were chosen in order to illustrate how USTs, LUSTs, applicable regulations, funding, and remediation technology intersect when discussing petroleum hydrocarbon remediation. Each site is unique in how the release occurred and was identified, and how funding for remediation was obtained. In each case the successful treatment technology was not the initial treatment technology selected by the consultant. Each site is in northwest Indiana with approximately 150 feet (46 m) of unconsolidated deposits beneath the location in previously glaciated regions (Church and Ryder, 1992). The glacial history has been studied by many, including Wood (1916). He discussed how glacial outwash and till affects the availability of shallow aquifers for drinking water (Wood, 1916). The last of the glaciers receded from these areas over 12,000 years ago. These receding glaciers left significant moraine deposits, assorted rock and debris carried by the glaciers (Johnson and Bleuer, 1980).

These deposits can hold a significant amount of water since they have high levels of porosity, and are highly permeable (Johnson and Bleuer, 1980). The contaminated groundwater aquifer that will be addressed with each site is considered a perched aquifer, above the actual water table (Shrock, and Malott, 1993). A perched aquifer refers to groundwater accumulating above a low-permeability unit or strata, such as a clay layer in an unsaturated aquifer zone. This term is generally used to describe localized groundwater accumulation occurring at an elevation higher than a regionally extensive aquifer (Roy, 2004).

DeMotte, Indiana

This location is located at 4541 East State Road 10, DeMotte, Indiana 46310, Newton County (Figures 5 and 6). The site is located in a previously glaciated region of northern Indiana approximately 40 miles (241 km) south of Lake Michigan. The unconsolidated deposits beneath the site are dune and outwash deposits. The site is located in the Kankakee Outwash Plain (Wilson, 2008).

Michigan City, Indiana

The Michigan City location is owned by Knoll Brothers and is a former truck stop, currently operating as a bulk petroleum storage facility. It is located at 1575 East US Highway 12 in Michigan City, Indiana, in LaPorte County (Figures 7 and 8). The location is in a formerly glaciated region of northwest Indiana. Glacial till and outwash deposits are more than 150 feet thick (46 m) (Shedlock, et al, 1993). It is located on the Valparaiso Outwash Moraine (Wilson, 2008). The site is less than one quarter mile (0.4 km) from Lake Michigan. A rail system and Lake Michigan border the site to the north.

Abandoned light commercial properties border the location to the east and the west. US Highway 12 borders the location to the south. South of US Highway is the commercial office of Knoll Brothers. Knoll Brothers operates ten retail outlets in northwest Indiana. West of the Knoll Brothers office is a large casino complex operated by Boyd Gaming (Creek Run, RWP Michigan City, 2013).

The USTs were removed in 1989, and a closure report was completed but has not been located. IDEM issued a directive in December 2005 requesting additional information. The owner/operator hired SESCO Environmental (SESCO) to complete the investigation. IDEM initiated this request because of a concern expressed by the owners of the now-abandoned foundry to the west of Knoll Brothers. Their request noted evidence of a petroleum release expanding from the Knoll Brothers property onto their location.

Westville, Indiana

Family Express store #16 is located at 11011 West US Highway 6 in Westville, Indiana, in LaPorte County (Figures 9 and 10). It is one of 62 locations owned and operated by Family Express. It is an operating retail gas station and convenience store located just outside of a small town in northwest Indiana. New USTs were installed in 1988, ahead of all regulatory guidelines, and the former USTs were removed. The original USTs were installed in the 1960s. Minimal hydrocarbon contamination was found during the UST removal and the incident number was closed in 1999 after an over-excavation project was completed. The site is located about 30 miles (87 km) south of Lake Michigan. It is bordered to the south and west by light industry zoned property and US Highway 6, residential property to the north, and a city street to the east. East of the city street is a heavily petroleum-impacted location. That site, known as Prassus Brothers, is a former truck stop, now closed. It had an unsuccessful remediation system in operation from 2008 until 2011. The Prassus Brothers remediation system is on site but currently not in service, and the former tank owner/operator is in violation of IAC 328 (SESCO, FSI, 2010). The Family Express and Prassus Brothers sites are located in a previously glaciated region of northwest Indiana. Glacial moraine and outwash deposits are more than 100 feet (30.5 m) thick in this area, overlying less permeable material (Norton, 1986). It is located on the Valparaiso Outwash Moraine (Wilson, 2008).

CHAPTER III

METHODOLOGY

Sites Chosen

The three sites chosen are in the same geologic setting in northwest Indiana. Each location had historical petroleum release. Each site had an unsuccessful remediation strategy. Subsequently, each site had successful remediation techniques. The role of applicable environmental regulations, remediation strategies, and cost were assessed. Analytical data collected at each site were compared to assess the effectiveness of all systems at each location. Groundwater samples were collected from groundwater monitoring wells for dissolved Benzene, Ethyl Benzene, Toulene, and Xylenes (BTEX). Cost effectiveness were determined by comparing actual cost of the project and the length of time to obtain desired results based upon regulatory compliance and unacceptable contamination levels.

Excess Liability Trust Fund

The ELTF plays a key role in ensuring that fund-eligible sites can be remediated effectively in Indiana. The three study locations illustrate how this works. Sites that are eligible and sites that are not were compared and contrasted as to why the latter is not eligible is provided. Also illustrated is what happens when available funds are misused and misspent. Using the ELTF effectively ensures that funds are available to finance site mitigation is demonstrated. Misuse of ELTF funds suspends reimbursements, halts remediation progress, and takes funds away from UST owner/operators.

The owner/operator of the DeMotte, Indiana location improperly managed ELTF funds and failed to meet IDEM's expectations for remediation. How this happened is shown and how litigation and the owner/operator's failure to oversee the project affected the site clean-up. Also shown is how $3.6 million USD was spent by documenting the subsequent effective remediation efforts (Creek Run, SI and CAPA DeMotte, 2012).

The Michigan City, Indiana location has been denied ELTF eligibility, which has hampered the owner/operator's efforts at remediation (Creek Run, RWP, CAPR Michigan City, 2013). This is shown by documenting efforts of IDEM and the owner/operator to effectively clean up this location, despite off-site concerns and the lack of ELTF funds.

The Westville, Indiana location has 90% ELTF eligibility. This is due to an active owner/operator dedicated to the remediation of this location. The owner/operator is using available ELTF funds and other funds to finance the cleanup. They have been active in the management of the project and have documented their concerns with off-site sources (Prassus Brothers) to help IDEM enforce the clean-up of the off-site contamination. They have sought legal counsel and considered litigation to force the resolution of off-site contamination. It is illustrated what happens when neighboring properties fail to participate in the mitigation process because of a lack of funding, interest, or environmental consciousness (Creek Run, IIR Westville, 2008).

Clean-Up Objectives in Groundwater

Indiana has separate contaminant closure levels for areas zoned residential and for areas zoned commercial. Although these closure levels loosely follow local zoning ordinances, and those zoning ordinances affect clean-up objectives, the definitions of residential or commercial uses depend on the current land use and on anticipated future use. Clean-up objectives for petroleum hydrocarbon-impacted sites in Indiana are determined by the benzene and MTBE concentrations in groundwater. Progress toward groundwater clean-up objectives is documented by the laboratory analysis of groundwater samples collected at three-month intervals from remediation sites and reported in CAPRs. Clean-up objectives in soil are documented by the analysis of confirmatory soil samples collected from soil borings installed after groundwater objectives have been met. It is important to note that a number of factors will determine if a site is designated residential or commercial. Local zoning regulations will play a role in that determination. Environmentally sensitive areas, public utilities, drinking water wells, neighboring property use, and owners' desires will all affect property designation. The IDEM project manager will ultimately select a site's designation. (IDEM, Risk Integrated System of Closure, 2001).

A maximum of 5 ppb (5µg/L) benzene is the residential standard for groundwater contamination, and is the clean-up objective for residential properties in Indiana. A federal drinking water standard for MTBE has not been established. The acceptable closure level for residential properties in Indiana is usually 40 ppb (40µg/L) MTBE. Achieving closure status at properties designated as residential in Indiana requires meeting the objectives listed above (IDEM, Risk Integrated System of Closure, 2001).

The commercial and industrial standard for petroleum hydrocarbon contamination in groundwater is a maximum of 52 ppb (52µg/L) benzene, as is the groundwater clean-up objective for commercial and industrial properties in Indiana. MTBE has no federal drinking water standards. Closure levels at commercial and industrial properties in Indiana are usually 720 ppb (720µg/L) MTBE. Achieving closure status in Indiana at properties designated as commercial or industrial requires meeting the objectives listed above (IDEM, Risk Integrated System of Closure, 2001).

By comparing three sites in northwest Indiana, it is shown that AS and SVE can effectively remediate petroleum-impacted soil and groundwater in northwest Indiana to residential closure levels in a more cost effective manner and shorter time frame, than other types of remediation. Subject locations will achieve residential levels of MTBE in shorter time frames and at a reduced cost than with other remediation methods: Data was collected from sites using AS and SVE, as well as sites not using AS and SVE. The data was compared for remediation effectiveness through variables of historical data. Each subject location was compared with previous remediation efforts that did not include AS and SVE.

Clean-Up Objectives in Soil

In Indiana, the residential standard for petroleum hydrocarbon contamination in soil is 0.034 parts per million (ppm) (0.034 mg/L) benzene. Therefore, it is the clean-up objective for residential properties in Indiana for soil. MTBE has no federal standards for a petroleum release. Closure at residential properties in Indiana is 0.18 ppm (0.18 mg/L) for MTBE. Achieving closure status in Indiana at properties designated as residential in

Indiana requires meeting the objectives listed above (IDEM, Risk Integrated System of Closure, 2001).

In Indiana, 0.35 ppm (0.35 mg/L) benzene is the commercial/industrial standard for petroleum hydrocarbon contamination in soil, and therefore is the clean-up objective for industrial properties in Indiana. MTBE has no federal standards for a petroleum release. Closure at commercial properties in Indiana is 3.2 ppm (3.2 mg/L) MTBE. Achieving closure status in Indiana at properties designated as commercial in Indiana requires meeting the objectives listed above (IDEM, Risk Integrated System of Closure, 2001).

Active Releases in Indiana

The number of active releases in Indiana since the current 1998 upgrade requirements took effect was investigated. It is hypothesized that data from each year since 1998 will reveal that both the number of active USTs continues to decline, as well the number of releases from these active USTs.

IDEM tracks all the USTs in its data base. This information was used to determine if the number of USTs continues to diminish, and are correlated with the current state and federal regulations. It will also be determined whether the existing USTs are safer and correlated with fewer reportable incidents each year since the new 1998 upgrade requirements went into effect.

Soil Vapor Extraction and Air Sparging

The effectiveness of SVE and AS in northwest Indiana at three locations was researched. It is predicted that SVE and AS are the best remedial approaches in northwest Indiana. Figure 17 shows a typical SVE/AS system. Figure 18 shows a typical DPE system. Figure 19 shows a typical AS system.

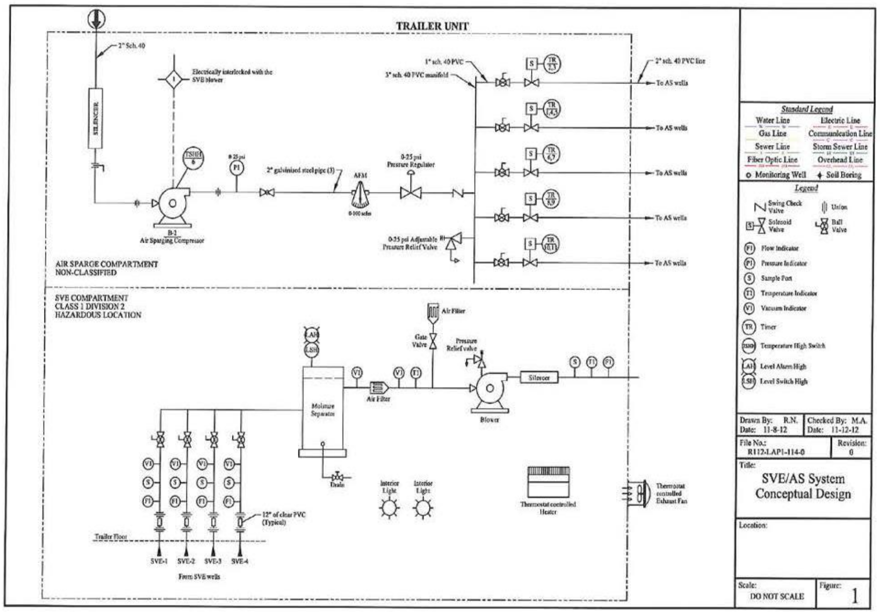


Figure 17 Typical Soil Vapor Extraction/Air Sparging (SVE/AS) System Conceptual Design.

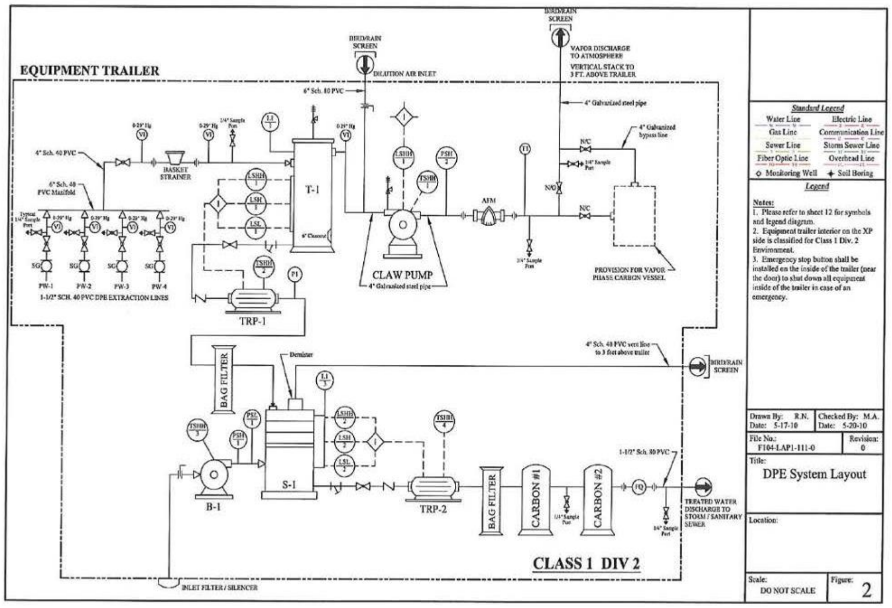


Figure 18 Typical Dual Phase Extraction (DPE) System Layout.

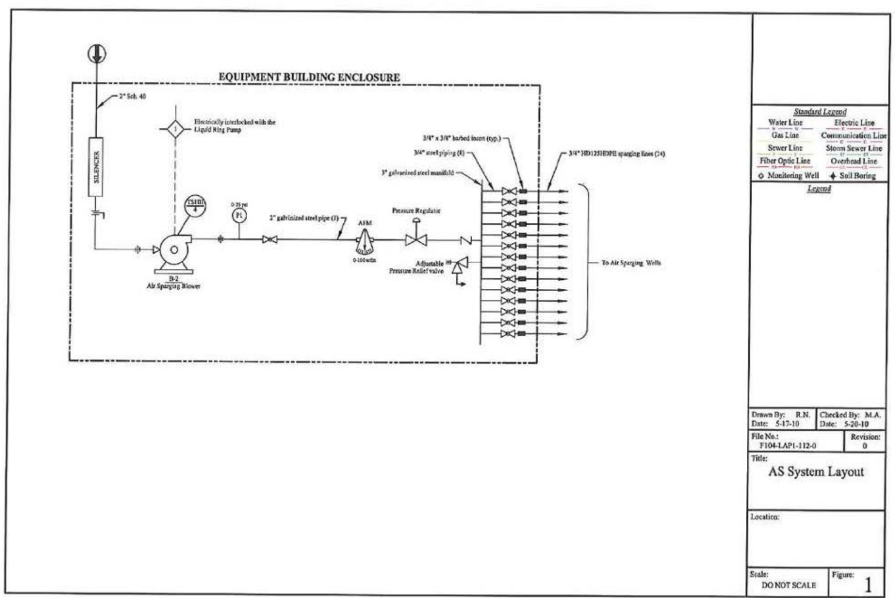


Figure 19 Typical Air Sparging (AS) System Layout.

In DeMotte, Indiana the site was 100 % ELTF eligible. The release, in 2002, was the highest profile release in Indiana. The former consultant documented his work in a professional journal, and presented it in 2010 at a national conference. The former consultant used a remediation technology different form the current consultant, without success. The consultant also used all ELTF funds available for remediation of the release. Litigation documents, insurance settlement documents, and CAPRs were used to analyze the effectiveness of the SVE and AS at this location (Creek Run, CAPA, SI & CAPR DeMotte, Indiana, 2012).

Using the Michigan City, Indiana site, the AS and SVE approach was compared to that of an adjoining property that failed to use that approach and document those efforts to complete mitigation. Quarterly CAPR documents were accessed and results compared (Creek Run, CAPR Michigan City, 2013).

For the Westville, Indiana site, the current remediation approach was compared to another technology at a neighboring property. The neighboring property was not ELTF eligible and it appears the owner/operator did not select an aggressive remediation technology. The selected technology has failed to remediate the petroleum impacts at this location. Available litigation documents and CAPRs should show that SVE combined with AS is the best remedial technology in northwest Indiana (Creek Run, CIIR Westville, 2008).

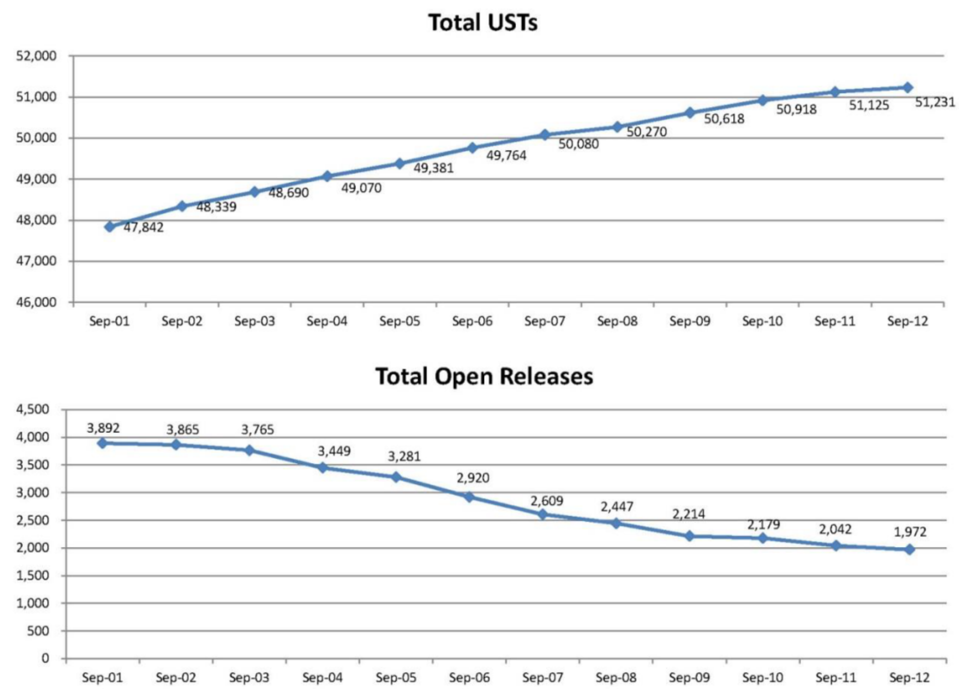
CHAPTER IV

TYPES AND SIGNIFICANCE OF HISTORICAL RELEASES

Introduction

Releases can occur from piping improperly installed to leaking tanks that have corroded over-time or were improperly installed. They can also occur from lack of inventory control and oversight leading to tanks being over filled. This may be the most common issue. Before the 1986 federal requirements went into effect that mandated overspill protection and inventory reconciliation, no or few measures were taken to prevent a tank from being filled beyond its capacity (IDEM, 2004). Overfilling a tank a few gallons every year for 30 years adds up very quickly. This chapter describes three different sites and the releases and impact that have occurred because of these spills. Chapter V will discuss the types and the effectiveness of the various types of environmental remediation that has taken place at each location and the results of those remedial strategies as well as the cost involving the three subject locations and the role played by the Excess Liability Trust Fund (ELTF) is discussed.

The number of active releases has continued to decrease in Indiana. As UST have been removed and sites have been closed there are fewer and fewer UST. IDEM currently tracks only 13,000 UST. Active releases are less than 2,000. IDEM accounts for more than 50,000 UST, but 37,000 of these tanks have been removed. And as recently as the year 2000, IDEM tracked over 9,000 releases, less than 2,000 remain. Fewer tanks have meant fewer releases and this shown in Figure 20.



Source: United States Environmental Protection Agency: UST Performance Measures - http://www.epa.gov/oust/cat/camarchv.htm

Figure 20 UST Open Releases.

The three subject locations all have a historical release from Underground Storage Tanks (UST) or from Aboveground Storage Tanks. They each occurred in northwest Indiana in LaPorte or Newton Counties. LaPorte County borders Lake Michigan to the north and the Michigan City location is within 1,500 feet (457.2 meters) of and within view of the lake. Newton County borders Illinois to the west and Demotte location is on the northeastern border. Ironically DeMotte the city is not located in Newton County, but in the adjacent Jasper County to the east. All three sites have or have had a remediation system to clean up the environmental impacts. All three sites will soon have a No Further Action (NFA) from the state of Indiana. They also each have data from previous on-site or adjacent off-site remedial activities that we can compare to in order which activities worked or can work. It also allows for cost comparisons of the remedial activities. All three sites are still in operation. Each location is located in the glaciated region of northwest Indiana approximately 800 feet (243.8 meters) above sea level; with bedrock 200 feet Below Grade Surface (bgs), overlain by 150 feet to 200 feet (45.7 meters to 60.9 meters) of unconsolidated fill material of mixed drift till and stratified drift in chaotic form (Wilson, 2008).

DeMotte, Indiana

Background

Nine Underground Storage Tanks (UST) are located and in operation at DeMotte, IN. It is believed that the release occurred from overspills and from UST, improper filling of the tanks. A number of Aboveground Storage Tanks (AST) are also located on the property located in Newton County in northwest Indiana. Releases have occurred from the AST from improper filling of these tanks and transfer operations from one tank to another (Creek Run, CAPR Boezeman, 2013). A significant event did not take place to confirm when a release occurred. Instead the release occurred over a long period of time due to overuse and inappropriate use of and lack of inventory control. The site has been in operation since 1962. As in many cases of petroleum release in Indiana, lack of inventory reconciliation, bare steel improperly installed piping all contributed to this historical release.

Release

On February 14, 2002 a petroleum odor was noticed from county health department employee from a bathroom sink when they were washing their hands (Creek Run, Boezemen, 2013). Drinking water came from a nearby shallow drinking water well approximately 23 feet (7 meters) deep that had been hand dug in 1962 (Boezemen, CAPR 2013). The county employee then reported a release to the Indiana Department of Environmental Management (IDEM), and the United States Environmental Protection Agency (EPA). IDEM and the EPA arrived on-site on March 8, 2002 to investigate. A March 12, 2002 analytical sample taken by the first consultant hired by the responsible party indicated the station water supply was impacted by gasoline. A documented release was investigated and determined that over a 30 year period lack of inventory reconciliation. Petroleum was released into the shallow aquifer and migrated north and west impacting the store water supply, one private residence, and an elementary school. Unsaturated soil and groundwater had been impacted beneath the site from the UST and AST with benzene, toluene, ethyl benzene, and total xylenes (BTEX) and methyl tertiary butyl ether (MTBE). This dissolved plume contaminant plume extended off-site to the north and northwest more than 1,500 feet, between 25 and 50 feet (7.6 meters to 15.24 meters) Below Grade Surface (bgs) The site was assigned Leaking Underground Storage Tank (LUST) incident number 200202509 (Creek Run, Boezemen, 2012). The lithology encountered during drilling activities at this site and on adjacent properties is very uniform. Depending on the use of the property where a boring was located, the upper 1 foot (0.3 m) of soil consisted of uniform, poorly graded, fine to medium sand. Over the majority of the site and in off-site borings, groundwater was typically encountered between 3 and 10 feet (0.9 and 3 m) Below Grade Surface (bgs), where soil borings encountered a very dense and much harder material. Figure 21 shows GW flow direction and part A. of Figure 22 shows GW contaminant levels prior to use of SVE/AS remediation techniques.

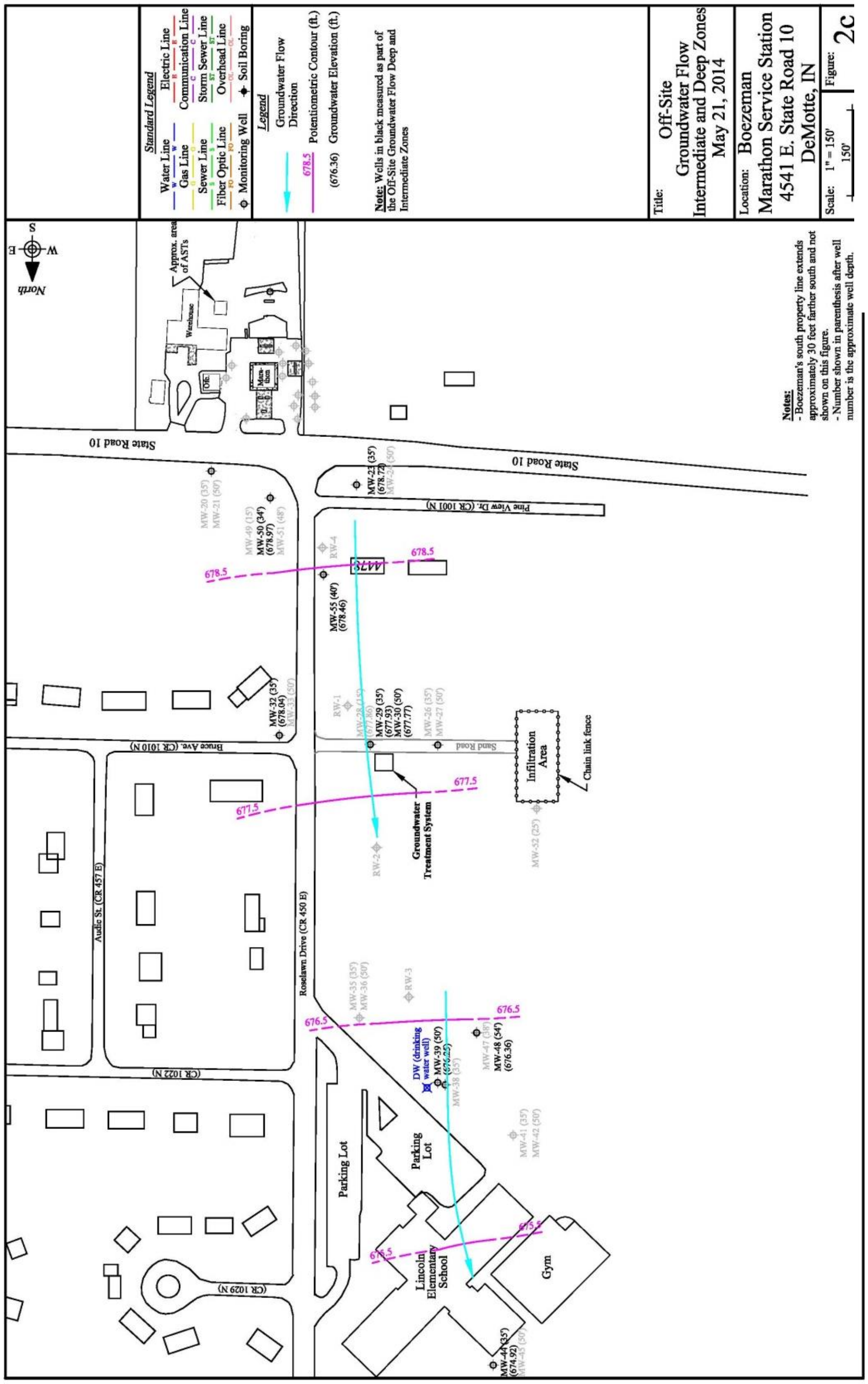
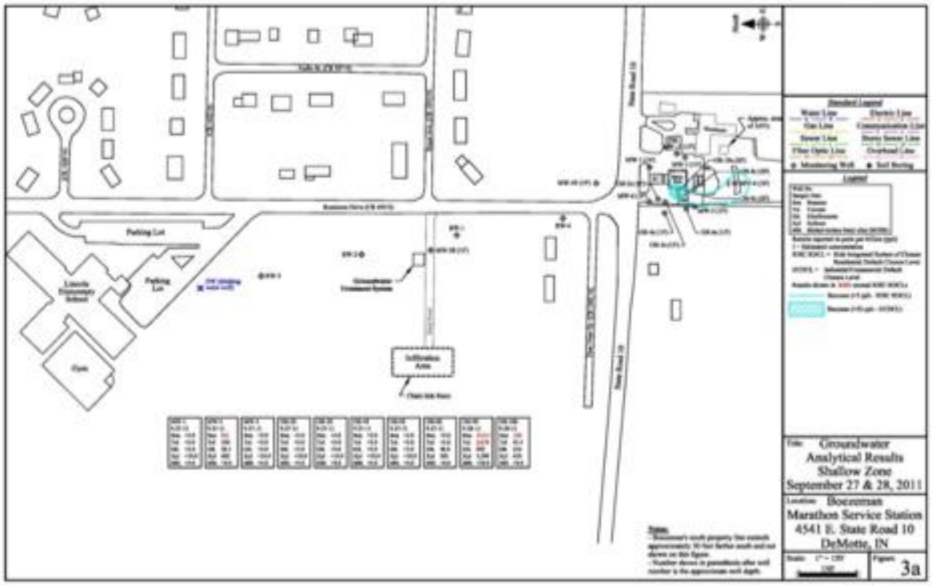


Figure 21 GW Flow Directions – Demotte.



A. Initial

B. After AVE/AS remediation

Figure 22 GW Impact Levels – Demotte

Impact

Off-site impacts affected the drinking water supply of Lincoln Elementary school and one private residence. Emergency response measures included providing clean water and activated carbon to the water supply to ensure clean water for all affected parties, including the elementary school. Long term remediation efforts initially included Ozone Sparging, beginning in July 2004 and limited off-site pump and treat, beginning in 2002, all approved by IDEM and installed by a second environmental consultant hired by the responsible party (Mundell, 2002). The overspill and lack of inventory control issues were never reconciled. The shallow impacted drinking water well remained in-service. The emergency response efforts continued for nearly eight years while little effort was made by the consultant, the responsible party, or the consultant to move the project past short term measures to long term corrective action. Additions to the system were added in 2005, 2006, and 2009. This added years' to the project at a cost of more than 3.5 million dollars. In 2010 efforts were made by the responsible party and the insurance carrier to move the project forward by replacing the second consultant (Creek Run, Boezemen, 2013).

Long-Term Remediation

To achieve NFA status it was believed imperative in 2010 to move away from continued emergency response measures to active long-term measures that would lead to closure of this site. The Ozone Sparge was not designed or should never have been intended to be used as a long-term closure strategy. Evan Nyer concluded in past research that it was not effective in the remediation of petroleum impacted soil and groundwater (Nyer, et al, 1992). Greater use of the pump and treat was also undertaken.

It was necessary to increase pumping operations in 2010, if the pump and treat system was going to continue to be utilized. Years of use had clogged the pumps and lines with sediment bringing pumping operations and therefore treatment operations to a minimum. Cost to operate and maintain an ineffective and underused remediation system were no longer feasible.

In 2010 the Ozone Sparge was shut down and disassembled and Soil Vapor Extraction (SVE) and Air Sparge (AS) were installed as a long term treatment option. In unsaturated unconsolidated soils, such as those in Northwest Indiana which are glacially deposited sediments, SVE should be an effective remediation strategy. Combined with AS for the removal of the volatile organic vapors created by SVE this site will achieve closure status in 2016. Part B. of Figure 22 shows analytical results after the utilization of SVE/AS remediation technology. Figure 23 shows reduction in contamination of the two most impacted wells using this remediation technology. In conjunction with a more effective system and technology, a new drinking water well was installed at the station outside the plume of contamination to a depth of 48 feet (14.6 meters). The well was installed with a stainless casing for more added protection. Moving the well outside the existing plume will ensure that the station is provided clean drinking water. Increasing the well depth also will allow for another measure of protection. This should expedite closure and options to achieve closure (Haneman, 1991).

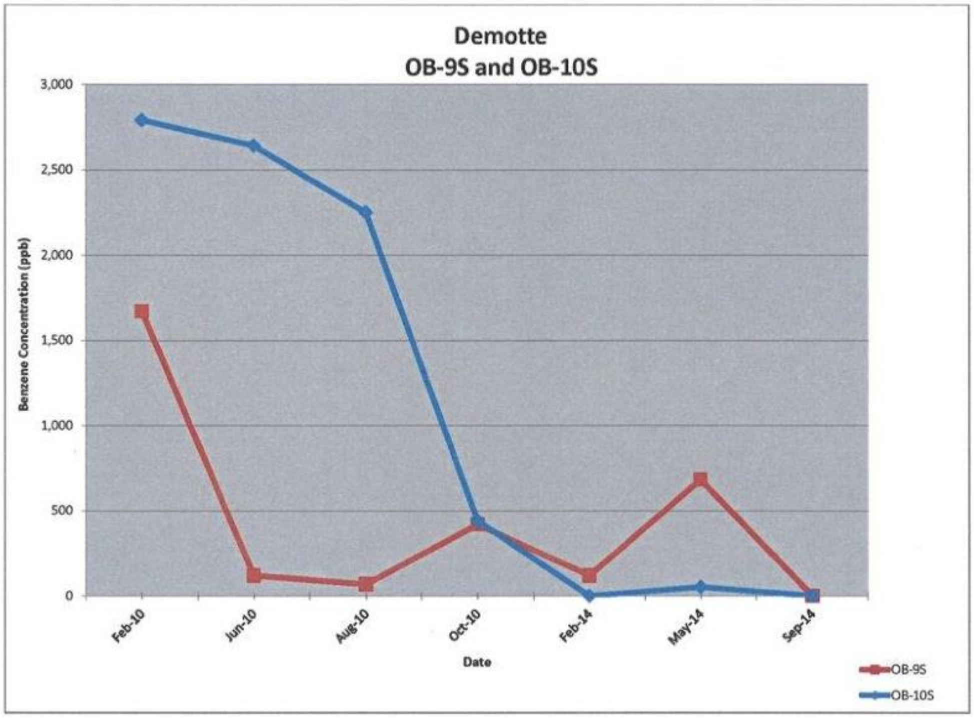


Figure 23 Graph of Analytical Data – Demotte

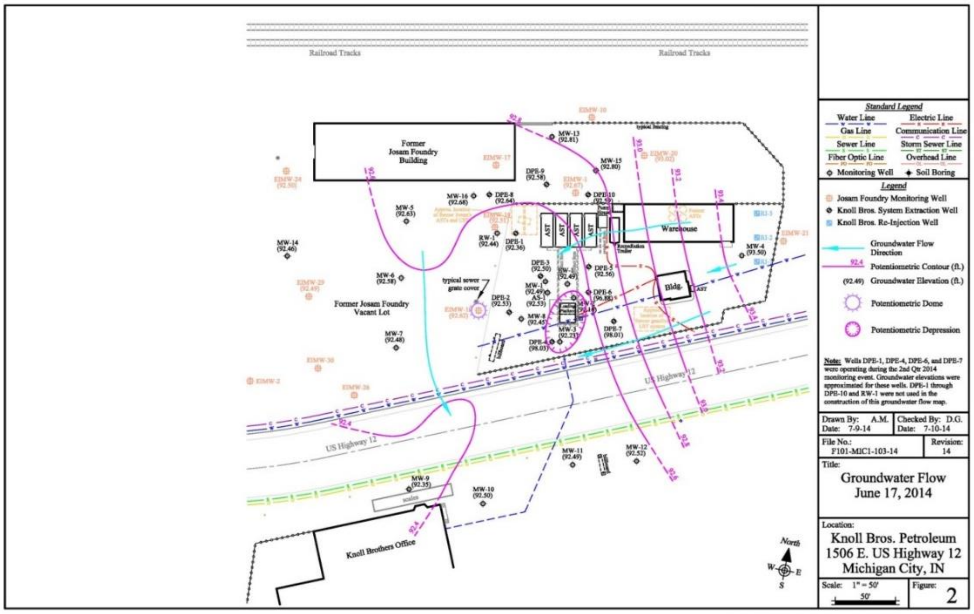
Michigan City, Indiana

Background

The release at this location in Michigan City, Indiana in LaPorte County, within sight of Lake Michigan - also in Northwest Indiana occurred from AST and the loading rack and loading areas from the AST. The site has been a bulk plant for more than 80 years, opening on or before 1928. Releases occurring to fill the AST and to unload the AST have been speculated to happen almost daily since they opened, continuing to present day. Piping issues have also been noted in small drips from deteriorating lines, and lines no longer tight as well as seeps from the rivets and seams in the AST. Additionally the fittings from the loading racks have leaked and have continued to pose an environmental threat. It was believed that this release is historical and occurred from many surface releases over many years, from small daily drips to 1,000 of gallons (3785 liters) of released product into and outside of an earthen dike. The site is located in Michigan City, Indiana in Michigan Township in LaPorte County. The site is located in a mixed primarily commercial/industrial area along US 12 (SESCO, 2008).

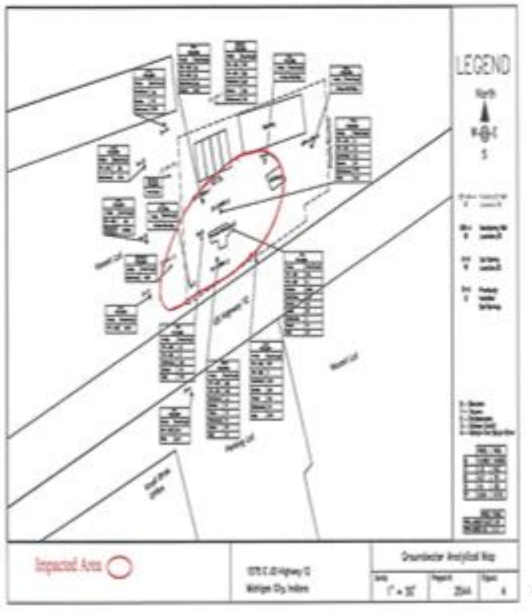
Release

Investigation into the extent of this location and the numerous documented and undocumented releases began in December 2005. Characterization of the release was approved in 2011 and a Corrective Action Plan (CAP) was approved in 2013 (Creek Run, Michigan City, 2013). The plume of dissolved petroleum is in the soil and groundwater. Groundwater is less than 20 feet (6 meters) below grade. The plume spreads south and west underneath a state highway and onto an adjacent property, Josam Manufacturing. Josam Manufacturing has had an incident and is undergoing its environmental clean-up. The site is approximately 600 feet (182.7 meters) above sea level with groundwater at approximately 10 (3 meters) Below Grade Surface (bgs). Storm water run-off is captured by storm water gates along the state highway and flows into Trail Creek, which flows into Lake Michigan, 0.25 miles (402.3 meters) away. The release is believed to have occurred from the AST over time in various amounts and quantity. There was not a specific incident that defined this release other than the initial investigation. IDEM assigned Site State Clean (Creek Run, Michigan City, RWP, 2013). Soil borings encountered coarse grain sand and groundwater at 9 feet (2.7 m) bgs. Figure 24 shows groundwater flow direction and part A. of Figure 25 illustrates groundwater impacts prior to use of SVE/AS remediation techniques.

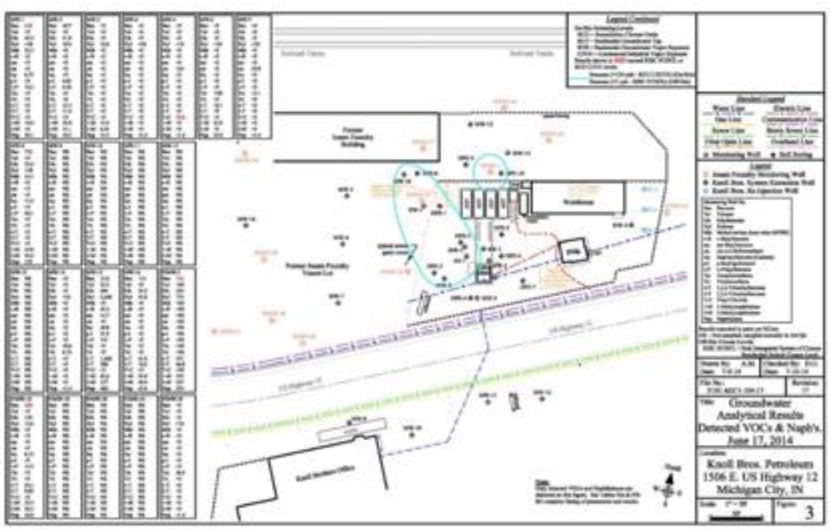


Figur

Figure 24 Groundwater Flow Direction – Michigan City.



A. Initial



B. After AVE/AS remediation

Figure 25 Groundwater Impact Levels – Michigan City

Impact

No private drinking water wells exist in the immediate affected area, but there are three (3) low capacity wells located within a one mile radius of the location. The site is supplied by city water and sanitary services. The area is growing with a casino complex just south of the location and rail lines, a marina, and Lake Michigan to the north. The adjacent property also has impacts from their own chlorinated solvents release stemming from manufacturing operations. No emergency response activities were initially implemented. Although at different times buckets and absorbent pads were used to capture product from the leaking product lines and from seams and rivets from the AST. A temporary remediation system utilizing AS and SVE was installed in 2012. Funding of the release and remediation activities have come from primarily the insurance carriers (SESCO, 2010).

Long-Term Remediation

On-going remediation efforts have been hampered by continual release of product from the AST and piping. In 2013 a 2,000 gallon (7,570.8 L) release incurred inside the earthen dike. A permanent SVE and AS system was installed in 2012 and efforts have continued to make sure that no future releases occur or at least can be reduced. No other remediation strategies have been employed other than AS and SVE. However, remediation efforts off-site on the adjoining property that are not related to this release are Natural Attenuation (NA). It is unknown at this time, but unlikely that these efforts will result in closure status. Monitoring and sampling cost continue to escalate (Buehlman, 1998).

The myth about NA is that it is relatively inexpensive. The responsible party does not always seem to care about the long term effects of inventory reconciliation and preventing future releases. It is believed that without any further incidents the site will achieve closure status in 2016. Part B. of Figure 25 shows analytical results after the utilization of SVE/AS remediation technology. Figure 26 shows reduction in contamination of the two most impacted wells using this remediation technology. All costs are being paid for by the insurance carriers. This action may be hampering closure efforts as the responsible party does care about their stake in the remediation efforts, but is tough to explain and difficult to prove.

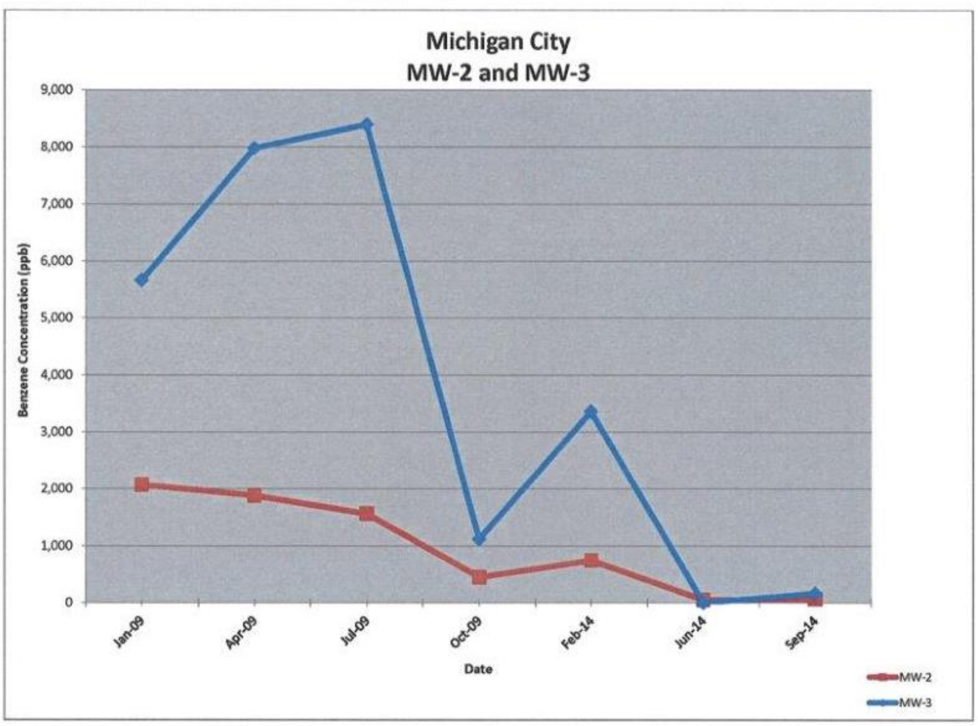


Figure 26 Graph of Analytical Data – Michigan City.

Westville, Indiana

Background

The Westville location is also located in LaPorte County in the southwest corner in Durham Township on West US 6. This site is unique from the other two locations in that the UST and piping that was installed in the 1971 was removed in 1988 and new USTs were installed on the property but in a different location that year. UST that had previously leaked were also located across the street to the east. Identified USTs on both properties that had leaked were removed in 1988. Each had an identifiable hydrocarbon plume in the soil and groundwater. The property owners from each location believed that the other property owner was responsible for the petroleum impacts located on their property. Beginning in 2007, IDEM began the process of forcing each property owner to take responsibility. Litigation put both projects on hold until 2010. Each responsible party then began the investigation of their reported incident that resulted from former USTs that were now removed (Satkus, 2009).

Release

The release was identified during the course of a subsurface investigation that was initiated for financing, on the property directly east of this location in 2007, identified as Prassus Brothers. In the course of the investigation on that location they collected soil and groundwater in the road right of way. IDEM believed that this site location at least contributed to the impacts found and that a co-mingled plume existed in the intersection separating the two locations. IDEM assigned LUST site incident number 200711506 to this location.

It is believed that the release is from the original UST and piping and occurred prior to the UST removal. Release from the tanks and piping from these bare steel tanks and lines occurred most likely overtime from normal use of the UST system, but the UST system was deteriorating. The former USTs were removed at a time when no environmental investigation was necessary. UST owners in fact were encouraged to remove tanks that they did not plan to use anymore before December 1988. UST owners did not want to pay tank fees that would begin in 1989 on tanks that they were no longer using. No reporting of the removal activities was required or necessary and no permit or closure documents were needed**.** Inventory reconciliation records, used today to determine if product had been loss were also not required. It would be difficult to know how many UST were removed in Indiana before December 1988 that followed this same scenario. Any impacts to the soil and groundwater had simply been left for someone to deal with at a later time. This appears to be a strategy that was utilized for these USTs removed at this time. In some cases soil would be removed for disposal, especially if the old USTs were being replaced by new USTs. In this case, it appears that at the Prassus Brothers location that the USTs had been removed but no environmental remediation took place. At this location, the current owner and operator bought the site in 1988 and removed the former USTs, and installed the new USTs at a separate location on the property. They did little or no environmental remediation, that they recalled and did not believe any was required. That led to the IDEM assigning each site a separate incident number. The Prassus Brothers location began remediation efforts at the time while the other location fought the legality that they needed to investigate a release and conduct an environmental clean-up. This issue was resolved in 2010 and the investigation efforts began (SESCO, 2008). Perched groundwater on top of the less-permeable material is very close to the surface. Less than 10 feet (3 m) bgs in many of the monitoring wells on site. Groundwater was moving in southeasterly direction. Figure 27 illustrates the groundwater flow direction. Part A of Figure 28 shows groundwater impact levels prior to use of SVE/AS remediation techniques.

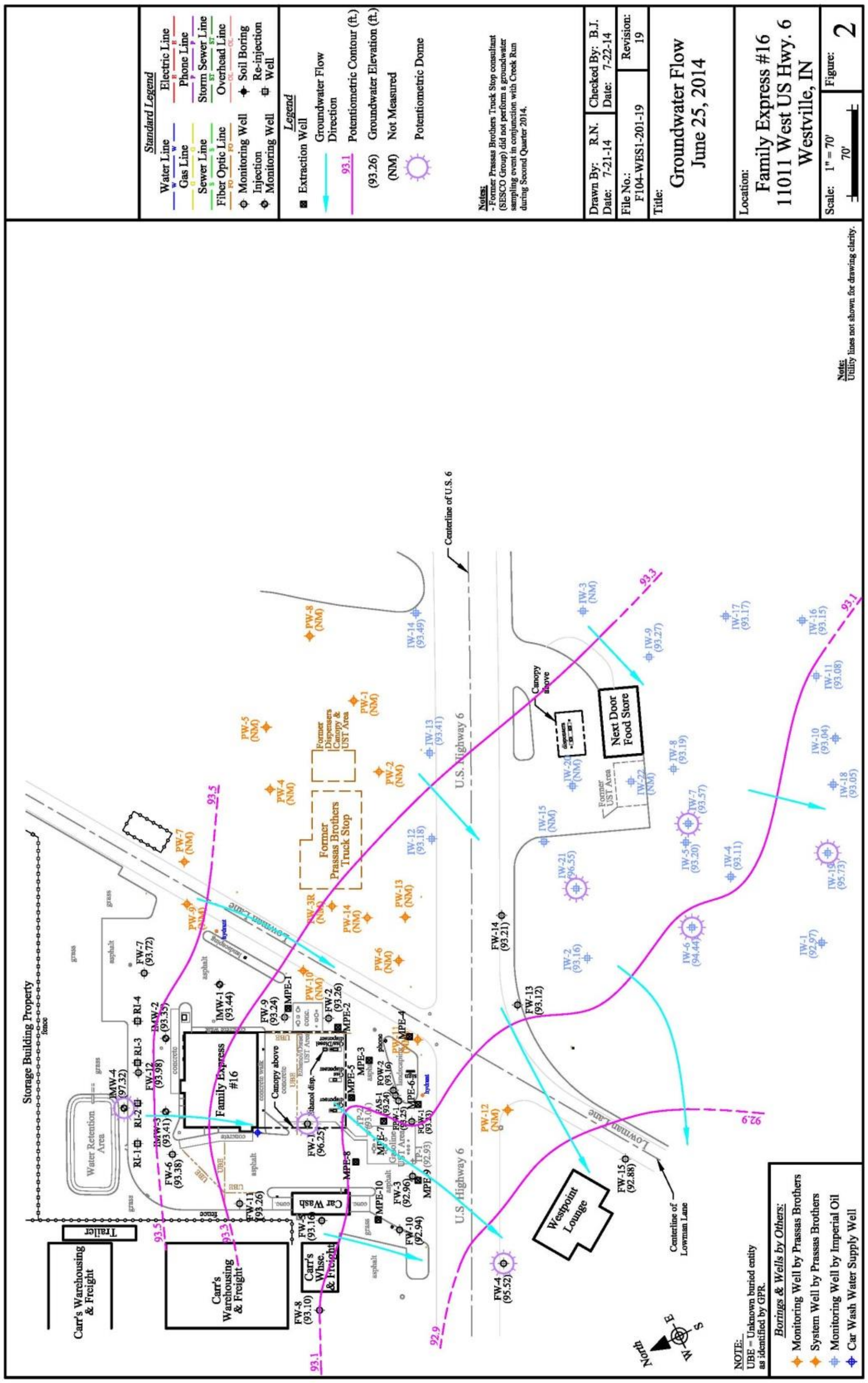
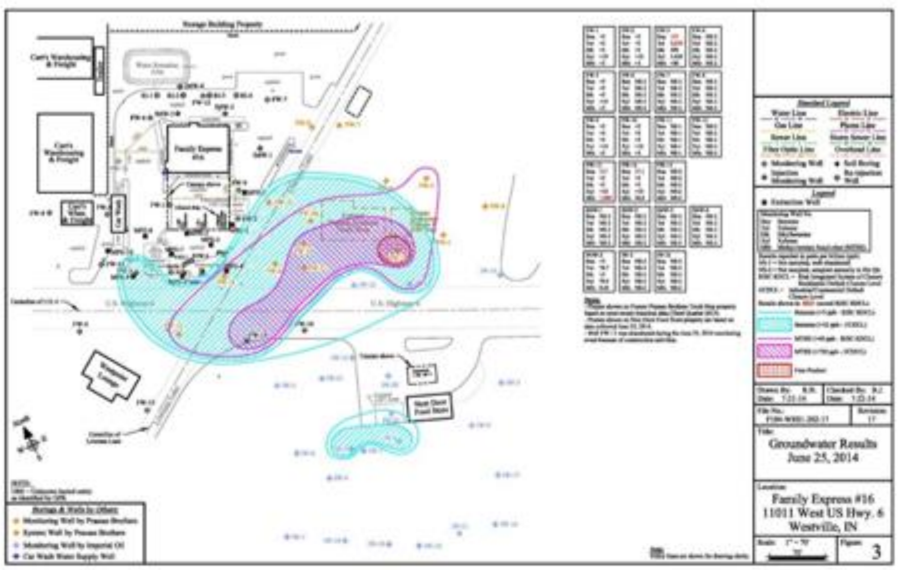


Figure 27 Groundwater Flow Direction – Wentville.

A. Initial



B. After AVE/AS remediation

Figure 28 Groundwater Impact Levels – Wentville.

Impact

Each site was assigned an individual incident number and IDEM mandated that each responsible party undertake the remediation of their own property. Litigation efforts began between the two parties each trying to force the other to be responsible for the impacts found on the others properties. In 2010 this site began the investigation process to identify the plume of dissolved product. The plume had spread off-site in to the intersection and had comingled with a plume from neighboring property petroleum release. A Dual Phase Extraction (DPE) system was installed. The DPE system was designed to pump both vapors and water from the subsurface to allow for volatilization and oxygenation of the impacted area (Johnson. 1994).

The neighboring property installed an undersized and inefficient SVE/AS system that ran for only a short time and was ineffective. Funding issues also played a role in the system not running very long. The DPE system proved to be very effective and was able to reach the desired cleanup's objective. NFA status is expected in the 4th quarter of 2014. Conversely, the neighboring property has ceased remediation and the site is not expected to reach closure status without another accepted treatment technology being implemented. Litigation efforts have resumed between both parties, which has further delayed implementation of a new system (Satkus, 2011).

Long-Term Remediation

The question became who was responsible for two historical releases that occurred more the 25 years ago. Why was it necessary to clean them up now, when it was not necessary to do so when it occurred or when the tanks were removed? When the plumes are comingled which responsible party should take the initiative and the cost burden to remediate the property? IDEM guidance was not clear and caused confusion. Initially the neighboring property location began an investigation and felt confident that they had proved that it should be cleaned up by the responsible party of this site. IDEM agreed until an investigation was completed on this site. At that time, IDEM seemed to reverse their decision and asked each party to take responsibility for the contamination on their property and allow for some expansion of the system to address the issue in the intersection at a later time.

By 2010 the neighboring property had begun the cleanup of environmental impacts on their property. Their efforts proved ineffective as the system was undersized and the technology proved to be ineffective. Funding was also an issue, as only partial ELTF were available because of when the tanks were removed and when it was reported. Efforts began in 2011 to clean up this site property with DPE technology and adequate funding. DPE is an aggressive remedial technology especially well- suited for lower permeability soil. SVE and AS technology is not well suited for a site with a high water table, such as what is in place in Westville (Hinchee, 1994). It is anticipated that this location will have an NFA in 2014 or early 2015. Part B. of Figure 28 shows analytical results after the utilization of SVE?AS remediation technology. Figure 29 shows reduction in contamination of the two most impacted wells using this remediation technology. It is unknown when the neighboring property location will receive an NFA. But what is known is which strategy worked at this location and how much money was spent on a successful remediation project and what was spent on an unsuccessful neighboring one (Creek Run, Westville, 2010).

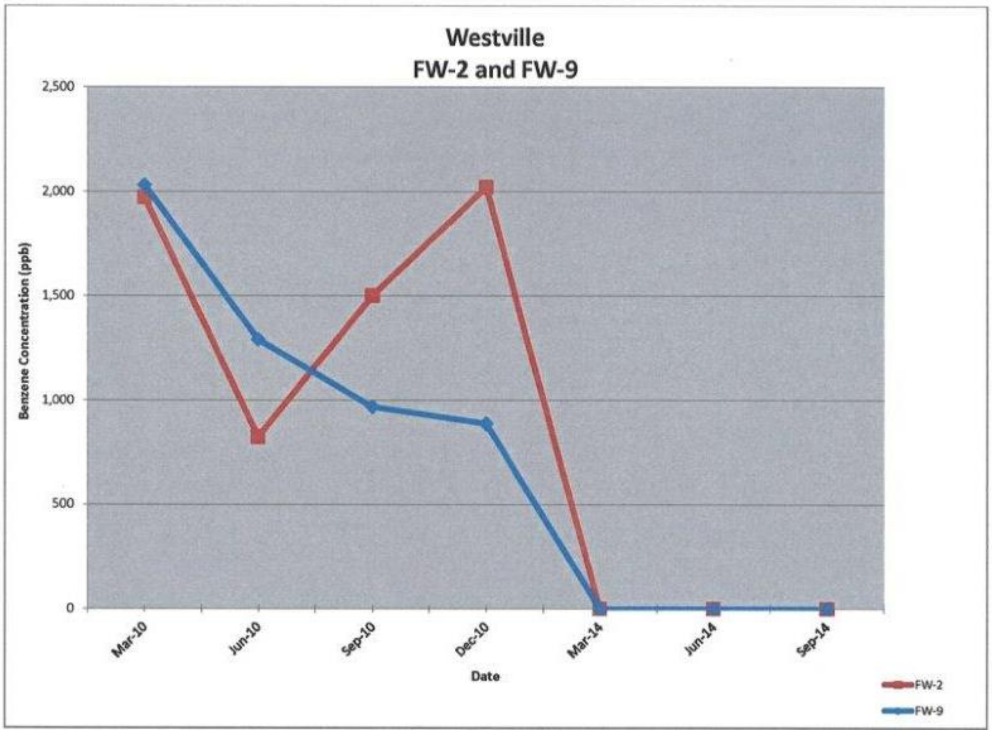


Figure 29 Graph of Analytical Data – Westville

CHAPTER V

REMEDIATION TECHNOLOGIES, APPLICATION AND EFFECTIVENESS

Introduction

The various types of environmental remediation are discussed in this chapter, focusing on the applications that have been used at the three subject locations illustrated in Chapter IV. First the premise of the various applications will briefly be discussed in general and then each site is discussed specifically.

Ozone Sparging is not a proven long-term effective remediation application. The premise is that ozone, an oxidizing agent, can effectively treat hydrocarbons. It was a popular and costly alternative 15 years ago (Nyer, 1992). Ozone Sparging employs an oxidizing process using ozone microbubbles and hydroperoxide – coated ozone microbubbles that are pulsed through the soil and groundwater. The Ozone Sparging is injected into the impacted area, allowing for *In-Situ* destruction of targeted compounds (Cole, 1994). Benefits included lack of vapor control and minimal site disturbance. It was primarily used to treat soil and groundwater at areas of impacts that were adjacent to property boundaries, as attempt to treat groundwater before it moved off-site (Cole, 1994).

Air Sparging (AS) promotes the volatilization and biodegradation of petroleum impacted soil and groundwater by introducing air into the aquifer under pressure. The injected air will migrate up and through the aquifer material to the vadose zone or the unsaturated zone. The volatilizing of petroleum hydrocarbons will produce vapors evaporation extracts contaminants in the process. If vapors are not produced, then the technology is not working as it was designed. Creating vapors is a necessary negative consequence because of the unpredictability of where the vapors will travel (Hinchee, 1994).

Capturing the created vapors is called Soil Vapor Extraction (SVE), and as previously stated is a technology that is often utilized and most often must be utilized when using AS as a remediation technology. Air Sparging creates vapors that will migrate upward through cracks, crevices, openings and other channels above the water table. The biggest issue with this is that they will escape into the atmosphere, usually in violation of some air permitting codes. Other issues can be escalated if the vapors are left untreated and enter into basements or drains that can lead into dwellings without basements. SVE is deigned to capture these vapors and treat them before they are released into the atmosphere and should be used in conjunction with AS (Johnson, 1994).

Dual Phase Extraction (DPE) is an effective technology for the remediation of petroleum-impacted unsaturated soil, saturated soil, and groundwater. Site hydrogeology and the efficiency of the DPE system determine the time the time required to remediate petroleum vapors and impacted groundwater and achieve cleanup goals. DPE systems are expensive to install in comparison to other technologies and expensive to operate. During installation there can be extensive disruption to the site including well installation, trenching and excavation for the installation of air lines, water lines, and extraction lines. DPE is designed to extract both vapor and groundwater, separating and treating each so that proper disposal can take place. The process is cleaning up both soil and groundwater utilizing only one technology that creates incredible vacuum in a very concentrated area (Simon, et al, 1988).

Pump and treat technology is designed to clean up impacted groundwater, but it leaves impacted soil in place. It utilizes aspects of DPE by removing impacted groundwater, bringing the water to the surface to be treated and then either re-injected into the water table or disposed of in the sanitary system. It is expensive since groundwater is pumped to the surface for treatment. (It is one of the reasons DPE is so expensive.) It requires a maintenance commitment, a structure to house the equipment that has to be heated in the northwest US in the winter months, and continual resources to ensure proper operation. This technology, when used, is usually in conjunction with other remedial options. It has been utilized when impacts are high and have moved down gradient rather quickly. It becomes an emergency response and an attempt to protect the aquifer. Pump and treat prevents migration of contaminants by establishing hydraulic control of the plume area. It can also lower the water table exposing saturated soil to air movement. The equipment is simple, but is very labor intense (Buehlman, et al, 1998).

Monitoring Natural Attenuation (MNA) is a viable treatment technology when impact levels are reduced or deemed to be at an acceptable level. MNA documents the impacts as contaminants naturally attenuate without means of a remedial system. It is often used a means to save cost or as a means to do very little. It is actually a very expensive technology to get approved. Sampling to delineate the plume and then to prove plume stability requires an extensive monitoring well network that also must be maintained and is commonly required to be sampled quarterly. Property owners often wish to gravitate to this technology without understanding the cost associated with getting it approved and length of time the site will have to be monitored, decades in many cases. As opposed to many conventional types of remediation projects which can receive closure in five years using other treatment options listed above. MNA is expensive and can take decades to reach acceptable closure levels (Hanemann, 1991).

DeMotte, Indiana

This location had a significant historical release that was discovered in 2002. Within the first the owner/operator went through two environmental consultants before seeking legal advice as a means to deal with the Indiana Department of Environmental Management (IDEM), and selecting an appropriate, although belated emergency response. The emergency response actions included providing clean drinking water to those individuals affected, and to ultimately determine who was affected, which was difficult. Ultimately a pump and treat system was installed off site to provide hydraulic control of the impacted aquifer, long term and short term to make sure those affected are not drinking impacted groundwater. Ozone Sparging was also installed at the property boundary in an attempt to provide a barrier of protection as the groundwater moved off site (Mundell, 2002).

The Pump and Treat System was started on September 30, 2005. Between that time and August 2011, 62 million gallons (282,100,000 L) were treated and re-injected into the water table. Effluent levels remained above IDEM action levels of 5 PPB benzene during this time of operation. The responsible party concluded in August 2011 that the system was not working as designed and another consultant was brought on to investigate and take over operations and evaluate the effectiveness of the system. It was concluded that the Ozone Sparging system was ineffective and that was the reason that the Pump and Treat had to remain active. Impacted soil continued to contaminate the groundwater as it moved through this zone of soil contamination. The question that Evan Nyer (1992) has repeatedly pointed out is not whether pump and treat works, because it does, but not when it is the only remedial strategy. If the Ozone Sparging would have been effective, then the soil would have been effectively treated and impacts would have dropped below IDEM action levels for Total Petroleum Hydrocarbons in the soil. If that would have happened, then the initial emergency response measures to control plume movement may have been effective and the site could have been fully remediated. Instead Ozone Sparging was ineffective, the pump and treat system was strategically placed down gradient pulling impacted groundwater to it, essentially making it a critical necessity in the process. Without it, students would have been drinking impacted water at Lincoln Elementary School (Creek Run, DeMotte, SI & CAPA 2012).

Due to the lack of success with Ozone Sparging and the subsurface glacial deposits, it was decided very quickly that the Ozone Sparging needed to be replaced with a SVE/AS system. IDEM approval was sought and approved and the system was installed. In the summer of 2012 the Ozone Sparging system was shut down and replaced with a new SVE/AS system. At that time Benzene levels near the UST area and property line where the Ozone Sparging points were located were at 1,330 PPB. The Pump and Treat System remained active for another calendar year while effluent samples dropped below IDEM action levels, and another 21 million gallons (95,550,000 L) were treated. The Pump and Treat System was shut down on October 29, 2013. The system was dismantled in November/December 2013. The SVE/AS system remained operational through the first quarter of 2014 until it was shut down. Confirmatory samples in the summer of 2014 did show that the site is now clean and that the historical release has now been fully remediated. Benzene levels from February 2014 were below action and were measured at less than 5 PPB benzene (Figure 28). Although IDEM has not written a No Further Action (NFA) for the site, IDEM is seeking approval from the local school board and the responsible party to ensure that everyone is in agreement on closing out this incident number. Seeking approval from the school board is an unusual step, but because of the sensitive nature of this particular release they deemed it necessary. IDEM expects closure in 2015 (Creek Run, DeMotte, 2012). Table 6 contains remediation costs.

Table 6 Graph of Totals Spent Broken Down by Remedial Strategy

Location	Amt. Spent Previous Tech	Amt. Spent Current Tech	Total Spent
Demotte 4541	$3,600,000.00	$759,418.53	$4,359,418.53
Michigan City 1506 (1575)	$500,000.00	$741,602.98	$1,241,602.98
Westville, 11011	$600,000.00	$1,021,488.53	$1,621,488.53

To date $ 4,350,418.43 has been spent on environmental remediation by the three consultants who worked on this project. The $3,591,000.00 was spent prior to August 2011 when the third and final consultant was hired by the insurance carriers of the responsible party to evaluate and redesign the system and make and perform tasks to ensure closure. About $2,000,000 of the funds spent on this site came from the ELTF, the LUST funding mechanism in the state of Indiana. The remainder $ 2,350,418.43 came from the insurance carrier. Any remaining balance will be paid for by the insurance carrier. As Evan concluded in 1992, pump and treat is expensive and should only be used in conjunction with a proven long term remedial approach. Ozone Sparging is not a proven long term remedial for petroleum constituents in the soil and groundwater (Nyer, et al, 1992). Table 6 outlines the total dollars spent on this project and breaks down costs in accordance with the remediation strategy.

Michigan City, Indiana

This location has a historical release from the AST and from the former UST that was identified in December 2005. The initial identification process was because of an impacted location adjacent to the site to the west. The adjacent facility was a manufacturing operation that was in the process of its own environmental cleanup. The remediation technology they were using and are still using is MNA. The off-site property owners were not doing any active environmental remediation other than MNA. They were monitoring the well network ensuring plume stability and documenting the degradation process that is occurring naturally. MNA is an expensive process. By most estimates today it takes $6,000 a quarter to complete the sampling and documenting process. The majority of this expense is used for analytical cost. During a one year period, it could cost $96,000 USD, and over a 20 year period this adjacent property has spent $ 1.9 million USD, although it is not near closure level status. Monitoring wells at the property line had exhibited plume stability but the contaminant levels at the property were still exceeding action levels by IDEM (SESCO, 2008).

At this location a second consultant took over in December 2010. In November 2011, a temporary SVE system was installed and ran until August 2013. During this time the system ran for 13,831 hours and recovered and treated 377.34 pounds (169.8 kg) of volatile organic compounds. The system was designed to extract petroleum vapors from the source area from near the loading rack and the AST. Benzene levels in MW – one was over 1,000 PPB. By August 2013 Benzene levels had fallen to 188 PPB Benzene. In December 2013 a SVE and AS permanent system was installed that was approved by IDEM. The temporary system was not approved by IDEM but was used as a means of emergency response to remove VOC while waiting for IDEM approval on the permanent system. The location is still in operation. The consultant of record continues to battle spills from the AST and from daily operations that includes leaks and spills from the loading rack to fill tankers from the AST, and from the process of filling the AST (Dorsey, 2013).

The permanent SVE/AS system thru June 2014 had recovered and treated 13.6 pounds (6.12 Kg) volatile of organic compounds running for 3,447 hours. The system continues to run. Benzene levels in June 2014 were below IDEM action levels at 48 PPB. The monitoring well network is composed of more than 20 monitoring wells. All but three wells by the end of June were below IDEM actions levels. Nine monitoring wells in December 2011 were above action levels. In December 2013 seven monitoring wells were above IDEM action levels. It is expected that the system will continue to run continuously through 2014 and after confirmation sampling is completed with a NFA expected from IDEM in late 2015 (Creek Run, CAPR, Michigan City, 2013).

Between the initial reporting of the release in 2005, because of the adjacent investigation, the first environmental consultant spent more than $ 500,000 USD during the investigation that was never approved by IDEM. No remediation was completed by the first environmental consultant even though $500,000 USD had been spent. The second consultant, taking over in December 2010, has spent $741,602.98 USD. Funds had been spent for the temporary system and for the permanent system. The $741,602.98

USD has led to the environmental clean-up of the property except three of the monitoring wells. The remaining three are expected to be below IDEM action levels by the end of 2015. In this situation, SVE/AS was the remediation technology needed to meet closure requirements by the IDEM. MNA completed on the adjacent property at the expense of $1.9 million USD over a 20 year period has not led to the expected results. Nor did cost spent on this project prior to 2010 lead to positive results. Table 6 contains the total cost spent broken down by remedial strategy. SVE/AS was the needed technology for closure at this location, and as previously discussed, it is the appropriate technology for the glacial deposits of northwest Indiana in LaPorte and Newton Counties (Creek Run, Michigan City, CAPA, 2013).

Westville, Indiana

This location removed USTs in 1988, with new USTs installed at this time. The USTs were removed as required to meet new requirements under new federal mandates requiring all bare steel tanks and product piping storing petroleum to be replaced by December 1999. It is believed that the release on this property occurred from 1971 until 1988, the date the former USTs were installed and the date of the USTs removals. All removed USTs were steel tanks and all product piping was steel. New fiberglass tanks and piping were installed at this time. It is not known exactly why no environmental remediation had taken place except that the USTs were removed in 1988; no environmental reporting was required or mandated at that time. The USTs were simply required to be removed. New UST were installed at this location and properly registered at this time but at a different location on the property. These USTs remain in place today and the facility remains in operation (Sesco, 2010).

On a neighboring property across the intersection, a similar UST removal took place in 1988. These UST were not replaced they were simply removed. During a property transfer on the neighboring property in 2005 an environmental study was conducted and petroleum impacts were found. This investigation led the consultant on the neighboring property to complete sampling in the intersection. They concluded and IDEM agreed that the Westville location could be a contributor to the impacts in the intersection. IDEM then asked for an investigation on the subject location. The adjacent property owner began an environmental cleanup utilizing SVE only. The system was undersized, and underfunded. It ran from 2007 until 2011 and was abandoned. The site is still not cleaned up and impacts remain. That property owner is in litigation with the consultant and with IDEM. In 2010, litigation between the property owner was initiated but not pursued and eventually was dropped at arbitration. The property owner has argued that he is no longer responsible because he simply did not have the funds to continue running the system, and was hoping the state could assist with additional funding because he had only received 65% of their cost reimbursed by ELTF. This request was denied. More than $600,000 USD was spent on the investigation and remediation on this adjacent property. Impacts above IDEM action levels remain and the site remains a priority with IDEM (Sesco, 2010).

The Westville DPE/AS system was approved and installed on the subject property in September 2011. Since that time 27,574.25 pounds (12,408.41 Kg) of volatile organic compounds have been removed and treated since the system startup. The DPE/AS has also treated 3,968,594 gallons (18,057,102.7 Liters) of petroleum impacted groundwater. Only two of the monitoring wells have any impacts of benzene remaining. In 2011 when the system started seven of the 20 monitoring wells within the monitoring well network had benzene impacts above action levels. It is projected that all monitoring wells will be below IDEM action levels by the end of 2014. After confirmation sampling and IDEM approval it is estimated that this site will be closed in the fall of 2015. Table 6 contains the total cost spent broken down by remedial strategy. $915,483.26 has been spent toward the environmental cleanup at the Westville location and closure is expected and system shutdown should occur. The adjacent property has spent more than $ 600,000 on an undersized SVE system. Impacts remain high and closure is not expected until funding is found and the system can be replaced with one that is adequate. DPE/AS was the proven technology at this location in glacial deposits of northwest Indiana in southwest LaPorte County (Creek Run, CAP, Westville, 2010. It is imperative that the appropriate technology and the appropriate funding are in place to complete the remediation necessary. The value of time should also be considered when compared to cost strategies. Time is a factor when determining property values when environmental impacts remain.

CHAPTER VI

CONCLUSION

Environmental remediation is very expensive and can take years to complete with the correct technology. In northwest Indiana in Newton and LaPorte Counties it is imperative to select the proper remediation strategy for the subsurface soils and the underlying deposits. The three cases illustrated show that using an inappropriate technology for the subsurface soil characteristics will not be effective, and can be very expensive. Ozone Sparging has been proven to be ineffective for long term remediation. Data from the DeMotte, Indiana location in Newton County showed the SVE/AS was the appropriate technology and is projected to lead to closure in 2015. The location in Michigan City has shown that SVE/AS is the appropriate technology and that MNA is ineffective in the soils in Michigan City, Indiana in northwest LaPorte County. SVE/AS was the appropriate technology and is projected to lead to closure in 2015. The site in Westville, Indiana has shown the appropriate technology was SVE/AS. SVE without AS or groundwater treatment is not an appropriate technology for this location in northwest Indiana in southwest LaPorte County. Cost using the appropriate technology regardless of where funding comes from is expensive. These three sites may exceed one million dollars each by the current consultant by the time an NFA is received. In the case of DeMotte more than 3.5 million dollars was spent before the appropriate technology was selected. In Michigan City more than 1.9 million has been spent on an inappropriate technology at an adjacent site. In Westville more than $ 600,000 was spent on an ineffective technology at an adjacent site. SVE/AS is the most appropriate technology to use in highly permeable soils when the static water table allows for the mass transport of contaminates vapors to be pulled through sediments and removed from the subsurface. IDEM plays an important management role and the regulations direct appropriate remediation guidance and when followed will prevent a petroleum release. The ELTF provides funding necessary to complete task directed by IDEM and the corresponding regulations, allowing for a mechanism for reimbursement for all applicable cost related to an environmental remediation from registered UST.

In addition to the three case histories provided Appendix B contains all NFA notices received in which the consultant that used the ASE/AS remediation techniques has successfully used proper remediation techniques at over 100 sites resulting in receipt of the NFA.

REFERENCES

Amendments, "Superfund Reauthorization Act (SARA) of 1986." Public Law 99, 1986
.

American Petroleum Institute (API) Recommended Practice (RP) 1604, "Removal and Disposal of Used Underground Petroleum Storage Tanks," 1987.

American Petroleum Institute (API) Recommended Practice (RP) 1632, "Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems," 1992.

Beck, Edkardt C. "Love Canal Tragedy, The." EPA J 5, 1979.

Braun, Chris, "IDEM Threatens Independence and Solvency of Indiana's Successful Tank Fund," Fueling Indiana, December 2013.

Buehlman, Mark D., Daniel T. Rogers, and Frederick C. Payne, "Science plus management equals successful remediation: A case study." Environmental Progress 17, no. 2, 1998.

Church, Michael, and June M. Ryder, "Paraglacial Sedimentation: A Consideration of Fluvial Processes Conditioned by Glaciation." Geological Society of America Bulletin 83, no. 10, 1972.

Clayton, Lee, and Stephen R. Moran, "Chronology of late wisconsinan glaciation in middle North America." Quaternary Science Reviews 1, no. 1, 1982.

Cole, Mattney, G., "Assessment and Remediation of Petroleum Contaminated Sites," Editor Cole Mattney, 1994.

Comprehensive Emergency Response & Liability Act (CERLA 1980 – 1985: "A Research Guide." Ecology LQ 13, 1986.

Creek Run L.L.C, "Initial Investigation Report, (IIR) Brookston," July 18, 2008.

Creek Run L.L.C, "UST System Closure Report, (CR) Huntington, IN," April 2006.

Creek Run L.L.C., "Corrective Action Implementation (CAI) Crown Point," February 18, 2013.

Creek Run L.L.C., "Corrective Action Plan (CAP) Middletown," January 8, 2004.

Creek Run L.L.C., “Corrective Action Plan (CAP) Westville,” July 23, 2010.

Creek Run L.L.C., “Corrective Action Plan (CAPA) Addendum Implementation Report Demotte,” December 14, 2012.

Creek Run L.L.C., “Corrective Action Progress Report (CAPR) – Third Quarter 2013 Demotte,” October 23, 2013.

Creek Run L.L.C., “Corrective Action Progress Report (CAPR) – Third Quarter 2013 Michigan City,” October 31, 2013.

Creek Run L.L.C., “Corrective Action Progress Report (CAPR) – Third Quarter 2013 Westville,” October 28, 2013.

Creek Run L.L.C., “Further Site Investigation and Corrective Action Plan Addendum (SI & CAPA) #5 Demotte,” August 24, 2012.

Creek Run L.L.C., “Initial Investigation Report (IIR) Westville,” May 30, 2008.

Creek Run L.L.C., “Remediation Work Plan (RWP) Michigan City,” April 19, 2013
.
Creek Run L.L.C., “Remediation Work Plan (RWP) Rushville,” December 1, 2009.

Creek Run L.L.C., “Subsurface Soil Investigation Lake Station,” 2013.

Creek Run L.L.C., “UST Closure and Site Assessment (CSA) Coldwater, Michigan,” July 2, 1997
.
Creek Run L.L.C., “UST System Closure Report (SCR) Angola,” August 26, 1997.

Creek Run L.L.C., “UST System Closure Report (SCR) Lexington, Kentucky,” November 8, 2006.

Creek Run L.L.C., “UST System Closure Report (SCR) Mt. Etna,” October 22, 2010
.
Dorsey, Peggy, “Letter for Remediation Work Plan Approval Michigan City, to Creek Run L.L.C.,” IDEM. September 12, 2013.

Financial Assurance Board (FAB) Board Meeting Minutes, IDEM, 2013.

Fowlkes, Martha R., and Patricia Y. Miller. Love Canal: The Social Construction of Disaster. FEMA, 1982.

Hinchee, R.E., “Air Sparging State of the Art,” Air Sparging for Site Remediation, Editor Robert Hinchee, 1994.

Huber, Matthew T. "The Use of Gasoline: Value, Oil, and the “American way of life”." Antipode 41, no. 3, 2009.

Indiana Code (IC) 13-23 Underground Storage Tanks, 1984.

Indiana Department of Environmental Management (IDEM) “RISK Integrated System of Closure,” February 15, 2001.

Indiana Department of Environmental Management (IDEM) “UST Branch Guidance Manual,” 2004.

Indiana Department of Environmental Management (IDEM), Non-Rule Policy (NPD), Waste – 0063, 2013.

Indiana Department of Environmental Management (IDEM) Financial Assurance Board (FAB) Meeting Minutes, 2013.

James, Simon P., “Finding – and Failing to Find – Meaning in Nature,” Environmental Values, vol. 22, no. 5, October 2013.

Jim Allen Maintenance, Van Wert North, Ohio, BUSTR, 1992.

Johnson W. Hilton, and Ned K. Bleuer. “Quaternary geology of East Central Illinois and West Central Indiana.” Sedimentology of the Late Wisconsin Terrace deposits along the Bend Area of the Wabash River. Tenth Annual Great Lakes Section, Society of Economic Paleontologist and Mineralogist, 1980.

Johnson, R. L., “Enhancing Bioremediation with In-Situ Air Sparging: A conceptual model,” Air Sparging for Site Remediation, Editor Robert Hinchee, 1994.

Lenz, Richard J., “Orphaned USTs,” Report, 2011.

Liberti, Francesco A. “Underground Storage Tank Design, Leak Prevention Technology, and Corrosion Protection.” Pollution Reduction and Containment Control 6, 1993: 159.

Mundell and Associates, “Further Site Investigation Demotte,” December 12, 2002.

Nation Institute for Occupational Safety & Health (NIOSH)/Occupational Safety & Health Association (OSHA), 1987, Pocket Guide to Chemical Hazards, NIOSH/OSHA DHHS Publication #85-114, 1987.

National Association of Corrosion Engineers (NACE) Recommended Practices (RP) – 0285 – 85, “Standard Recommended Practice: Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems,” 1985

.Norton, L. Darrel. “Erosion – sedimentation in a Closed Drainage Basin in Northwest Indiana.” Soil Science Society of America Journal 50, no. 1, 1986

.

Nyer, Evan K., “Priming the Pump for In-Situ Treatment,” Practical Techniques to Groundwater and Soil Remediation, Editor, Evan K. Nyer, 1992.

Nyer, Evan K., Paul Bitter, “Laboratory and Pilot Plans Evaluation of Ultraviolet (UV)-oxidation Treatment Methods.” Practical Techniques for Groundwater and Soil Remediation, Editor Evan K. Nyer, 1992.

Nyer, Evan, K., and George J. Skladany, “Relating the Physical and Chemical Properties of Petroleum Hydrocarbons to Soil and Aquifer Remediation,” Practice Techniques for Groundwater and Soil Remediation, Editor Evan K. Nyer, 1992.

Rawson, E. Blaine, “Are We Properly Controlling Our LUSTs?” A Review of the Problems with Underground Storage Tank Regulations. Idaho L. Rev. 40 2003.

Roy, A.B., “Fossil Fuels: Petroleum and Coal,” Fundamentals of Geology, 2010.

Ryan, Joe, BASIN, University of Colorado, 2013

.

Satkus, Cheryl, “Letter for Corrective Action Plan Approval with Modifications Westville, to Creek Run L.L.C.,” IDEM. January 24, 2011

.

Satkus, Cheryl, “Letter for Site Characterization Approval and Corrective Action Plan Request Westville, to Creek Run L.L.C.,” IDEM. December 28, 2009.

Sesco, “Further Site Investigation (FSI) -3 Report and Response to IDEM Comments,” April 14, 2010.

Sesco, “Revised Corrective Action Plan (CAP),” June 5, 2008.

Shedlock, Robert J., Douglas A. Wilcox, Todd A. Thompson, and David A. Cohen, “Interactions between ground water and wetlands, southern shore of Lake Michigan, USA.” Journal of Hydrology 141, no. 1, 1993.

Shrock, Robert R., and Clyde A. Malott. “The Kentland Area of Disturbed Ordovician Rocks In Northwestern Indiana.” The Journal of Geology, 1993.

Simon, John A., and Eileen O’Neill. “Current Technical Developments: Regulations and New Standards for Clean-Up and Investigation Technologies.” Environmental Claims Journal 1, no. 1, 1988.

Spirm, Anne W. “Constructing Nature: The Legacy of Frederick Law Olmstead,” Uncommon Ground, Editor William Cronin, 1996.

Stiglitz, Joseph E., "Monopoly and the Rate of Extraction of Exhaustible Resources," The American Economic Review, 1976.
Title 328 Indiana Administrative Code (IAC), 1989
.

Title 40 Code of Federal Regulations (CFR) Conservation Resource Recovery and Act of 1976 (RCRA) Public Law: 94-580.

Wayne, William J. "The Erie Lobe Margin in East-Central Indiana During the Wisconsin Glaciation." In Proceedings of the Indiana Academy of Science, vol. 77, 2013
.

Webb, Michael C., "Double wall piping systems." U. S. Patent 4,932,257, issued June 12, 1990
.

Weber, Anne D. "Misery Loves Company: Spreading The Costs of CERLA Cleanup," Vanderbilt Law Review 42, 1989.

West, Terry R. and Kyuho Cho., "Environmental and social issues associated with aggregate extraction: The Lafayette and West Lafayette, Indiana, and other examples, USA." 2006
.

White, Richard, "Are You an Environmentalist or Do You Work For a Living? Work and Nature," Uncommon Ground, Editor William Cronon, 1996.

Wilson, Jerry, "How the ice age shaped Indiana," Wilstar Media, www.wilstar.com, Indianapolis, Indiana, 2008.

Wilson, Jerry, "The Topography of Indiana: Ice Age Legacy," Wilstar Media, www.wilstar.com, Indianapolis, 1988.

Wood, Harry Warren. "The History of Indiana During the Glacial Period." 1916.

APPENDIX A

FIGURES

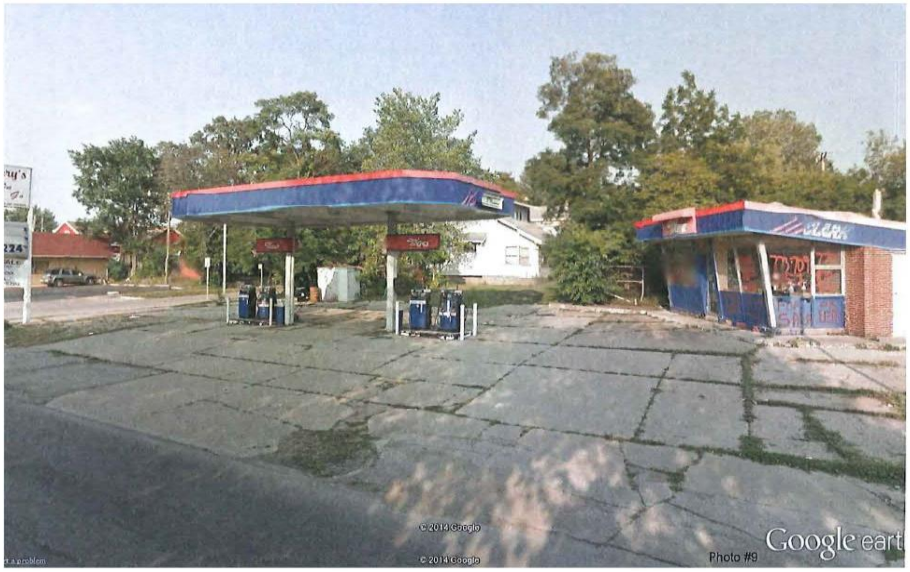


Figure 30 Abandoned UST Location.

Figure 31 Abandoned UST Location.

APPENDIX B

NO FURTHER ACTION SITES

Creek Run Obtained No Further Action Letters

Site ID	Incident #	Start Date	End Date	Treatment Technology	Approximate Dollar Amount
Demotte, E. SR 10	200202509	May 2011	* Estimated September 2015	AS / SVE system	$ 759,418.53
Michigan City, E. US HWY 12	6120202	December 2010	* Estimated September 2015	AS / SVE System	$ 741,602.98
Westville, W. US 6	200711506	May 2008	* Estimated September 2015	AS / SVE System	$ 1,021,488.53
Butler, S. Broadway St.	200609515	August 2011	September 2014	MNA / Risk Assessment	$ 84,788.81
Bluffton, S. Main St.	201307513	May 2013	September 2014	Risk Assessment / CSM	$ 17,177.54
Fort Wayne, Leo Rd.	201004501	December 1997	July 2014	Excavation / source removal	$ 100,000.00
Bedford, SR 37	201403509	October 2013	July 2014	UST Closure / Risk Assessment	$ 57,473.51
Indianapolis, E. 96th St.	201401508	December 2013	July 2014	Spill Recovery and Response	$ 7,428.85
Tipton, E. Jefferson St.	201403500	October 2013	July 2014	UST Closure / Risk Assessment	$ 75,000.00
Fort Wayne, Coldwater Rd.	200710508	October 2005	June 2014	Monitored Natural Attenuation	$ 108,806.22
Crown Point, E. 109th Ave.	201206509	April 2012	May 2014	Monitored Natural Attenuation	$ 35,072.98
Brownsburg, N. Green St.	201402500	October 2008	May 2014	Spill Recovery and Response	$ 30,170.03
Anderson, 38th St.	199601527	May 1996	May 2014	AS / SVE System	$ 1,090,933.64
Flora, E. Columbia St.	200706502	July 2007	April 2014	AS / SVE System	$ 694,538.33
Middletown, Maple Village Pantry	200110518	August 1994	April 2014	AS / SVE System	$ 500,000.00
Valparaiso, Lincolnway	200906054	May 2009	April 2014	ORC / MNA	$ 171,345.23
Indianapolis, Oaklandon Rd.	200207038	October 2008	February 2014	Excavation / CSM	$ 21,970.17
Kendallville, W. North St.	199903519	April 1999	February 2014	Monitored Natural Attenuation	$ 95,760.72
Butler, E. Willow St.	200610504	August 2011	February 2014	MNA / Risk Assessment	$ 78,695.84
New Castle, S. 125 W.	200703507	November 2006	February 2014	Excavation / source removal	$ 236,839.43
Crown Point, S. Court St.	201310507	October 2013	January 2014	UST Closure / Risk Assessment	$ 25,000.00
Berne, US 27 N.	199304021	March 2006	November 2013	Excavation / source removal	$ 292,286.74
Anderson, Noble St.	199910503	December 2010	October 2013	Monitored Natural Attenuation	$ 82,144.59
Hartford City, Evergreen Way	37873	June 2013	October 2013	UST Closure / over excavation	$ 15,426.19
Mooreland, Broad St.	199606530	November 2005	September 2013	AS / SVE system	$ 397,495.38
Walton, N. Main St.	199901521	January 1999	August 2013	Excavation / source removal	$ 186,592.48
Connersville, Grand Ave.	199710528	September 1997	August 2013	Monitored Natural Attenuation	$ 43,525.00
Cambridge City, E. Main St.	201005507	December 2009	August 2013	Monitored Natural Attenuation	$ 53,652.44
Fort Wayne, Spring St.	200609504	August 2008	August 2013	AS / SVE System	$ 146,984.82
Rushville, N. 150 W.	6081203	January 1997	July 2013	Excavation / source removal	$ 600,000.00
Kendallville, W. North St.	199903522	April 1999	June 2013	Monitored Natural Attenuation	$ 14,855.40
Veedersburg, E. US HWY 136	201206515	June 2012	June 2013	Risk Assessment / CSM	$ 30,000.00
Fort Wayne, W. Coliseum Blvd.	200310502	April 1996	June 2013	Excavation / Risk Assessment	$ 250,000.00
Prairieton, SR 63	6110401	August 2006	June 2013	AS / SVE system	$ 1,000,000.00
Fort Wayne, Coldwater Rd.	200708524	October 2005	June 2013	Risk Assessment / CSM	$ 108,806.22
Richmond, NW 5th St.	201103506	November 2011	June 2013	Risk Assessment / CSM	$ 100,000.00
Mariah Hill, E. SR 62	199801540	December 2010	June 2013	Risk Assessment / CSM	$ 91,516.29
Bunker Hill, S. US 31	199812577	December 2001	April 2013	Risk Assessment / CSM	$ 73,406.85
Rushville, S. Main St.	201105502	February 2006	February 2013	Monitored Natural Attenuation	$ 100,000.00
Connersville, S. SR 121	200910508	October 2009	January 2013	Monitored Natural Attenuation	$ 100,000.00
Orland, N. SR 327	199902520	April 1999	January 2013	AS / SVE system	$ 883,690.67
Rushville, W. 3rd St.	201111501	November 2011	January 2013	Monitored Natural Attenuation	$ 100,000.00
Lagrange, E. Central Ave.	200510508	July 2005	January 2013	AS / SVE system	$ 511,665.83
Bremen, E. 2nd St.	200809517	December 2010	November 2012	Risk Assessment / CSM	$ 50,000.00
Liberty, N. Main St.	200904509	March 2009	October 2012	Risk Assessment / CSM	$ 65,626.71
Rensselaer, Interstate 65	27005	February 2012	September 2012	Excavation / source removal	$ 50,000.00
Fort Wayne, Bluffton Rd.	200106512	March 2000	August 2012	AS / SVE system	$ 509,494.81
Kokomo, N. Washington St.	199712528	June 2002	August 2012	AS / SVE system	$ 816,602.64
Parker City, W. Jackson St.	200506516	November 2002	July 2012	Risk Assessment / CSM	$ 150,000.00
Galveston, E. North St.	28746	July 2008	July 2012	Spill Recovery and Response	$ 50,000.00
Richmond, S. 8th St.	201111500	November 2011	June 2012	Monitored Natural Attenuation	$ 50,000.00
Walton, N. Main St.	200010507	November 2000	March 2012	Excavation / MNA	$ 86,196.54
Angola, W. Maumee St.	199902502	March 1999	February 2012	Excavation / MNA	$ 268,470.89
Indianapolis, N. Post Rd.	199012506	February 2007	January 2012	Monitored Natural Attenuation	$ 36,361.91
Anderson, S. Scatterfield Rd.	200103507	June 2002	December 2011	Monitored Natural Attenuation	$ 52,850.82
Austin, N. Dowling	201006509	November 2002	August 2011	AS / SVE System	$ 100,000.00
Logansport, S. 3rd St.	200609509	September 2006	April 2011	Monitored Natural Attenuation	$ 100,000.00
Plymouth, W. Jefferson St.	199712527	January 2003	March 2011	AS / SVE system	$ 343,652.62

Site ID	Incident #	Start Date	End Date	Treatment Technology	Approximate Dollar Amount
Linden, Old US 231	199609530	September 2006	December 2010	Excavation / source removal	$ 164,216.59
Auburn, S. Main St.	199310525	April 1999	September 2010	AS / SVE system	$ 405,701.16
Warsaw, E. Center St.	201006041	October 2009	August 2010	Excavation / source removal	$ 27,792.93
Huntington, N. Jefferson St.	199712532	August 1999	June 2010	AS / SVE System	$ 385,645.47
Portland, S. 200 W.	200801503	August 2002	June 2010	Risk Assessment / CSM	$ 126,818.30
Dunkirk, S. Main St.	199105031	June 2002	June 2010	AS / SVE System	$ 358,137.96
Cambridge City, E. Main St.	200912510	December 2009	June 2010	Monitored Natural Attenuation	$ 250,000.00
Bluffton, N. SR. 1	201006507	March 2010	February 2010	UST Closure / Risk Assessment	$ 25,000.00
Columbia City, N. Main St.	199903542	April 2000	February 2010	Excavation / source removal	$ 61,233.23
Portland, W. 75 S.	199707512	October 2009	December 2009	Monitored Natural Attenuation	$ 100,000.00
Angola, N. Wayne St.	199705529	December 1994	November 2009	Monitored Natural Attenuation	$ 50,231.73
Marion, N. 700 W.	200903020	February 2009	June 2009	Spill Recovery and Response	$ 8,404.88
Austin, N. Dowling	200904064	November 2002	June 2009	Spill Recovery and Response	$ 202,203.09
Michigan City, S. Franklin St.	200904502	June 2008	May 2009	Spill Recovery and Response	$ 276,676.81
Bedford, Mitchell Rd.	200901509	January 2009	May 2009	UST Closure / Risk Assessment	$ 6,620.00
Decatur, W. Monroe St.	200604517	April 2006	December 2008	Excavation / source removal	$ 70,715.75
Connersville, W. 3rd St.	198905127	July 1999	November 2008	Monitored Natural Attenuation	$ 147,478.16
Greensburg, N. Lincoln St.	199902536	December 1998	November 2008	Monitored Natural Attenuation	$ 50,000.00
Connersville, E. 5th St.	200308513	August 2003	February 2008	Monitored Natural Attenuation	$ 114,771.08
Hartford City, W. Water St.	200707514	July 2007	September 2007	UST Closure / Risk Assessment	$ 3,500.00
Garrett, S. Randolph St.	199808528	June 2002	September 2007	Excavation / source removal	$ 216,250.64
Hartford City, N. Walnut St.	200707516	April 2008	July 2007	Risk Assessment / CSM	$ 40,000.00
Portland, W. Water St.	199811521	May 2007	June 2007	Monitored Natural Attenuation	$ 50,000.00
Columbia City, N. Line St.	200310515	August 2003	June 2007	Risk Assessment / CSM	$ 80,039.40
Anderson, N. Madison Ave.	200301501	November 1996	June 2007	Monitored Natural Attenuation	$ 77,159.65
Portland, N. Meridian St.	200403502	March 2004	January 2007	Excavation / source removal	$ 151,029.64
Markle, Logan St.	199402525	March 2002	January 2007	Risk Assessment / CSM	$ 52,520.40
Auburn, S. Grandstaff Dr.	199311551	December 2005	December 2006	Monitored Natural Attenuation	$ 100,000.00
Fort Wayne, Lima Rd.	199712531	November 2006	December 2006	Monitored Natural Attenuation	$ 150,000.00
Fort Wayne, Washington Center	199908505	December 2001	November 2006	Monitored Natural Attenuation	$ 59,234.46
Marion, W. Kem Rd.	0000235	December 2005	September 2006	Excavation / source removal	$ 75,000.00
Ligonier, W. 4th St.	199712529	October 1997	September 2006	Monitored Natural Attenuation	$ 105,000.00
Huntington, S. Jefferson St.	199810522	October 1998	August 2006	Risk Assessment / CSM	$ 60,000.00
Marion, S. Western Ave.	199404524	November 2005	August 2006	Monitored Natural Attenuation	$ 40,000.00
Spencer, W. Morgan St.	199809538	May 2005	July 2006	Monitored Natural Attenuation	$ 9,997.18
Hartford City SR 3	200605013	May 2006	June 2006	Spill Recovery and Response	$ 225,000.00
Warsaw, E. Center St.	199403030	June 2002	May 2006	AS / SVE system	$ 302,760.90
Fort Wayne, S. Anthony Blvd.	200002502	November 2005	April 2006	Monitored Natural Attenuation	$ 110,000.00
Richmond, NW 5th St.	200505508	June 2005	February 2006	Excavation / source removal	$ 80,000.00
Austin, N. Dowling	199306142	November 2002	January 2006	Spill Recovery and Response	$ 100,000.00
Frankfort, W. Kyger St.	200407505	March 2004	January 2005	Monitored Natural Attenuation	$ 12,769.00
Hartford City, E. Main St.	200402126	March 2004	October 2004	UST Closure / Risk Assessment	$ 2,739.15
New Palestine, E. Main St	199301141	January 1993	June 2004	Monitored Natural Attenuation	$ 40,000.00
Howe, N. SR. 9	199901532	July 1998	June 2004	Monitored Natural Attenuation	$ 175,000.00
Huntington, Guilford St.	200008507	August 2000	May 2003	UST Closure / Risk Assessment	$ 40,000.00
Fort Wayne, Stellhorn Rd.	200101511	June 1995	November 2002	Risk Assessment / CSM	$ 125,000.00
Muncie, S. Madison St.	9301525	November 1998	April 1999	Excavation / source removal	$ 90,000.00
Berne, W. Main St.	9806545	June 1998	September 1998	Excavation / source removal	$ 50,000.00
Lexington, KY, Winchester Rd.	3173034	September 2006	January 2007	UST Closure / Risk Assessment	$ 150,000.00
Fort Recovery, OH, N. Wayne St.	54000064-N00001	February 2010	October 2010	UST Closure / Risk Assessment	$ 100,000.00
Van Wert, OH, N. Washington St.	81000088-N00001	April 2003	October 2010	Risk Assessment / CSM	$ 200,000.00
Saint Marys, OH, Celina Rd.	06000087-N00002	August 2008	June 2009	Monitored Natural Attenuation	$ 150,000.00
Vandalia, OH, Valet Rd.	57004059-N00001	February 2007	November 2007	Risk Assessment / CSM	$ 300,000.00

* = NFA in 2015
P&T = Pump and treat
AS = Air sparge
SVE = Soil vapor extraction
DPE = Dual-phase extraction
MPE = Multi-phase extraction
MNA = Monitored natural attenuation
CSM = Conceptual site model
UST = Underground storage tank
ORC = Oxygen release compound