RECORD OF DECISION

CRISTEX DRUM SUPERFUND SITE

OXFORD, GRANVILLE COUNTY, NORTH CAROLINA

CERCLIS ID: NC0001606250

PREPARED BY:
U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA, GEORGIA

SEPTEMBER 2017

11070129

RECORD OF DECISION

TABLE OF CONTENTS

Acronyms and Abbreviations v

PART 1: DECLARATION

1.0 Site Name and Location 1
2.0 Statement of Basis and Purpose 1
3.0 Assessment of the Site 1
4.0 Description of Selected Remedy 1
5.0 Statutory Determinations 3
6.0 Data Certification Checklist 3
7.0 Authorizing Signature 4

PART 2: THE DECISION SUMMARY

1.0 Site Name, Location, and Brief Description 5
2.0 Site History and Enforcement Activities 5
2.1 Site Operational History 5
2.2 Regulatory and Investigation History 6
3.0 Community Participation 9
4.0 Scope and Role of the Response Action 10
5.0 Site Characteristics 10
5.1 Conceptual Site Model 10
5.2 Overview of the Site 11
5.2.1 Topographic, Geologic, and Hydrogeologic Information 11
5.2.2 Surface and Subsurface Features 13
5.3 Sampling Strategy 14
5.4 Known or Suspected Releases of Contamination 14
5.5 Nature and Extent of Contamination 15
5.5.1 NAPL Contamination 15
5.5.2 Soil Contamination 16
5.5.3 Groundwater Contamination 17
5.5.4 Surface Water and Sediment Contamination 19
5.5.5 Contaminant Sources 19
6.0 Current and Potential Future Land and Water Uses 20
6.1 Land Uses 20
6.2 Ground and Surface Water Uses 21
7.0 Summary of Site Risks 21
7.1 Summary of the Human Health Risk Assessment 21
7.1.1 Identification of Chemicals of Concern 21
7.1.2 Exposure Assessment 21
7.1.3 Toxicity Assessment 23
7.1.4 Risk Characterization 24
7.1.5 Uncertainties 25
7.2 Summary of the Ecological Risk Assessment 25

7.2.1 Identification of Chemicals of Concern 26
7.2.2 Exposure Assessment 26
7.2.3 Ecological Effects Assessment 26
7.2.4 Ecological Risk Characterization 26
8.0 Remedial Action Objectives 27
9.0 Description of Alternatives 27
9.1 Description of the Unsaturated Zone (UZ) Remedial Alternatives 28
9.1.1 UZ Alternative 1: No Action 28
9.1.2 UZ Alternative 2: Soil Vapor Extraction 28
9.1.3 UZ Alternative 3: Soil Excavation 29
9.1.4 UZ Alternative 4: ISCO with Shallow Soil Mixing 30
9.2 Description of the Saturated Source Zone (SSZ) Remedial Alternatives 30
9.2.1 SSZ Alternative 1: No Action 31
9.2.2 SSZ Alternative 2: EISB with Chemical Reduction 31
9.2.3 SSZ Alternative 4: EK-BIO with Biobarriers 33
9.2.4 SSZ Alternative 5: BiRD with Recirculation 34
9.3 Description of the Dilute Plume (DP) Remedy Alternatives 34
9.3.1 DP Alternative 1: No Action 35
9.3.2 DP Alternative 2: EISB Biobarrier 35
9.3.3 DP Alternative 3: Hydraulic Capture/Containment 36
9.3.4 DP Alternative 4: Monitored Natural Attenuation (MNA) 36
9.4 Common Elements of Each Alternative 37
9.4.1 Institutional Controls 37
10.0 Comparative Analysis of Alternatives 38
10.1 Unsaturated Zone 38
10.1.1 Overall Protection of HH&E 38
10.1.2 Compliance with ARARs 38
10.1.3 Long-Term Effectiveness and Permanence 40
10.1.4 Reduction of Toxicity, Mobility or Volume through Treatment 40
10.1.5 Short-Term Effectiveness 41
10.1.6 Implementability 41
10.1.7 Cost 41
10.2 Saturated Source Zone 42
10.2.1 Overall Protection of HH&E 42
10.2.2 Compliance with ARARs 42
10.2.3 Long-Term Effectiveness and Permanence 43
10.2.4 Reduction of Toxicity, Mobility or Volume through Treatment 43
10.2.5 Short-Term Effectiveness 43
10.2.6 Implementability 43
10.2.7 Cost 44
10.3 Dilute Plume 44
10.3.1 Overall Protection of HH&E 44
10.3.2 Compliance with ARARs 44
10.3.3 Long-Term Effectiveness and Permanence Dilute Plume 44
10.3.4 Reduction of Toxicity, Mobility or Volume through Treatment 45
10.3.5 Short-Term Effectiveness 45
10.3.6 Implementability 45

10.3.7 Cost 45
11.0 Principal Threat Waste (PTW) 46
12.0 Selected Remedy 46
12.1 Summary of the Rationale for the Selected Remedy 46
12.2 Description of the Selected Remedy 47
12.2.1 Unsaturated Zone 47
12.2.2 Saturated Source Zone 48
12.2.3 Dilute Plume 49
12.2.4 Institutional Controls 49
12.3 Cost Estimate for the Selected Remedy 50
12.4 Estimated Outcomes of the Selected Remedy 50
13.0 Statutory Determination 51
13.1 Protection of HH&E 51
13.2 Compliance with ARARs 51
13.3 Cost Effectiveness 52
13.4 Use of Permanent Solutions and Alternative Treatment Technologies to the Maximum Extent Practicable 52
13.5 Preference for Treatment as a Principal Element 52
13.6 Five-Year Review Requirements 53
14.0 Documentation of Significant Changes 53
15.0 References 53

PART 3: RESPONSIVENESS SUMMARY

TABLES

Table 1 Summary of Groundwater Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, North Carolina
Table 2 Summary of Surface Water and Sediment Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, North Carolina
Table 3 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations Used in the Human Health Risk Assessment
Table 4a Cancer Toxicity Data Summary
Table 4b Non-Cancer Toxicity Data Summary
Table 5 Risk Characterization Summary - Carcinogens
Table 6 Risk Characterization Summary – Non-Cancer Hazards
Table 7 Occurrence, Distribution and Selection of Chemicals of Ecological Concern
Table 8 Ecological Exposure Pathways of Concern
Table 9 Remedial Goals for Subsurface Soil and Groundwater
Table 10 Remedial Goals for Subsurface Indoor Air
Table 11 Selected Remedy Cost Estimate Summary
Table 12 Chemical-Specific ARARs
Table 13 Location-Specific ARARs and TBC
Table 14 Action-Specific ARARs and TBCs
Table 15 Matrix of Cost and Effectiveness Data

FIGURES

Figure 1 Site Location Map
Figure 2 Site Layout
Figure 3 Contaminated Media Zone (CMZ) Designations
Figure 4 Conceptual Site Model
Figure 5 Conceptual Site Model
Figure 6 Soil Sample Locations (2007, 2010, 2015, 2016)
Figure 7 PCE Concentrations in Groundwater, 2015-2016
Figure 8 TCE Concentrations in Groundwater, 2015-2016
Figure 9 cDCE Concentrations in Groundwater, 2015-2016
Figure 10 VC Concentrations in Groundwater, 2015-2016
Figure 11 Conceptual Site Model for Human Health Risk
Figure 12 Selected Remedy for Cristex Drum

APPENDICES

Appendix A Proposed Plan and Proposed Plan Fact Sheet, Cristex Drum Site
Appendix B Comments Received on the Proposed Plan and Proposed Plan Fact Sheet
Appendix C Transcript of June 2017 Public Meeting
Appendix D State of North Carolina Concurrence with Selected Remedy
Appendix E Selected Remedy Detailed Cost Estimate Sheets

ACRONYMS AND ABBREVIATIONS

%	percent
95UCL	95 percent upper confidence limit
ADD	average daily dose
amsl	above mean sea level
AOC	Administrative Order on Consent
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tanks
BaP	benzo(a)pyrene
BiRD	Biochemical Reductive Dehalogenation
Black & Veatch	Black & Veatch Special Projects Corp.
bcy	bank cubic yards
bgs	below ground surface
BRA	Baseline Risk Assessment
BTEX	benzene, toluene, ethylbenzene, xylene
cDCE	cis-1,2-dichloroethene, cis-1,2-dichloroethylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CMZ	contaminated media zone
COC	chemical(s) of concern
COPC	chemical(s) of potential concern
CSF	cancer slope factor
CSM	conceptual site model
CVOC	chlorinated volatile organic compound
CWA	Clean Water Act of 1972
cy	cubic yard(s)
DC	direct current
DCB	1,4-dichlorobenzene
DEACT	deactivation
DHC	Dehalococcoides sp
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DOT	U.S. Department of Transportation
DP	dilute plume
ECD	electron capture detector
EISB	Enhanced *In Situ* Bioremediation
EK	electrokinetics
EK-BIO	Electrokinetics-*In Situ* Bioremediation
EK-ISCO	Electrokinetics-*In Situ* Chemical Oxidation
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk assessment
EPC	exposure point concentration

ERRB	Emergency Response and Removal Branch
ESD	Explanation of Significant Differences
ESI	Expanded Site Investigation
FS	Feasibility Study
ft	foot or feet
ft^2	square feet
ft^3	cubic feet
FYR	Five-Year Review
GA	Georgia
GR&T	groundwater recovery and treatment
HDPE	high density polyethylene
HH&E	human health and the environment
HHRA	Human Health risk Assessment
HI	hazard index
HMR	Hazardous Materials Regulations
HMTA	Hazardous Materials Transportation Act
HPT	hydrological profiling tool
HRS	Hazard Ranking System
HQ	hazard quotient
IC	institutional control(s)
ISCO	*In Situ* Chemical Oxidation
ISCR	*In Situ* Chemical Reduction
IUR	Inhalation Unit Risk
JFD	JFD Electronics/Channel Master
LADD	lifetime average daily dose
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MiHPT	Membrane Interface Probe – Hydrological Profiling Tool
MIP	Membrane Interface Probe
mol%	molar percent
MNA	Monitored Natural Attenuation
MW	monitoring well
N/A	not applicable
NC	North Carolina
NCAC	North Carolina Administrative Code
NCDENR	North Carolina Department of Environment and Natural Resources
NCDEQ	North Carolina Department of Environmental Quality
N.C.G.S	North Carolina General Statutes
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPW	net present worth
NSW	Nutrient Sensitive Water
O&M	operation and maintenance

ORP	oxidation-reduction potential
OSWER	Office of Solid Waste and Emergency Response
OWS	oil/water separator
PAH	polycyclic aromatic hydrocarbon
PA/SI	Preliminary Assessment/Site Investigation
PCB	polychlorinated biphenyl
PCE	tetrachloroethene (tetrachloroethylene)
PCP	pentachlorophenol
pH	hydrogen ion concentration
POTW	Publicly Owned Treatment Works
PRP	Principally Responsible Party
PTW	Principal Threat Waste
RA	remedial action
RAC	Remedial Action Contract
RAO	Remedial Action Objective
REC	Registered Environmental Consultant
RCRA	Resource Conservation and Recovery Act of 1976
RfC	reference concentration
RfD	reference dose
RG	Remedial Goal
RGO	Remedial Goal Option
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
RSL	Regional Screening Level
RSV	refinement screening value(s)
SARA	Superfund Amendments and Reauthorization Act of 1986
Site	Cristex Drum Superfund Site
SSL	Soil Screening Level
SSZ	Saturated Source Zone
SVE	Soil Vapor Extraction
SVOC	semi-volatile organic compound(s)
TBC	To Be Considered
TCE	trichloroethene, trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	toxicity equivalents
T/M/V	toxicity/mobility/volume
UIC	underground injection control
USGS	U.S. Geological Survey
UTS	Universal Treatment Standard
UZ	Unsaturated Zone
VC	vinyl chloride
VI	vapor intrusion
VOC	volatile organic compound
WWTU	waste water treatment unit
ZVI	zero valent iron

PART 1: DECLARATION

1.0 Site Name and Location

This Record of Decision (ROD) is for the site-wide remedial action (RA) at the Cristex Drum Superfund Site (Site) located in Oxford, Granville County, North Carolina. The Site's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number is: NC0001606250. The Site was listed on the National Priorities List (NPL) on December 12, 2013. The property is bordered on the north by the Norfolk Southern Railroad, to the west and south by West Industry Drive, and on the east by several private parcels.

2.0 Statement of Basis and Purpose

This decision document presents the Selected Remedy for the site-wide RA at the Site, which was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) 42 U.S.C. Section 9601 *et seq.*, and, to the extent practicable, the National Contingency Plan (NCP) 40 Code of Federal Regulations (CFR) Part 300. This decision is based on the Administrative Record (AR) for the Site. This decision represents the final remedy selected for the Site and following completion of the RA, the Site will be ready for reuse.

The State of North Carolina, as represented by the North Carolina Department of Environmental Quality (NCDEQ), is the support agency. In accordance with 40 CFR Sec 300.430, NCDEQ has provided input during the Remedial Investigation (RI)/Feasibility Study (FS) and decision-making process. The State of North Carolina concurs with the Selected Remedy.

3.0 Assessment of the Site

Contaminants of concern (COC) at the site include tetrachloroethene in subsurface soil; tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, vinyl chloride, benzene, 1,4-dichlorobenzene, and benzo(a)pyrene toxicity equivalents in groundwater; and tetrachloroethene, trichloroethene, vinyl chloride, benzene, 1,4-dichlorobenzene, and carbon tetrachloride in indoor air. The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances to the environment.

4.0 Description of Selected Remedy

The Site was divided into three Contaminated Media Zones (CMZs) in order to aid in the screening, evaluation and selection of remedies: unsaturated zone (UZ); saturated source zone (SSZ), and dissolved plume (DP). Affected media include contaminated subsurface soil and possible NAPL (UZ and SSZ) and contaminated groundwater (SSZ and DP). The selected remedy for these media at the site is:

- UZ: Soil Excavation
- SSZ: Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with Biobarriers
- DP: Enhanced *In Situ* Bioremediation (EISB) Biobarriers

Soil excavation will require partial demolition of the existing Cristex building, removal of an asphalt former drum storage pad and building slab, excavation and removal of soil from the unsaturated zone, and back-filling of the excavation with clean soil. The RI studies at the Cristex Drum Site identified CVOC as the primary contaminants, with local exceedances of criteria for benzene, dichlorobenzenes, PAH compounds, and metals. The primary contaminant source is believed to be soil initially impacted by spills and leaks near the Cristex building in the area of the drum storage pad, former OWS, and above ground fuel oil storage tanks. The highest concentrations of CVOCs in soil occur at the eastern edge of the asphalt drum storage pad. The EK-ISCO remedy for the SSZ will require the installation of injection wells for the ISCO amendment, wells for anode and cathode electrodes to facilitate electrokinetics, and injection wells for the shallow EISB biobarriers. The EISB remedy for the DP will require the installation of injection wells for the EISB amendments. The major components of this Selected Remedy are listed below in the order of their expected implementation during construction:

- Demolish the former drum storage pad and a portion of the Site building (and slab) to accommodate work in the soils below.
- Demolition debris will be characterized, temporarily staged and transported off-site for disposal at a RCRA permitted landfill. Excavate approximately 12,400 bank cubic yards (bcy) of contaminated soils (16,800 square feet [ft^2] to a depth of 20 ft).
- Excavated soil will be characterized, temporarily staged, then transported off-site for disposal at a permitted RCRA Subtitle C or D landfill. Soil considered RCRA hazardous waste may require treatment off-site prior to disposal.
- Backfill 12,400 bcy of clean soil into the excavated area.
- Construct the EK-ISCO well network into the saprolite and transition zones (28 ISCO injection wells plus 32 electrode wells) and complete injection of ISCO amendments. Complete one additional injection event as needed to counteract potential rebound of chemicals of concern (COCs).
- Install 27 biobarrier wells in two transects into the saprolite and transition zones. Batch mix the carbon substrate solution on site and inject the substrate, a hydrogen ion concentration (pH) buffer, and a bioaugmentation culture.
- Install 16 biobarrier wells in one transect into the fractured bedrock. Batch mix the carbon substrate solution on site and inject the substrate, a pH buffer, and a bioaugmentation culture.
- Install 20 shallow direct push technology borings to assess soil contamination around the treated SSZ and DP area. Conduct quarterly groundwater sampling of the SSZ for five years and annual sampling of the DP for 20 years in accordance with a monitoring plan which will be developed and implemented as part of the Remedial Action.
- Restrict access to the Site by installing a fence.
- The property owner will implement institutional controls (ICs) to limit the use of groundwater in the Site vicinity and future land use to those uses compatible with industrial/commercial purposes.

The Selected Remedy will be completed in five phases:

- Demolish site structures

- Excavate and replace soils in the UZ
- Construct the EK-ISCO well network in the SSZ and complete injections
- Construct the EISB biobarrier networks in the SSZ and DP and complete injections
- Conduct performance monitoring.

5.0 Statutory Determinations

Based on the information currently available, the U.S. Environmental Protection Agency (EPA) believes the Selected Remedy meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing and modifying criteria. The Selected Remedy also satisfies the preference for treatment as a principle element of the remedy. In compliance with CERCLA Section 121(b) and Section 121(d), the Selected Remedy is protective of human health and the environment (HH&E), complies with Federal and any more stringent State requirements that are applicable or relevant and appropriate to the RAs, is cost effective, and utilizes permanent solutions and treatment technologies to the maximum extent practicable.

The NCP establishes an expectation that the EPA will use treatment to address the principal threats posed by a site whenever practicable [NCP §300.430(a)(1)(iii)(A)]. The NCP defines Principal Threat Waste (PTW) as source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present significant risk to human health or the environment should exposure occur. NAPL and DNAPL are considered a principal threat wastes under EPA guidance and there is an expectation in the NCP to treat such wastes wherever practicable unless EPA determines that such wastes can be reliably contained. Highly contaminated soil can also be PTW when considered highly toxic, or would present significant risk to human health should exposure occur, or it acts as reservoir for mobile contaminants.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on the Site above levels that would allow for unlimited use and unrestricted exposure, a CERCLA Section 121(c) statutory review will be conducted every five years after initiation of the RA to ensure that the remedy remains protective of HH&E, inclusive of the applicable ICs. If results of the five-year reviews reveal that remedy integrity is compromised and protection of human health is insufficient, then additional remedial actions will be evaluated by the EPA and NCDEQ. The statutory five-year reviews will be conducted in accordance with EPA policy and guidance.

6.0 Data Certification Checklist

The following information is included in the Decision Summary Section of this ROD. Additional information can be found in the AR file for this Site.

- COCs and their respective concentrations (Section 7);
- Baseline risk represented by the COCs (Section 7);
- Cleanup levels established for COCs and the basis for these levels (Section 8);
- How source materials constituting principal threats are addressed (Section 11);
- Current and reasonably anticipated future land use assumptions (Section 6);

- Potential land use that will be available at the site as a result of the Selected Remedy (Section 6);
- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected (Section 12); and
- Key factors that led to selecting the remedy (Section 12).

7.0 Authorizing Signature

for Franklin E. Hill, Director
Superfund Division

9/29/17
Date

PART 2: THE DECISION SUMMARY

1.0 Site Name, Location, and Brief Description

This Record of Decision (ROD) is for the Cristex Drum Superfund Site (EPA ID: NC0001606250), Oxford, Granville County, North Carolina which encompasses 22 acres in the southwestern portion of the City of Oxford (**Figure 1**). The Site is a former textile plant in a predominantly industrial, commercial, and undeveloped area with limited residential development. The property is located at 500 West Industry Drive, Oxford, NC 27565. It is bordered on the north by the Norfolk Southern Railroad, to the west and south by West Industry Drive, and on the east by several private parcels. The Site coordinates are latitude 36° 17' 50" N and longitude 78° 37' 00" W.

The Site was originally two parcels of farmland which were purchased for use as a warp knit fabric mill that knitted, dyed, and finished nylon acetate Tricot from 1966 to 1986 (**Figure 2**). Upon ceasing fabric mill operations, the Site building is known to have been used intermittently as a warehouse for various industries until 2006, a Habitat for Humanity Re-Store in 2010, and a pre-cure tire retreading operation until 2015. The Site parcel is presently owned by Jomar Ventures LLC. The Site primarily consists of the 150,000 square foot (ft^2) Cristex plant building and facility operations area and undeveloped wooded land (**Figure 2**). A former above-ground storage tank (AST) area, oil/water separator (OWS) area, and drum storage pad area are located east of the building in the facility operations area; the AST and OWS have been removed. A small (0.5 acres), unlined lagoon is located northeast of the building.

The U.S. Environmental Protection Agency (EPA) is the lead agency for the cleanup of the Site and the North Carolina Department of Environmental Quality (NCDEQ) is the support agency. To date, the EPA has used the Superfund Trust Fund to finance activities at the Site, including an Integrated Removal and Expanded Site Inspection, a Removal Action, and the Remedial Investigation (RI)/Feasibility Study (FS).

2.0 Site History and Enforcement Activities

2.1 Site Operational History

The Site originally comprised two parcels of wooded farmland (11.13 and 11.28 acres). These were purchased by Steinfield Mills in 1965 which constructed the 150,000 ft^2 building and a 0.5 acre unlined lagoon on the property. Steinfield Mills changed its name to I.M.I. Warp Knits, Inc. on June 15, 1971 and to Cristex Corporation in 1981. From 1966 to 1986, Cristex operated as a warp knit fabric mill that knitted, dyed, and finished nylon acetate Tricot. Boilers were fueled by natural gas and fuel oil; chemicals were stored mostly on the east side of the building. Dyes, dyeing assistants and cellulosic and synthetic yarns were used in the manufacturing process. The dyeing process used metals such as zinc, copper and chromium. Chlorinated solvents were used to clean equipment, dry clean fabric, and as part of the dyeing process. Wastewater was discharged to the lagoon from which it entered the city sewer system. The earthen impoundment dam of the lagoon was partly breached in 1998 and the lagoon is no longer operational.

The Cristex building was used as a Revlon warehouse from about 1991 to 1996 and in 2000 as a warehouse for CVS Pharmacies. The latter stored packaged merchandise for sale in their stores;

no hazardous materials were stored at the property while CVS occupied the Cristex building. For an undetermined amount of time between 2000 and 2006, the property was used as a warehouse to cure tobacco.

Jomar Ventures, LLC purchased the Cristex Site in 2006. For an unknown amount of time in 2010, the front of the building was used by Habitat for Humanity as a Re-Store. The property was subsequently leased by Stutts Truck Tires which operated a pre-cure tire retreading operation in the manufacturing portion of the building. Stutts Truck Tires ceased operations in 2015 and did not contribute to contamination at the site. The building has been abandoned since that time.

2.2 Regulatory and Investigation History

Cristex operated under an air quality permit issued by the State, but did not have National Pollutant Discharge Elimination System (NPDES) or Resource Conservation and Recovery Act (RCRA) permits. The facility received a wastewater discharge permit in 1984 allowing discharge to the Oxford Publicly Owned Treatment Works (POTW).

Cristex was cited by the State of North Carolina on several occasions for noncompliance with their air quality permit, including in 1976 and 1978.

Spills and releases were identified during regulatory inspections and also were self-reported by the facility. Known contaminant releases are summarized below.

- 1982 - City of Oxford reports a discharge of warm water flowing through a ditch on the east side of the lagoon to surface water resulting from a broken wastewater line.
- 1983 - Oil spill noted in lagoon during air permit inspection.
- 1986 - Spill of No. 6 fuel oil into lagoon. Collected with booms and disposed of in accordance with State requirements.
- 1993 - 14,000 gallons of No. 6 fuel oil spilled into lagoon.
- 1996 and 1997 – EPA lead removal of 26 buried drums, 137 empty drum carcasses, and 3 roll-off boxes of contaminated soil. Landfilled waste included fuel oil sludge, printing ink, and ink solvents.
- 2001 - Personnel leasing the Site report a release of fuel oil to the lagoon. The owner reported the spill to the State of North Carolina and contained and removed the contamination. The spill was attributed to a drain on the boiler.

In April 2002, Cristex joined North Carolina's Registered Environmental Consultant Program under an Administrative Order on Consent (AOC) pursuant to the North Carolina Inactive Hazardous Sites Response Act of 1987 (15A NCAC 13C) Cristex submitted data collected under the program to NCDENR. Cristex withdrew from the program in September 2004.

Data collected by the State of North Carolina, the EPA, and Cristex and their consultants were used to develop a Hazard Ranking System (HRS) Documentation Record for the Cristex Site (EPA, 2013a). The Site was proposed for the National Priorities List (NPL) on May 24, 2013, and was finalized on the NPL on December 12, 2013 (EPA, 2013b).

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response actions were conducted at the Site prior to its inclusion on the NPL. In 1997, 26 buried drums, 137 drum carcasses and 3 roll-off containers of contaminated soils were removed and disposed offsite. Limited soil excavations were conducted in 2001, primarily in the surface ditch on the east side of the building and in the areas of the drum storage pad and above-ground fuel oil storage tanks. A summary of environmental investigations and CERCLA response actions conducted at the Site to date are presented in the table below.

Environmental Investigations and CERCLA Response Actions at Cristex Drum

Date Completed	Investigations / Response Actions / Report	Scope
1991	Phase 1 Environmental Audit (Cristex Corporation)	A consultant for the Cristex Corporation collected one sample of lagoon sludge. The audit identified numerous drums on the property, oily contamination associated with the OWS vat, and asbestos in ceiling and floor tiles in the building.
1992	Lagoon Water Sampling (City of Oxford)	The City of Oxford analyzed one sample of lagoon water for RCRA metals in an effort to identify the source of problems at the POTW.
1996 - 1997	Removal Investigation and Action (EPA)	The EPA Emergency Response & Removal Branch (ERRB) conducted removal investigation activities and an action that removed drums and contaminated soil from the Site. Drums were found to contain chemicals in varying concentrations including tetrachloroethene (PCE), toluene, ethylbenzene, xylenes, methylene chloride, methyl phenol compounds, arsenic, barium, chromium, lead, and beta-endosulfan. Twenty-six buried drums were excavated and 137 drum carcasses were removed from the surface. Three roll-off containers of soil also were removed. Figure 2 shows the former location of the buried drums.
1998	Lagoon Sampling (Cristex Corporation)	A consultant for the Cristex Corporation collected one water and three sludge samples from the lagoon for analysis. Concentrations in the Toxicity Characteristic Leaching Procedure (TCLP) extracts exceeded North Carolina's groundwater standards for chlorobenzene and benzene.
1998	Preliminary Assessment/Site Inspection (PA/SI) (State of North Carolina)	The State of North Carolina conducted a PA/SI. The SI identified approximately 150 cubic feet (ft^3) of soil contaminated with PCE, trichloroethene (TCE), zinc, and polychlorinated biphenyl (PCB) compound Aroclor-1254 near the former drum storage pad, OWS, and the surface ditch leading from these areas. In addition, approximately 10 ft^3 of soil contaminated with zinc was identified near the ASTs. The SI estimated that the lagoon contained 1,613 cubic yards (cy) of sludge contaminated with benzene, toluene, ethylbenzene, xylene (BTEX) compounds, chlorobenzene compounds, TCE, cis-1,2-dichloroethylene (cDCE), naphthalene, and metals. The results indicated releases of contaminants to groundwater. The State of North Carolina recommended the Cristex Drum Site for further action under CERCLA.

Date Complete	Investigations / Response Actions / Report	Scope
2001	Removal Action (Cristex Corporation)	Contractors for Cristex excavated and removed soil along drainage ditches to depth of 1 foot (ft) and excavated and removed soil adjacent to drum storage pad to depth of 2 ft. They additionally removed vertical above-ground oil storage tanks and associated piping, 81.2 tons of tank sludge, and 394.4 tons of associated soil.
2002	Environmental Assessment Report (Cristex Corporation)	Cristex and their consultants prepared an Environmental Assessment Report to summarize additional assessment and remedial activities conducted from 1999-2001 at the Site prior to Cristex's enrollment in North Carolina's Registered Environmental Consultant (REC) Program.
2000-2003	Expanded Site Inspection (ESI) (State of North Carolina)	An ESI completed by NCDENR recommended no further remedial action (RA) under CERCLA.
2002	AOC	Cristex Corporation entered into an AOC with the NCDENR Superfund Section for voluntary cleanup of the property. The AOC enrolled the Site into the REC program under the Inactive Sites Branch of the Superfund Section. Part of the AOC required Cristex to further investigate and address the areas of concern identified during the previous investigations.
2004	REC Program Withdrawal	Cristex Corporation withdrew from the REC Program after the ESI recommended no further RA under CERCLA. The firm submitted additional data to NCDENR and the AOC was dissolved.
2007	Site Reassessment Report (State of North Carolina)	NCDENR completed a Site Reassessment due to Superfund Chemical Data Matrix revisions and Cristex Corporation's withdrawal from the REC Program. The Site was recommended for further action under CERCLA.
2008	Integrated Removal and ESI Report (EPA)	The EPA conducted an investigation to provide additional data to support generation of a HRS score, including the collection and analysis of surface and subsurface soil, sediment, lagoon sludge, surface water, and groundwater samples. The report identified source areas as the 26 drums removed in 2006, contaminated soil, and the lagoon. In addition, elevated concentrations of acetone, benzene, PCE, numerous metals, and a few pesticides were identified in surface soil samples and elevated concentrations of acetone, benzene, and metals were found in subsurface soil samples.
2012	Integrated Expanded Site Inspection (State of North Carolina)	NCDENR completed an integrated expanded site inspection to assess threats to HH&E and collect information to support a decision to be made by the EPA. Based on findings of soil and groundwater contamination by PCE, documented releases of metals to surface water, and potential contributions of solvents to the JFD Electronics/Channel Master (JFD) groundwater plume, NCDENR recommended further RA under CERCLA.

2013	HRS Documentation (State of North Carolina)	An HRS Documentation Record was prepared for the Site. Cristex Drum Site was added to the NPL.

Date Complete	Investigations / Response Actions / Report	Scope
2016	RI Report, Revision 1 (EPA)	EPA's Remedial Action Contract (RAC) contractor conducted the RI, including the collection and analysis of surface water, sediment, surface soil, subsurface soil, and groundwater samples; screening of soil locations using a Membrane Interface-Hydraulic Profiling Tool (MiHPT), and installation of 8 monitoring wells (MWs). The report included a Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA).
2017	FS Report, Revision 1 (EPA)	EPA's RAC contractor completed screening and evaluation of remedial alternatives and recommended the remedy solution for the chemicals of concern (COCs) in the media at the Site.

Adjoining the Cristex property to the north (on the north side of the Norfolk Southern rail line) is the JFD Electronics/Channel Master NPL Site (JFD) (NCD122263825). This Site, which is being investigated by the Potentially Responsible Party (PRP), has a significant groundwater plume of chlorinated solvent contamination, tetrachloroethene (PCE) and trichloroethene (TCE) (AECOM, 2014). The JFD plume is being remediated by a groundwater recovery and treatment (GR&T) system. The JFD contaminant plume flows southeast from its source, then turns east and flows beneath the northern part of the Cristex property. Two monitoring wells (MWs) and one extraction well were installed by JFD on the Cristex property. West of the JDF property is the former Oxford Printing facility (fabric screen printing, dyeing and finishing) which participates in NC's Brownfields Redevelopment Program. This facility formerly operated as a sewing plant. Cyanide is reportedly present in the groundwater beneath the Oxford Printing parcel (NCDENR, 2012).

3.0 Community Participation

Site documents including the RI Report, FS Report, and Proposed Plan for the Cristex Drum Site were made available to the public on June 20, 2017 in the Administrative Record (AR) file repositories. The AR repositories are located at the EPA Region 4 Superfund Records Center (61 Forsyth Street, Atlanta, GA 30303) and the at the local repository located at the Richard H. Thornton Library, 210 Main Street, Oxford, North Carolina 27565. A Notice of Availability was published in the Oxford Public Ledger on June 15, 2017. A public comment period on the Proposed Plan was held from June 20, 2017 through July 20, 2017.

On June 27, 2017, the EPA hosted a Proposed Plan meeting at the NC Cooperative Extension, Granville County, located in Oxford, North Carolina. During the meeting the EPA presented a description of the Preferred Alternative and other alternatives in the Proposed Plan, a schedule for remedy implementation and invited nearby residents and interested parties to comment and

ask questions of EPA officials. Approximately 15 people attended the meeting; a transcript of the meeting is included as **Appendix C.**

There were a number of comments and questions during the public meeting and representatives of the EPA responded during the meeting. EPA responses to written comments received during the public comment period is included in the Responsiveness Summary, Part 3 of this ROD.

4.0 Scope and Role of the Response Action

This ROD presents the final CERCLA remedial action at the Cristex Drum Site. The Site has been divided into three Contaminated Media Zones (CMZs), all of which are being addressed under this ROD and which combine to form a single operable unit. These are the unsaturated zone (UZ); the saturated source zone (SSZ); and dissolved plume (DP). The CMZs are illustrated in **Figure 3**.

A CERCLA removal action was conducted in 1996-1997 to remove buried drums and the underlying soil from the Site. In 2001, Cristex removed contaminated soil from surface ditches draining the OWS and the former drum storage pad, and soil adjacent to the ASTs. These completed actions, in conjunction with the Selected Remedy in this ROD, will achieve the overall site goals of removing contamination that is a source of groundwater contamination, treating contaminants of concerns to levels that do not present an unacceptable risk to humans and ecological receptors and restoring groundwater to attain drinking water levels. These actions will also protect humans from exposure to vapor intrusion (VI) and indoor air contamination on-site. The Selected Remedy is compatible with the planned and existing use of the Site and with the ongoing RA at the adjacent JFD NPL Site.

5.0 Site Characteristics

5.1 Conceptual Site Model

The Cristex site is underlain by a complex groundwater system comprising a regolith aquifer and an underlying fractured bedrock aquifer. **Figures 4 and 5** are simplified, idealized conceptual site models (CSMs) developed for the Site. The models depict important features of the subsurface, known sources of contamination, and aspects of contaminant degradation and migration. The CSMs are not drawn to either a vertical or horizontal scale, but instead represent important relationships in the subsurface to the extent they are presently understood. Fracture density is depicted conceptually; residual dense non-aqueous phase liquid (DNAPL) does not represent the volume of contaminant which may be present (site investigations did not positively identify residual DNAPL but suggest a small amount may be present). **Figure 4** was developed for the portion of the Site that includes the Cristex building and immediate surrounding area. This CSM focuses on chlorinated volatile organic compound (CVOC) and BTEX contamination. **Figure 5** is a similar CSM developed to depict the relationship between the surface ditch east of the building, the lagoon and areas downstream of the lagoon including the delineated wetland and includes aspects of potential metal and polycyclic aromatic hydrocarbon (PAH) contamination transport. These models depict important features of the subsurface, known sources of contamination, and aspects of contaminant degradation and migration.

The CSM illustrates the change from intergranular groundwater flow in the regolith aquifer to fracture flow in the underlying bedrock aquifer. Clay-rich intervals within the saprolite portion of the regolith aquifer complicate groundwater transport and the migration pathways potentially taken by DNAPL fluids such as PCE which are denser than water. The hydrogeologic transition zone at the base of the regolith is expected to have the highest lateral transmissivity and thus serves as a preferential pathway for contaminant migration. The CSM also illustrates natural degradation of PCE to form daughter products of TCE, cis-1,2-dichloroethene (cis-DCE), and vinyl chloride (VC) by abiotic or biotic reductive dechlorination or oxidation. The contrasting behavior of benzene as a fuel oil component, which is lighter than water and was identified in the area of the ASTs, also is depicted on the CSM.

5.2 Overview of the Site

The site location and a description of the property are provided in Section 1.0. The property is zoned by the City of Oxford as I-2 General Industrial.

Land use surrounding the Site is predominantly industrial, commercial, undeveloped, and limited residential. Adjoining the Cristex property to the north (on the north side of the Norfolk Southern rail line) is the JFD NPL Site. West of the JFD property is the former Oxford Printing facility (fabric screen printing, dyeing and finishing) which participates in North Carolina's Brownfields Redevelopment Program. Businesses located west of West Industry Drive include Ideal Fastener (manufactures buttons and zippers) and Bandag Tires (tire retreader). Several warehouses are present to the south of West Industry Drive. An undeveloped parcel borders the southeast corner of the Cristex property while Energy United owns a propane storage tank farm adjacent to the east. The northeast corner of the property abuts an undeveloped parcel and a residential parcel.

5.2.1 Topographic, Geologic, and Hydrogeologic Information

The Site is situated on a flat to gently sloping topographically high area with runoff generally flowing to the east-northeast and south. Site elevations range from 480 to 450 ft above mean sea level (amsl).

The site geology comprises an upper residual clay-rich soil that rests on saprolite (bedrock that has been chemically weathered in place and which preserves features of the parent rock). The saprolite is underlain by a transition zone of partially weathered rock that overlies fractured meta-igneous bedrock.

Soil types at the Site include natural clay-rich soil and disturbed areas with and without soil fill. Native (undisturbed) soil is expected to be present only in small areas north and northeast of the Cristex building due to grading prior to building construction and even these areas may have been disturbed by agricultural practices prior to construction of the Cristex building. Organic-rich topsoil is thin to absent across the Site. Most surface and near-surface material consists of sandy clay and clayey sand that tends to become sandier and coarser with depth; these materials are laterally discontinuous. The residual clay unit is typically 1 to 20 ft thick. Its contact with the underlying saprolite is gradational and uneven.

The saprolite is deeply weathered and consists of loosely to moderately cemented silty to fine sandy material with intervals that are more clay-rich. Saprolite was identified in some subsurface borings beginning at about 12 to 15 ft below ground surface (bgs), but in other locations it was not apparent until 20 or more ft bgs. Marker beds are absent and overall, the saprolite appears to be laterally and vertically discontinuous in drill cores and on geophysical logs of electrical conductivity and hydrological profiling tool (HPT) pressure response collected from the surface to about 30 to 40 ft depth. Although porous and likely permeable, pore spaces within the silty/sandy saprolite appear to be comparatively small. Clay-rich zones within the unit may have formed in localized areas of more intense weathering. While the geometry of the clay intervals is unknown, there is little evidence they are present as discrete layers. With depth, the saprolite becomes harder and HPT logs indicate that low transmissivity materials (interpreted to be clay-rich) predominate at depth, in some cases comprising the majority of the subsurface interval that was probed. The increase in hardness occurs at an average of 30 ft bgs but it occurs over a range of about 11 to 45 ft bgs. Discontinuous gravel-rich zones up to 5 ft thick were noted in drill cores of the saprolite, typically below 30 to 60 ft bgs. Fractures are occasionally preserved and may influence fluid flow through the unit. In most locations, the saprolite recovered in drill core was comparatively dry, but it appears capable of storing water and it commonly is saturated near the base of the unit. Groundwater flow is expected to occur primarily through the matrix of the unit and secondarily along structural features inherited from the parent metamorphic rock. The hydraulic conductivity of the saprolite was not measured at the Cristex Site; however, measurements in similar rock types in other locations in the North Carolina Piedmont found that it was lower than the underlying transition zone by 2 to 3 orders of magnitude (Black & Veatch Special Projects Corp. [Black & Veatch], 2017b). In most locations, the saprolite is about 35 ft thick, although its gradational upper and lower contacts are likely to be uneven and the lower contact with the underlying transition zone was difficult to identify in cores recovered at the Cristex Site.

Saprolite grades down into a transition zone comprising partly weathered rock that was poorly recovered in drill core. Where identified in site borings, it occurs at depths ranging from 60 to 90 ft bgs and it appears to have a thickness of a few feet to less than 1 ft. However, in boring MW-16D, thin intervals of gravel and broken rock occur intermittently in the lower part of the saprolite section, suggesting that the transition zone locally may be up to 60 ft in thickness. Its formation is attributed to a downward decrease in the degree of weathering at the base of the saprolite and a corresponding lithologic change from silty/sandy saprolite to gravel enclosed within a saprolitic matrix to fractured, dislocated rock enclosing saprolite, to fractured bedrock. This general scheme, which is supported by observations of fracture surfaces recovered in bedrock core immediately below the zone, gives rise to a variety textures which include intervals of gravel fragments with planar faces derived from joints or fractures, larger cobble- or boulder-sized clasts of bedrock enclosed in a saprolitic matrix, and layers of bedrock a few inches to perhaps a ft thick sandwiched within saprolite. Based on the model of Harned and Daniel (1989) and measurements of hydraulic conductivity in the saprolite and transition zone at the Ram Leather Care Site outside of Charlotte NC (Black & Veatch, 2017b), the transition zone at the Cristex Drum Site is expected provide a zone of preferential flow that permits significant lateral transport. The lower contact of the transition zone is likely to be irregular and reflective of the fractured surface of the underlying bedrock although the amplitude of any irregularities is unknown.

Bedrock was cored in three locations during MW installation at the Site. Bedrock lithologies identified in core include metadiorite, granodiorite, and metabasalt. Fractures are evident in cores of bedrock recovered from each of the three locations. The upper portion of the bedrock contains abundant moderately high angle fractures (typically 50 to 70 degree dip), most of which are smooth faced. While some fractures are annealed with epidote and iron oxides, others may be open or perhaps were rebroken by the drilling process. The fractures diminish in frequency with depth yielding more competent bedrock. Some fracture surfaces have hematite (iron) staining suggesting groundwater movement. Boring MW-3D penetrated a possible shear zone in the bedrock extending from about 80 to 117 ft bgs, as shown clearly on the optical televiewer log of the borehole wall prepared by the U.S. Geological Survey (USGS; see Black & Veatch, 2016a). The shear comprises a thick interval of brecciated hornfels sandwiched between layered zones. Breccia fragments are gravel-sized pieces of hornfels consisting of green epidote and white feldspar with iron staining locally present. The breccia is enclosed in a white matrix that appears to have annealed the interval; consequently, it is expected to exert little control on groundwater migration. Competent, equigranular metadiorite is present beneath the potential shear.

The saturated zone of the saprolite and the transition zone combine to form the regolith aquifer at the Site. Saturated saprolite provides the bulk of groundwater storage within the Piedmont and it serves as a reservoir supplying groundwater to interconnected fractures within the bedrock (Heath, 1980). The water table varies seasonally and was measured at 12 to 24 ft bgs in most locations in 2015 and 2016. Potentiometric surface maps developed for wells screened in the saprolite zone of the regolith aquifer show flow generally to the north-northeast and a "valley" in the potentiometric surface that would direct flow toward the northeastern corner of the property. Although poorly constrained, potentiometric surface contours developed for wells screened in the transition zone and underlying fractured bedrock aquifer show generally similar flow directions.

Measurements of hydraulic conductivity in wells screened in the transition zone at other Piedmont sites suggest values that are two orders of magnitude higher than in the saprolite zone. Consequently, the transition zone represents a preferential pathway for lateral groundwater movement. Groundwater flow within the crystalline bedrock occurs along fractures and is anisotropic. Few fractures are believed to convey substantial amounts of water below 300 to 400 ft depth (Heath, 1980). The regolith and bedrock aquifers are expected to be unconfined or only locally confined and to be in hydraulic communication with one another.

5.2.2 Surface and Subsurface Features

The developed portion of the property comprises the Cristex plant building and former facility operations area, which consists of a 150,000 ft^2 building, several gravel driveways and parking lots, and concrete and asphalt pads. The remainder of the property is undeveloped wooded land (**Figure 2**). A former AST area, OWS area, and drum storage pad area are located adjacent to the building. The AST and OWS have been removed; there are no known underground tanks remaining on site. A small, unlined lagoon (0.5-acre) is located northeast of the building. The lagoon is separated from the Cristex building by an overgrown area of dense brush. The former

operations area is surrounded by an eight-foot high fence that prevents unauthorized access. The remainder of the property is open.

A small brick building on the northwest corner of the Cristex property (southeast corner of the intersection of West Industry Drive and the rail tracks) serves as a satellite office of the Granville County School District and hosts offices for a few school district personnel.

Runoff east of the Cristex building drains to a surface water drainage channel which flows north to the unlined lagoon. The lagoon also received flow from a buried pipeline during operations. In 1998, the earthen dam surrounding the lagoon was breached, lowering the water pool elevation and allowing discharge to flow to a small wetland and eventually to Fishing Creek in the Tar River Basin via an intermittent stream at the northeastern corner of the Site. A small intermittent stream which conveys runoff from the JFD NPL Site and the Oxford Printing Site joins the discharge path from the lagoon in the wetlands area (**Figure 2**). The State of North Carolina has assigned beneficial use classifications to Fishing Creek of C (aquatic life and secondary recreation) and NSW (nutrient sensitive waters).

5.3 Sampling Strategy

Multi-media sampling was guided by the CSMs that were refined as understanding of the Site increased over time. Samples were collected to fill gaps in knowledge identified by previous site investigations and to provide a current view of site contamination. Samples of surface water, sediment, surface soil, subsurface soil, and groundwater were collected and evaluated to determine the nature and extent of contamination in these media, support assessment of human health and ecological risks, improve hydrogeologic understanding, and evaluate potential remedy alternatives and treatment options.

The fieldwork documented in the 2016 RI Report was completed between April 2015 and April 2016. RI sampling activities included:

- Collection and analysis of 6 surface water samples, 5 sediment samples, 5 surface soil samples, 57 subsurface soil samples and 49 groundwater samples from 27 MWs and 12 samples from 11 temporary well points;
- Screening of 33 soil locations inside and east of the Cristex building using a membrane interface-hydrological profiling tool (MiHPT) to typical depths of 30 ft bgs;
- Installation of 8 MWs to supplement the existing Site MW network including wells screened in the hydrogeologic transition zone and underlying fractured bedrock;
- Geologic logging of cores recovered from all MWs and 16 cores recovered during MiHPT confirmation sampling; and
- Geophysical logging of the three borings completed in fractured bedrock by USGS personnel to characterize fractures using optical and acoustic televiewers, caliper logs, and heat pulse flow meters.

5.4 Known or Suspected Releases of Contamination

Spills and releases were identified during regulatory inspections and also were self-reported by the facility. Known contaminant releases are summarized below.

- 1982 - City of Oxford reports a discharge of warm water flowing through a ditch on the east side of the lagoon to surface water resulting from a broken wastewater line.
- 1983 - Oil spill noted in lagoon during air permit inspection.
- 1986 - Spill of No. 6 fuel oil into lagoon. Collected with booms and disposed of in accordance with State requirements.
- 1993 - 14,000 gallons of No. 6 fuel oil spilled into lagoon.
- 1996 and 1997 - Removal of 26 buried drums, 137 empty drum carcasses, and 3 roll-off boxes of contaminated soil. Landfilled waste materials included fuel oil sludge, printing ink, and ink solvents.
- 2001 - Personnel leasing the Site report a release of fuel oil to the lagoon. The owner reported the spill to the State of North Carolina and contained and removed the contamination. The spill was attributed to a drain on the boiler.

5.5 Nature and Extent of Contamination

The extent of contamination of the COCs identified by the remedial investigation and risk assessment processes is summarized below for each environmental medium.

5.5.1 NAPL Contamination

DNAPL has not been positively identified visually or through measurements of soil or groundwater contamination. Its former or current presence may be inferred from continued elevated concentrations in down-gradient MWs and increases in contaminant concentrations in some wells over time. The highest concentration of PCE in soil was identified in 2010 by NCDENR (180,000 micrograms per kilogram [µg/kg]) at the eastern edge of the drum storage pad. Samples collected from nearby MiHPT and well borings installed in 2015 and 2016 during the RI did not measure similarly high values (23 µg/kg maximum value), suggesting that any DNAPL present in the subsurface has a comparatively small volume and restricted areal extent. Comparatively modest concentrations of PCE in groundwater do not suggest the presence of a widespread DNAPL phase but are suggestive of a small source in an area where wells have not been installed. DNAPL and DNAPL saturated soils are considered to be PTW under EPA guidance and there is an expectation in the NCP to use treatment to address principal threats posed by site, wherever practicable. [40 CFR § 300.430(a)(1)(iii)(A)]

Key observations regarding the potential distribution of DNAPL at the Site are:

- DNAPL is thought to have migrated vertically through the subsurface via density-driven flow in the unsaturated and saturated zones of the saprolite as indicated by strong responses on the MiHPT electron capture detector (ECD) at depths of 25 to 35 ft bgs. Migration of DNAPL into the transition zone has not been confirmed but cannot be ruled out.
- Discontinuous clay-rich intervals in the saprolite zone are expected to create vertical and lateral anisotropy that may influence DNAPL transport.
- Residual DNAPL below the soil saturation limit may be present in hydraulically isolated pockets within the saprolite but these have not been confirmed. If present, this may present a long-term dissolution source. Elevated PCE concentrations (13,000 µg/L) in

groundwater from well MW15S, located east of the aboveground storage tanks may indicate the presence of nearby or upgradient DNAPL in this area.

5.5.2 Soil Contamination

The nature and extent of soil contamination is described in Section 4.4 of the RI (Black & Veatch, 2016a). Soil sample results were compared to a variety of soil screening values in the RI including the EPA's risk-based Regional Screening Levels (RSLs) for industrial soil and residential soil, and the risk-based soil screening level (SSL) for protection of groundwater at hazard quotients (HQ of 0.1; May 2016 values). Sample results also were screened against values developed in the ERA to identify those constituents presenting ecological risk.

Surface Soil

Surface soil samples (0 to 24inch depth) were collected in 2007 and 2015 from 15 locations (**Figure 6**). Samples were collected from the east side of the building and the areas of the lagoon and delineated wetland in 2007 and from the lagoon and delineated wetland in 2015. Sample CR-SS-01, collected in 2007 south of the Cristex, building serves as the background surface soil sample.

The ERA identified antimony, chromium, copper, lead, manganese, mercury, vanadium, yttrium, and zinc as chemicals of potential concern (COPCs) in surface soil. These metal concentrations were generally elevated adjacent to the concrete/asphalt pads used in former operations where erosion of the pads and runoff from rusted debris and the metal building has occurred. There were no indications of any metal chemical concentration gradient.

Subsurface Soil

Samples of unsaturated subsurface soil (collection depth between 2 and 20 ft bgs) and saturated subsurface soil (>20 ft bgs) were collected in 2007, 2010, 2015, and 2016. Most samples were located on the east side of the Cristex building. Subsurface soil sample locations are shown in **Figure 6**. A sample collected south of the Cristex building in 2007 (location CR-SB-01) at a depth of 26 to 30 ft bgs serves as background for saturated subsurface soil. This sample contained copper of 65 J,O mg/kg, chromium of 15 mg/kg, and zinc of 69 J,O mg/kg. The presence of metals in background soil samples suggests that the saprolite in the region naturally contains variable, slightly elevated concentrations of several metals.

The HHRA identified aluminum, manganese and PCE as COCs in subsurface soil. Aluminum had a 95 percent (%) upper confidence limit (95UCL) exposure concentration of 15,024 mg/kg which is below twice the background concentration of 22,000 mg/kg. The arsenic 95UCL concentration of 1.9 mg/kg is also within naturally occurring levels. The manganese 95UCL concentration of 355 mg/kg is approximately 5 times the local background soil concentration.

The maximum and 95UCL concentrations of PCE in subsurface soils are 180,000 µg/kg and 74,790 µg/kg, respectively. PCE exceeded the RSL for the protection of groundwater in 4 of 29 subsurface soil samples collected from the unsaturated zone and none of the 20 samples collected from below the water table. At two locations, both along the eastern margin of the former drum storage pad, PCE concentration in shallow subsurface soil (3 ft bgs) exceeded the risk-based SSL

by factors of 5,000 or more (180,000 µg/kg at CB01SB and 100,000 µg/kg at CR03SB; NCDENR, 2012). These two samples also equaled or exceeded the residential non-cancer value for the soil vapor pathway for PCE of 100 mg/kg developed as part of the HHRA (Black & Veatch, 2016).

One or more PCE degradation products including TCE, cDCE, and VC are found in almost all subsurface soil samples where PCE is present, consistent with natural biotic degradation. The high concentrations of PCE measured along the east edge of the former drum storage pad coincide with the most significant area of contamination indicated by MiHPT probing of the area east of the Cristex building (see **Figure 7**). Subsurface soil samples collected from MW borings installed on the drum storage pad and MiHPT probing of locations on and east of the pad during the RI did not encounter similarly high concentrations. This suggests that any DNAPL that may be present in this area is likely to have a limited areal extent.

5.5.3 Groundwater Contamination

The nature and extent of groundwater contamination in the regolith and fractured bedrock aquifers was discussed in Section 4.5 of the RI (Black & Veatch, 2016a). The RI compared analytical results for groundwater samples to the most stringent of the Safe Drinking Water Act Federal Maximum Contaminant Level (MCL), North Carolina Groundwater Quality Standards at 15 A NCAC 02L.0202 Class GA standards or interim criterion (15A NCAC 02L.0202), and tap water RSL values. The tap water RSL was used only for those constituents for which a Federal or State standard has not been promulgated.

Regolith Aquifer

Nineteen MWs are screened within the regolith aquifer at the Site, including 15 wells screened in saprolite and 4 wells screened in the transition zone. Five of these wells (2 saprolite, 3 transition zone) were installed in 2016 as part of the RI; the remaining 14 wells were installed previously by Cristex. The 14 existing wells were sampled in the initial phase of RI sampling in 2015 and samples were collected from all existing and new wells as part of the RI in 2016. In addition to these wells, five wells installed as part of the adjacent JFD NPL Site (4 saprolite, 1 transition zone) were sampled in 2015 and three of these (2 saprolite, 1 transition zone) were sampled again in 2016. Eleven groundwater samples were collected from temporary well points installed during the MiHPT investigation in 2015.

The HHRA identified benzo(a)pyrene (BaP) toxic equivalents (TEQ), 1,4-dichlorobenzene (DCB), benzene, cDCE, PCE, TCE, and VC as COCs in groundwater. **Table 1** summarizes screening values considered for groundwater; detection frequencies for groundwater samples included in the RI; and the mean, minimum, and maximum measured concentrations. To provide a snapshot of water quality, **Table 1** includes only the MW samples collected in 2016 and the temporary well point samples collected in 2015. One or more PAH compounds were measured above detection in 6 wells screened in the regolith aquifer (3 in saprolite, 3 in the transition zone). These wells are located east of the Cristex building near the ASTs, at the drum storage pad, and adjacent to the lagoon. PAHs were not detected in most MW samples (they were not analyzed in the temporary well point samples). In 3 locations (1 saprolite well and 2 transition zone wells), the calculated concentrations of BaP TEQ exceeded the North Carolina water quality standards (all were below the MCL). The highest concentration was measured in

well MW15I, which is located on the south side of the gravel driveway, east of the surface water drainage ditch and is screened in the transition zone at 80 to 90 ft bgs. Additional BaP contamination in excess of the NCAC 2L standard may be present but was not detected by the analytical method used during the RI which had a detection limit that exceeded the NCAC 2L standard.

DCB was measured above detection in 4 MWs and 3 locations where temporary well points were installed during the MiHPT investigation (all depths less than 30 ft bgs). Three of the MWs are located in the northeast corner of the Cristex building. However, the NCAC 2L standard was exceeded only in one well (CMMW19) located in the northeast corner of the property and on the opposite side of an intermittent stream north of the Cristex building. This well was installed as part of the adjacent JFD NPL Site investigations and is screened at 30.5 to 40 ft bgs; it is uncertain if DCB contamination in this well is related to the Cristex Drum Site.

Benzene exceeded the NCAC 2L groundwater standard in one Cristex MW, one JFD MW, and two temporary well point locations. Only at well MW9, adjacent to the former aboveground storage tanks off the northeast building corner, did benzene significantly exceed the standard (70 micrograms per liter [µg/L]). This well is screened at 15 to 30 ft bgs.

PCE, TCE, cDCE, and VC exceeded NCAC 2L groundwater standards in numerous wells screened in regolith aquifer. The highest concentrations occurred in wells east of the Cristex building where the maximum PCE concentration (13,000 µg/L) exceeded the MCL by a factor of 2,600 and the NCAC 2L standard by a factor of 18,570. **Figures 7 through 10** illustrate the extent of PCE, TCE, cDCE, and VC contamination in groundwater at the Cristex Drum Site. The regolith aquifer extends from 0 to 90 ft on these diagrams which compare concentrations to Federal MCL values for each constituent. Depicted on the 0 to 30 ft bgs panel of **Figures 7 through 10** are contours of ECD response measured during the MiHPT investigation illustrating the area of strongest contamination identified by high resolution sampling. The known extent of contamination extends to the northeast, consistent with the potentiometric surface gradient. The full extent of down-gradient contamination has not been delineated.

Groundwater collected from most wells screened in the regolith aquifer shows some amount of degradation of PCE to biotic daughter products TCE, cDCE, and VC. Only at two temporary well point locations (MIP02 and MIP07) was degradation not apparent (PCE comprised 98 molar percent [mol %] of the total CVOC concentration). In general, PCE comprises from 32 to 90 mol % of the CVOCs in samples collected from the saprolite and transition zone portions of the regolith aquifer. cDCE comprises the largest proportion of degradation products in most wells (2 to 54 mol %). Two wells showed significant degradation: Well MW9, located at the northeast corner of the Cristex building contained less than 1 mol % PCE (2016 sample) and is dominated by VC (71 mol %). Well MW10, located within the Cristex building, contained 9 mol % PCE, 56 mol % cDCE, and 25 mol % VC (2015 sample; total CVOCs of 7.0 µg/L).

Bedrock Aquifer

Three MWs were screened within the bedrock aquifer at the site; these wells were installed in 2016 as part of the RI and have been sampled on only one occasion in 2016.

In contrast to the regolith aquifer, DCB and benzene did not exceed their NCAC 2L standards in any wells screened in the bedrock aquifer. Calculated BaP TEQ exceeded the North Carolina standard only in bedrock well MW-12D; the calculated value 0.1115 µg/L was below the MCL. Elevated concentrations of PCE, TCE, and cDCE were measured in concentrations above their NCAC 2L Federal MCL standards down-gradient bedrock well MW-16D and PCE exceeded its standard in well MW-3D. Maximum PCE concentration exceeded the Federal MCL by a factor of 50 and the NCAC 2L standard by a factor of 357. VC was not detected in the bedrock wells at a detection limit above the MCL and NCAC 2L standards.

Figures 7 through 10 illustrate the extent of PCE, TCE, cDCE, and VC contamination in groundwater at the Cristex Drum Site. Wells screened in the bedrock aquifer are shown in the right panel on each figure (titled >90 ft bgs). Similar to the regolith aquifer, the known extent of contamination extends to the northeast, consistent with the potentiometric surface gradient. The full extent of down-gradient contamination has not been delineated. Limited results from wells screened in the bedrock aquifer suggest a similar level of degradation as observed in the regolith aquifer (PCE of 50 to 60 mol %; cDCE of about 30 mol %). This suggests that migration deeper into the subsurface may not result in more complete degradation.

5.5.4 Surface Water and Sediment Contamination

The nature and extent of surface water and sediment contamination was described in Section 4.3 of the RI (Black & Veatch, 2016a). The HHRA did not identify any COCs in surface water; the ERA identified aluminum, copper, iron, titanium and zinc as COPCs.

Surface water samples were collected from two depths at each of the 2 locations within the on-site lagoon and one location in the delineated wetland, in 2015. **Table 2** shows exceedances of refinement screening values (RSVs) for surface water, which were developed as part of the ERA. No volatile organic compounds (VOC) or semi-volatile organic compounds (SVOCs) exceeded the screening values in surface water. Copper and zinc slightly exceeded the North Carolina chronic surface water quality standards and nickel equaled its chronic standard in one sample collected from a location in the small stream at the downstream end of the delineated wetland. This sample location appears to be influenced by surface runoff from off-site locations.

No VOCs or SVOCs exceeded screening values in sediment. Exceedances of the ecological RSV were noted for antimony, barium, beryllium, chromium, vanadium, and zinc. Sediment exceedances are not associated with just one sample location but are distributed through the site. There was no concentration gradient or clear pattern to the elevated metals and no single station was considered a multiple-contaminant hotspot.

5.5.5 Contaminant Sources

Groundwater results, coupled with observations from the MIP, suggest that a PCE source area was or is present along the eastern side of the Cristex building at the former drum storage pad; the former drum burial area may represent an additional source.

Sections 4 and 5 of the RI report summarizes known and suspected contaminant sources and the concentration data supporting these interpretations. The RI studies at the Cristex Drum Site identified CVOC as the primary contaminants, with local exceedances of criteria for benzene,

dichlorobenzenes, PAH compounds, and metals. The primary contaminant source is believed to be soil initially impacted by spills and leaks near the Cristex building in the area of the drum storage pad, former OWS, and above ground fuel oil storage tanks. The highest concentrations of CVOCs in soil occur at the eastern edge of the asphalt drum storage pad (North Carolina Department of Environment and Natural Resources [NCDENR], 2012). An additional primary source was present in the former buried drum area which was excavated in 1997. Secondary sources include a surface water drainage channel that drains the area east of the Cristex building and which runs north to the lagoon, and the lagoon itself including the berms surrounding it. Soil was excavated from portions of the drainage channel in 2001.

A dissolved plume of CVOC contamination is present east and northeast of the Cristex building. It extends vertically from the saprolite into the underlying transition zone and fractured bedrock. The maximum migration depth is at least 136 ft (depth of the base of the screen in well MW-16D). Elevated contaminant concentrations in groundwater samples collected from the transition zone confirm the importance of this interval as a preferred pathway for groundwater migration.

One or more degradation products of PCE including TCE, cDCE, and VC are found in almost all subsurface soil and groundwater samples where PCE is present. Only in one location (MW-9) is degradation to VC nearly complete.

Sediment within the lagoon, which was contaminated during past operations may represent a current or previous secondary source of contamination to down-gradient surface water and sediment, including that within the delineated wetland. It is unknown if this sediment also contributes to groundwater contamination.

6.0 Current and Potential Future Land and Water Uses

6.1 Land Uses

The facility is currently developed as a commercial/industrial property. Land use surrounding the Site is predominantly industrial, commercial, undeveloped, and limited residential.

Between 1991 and 2015, the Cristex building was used by several businesses. The last business ceased operations in 2015 and the building has been vacant since that time. Although used for industrial/commercial purposes in the past, there is no current industrial activity at the Site. The closest residential property is the Oakridge Apartment complex approximately 1,350 ft to the east of the Cristex property. Oakridge houses around 200 residents and is served by municipal water (EPA, 2013a).

The Site is serviced by utilities including electric, gas, water, and sewer. An abandoned gas main valve is present east of the building and is fed by an underground gas pipeline which runs along the eastern property line before cutting west and south across the site. A City of Oxford sanitary sewer line runs eastward across the site, and generally paralleling the Norfolk Southern rail grade. During Cristex operations, this sewer line accepted wastewater discharge from the onsite lagoon. Overhead utilities are present along the West industry Drive. The utilities for the site also run along the eastern property line.

6.2 Ground and Surface Water Uses

Groundwater contained within the regolith and bedrock aquifers at the Cristex Drum Site is classified as Class GA under the North Carolina groundwater regulations. North Carolina defines the best usage for Class GA water as an existing or potential source of drinking water supply for humans. The Site is serviced by municipal water. The nearest private residences served by drinking water wells are within ½ mile of the adjacent JFD NPL site (EPA, 2013a). No nearby drinking water wells contain site-related contaminants above North Carolina groundwater or EPA drinking water standards (EPA, 2013a).

Surface water from the Site drains from the lagoon to the wetland area and eventually to Fishing Creek in the Tar River Basin via an intermittent stream at the northeastern corner of the Site. The State of North Carolina has assigned beneficial use classifications to Fishing Creek of C (aquatic life and secondary recreation) and NSW (nutrient sensitive waters).

7.0 Summary of Site Risks

The response action selected in this ROD is necessary to protect public health and the environment from actual or threatened releases of hazardous substances, contamination and pollutants into the environment. The Baseline Risk Assessment (BRA) is contained in the *Human Health Risk Assessment (HHRA), Revision 1* and an *Ecological Risk Assessment (ERA), Revision 1* (Black & Veatch, 2016b and 2016c). The BRA estimates the risk a site poses if no action is taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the RA.

7.1 Summary of the Human Health Risk Assessment

A summary of the HHRA for the Cristex Drum Site completed in 2016 is provided in the following subsections. The purpose of the HHRA was to assess the potential current and future human health effects associated with past releases of contaminants at the site.

7.1.1 Identification of Chemicals of Concern

Media sample results were compared to a variety of screening values in the HHRA to identify COPCs. The COPCs represent potential site related hazards based on toxicity, concentration, frequency of detection, mobility and persistence in the environment.

The baseline HHRA identified a subset of the COPCs that presented significant current or future risks and are referred to as COCs in this ROD. **Table 3** presents a summary of the COCs in each exposure medium and includes the range of concentrations detected for each COC, as well as frequency of detection, the exposure point concentration (EPC), and how the EPC was derived.

7.1.2 Exposure Assessment

The CSM for the HHRA at the Cristex Drum Site incorporated information on the potential chemical sources, affected media, release mechanisms, routes of migration, and known or potential human receptors. **Figure 11** presents the CSM developed for the HHRA (Black & Veatch, 2016b). The CSM was used to identify those exposure pathways that may be potentially

complete considering current and potential future land uses. Exposure pathways evaluated in the HHRA were:

- Incidental ingestion, dermal contact, and inhalation of fugitive dusts and outdoor vapors from surface soil (Residents, Trespassers, Industrial/Commercial Workers, Construction Workers, Utility Workers);
- Incidental ingestion, dermal contact, and inhalation of fugitive dusts from subsurface soil (Construction Workers, Utility Workers);
- Inhalation of outdoor vapors from subsurface soil (Residents, Trespassers, Industrial/Commercial Workers, Construction Workers, Utility Workers);
- Incidental ingestion and dermal contact with surface water (Residents, Trespassers, Industrial/Commercial Workers, Construction Workers, Utility Workers);
- Incidental ingestion and dermal contact with sediment (Residents, Trespassers, Industrial/Commercial Workers, Construction Workers, Utility Workers);
- Ingestion of groundwater, dermal contact with groundwater, and inhalation of VOCs released from groundwater during household water use (Residents);
- Ingestion of groundwater only (Industrial/Commercial Workers);
- Incidental ingestion, dermal contact and inhalation of vapors from groundwater in an excavation trench (Construction Workers, Utility Workers);
- Inhalation of Indoor Vapors from subsurface VI (Residents, Industrial/Commercial Workers).

The EPCs for the COCs were calculated in accordance with *EPA Region 4 Human Health Risk Assessment Supplemental Guidance* (EPA, 2014) and are shown in **Table 3**.

Human intakes were calculated for each COC and receptor using the EPCs. Estimates of human intake, expressed in terms of mass of chemical per unit body weight per time (mg/kg/day), were calculated differently depending on whether the COC is a non-carcinogen or a carcinogen. For non-carcinogens, intake was averaged over the duration of exposure and is referred to as the average daily dose (ADD). For carcinogens, intake was averaged over the average lifespan of a person (70 years) and is referred to as the lifetime average daily dose (LADD).

EPA standard default exposure assumptions were generally used. The future residential scenario assumed that individuals live in the same residence for 26 years. Two age groups were evaluated: a child (age 1 to 6) and an adult; therefore, exposure durations of 6 and 20 years, respectively were used. The current/future on-site trespasser scenario assumed that an adolescent (age 7 to 16) periodically visits the Site one day a week, or 52 days per year. The future industrial worker scenario assumed that an individual works at the Site for 25 years. It was further assumed that an adult industrial worker (body weight of 80 kg) is at work five days a week for 50 weeks per year. For the construction worker, it was assumed that temporary construction activities may occur at the Site for one year. The utility worker was assumed to be exposed for repeated short periods of time (i.e., five days a week for 6 weeks) per year for a period of 25 years.

EPA default parameters were used for ingestion and dermal contact with each medium and inhalation of fugitive dusts and/or volatile emissions from soil. The inhalation pathway for

volatile compounds was also evaluated for household use of water and for construction/utility workers exposed to volatiles in an excavated trench. Inhalation of indoor air from subsurface VI was also evaluated as a potential exposure route for future residents and future industrial/commercial workers.

Table 3 presents the COCs and EPCs for each of the COCs detected in subsurface soil, sediment, and groundwater (i.e., the concentration that was used to estimate the exposure and risk from each COC). The table includes the range of concentrations detected for each COC, as well as the frequency of detection (i.e., the number of times the chemical was detected in the samples collected at the site), the EPC, and how the EPC was derived. Table 3 indicates that aluminum and manganese were detected in all subsurface soil samples, while chlorinated solvents (PCE, TCE, cDCE) were detected in more than 69% of groundwater samples. The EPC for aluminum in subsurface soil was determined using the 95% UCL calculated using Student's t-test while that for manganese in subsurface soil was calculated using an adjusted gamma distribution. The EPCs for PCE in subsurface soil and BaP TEQ in sediment were calculated using the 99% UCL determined using the Kaplan-Meier Chebyshev test. EPCs for all constituents in groundwater were determined using the maximum measured concentrations.

7.1.3 Toxicity Assessment

EPA toxicity assessments and the resultant toxicity values were used in the HHRA to determine both carcinogenic and non-carcinogenic risks associated with each COC and route of exposure. EPA toxicity values used in the HHRA included:

- Chronic and sub-chronic Reference Dose (RfD) and Reference Concentration (RfC) values for non-carcinogenic effects,
- Oral Cancer Slope Factors (CSFs) and Inhalation Unit Risk (IUR) values for carcinogenic effects,
- Primary target organ effects,
- Oral or dermal absorption efficiencies,
- Uncertainty or modifying factors.

Tables 4a and 4b summarize the cancer and non-cancer toxicity data, respectively that were used in the HHRA.

Table 4a provides carcinogenic risk information that is relevant to the contaminants of concern in soil, sediment, groundwater, and indoor air. At this time slope factors are not available for the dermal route of exposure; thus, the oral and dermal slope factors are the same. No adjustments based on oral absorption factors were necessary for these COCs.

Table 4b provides non-carcinogenic risk information that is relevant to the contaminants of concern in soil, sediment, groundwater, and indoor air. Each of the COCs has both chronic and subchronic reference doses (RfDs), with the exception of aluminum and manganese via the inhalation pathway. The chronic RfDs are more protective than subchronic values. As with the case for carcinogenic data, both oral and dermal RfDs are the same with no adjustments. The available toxicity data indicate that tetrachloroethene , aluminum and manganese primarily affect

the central nervous system. Trichloroethene affects the immune and developmental systems while cis-1,2-DCE targets the kidney.

7.1.4 Risk Characterization

Risk characterization integrates the results of the exposure and toxicity assessments to estimate potential cancer risks and non-cancer hazards. Carcinogenic risk is expressed as a probability of developing cancer as a result of lifetime exposure. For a given chemical and route of exposure, excess lifetime cancer risk is calculated as follows:

$$\text{Risk} = \text{LADD} \times \text{CSF}$$

These risks are probabilities that are generally expressed in scientific notation (i.e., 1E-06). An incremental lifetime cancer risk of 1E-06 indicates that, as a plausible upper-bound, an individual has a one-in-one-million chance of developing cancer as a result of site-related exposure to a carcinogen over a 70-year lifetime under the specific exposure conditions at the Site. For exposures to multiple carcinogens, the EPA assumes that the risk associated with multiple exposures is equivalent to the sum of their individual risks. Increased cancer risks less than 1E-06 indicate no action is required. Cancer risks between 1E-06 and 1E-04 generally do not warrant cleanup unless dictated by site-specific circumstances or other considerations. Increased cancer risks greater than 1E-04 indicate some type of action needs to be considered.

Table 5 presents a summary of the unacceptable cancer risks identified in the HHRA associated with exposure to the COCs. For the hypothetical future resident, unacceptable cancer risks primarily occur from exposure to groundwater contaminated with volatile compounds. Exposure to soil and sediment is a relatively small contribution to cancer risk at the site. When indoor air from the VI pathway is included, cancer risks are increased to 3.5E-03.

Unacceptable cancer risk also would occur to the future industrial/commercial worker (2.2E-04) without VI and 4.2E-04 with VI (**Table 5**).

There were no unacceptable cancer risks from COCs in any of the other exposure scenarios (i.e., trespasser, construction worker and utility worker).

To characterize the overall potential for non-carcinogenic effects associated with exposure to multiple chemicals, the EPA uses a hazard index (HI) approach. This approach assumes that simultaneous sub-threshold chronic exposures to multiple chemicals that affect the same target organ are additive and could result in an adverse health effect. The HI is calculated as follows:

$$HI = ADD1 / RfD1 + ADD2 / RfD2 + \ldots ADDi / RfDi, \text{ where:}$$

$$ADDi = \text{Average Daily Dose for the ith toxicant}$$

$$RfDi = RfD \text{ for the ith toxicant}$$

The term ADDi/RfDi is referred to as the hazard quotient (HQ).

Calculation of an HI in excess of unity indicates the potential for adverse health effects. Indices greater than one are generated when intake for any of the COCs exceeds its RfD or RfC.

However, given a sufficient number of chemicals under consideration, it is also possible to generate an HI greater than one even if none of the individual chemical intakes exceeds its respective RfD or RfC.

Table 6 provides a summary of the non-cancer hazards. For the future resident, the HI is 228 without VI and 426 with VI. Exposure to PCE (tetrachloroethene) provides the highest hazard that targets the central nervous system.

Unacceptable non-cancer hazards also occur for the future workers with HIs of 78, 16, and 18 for the industrial, construction, and utility workers, respectively (**Table 6**). Exposure to PCE and trichloroethene in groundwater in an excavated trench would result in the highest hazard. There were no hazards identified for the trespasser scenario.

In summary, the results of the HHRA at the Cristex Drum Site indicate that future residential, industrial/commercial workers, construction workers and utility workers exposed to the COCs in soil and groundwater result in unacceptable cancer risks and non-cancer hazards. Therefore, action under CERCLA is warranted.

7.1.5 Uncertainties

The calculations presented in the HHRA are meant to assist the EPA Remedial Project Manager (RPM) with information on which to base risk management decisions. A combination of site-specific exposure information, standard default assumptions, and professional judgment were used to select exposure units and develop exposure assumptions for the various receptors evaluated in the HHRA. These exposure assumptions are conservative and are likely to overestimate hazards and risks.

The HHRA compared the concentrations of aluminum, arsenic, and manganese (COCs in soil) to the potential for being within naturally occurring background levels. It was determined that these three metal COCs appear to be attributable to background. This uncertainty may have overestimated risks and hazards.

Risks associated with the VI pathway and vapors in an excavation trench were based on modeled concentrations based on groundwater data. These models use conservative model input assumptions which often result in overestimates of risk. Caution should be used when making risk management decisions based on modeled exposure and risk due to the conservative nature of model input assumptions.

7.2 Summary of the Ecological Risk Assessment

A summary of the ERA for the Cristex Site completed in 2016 is provided in the following subsections. The purpose of the ERA is to provide information necessary to assist risk managers in making informed decisions regarding the potential effects to the environment from hazardous substances released at the Site.

7.2.1 Identification of Chemicals of Concern

To identify COPCs in soil, sediment and surface water, the site concentrations were compared to the EPA Region 4 ecological screening levels. The following COCs were identified and evaluated in the ERA:

- Surface Water – aluminum, copper, iron, titanium and zinc
- Sediment – antimony, barium, beryllium, chromium, vanadium and zinc
- Soil – antimony, chromium, copper, lead, manganese, mercury, vanadium, yttrium and zinc.

Table 7 provides summary data on the occurrence and distribution of the ecological COCs.

7.2.2 Exposure Assessment

The ERA evaluated the areas at the Site identified as having contaminated media, either by direct contamination from process or waste management activities during facility operation or through subsequent transport. These areas included: 1) small areas of onsite soils in the vicinity of the former OWS, the former AST, and near the former drum disposal area; and 2) potential migration of runoff from these areas in the ditch to the lagoon and downstream through the wetland. **Table 8** summarizes the ecological exposure pathways of concern.

Surface soils support terrestrial receptors such as plants, soil invertebrates, small mammals, and birds. The exposure routes to these ecological receptors include direct contact and ingestion/uptake of contaminated media and indirect exposure through the food chain.

Surface water at the Site is limited to runoff from the northeast and east portions of the building area that eventually drain into the lagoon. During high precipitation events, some of the lagoon water then flows into a wetland which connects to a small headwater stream that originates offsite as a storm water ditch. Aquatic organisms are generally not permanently present in this local environment.

7.2.3 Ecological Effects Assessment

The ERA compared the Site media concentrations with screening-level benchmarks considered protective of various ecological receptors such as plants, invertebrates, ground birds and small rodents. **Table 7** shows the maximum HQ (the ratio of the maximum site concentration with the most conservative benchmark and most sensitive terrestrial receptor). Due to the intermittent water in the wetland and ditch/stream and the lack of a permanent aquatic system, surface water concentrations were compared to water quality benchmarks for acute effects.

7.2.4 Ecological Risk Characterization

Surface water does not pose an unacceptable risk to aquatic life. Although aluminum, copper and zinc exceed the water quality benchmarks, the source of the headwater stream is from an offsite storm water conveyance system. Thus, any exposures to aquatic and semi-aquatic life are temporary and of short duration. Benthic organisms inhabiting sediments in the lagoon, wetland and stream are at low risk from exposure to scattered locales of elevated metals with no clear contamination pattern.

Risks to terrestrial receptors from exposure to scattered pockets of elevated metals in soil were determined to be at low to negligible risk. Therefore, protective media levels were not developed for ecological receptors.

8.0 Remedial Action Objectives

Remedial Action Objectives (RAOs) were developed for the Cristex Drum Site to protect HH&E. The objectives address the contaminants and media of concern, the exposure route(s) and receptor(s), and the acceptable contaminant levels or range of levels for each exposure route. The COCs determined from the results of the HHRA and ERA were identified based on the EPA's guidance. COCs are chemicals that significantly contribute to an exposure pathway that either exceeds a 1×10E-04 cumulative Site cancer risk or exceeds a non-cancer HI of 1. **Tables 9 and 10** list the COCs for subsurface soil and groundwater and indoor air, respectively, and their associated remedial goal (RG) cleanup levels. The site is located in a low density industrial area. The COCs to be addressed by this ROD are summarized in Table 9 and include:

- PCE in subsurface soil,
- BaP TEQ, 1,4-DCB, benzene, cDCE, PCE, TCE, and VC in groundwater, and
- 1,4-DCB, benzene, carbon tetrachloride, PCE, TCE, and VC in indoor air.

Site-specific RAOs for the Cristex Drum Site are:

1) Prevent future residential exposure to contaminated soils and groundwater above acceptable risk levels.
2) Prevent intrusion of vapor contaminated above risk levels into the existing building by reducing DNAPL and absorbed phase COCs and groundwater by treating these constituents in the UZ and SSZ media zones.
3) Reduce or eliminate the leaching of soil COCs into groundwater to levels that are protective of HH&E.
4) Prevent the migration of COCs into the lagoon basin sediments from adjacent building area to levels that are protective of HH&E.
5) Prevent down-gradient migration of contaminated groundwater within the transition zone and bedrock aquifer.
6) Restore groundwater quality to meet NCDEQ groundwater standards throughout the plume, based on the classification of the aquifers as a potential source of drinking water [Class GA or Class GSA] under 15A NCAC 02L.0201.

9.0 Description of Alternatives

To develop and focus the remedial alternative evaluation process in the FS, the Site was divided into three areas called Contaminated Media Zones (CMZs). A CMZ represents a portion of the site contamination which has a particular characteristic that defines the optimal remediation approach. CMZs are defined by one or more of the following characteristics; lithology, COCs, depth, areal extent, and/or presence of NAPL. The three CMZs defined at the Cristex Drum Site

are the Unsaturated Zone (UZ), Saturated Source Zone (SSZ), and Dilute Plume (DP). **Figure 3** depicts the CMZs. A summary of the remedial alternatives retained for evaluation for each CMZ is presented in this section. A detailed screening and comparative analysis of the potential remedy alternatives is included in the *Feasibility Study Report, Revision 1,* located in the AR in the Information Repositories at the Richard H. Thornton Library in Oxford, NC and the EPA's Records Center in Atlanta, GA.

9.1 Description of the Unsaturated Zone (UZ) Remedial Alternatives

The UZ encompasses significantly contaminated surface and subsurface soils with significant leachable CVOCs in concentrations from 0 to about 20 ft bgs in the suspected source area on the eastern side of the Cristex building near the former drum storage pad area. The unsaturated soil impacted with CVOCs, primarily PCE, and trace levels of petroleum compounds presents an ongoing threat of release of contaminants into the groundwater from soil leachate. Remediation of this zone is focused on protecting HH&E from adsorbed phase COCs or residual DNAPL, if present, and reducing or eliminating the leaching of soil PCE into groundwater. Four remedial alternatives were developed and evaluated for the UZ.

9.1.1 UZ Alternative 1: No Action

Estimated Capital Cost: $0
Estimated Operation and Maintenance (O&M) Cost: $14,200
Estimated Net Present Worth (NPW) Cost: $42,000
Estimated Construction Timeframe: 0 months
Estimated Time to Achieve RAO/Cleanup Levels: Not Applicable (N/A)

Section 300.430(e)(6) of the National Contingency Plan (NCP) directs that a "No Action Alternative" be evaluated to provide a baseline scenario against which to compare all other alternatives (EPA, 1992). Typically, the No Action Alternative only includes compliance monitoring. In general, the alternative is applicable when there is no current or potential threat to HH&E or when CERCLA exclusions preclude taking an action. Under the No Action Alternative, no funds would be expended to control or remediate the contaminated media. Funds are required for the statutory Five-Year Reviews (FYRs) of the Site, for site visits, minimal compliance sampling and analyses of select contaminated media, review of regulatory changes, and report preparation.

Under Alternative 1, the UZ would remain in its present condition. Minimal periodic sampling and analysis of COCs in groundwater and soil (for VI performance) would be used to track contaminant concentrations over the course of a 30-year monitoring period. The O&M cost includes sampling 10 site wells for VOCs once every 5 years over a 30-year period (6 events) and would be incurred only during these years. This information will permit conditions within the CMZ to be evaluated for the FYR.

9.1.2 UZ Alternative 2: Soil Vapor Extraction

Estimated Capital Cost: $846,400
Estimated Annual O&M Cost: $135,900
Estimated NPW Cost: $1,607,400

Estimated Construction Timeframe: 6 months
Estimated Time to Achieve RAOs/Cleanup Levels: 5 yrs

Alternative UZ #2 consists primarily of Soil Vapor Extraction (SVE) as a prescribed remedy for treatment of UZ soil. It can be implemented alongside and under the eastern side of the Cristex building and the former drum storage pad where it will likely reduce VI into the building and reduce or prevent the migration of PCE in subsurface soils to groundwater. This alternative would include installation of thirty-one (31) 4-inch diameter SVE wells screened from 5 to 20 ft bgs with four wells installed inside the Cristex building. These wells were assumed to have an average 15-ft SVE overlapped radius of influence to treat approximately 12,444 cy of PCE-contaminated soil located throughout the entire UZ. Additionally, angled wells may be installed along the periphery of the building in the event that wells cannot be safely installed inside the building. A contingency has been included for twenty-two (22) 2-inch diameter air entry wells screened from 5 to 20 ft bgs to facilitate more uniform subsurface airflow. Equipment includes a trailer-mounted system with extraction blower, air/fluid separation (knockout tank), and vapor phase carbon. A manifold extraction system would allow phased operation of approximately 10 out of 31 points simultaneously. Sequencing of SVE well operation may also be used to allow their use as air entry wells.

9.1.3 UZ Alternative 3: Soil Excavation

Estimated Capital Cost: $1,873,000
Estimated Annual O&M Cost: $0
Estimated NPW Cost: $1,873,000
Estimated Construction Timeframe: 3 months
Estimated Time to Achieve RAOs/Cleanup Levels: 3 months

Alternative UZ #3 consists of soil excavation of the majority of the UZ to remove a total of approximately 12,400 cy of contaminated soil. The soil would be excavated to a depth of approximately 20 ft bgs with 3,935 cy excavated from sloped sidewalls to remove PCE-contaminated soil from the suspected source area: the former drum storage pad. Soil excavation to 20 ft will require the use of side-walls graded at a presumed 1:1 slope. A portion or complete part of the building in the vicinity of the UZ will need to be demolished and the concrete foundation and adjacent former drum storage pad removed. A sampling plan will be developed as part of the Remedial Design to determine if additional building demolition and soil excavation is warranted. Expanded (or complete) demolition of the Cristex building would allow for full excavation of the presumed area of soil contamination. Under this scenario, an additional 4,812 bank cubic yard (bcy) of soil plus 765 bcy of sidewall slopes would be excavated. This would add $849,600 to the cost of Alternative UZ #3 (total NPW cost of $2,722,600). Soil excavation is expected to remove the majority of the suspected source area and any NAPL present in the UZ.

Soil excavation may require the use of side-wall shoring or other precautions to protect the building structure. Excavated soil would be sampled for waste profiling, segregated if necessary, and loaded on trucks for off-facility disposal. Approximately 60 % of the excavated soils were assumed to require disposal. The remaining 40 % of soils is estimated to not exceed a predefined level that is protective of construction worker direct contact, soil leachability and VI limits. Composite soil sampling of excavated soils would be used to confirm soil disposition and

classification. Contaminated soils are expected to be classified as solid waste and be disposed of in a RCRA Subtitle D landfill. Any soils exceeding the RCRA Subtitle D Landfill requirements or exceeding a RCRA characteristic waste threshold (e.g., fails Toxicity Characteristic Leaching Procedure) will be segregated for disposal at an off-site permitted RCRA Subtitle C hazardous waste landfill. Treatment of the soils to meet RCRA Land Disposal Requirements (LDR) treatment standards would be performed at an off-site permitted facility. Nine high density polyethylene (HDPE) laterals would be placed at the bottom of the excavation for future application of treatment amendments below the excavated area. The laterals would then be covered with clean sand and a liner prior to placement of clean compacted fill.

9.1.4 UZ Alternative 4: ISCO with Shallow Soil Mixing

Estimated Capital Cost: $1,332,700
Estimated Annual O&M Cost: $29,800
Estimated NPW Cost: $1,370,800
Estimated Construction Timeframe: less than 6 months
Estimated Time to Achieve RAOs/Cleanup Levels: less than 1 year

Alternative UZ #4 consists primarily of shallow soil mixing of an *In Situ* Chemical Oxidation (ISCO) agent (assumed to be potassium permanganate) in the top 20 ft of soil beneath the majority of the UZ. Soils would be mixed with oxidants in 20-ft by 20-ft cells to a depth of 20 ft bgs using an ALLU or Lang tool on tracked excavators to treat approximately 10,800 cy of contaminated soil (treatment area of 14,578 ft^2). A portion of the building in the vicinity of the UZ would be demolished and the concrete foundation and adjacent former drum storage pad would be removed. Expanded (or complete) demolition of the Cristex building would allow for complete access for oxidation of the presumed area of soil contamination. Under this scenario, an additional 1,680 bcy would be treated at an additional cost of $125,300.

In situ mixing of the ISCO agent will enhance the contact of the oxidant with the most contaminated soil for uniform coverage throughout the UZ. The ISCO agent would be batch mixed into a slurry with hydrant water or recovered groundwater, stored in a polyethylene feed tank, applied to the soils in each grid, and then thoroughly mixed. This remedy would result in a slight increase in ground surface elevation due to the soils being less consolidated. Approximately 22,426 pounds of ISCO agent was estimated for this remedy (25,914 pounds for the expanded remedy).

9.2 Description of the Saturated Source Zone (SSZ) Remedial Alternatives

The SSZ encompasses the contaminated soil beneath the former drum storage pad and down-gradient toward the lagoon from the water table at approximately 20 ft bgs to bedrock at a depth ranging from 60 to 90 ft bgs. Remediation of the SSZ zone includes treating an approximately 70 ft thick zone of saturated soil and groundwater beneath the suspected source areas (between approximately 20 and 90 ft bgs). This zone is impacted with CVOCs and petroleum hydrocarbons in groundwater; however, there are significant data gaps in measurements of SSZ soil concentrations and the potential presence of residual DNAPL within this zone. This zone was configured to represent the area with the highest concentrations of groundwater contamination and potential adsorbed or residual source material contributing to dissolved

contamination. The SSZ encompasses the footprint of the UZ (eastern side of the Cristex building in the vicinity of the former drum storage pad) and extends to the north along the drainage ditch. There is also a small secondary area in the SSZ beneath the former location of the buried drums. Remediation of this zone is focused on protection of human health and groundwater resources from continued migration and dissolution of adsorbed COCs into groundwater, and possible residual DNAPL. Five remedial alternatives were developed and evaluated for the SSZ.

9.2.1 SSZ Alternative 1: No Action

Estimated Capital Cost: $0
Estimated O&M Cost: $14,200
Estimated NPW Cost: $42,000
Estimated Construction Timeframe: 0 months
Estimated Time to Achieve RAO/Cleanup Levels: N/A

This remedy is the same as the No Action Alternative UZ #1.

9.2.2 SSZ Alternative 2: EISB with Chemical Reduction

Estimated Capital Costs: $2,749,800
Estimated Annual O&M Costs: $143,600
Estimated NPW Costs: $3,554,300
Estimated Construction Timeframe: 1 year
Estimated Time to Achieve RAOs/Cleanup Levels: 5 years

Alternative SSZ #2, *In Situ* Bioremediation (EISB) with *In Situ* Chemical Reduction (ISCR), involves injection of amendments such as a carbon substrate with zero valent iron (ZVI) or soluble ferrous iron to reduce residual DNAPL, COCs adsorbed on saturated soil, and COCs dissolved in groundwater. These amendments would be added via a dense array of injection wells in the southern portion of the SSZ and as permeable treatment barriers for the northern half of the SSZ. The denser coverage in the southern portion of the SSZ coincides with the suspected release area. This remedy offers the benefit of both anaerobic biodegradation and chemical reduction treatment mechanisms.

This alternative would include installing 80 2-inch diameter permanent wells for EISB/ISCR injection to treat saturated soil and groundwater in the SSZ. Thirty-six (36) wells would cover the southern SSZ area in a dense array. An additional 36 wells would be installed as treatment barriers in the northern SSZ; each barrier would consist of two rows of injection wells with the barriers located at the midpoint and toe of the SSZ. Eight more EISB/ISCR injection wells would be located to directly remediate the area where buried drums were removed in 1997.

Each well would be installed to a total depth of between 70 and 90 ft (to the top of bedrock) and screened from 20 ft bgs to the well termination depth. The injection array is based on a 16-ft lateral well spacing (8 ft radius of influence) and a manifold delivery system would be used to inject the amendments. Specific depth intervals in the saprolite and transition zone in each well would be targeted for injection using inflatable packers. A portion of the building would need to

be demolished and the concrete foundation and adjacent former drum storage pad would be removed.

Treatability testing would be required to select the optimal EISB/ISCR amendment for the Site. For purposes of developing a cost estimate, the FS assumed a mixture of a carbon substrate and approximately 65,500 pounds of micro-scale iron would be injected at up to 6 wells simultaneously over a 17-week period. A hydrogen ion concentration (pH) buffer would be required to offset the production of acid from the reaction and to raise the natural pH to optimal levels for biodegradation. The remedy also assumes that bioaugmentation of the subsurface with halorespiring bacteria would be required. The remedy includes installation of 6 performance monitoring wells (MWs).

9.2.3 SSZ Alternative 3: EK-ISCO with Biobarriers

SSZ Alternative 3: EK-ISCO with Biobarriers
Estimated Capital Cost: $3,710,700
Estimated Annual O&M Cost: $272,100
Estimated NPW Cost: $4,609,700
Estimated Construction Timeframe: 1 year
Estimated Time to Achieve RAOs/Cleanup Levels: 5 years

Alternative SSZ #3, Electrokinetics – *In Situ* Chemical Oxidation (EK-ISCO) with Biobarriers, involves the application of electrokinetics using a direct current (DC) to enhance the transport of oxidant from ISCO injection wells. EISB biobarriers would be installed down-gradient of the EK-ISCO application.

Through a series of anode/cathode wells installed in the subsurface, an electrical current is applied which results in the migration of ions towards their oppositely charged electrode. The applied voltage gradient also results in the bulk movement of groundwater from one electrode to another. Injection of a chemical oxidant, assumed to be will be used to reduce residual DNAPL, COCs adsorbed on saturated soil, and COCs dissolved in groundwater. Organic compounds in contact with the oxidant would be quickly oxidized; thereby eliminating contaminant mass available for dissolution and lateral transport. EK-ISCO would be administered via a dense array injection well in the southern portion of the SSZ.

Effective implementation of ISCO depends on uniform amendment distribution and contact of the oxidant with contaminants; electrokinetics (EK) is intended to augment these processes. The denser coverage by EK-ISCO in the southern portion of the SSZ coincides with the suspected release area and the presumed highest levels of soil contamination.

Two EISB permeable treatment barriers would be deployed in the northern half of the SSZ. Each of the two EISB passive barriers would consist of a single row of injection wells, across the mid-point and toe of the SSZ. The injection wells would be injected with emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater.

This alternative would include installing 87 2-inch diameter wells: 32 EK electrode wells, 28 ISCO injection wells and 27 EISB biobarrier injection wells, to treat the saturated soil and groundwater in the SSZ. Each well would be installed to a total depth of between 70 and 90 ft (to the top of bedrock) and screened from 20 ft bgs to the well termination depth. A 16-ft lateral well spacing is assumed (8 ft radius of influence) and a manifold delivery system would be used to inject the amendments and the oxidant solution. A portion of the building would need to be demolished and the concrete foundation and former drum storage pad would be removed. Treatability testing would be required to select the optimal oxidants and amendments, and the pH adjustment dosing for the biobarriers.

The biobarrier conceptual approach includes the preparation of the substrate solutions at the Site and storage of the solution in a 6,500-gallon HDPE tank prior to injection. An injection period of 18 weeks is assumed with approximately 69,400 pounds of oxidant and 43,500 pounds of emulsified oil injected at up to 6 wells simultaneously. Treatability testing would be required to select the optimal EISB amendment for the Site. A pH buffer would be required to offset the production of acid from the reaction and to raise the natural pH to optimal levels for biodegradation. The remedy also assumes that bioaugmentation would be required. A total operation of 5 years was assumed for the EISB component, this period being contingent upon the effectiveness of up-gradient source reduction.

9.2.4 SSZ Alternative 4: EK-BIO with Biobarriers

Estimated Capital Cost: $3,474,300
Estimated Annual O&M Cost: $285,800
Estimated NPW Cost: $4,409,100
Estimated Construction Timeframe: 9 months
Estimated Time to Achieve RAOs/Cleanup Levels: 5 years

Alternative SSZ #4 is an analogous remedy to SSZ #3 (EK-ISCO) except that electrokinetics is used to enhance movement of EISB amendments (e.g., carbon substrate) in lieu of an oxidant. The Electrokinetics – *In Situ* Bioremediation (EK-BIO) alternative has an identical rationale and placement of remedy elements for the layout.

Through a series of anode/cathode wells installed in the subsurface, an electrical current is applied which results in the migration of ions towards their oppositely charged electrode. The applied voltage gradient also results in the bulk movement of groundwater from one electrode to another. Injection of a carbon substrate, pH adjustment, and bioaugmentation culture will result in treatment of adsorbed and dissolved phase COCs.

This alternative would include installing 87 2-inch permanent wells: 32 electrode wells, 28 EISB source injection wells and 27 EISB biobarrier injection wells, to treat the saturated soil and groundwater in the SSZ. Each well would be installed to a total depth of approximately 70 to 90 ft (to the top of bedrock) and screened from 20 ft bgs to the well termination depth. A 16-ft lateral well spacing is assumed (8 ft radius of influence) and a manifold delivery system would be used to inject the amendments. A portion of the building will need to be demolished and the concrete foundation removed, along with the former drum storage pad. Treatability testing

would be required to select the optimal carbon source and amendments, and the pH adjustment dosing.

9.2.5 SSZ Alternative 5: BiRD with Recirculation

Estimated Capital Cost: $3,651,000
Estimated Annual O&M Cost: $581,500
Estimated NPW Cost: $4,054,900
Estimated Construction Timeframe: 6 months
Estimated Time to Achieve RAOs/Cleanup Levels: 4 years

Alternative SSZ #5 consists of the Biochemical Reductive Dehalogenation (BiRD) technology applied to the SSZ using an injection well and recirculation well approach. A series of transverse recirculation cells would be used to inject carbon substrate, sulfate, and iron solution to reduce residual DNAPL, COCs adsorbed on saturated soil, and COCs dissolved in groundwater. This remedy is intentionally dissimilar to Alternatives SSZ #2 (EISB/ISCR), SSZ #3 (EK-ISCO) and SSZ #4 (EK-BIO), which used a dense array for full injection coverage. The recirculation scheme provides a reduced level of initial amendment distribution but offsets this with the hydraulic flushing/recirculation and the inherent flexibility of this injection pattern. The BiRD technology relies principally on the *in situ* production of iron sulfides for chemical reduction and is designed to leverage any indigenous divalent metals that will facilitate this process. Biodegradation is also available as an ancillary process due to the reduced conditions induced by adding a carbon substrate to lower the oxidation-reduction potential. As with other *in situ* technologies, amendment distribution and contact with contaminants, along with suitable soil mineralogy is important to the success of the BiRD process.

This alternative would include installation of 34 4-inch diameter injection wells with screen intervals from 50 to 75-ft bgs for EISB/ISCR injection. Eighteen (18) 6-inch diameter recovery wells would be located on alternate transverse arrays at varying intervals, forming four separate recirculation cells within the SSZ. The recirculation cells will use an injection manifold, and an equipment trailer with air stripping, bag filtration, activated carbon, and supplemental water conditioning with an oxygen scavenger for water treatment prior to reinjection. A portion of the building would need to be demolished and the concrete foundation and former drum storage pad would be removed.

Treatability testing would be required to analyze the site mineralogy and select the optimal amendments for the Site. The remedy also assumes that bioaugmentation with *Dehalococcoides sp.* (DHC) and other halorespiring bacteria would be required. The remedy also includes the installation of 6 performance MWs.

9.3 Description of the Dilute Plume (DP) Remedy Alternatives

The DP comprises the wider band of dissolved contamination in the bedrock and regolith aquifers (saprolite and the partially weathered bedrock transition zone) adjacent to the SSZ. Remediation of this zone is focused on preventing the further vertical and horizontal migration of contaminated groundwater. Dissolved contamination in the saprolite portion of the DP is principally addressed through the down-gradient biobarriers walls or BiRD recirculation scheme for the SSZ remedies. Consequently, the DP remedial alternatives are focused on treatment of

the transition zone and bedrock aquifer. Four remedial alternatives were developed and evaluated for the DP.

9.3.1 DP Alternative 1: No Action

Estimated Capital Cost: $0
Estimated O&M Cost: $14,200
Estimated NPW Cost: $42,000
Estimated Construction Timeframe: 0 months
Estimated Time to Achieve RAO/Cleanup Levels: N/A

The DP Zone No Action Alternative is the same as the UZ #1 No Action alternative.

9.3.2 DP Alternative 2: EISB Biobarrier

Estimated Capital Cost: $1,201,400
Estimated Annual O&M Cost: $78,200
Estimated NPW Cost: $2,264,500
Estimated Construction Timeframe: 6 months
Estimated Time to Achieve RAOs/Cleanup Levels: 20 years

Alternative DP #2 involves the use of an EISB passive barrier consisting of a row of injection wells across the DP at the toe of the SSZ. The injection wells would be injected with emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater. BiRD amendments may also be added in the future if deemed necessary.

This alternative would include the installation of 16 2-inch diameter deep injection wells with 10-ft overlapped effective radii for injection of emulsified oil substrate for enhanced bioremediation. The wells would be screened between about 70 ft and approximately 140 ft bgs. The emulsified oil carbon substrate will potentially provide a long-term source of carbon (electron donor); from 2 to 5 years for treatment of the advected COC flux. The relatively close spacing will provide good coverage along the barrier. In addition, a zone of reduced conditions will develop down-gradient from the barriers. The injections would occur using a temporary manifold delivery system and associated equipment.

Treatability testing would be required to select the optimal EISB amendment for the DP. The remedy includes the installation of 4 performance MWs. A total operation of 15 years was assumed, this period being contingent upon the effectiveness of up-gradient source reduction.

The addition of colloidal (micro-scale) activated carbon was considered as an augmentation to the DP #2 biobarrier option. Colloidal carbon can be injected in the same injection wells and would provide *in situ* carbon adsorption and a potential zone for aggregation of halorespiring bacteria. This supplemental approach would conceptually improve the biobarrier performance and could extend its useful life if the COCs adsorbed on the carbon are biodegraded *in situ*. Colloidal carbon may not be compatible with emulsified oils as they may coat the carbon. This patented technology would require specialized testing and design and cannot be adequately costed at this stage. The incremental cost should consist of the colloidal carbon itself and the

preparation and injection of the mixture. The formal evaluation of this Alternative did not include colloidal activated carbon. However, if selected as the recommended alternative, this variation will be considered a viable expansion of the remedy.

9.3.3 DP Alternative 3: Hydraulic Capture/Containment

Estimated Capital Cost: $594,100
Estimated Annual O&M Cost: $124,500
Estimated NPW Cost: $1,757,500
Estimated Construction Timeframe: 3 months
Estimated Time to Achieve RAOs/Cleanup Levels: 20 years

Alternative DP #3 involves the use of hydraulic containment using groundwater recovery wells to provide limited mass removal and prevent the lateral solute transport of COCs. The water is then treated with air stripping and activated carbon and infiltrated back into the aquifer via injection wells or discharged to the sanitary sewer. This alternative would include installing four deep groundwater recovery wells oriented perpendicular to groundwater flow. The proposed row of recovery wells needed to capture the groundwater flux at the well transect and to capture a significant down-gradient portion of the undefined dissolved plume would be in a location just beyond the extent of the SSZ. Groundwater flow modeling would be advantageous to optimize the number and placement of wells.

The four 6-inch diameter groundwater recovery wells would be screened from about 70 ft to approximately 140 ft bgs. Confirmation of the transition zone and bedrock aquifer hydraulic conductivity and down-gradient delineation of the dissolved COC plume are critical data gaps for this alternative.

9.3.4 DP Alternative 4: Monitored Natural Attenuation (MNA)

Estimated Capital Cost: $0
Estimated O&M Cost: $26,500
Estimated NPW Cost: $189,100
Estimated Construction Timeframe: 0 months
Estimated Time to Achieve RAOs/Cleanup Levels: greater than 30 years

Alternative DP #4 MNA is a viable supplemental alternative for the DP zone when used in conjunction with treatment of source areas/higher concentration areas. MNA is the use of natural biotic degradation or natural abiotic degradation (e.g., due to reduced iron species, soil attenuation, advection, dispersion, dilution, etc.) for contaminant reduction. Due to the largely aerobic groundwater conditions onsite, natural biodegradation may be limited. However, the presence of PCE/TCE daughter products implies at least a marginal degree of anaerobic reductive dehalogenation. Natural abiotic degradation is assumed to also be a limited but active degradation mechanism.

As a stand-alone treatment option, MNA's effectiveness would depend largely on the aggressiveness of the treatment options selected for the UZ and SSZ and likely does not have an effective biotic treatment due to the naturally high dissolved oxygen (DO) and oxidation-reduction potential (ORP) levels. Microbial populations of halorespiring bacteria have not been

analyzed at the Site, but are not expected to be present in significant concentrations. There is insufficient information concerning the extent and magnitude of the source to develop a predictive solute transport model for the likely duration of an MNA remedy with or without source reduction.

This remedy uses analyses of COCs and natural attenuation parameters from MWs to gauge the effectiveness of natural biotic and abiotic degradation mechanisms. O&M costs assume this occurs once every five years. The historical analyses of total VOCs and natural attenuation parameters indicate that biotic degradation may be occurring as evidenced by the presence of PCE daughter products. This degradation requires reduced conditions, so it is assumed that isolated pockets of low permeability zones exist with correspondingly lower groundwater velocities and oxygen flux. This remedy will be ineffective without source area treatment and will require an extended time for site restoration (estimated at 30 years) even if source area remedies are not treated aggressively.

9.4 Common Elements of Each Alternative

With the exception of the No Action alternatives, all of the action alternatives evaluated for each CMZ allow for a pre-design investigation to fill design data gaps prior to designing and implementing the remedy. All action alternatives also include periodic monitoring of the site to document the effectiveness and continued protectiveness of the remedy and placement of institutional controls (ICs) to restrict groundwater use and limit exposure to COCs.

9.4.1 Institutional Controls

ICs will be required for all the alternatives because contaminants will remain in place at levels above that suited for unlimited use and unrestricted exposure after treatment of contamination within the SSZ and UZ. ICs will be used to increase public awareness of the actions taken to address site hazards and to minimize the potential for exposure to any residual contamination in site media. The following generally describes those ICs to be considered for implementation at the Site to achieve the bulleted performance objectives:

- Prohibit installation of potable wells at the site.
- Prohibit any consumptive use of groundwater including but not limited to drinking water, irrigation or industrial use.
  Prohibit intrusive activities such as excavation in the contaminated media areas that would interfere with the integrity of any existing or future monitoring or remediation system.

ICs considered for implementation include using the State of North Carolina Declaration of Perpetual Land Use Restrictions process, which requires the recordation of a survey plat map defining the boundaries of the Site and a Notice of Contaminated Site filed in County real property records in accordance with North Carolina General Statutes (NCGSs) 143B-279.9 and 143B-279.10.

- Restrictive covenants, if possible, could be executed by the property owners and recorded that outline land and groundwater use restrictions including the prohibition of any residential, industrial, or recreational reuse of the property unless prior written approval is

obtained from the EPA and NCDEQ. The covenant would also prohibit interference with the integrity of any existing or future monitoring or remediation system without prior EPA and NCDEQ approval. Notice of the application of land and groundwater use restrictions to the Site via the restrictive covenant would be provided to the local regulatory agencies.

10.0 Comparative Analysis of Alternatives

The NCP establishes a framework of nine criteria for evaluating remedial alternatives. Each alternative must meet the threshold criteria of Overall Protection of HH&E and Compliance with applicable or relevant and appropriate requirements (ARARs) in order to be considered for further evaluation against the five balancing criteria. The FS used a comparative analysis to assess the relative performance of each alternative in relation to the nine criteria (excluding the two modifying criteria, state acceptance and community acceptance). The purpose of this analysis was to identify the advantages and disadvantages of each alternative relative to the other alternatives. Analysis of alternatives was conducted separately for each of the three CMZs although consideration was given to the other CMZs.

10.1 Unsaturated Zone

10.1.1 Overall Protection of HH&E

Overall protection of HH&E addresses whether each alternative provides adequate protection of HH&E and describes how risks posed through exposure pathway are eliminated, reduced or controlled, through treatment, engineering controls and/or ICs.

The No Action alternative (UZ #1) was not considered to be protective of HH&E. All of the UZ action alternatives scored well for protection of HH&E. Alternatives UZ #3 (Soil Excavation) and UZ #4 (ISCO with Shallow Soil Mixing) were tied with the highest ranking for relative overall protection of HH&E as they both offer complete destruction or removal of COCs. However, excavation of the contamination is a more assured technology as the success of any ISCO application depends on contact and thorough mixing of the contaminants with the oxidant. Alternative UZ #2, SVE, also provides strong overall protection of HH&E with little differentiation between this and the top two scoring alternatives.

10.1.2 Compliance with ARARs

Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that RAs at CERCLA sites attain legally applicable or relevant and appropriate Federal and more stringent State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA section 121(d)(4). Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, RA, location, or other circumstance found at a CERCLA site. Relevant and appropriate requirements, are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, RA, location,

or other circumstance at a CERCLA site address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site.

For purposes of ease of identification, the EPA has created three categories of ARARs: Chemical-, Location- and Action-Specific. Under 40 CFR §300.400(g)(5), the lead and support agencies shall identify their specific ARARs for a particular site and notify each other in a timely manner as described in 40 CFR §300.515(d). The ARARs tables in the Feasibility Study include requirements that apply to any of the remedial alternatives that were analyzed and compared.

Chemical-Specific ARARs/TBC Guidance
Chemical-specific ARARs are usually health or risk-based numerical values limiting the amount or concentration of a chemical that may be found in, or discharged to, the environment. The chemical-specific ARARs include drinking water or groundwater quality standards for restoring groundwater.

Location-Specific ARARs/TBC Guidance
Location-specific requirements establish restrictions on permissible concentrations of hazardous substances or establish requirements for how activities will be conducted because they are in special locations (e.g., wetlands, floodplains, critical habitats, streams).

Action-Specific ARARs/TBC Guidance
Action-specific ARARs are usually technology-based or activity-based requirements or limitations that control actions taken at hazardous waste sites. Action-specific requirements often include performance, design and controls, or restrictions on particular kinds of activities related to management of hazardous substances. Action-specific ARARs are triggered by the types of remedial activities and types of wastes that are generated, stored, treated, disposed, emitted, discharged, or otherwise managed. Potential action-specific ARARs include federal and state requirements for general construction management requirements (preventing fugitive dust and control of stormwater runoff from land disturbing activities), underground injection control (UIC well regulations for injecting reagents to remediate groundwater, air emission limitations for treating VOC contaminated groundwater, and RCRA waste characterization, treatment, storage and disposal requirements for soils and secondary wastes that are generated by remedial activities.

The chemical-specific ARARs were considered the most important for the detailed analyses of alternatives at the Cristex Drum Site. Particularly important is the ability of a remedial alternative to meet the cleanup level(s) for the COCs that are based upon MCLs or more stringent NCAC 2L Groundwater Quality Standards.

The No Action alternative (UZ #1) would not meet ARARs. All UZ action alternatives were ranked similarly in their ability to meet ARARs. Alternative UZ #4, ISCO with Shallow Soil Mixing, is projected to be the most aggressive treatment alternative and is expected to have the most comprehensive success at reducing the mass and concentration of contaminants, and should do so in a short timeframe (less than six months). The soil excavation remedy (UZ #3) offers an incremental advantage to the other alternatives as it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. Alternative UZ #2, SVE, scored

lower on chemical-specific ARARs due to it being the least robust of the active remedies at removing or destroying contaminant mass in the subsurface.

The following five Balancing Criteria were not evaluated for the No Action alternative (UZ #1) because it would fail to satisfy the Threshold Criteria of Overall Protectiveness of HH&E and Compliance with ARARs.

10.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of HH&E over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain on-site following remediation and the adequacy and reliability of controls.

This criterion has particular importance for the UZ remediation due to the RAO of preventing human exposure to site-related contaminants and isolation or treatment of potential NAPL. Thus, aggressive and comprehensive technologies can be expected to provide better assurance of long-term effectiveness and permanence. Alternatives that physically remove contaminants from the site media provide the most protection for the longest period, which all three active remedial alternatives offer.

The Soil Excavation alternative (UZ #3) would provide a guaranteed successful outcome and eliminate all COCs from the source area. While it scored the same as ISCO with Shallow Soil Mixing (UZ #4), the soil excavation remedy offers an incremental advantage as it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. SVE (UZ #2) was ranked slightly lower than the other alternatives as it is it more likely to leave residual COCs due to the heterogeneous, low permeability soils. The likelihood that each of the action alternatives would meet performance specifications in the near term is high.

10.1.4 Reduction of Toxicity, Mobility or Volume through Treatment

Reduction of toxicity, mobility or volume (T/M/V) of hazardous substances through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternative UZ #3 (Soil Excavation) was rated slightly higher in reduction of T/M/V because it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. However, the UZ #3 transfers the contaminant volume and toxicity to a landfill. Alternative UZ #4 (ISCO with Shallow Soil Mixing) may have technical limitations getting sufficient mixing of oxidants with the saprolitic clays which could result in some pockets of long-term desorption and a potential for continued T/M/V. The remaining alternative, SVE (UZ #2), has comparable reductions in T/M/V as it provides reduction of T/M/V through mass destruction, but has the longest timeframe for success (five years) and may also be limited by inadequate air-phase contact in the saprolite.

10.1.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement a remedy and any adverse impacts that may be posed to workers, the community and the environment during construction and operation of the remedy until cleanup levels are achieved.

Alternatives UZ #4 (ISCO with Shallow Soil Mixing) and UZ #3 (Soil Excavation) were ranked similarly because both alternatives would have minimal environmental impacts with prudent safeguards, and a relatively short implementation timeframe. The excavation alternative (UZ #3) increases the potential for impacts to the community and workers via fugitive emissions and truck traffic, although these issues can be effectively managed. The use of oxidants for UZ #4 carries the potential for spills and chemical injuries. Alternative UZ #2 (SVE) is limited by non-uniform air contact with soils and would have the longest timeframe for meeting RAOs. SVE has few construction concerns, but does have the potential for excursions of untreated air upon vapor phase carbon breakthrough.

10.1.6 Implementability

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

Each of the three active alternatives for the UZ should be implementable with little differentiation. Alternative UZ #2 (SVE), was scored the highest because it would be simplest to construct, easier to monitor for remedial effectiveness and simpler to modify with minor Site disruption. However, this alternative has the longest implementation timeframe (5 years). Alternative UZ #3 (Soil Excavation) would be easy to implement and monitor for remedial effectiveness, but may require more significant structural mitigations or expanded removal of the building. UZ #4 (ISCO with Shallow Soil Mixing) would be easy to implement to depth, but may have uncertainties related to clumping of clayey soils in the saprolite.

10.1.7 Cost

The cost criterion involves an evaluation of the capital costs, the annual O&M costs, and a present worth analysis. The cost estimates are order-of-magnitude level estimates, which are defined by the American Association of Cost Engineers as approximate estimates made without detailed engineering data. It is normally expected that an estimate of this type would be accurate to +50 percent and -30 percent. The actual costs of the project would depend on the final scope of the RA, the schedule of implementation, actual labor, material costs at the time of implementation, competitive market conditions, and other variable factors that may impact the project costs. The NPW for each alternative was developed using the modified uniform present value method. In accordance with current EPA guidance, Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-75, July 2000, a discount rate of 7 % before taxes and after inflation (for a non-Federal facility) was used to account for the time value of money. Costs for the implementation of statutory FYRs and groundwater monitoring are included as the site-wide Costs. These costs were estimated separately as they apply to all remedy alternatives since waste will remain in place at the Site.

The three action alternatives for the UZ vary considerably in capital and annual O&M costs. Alternative UZ #3 (Soil Excavation) had the highest projected net worth cost ($1,873,000; $2,722,680 if the Cristex building is completely removed and an expanded area is excavated), owing partly to the high capital cost associated with off-site transport and disposal (there are no O&M costs associated with this alternative). Alternative UZ #2 (SVE) had the lowest capital cost but the highest O&M cost and the second highest NPW cost ($1,607,400). Alternative UZ #4 (ISCO with Shallow Soil Mixing) had the lowest NPW cost ($1,370,800).

10.2 Saturated Source Zone

10.2.1 Overall Protection of HH&E

The No Action alternative (SSZ #1) was not considered to be protective of HH&E. The four action alternatives for the SSZ scored well for protection of HH&E with little significant differentiation between them. Each alternative would conceptually reduce the contaminant mass; what varies most between the alternatives is the expected efficiency and surety of successful remediation. Alternative SSZ #3, EK-ISCO is the most aggressive of the approaches and is projected to achieve effective mass reduction in a timeframe of 2 years. Each of the three remaining active approaches relies on a biological or chemical reduction process to achieve mass reduction and are, therefore, somewhat less aggressive than achieving mass reduction via chemical oxidation. Alternatives SSZ #2 (EISB with ISCR) and SSZ #5 (BiRD) would provide slightly less protection for HH&E due to their reliance on reducing geochemical conditions and the potentially longer treatment timeframe. Alternative SSZ #2 scored the lowest as it relies on direct injection only for amendment distribution and could be less effective.

10.2.2 Compliance with ARARs

The No Action alternative (SSZ #1) would not meet ARARs. The biggest discriminator between the various action alternatives for the SSZ is the surety and timeframe in which they would comply with the ARARs. Alternatives SSZ #3 (EK-ISCO) and SSZ #4 (EK-BIO) each have a projected timeframe of 2 years and have a more aggressive method for achieving contact between COCs and chemical amendments. Although not directly ARAR related, EK-ISCO has a few more operational and permitting concerns related to U.S. Department of Homeland Security Chemical Facility Anti-Terrorism Standard for use of specific oxidants. State-specific underground injection control (UIC) well requirements apply to injections of reagents into the groundwater and require protection of the water quality. Achieving compliance with chemical-specific ARARs under Alternative SSZ #5 (BiRD with Recirculation) depends on the rate of formation of iron sulfide complexes under specific biogeochemical conditions. Mineralogical testing to further support this treatment approach has not been completed; hence this alternative has a less rigorous design basis. Alternative SSZ #2 (EISB with Chemical Reduction) is the least reliable approach for meeting chemical-specific ARARs since it has more uncertainty with respect to the subsurface distribution of amendments and may be more reliant on COC desorption and natural transport within the saprolite. All of the alternatives provide reasonable assurances of meeting the location- and action-specific ARARs.

The following five Balancing Criteria were not evaluated for the No Action alternative (SSZ #1) because it would fail to satisfy the Threshold Criteria of Overall Protectiveness of HH&E and Compliance with ARARs.

10.2.3 Long-Term Effectiveness and Permanence

The rankings for long-term effectiveness and permanence are very similar for the four SSZ action alternatives and there was little differentiation between the remedies. All of the remedies evaluated would achieve similar outcomes with successful long-term results. Alternatives SSZ #3 (EK-ISCO) and SSZ #4 (EK-BIO) are the highest rated as they should have the fewest post-remediation risks and provide a dynamic control mechanism for real time adjustments in amendment distribution. The success of the EK-ISCO alternative is sensitive to the oxidant dosing, although the remedy allows for continued oxidant inputs as needed. EK-ISCO and EK-BIO have relative tradeoffs for overall effectiveness: EK-ISCO (SSZ #3) is a more robust remedy; EK-BIO (SSZ #4) is more compatible with the reduced chemistry of the down-gradient biobarrier. The comparatively innovative status of EK lowered the overall scoring for SSZ #3 and SSZ #4 as this supplemental technology is less proven. The BiRD (SSZ #5) and EISB/ISCR (SSZ #2) remedies had slightly lower rankings due to the added concern of changing and maintaining the subsurface site geochemistry to a reduced state for these remedies to be effective.

10.2.4 Reduction of Toxicity, Mobility or Volume through Treatment

All of the action alternatives for the SSZ would achieve similar reductions in T/M/V with a projection for successful long-term results. The two biobarrier alternatives (SSZ #2 and SSZ #3) and the BiRD recirculation (SSZ #5) alternative all provide good restrictions on down-gradient mobility in the saprolite and transition zone. With proper engineering, all alternatives are capable of complete reductions in toxicity and volume. Alternative SSZ #3, EK-ISCO was rated marginally higher for being the most aggressive option. Alternative SSZ #5 (BiRD) was ranked slightly lower than the other two active treatment approaches due to uncertainty with the overall effectiveness of the phased biogeochemical treatment approach and a lack of bench scale test results. However, the recirculation approach with the BiRD remedy would remediate marginal levels of dissolved contamination around the SSZ as an ancillary benefit.

10.2.5 Short-Term Effectiveness

All of the active alternatives for the SSZ provide good short-term effectiveness. They are all equally protective of workers and the community during RA and have no anticipated environmental impacts. EK-ISCO (SSZ #3) has a marginal advantage over EK-BIO (SSZ #4) in that the more aggressive ISCO approach should obtain RAOs faster. The electrokinetic enhanced alternatives ranked best as they are projected to have shorter remedial timeframes than either SSZ #2 (EISB with Chemical Reduction) or SSZ #5 (BiRD with Recirculation).

10.2.6 Implementability

All of the alternatives evaluated for the SSZ are implementable with only minor issues and have equivalent ratings. SSZ #5 (BiRD) was scored lowest due to the higher complexity of the geochemical reactions. Alternatives SSZ #3 and SSZ #4 could have implementation issues related to their complexity and the innovative nature of EK; but counter this with potentially higher remedial effectiveness. All of the remedies depend on reliable technology that is easy to construct and implement. The two options using electrokinetics, SSZ #3 and SSZ #4, do rely on

a patented technology that rely on limited vendors, which could present scheduling issues during implementation.

10.2.7 Cost

Costs for the active SSZ remedial alternatives ranged varied between $3.6M and $4.6M. All had significant capital and annual O&M costs. The EK-ISCO alternative (SSZ #3) had the highest NPW cost ($4,609,100), primarily due to the vendor and chemical cost for injection. Alternatives SSZ #4 (EK-BIO) and SSZ #5 (BiRD) were the next most expensive options ($4,409,100 and $4,054,900, respectively); the BiRD alternative had the highest estimated annual O&M costs ($1,365,336) due to higher personnel and chemical costs. Alternative SSZ #2 (EISB with Chemical Reduction) was projected as the lowest cost alternative for active remedies ($3,554,300).

10.3 Dilute Plume

10.3.1 Overall Protection of HH&E

The No Action alternative (DP #1) was not considered to be protective of HH&E. Alternative DP #3 (Hydraulic Capture/Containment) is expected to provide the highest level of protection for HH&E as it provides both hydraulic containment and long-term mass reduction. Alternative DP #2 (EISB Biobarrier) was subjectively scored next as it creates a passive treatment wall that will treat groundwater as it continues to flow down-gradient. DP #2 will effectively limit any significant dissolved phase contamination from migrating past the barrier, but will not accelerate the mass recovery and subsequent treatment to the extent that the hydraulic containment option does. DP #4 (MNA) is the least protective of the three active approaches evaluated as it provides only for monitoring of the plume and evaluation of conditions favorable to MNA.

10.3.2 Compliance with ARARs

Compliance with ARARs is best afforded by Alternatives DP #3 (Hydraulic Capture / Containment) and DP #2 (EISB Biobarrier). Both of these options provide a good level of treatment or capture of COCs in the DP to preclude off-site migration and contact with COCs in groundwater above Remedial Goal Options (RGOs). DP #3 provides better overall surety as the positive hydraulic control will prevent excursions within the capture zone. DP #2 is expected to have the most comprehensive success at reducing the contiguous adsorbed phase mass at and immediately down-gradient of the barrier. The MNA alternative (DP #4) was scored low based upon the lack of treatment. All of the alternatives provide reasonable assurances of meeting the location- and action-specific ARARs. The No Action alternative (DP #1) would not meet ARARs.

The following five Balancing Criteria were not evaluated for the No Action alternative (DP #1) because it would fail to satisfy the Threshold Criteria of Overall Protectiveness of HH&E and Compliance with ARARs.

10.3.3 Long-Term Effectiveness and Permanence Dilute Plume

Alternatives DP #3 (Hydraulic Capture/Containment) and DP #2 (EISB Biobarrier), offer containment and COC removal and have adequate and reliable controls, but will require the same

long-term monitoring as required for DP #4 (MNA). Functionally, remedies DP #2 and DP #3 are similar; both will treat the groundwater flux and contain a portion of the dissolved plume. These alternatives should have no significant issues with residual risks, reliability, or treatment irreversibility. Both remedies are susceptible to long-term O&M costs in the event that SSZ remediation does not adequately limit the incoming flux of COCs; DP #3 through continued operating costs and DP #2 through reinjections of substrate. Alternative DP #2 depends on direct hydraulic contact that could be limited in the heterogeneous subsurface lithology. DP # 3 relies on long-term back diffusion of COCs from transition zone soil.

10.3.4 Reduction of Toxicity, Mobility or Volume through Treatment

Alternatives DP #3 (Hydraulic Capture and Containment) and DP #2 (EISB Biobarrier) have equivalent rankings for reduction of T/M/V. DP #2 is an active treatment approach that destroys contaminants; hence it is expected to effectively reduce toxicity and mobility and ultimately reduce the plume volume. The EISB barrier would require complete sequential degradation through vinyl chloride to prevent residual risks from vinyl chloride. Bioaugmentation should provide the engineering control to meet this goal. Alternative DP #3 provides greater reductions in mobility and volume, but would be less effective in the short-term at lowering adsorbed phase COCs. MNA, alternative DP #4, scored lower as it lacks active treatment. However, the presence of PCE degradation products implies that natural attenuation occurs to a limited extent at the site, although it is uncertain whether biotic or abiotic processes predominate. In this regard, MNA may be viable with the up-gradient source zone treated.

10.3.5 Short-Term Effectiveness

None of the active remedies for the UZ would have a distinguishable difference in community impacts or worker protection. All options are generally protective of the local community, though MNA (DP #4) has the greatest uncertainty regarding the overall remedial timeframe. The EISB with Biobarriers (DP #2) and Hydraulic Capture and Containment (DP #3) alternatives provide good short-term effectiveness and are protective of workers and the community during RA. Alternative DP #3 should be more effective at meeting RAOs in a shorter timeframe. This benefit is offset by the potentially longer operational timeframe and ongoing emission of treated exhaust.

10.3.6 Implementability

All of the action alternatives evaluated for the DP are implementable with only minor issues and have similar cumulative ranks. The MNA alternative (DP #4) was scored lower since NA may not be a reliable treatment method based on Site geochemical conditions. DP #2 (EISB Biobarrier) offers more complexity due to the reliance on establishing and maintaining reduced conditions. All remedies offer reliable and proven technology that is easy to implement, though the hydraulic capture and containment system (DP #3) is more easily modified.

10.3.7 Cost

Costs for the DP zone active remedial alternatives varied widely. Projected NPW costs for DP #2 (EISB Biobarrier; $2,264,500) and DP #3 (Hydraulic Capture/Containment; $1,757,500) are relatively high due largely to O&M costs for labor and chemicals. Alternative DP #3 (Hydraulic Capture/Containment) has slightly lower projected capital costs, but O&M costs are higher due

to a projected longer term operation. MNA (DP #4) is the least costly of the active alternatives ($189,000) and has no associated capital cost.

11.0 Principal Threat Waste (PTW)

The NCP establishes an expectation that the EPA will address the principal threats posed by a site through treatment wherever practicable (NCP §300.430(a)(1)(iii)(A)). PTW is defined on a site-specific basis for source material that acts as a reservoir for migration of contaminants or acts as a source for direct exposure. In general, the priority for treatment for PTW is placed on source materials considered to be liquid, highly toxic and/or highly mobile, which generally cannot be contained in a reliable manner or would present a significant risk to human health or the environment should exposure occur. NAPL and DNAPL are considered as principal threat wastes under EPA Superfund Publication 9380.3-06FS, "A Guide to Principal Threat and Low Level Threat Wastes" (EPA, 1991), and there is an expectation in the NCP to treat such wastes wherever practicable unless EPA determines that such wastes can be reliably contained. Highly contaminated soil can also be PTW when considered highly toxic, or would present significant risk to human health should exposure occur, or it acts as reservoir for mobile contaminants.

Where the EPA determines that it is not practical to use treatment to address PTW, the material may be transported off-site for disposal, consistent with Off-Site Rule, 40 CFR 300.440, or contained on-site provided it is protective of HH&E and complies with all ARARs. Engineering controls, such as containment and consolidation in a cell that has a secure liner and final cover system, may be used for such wastes that pose a relatively low long-term threat or where treatment is deemed impracticable.

Investigations at the Cristex Drum Site did not positively identify residual NAPL or DNAPL on the surface or in the subsurface of the site although residual DNAPL is suspected in the unsaturated zone. Consequently, there is no direct indication that there is source material at the Site that would be classified as a PTW with the exception of a single surface soil boring which contained a subsurface soil concentration of PCE of 180,000 µg/kg (location CR01SB sampled May 19, 2010 at 3 ft bgs). This sample result coupled with elevated concentrations of CVOC measured during the MiHPT investigation suggest that residual NAPL or DNAPL locally may be present east of the Cristex building. Any NAPL- or DNAPL-impacted subsurface soils would be identified as PTW.

12.0 Selected Remedy

12.1 Summary of the Rationale for the Selected Remedy

The Selected Remedy for the Cristex Drum Site is:

- Unsaturated Zone: Soil Excavation (Alternative UZ #3);
- Saturated Source Zone: EK-ISCO with Biobarriers (Alternative SSZ #3); and
- Dilute Plume: EISB Biobarriers (Alternative DP #2).

These alternatives were chosen based on the comparative analysis of all of the alternatives. The Selected Remedy meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to balancing and modifying criteria. The EPA and NCDEQ

determined that the Preferred Alternative presented in the Proposed Plan best satisfies the nine criteria of the NCP as compared to the other alternatives.

Based on the information available at this time, the EPA and NCDEQ believe that the Selected Remedy combination satisfies the following statutory requirements of CERCLA Section 121(b) and Section 121(d): 1) protects HH&E; 2) complies with ARARs; 3) is cost effective; 4) utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and 5) satisfies the preference for treatment as a principal element. Alternatives UZ #3, SSZ #3 and DP #2 in combination and conjunction with the previous Interim Removal Actions performed in 1997 and 2001, will achieve substantial risk reduction to all potential exposures routes in a reasonable timeframe. The *in situ* treatment of COCs will over time reduce groundwater contamination and eventually restore groundwater to attain cleanup levels throughout the plumes.

The modifying criteria of State and Community Acceptance have been incorporated into the selected remedy. The State of North Carolina, as represented by NCDEQ, has been the support agency during the RI/FS process. NCDEQ provided input during the process in accordance with 40 CFR §300.430 and concurs with the selected remedies for each CMZ (Appendix D). The community has participated in the review of the Proposed Plan, and based on the comments received, supports the Selected Remedy (Appendix B).

12.2 Description of the Selected Remedy

12.2.1 Unsaturated Zone

Alternative UZ #3 (Soil Excavation) is the selected remedy for the unsaturated zone. **Figure 12** illustrates this remedy. The remedy consists of demolishing a portion or complete part of the Cristex building including foundations and the former drum storage pad, excavating the majority of the UZ to remove a total of approximately 12,444 cy of CVOC-contaminated soil from the suspected source area, and transporting the demolition debris and excavated soil to an offsite, EPA approved, permitted disposal facility. The soil would be excavated to a depth of approximately 20 ft bgs with 3,935 cy excavated from sloped sidewalls to remove CVOC-contaminated soil from the suspected source area: the former drum storage pad. The soils and demolition debris may be staged temporarily prior to transport off-site. As part of the Remedial Design, a plan will be developed to conduct sampling of the unsaturated zone beneath the building slab to determine if additional building demolition and soil excavation are required to meet the Remedial Goals. The excavated area will be backfilled with clean fill. Excavated soil will be characterized based on waste profile sampling and analysis (e.g. TCLP result) to determine if it must be managed as RCRA hazardous waste. Any soils exceeding the Subtitle D Landfill requirements or exceeding a RCRA characteristic hazardous waste threshold (i.e., fails TCLP) will be segregated for treatment and disposal at an off-site permitted RCRA Subtitle C hazardous waste landfill. Treatment of the soils to meet RCRA LDR treatment standards would be performed at an off-site permitted facility.

Alternative UZ #3 would remove a large volume of the suspected source area (highest contaminant mass) and any NAPL or residual DNAPL present in the UZ. Soil excavation can be completed in a short timeframe, and will likely reduce or eliminate VI issues on-site. Removal of contaminated soil would result in permanent removal of contaminants from the Site. This

alternative is easy to implement, is protective of HH&E and can be implemented in a short timeframe with minimal disruption to the community.

The selected remedy for the unsaturated zone has an estimated capital cost of $1,873,000. Expanded building demolition and excavation would increase the capital cost by $849,600. Because contaminated soil would be excavated and removed, there are no O&M costs associated with this remedy.

12.2.2 Saturated Source Zone

The selected remedy for the saturated source zone is EK-ISCO with Biobarriers (Alternative SSZ #3). The selected remedy for the SSZ is illustrated in **Figure 12**. This remedy will inject a chemical oxidant through a dense array of injection wells installed in the southern half of the SSZ to destroy the contaminants in the subsurface. A direct current applied to the subsurface (electrokinetics) will enhance the transport of oxidant through the area to enhance contact of the oxidant with COCs. The EK-ISCO approach will target the suspected source area and the most strongly contaminated portion of the SSZ where residual DNAPL and adsorbed phase CVOCs may be present. EISB biobarriers will be installed down-gradient of the ISCO array to accelerate degradation of dissolved contamination in the northern half of the SSZ, which has lower contaminant concentrations primarily in the dissolved phase. To implement this alternative, a portion of the building will be demolished and the concrete foundation and former drum storage pad will be removed. The demolition debris and any excavated soil will be characterized, temporarily staged and then transported to an offsite, EPA approved, permitted disposal facility. The selected remedy includes performance monitoring and installation of performance MWs.

Application of EK augments amendment distribution and increases contact between the oxidant and contaminants. The electrical current will be applied through a series of anode/cathode wells installed in the subsurface to the top of bedrock. The applied voltage gradient will result in the bulk movement of groundwater and chemical oxidant from one electrode to another. The chemical oxidant, assumed to be sodium permanganate ($NaMnO_4$), will destroy residual DNAPL, CVOCs adsorbed on saturated soil, and CVOCs dissolved in groundwater. Organic compounds in contact with the oxidant would be quickly oxidized; thereby eliminating contaminant mass available for dissolution and lateral transport in groundwater.

EISB passive barriers will be installed by subsurface injection across the mid-point and toe of the SSZ. The injection wells will be injected with emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater. Dissolved contamination migrating through the barrier in response to the local hydraulic gradient will be destroyed by chemical reduction. Alternative SSZ #3 will provide aggressive treatment of the contaminated soil and groundwater expected to be present in the SSZ. This alternative will be easy to implement, is protective of HH&E and can be implemented in a short timeframe with minimal disruption to the community. The ISCO component itself is proven and fully developed; however, the EK element is still considered innovative.

The selected remedy for the SSZ has an estimated capital cost of $3,710,700 and NPW O&M expense of approximately $899,000. O&M costs include monitoring of contaminant

concentrations following the initial injection, reinjection of oxidants to address contaminant rebound, and long-term performance monitoring.

12.2.3 Dilute Plume

The selected remedy for the dilute plume is EISB Biobarriers (Alternative DP #2). Figure 12 illustrates the selected remedy for the DP. This remedy will create a barrier wall in the bedrock aquifer at the toe of the SSZ down-gradient of the main source contamination. The barrier would be created by injecting emulsified oil amendments through wells to create chemically reducing conditions in the subsurface; these amendments would be potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater. The carbon substrate would be designed to potentially provide a long-term source of carbon lasting from 2 to 5 years to treat COCs in groundwater flowing through the area. Other amendments could be added if deemed necessary for down-gradient treatment and to improve barrier performance and longevity. Should additional investigation indicate higher than expected concentrations in the bedrock aquifer, a second row of injection wells may be necessary further down-gradient (not considered in projected remedy cost). The remedy includes performance monitoring and installation of performance MWs.

The injection wells will be screened in the transition zone and bedrock aquifer utilizing a tight well spacing that provides overlapping coverage. Injection is expected to create a zone of reduced conditions down-gradient from the barriers. Performance monitoring will be used to identify whether a follow-up injection is required during the first five years of operation. The required operational period is contingent on the effectiveness of up-gradient source reduction in the UZ and SSZ.

The selected remedy will be easy to construct, is protective of HH&E. It offers a proven, reliable, scalable, and effective means for treatment of the dissolved-phase contamination. Biobarriers are also a component of the selected remedy for the SSZ allowing the remedies for these two CMZs to be coordinated to optimize the effectiveness in both zones. Success of the DP remedy depends on application of sufficient amendments to generate highly reducing conditions and stimulate bioremediation, and provide sufficient contact with contamination. The addition of colloidal carbon to enhance the biobarrier performance may be further evaluated at the design stage following treatability testing.

The selected remedy for the DP has an estimated capital cost of $1,201,400 and projected NPW O&M cost of $1,063,000. O&M costs include monitoring of contaminant concentrations following the initial injection, reinjection of reductants to address contaminant rebound, and long-term performance monitoring.

12.2.4 Institutional Controls

ICs will be required as part of the selected remedy because contaminants will remain at levels above that suited for unlimited use and unrestricted exposure despite treatment of contamination in the SSZ and UZ.

The following generally describes those ICs to be considered for implementation at the Site to achieve the bulleted performance objectives:

- Prohibit installation of potable and groundwater wells at the site.
- Prohibit any consumptive use of groundwater including but not limited to drinking water, irrigation or industrial use.
- Prohibit intrusive activities such as excavation in the contaminated media areas.
- Prevent interference with the integrity of any existing or future monitoring or remediation system.

ICs will be placed on the property using the State of North Carolina Declaration of Perpetual Land Use Restrictions process, which requires the recordation of a survey plat map defining the boundaries of the Site and a Notice of Contaminated Site filed in County real property records in accordance with North Carolina General Statutes (NCGSs) 143B-279.9 and 143B-279.10. Restrictive covenants, if possible, could be executed by the property owners and recorded that outline land and groundwater use restrictions including the prohibition of any residential, industrial, or recreational reuse of the property unless prior written approval is obtained from EPA and NCDEQ. The covenant would also prohibit interference with the integrity of any existing or future monitoring or remediation system without prior EPA and NCDEQ approval. Notice of the application of land and groundwater use restrictions to the Site via the restrictive covenant would be provided to the local regulatory agencies.

12.3 Cost Estimate for the Selected Remedy

The estimated total NPW cost for the Selected Remedy is $8.8 million. This includes $1,873,000 for the UZ remedy, $4,609,700 for the SSZ remedy, $2,264,500 for the DP remedy, and $51,000 in site-wide costs (5-year reviews, sampling and monitoring, and ICs). The cost estimate for the Selected Remedy is included in **Table 11.** Detailed cost breakdown sheets of the components of each alternative are included in **Appendix E**. The cost estimate is based on the available information regarding the anticipated scope of the RA. Changes in the cost elements are likely to occur as a result of new information and data collected during the remedial design phase. Major changes may be documented in the form of a memorandum to the AR file, an Explanation of Significant Differences (ESD), or a ROD Amendment. The projected cost is based on an order-of-magnitude engineering cost estimate that is expected to be within +50 or -30 percent of the actual project cost. Costs are based on the conservative estimate of a 30-year timeframe until all cleanup levels are met.

12.4 Estimated Outcomes of the Selected Remedy

The Selected Remedy will protect HH&E by eliminating, reducing, or controlling risks at the Site through physical removal of waste from areas of access by receptors, monitoring of engineering controls, and implementation of the ICs. The selected remedy aggressively targets the area where highest contaminant concentrations were identified in the UZ (excavation) and SSZ (EK-ISCO). Future land use of the Site property is anticipated to continue to be industrial/commercial with the remediated area to remain as undeveloped land.

Implementation of the Selected Remedy and achievement of the final cleanup levels will accomplish the final site-wide RAOs for the Site. The final cleanup levels determined for this remedy are the same as those determined during the FS, and are shown in **Tables 9 and 10**.

13.0 Statutory Determination

Based on the information currently available, the EPA believes the Selected Remedy for each of the three CMZs meets the Threshold Criteria and provides the best balance of tradeoffs among the other alternatives with respect to the Balancing and Modifying Criteria. The EPA expects the Selected Remedy will satisfy the following statutory requirements of CERCLA Section 121(b):

- Be protective of HH&E.
- Comply with ARARs;
- Be cost effective; and
- Use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

13.1 Protection of HH&E

Protection of HH&E will be achieved by removal of the top 20 ft of contaminated soils in suspected source areas, and contaminant destruction using ISCO and EISB. Excavating contaminated unsaturated soil will eliminate potential risk to humans and animals at the Site, although it will transfer contaminants to a landfill. Chemical oxidation of contaminants in the saturated soils and groundwater would permanently destroy organic compounds and would not result in the formation of daughter products. Electrokinetics is expected to increase contact between the oxidant and contaminants in the tight formations underlying the site thereby decreasing the potential for significant untreated contaminants to remain behind. The dilute plume remedy may be limited by the low permeability of the formation and imperfect knowledge of fracture orientations and their control on subsurface fluid flow; the DP remedy will not address contamination that has already migrated to locations down-gradient of the barrier.

13.2 Compliance with ARARs

Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that RAs at CERCLA sites attain legally applicable or relevant and appropriate federal and more stringent state requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA section 121(d)(4). The Selected Remedy will comply with all ARARs and To Be Considered guidance presented in **Tables 12, 13 and 14**.

The excavation component (UZ #3) will meet action-specific ARARs related to controlling stormwater runoff and fugitive dust emissions during land disturbing activities and RCRA requirements for characterization, temporary storage and off-site treatment of contaminated soil and demolition debris (when necessary for RCRA hazardous wastes) and disposal. The *in situ* groundwater and soil treatment components (SSZ #3 and DP #2) will meet action-specific ARARs which include underground injection and remediation wells requirements as well as requirements for installation of groundwater monitoring wells. The treatment components (SSZ #3 and DP #2) both meet the location-specific ARARs. Location-specific ARARs do not apply to the excavation component (UZ #3). Treatment components are expected to meet cleanup levels for the groundwater COCs that are based upon chemical-specific ARARs which include MCLs and more stringent NC groundwater quality standards at 15A NCAC 02L.0202.

Groundwater monitoring will be used to document attainment of chemical-specific ARARs throughout the plumes.

13.3 Cost Effectiveness

The EPA has determined that the Selected Remedy is cost-effective and that the overall protectiveness of the remedy is proportional to the overall cost. As specified 40 CFR §300.430(f)(1)(ii)(D), the cost-effectiveness of the Selected Remedy was assessed by comparing the protectiveness of human-health and the environment in relation to three balancing criteria (i.e., long-term effectiveness and permanence; reduction in T/M/V; and short-term effectiveness) with the other alternatives considered.

The basis for the EPA's determination of cost-effectiveness is summarized in **Table 15**. While more than one remedial alternative can be considered cost-effective, CERCLA does not mandate that the most cost-effective or least expensive remedy be selected. The estimated total cost (i.e., capital plus present worth of O&M costs) of the Selected Remedy is $8.8M at a seven percent discount rate.

13.4 Use of Permanent Solutions and Alternative Treatment Technologies to the Maximum Extent Practicable

The Selected Remedy uses permanent solutions and alternative treatment solutions to the maximum extent practicable. The Selected Remedy will provide an acceptable degree of long-term effectiveness and permanence. The remedy will require ICs until it is demonstrated that groundwater cleanup goals are obtained, but these remedy components are neither unusual nor exceptional in degree or cost. The remedy can be reliably considered permanent.

13.5 Preference for Treatment as a Principal Element

The NCP at 40 CFR §300.430(a)(I)(iii)(A) establishes an expectation that treatment will be used to address PTW posed by a site wherever practicable. In general, the priority for treatment for PTW is placed on source materials considered to be liquid, highly toxic or highly mobile, which generally cannot be contained in a reliable manner or would present a significant risk to human health or the environment should exposure occur. NAPL and DNAPL are considered a principal threat wastes under EPA guidance and there is an expectation in the NCP to treat such wastes wherever practicable unless EPA determines that such wastes can be reliably contained. Highly contaminated soil can also be PTW when considered highly toxic, or would present significant risk to human health should exposure occur, or it acts as reservoir for mobile contaminants.

A DNAPL phase was not identified in samples collected from the Cristex Drum Site. However, its presence is inferred from elevated contaminant concentrations in a few analytical samples and probing of the subsurface using a MIP and electron capture detector. The area where DNAPL may be present is being addressed through excavation and treatment using a chemical oxidant. While excavation will remove contaminants from the Site, chemical treatment by oxidation will destroy contaminants that are adsorbed to soil, present as residual DNAPL, and present in dissolved form. Contamination that occurs in lower concentrations down-gradient of the suspected source area is being addressed by treatment using a chemical reductant that is also expected to destroy the COCs. COCs will be destroyed as they pass through treatment barriers

preventing migration to down-gradient areas. To the greatest extent practical, these *in situ* treatment components of the remedy satisfy the statutory preference for reducing the toxicity, mobility, and volume of hazardous substances through treatment.

13.6 Five-Year Review Requirements

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of the RA to ensure that the Selected Remedy is, or will be, protective of HH&E. The EPA will conduct a FYR as specified by 40 CFR §300.430(f)(4)(ii) in accordance with EPA policy and guidance until levels that allow for unlimited use and unrestricted exposures are achieved. If results of the five-year reviews reveal that remedy integrity is compromised and protection of human health is insufficient, then additional remedial actions will be evaluated by the EPA and NCDEQ.

14.0 Documentation of Significant Changes

Pursuant to CERCLA 117(b) and NCP §300.430(f)(3)(ii), the ROD must document any significant changes made to the Preferred Alternative discussed in the Proposed Plan. The Proposed Plan, which was released for public comment in June 2017, identified Alternatives UZ #3 (Soil Excavation), SSZ #3 (EK-ISCO with Biobarriers), and DP #2 (EISB Biobarriers) as the site-wide Preferred Remedy for the Cristex Drum Site. ICs to restrict land use, and prevent disturbance of on-site engineering controls (e.g., capped area) are included in the Selected Remedy. The ICs may include a restrictive covenant, property deed notice, and governmental controls such as local ordinances or zoning restrictions.

The EPA reviewed all written and verbal comments submitted during the public comment period. It was determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

15.0 References

AECOM, 2014. *Summary Report of Membrane Interface Probe and Direct-Push Technique Investigations and Work Plan – Revised January 2014*, JFD Electronics/Channel Master Site, 620 West Industry Drive, Oxford, North Carolina. Prepared by AECOM, Raleigh, North Carolina for JFD Electronics/CMSS, Inc.

Black & Veatch, 2016a. Black & Veatch Special Projects Corp. *Remedial Investigation Report for the Cristex Drum Site, Oxford, Granville County, NC, Revision 1*, December, 2016. Prepared by Black & Veatch Special Projects Corp. for EPA Region 4.

Black & Veatch, 2016b. Black & Veatch Special Projects Corp. *Human Health Risk Assessment for the Cristex Drum Site, Oxford, Granville County, NC, Revision 1*, December, 2016. Prepared by Black & Veatch Special Projects Corp. for EPA Region 4.

Black & Veatch, 2016c. Black & Veatch Special Projects Corp. *Ecological Risk Assessment for the Cristex Drum Site, Oxford, Granville County, NC, Revision 1*, December, 2016. Prepared by Black & Veatch Special Projects Corp. for EPA Region 4.

Black & Veatch, 2017a. Black & Veatch Special Projects Corp. *Feasibility Study Report for the Cristex Drum Site, Oxford, Granville County, NC, Revision 1*, March, 2017. Prepared by Black & Veatch Special Projects Corp. for EPA Region 4.

Black & Veatch, 2017b. Black & Veatch Special Projects Corp. *Remedial Investigation Addendum for the Ram Leather Care Site, Charlotte, Mecklenburg County, NC, Revision 3*, March, 2017. Prepared by Black & Veatch Special Projects Corp. for EPA Region 4.

EPA, 1991 (November). U.S. Environmental Protection Agency, *A Guide to Principal Threat and Low Level Threat Wastes*. OSWER Directive 9380.06FS.

EPA, 1992 (January). U.S. Environmental Protection Agency, *National Oil and Hazardous Substances Pollution Contingency Plan (NCP)*. EPA 540-Z-00-001.

EPA, 2013a (May). U.S. Environmental Protection Agency, *HRS Documentation Record,* Cristex Drum, NC0 001 606 250.

EPA, 2013b (December 12). U.S. Environmental Protection Agency, National Priorities List, Final Rule No. 57. Federal Register, vol. 78, no. 239, pp. 75475-75482.

EPA, 2014 (January). U.S. Environmental Protection Agency, *Region 4 Human Health Risk Assessment Supplemental Guidance. EPA Region 4 Technical Services Section, Superfund Division*. January 2014. *https://www.epa.gov/risk/region-4-human-health-risk-assessment-supplemental-guidance*

EPA (U.S. Environmental Protection Agency), 2017 (May). Proposed Plan Fact Sheet, Cristex Drum Site, Oxford, Granville County, NC.

Harned, D.A. and Daniel, III, C.C., 1989. The Transition Zone between Bedrock and Regolith: Conduit for Contamination? In: C.C. Daniel, III, R.K. White, and P.A. Stone, eds. Ground Water in the Piedmont, Proceedings of a Conference on Ground Water in the Piedmont of the Eastern United States, October 16-18, 1989, Charlotte, NC. Clemson University, pp. 336-348.

Heath, R.C., 1980. Basic Elements of Ground-Water Hydrology with Reference to Conditions in North Carolina. U.S. Geological Survey Water Resources Investigations Open-File Report 80-44.

NCDENR, 2012 (May 15). North Carolina Department of Environment and Natural Resources. Integrated Expanded Site Inspection (iESI), Cristex Drum Site (NC0 001 606 250), Oxford, Granville County, North Carolina. Prepared by Jeanette Stanley, Division of Waste Management, Superfund Section.

PART 3: RESPONSIVENESS SUMMARY

This Responsiveness Summary is the third and final part of the Record of Decision (ROD) for the Cristex Drum Site. There was one comment received during the public comment period. On behalf of JFD Electronics Corporation and CMSS, Inc., AECOM submitted concerns regarding the EPA's Remedial Investigation (RI), Feasibility Study (FS) and the Proposed Plan. The comments stated that the Cristex investigation is substantially incomplete because dissolved groundwater contamination from the Cristex Drum Site comingles with groundwater contamination from the JFD Electronics/Channel Master NPL Site (JFD/CM site) in an area south and east of the railway that separates the properties. In addition, they stated that the RI fails to delimit the down-gradient lateral extent of groundwater contamination from Cristex sources. The groundwater contamination is at least 340 feet and beyond that distance the RI concludes the extent is uncertain.

The EPA has delineated the Cristex site. From January 2014 – March 2017, the EPA's Contractor (Black & Veatch) conducted several environmental investigations at site under NCDENR and EPA oversight. The Key Activities were as follows:

- Sampling and Analysis
  - Soil, Groundwater, Surface water and Sediments
- Hydrogeologic Investigation
  - Site Geology
  - Site Hydrogeology
- Risk Assessments
  - Human Health Risk Assessments
  - Ecological Risk Assessments

Soil and groundwater contamination requiring remediation at the Site was classified into three contaminated media zones (CMZs). A CMZ represents a portion of the Site contamination which has a particular characteristic, such as lithology, COC presence, depth, areal extent, and/or presence of DNAPL that defines the optimal remediation approach. Segregation of the Site into CMZs allows remedial alternatives to be tailored to these conditions, thereby resulting in a more economical and focused remedy.

The general remedial strategy at the Site is driven by the need to restore and protect the drinking water resource that exists under the Site. The remedial strategy for the Site, which utilizes an adaptive management approach is: (1) aggressive remediation of source contamination (e.g., soil and groundwater with high concentrations of contaminants or DNAPL); and (2) phased active remediation of groundwater in the greater dilute plume. Remediation will be optimized by targeting the highest levels of mass first. Restoration of the full DP zone will rely on monitored natural attenuation (MNA) to identify the flux reduction of COCs from source treatment and further evaluate the scope of treatment required for the DP.

As discussed in Section 3.0 (Community Participation), over 100 copies of the Proposed Plan Fact Sheet and Proposed Plan were distributed to the site mailing list in June 2017. The AR and information repositories were also updated with supporting documents. A formal 30-day public comment period on the Proposed Plan was held from June 20 to July 20, 2017. The EPA held a

public meeting on June 27, 2017 at the NC Cooperative Extension to present the results of the Remedial Investigation/Feasibility Study, its reasoning for the Proposed Alternative presented in the Proposed Plan, and to answer questions from the community. Approximately 15 people attended the meeting. A verbatim transcript of the June 27th public meeting is attached as Appendix C. Comments received on the Proposed Plan are attached as Appendix B. The comments responded to in this Responsiveness Summary were taken from the transcript of the public meeting for the Proposed Plan held on June 27, 2017 (Appendix C) and submitted to the EPA subsequent to the public meeting (Appendix B).

TABLES

Table 1: Summary of Groundwater Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, NC

		MCL[1]	NCAC 2L[2]	Number of Samples Analyzed[3]	Number of Samples ≥ Screening Value[3,4]	Number of Samples Non-detected at DL > Screening Value[3]	Concentration Minimum Median Maximum
Regolith Aquifer (Saprolite plus Transition Zone)							
BaP TEQ (calculated)	µg/L	0.2	0.005	24	3 of 3	21 of 24	0.1095 0.1156 U 0.1490
1,4-Dichlorobenzene	µg/L	75	6	33	1 of 30	30 of 33	0.5 U 5 U 11
Benzene	µg/L	5	1	33	4 of 13	20 of 33	0.1 J,O 5 U 70
cis-1,2-Dichloroethene	µg/L	70	70	33	9 of 33	0 of 33	0.21 J,O 5 U 2,900
Tetrachloroethene	µg/L	5	0.7	33	26 of 27	6 of 33	0.5 U 23 13,000
Trichloroethene	µg/L	5	3	33	16 of 23	10 of 33	0.5 U 5 U 620 J
Vinyl Chloride	µg/L	2	0.03	33	4 of 4	29 of 33	0.5 U 5 U 54
Bedrock Aquifer							
BaP TEQ	µg/L	0.2	0.005	3	1 of 3	2 of 3	0.1115 0.1156 U 0.1115
Bedrock Aquifer							
1,4-Dichlorobenzene	µg/L	75	6	3	0 of 3	0 of 3	5 U 5 U ---

Table 1: Summary of Groundwater Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, NC

		MCL[1]	NCAC 2L[2]	Number of Samples Analyzed[3]	Number of Samples ≥ Screening Value[3,4]	Number of Samples Non-detected at DL > Screening Value[3]	Concentration Minimum Median Maximum
Benzene	µg/L	5	1	3	0 of 0	3 of 3	5 U 5 U ---
cis-1,2-Dichloroethene	µg/L	70	70	3	1 of 3	0 of 3	1 J 2.7 J 76
Tetrachloroethene	µg/L	5	0.7	3	2 of 2	1 of 3	5 U 7.5 250
Trichloroethene	µg/L	5	3	3	1 of 2	1 of 3	1.3 J 5 U 28
Vinyl Chloride	µg/L	2	0.03	3	0 of 0	3 of 3	5 U 5 U ---

Notes:

1 - Maximum Contaminant Levels - National Primary Drinking Water Regulations, 40 CFR Part 141.

2 - North Carolina Groundwater Standards - 15A NCAC 02L.0202 (May, 2013).

3 - Data from Appendix E-4 in Black & Veatch (2016a) includes samples collected in 2015 from MIP temporary well points (11 locations) and samples collected from monitoring wells in 2016 (22 regolith and 3 bedrock locations). Sample counts exclude field duplicates.

4 - Excludes samples reported as non-detected at a reporting limit exceeding the screening value.

5 - Maximum is the maximum detected value; minimum and median include all results including non-detected values.

BaP TEQ - Benzo(a)pyrene toxic equivalents
CFR - Code of Federal Regulations
DL - Detection level
HHRA - Human health risk assessment (Black & Veatch, 2016b)
HQ - Hazard quotient
mg/kg - milligrams per kilogram
NA - Not applicable
NCAC - North Carolina Administrative Code
RSL - Regional screening level
SSL - Soil screening level
J,O - J: The reported value is an estimate; O: Other qualifiers may apply.
U - The analyte was not detected at or above the reporting limit; the value shown is the reporting limit.
Screening value used to determine sample exceedances

Table 2. Summary of Surface Water and Sediment Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, NC

		NCAC 02B Freshwater Aquatic Life[1]	Number of Samples Analyzed[2]	Number of Samples ≥ Screening Value[2,3]	Number of Samples Non-detected at DL > Screening Value[2]	Concentration[2,4] Minimum Median Maximum
Surface Water (2015 Samples)						
Copper	µg/L	2.7	5	1 of 1	4 of 5	10 U 10 U 12
Nickel	µg/L	16	5	1 of 5	0 of 5	10 U 10 U 16
Zinc	µg/L	36	5	1 of 5	0 of 5	10 U 10 U 38
		Refinement Screening Value[5]	**Number of Samples Analyzed[6]**	**Number of Samples ≥ Screening Value[3,6]**	**Number of Samples Non-detected at DL > Screening Value[6]**	**Concentration[4,6] Minimum Median Maximum**
Sediment (2007, 2010, 2015 Samples)						
Antimony	mg/kg	25	14	3 of 14	0 of 16	0.2 U 7.8 U 59
Barium	mg/kg	60	20	14 of 20	0 of 20	9.6 J,O 68 110
Beryllium	mg/kg	0.12	20	7 of 10	10 of 20	0.062 J,O <0.3 0.93
Chromium	mg/kg	149	20	4 of 20	0 of 20	11 42.5 590
Copper	mg/kg	111	20	0 of 20	0 of 20	1.5 U,J,O 33 130

Table 2. Summary of Surface Water and Sediment Sample Results Compared to Screening Levels, Cristex Drum Site, Oxford, NC

		Refinement Screening Value[5]	Number of Samples Analyzed[6]	Number of Samples ≥ Screening Value[3,6]	Number of Samples Non-detected at DL > Screening Value[6]	Concentration[4,6] Minimum Median Maximum
Sediment (2007, 2010, 2015 Samples)						
Vanadium	mg/kg	54	20	14 of 20	0 of 20	21 59.5 89
Zinc	mg/kg	459	20	2 of 20	0 of 20	8.8 110 1,000 J,O

Notes:

1 - North Carolina Surface Water Standards - 15A NCAC 02B.0200 (June, 2016). Standards are chronic criteria values expressed in dissolved form calculated using the minimum hardness of 25 mg/L.

2 - Samples collected in 2015; data are from Appendix E-2 in Black & Veatch (2016a) includes samples from 2 depths at each of 2 locations within the on site lagoon and 1 sample from the northeast corner of the wetland downstream of the lagoon. Sample counts exclude field duplicates.

3 - Excludes samples reported as non-detected at a reporting limit exceeding the screening value.

4 - Maximum is the maximum detected value; minimum and median include all results including non-detected values.

5 - Refinement Screening Values from Table 3-3 of the Ecological Risk Assessment, Appendix J in Black & Veatch (2016c).

6 - Samples collected in 2007, 2010, and 2015; data are from Appendix E-3 in Black & Veatch (2016a). Sample counts exclude field duplicates and background sediment samples.

DL - Detection level

µg/L - micrograms per liter

mg/kg - milligrams per kilogram

NA - Not applicable

NCAC - North Carolina Administrative Code

J,O - J: The reported value is an estimate; O: Other qualifiers may apply.

U - The analyte was not detected at or above the reporting limit; the value shown is the reporting limit.

Table 3: Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations Used in the HHRA

Exposure Point	Chemical of Concern	Concentration Detected		Units	Frequency of Detection	EPC	Statistical Measure
		Min	Max				
Scenarios Timeframe: Current/Future Construction, Utility Worker **Exposure Medium: Subsurface Soil (mg/kg)**							
Ingestion, Direct Contact, Inhalation	Aluminum	4,200	31,000	mg/kg	24/24	15,024	95% Student's-t UCL
	Manganese	9.6	1,100	mg/kg	24/24	355	95% Adjusted Gamma UCL
	PCE	0.62	180	mg/kg	8/31	74.79	99% UCL KM Chebyshev
Scenarios Timeframe: Current/Future Resident, Industrial Worker **Exposure Medium: Sediment**							
Ingestion and Direct Contact	BaP TEQ	0.011	1.733	mg/kg	3/13	1.566	99% UCL KM Chebyshev
Scenarios Timeframe: Current/Future Resident, Industrial Worker **Exposure Medium: Groundwater (µg/L)**							
Ingestion, Direct Contact, Inhalation Ingestion, Direct Contact, Inhalation	1,4-Dichlorobenzene	0.14	11	µg/L	15/62	11	Maximum
	BaP TEQ	0.11	0.149	µg/L	4/26	0.149	Maximum
	Benzene	0.1	82	µg/L	17/62	82	Maximum
	cis-1,2-Dichloroethene	0.17	1,200	µg/L	45/62	1,200	Maximum
	Tetrachloroethene	34	13,000	µg/L	52/62	13,000	Maximum
	Trichloroethene	0.52	430	µg/L	43/62	430	Maximum
	Vinyl Chloride	0.06	33	µg/L	12/62	33	Maximum

Notes:
EPC = Exposure Point Concentration
Bap TEQ = Benzo(a)pyrene toxicity equivalent

Table 4a. Cancer Toxicity Data Summary

Chemical of Concern	Oral & Dermal Slope Factor	Units	Cancer Guideline Description	Source	Date
Pathway: Ingestion, Dermal					
BaP TEQ	7.3	(mg/kg)/day	B2	IRIS	08/01/2016
Benzene	0.055	(mg/kg)/day	Known	IRIS	08/01/2016
1,4-Dichlorobenzene	0.0054	(mg/kg)/day	B2	Cal EPA	08/01/2016
Tetrachloroethene	0.0021	(mg/kg)/day	Likely	IRIS	08/01/2016
Trichloroethene (Total)	0.046	(mg/kg)/day	Known	IRIS	08/01/2016
Vinyl Chloride (Lifetime)	1.4	(mg/kg)/day	Known	IRIS	08/01/2016
Chemical of Concern	**Inhalation Slope Factor**	**Units**	**Cancer Guideline Description**	**Source**	**Date**
Pathway: Inhalation					
1,4-Dichlorobenzene	0.000011	$\mu g/m^3$	B2	Cal EPA	08/01/2016
Benzene	0.0000078	$\mu g/m^3$	Known	IRIS	08/01/2016
Carbon Tetrachloride	0.000006	$\mu g/m^3$	Likely	IRIS	08/01/2016
Tetrachloroethene	0.00000026	$\mu g/m^3$	Likely	IRIS	08/01/2016
Trichloroethene (Total)	0.0000041	$\mu g/m^3$	Known	IRIS	08/01/2016
Vinyl Chloride (Lifetime)	0.0000044	$\mu g/m^3$	Known	IRIS	08/01/2016

Notes:
B2 = probable human carcinogen
IRIS = Integrated Risk Information System
Cal EPA = California Environmental Protection Agency

Table 4b. Non-Cancer Toxicity Data Summary

Chemical of Concern	Chronic/ Subchronic	Oral & Dermal RfD	Units	Primary Target Organ	Combined Uncertainty/ Modifying Factors	Source	Date
Pathway: Ingestion, Dermal							
Aluminum	Chronic	1	mg/kg-day	CNS	100	PPRTV	08/01/2016
Aluminum	Subchronic	1	mg/kg-day	CNS	30	ATSDR-MRL	08/01/2016
Manganese	Chronic	0.024	mg/kg-day	CNS	1	IRIS	08/01/2016
Manganese	Subchronic	0.024	mg/kg-day	CNS	1	HEAST	08/01/2016
Cis-1,2-Dichloroethene	Chronic	0.002	mg/kg-day	Kidney	3,000	IRIS	08/01/2016
Cis-1,2-Dichloroethene	Subchronic	0.002	mg/kg-day	Kidney	300	PPRTV	08/01/2016
Tetrachloroethene	Chronic	0.006	mg/kg-day	CNS	1,000	IRIS	08/01/2016
Tetrachloroethene	Subchronic	0.008	mg/kg-day	Neurological	300	ATSDR-MRL	08/01/2016
Trichloroethene	Chronic	0.0005	mg/kg-day	IS, DS	10 - 1,000	IRIS	08/01/2016
Trichloroethene	Subchronic	0.0005	mg/kg-day	IS, DS	10 - 100	ATSDR-MRL	08/01/2016
Chemical of Concern	**Chronic/ Subchronic**	**Inhalation RfD**	**Units**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Source**	**Date**
Pathway: Inhalation							
Aluminum	Chronic	0.005	mg/m^3	CNS	300	PPRTV	08/01/2016
Manganese	Chronic	0.00005	mg/m^3	CNS	1,000	IRIS	08/01/2016
Tetrachloroethene	Chronic	0.04	mg/m^3	CNS	1,000	IRIS	08/01/2016
Tetrachloroethene	Subchronic	0.041	mg/m^3	Neurotoxicity	300	ATSDR-MRL	08/01/2016
Trichloroethene	Chronic	0.002	mg/m^3	IS, DS	10 - 100	IRIS	08/01/2016
Trichloroethene	Subchronic	0.0022	mg/m^3	IS, DS	10 - 100	ATSDR-MRL	08/01/2016

Notes:
ATSDR-MRL = Agency for Toxic Substances and Disease Registry Minimal Risk Level
CNS = Central nervous systemDS = Developmental system
HEAST = Health Effects Assessment Summary Tables
IRIS = Integrated Risk Information System
IS = Immune system
PPRTV = value from Appendix A of the Provisional Peer Reviewed Toxicity Value support document.

Table 5. Risk Characterization Summary - Carcinogens

Exposure Medium	Chemical of Concern	Ingestion	Dermal	Inhalation	Exposure Routes Total
Scenario Timeframe: Future **Receptor Population: Resident - Lifetime**					
Subsurface Soil [a]	Tetrachloroethene	--	--	2.9E-06	2.9E-06
Groundwater	1,4-Dichlorobenzene	7.6E-07	5.0E-07	4.3E-06	5.6E-06
	BaP TEQ	3.4E-05	6.8E-04	--	7.1E-04
	Benzene	7.1E-07	1.1E-07	2.8E-07	1.1E-06
	Tetrachloroethene	3.5E-04	2.1E-04	1.2E-04	6.8E-04
	Trichloroethene	3.3E-04	5.2E-05	7.7E-05	4.6E-04
	Vinyl Chloride	5.9E-04	4.6E-05	1.0E-05	6.5E-04
Sediment	BaP TEQ	1.1E-05	3.8E-06	--	1.5E-05
				Cancer Risk	**2.5E-03**
Indoor Air from Vapor Intrusion	1,4-Dichlorobenzene	--	--	2.5E-06	2.5E-06
	Benzene	--	--	3.5E-05	3.5E-05
	Carbon Tetrachloride	--	--	3.0E-06	3.0E-06
	Tetrachloroethene	--	--	5.5E-04	5.5E-04
	Trichloroethene	--	--	2.1E-04	2.1E-04
	Vinyl Chloride	--	--	2.2E-04	2.2E-04
				Total Cancer Risk with Vapor Intrusion	**3.5E-03**
Scenario Timeframe: Future **Receptor Population: Industrial/Commercial Worker**					
Groundwater	BaP TEQ	3.3E-06	--	--	3.3E-06
	Tetrachloroethene	8.3E-05	--	--	8.3E-05
	Trichloroethene	6.0E-05	--	--	6.0E-05
	Vinyl Chloride	7.3E-05	--	--	7.3E-05

Table 5. Risk Characterization Summary - Carcinogens

Exposure Medium	Chemical of Concern	Ingestion	Dermal	Inhalation	Exposure Routes Total
Scenario Timeframe: Future **Receptor Population: Industrial/Commercial Worker**					
Sediment	BaP TEQ	7.0E-07	3.8E-07	--	1.1E-06
				Cancer Risk	**2.2E-04**
Indoor Air from Vapor Intrusion	Benzene	--	--	8.0E-06	8.0E-06
	Tetrachloroethene	--	--	1.3E-04	1.3E-04
	Trichloroethene	--	--	3.8E-05	3.8E-05
	Vinyl Chloride	--	--	2.5E-05	2.5E-05
				Total Cancer Risk with Vapor Intrusion	**4.2E-04**

Notes:
a = Inhalation of outdoor vapors
Bap TEQ = Benzo(a)pyrene toxicity equivalent

Table 6. Risk Characterization Summary – Non-Cancer Hazards

Exposure Medium	Chemical of Concern	Primary Target Organ	Ingestion	Dermal	Inhalation	Exposure Routes Total
Scenario Timeframe: Future **Receptor Population: Resident - Lifetime**						
Subsurface Soil [a]	Tetrachloroethene		--	--	0.7	0.7
Groundwater	Cis-1,2-Dichlorobenzene	Kidney	21	3	--	23
	Tetrachloroethene	CNS	75	44	31	150
	Trichloroethene	IS, DS	29	5	20	55
					Hazard Index	**228**
Indoor Air from Vapor Intrusion	Tetrachloroethene	CNS	--	--	142	142
	Trichloroethene	IS, DS	--	--	55	55
					Total Hazard Index with Vapor Intrusion	**426**
Scenario Timeframe: Future **Receptor Population: Industrial/Commercial Worker**						
Subsurface Soil [a]	Tetrachloroethene		--	--	0.2	0.2
Groundwater	Cis-1,2-Dichlorobenzene	Kidney	5	--	--	5
	Tetrachloroethene	CNS	19	--	--	19
	Trichloroethene	IS, DS	7	--	--	7
					Hazard Index	**31**
Indoor Air from Vapor Intrusion	Tetrachloroethene	CNS	--	--	34	34
	Trichloroethene	IS, DS	--	--	13	13
					Total Hazard Index with Vapor Intrusion	**78**
Scenario Timeframe: Future **Receptor Population: Utility Worker**						
Surface Soil	Manganese	CNS	0.006	--	1	0.1
Subsurface Soil	Manganese	CNS	0.005	--	0.1	0.1
Groundwater in Excavation Trench	Tetrachloroethene	CNS	0.01	0.4	9	9
	Trichloroethene	IS, DS	0.005	0.04	7	7
					Hazard Index	**16**

Table 7. Occurrence, Distribution and Selection of Chemicals of Ecological Concern

Chemical of Concern	Frequency of Detection	Minimum Conc.	Maximum Conc.	Mean Conc. [1]	Background Conc.	ESL	ESL Source	Maximum HQ	Number Exceeding ESL
Exposure Medium: Surface Water – Unfiltered (µg/L)									
Aluminum	3 / 8	110	5,700	1,120	< 24	750	a	7.6	2
Copper	9 / 13	1	41	15.1	12	3.6	b	11	7
Iron	8 / 8	430	14,000	5,590	1,100	2,200	c	6.4	7
Titanium	1 / 5	< 5	62	14.4	--	10	d	6.2	1
Zinc	11 / 13	4	120	43.8	4.9	36	b	3.3	6
Exposure Medium: Sediment (mg/kg)									
Antimony	5 / 14	0.38	59	12.2	< 8.8	25	e	2.4	3
Barium	20 / 20	20	110	69	29	60	e	1.8	14
Beryllium	8 / 20	0.096	0.93	0.32	0.062	0.12	c	7.8	7
Chromium	20 / 20	12	590	118	14	111	e	5.3	4
Vanadium	19 / 20	28	89	59.6	27	54	c	1.6	14
Zinc	20 / 20	24	1,000	197	40	459	e	2.2	2
Exposure Medium: Soil (mg/kg)									
Antimony	1 / 6	< 0.2	0.81	0.8	--	0.38	f	2.1	1
Chromium	12 / 12	7.8	350	52.1	20	40	c	8.8	4
Copper	12 / 12	4.2	48	18.2	9	28	e	1.7	2
Lead	12 / 12	2.8	65	20.4	5.8	56	e	1.2	1
Manganese	12 / 12	31	660	259	35	450	e	1.5	3
Mercury	3 / 9	0.14	0.15	0.075	< 0.076	0.1	e	1.5	3
Vanadium	12 / 12	27	91	58.6	81	81	c	1.1	2
Yttrium	3 / 3	2.6	25	11.7	--	14	f	1.8	1
Zinc	12 / 12	7.4	160	51.4	< 6.5	79	e	2.0	2

Notes:

1 - Includes ½ detection limit
a - National Water Quality Recommendations – acute effects
b - North Carolina water quality standards - acute effects
c - 2x background
d - 2x detection limit
e – EPA Region 4 refined screening value
f - USGS (2013) soil background levels (3rd quartile) for North Carolina

ESL – Ecological Screening Level
HQ – Hazard Quotient

Table 8. Ecological Exposure Pathways of Concern

Exposure Medium	Sensitive Environment Flag	Receptor	Endangered/ Threatened	Exposure Routes	Assessment Endpoints	Measurement Endpoints
Sediment	No	Benthic organisms	No	Direct contact with COCs in sediment.	Protection of benthic community in the lagoon and intermittent stream from adverse reproductive and growth effects.	Comparison of sediment COC concentrations to sediment quality screening-level benchmarks.
Surface Water	No	Aquatic organisms	No	Direct contact and uptake of COCs in surface water.	Protection of aquatic community in the lagoon and intermittent stream from adverse reproductive and growth effects.	Comparison of surface water COC concentrations to general literature-based water quality benchmarks.
Soil	No	Insectivorous ground birds and mammals	No	Direct contact and ingestion of contaminated soil.	Protection of insectivorous birds and mammals from adverse effects from exposure to soil/sediment in the lagoon and wetland area.	Comparison of soil/sediment COC concentrations to soil quality screening-level benchmarks.

Table 9. Remedial Goals for Subsurface Soil and Groundwater

Analyte	Highest Measured Value	Remedial Goal	Rationale
Subsurface Soil (mg/kg)			
Tetrachloroethene	180	0.0023	Exceeds EPA risk-based SSL for protection of groundwater
Groundwater (µg/L)			
Benzo(a)pyrene Toxic Equivalents	0.15	0.005	Exceeds NC 2L Groundwater Standard
1,4-Dichlorobenzene	11	6	Exceeds NC 2L Groundwater Standard
Benzene	82	1	Exceeds MCL and NC 2L Groundwater Standard
cis-1,2-Dichloroethene	2,900	70	Exceeds MCL and NC 2L Groundwater Standard
Tetrachloroethene	13,000	0.7	Exceeds MCL and NC 2L Groundwater Standard
Trichloroethene	620	3	Exceeds MCL and NC 2L Groundwater Standard
Vinyl Chloride	77	0.03	Exceeds MCL and NC 2L Groundwater Standard

Notes:
mg/kg – milligrams per kilogram
µg/L – micrograms per liter

Table 10. Remedial Goals for Indoor Air

Analyte	Calculated Exposure Point Concentration ($\mu g/m^3$)	Remedial Goal ($\mu g/m^3$)
1,4-Dichlorobenzene	0.631	2.6
Benzene	12.6	3.6
Carbon Tetrachloride	1.39	4.7
Tetrachloroethene	5,940	42
Trichloroethene	114	2.1
Vinyl Chloride	68.9	3.2

Notes:
$\mu g/m^3$ - micrograms per cubic meter

Table 11. Selected Remedy Cost Estimate Summary

CMZ Selected Alternative		Capital Cost	Estimated Annual O&M Costs*	Estimated Present Worth Cost	Estimated Construction Timeframe	Estimated Time to Achieve RAO/Cleanup Levels
Unsaturated Zone (UZ)						
UZ #3	Soil Excavation	$1,873,000	$0	**$1,873,000**	3 months	3 months
Saturated Source Zone (SSZ)						
SSZ #3	EK-ISCO with Biobarriers	$3,710,700	$272,100	**$4,609,700**	1 year	2 years
Dilute Plume (DP)						
DP #2	EISB Biobarrier	$1,201,400	$78,200	**$2,264,500**	6 months	20 years
Site-wide Costs						
Statutory Costs	Institutional Controls, Site Visits, Five-Year Reviews	$0	$17,284	**$51,000**	NA	30 yrs
			Total Costs:	**$8,798,200**		

Notes:

* - Long term O&M and monitoring costs specific to remedy; cost per year

Table 12. Chemical-Specific ARARs and TBCs, Cristex Drum Superfund Site, Oxford, North Carolina

Action/Media	Requirements	Prerequisite	Citation(s)
Classification of contaminated groundwater	Groundwaters in the state naturally containing 250 mg/L or less of chloride are *classified as GA* under 15A NCAC 02L .0201(1) Best usage: Existing or potential source of drinking water supply for humans.	Groundwaters located within the boundaries or under the extraterritorial jurisdiction of the State of North Carolina – **applicable**	15A NCAC 02L .0201(1) Groundwater Classifications
	Groundwaters in the state naturally containing greater than 250 mg/L of chloride are *classified as GSA* under 15A NCAC 02L .0201(2) Best usage: Existing or potential source of water supply for potable mineral water and conversion to fresh waters.		15A NCAC 02L .0201(2)
Restoration of Groundwater	Shall not exceed the groundwater quality standards[1] for contaminants specified as the site related contaminants of concern. • Benzo(a)pyrene (0.005 ug/L) • Benzene (1ug/L) • cis- 1,2-Dichloroethene (70 ug/L) • 1,4-Dichlorobenzene (6 ug/L) • Pentachlorophenol (0.3 ug/L) • Tetrachloroethylene (PCE) (0.7 ug/L) • Trichloroethylene (TCE) (3 ug/L) • Vinyl Chloride (0.03 ug/L)	Class GA or GSA groundwaters with contaminant(s) concentrations exceeding standards listed in 15A NCAC 02L .0202 – **relevant and appropriate**	15A NCAC 02L .0202(a) and (b) Groundwater Quality Standards
	Shall not exceed the Safe Drinking Water Act National Revised Primary Drinking Water Regulations: maximum contaminant levels (MCLs) for organic contaminants specified in 40 CFR § 141.61(a).	Groundwaters classified as GA or GSA which are an existing or potential source of drinking water – **relevant and appropriate**	40 CFR § 141.61(a) 15A NCAC 18C .1517

[1] Unless otherwise indicated, the standard refers to the total concentration in micrograms per liter of any constituent in a dissolved, colloidal or particulate form which is mobile in groundwater. This does not apply to sediment or other particulate matter which is preserved in a groundwater sample as a result of well construction or sampling procedures.

Notes:

ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulation*
EPA = U.S. Environmental Protection Agency
NCAC = *North Carolina Administrative Code*

Table 13. Location-Specific ARARs and TBCs, Cristex Drum Superfund Site, Oxford, North Carolina

Location	Requirements	Prerequisite	Citation(s)
	Wetlands		
Presence of Wetlands	Shall take action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance beneficial values of wetlands.	Federal actions that involve potential impacts to, or take place within, wetlands – **TBC**	Executive Order 11990 Section 1.(a) *Protection of Wetlands*
	Shall avoid undertaking construction located in wetlands unless: (1) there is no practicable alternative to such construction, and (2) that the proposed action includes all practicable measures to minimize harm to wetlands which may result from such use.		Executive Order 11990, Section 2.(a) *Protection of Wetlands*
Presence of wetlands or other waters influenced by wetlands	Concentrations or combination of substances which are toxic or harmful to human, animal, or plant life may not be present in amounts which individually or cumulatively may cause adverse impacts on existing wetland uses.	Activities within, wetlands as defined by G.S. 143-212(6) – **applicable**	15A NCAC 02B.0231(b)(4)
	Standards provided in 15A NCAC 02B.0231(b)(1), (2), (3), (5), and (6) shall be used to assure the maintenance or enhancement of the existing uses of wetlands identified in 15A NCAC 02B.0231(a)		15A NCAC 02B.0231(b)

Notes:
ARAR = applicable or relevant and appropriate requirement
CFR = Code of Federal Regulations
NCAC = North Carolina Administrative Code
NCGS = North Carolina General Statutes
TBC = To Be Considered

Table 14. Action-Specific ARARs, Cristex Drum Superfund Site, Oxford, North Carolina

Action	Requirements	Prerequisite	Citation(s)
General construction standards – All land–disturbing activities (i.e., excavation, trenching, grading etc.)			
Managing storm water runoff from land-disturbing activities	Shall install erosion and sedimentation control devices and practices sufficient to retain the sediment generated by the land-disturbing activity within the boundaries of the tract during construction.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-53) of more than 1 acre of land – **applicable**	N.C.G.S. Ch.113A-157(3) *Mandatory standards for land-disturbing activity*
	Shall plant or otherwise provide permanent ground cover sufficient to restrain erosion after completion of construction.		N.C.G.S. Ch.113A-157(3)
	The land-disturbing activity shall be conducted in accordance with the approved erosion and sedimentation control plan. *NOTE: Plan which meets the objectives of 15A NCAC 4B.0106 would be included in the CERCLA Remedial Design or Remedial Action Work Plan*		N.C.G.S. Ch.113A-157(5)
	Shall take all reasonable measures to protect all public and private property from damage caused by such activities.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-52) of more than 1 acre of land – **applicable**	15A NCAC 4B.0105
Managing storm water runoff from land-disturbing activities con't	Erosion and sedimentation control plan must address the following basic control objectives: (1) Identify areas subject to severe erosion, and off-site areas especially vulnerable to damage from erosion and sedimentation. (2) Limit the size of the area exposed at any one time. (3) Limit exposure to the shortest feasible time. (4) Control surface water run-off originating upgrade of exposed areas (5) Plan and conduct land-disturbing activity so as to prevent off-site sedimentation damage. (6) Include measures to control velocity of storm water runoff to the point of discharge.		15A NCAC 4B.0106

Action	Requirements	Prerequisite	Citation(s)
Managing storm water runoff from land-disturbing activities con't	Erosion and sedimentation control measures, structures, and devices shall be planned, designed, and constructed to provide protection from the run-off of 10-year storm.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-52) of more than 1 acre of land – **applicable**	15A NCAC 4B.0108
	Shall conduct activity so that the post-construction velocity of the 10-year storm run-off in the receiving watercourse to the discharge point does not exceed the parameters provided in this Rule.		15A NCAC 4B.0109
	Shall install and maintain all temporary and permanent erosion and sedimentation control measures.		15A NCAC 4B.0113
Control of fugitive dust emissions	The owner/operator of a facility shall not cause fugitive dust emissions to cause or contribute to the substantive complaints or visible emissions.	Activities potentially generating fugitive dust as defined in 15A NCAC 02D .0540 (a)(2) – **relevant and appropriate**	15A NCAC 02D .0540
Waste characterization – primary wastes (contaminated media) and secondary wastes (wastewaters, spent treatment media, etc.)			
Characterization of *solid waste* (all primary and secondary wastes)	Must determine if solid waste is a hazardous waste using the following method: • Should first determine if waste is excluded from regulation under 40 CFR261.4; and • Must then determine if waste is listed as a hazardous waste under subpart D 40 CFR part 261.	Generation of solid waste as defined in 40 CFR261.2 – **applicable**	40 CFR § 262.11(a) and (b) 15A NCAC 13A .0106, .107
	Must determine whether the waste is (characteristic waste) identified in subpart C of 40 CFR part 261by either: (1) Testing the waste according to the methods set forth in subpart C of 40 CFR part 261, or according to an equivalent method approved by the Administrator under 40 CFR §260.21; <u>or</u> (2) Applying knowledge of the hazard characteristic of the waste in light of the materials or the processes used.		40 CFR § 262.11(c) 15A NCAC 13A .0106

Action	Requirements	Prerequisite	Citation(s)
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Chapter 40 for possible exclusions or restrictions pertaining to management of the specific waste	Generation of solid waste which is determined to be hazardous – **applicable**	40 CFR § 262.11(d); 15A NCAC 13A .0106
Characterization of *hazardous waste* (all primary and secondary wastes)	Must obtain a detailed chemical and physical analysis on a representative sample of the waste(s), which at a minimum contains all the information that must be known to treat, store, or dispose of the waste in accordance with pertinent sections of 40 CFR 264 and 268.	Generation of RCRA-hazardous waste for storage, treatment or disposal – **applicable**	40 CFR § 264.13(a)(1) 15A NCAC 13A .0109
Determinations for management of hazardous waste	Must determine if the hazardous waste has to be treated before land disposed. This is done by determining if the waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods <u>or</u> use of generator knowledge of waste. This determination can be made concurrently with the hazardous waste determination required in 40 CFR 262.11.	Generation of RCRA hazardous waste for storage, treatment or disposal – **applicable**	40 CFR § 268.7(a)(1) 15A NCAC 13A .0106
	Must comply with the special requirements of 40 CFR § 268.9 in addition to any applicable requirements in 40 CFR § 268.7.	Generation of waste or soil that displays a hazardous characteristic of ignitability, corrosivity, reactivity, or toxicity for storage, treatment or disposal – **applicable**	40 CFR § 268.7(a)(1) 15A NCAC 13A .0112
	Must determine each EPA Hazardous Waste Number (waste code) applicable to the waste in order to determine the applicable treatment standards under 40 CFR 268 *et seq.* This determination may be made concurrently with the hazardous waste determination required in Sec. 262.11 of this chapter.	Generation of RCRA characteristic hazardous waste for storage, treatment or disposal – **applicable**	40 CFR § 268.9(a) 15A NCAC 13A .0112

Action	Requirements	Prerequisite	Citation(s)
	Must determine the underlying hazardous constituents [as defined in 40 CFR 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non–wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal – **applicable**	40 CFR § 268.9(a) 15A NCAC 13A .0112
Waste Storage – primary wastes (contaminated media) and secondary wastes (wastewaters, spent treatment media, etc.)			
Storage of solid waste	All solid waste shall be stored in such a manner as to prevent the creation of a nuisance, insanitary conditions, or a potential public health hazard.	Generation of solid waste which is determined *not* to be hazardous – **relevant and appropriate**	15A NCAC 13B .0104(f)
	Containers for the storage of solid waste shall be maintained in such a manner as to prevent the creation of a nuisance or insanitary conditions. Containers that are broken or that otherwise fail to meet this Rule shall be replaced with acceptable containers.		15A NCAC 13B .0104(e)
Temporary Storage of hazardous waste in Containers	A generator may accumulate hazardous waste at the facility provided that: • waste is placed in containers that comply with 40 CFR 265.171–173; and	Accumulation of RCRA hazardous waste on site as defined in 40 CFR §260.10 – **applicable**	40 CFR § 262.34(a); 15A NCAC 13A .0107 40 CFR §262.34(a)(1)(i); 15A NCAC 13A .0107
	• the date upon which accumulation begins is clearly marked and visible for inspection on each container; • container is marked with the words "hazardous waste"; or		40 CFR § 262.34(a)(2) and (3) 15A NCAC 13A .0107
	• container may be marked with other words that identify the contents.	Accumulation of 55 gal. or less of RCRA hazardous waste <u>or</u> one quart of acutely hazardous waste listed in §261.33(e) at or near any point of generation – **applicable**	40 CFR § 262.34(c)(1) 15A NCAC 13A .0107

Action	Requirements	Prerequisite	Citation(s)
Use and management of hazardous waste in containers	If container is not in good condition (e.g. severe rusting, structural defects) or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers – **applicable**	40 CFR § 265.171 15A NCAC 13A .0109
	Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired.		40 CFR § 265.172 15A NCAC 13A .0109
	Containers must be closed during storage, except when necessary to add/remove waste. Container must not opened, handled and stored in a manner that may rupture the container or cause it to leak.		40 CFR § 265.173(a) and (b) 15A NCAC 13A .0109
Storage of hazardous waste in container area	Area must have a containment system designed and operated in accordance with 40 CFR §264.175(b).	Storage of RCRA–hazardous waste in containers with *free liquids* – **applicable**	40 CFR §264.175(a) 15A NCAC 13A .0109
	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or Containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA–hazardous waste in containers that *do not contain free liquids* (other than F020, F021, F022, F023,F026 and F027) – **applicable**	40 CFR § 264.175(c)(1) and (2) 15A NCAC 13A .0109
Closure performance standard for RCRA container storage unit	Must close the facility (e.g., container storage unit) in a manner that: • Minimizes the need for further maintenance; • Controls minimizes or eliminates to the extent necessary to protect human health and the environment, post–closure escape of hazardous waste, hazardous constituents, leachate, contaminated run –off, or hazardous waste decomposition products to the ground or surface waters or the atmosphere; and • Complies with the closure requirements of subpart, but not limited to, the requirements of 40 CFR 264.178 for containers.	Storage of RCRA hazardous waste in containers – **applicable**	40 CFR § 264.111 15A NCAC 13A .0109

Action	Requirements	Prerequisite	Citation(s)
Closure of RCRA container storage unit	At closure, all hazardous waste and hazardous waste residues must be removed from the containment system. Remaining containers, liners, bases, and soils containing or contaminated with hazardous waste and hazardous waste residues must be decontaminated or removed. [Comment: At closure, as throughout the operating period, unless the owner or operator can demonstrate in accordance with 40 CFR 261.3(d) of this chapter that the solid waste removed from the containment system is not a hazardous waste, the owner or operator becomes a generator of hazardous waste and must manage it in accordance with all applicable requirements of parts 262 through 266 of this chapter].	Storage of RCRA hazardous waste in containers in a unit with a containment system – **applicable**	40 CFR § 264.178 15A NCAC 13A .0109
Treatment/disposal of RCRA wastes – primary (contaminated media) and secondary wastes (RCRA wastewaters, spent treatment media, etc.)			
Disposal of solid waste	Shall ensure that waste is disposed of at a site or facility which is permitted to receive the waste.	Generation of solid waste intended for off-site disposal – **relevant and appropriate**	15A NCAC 13B .0106(b)
Disposal of RCRA–hazardous waste in a land–based unit	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 CFR 268.40 before land disposal.	Land disposal, as defined in 40 CFR268.2, of restricted RCRA waste – **applicable**	40 CFR § 268.40(a) 15A NCAC 13A .0112
	All underlying hazardous constituents [as defined in 40 CFR 268.2(i)] must meet the Universal Treatment Standards, found in 40 CFR 268.48 Table UTS prior to land disposal.	Land disposal of restricted RCRA characteristic wastes (D001 –D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well – **applicable**	40 CFR §268.40(e) 15A NCAC 13A .0112

Action	Requirements	Prerequisite	Citation(s)
	To determine whether a hazardous waste identified in this section exceeds the applicable treatment standards of 40 CFR 268.40, the initial generator must test a sample of the waste extract or the entire waste, depending on whether the treatment standards are expressed as concentration in the waste extract or waste, or the generator may use knowledge of the waste. If the waste contains constituents (including UHCs in the characteristic wastes) in excess of the applicable UTS levels in 40 CFR 268.48, the waste is prohibited from land disposal, and all requirements of part 268 are applicable, except as otherwise specified.	Land disposal of RCRA toxicity characteristic wastes (D004 –D011) that are newly identified (i.e., wastes, soil, or debris identified by the TCLP but not the Extraction Procedure) – **applicable**	40 CFR § 268.34(f) 15A NCAC 13A .0112
Disposal of RCRA–hazardous waste soil in a land–based unit	Must be treated according to the alternative treatment standards of 40 CFR268.49(c) or according to the UTSs [specified in 40 CFR268.48 Table UTS] applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 CFR § 268.2, of restricted hazardous *soils* – **applicable**	40 CFR § 268.49(b) 15A NCAC 13A .0112
Disposal of RCRA wastewaters into CWA wastewater treatment unit	Are not prohibited, if the wastes are managed in a treatment system which subsequently discharges to waters of the U.S. pursuant to a permit issued under 402 of the CWA (i.e., NPDES permitted) unless the wastes are subject to a specified method of treatment other than DEACT in 40 CFR 268.40, or are D003 reactive cyanide.	Land disposal of hazardous wastewaters that are hazardous only because they exhibit a hazardous characteristic and are not otherwise prohibited under 40 CFR Part 268 – **applicable**.	40 CFR § 268.1(c)(4)(i) 15A NCAC 13A .0112
Disposal of RCRA characteristic wastewaters in a POTW	Are not prohibited, if the wastes are treated for purposes of the pre-treatment requirements of section 307 of the CWA unless the wastes are subject to a specified method of treatment other than DEACT in 40 CFR §268.40, or are D003 reactive cyanide.		40 CFR § 268.1(c)(4)(ii) 15A NCAC 13A .0112

Groundwater Remediation Wells – Injection wells and UIC wells for groundwater treatment additives (e.g., ISCO and emulsified oil)			
Design criteria for all injection wells	No person shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water if the presence of that contaminant may cause a violation of any applicable groundwater quality standard specified in Subchapter 02L or may otherwise adversely affect human health.	Design, construction, or operation of any injection well – **applicable**	40 CFR § 144.12 15A NCAC 02C.0211(c)
Injection of substances into underground well	Groundwater remediation wells used to inject additives, treated groundwater, or ambient air for treatment of contaminated soil or groundwater may inject only additives determined by Department of Health and Human services not to adversely affect human health.	Injection of fluids into or air into an underground well for the purposes of groundwater remediation – **applicable**	15A NCAC 02C .0225(a)
	Rule requirements for other wells shall be treated as one of the injection well types in Rule .0209(5)(b) that most closely resembles the equivalent hydrogeologic complexity and potential to adversely affect groundwater quality. The Director may permit by rule the emplacement or discharge of a fluid or solid into the subsurface for any activity that meets the definition of an "injection well" that the Director determines not to have the potential to adversely affect groundwater quality and does not fall under other rules in this Section. *NOTE:* NCDEQ concurrence on the selected remedy, or approval of Remedial Design and/or Remedial Action Work plan addresses this determination.	Injection of substances into an underground well other than liquids or air – **applicable**	15A NCAC 02C .0230
	Multi-screened wells shall not connect aquifers or zones having differences in water quality which would result in a degradation of any aquifer or zone.		15A NCAC 02C.0225(g)(17)

Construction of air injection well [as defined in 15A NCAC 02C.0224(2)]	The air injected shall not exceed ambient air quality standards set forth in 15A NCAC 02D.0400 and shall not contain petroleum or any constituent that would cause a violation of groundwater standards specified in Subchapter 02L. Shall be constructed in accordance with the well construction standards applicable to monitoring wells specified in Rule .0108 of this Subchapter.	Installation of groundwater remediation wells for the subsurface *injection of ambient air* for the treatment of contaminated soil or groundwater (permitted by Rule)– **applicable**	15A NCAC 02C.0225(b)(4)(A) and (B)
Injection zone determination	Shall specify the horizontal and vertical portion of the injection zone within which the proposed injection activity shall occur based on the hydraulic properties of that portion of the injection zone specified. No violation of groundwater quality standards specified in Subchapter 02L resulting from the injection shall occur outside the specified portion of the injection zone as detected by a monitoring plan approved by the Division. *NOTE: The Monitoring will be specified in a monitoring plan included as part of a CERCLA document (e.g., Remedial Design or Remedial Action Work Plan).*	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(e)(2)
Location of groundwater remediation wells	Wells shall not be located where: (A) surface water or runoff will accumulate around the well due to depressions, drainage ways, or other landscapes that will concentrate water around the well; (B) a person would be required to enter confined spaces to perform sampling and inspection activities; and (C) injectants or formation fluids would migrate outside the approved injection zone as determined by the applicant in accordance with Subparagraph (e)(2) of this Rule.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(1)
Construction of remediation wells	The methods and materials used in construction shall not threaten the physical and mechanical integrity of the well during its lifetime and shall be compatible with the proposed injection activities.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(3)

	The well shall be constructed in such a manner that surface water or contaminants from the land surface cannot migrate along the borehole annulus either during or after construction.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(4)
	The borehole shall not penetrate to a depth greater than the depth at which injection will occur unless the purpose of the borehole is the investigation of the geophysical and geochemical characteristics of an aquifer. Following completion of the investigation the borehole beneath the zone of injection shall be grouted completely to prevent the migration of any contaminants.		15A NCAC 02C.0225(g)(5)
Construction of remediation wells *con't* Grouted Wells	Only allowable grout listed under Rule .0107 of this Subchapter shall be used with the exception that bentonite grout shall not be used: (A) to seal zones of water with a chloride concentration of 1,500 milligrams per liter or greater as determined by tests conducted at the time of construction, or (B) in areas of the State subject to saltwater intrusion that may expose the grout to water with a chloride concentration of 1,500 milligrams per liter or greater at any time during the life of the well.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(8)
Grouted Wells	The annular space between the borehole and casing shall be grouted: (A) with a grout that is non-reactive with the casing or screen materials, the formation, or the injectant; (B) from the top of the gravel pack to land surface and in such a way that there is no interconnection of aquifers or zones having differences in water quality that would result in degradation of any aquifer or zone; and (C) so that the grout extends outward from the casing wall to a minimum thickness equal to either one-third of the diameter of the outside dimension of the casing or two inches, whichever is greater; but in no case shall a well be required to have an annular grout seal thickness greater than four inches.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(9)

Construction of remediation wells *con't* Grouted Wells	Grout shall be emplaced around the casing by one of the following methods: (A) Pressure. Grout shall be pumped or forced under pressure through the bottom of the casing until it fills the annular space around the casing and overflows at the surface; (B) Pumping. Grout shall be pumped into place through a hose or pipe extended to the bottom of the annular space which can be raised as the grout is applied. The grout hose or pipe shall remain submerged in grout during the entire application; or (C) Other. Grout may be emplaced in the annular space by gravity flow in such a way to ensure complete filling of the space. Gravity flow shall not be used if water or any visible obstruction is present in the annular space at the time of grouting.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(10)
Grouted Wells	All grout mixtures shall be prepared prior to emplacement per the manufacturer's directions with the exception that bentonite chips or pellets may be emplaced by gravity flow if water is present or otherwise hydrated in place. If an outer casing is installed, it shall be grouted by either the pumping or pressure method. The well shall be grouted within seven days after the casing is set or before the drilling equipment leaves the site, whichever occurs first. No additives that will accelerate the process of hydration shall be used in grout for thermoplastic well casing.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(11)-(14)

Construction of remediation wells *con't* Well casings	A casing shall be installed that extends from at least 12 inches above land surface to the top of the injection zone. Wells with casing extending less than 12 inches above land surface and wells without casing may be approved when one of the following conditions is met: (A) site specific conditions directly related to business activities, such as vehicle traffic, would endanger the physical integrity of the well; or (B) it is not operationally feasible for the well head to be completed 12 inches above land surface due to the engineering design requirements of the system.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(15) and (16)
	Prior to removing the equipment from the site, the top of the casing shall be sealed with a water-tight cap or well seal, as defined in G.S. 87-85, to preclude contaminants from entering the well.		15A NCAC 02C.0225(g)(18)
Gravel and sand packed wells	Packing materials for gravel and sand packed wells shall be: (A) composed of quartz, granite, or other hard, non-reactive rock material; (B) clean, of uniform size, water-washed and free from clay, silt, or other deleterious material; (C) disinfected prior to subsurface emplacement; (D) emplaced such that it shall not connect aquifers or zones having differences in water quality that would result in the deterioration of the water qualities in any aquifer or zone; and (E) evenly distributed around the screen and shall extend to a depth at least one foot above the top of the screen. A minimum one foot thick seal comprised of bentonite clay or other sealing material approved by the Director shall be emplaced directly above and in contact with the packing material.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(19)

Construction of remediation wells *con't*	A hose bibb, sampling tap, or other collection equipment approved by the Director shall be installed on the line entering the injection well such that a sample of the injectant can be obtained immediately prior to its entering the injection well.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(21)
	If applicable, all piping, wiring, and vents shall enter the well through the top of the casing unless otherwise approved by the Director based on a design demonstrated to preclude surficial contaminants from entering the well.		15A NCAC 02C.0225(g)(22)
Construction of remediation wells *con't* Well head	The well head shall be completed in such a manner so as to preclude surficial contaminants from entering the well and well head protection shall include: (A) an accessible external sanitary seal installed around the casing and grouting; and (B) a water-tight cap or seal compatible with the casing and installed so that it cannot be removed without the use of hand or power tools.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(g)(23)
	Unless permitted by this rule, pressure at the well head shall be limited to a maximum which will ensure that the pressure in the injection zone does not initiate new fractures or propagate existing fractures in the injection zone, initiate fractures in the confining zone, or cause the migration of injected or formation fluids outside the injection zone or area. Injection between the outermost casing and the well borehole is prohibited. Monitoring of the operating processes at the well head shall be provided for by the well owner, as well as protection against damage during construction and use.		15A NCAC 02C.0225(i)(1)-(3)

Mechanical integrity of wells	All permanent injection wells require tests for mechanical integrity, which shall be conducted in accordance with Rule .0207 of this Section. An injection well has internal mechanical integrity when there is no leak in the casing, tubing, or packer. An injection well has external mechanical integrity when there is no fluid movement into groundwaters through vertical channels adjacent to the injection well bore.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(h) 15A NCAC 0207(a) and (b)
Operation and maintenance of treatment system	Shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used. Proper operation and maintenance includes effective performance and adequate laboratory and process controls, including appropriate quality assurance procedures.	Operation of a well for *injection of additives* or groundwater underground – **applicable**	15A NCAC 02C .0211(k)
Monitoring of injection wells	Monitoring wells shall be of sufficient quantity and location so as to detect any movement of injection fluids, injection process byproducts or formation fluids outside the injection zone as determined by the applicant in accordance with Subparagraph (e)(2) of this Rule. The monitoring schedule shall be consistent with the proposed injection schedule, pace of the anticipated reactions, and rate of transport of the injectants and contaminants. *NOTE: The Monitoring will be specified in a monitoring plan included as part of a CERCLA document (e.g., Remedial Design or Remedial Action Work Plan).*	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(e)(9)

Monitoring of injection wells *con't*	If affected, may require additional monitor wells located to detect any movement of injection fluids, injection process byproducts, or formation fluids outside the injection zone as determined by the applicant in accordance with Subparagraph (e)(2) of this Rule. If the operation is affected by subsidence or catastrophic collapse, the monitoring wells shall be located so that they will not be physically affected and shall be of an adequate number to detect movement of injected fluids, process byproducts, or formation fluids outside the injection zone or area.	Installation of monitoring wells in (or adjacent to) the injection zone that may be affected by injection operations – **applicable**	15A NCAC 02C.0225(j)(3)
Monitoring Well Installation, Operation, and Abandonment			
Implementation of groundwater monitoring system	Must install and implement a monitoring system to evaluate the effects of the discharge upon waters of the state, including the effect of any actions taken to restore groundwater quality, and the efficiency of any treatment facility. NOTE: *The Monitoring will be specified in a monitoring plan included as part of a CERCLA document (e.g., Remedial Design or Remedial Action Work Plan).*	Groundwater remediation activities – **applicable**	15A NCAC 02L .0110(a)
	Shall be constructed in a manner that will not result in contamination of adjacent groundwaters of a higher quality.	Installation of monitoring system to evaluate effects of any actions taken to restore groundwater quality, as well as the efficacy of treatment – **applicable**	15A NCAC 02L .0110 (b)
Construction of groundwater monitoring well(s)	No well shall be located, constructed, operated, or repaired in any manner that may adversely impact the quality of groundwater.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(a)
Construction of groundwater monitoring well(s) *con't*	Shall be located, designed, constructed, operated and abandoned with materials and by methods which are compatible with the chemical and physical properties of the contaminants involved, specific site conditions, and specific subsurface conditions.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(c)

Construction of groundwater monitoring well(s) *con't*	Monitoring well and recovery well boreholes shall not penetrate to a depth greater than the depth to be monitored or the depth from which contaminants are to be recovered. Any portion of the borehole that extends to a depth greater than the depth to be monitored or the depth from which contaminants are to be recovered shall be grouted completely to prevent vertical migration of contaminants.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(d)
	Shall be constructed in such a manner as to preclude the vertical migration of contaminants with and along borehole channel.		15A NCAC 02C .0108(f)
	The well shall be constructed in such a manner that water or contaminants from the land surface cannot migrate along the borehole annulus into any packing material or well screen area.		15A NCAC 02C .0108(g)
Construction of groundwater monitoring well(s) *con't*	Packing material placed around the screen shall extend at least one foot above the top of the screen. Unless the depth of the screen necessitates a thinner seal, a one foot thick seal, comprised of chip or pellet bentonite or other material approved by the Department as equivalent, shall be emplaced directly above and in contact with the packing material.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(h)
	Grout shall be placed in the annular space between the outermost casing and the borehole wall from the land surface to the top of the bentonite seal above any well screen or to the bottom of the casing for open end wells. The grout shall comply with Paragraph (e) of Rule .0107 of this Section except that the upper three feet of grout shall be concrete or cement grout.		15A NCAC 02C .0108(i)
	All wells shall be grouted within seven days after the casing is set. If the well penetrates any water-bearing zone that contains contaminated or saline water, the well shall be grouted within one day after the casing is set.		15A NCAC 02C .0108(j)

Construction of groundwater monitoring well(s) *con't*	Shall be secured with a locking well cap to ensure against unauthorized access and use. Shall be equipped with a steel outer well casing or flush-mount cover, set in concrete, and other measures sufficient to protect the well from damage by normal site activities.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(k) and (l)
	The well casing shall be terminated no less than 12 inches above land surface unless all of the following conditions are met: (1) site-specific conditions directly related to business activities, such as vehicle traffic, would endanger the physical integrity of the well; and (2) the well head is completed in such a manner so as to preclude surficial contaminants from entering the well.		15A NCAC 02C .0108(n)
Construction of groundwater monitoring well(s) *con't*	Shall have permanently affixed an identification plate. The identification plate shall be constructed of a durable, waterproof, rustproof metal or other material approved by the Department as equivalent and shall contain the following information: (1) well contractor name and certification number; (2) date well completed; (3) total depth of well; (4) a warning that the well is not for water supply and that the groundwater may contain hazardous materials; (5) depth(s) to the top(s) and bottom(s) of the screen(s); and (6) the well identification number or name assigned by the well owner.	Installation of wells (including temporary wells, monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0108(o)
	Shall be developed such that the level of turbidity or settleable solids does not preclude accurate chemical analyses of any fluid samples collected or adversely affect the operation of any pumps or pumping equipment.		15A NCAC 02C .0108(p)

	Shall be constructed in such a manner as to preclude the vertical migration of contaminants within and along the borehole channel.	Installation of temporary wells and all other non-water supply wells – **applicable**	15A NCAC 02C .0108(s)
Maintenance of groundwater monitoring well(s)	Every well shall be maintained by the owner in a condition whereby it will conserve and protect groundwater resources, and whereby it will not be a source or channel of contamination or pollution to the water supply or any aquifer.	Installation of wells (including temporary wells and monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0112(a)
Maintenance of groundwater monitoring well(s) *con't*	Broken, punctured, or otherwise defective or unserviceable casing, screens, fixtures, seals, or any part of the well head shall be repaired or replaced, or the well shall be abandoned pursuant to 15A NCAC 02C .0113	Installation of wells (including temporary wells and monitoring wells) other than for water supply – **applicable**	15A NCAC 02C .0112(d)
	All materials used in the maintenance, replacement, or repair of any well shall meet the requirements for new installation.		15A NCAC 02C .0112(c)
	No well shall be repaired or altered such that the outer casing is completed less than 12 inches above land surface. Any grout excavated or removed as a result of the well repair shall be replaced in accordance with Rule .0107(f) of this Section.		15A NCAC 02C .0112(f)
Abandonment of groundwater monitoring and remediation well(s)	Shall be abandoned by filling the entire well up to land surface with grout, dry clay, or material excavated during drilling of the well and then compacted in place; and	Permanent abandonment of wells (including temporary wells, monitoring wells, and test borings) other than for water supply *less than 20 feet in depth* and which do not penetrate the water table – **applicable**	15A NCAC 02C .0113(d)(1)
	Shall be abandoned by completely filling with a bentonite or cement - type grout.	Permanent abandonment of wells (including temporary wells, monitoring wells, and test borings) other than for water supply *greater than 20 feet in depth* and which do not penetrate the water table – **applicable**	15A NCAC 02C .0113(d)(2)

	All wells shall be permanently abandoned in which the casing has not been installed or from which the casing has been removed, prior to removing drilling equipment from the site.	Permanent abandonment of wells (including temporary wells) other than for water supply – **applicable**	15A NCAC 02C .0113(f)
Transportation of Wastes – Primary and Secondary Wastes			
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMTA and HMR at 49 CFR 171–180.	Any person who, under contract with a department or agency of the federal government, transports "in commerce," or causes to be transported or shipped, a hazardous material – **applicable**	49 CFR § 171.1(c)
Transportation of hazardous waste *off site*	Must comply with the generator requirements of 40 CFR Sect. 262.20–23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding and Sect. 262.40, 262.41(a) for record keeping requirements and Sect. 262.12 to obtain EPA ID number.	Preparation and initiation of shipment of RCRA hazardous waste off-site – **applicable**	40 CFR § 262.10(h) 15A NCAC 13A .0108
Transportation of hazardous waste *on–site*	The generator manifesting requirements of 40 CFR Sect. 262.20–262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR § 263.30 and § 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right–of–way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way – **applicable**	40 CFR § 262.20(f) 15A NCAC 13A .0108
Management of samples (i.e. contaminated soils and wastewaters)	Are not subject to any requirements of 40 CFR Parts 261 through 268 or 270 when: • The sample is being transported to a laboratory for the purpose of testing; • The sample is being transported back to the sample collector after testing; and • The sample collector ships samples to a laboratory in compliance with U.S.DOT, U.S. Postal Service, or any other applicable shipping requirements, including packing the sample so that it does not leak, spill or vaporize from its packaging.	Generation of samples of hazardous waste for purpose of conducting testing to determine its characteristics or composition – **applicable**	40 CFR § 261.4(d)(1)(i) and (ii) 15A NCAC 13A .0108 40 CFR § 261.4(d)(2) 15A NCAC 13A .0108

Institutional Controls for Contamination Left in Place			
Notice of Contaminated Site	Prepare and certify by professional land surveyor a survey plat which identifies contaminated areas which shall be entitled "NOTICE OF CONTAMINATED SITE". Notice shall include a legal description of the site that would be sufficient as a description in an instrument of conveyance and meet the requirements of NCGS 47-30 for maps and plans.	Contaminated site subject to current or future use restrictions included in a remedial action plan as provided in N.C.G.S. 143B-279.9(a) – **TBC**	NCGS 143B-279.10(a)
	The Survey plat shall identify: • the location and dimensions of any disposal areas and areas of potential environmental concern with respect to permanently surveyed benchmarks; • the type location, and quantity of contamination known to exist on the site; and •any use restriction on the current or future use of the site.		NCGS 143B-279.10(a)(1)-(3)
Notice of Contaminated Site con't	Notice (survey plat) shall be filed in the register of deeds office in the county which the site is located in the grantor index under the name of the owner.	Contaminated site subject to current or future use restrictions included in a remedial action plan as provided in N.C.G.S. 143B-279.9(a) – **TBC**	NCGS 143B-279.10(b) and (c)
	The deed or other instrument of transfer shall contain in the description section, in no smaller type than used in the body of the deed or instrument, a statement that the property is a contaminated site and reference by book and page to the recordation of the Notice.	Contaminated site subject to current or future use restrictions as provided in N.C.G.S. 143B-279.9(a) that is to sold, leased, conveyed or transferred — **TBC**	NCGS 143B-279.10(e)

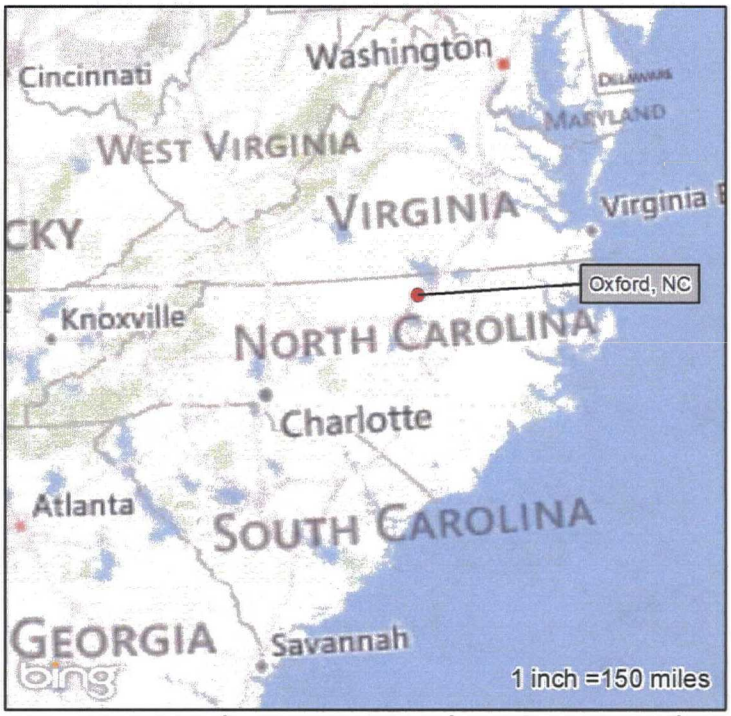
Notes:
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
CWA = Clean Water Act of 1972
DOT = U.S. Department of Transportation
EPA = U.S. Environmental Protection Agency
NCAC = *North Carolina Administrative Code*
N.C.G.S = North Carolina General Statutes
NPDES = National Pollutant Discharge Elimination System
POTW = Publicly Owned Treatment Works

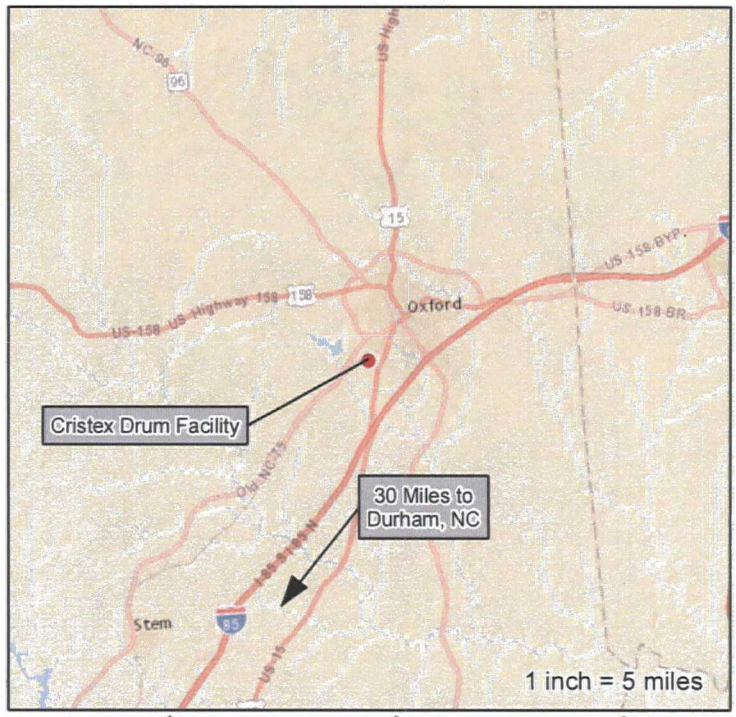
HMR = Hazardous Materials Regulations
HMTA = Hazardous Materials Transportation Act
RCRA = Resource Conservation and Recovery Act of 1976
TBC = to be considered
UTS = Universal Treatment Standard
WWTU = waste water treatment unit

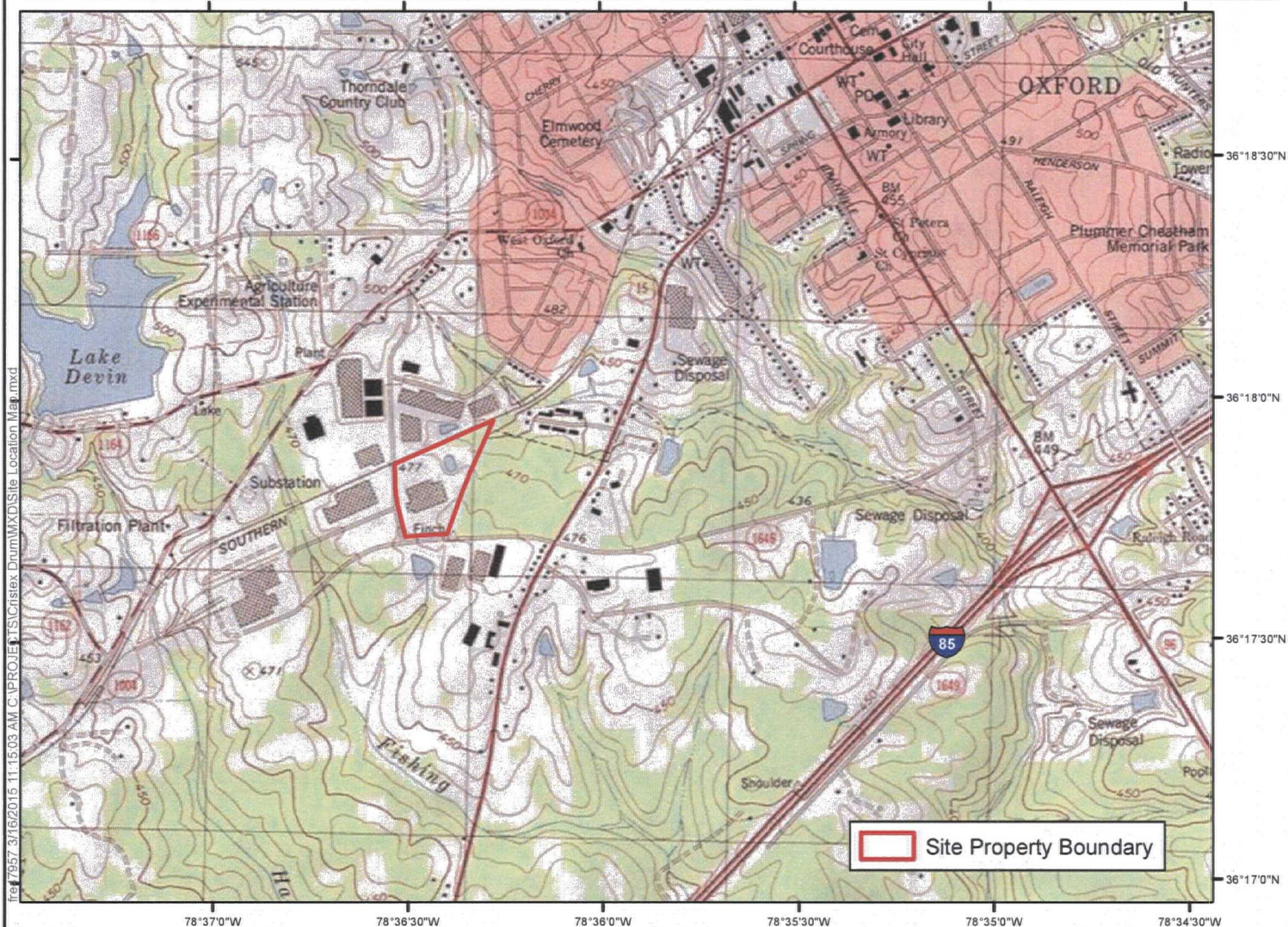
Table 15 Summary of Selected Remedy Cost-Effectiveness

Relative Order	Alternative #	Description	Composite Effectiveness Ranking[1]	Total NPW Cost ($M)	Effectiveness/ Cost Ratio[2]	Discussion
Unsaturated Zone (UZ)						
1	UZ #4	ISCO with Shallow Soil Mixing	24.81	1.37	**18.1**	Minor differential in overall effectiveness ranking; ratio is driven principally on cost basis. UZ #3 selected as surety of meeting threshold/balancing criteria was deemed mitigating for higher cost. All alternatives can be considered cost effective.
2	UZ #2	SVE	23.13	1.61	14.4	
3	UZ #3	Soil Excavation	24.95	2.72	9.1	
4	UZ #1	No Action	12.50	0.04	--	
Saturated Soil Zone (SSZ)						
1	SSZ #2	EISB with Chemical Reduction	22.15	3.55	**6.2**	Minor differential in overall effectiveness ranking; ratio is driven principally on similar cost basis. All alternatives can be considered cost effective. SSZ #3 provides the highest surety of results at an equivalent price.
2	SSZ #4	Electrokinetics-EISB with Biobarriers	23.90	4.41	5.4	
3	SSZ #3	Electrokinetics-ISCO with Biobarriers	24.50	4.61	5.3	
4	SSZ #5	BiRD with Recirculation	23.12	5.02	4.6	
5	SSZ #1	No Action	12.50	0.04	--	
Dilute Plume (DP)						
1	DP #4	MNA	18.42	0.19	**97.4**	DP #2 and DP #3 have similar composite rankings. DP #2 (EISB Barrier) is considered to be a more robust treatment technology that can enhance downgradient MNA. Cost differential between DP #2 and DP #3 was considered negligible. Both remedies are considered cost effective although DP#3 has associated long-term operational costs. The low NPW cost for DP #4 skews the overall effectiveness ratio. This remedy did not meet the subjective *de minimis* threshold for effectiveness.
2	DP #3	Hydraulic Capture/Containment	23.91	1.76	13.5	
3	DP #2	EISB Biobarrier	22.85	2.26	10.2	
4	DP #1	No Action	12.50	0.04	--	

Notes:
1 – Based upon weighted result for all six threshold/balancing criteria excluding cost; subjective determination
2 - Composite effectiveness/cost ($Millions); highest value shown in bold
EISB – enhanced *in situ* bioremediation
ISCO – *in situ* chemical oxidation
MNA – monitored natural attenuation
NPW – net present worth
SVE – soil vapor extraction







N

0 0.25 0.5

Miles

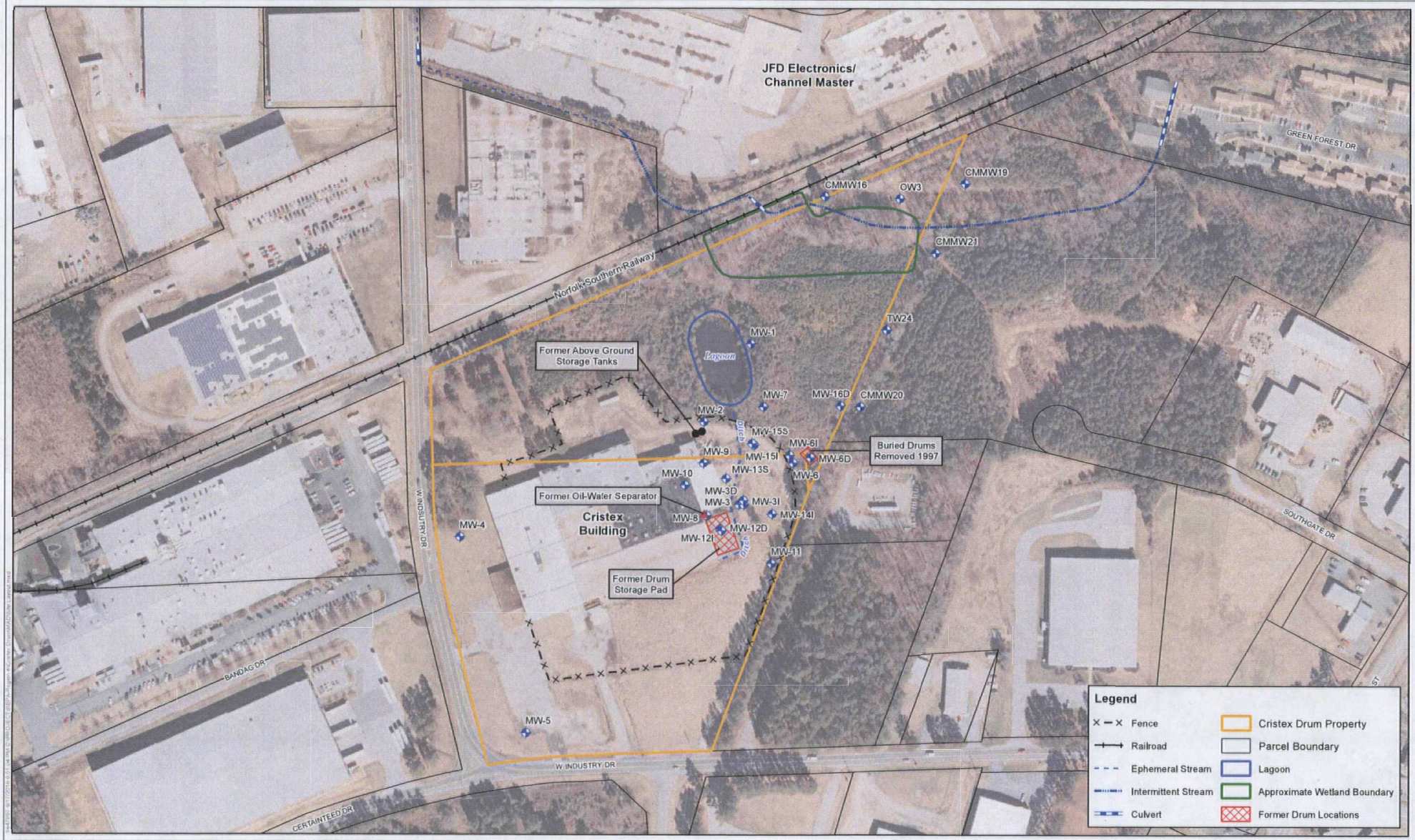
USGS Quadrangle: Oxford
10' Topographic Contours
NAD 83 State Plane North Carolina, Feet

Site Location Map
Cristex Drum
Oxford, Granville County, North Carolina

Figure 1

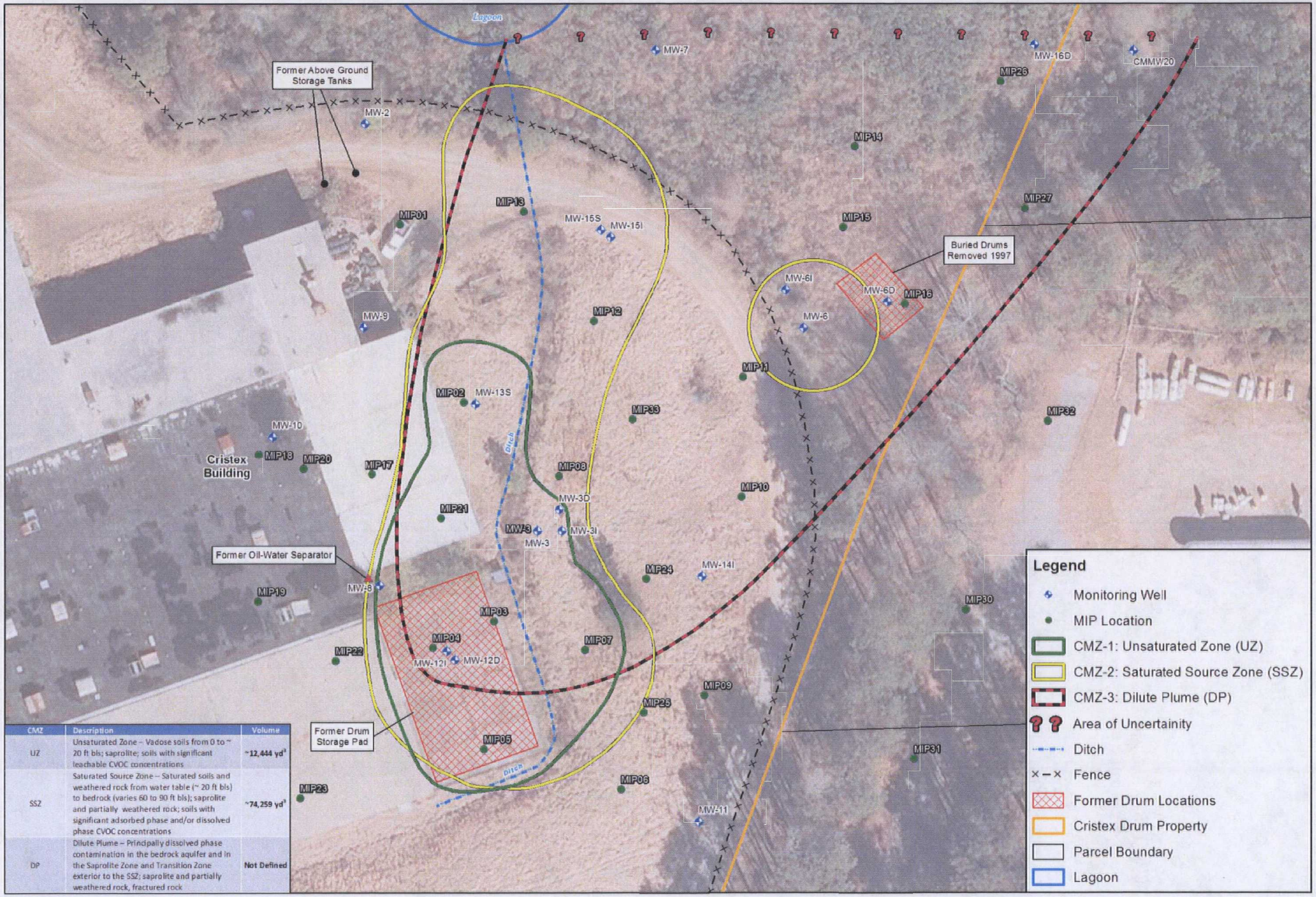
Map Sources: ESRI, USGS, Microsoft, Navteq

fre 7957 3/16/2015 11:15:03 AM C:\PROJECTS\Cristex Drum\MXD\Site Location Map.mxd



Site Layout
Cristex Drum
Oxford, Granville County, North Carolina

Figure 2



CMZ	Description	Volume
UZ	Unsaturated Zone – Vadose soils from 0 to ~ 20 ft bls; saprolite; soils with significant leachable CVOC concentrations	~12,444 yd³
SSZ	Saturated Source Zone – Saturated soils and weathered rock from water table (~ 20 ft bls) to bedrock (varies 60 to 90 ft bls); saprolite and partially weathered rock; soils with significant adsorbed phase and/or dissolved phase CVOC concentrations	~74,259 yd³
DP	Dilute Plume – Principally dissolved phase contamination in the bedrock aquifer and in the Saprolite Zone and Transition Zone exterior to the SSZ; saprolite and partially weathered rock, fractured rock	Not Defined

N

0 30 60 120

Feet

NAD83 Stateplane North Carolina, Feet

Contaminated Media Zone (CMZ) Designations
Cristex Drum
Oxford, Granville County, North Carolina

Figure 3

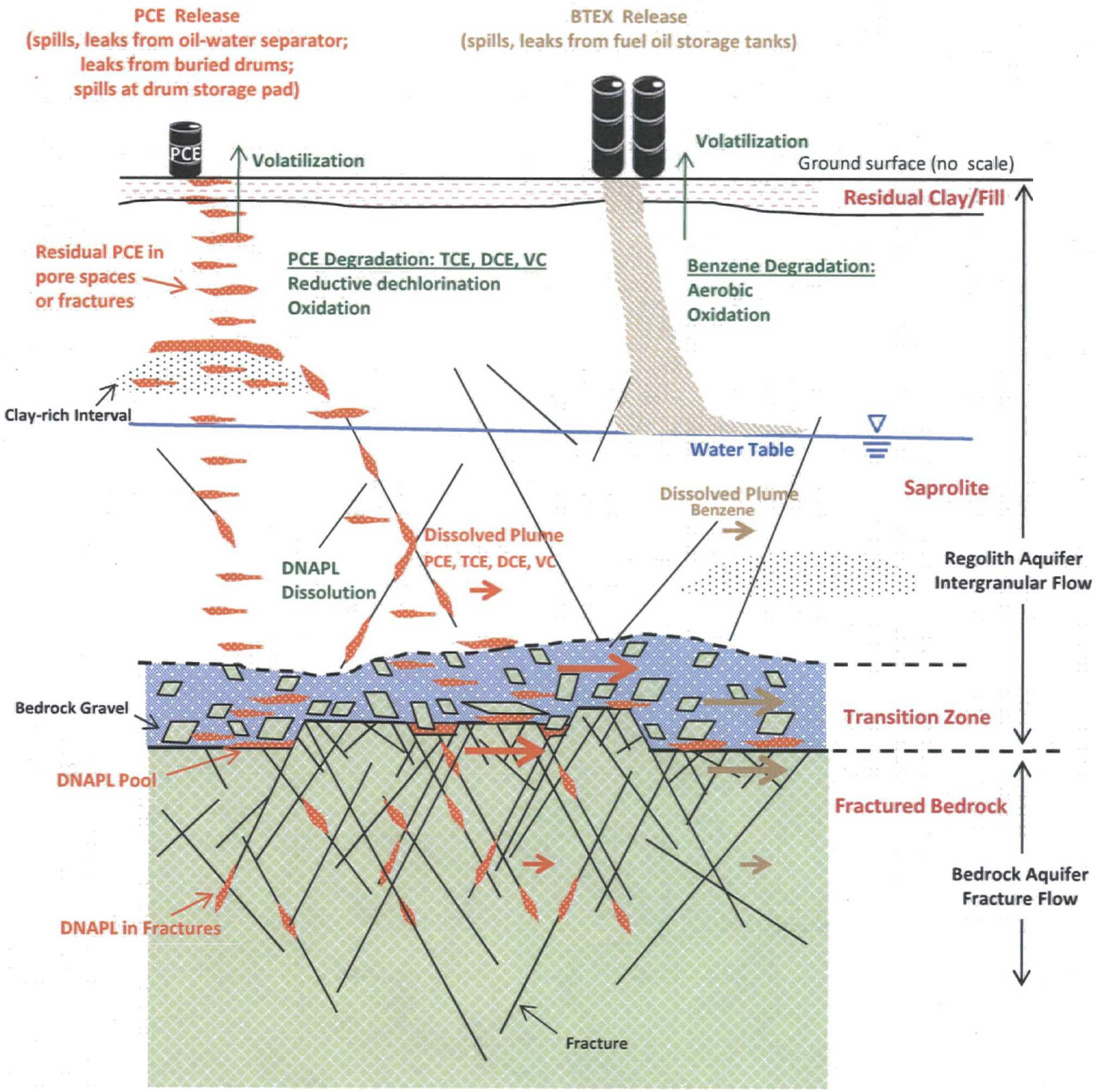


Figure 4. Conceptual Site Model of fate and transport at Cristex Drum. Length of horizontal arrows show higher transmission of dissolved plumes of cVOC and BTEX compounds in the transition zone and highly fractured upper bedrock. The amount of DNAPL depicted is for illustrative purposes and is not indicative of the actual amount that may be present.

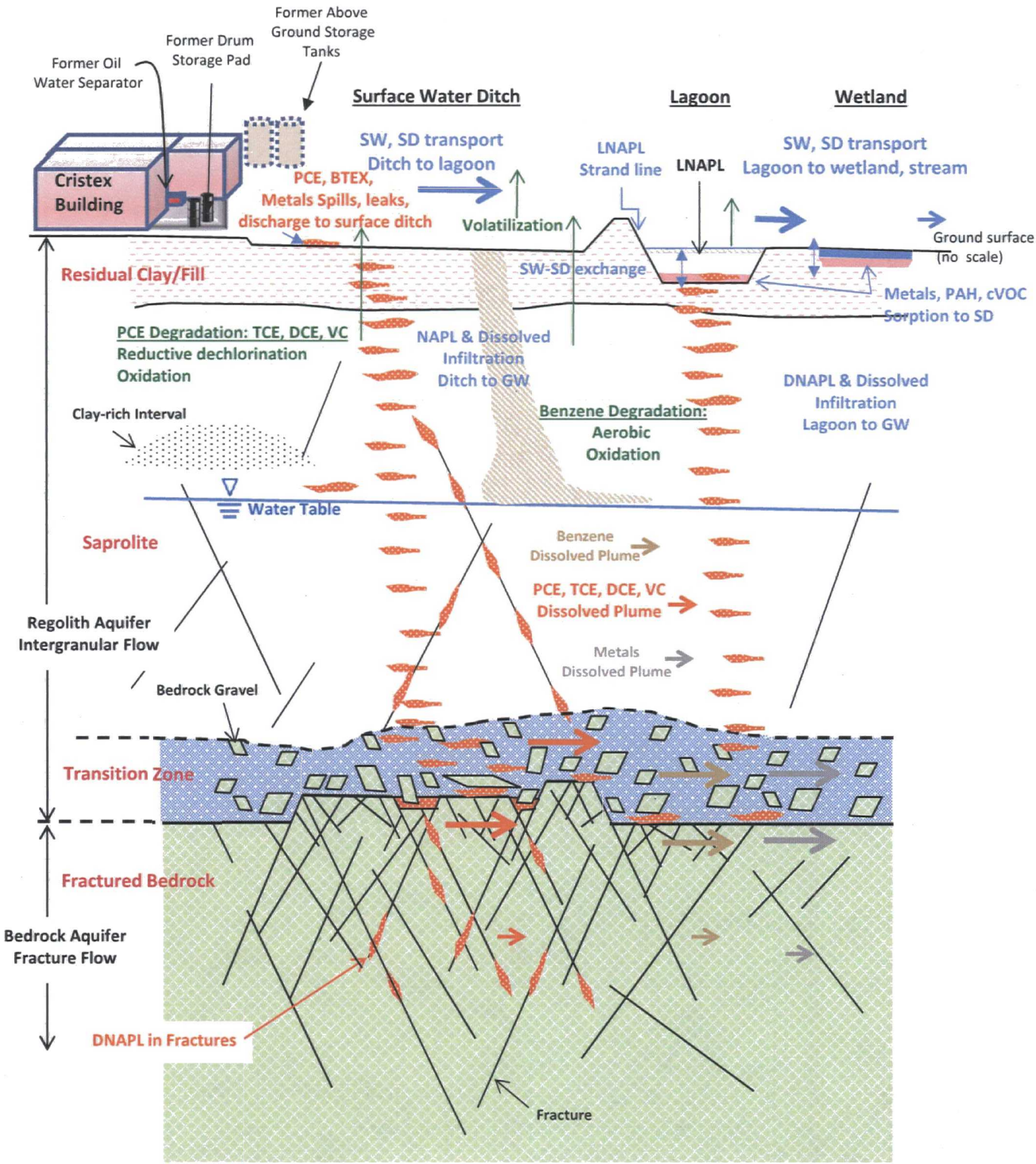
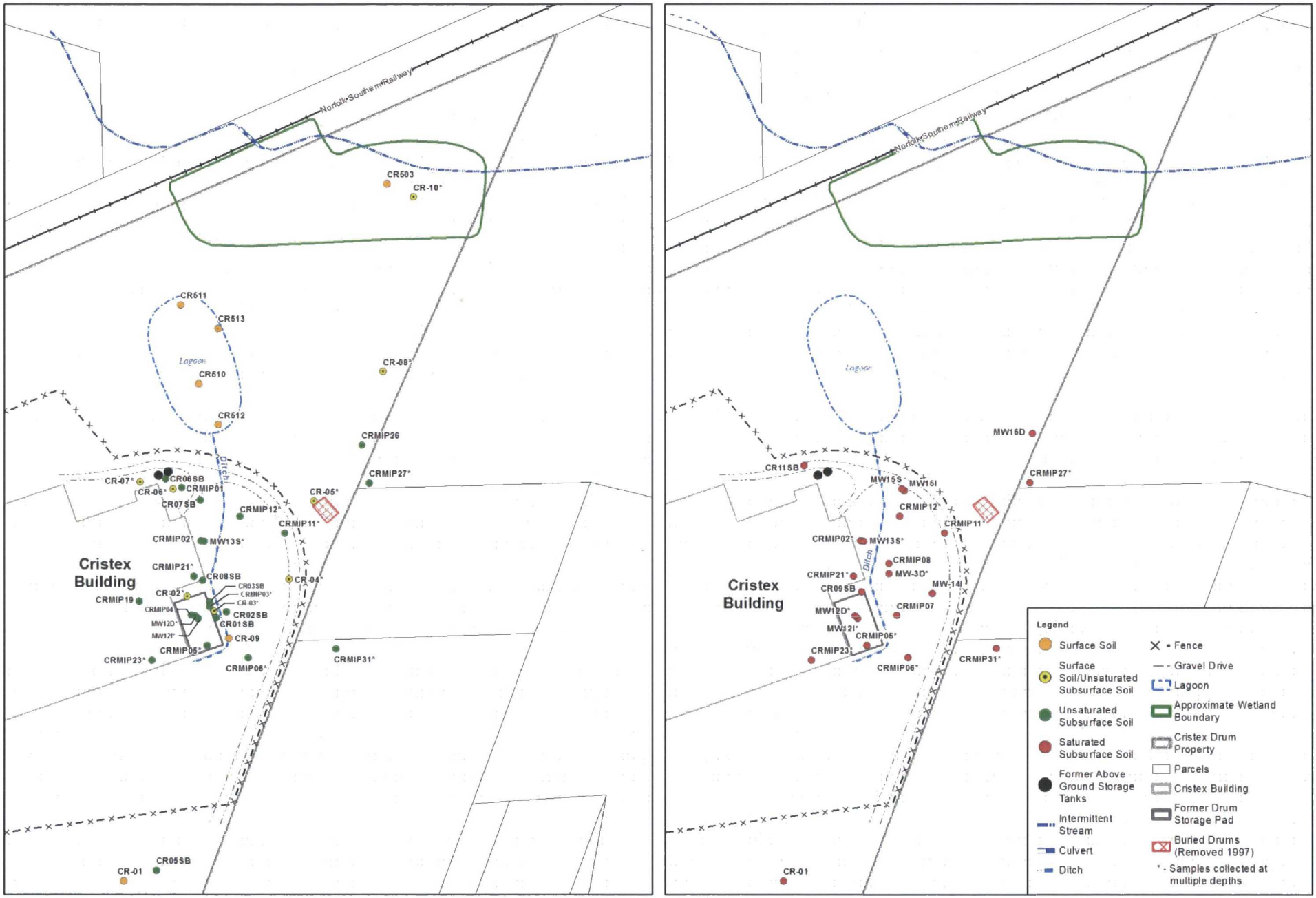


Figure 5. Schematic Conceptual Site Model of fate and transport at Cristex Drum depicting pathways for the surface water ditch, lagoon, and wetland. Length of horizontal arrows show higher transmission of dissolved plumes in transition zone and highly fractured upper bedrock. The amount of DNAPL depicted is for illustrative purposes and is not indicative of the actual amount that may be present. See Figure 4 for additional detail.



N

0 100 200 400

Feet

NAD83 Stateplane North Carolina, Feet

Soil Sample Locations (2007, 2010, 2015, 2016)
Cristex Drum
Oxford, Granville County, North Carolina

Figure 6

N 0 62.5 125 250 Feet

NAD83 Stateplane North Carolina, Feet

Basemap Features

- Former Above Ground Storage Tanks
- Fence
- Gravel Drive
- Ditch
- Lagoon
- Cristex Building
- Cristex Drum Property
- Parcels
- Former Drum Storage Pad
- Buried Drums (Removed 1997)

PCE Concentrations in Groundwater, 2015-2016
Cristex Drum
Oxford, Granville County, North Carolina

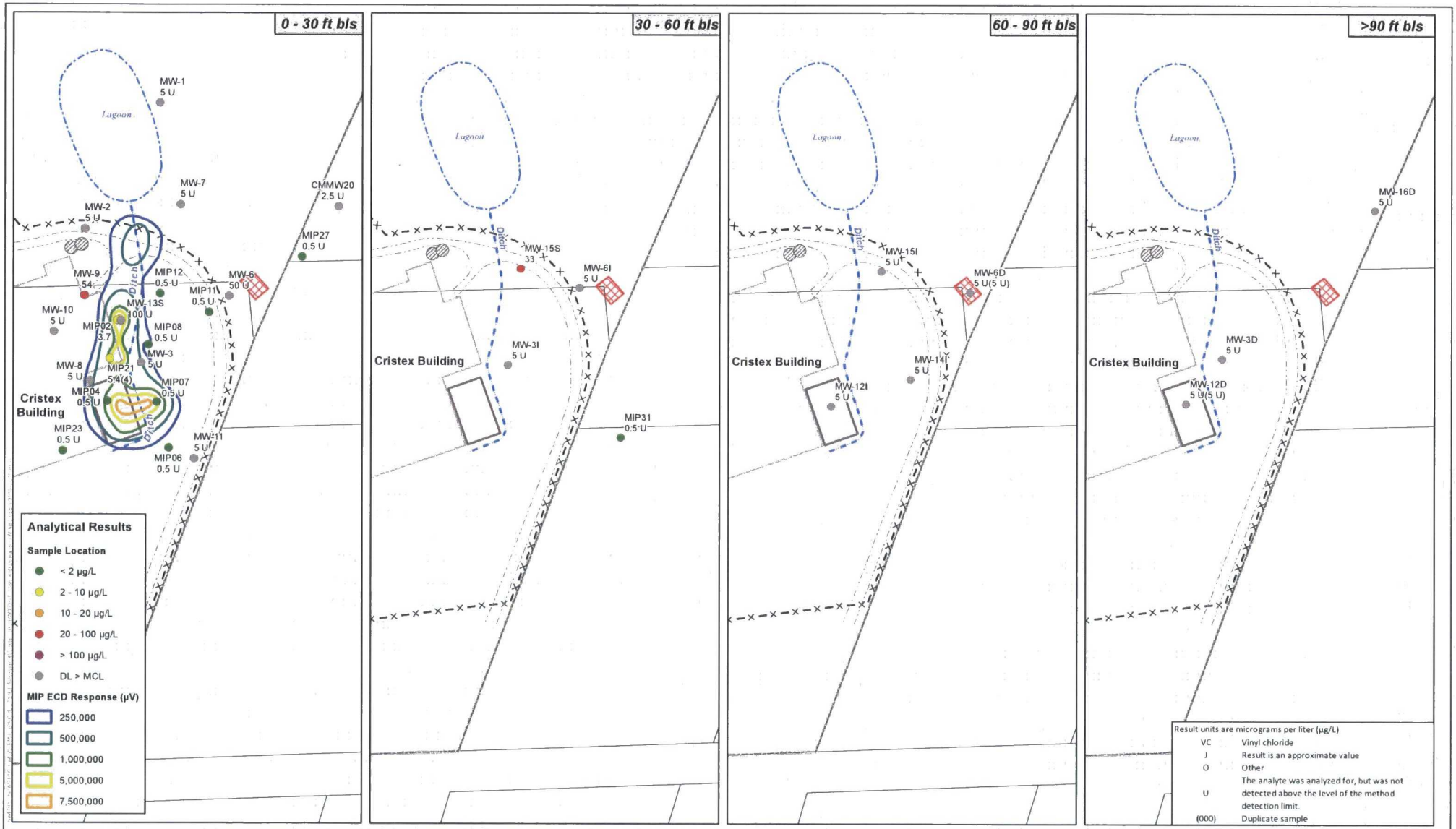
Figure 7

TCE Concentrations in Groundwater, 2015-2016
Cristex Drum
Oxford, Granville County, North Carolina

Figure 8

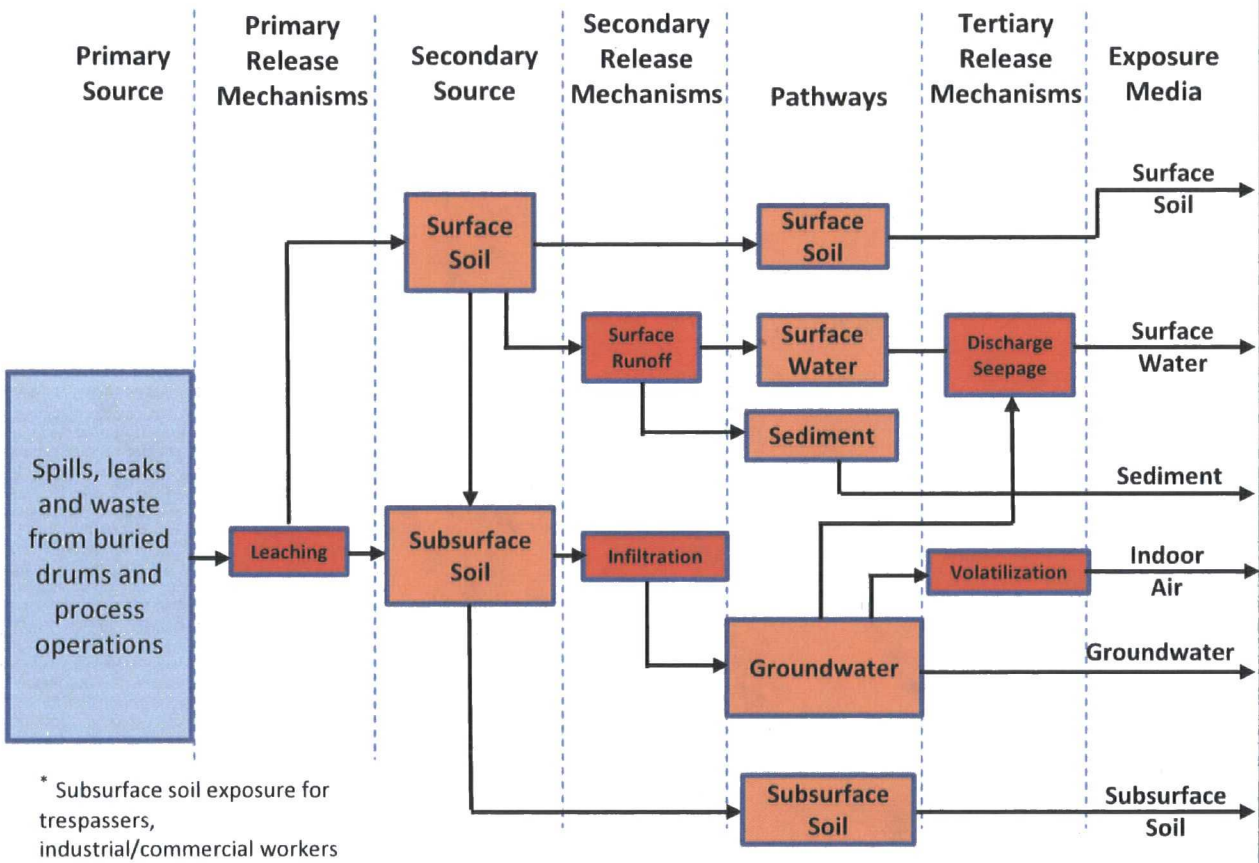
cis-DCE Concentrations in Groundwater, 2015-2016
Cristex Drum
Oxford, Granville County, North Carolina

Figure 9



VC Concentrations in Groundwater, 2015-2016
Cristex Drum
Oxford, Granville County, North Carolina

Figure 10



Potential Human Receptors						
	Current Receptors	Future Receptors				
Exposure Route	Trespasser	Construction Worker	Utility Worker	Industrial/Commercial Worker	Resident (Child & Adult)	Trespasser
Ingestion	•	•	•	•	•	•
Inhalation	•	•	•	•	•	•
Dermal Contact	•	•	•	•	•	•
Ingestion	•	•	•	•	•	•
Dermal Contact	•	•	•	•	•	•
Ingestion	•	•	•	•	•	•
Dermal Contact	•	•	•	•	•	•
Inhalation				•	•	
Ingestion		•	•	•	•	
Inhalation		•	•		•	
Dermal Contact		•	•		•	
Ingestion		•	•			
Inhalation	•*	•	•	•*	•*	•*
Dermal Contact		•	•			

* Subsurface soil exposure for trespassers, industrial/commercial workers and residents limited to inhalation of vapors from subsurface soil.

Figure 11. Conceptual site model for human health risk, Cristex Drum site, Oxford, North Carolina

Alternative UZ #3: Soil Excavation

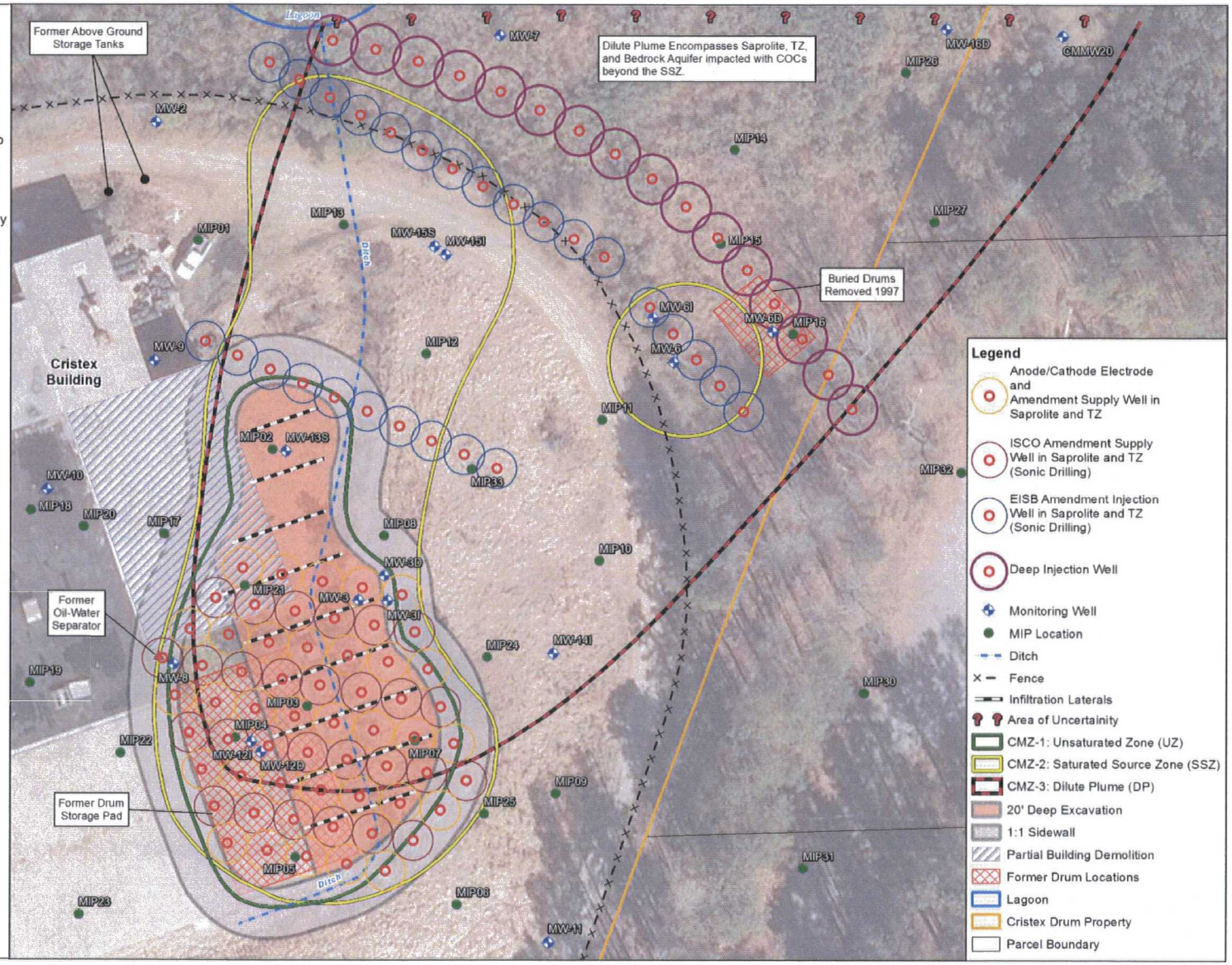
- Excavation of approximately 7,340 bcy of CVOC-laden soil to a depth of 20-ft bls plus 3,935 bcy of sidewall slope.
- Assumes partial building demolition and slab removal; removal of south slab
- Excavation sidewalls assumed to be 1:1 (45°)
- Excavated soils sampled for waste profile and transported to a Subtitle D landfill as a non-hazardous waste.
- Any soils exceeding the Subtitle D Landfill requirements will be segregated for disposal at a RCRA Subtitle C hazardous Landfill.
- Laterals/risers placed in base of excavation as a contingency for adding liquid amendments
- ~440-ft Infiltration laterals covered with clean sand and liner prior to placement of clean compacted fill

Alternative SSZ #3: Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with Biobarriers

- Installation of 60 wells: (32) anode/cathode wells and (28) oxidant injection wells for EK-ISCO
- Wells screened from ~20 to 70/80 ft bls in saprolite and TZ (to top of bedrock)
- Injection using packers over discrete intervals in saprolite and TZ; assuming radius of influence ~8-ft; no overlap
- Oxidant assumed to be potassium permanganate
- Batch preparation and oxidant amendment; manifold delivery system; hydrant water
- Installation of 27 injection wells for placement of EISB amendments: emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment.
- Biobarrier EISB Injection well radius of influence ~8-ft with overlap
- Biobarrier EISB wells screened from ~20 to 70 ft bls in saprolite and TZ (to top of bedrock)
- 3 weeks Injection
- Assumes partial building demolition and slab removal; removal of south slab
- No water or air phase treatment

Alternative DP #2: Enhanced (*In Situ*) Bioremediation (EISB) Biobarrier

- Installation of 16 deep injection wells in bedrock aquifer for addition of carbon substrate (e.g. emulsified oil), bioaugmentation, and pH adjustment; BiRD enhancements (e.g., sulfate, supplemental iron) may also be added
- Deep wells screened from ~ 70/80 to ~140 ft bls in bedrock aquifer
- COCs in saprolite addressed through SSZ remedy downgradient effects
- Assumed injection radius of influence ~10-ft with overlap
- Hydrant water used for addition of carbon substrate solution; location for recovered groundwater well not specified
- Batch preparation of carbon substrate /amendments; manifold delivery system
- 3 weeks Injection
- No water or air phase treatment



N 0 20 40 80
Feet
NAD83 Stateplane North Carolina, Feet

Selected Remedy
Cristex Drum Site
Oxford, Granville County, North Carolina

Figure 12

APPENDIX A
PROPOSED PLAN AND PROPOSED PLAN FACT SHEET

PROPOSED PLAN
CRISTEX DRUM SITE
OXFORD, GRANVILLE COUNTY, NORTH CAROLINA
JUNE 2017

This Proposed Plan is not to be considered a technical document but has been prepared to provide an abridged summary to the public.

You are Invited to Comment on this Proposed Cleanup for the Cristex Drum Site, Oxford, NC

This Proposed Plan presents the U.S. Environmental Protection Agency's (EPA) Preferred Remedial Alternative for the Cristex Drum Superfund Site (Site) to address soil, groundwater, and indoor air contamination at the Site. This Proposed Plan also presents the remedial alternatives evaluated in the 2016 Feasibility Study (FS):

- The preferred remedial alternative for the unsaturated zone (UZ) is Alternative UZ #3 – Soil Excavation;
- The preferred remedial alternative for the saturated source zone (SSZ) is Alternative SSZ #3 – Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with biobarriers;
- The preferred remedial alternative for the dissolved plume (DP) is Alternative DP #2 – Enhanced *In Situ* Bioremediation (EISB) Biobarrier; and
- Institutional Controls (ICs) on portions of the property affected by the dissolved plume and areas directly down-gradient using the State of North Carolina (NC) Declaration of Perpetual Land Use Restrictions (DPLURs) process, which requires the generation of a plat map defining the boundaries of the Site.

This document is issued by the EPA, the lead agency for Site activities, and the NC Department of Environmental Quality (NCDEQ), the support agency. NCDEQ is the successor of the NC Department of Environment and Natural Resources (NCDENR). EPA, in consultation with the NCDEQ, will select a final remedy for the Site after reviewing and considering all information submitted during the public comment period. EPA, in consultation with the NCDEQ, may modify the preferred alternatives or select other alternatives presented in this Proposed Plan based on new information or public comments. Therefore, the public is encouraged to review and comment on all the alternatives presented in this Proposed Plan.

EPA is issuing this Proposed Plan as part of its public participation responsibilities under the Superfund law (*Comprehensive Environmental Response, Compensation, and Liability Act* [CERCLA]), Section 117(c) and Section 300.435(f)(2) of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP). This Proposed Plan summarizes and identifies key information that can be found in greater detail in the Remedial Investigation (RI) and Feasibility Study (FS) documents, and other documents contained in the Administrative Record file for this Site. The Administrative Record and Information Repository can be found in the Richard H Thornton Library located at 210 Main Street, Oxford, NC and in EPA's, Region IV Information Center at 61 Forsyth Street, Sam Nunn Atlanta Federal Center, Atlanta, Georgia.

EPA and NCDEQ encourage the public to review these documents to gain a more comprehensive understanding of the Site and Superfund activities that have been conducted at the Site. These two agencies want to hear your views about this Proposed Plan and all the alternatives presented. You can comment on this Proposed Plan for the Cristex Drum Superfund ROD at the 6:00 p.m. public meeting on Tuesday June 27, 2017, at the NC Cooperative Extension, Granville County located at 125 Oxford Loop Road, Oxford, NC 27565. Comments can also be submitted through the mail, via facsimile, or email (refer to the following box for additional information).

You are encouraged to submit your comments during the public comment period. The public comment period runs from Tuesday, June 20, 2017 until Thursday, July 20, 2017 (extended one day due to July 4th holiday) to submit written comments on this Proposed Plan or other material in the Administrative Record file. At the end of the comment period, EPA and NCDEQ will review the comments/suggestions and make a final decision about the Site cleanup. Your input on this Proposed Plan is an important part of the decision-making process. We want to hear from you and will consider your comments in making the final decision.

Tell Us What You Think

Public Comment Period June 20 through July 20, 2017	Attend the Public Meeting	Locations of Administrative Record and Information Repository
EPA will accept written comments on this Proposed Plan during the public comment period. You may submit written comments three (3) ways: **BY MAIL** Beverly Stepter U.S. EPA - Region 4 61 Forsyth Street, SW Atlanta, Georgia 30303-3104 **BY EMAIL** stepter.beverly@epa.gov **BY FACSIMILE** 404-562-8816 Addressed to Beverly Stepter	You are invited to attend a public meeting sponsored by EPA to hear about this Proposed Plan. At the meeting you will be able to voice your views about the cleanup. The meeting will be held: Tuesday, June 27, 2017 at 6:00 p.m. Location: NC Cooperative Extension, Granville County, 125 Oxford Loop Road, Oxford, NC 27565	Richard H Thornton Library 210 Main Street Oxford, NC 27565 Phone: 919-693-1121 Hours: Mon. – Thurs. 10 a.m. – 8 p.m. Fri., Sat 10 a.m. – 5 p.m. Sun. 1 p.m. – 5 p.m. EPA, Region 4's Information Center 61 Forsyth Street Sam Nunn Atlanta Federal Center Atlanta, Georgia 30303 Phone: 404-562-8946 Hours: Mon – Fri, 8 a.m. – 5 p.m.

INTRODUCTION

This Proposed Plan provides:

- a brief description and history of the Site;
- a summary of the nature and extent of contamination;
- a summary of the Baseline and Human Health Risk Assessments;
- a summary of cleanup alternatives considered and evaluated
- the cleanup levels for the chemicals of concern;
- EPA's preferred alternative;
- encouragement to the public to submit comments on the proposed cleanup alternative; and
- a list of contacts and locations for more information.

SITE HISTORY/SITE CHARACTERISTICS

The Cristex Drum property encompasses 22 acres and is located in the southwestern portion of Oxford, NC about 0.25 miles west of the Route 15-Industry Drive intersection (**Figure 1**). The Site coordinates are latitude 36° 17' 50" N and longitude 78° 37' 00" W. Site terrain is flat to gently sloping to the east-northeast with elevations of 480 to 450 feet (ft) above mean sea level. The property is located in a predominantly industrial area and is bounded on the west and south by West Industry Drive, on the north by the Norfolk Southern Railroad, and on the east by several private parcels. The parcel is presently owned by Jomar Ventures LLC.

The Site is a former textile plant that operated from 1968 until 1986. The Site was purchased by Steinfield Mills in 1965 which constructed the 150,000 ft^2 building and 0.5 acre lagoon on the property. Steinfield Mills changed its name to IMI Knits, Inc. in 1971 and to Cristex Corporation in 1981. From 1966 to 1986, Cristex operated as a warp knit fabric mill that knitted, dyed, and finished nylon acetate Tricot. The operations area consists of the building, several gravel driveways and parking lots, and concrete and asphalt pads (**Figure 2**), which are surrounded by an eight-ft high fence that prevents unauthorized access. A former above-ground storage tank (AST) area, oil-water separator area, and drum storage pad area are located adjacent to the building; the AST and oil-water separator have been removed. The lagoon is located northeast of the building and is separated from the Cristex building by an overgrown area of dense brush.

When the facility was in operation, boilers were fueled by natural gas and fuel oil; chemicals were stored mostly on the east side of the building. Dyes, dyeing assistants and cellulosic and synthetic yarns were used in the manufacturing process. The dyeing process used metals such as zinc, copper and chromium. Chlorinated solvents were used to clean equipment, dry clean fabric, and as part of the dyeing process. During operations, the lagoon received wastewater via a buried pipeline and runoff from a surface ditch (**Figure 2**). From the lagoon, the wastewater entered the city sewer system. In 1998 the earthen impoundment was partly breached, allowing the lagoon to discharge flow to a small wetland area and to the intermittent creek. Between 1991 and 2015, the Cristex building was used by several businesses; however, none of these uses led to the current contamination found at the Site. The last business ceased operations in 2015 and the building has been vacant since that time.

The Site was placed on the National Priorities List (NPL) in 2013. Cristex was cited by the State of NC on several occasions for noncompliance with their air quality permit, including in 1976 and 1978. Spills and releases were identified during regulatory inspections and also were self-reported by the facility. An inspection by the City of Oxford in 1982 found a broken wastewater line releasing warm water through a ditch on the east side of the lagoon to the wetland down-gradient. An oil spill to the lagoon was noted during an air permit inspection by the State of NC in 1983 and a discharge from a boiler drain to the lagoon was reported by Cristex to the State of NC in 2001. EPA conducted interim remedial actions which involved the removal and offsite disposal of 26 buried drums, 137 drum carcasses and 3 roll-off containers of contaminated soil in 1997. Limited soil excavations were conducted in 2001, primarily in the surface ditch on the east side of the building and in the areas of the drum storage pad and above-ground fuel oil storage tanks.

2015/2016 REMEDIAL INVESTIGATION

The RI report summarizes data from the RI investigation as well as data collected previously at the Site, including surface and subsurface soil and groundwater data collected in 2007 (EPA) and groundwater and subsurface soil data collected in 2010 (NCDENR).

The fieldwork documented in the 2016 RI Report was completed between April 2015 and April 2016. Below is a summary of RI sampling activities and findings:

- Collection and analyses of 6 surface water samples, 5 sediment samples, 5 surface soil samples, 57 subsurface soil samples and 49 groundwater samples;
- Screening of soil locations using a Membrane Interface Probe (MIP)-Hydraulic Profiling Tool (MiHPT); and
- Installation of 8 monitoring wells (MWs) to supplement the existing Site MW network.

Soil: Contaminants detected in soils during historical sampling events completed in 2007 and 2010 consisted of metals, pesticides, one herbicide, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). Contaminants detected above screening values in soils collected during the RI consisted of metals (aluminum, barium, cobalt, copper, iron, manganese, nickel, vanadium, and zinc), VOCs (PCE, TCE, cDCE), and SVOCs (1,1-biphenyl, 2-methylnaphthalene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, and 1-methylnaphthalene). In 2007, the State of North Carolina established two background soil sampling locations south of the Cristex building, up-gradient of the site. Although VOC and SVOC were not detected in samples collected from these stations, the same metals found in the RI samples were present in the background soil samples collected during the 2007 Expanded Site Investigation. This suggests that the saprolite in the region naturally contains variable, slightly elevated concentrations of several metals. PCE was measured above detection in subsurface soil at a depth of 24-25 ft bgs and a maximum concentration of 23 µg/kg. Exceedances of SVOC in samples collected during the RI were confined to the soil berm surrounding the lagoon.

The primary contaminant source is believed to be a result of spills and leaks near the Cristex building in the area of the drum storage pad, former oil-water separator, and above ground fuel oil storage tanks, which

contaminated the soils beneath these areas. An additional contaminant source was identified in the former buried drum area which was excavated in 1997. The contaminated soils continue to act as an ongoing source of contamination to the groundwater below. The highest concentrations of carcinogenic VOCs (CVOCs) in soil occur at the eastern edge of the asphalt drum storage pad (**Figure 3**). Nearby MIP and well borings installed during the RI did not encounter similarly high values, suggesting that any dense non-aqueous phase liquid (DNAPL) present in the subsurface has a comparatively small volume and restricted areal extent. Refer to **Figure 4** for RI sample locations.

Secondary sources include a surface water drainage channel that drains the area east of the Cristex building and runs north to the lagoon, and the lagoon itself including the surrounding berms surrounding (**Figure 2**).

Groundwater: Groundwater at the Site consists of a two-part aquifer system. The surficial aquifer (regolith) includes saprolite overlying a basal transition zone. The underlying bedrock aquifer includes fractured metamorphic bedrock. These two aquifers are interconnected but have different characteristics that influence the speed at which groundwater flows and the transport mechanisms for the contaminants within them. The transport through the surficial aquifer is intergranular; flow through the bedrock aquifer occurs predominantly by transport along fractures. The transition zone between the regolith and bedrock aquifer serves as the primary transmitter of contaminated groundwater. The predominant vertical flow is downward: from the surficial aquifer to the bedrock aquifer. Laterally, the groundwater flow is predominantly toward the north-northeast in all of the aquifers.

Contaminants identified above water quality standards in one or more wells screened in the regolith aquifer include 1,2-dichlorobenzene, 1,3-dichlorobenzene, benzene, PCE, TCE, 1,1-DCE, cDCE, and vinyl chloride. PCE was the most widespread and exceeded its water quality standard in 26 of 33 samples with a maximum concentration of 13,000 µg/L. A few polycyclic aromatic hydrocarbon (PAH) compounds were measured in concentrations slightly exceeding water quality standards in 1 of 22 samples collected from the regolith aquifer including benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Metals measured in concentrations above water quality standards or interim standards in one or more samples from the regolith aquifer included chromium, cobalt, iron, lead, manganese, nickel, and vanadium; exceedances for cobalt, iron, manganese, and vanadium included both wells up-gradient of the site.

Contaminants identified above water quality standards in one or more wells screened in the bedrock aquifer include PCE, TCE, and cDCE; the maximum measured concentration of PCE was 250 µg/L. In addition, one or more bedrock water samples exceeded water quality standards for chromium, manganese, and vanadium.

Groundwater analytical results, coupled with observations from MIP results, suggest that a tetrachloroethylene (PCE) source area is present along the eastern side of the Cristex building. A dissolved plume of CVOC contamination is present east and northeast of the Cristex building. It extends vertically from the saprolite into the underlying transition zone (surficial aquifer) and fractured bedrock. The maximum depth of contamination in the bedrock aquifer is unknown but PCE, TCE, and cDEC have been identified in a well screened from 116 to 136 feet below ground. Concentrations in the bedrock similar to those in the overlying transition zone suggest that these contaminants migrated into the bedrock from the overlying regolith aquifer, although this pathway cannot be confirmed.

The former drum burial area may represent a secondary source. Comparatively modest concentrations of PCE in groundwater do not suggest the presence of a widespread DNAPL phase but are indicative of a small amount of residual DNAPL contamination.

Refer to **Figure 5** for the distribution of the MW network across the Site. **Figures 6** and **7** show the extent and concentrations of PCE and trichloroethene (TCE) in the surficial and bedrock aquifers. On these figures, depths from 0 to 60 ft occur within the saprolite portion of the surficial aquifer, depths from 60 to 90 ft represent the transition zone portion of the surficial aquifer, while depths greater than 90 ft represent the bedrock aquifer. PCE and TCE are not the only groundwater contaminants of concern but these isopleth maps give a fair

representation of the extent of groundwater contamination at the Site. A complete list of COCs can be found in **Tables 2, 3, 4, 5 and 6**.

Overall, the regolith aquifer can be characterized as slightly oxidized to slightly reduced, while the bedrock aquifer is reduced. Elevated DO concentrations in the regolith could be consistent with the absence of organic material in its lithology. The hydrogen ion concentration (pH) is favorable for all forms of biotic degradation and would limit the dissolution of metals.

Surface Water/Sediment: Surface water from the Site drains from the lagoon to the wetland area and eventually to Fishing Creek in the Tar River Basin via an intermittent stream at the northeastern corner of the Site. The State of NC has assigned beneficial use classifications to Fishing Creek of C (aquatic life and secondary recreation) and NSW (nutrient sensitive waters).

During facility operations, the lagoon received wastewater via a buried pipeline and runoff from a surface ditch. In 1998, the earthen dam surrounding the lagoon was breached, allowing discharge to flow to a small wetland. The intermittent stream, which conveys runoff from the JFD NPL Site and the Oxford Printing Site, bisects the wetlands area (**Figure 4**). Based data collected from the stream and wetland in 2010, it was concluded that a release of chromium, lead, nickel, vanadium, and zinc occurred via the surface water pathway. In order to trace the path of contaminants released to surface water historically, surface water samples were collected from the lagoon and from the delineated wetland area during the RI.

Metals can be traced from the lagoon inlet to the breach in the lagoon and down-gradient to the delineated wetlands. During the RI, only the most down-gradient surface water sample, collected from the eastern boundary of the delineated wetlands, had detections of chromium, lead, nickel, and vanadium; however, none exceeded their applicable water quality standard.

Similar to surface water, the only exceedances of conservative risk-based screening values for sediment samples were for antimony, barium, beryllium, chromium, vanadium, and zinc. Maximum exceedances were by less than a factor of 2.5 for all metals except chromium (4.8) and beryllium (7.8). PCE was identified in sediment collected from the onsite drainage ditch in 2007 but was not found downstream in sediment collected from the lagoon in 2015. Site-related contaminants may continue further downstream but, to date, samples have only been collected within the Site boundary.

Sediment within the lagoon may represent a continuing secondary source of contamination to down-gradient surface water and sediment, including that within the delineated wetland. Although sediment could potentially contribute to groundwater contamination, this effect cannot be quantified from the present data.

Refer to **Figure 4** for the surface water/sediment sampling locations.

SUMMARY OF SITE RISKS

As part of the RI, a baseline human health risk assessment (HHRA) and ecological risk assessment (ERA) were prepared for the Site. These assessments evaluated risks to human and ecological populations that may be exposed to chemicals present in surface soil, subsurface soil, groundwater, surface water, and sediment at the Site under current and potential future conditions. These risk assessments provide the basis for determining if remedial action is warranted and if so, to identify the contaminants and exposure pathways that need to be addressed by the preferred remedial alternative.

Human Health Risk Assessment (HHRA): Although used for industrial/commercial purposes in the past, there is no current industrial activity at the Site. Consequently, the only current exposure pathway is by trespasser/visitors. In the future, the Site could be used for either residential or industrial/commercial land use as well as by future trespassers, future construction workers and future utility workers.

An unacceptable cancer risk is identified when the Site-related cumulative cancer risk is above EPA's risk management limit of 1×10^{-4}. A non-cancer risk is identified when the Site-related cumulative hazard quotient results in a Hazard Index (HI) greater than 1. **Table 1** summarizes the cumulative cancer and non-cancer risks associated with contamination at the Site (the shaded values indicate unacceptable cancer risk or non-cancer hazard).

The results of the HHRA for sub surface soil, groundwater and indoor air at the Site indicate that residential, industrial/commercial worker, construction worker and utility worker exposures result in unacceptable cancer risks and non-cancer hazards. For the indoor vapor intrusion pathway, indoor air concentrations were developed using the EPA Vapor Intrusion Screening Level (VISL) Calculator. For these calculations, maximum groundwater EPCs were used as input to the VISL Calculator to generate predicted indoor air concentrations for residential and industrial/commercial scenarios. The HHRA concluded that:

- Cancer risks and non-cancer HIs are unacceptable for future residents and future industrial/commercial workers due to exposure to soil, groundwater, sediment and indoor air.
- Onsite: Cancer risks are within the acceptable range and non-cancer HIs are below the threshold for the current/future trespasser/visitor exposure scenario for all contaminated media.
- Onsite: Cancer risks are acceptable; however, non-cancer HIs are unacceptable for future construction workers and future utility workers due to exposure to soil and groundwater.
- Onsite: Cancer risks are within the acceptable range and non-cancer HIs are below the threshold for all receptors exposed to surface water. Consequently, there are no COCs for surface water.

Site-specific exposure information was unavailable; therefore, a combination of default exposure assumptions and professional judgment were used to evaluate impacts to the various receptors evaluated in the HHRA. These exposure assumptions are conservative and are likely to overestimate hazards and risks. Note that aluminum, arsenic, and manganese in soil may be present at naturally-occurring background levels which exceed applicable standards. Risk management decisions should take background levels into consideration.

Ecological Risk Assessment (ERA): The ERA evaluated the areas at the Site identified as having contaminated media, either by direct contamination from process or waste management activities during facility operation or through subsequent transport. These areas included:

- Small areas of onsite soils in the vicinity of the former oil/water separator, the former AST, and near the former drum disposal area; and
- Potential migration of runoff from these areas in the ditch to the lagoon and downstream through the wetland; however, surface water and sediment in the ditch, lagoon and headwater stream do not support a viable aquatic ecosystem, but rather semi-aquatic receptors.

Surface soils support terrestrial receptors such as plants, soil invertebrates, small mammals, and birds. The exposure routes to these ecological receptors may include the following:

- Uptake by vegetation;
- Direct contact to contaminated media by invertebrates or vertebrates;
- Direct ingestion of media (e.g., surface soil, surface water, or sediment); and
- Indirect exposure of predatory wildlife to bioaccumulative contaminants in contaminated prey tissue.

Surface water at the Site is limited to runoff from the northeast and east portions of the building area that eventually drain into the lagoon. During high precipitation events, some of the lagoon water then flows into a wetland which connects to a small headwater stream that originates offsite as a storm water ditch. Permanent aquatic organisms are generally not present in this local environment. Although aluminum, copper and zinc exceed NCDEQ water quality criteria for protection of aquatic life, the source of the headwater stream is from

an offsite storm water conveyance system. Thus, exposures and risks to aquatic and semi-aquatic life are temporary and of short duration.

Benthic organisms inhabiting sediments in the lagoon, wetland and stream are at low risk from exposure to scattered locales of elevated metals with no clear contamination pattern. Similarly, risks to terrestrial receptors from exposure to scattered pockets of elevated metals in soil are at low to negligible risk. Consequently, surface water and sediment do not pose a risk to ecological receptors.

CHEMICALS OF CONCERN

The COCs determined from the results of the HHRA and ERA were identified based on EPA's guidance. COCs are chemicals that significantly contribute to an exposure pathway that either exceeds a 1×10-4 cumulative Site cancer risk or exceeds a non-cancer HI of 1. **Tables 2, 3, 4, 5 and 6** list the COCs for sediment, surface soil, subsurface soil, groundwater and indoor air, respectively, and their associated cleanup levels (shown on the tables in yellow highlight).

SCOPE AND ROLE OF OPERABLE UNIT

The EPA is addressing this site under one action.

REMEDIAL ACTION OBJECTIVES

The Site-specific remedial action objectives (RAOs) are:

1) Reduce the risks to workers and the environment from exposure to contaminated soils, groundwater and indoor air to levels that are protective of the current and anticipated future uses.
2) Prevent any residual DNAPL, adsorbed-phase COCs or groundwater COCs from the UZ and SSZ media zones, as a source of vapor intrusion in structures.
3) Reduce or eliminate the leaching of soil COCs into groundwater to levels that are protective of human health and the environment.
4) Prevent the migration of COCs into the lagoon basin sediments from adjacent building area to levels that are protective of human health and the environment.
5) Prevent down-gradient migration of contaminated groundwater within the transition zone and bedrock aquifer.
6) Restore groundwater quality to meet NCDEQ and EPA primary drinking water standards throughout the plume, based on the classification of the aquifers as a potential source of drinking water [Class GA or Class GSA] under 15A NCAC 02L.0201.

REMEDIAL ALTERNATIVES

Soil and groundwater contamination requiring remediation at the Site were classified into three contaminated media zones (CMZs). A CMZ represents a portion of the Site contamination which has a particular characteristic, such as lithology, COC presence, depth, areal extent, and/or presence of DNAPL that defines the optimal remediation approach. Segregation of the Site into CMZs allows remedial alternatives to be tailored to these conditions, thereby resulting in a more economical and focused remedy. **Figure 8** illustrates the CMZ delineations.

The general remedial strategy at the Site is driven by the need to restore and protect the drinking water resource that exists under the Site. The remedial strategy for the Site, which utilizes an adaptive management approach is: (1) aggressive remediation of source contamination (e.g., soil and groundwater with high concentrations of contaminants or DNAPL); and (2) phased active remediation of groundwater in the greater dilute plume. Remediation will be optimized by targeting the highest levels of mass first. Restoration of the full

DP zone will rely on monitored natural attenuation (MNA) to identify the flux reduction of COCs from source treatment and further evaluate the scope of treatment required for the DP.

This section describes each of the remedial alternatives that were developed and evaluated in each CMZ. The cost of each alternative and an analysis of its ability to meet specific evaluation criteria are presented in the following section titled Evaluation of Alternatives. The alternatives presented below represent those technologies identified as having the ability to meet remedial action objectives of the cleanup given the contaminants of concern and other factors such as site geology. Other technologies that were identified but eliminated from consideration are described in the Feasibility Study report.

Unsaturated Zone (UZ): The UZ represents on-facility unsaturated soil between approximately 0 and 20 ft below ground surface (bgs) impacted with CVOCs and trace levels of petroleum compounds above RGO levels for: (1) protection of humans from direct contact with soils; (2) protection of construction workers; (3) protection for vapor intrusion; and (4) protection of underlying groundwater from soil contaminants. Remediation of this zone is focused on protection of human health and the environment (HH&E) from these adsorbed phase COCs. While no DNAPL has been detected in unsaturated soil to date, it is expected to be present based on the MIP results collected during the RI. The aerial extent of the UZ encompasses the former drum storage pad, a small portion of the onsite building, and to the northeast along a drainage ditch towards the lagoon.

The table below lists the four remediation alternatives developed for the contaminated soils in the UZ.

UNSATURATED ZONE REMEDIATION ALTERNATIVES		
UZ ALTERNATIVE		**DESCRIPTION OF REMEDIATION ALTERNATIVES**
1	No Action	This alternative is required for consideration by the National Contingency Plan (NCP). No active cleanup activities will be initiated. Periodic monitoring of existing wells and reporting will be completed every five years to confirm Site conditions.
2	Soil Vapor Extraction	Apply a vacuum to unsaturated soil to induce a controlled air flow to remove volatile and some semi-volatile contaminants from the soil for *ex situ* treatment before being discharged to the atmosphere. Soil vapor extraction (SVE) may be implemented alongside and under the former drum storage pad where it will likely reduce vapor intrusion into the building.
3	Soil Excavation	Excavate contaminated soil and dispose of these contaminated soils at an EPA approved offsite disposal facility.
4	*In Situ* Chemical Oxidation (ISCO) with Shallow Soil Mixing	*In situ* mixing of shallow contaminated soil with chemical oxidant. Direct oxidation breaks down COCs into non-hazardous minerals and byproducts.

Alternative UZ #1: No Action – This alternative would not expend funds for control, isolation, or remediation of contaminated soil or groundwater, and the Site would remain in its present condition. This alternative, required by the NCP and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. The O&M costs are for periodic groundwater monitoring and reporting every five years to confirm Site conditions.

Alternative UZ #2: Soil Vapor Extraction (SVE) – This alternative includes the installation of vapor extraction wells in the vicinity of the CVOC-contaminated soil. This alternative would include the installation of thirty one (31) 4-inch diameter SVE wells screened from 5 to 20 ft bgs with four wells installed inside the building. These wells were assumed to have an average 15-ft SVE overlapped radius of influence to treat approximately 12,152 cubic yards (cy) of CVOC-contaminated soil located throughout the entire UZ. SVE wells beneath the building would be installed either vertically from inside the building, or via angled drilling along the periphery of the building. Air entry wells may be required to facilitate more uniform subsurface airflow. A contingency has been included for twenty two (22) 2-inch diameter air entry wells screened from 5 to 20 ft bgs. System

equipment would include a trailer-mounted extraction blower, air/fluid separation tank, and vapor phase carbon filter to remove any contaminants in the air stream before being discharged to the atmosphere. A manifold extraction system would allow phased operation of multiple points simultaneously. The necessity to treat the recovered vapors would be made during the remedial design (RD) phase. Vapor samples would be collected periodically to confirm SVE system performance.

Alternative UZ #3: Soil Excavation – This alternative involves excavating the majority of the UZ to remove a total of approximately 11,275 cy of contaminated soil and transporting the excavated contaminated soil to an offsite, EPA approved, disposal facility. The FS assumed that excavated contaminated soil will be disposed as a non-hazardous waste. Approximately 7,340 cy of soil would be excavated to a depth of approximately 20 ft bgs with 3,935 cy excavated from sloped sidewalls to remove CVOC-contaminated soil from the suspected source area: the former drum storage pad. Soil excavation to 20 ft would require the use of sloped side-walls. Expanded (or complete) demolition of the Cristex building will allow for full excavation of the presumed area of soil contamination. Under this scenario, an additional 4,812 bcy would be excavated. Nine high density polyethylene (HDPE) laterals would be placed at the bottom of the excavation as a contingency for future application of treatment amendments below the excavated area. The laterals would then be covered with clean sand and liner prior to backfilling with clean compacted soil.

Alternative UZ #4: ISCO with Shallow Soil Mixing – This alternative primarily involves mixing a chemical oxidant (assumed to be potassium permanganate) into the top 20 ft of soil beneath the majority of the UZ. Approximately 10,800 cy of contaminated soil would be treated. The FS assumed that potassium permanganate would be batch mixed into a slurry with hydrant water or recovered groundwater, stored in a polyethylene feed tank, applied to the soils in 20-ft by 20-ft grids, and then thoroughly mixed *in situ* using an ALLU or Lang tool on tracked excavators. This *in situ* mixing would enhance oxidant contact with the most contaminated soil for uniform coverage throughout the UZ. Oxidants work through the breaking apart of chemical bonds and removal of electrons, resulting in COCs being transformed into harmless minerals (e.g. carbon dioxide, CO_2, and water) and byproducts. Chemical oxidation works relatively quickly to destroy organic compounds. Selection of chemical oxidant dosing would require treatability testing. Soil samples would be collected to confirm short-term and long-term effectiveness.

Saturated Source Zone (SSZ): The SSZ represents an approximately 70 ft thick zone of saturated soil and groundwater within the saprolite and transition zone (between approximately 20 and 90 ft bgs) beneath suspected source areas. The SSZ is impacted with CVOCs and petroleum hydrocarbons in groundwater. PCE concentrations indicative of very minor soil contamination were measured in soil but groundwater concentrations suggest that more significant soil contamination is present than has been identified to date. There are significant data gaps in SSZ soil concentration measurements and residual DNAPL is potentially present within this zone. Therefore, the SSZ was configured to represent the area with the highest concentrations of groundwater contamination and potential adsorbed or residual source material contributing to dissolved contamination. The aerial extent of the SSZ encompasses the footprint of the UZ (vicinity of the former drum storage pad) and extends to the north along the drainage ditch. There is also a small secondary area in the SSZ beneath the former location of the buried drums. Remediation of this zone is focused on protection of humans from continued migration and dissolution of adsorbed CVOCs and possible residual DNAPL. The depth of the zone and its location, in part, beneath the facility building, the COC properties, and the low permeability lithology govern the remedial options for the SSZ.

The following five remediation alternatives were developed for the contaminated saturated soil and groundwater in the SSZ:

SATURATED SOURCE ZONE REMEDIATION ALTERNATIVES		
	SSZ ALTERNATIVE	**DESCRIPTION OF REMEDIATION ALTERNATIVES**
1	No Action	This alternative is required for consideration by the NCP. No active cleanup activities will be initiated. Periodic monitoring of existing wells and reporting will be completed every five years to confirm Site conditions.
2	Enhanced *In Situ* Bioremediation (EISB) with Chemical Reduction	Injection of amendments and possibly a bacteria consortium into groundwater through an injection well array to facilitate direct chemical reduction of CVOCs in the solvent source area. Adjusting the geochemistry of the groundwater (creating reducing conditions in the aquifer) is a component of this alternative.
3	Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with Biobarriers	Injection of an oxidant into groundwater through an injection well array to facilitate direct chemical oxidation of CVOCs in the solvent source area. Application of electrokinetics using a direct current to enhance the distribution of oxidant, along with downgradient EISB biobarriers are components of this alternative.
4	Electrokinetics-Enhanced *In Situ* Bioremediation (EK-BIO) with Biobarriers	Injection of a mixture of carbon substrate amendments into groundwater through an injection well array to facilitate direct biodegradation of CVOCs in the solvent source area. Application of electrokinetics using a direct current to enhance distribution of amendments, along with downgradient EISB biobarriers are components of this alternative.
5	Biogeochemical Reductive Dehalogenation (BiRD) with Recirculation	Treatment using naturally occurring divalent minerals supplemented with a mixture of carbon substrate, sulfate, and soluble ferrous iron injected into groundwater through an injection well array to facilitate direct chemical reduction of CVOCs in the solvent source area using iron sulfides. Groundwater extraction and re-injection to create zones of recirculation is a component of this alternative.

Alternative SSZ #1: No Action – This alternative would not expend funds for control, isolation, or remediation of contaminated soil or groundwater, and the Site would remain in its present condition. This alternative, required by the NCP and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. The O&M costs are for periodic groundwater monitoring and reporting every five years to confirm Site conditions.

Alternative SSZ #2: Enhanced *In Situ* Bioremediation with Chemical Reduction – This alternative involves injection of amendments such as a carbon substrate with zero valent iron (ZVI) or soluble ferrous iron to reduce residual DNAPL, CVOCs adsorbed on saturated soil, and CVOCs dissolved in groundwater. It offers the benefit of both anaerobic biodegradation and chemical reduction treatment mechanisms. In the southern portion of the SSZ the amendments would be added via a dense array of injection wells to treat the suspected release area and the presumed highest levels of soil contamination. In the northern half of the SSZ the amendments would be added as permeable treatment barriers to treat lower levels of groundwater contamination. Effective implementation of EISB with Chemical Reduction (CR) is dependent upon uniform amendment distribution and contact with contaminants. This alternative assumes installation of permanent injection wells screened above bedrock for targeted injection of amendments in the saprolite and the transition zone using inflatable packers. To implement this alternative, a portion of the building would need to be demolished and the concrete building foundation and the former drum storage pad would be removed.

Two currently existing commercial products, Peroxychem's EHC-L® and EOS Remediation's EOS_{ZVI}® were used as potential materials that may be injected into the subsurface for this remedial alternative. EHC-L provides a water soluble soy lecithin carbon substrate and powdered ferrous iron salt mixture and nutrients for the EISB/CR amendment. EOS_{ZVI} is a water mixable soy bean oil based substrate with a micro-scale carbonyl iron with a surfactant, and pH stabilizer. The injection mixture make-up water would need to be conditioned to lower the oxidation-reduction potential (ORP) and adjust the pH. The amendment mixtures are both capable of direct push technology (DPT) and injection well delivery. The carbon substrate would potentially provide a long-term source of carbon (electron donor); from 2 to 5 years for these products. The ferrous iron and ZVI would contribute to reduced conditions favorable for the development of iron sulfides in the formation for

chemical reduction. The FS assumed an injection period of approximately 16 weeks, with approximately 65,500 pounds of EOS_{ZVI} injected at up to 6 wells simultaneously. Injection was estimated at 0.4 gallons per minute (gpm)/well with a 25% weight to weight (w/w) concentration of EOS_{ZVI}. A secondary injection of EOS_{ZVI} at 25% of the original dose was incorporated as a follow-up injection during the second year of operation. Performance monitoring and installation of performance monitoring wells was included in the FS.

Alternative SSZ #3: Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with Biobarriers – This alternative involves the application of electrokinetics using a direct current (DC) to enhance the transport of oxidant from ISCO injection wells (EK-ISCO) along with installation of downgradient EISB biobarriers. Through a series of anode/cathode wells installed in the subsurface, an electrical current would be applied, which results in the migration of ions toward their oppositely charged electrode. The applied voltage gradient would also result in the bulk movement of groundwater from one electrode to another. Injection of a chemical oxidant, assumed to be potassium permanganate ($KMnO_4$), would be used to destroy residual DNAPL, CVOCs adsorbed on saturated soil, and CVOCs dissolved in groundwater. Organic compounds in contact with the oxidant would be quickly oxidized; thereby eliminating contaminant mass available for dissolution and lateral transport in groundwater.

In the southern portion of the SSZ, the EK-ISCO would be applied via a dense array of injection wells to treat the suspected release area and the presumed highest levels of soil contamination. In the northern half of the SSZ the amendments would be added as permeable EISB treatment barriers to treat lower levels of groundwater contamination. Effective implementation of ISCO depends on uniform amendment distribution and contact with contaminants. Application of EK would help to distribute amendments through the subsurface to increase contact with contaminants. This alternative assumed installation of permanent injection wells screened above bedrock. To implement this alternative, a portion of the building would need to be demolished and the concrete building foundation and the former drum storage pad would be removed.

Two EISB passive barriers, which consist of two rows of injection wells, are proposed across the mid-point and toe of the SSZ. The wells would be injected with emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater.

EISB entails the addition of amendments and possibly a bacteria consortium to enhance the *in situ* biodegradation of COCs. The CVOCs present on-facility are generally amenable to biodegradation via direct anaerobic reductive dechlorination. Anaerobic reductive dechlorination is a microbial respiration process in which microorganisms use CVOCs as terminal electron receptors and hydrogen as an electron donor. Hydrogen is generated from the fermentation of organic substrate. Anaerobic EISB applications typically entail the addition of an organic substrate (e.g., lactate, emulsified vegetable oil) as an electron donor source to supplement lower levels of indigenous carbon substrate. The added substrate will produce a suitable reduced zone favorable for reductive dechlorination. Successful application of EISB is also dependent on a suitable pH (optimally between 6 and 8), and the presence of suitable halorespiring bacteria. *Dehalococcoides mycartyi* has been proven to be the most important and effective bacteria for degrading CVOCs although other bacteria such as *Dehalobacter* can anaerobically degrade specific CVOCs. These microorganisms may not be ubiquitous in the subsurface environment and may need to be added along with the carbon substrate, a process termed bioaugmentation. Anaerobic dechlorination from cDCE to VC also requires specific bacterial enzymes (i.e. VC reductase, *vcrA*).

The FS assumed an injection period of approximately 52 weeks, with approximately 69,400 pounds of $KMnO_4$ injected at up to 6 wells simultaneously. Injection was estimated at 0.4 gpm/well with a 2% (w/w) concentration of $KMnO_4$. A secondary injection of oxidant at 25% of the original dose was incorporated as a follow-up injection during the second year of operation. Performance monitoring and installation of performance monitoring wells was included in the FS.

Alternative SSZ #4: Electrokinetics-Enhanced *In Situ* Bioremediation (EK-BIO) with Biobarriers - This alternative is an analogous remedy to SSZ #3 (EK-ISCO) except that electrokinetics is used to enhance the movement of EISB amendments instead of an oxidant. Through a series of anode/cathode wells installed in the subsurface, an electrical current would be applied which results in the migration of ions towards their oppositely charged electrode. The applied voltage gradient would also result in the bulk movement of groundwater from one electrode to another. Injection of a carbon substrate, pH adjustment, and bioaugmentation culture would result in treatment of adsorbed and dissolved phase CVOCs. EK-BIO would be added via a dense array of injection wells in the southern portion of the SSZ. Two EISB permeable treatment barriers would be deployed in the northern half of the SSZ. Additionally, this alternative involves the use of an EISB passive barrier consisting of two rows of injection wells, across the toe of the UZ and at the toe of the SSZ. The injection wells would be injected with emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater.

This alternative assumed installation of permanent injection wells screened above bedrock. To implement this alternative, a portion of the building would need to be demolished and the concrete building foundation and the former drum storage pad would be removed. The FS assumed the use of an emulsified oil batch mixed slurry. The slurry make-up water would need to be conditioned to lower the ORP and adjust the pH. The FS assumed an injection period of approximately 5 weeks, with approximately 135,800 pounds of emulsified oil injected at up to 6 wells simultaneously. Injection was estimated at 0.4 gpm/well with an 18% (w/w) concentration of oil. A pH buffer would be required to offset the production of acid from the reaction and to raise the natural pH to optimal levels for biodegradation. The remedy also assumes that bioaugmentation of the formation with halorespiring bacteria would be required. A secondary injection of oil at 25% of the original dose was incorporated as follow-up injection during the second year of operation. Performance monitoring and installation of performance monitoring wells was included in the FS.

Alternative SSZ #5: Biogeochemical Reductive Dehalogenation (BiRD) with Recirculation - This alternative involves the patented BiRD technology applied to the SSZ using an injection well and recirculation well approach. The BiRD *in situ* process would promote abiotic reductive dechlorination of chlorinated aliphatic hydrocarbons (CAHs). This technology relies upon the injection of carbon substrates (e.g., emulsified oil) to promote reduced conditions in an aquifer and to facilitate the conversion of naturally occurring iron minerals (typically ferric) to mineral iron sulfide (i.e., Fe_xS_y) that can promote abiotic degradation. BiRD can also be used to enhance reducing geochemical conditions for metals stabilization. This remedy would include a series of recirculation cells used to inject carbon substrate, sulfate, and iron solution to reduce residual DNAPL, CVOCs adsorbed on saturated soil, and CVOCs dissolved in groundwater. The recirculation scheme is expected to be more flexible and provide enhanced hydraulic flushing/amendment recirculation. As with other *in situ* technologies, amendment distribution and contact with contaminants, along with suitable soil mineralogy is important to the success of the BiRD process. The carbon substrate and iron sulfides produced from the process will potentially allow secondary contact with COCs in groundwater flowing through the area for an extended duration.

This alternative assumed installation of injection wells screened above bedrock for EISB/CR injection. Recovery wells were assumed to be located on alternate arrays at varying intervals, forming four separate recirculation cells within the SSZ. The amendment make-up water would need to be conditioned to lower the ORP and adjust the pH. The recirculation cells would use an injection manifold, and an equipment trailer with air stripping, bag filtration, activated carbon, and supplemental water conditioning with an oxygen scavenger for water treatment prior to reinjection. Separate injection wells would be used to handle supplemental discharge of treated water as needed. To implement this alternative, a portion of the building would need to be demolished and the concrete building foundation and the former drum storage pad would be removed.

The FS assumed approximately 64,800 pounds of carbon substrate would be injected. Injection was estimated at an average of 0.4 gpm/well. A pH buffer would be required to offset the production of acid from the reaction and to raise the natural pH to optimal levels for biodegradation. The remedy also assumes that bioaugmentation of the formation with halorespiring bacteria would be required. A secondary injection of amendments at 25% of the original dose was incorporated as follow-up injection during the second year of operation. The recirculation system was estimated to operate for 3 years. Performance monitoring and installation of performance monitoring wells was included in the FS.

Dilute Plume (DP): The DP consists of groundwater and contiguous soils/partially weathered bedrock that are impacted with CVOCs. The DP encompasses groundwater with total VOC concentrations less than 310 micrograms per liter (µg/L). Soil contamination adsorbed on DP soil is considered low. The DP is comprised primarily of the bedrock aquifer, but also of the shallower saprolite and partially weathered bedrock transition zone surrounding the SSZ. The depth of the area to be treated (up to 140 ft bgs), along with the large footprint of the plume present economic and implementation challenges for groundwater restoration. Remediation of this zone is focused on preventing the further vertical and horizontal migration of contaminated groundwater. The presence of varying lithology in the saprolite and transition zone as well as the higher hydraulic conductivity and different geochemistry in the bedrock aquifer are further remediation considerations. The DP remedial alternatives are focused on treatment of the transition zone and bedrock aquifer.

The following remediation alternatives were developed for the contaminated groundwater and contiguous soils in the DP.

DILUTE PLUME REMEDIATION ALTERNATIVES		
DP ALTERNATIVE		**DESCRIPTION OF REMEDIATION ALTERNATIVES**
1	No Action	This alternative is required for consideration by the NCP. No active cleanup activities will be initiated. Periodic monitoring of existing wells and reporting will be completed every five years to confirm Site conditions.
2	Enhanced *In Situ* Bioremediation (EISB) Biobarrier	Injection of amendments and possibly a bacterial consortium into groundwater through a row of injection wells to create an EISB passive barrier for accelerating biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater. Adjusting the geochemistry of the groundwater (creating reducing conditions in the aquifer) is a component of this alternative.
3	Hydraulic Capture/Containment	Installation of groundwater recovery wells to capture the CVOC plume in the transition zone and bedrock zone and control contaminated groundwater migration. Treating extracted groundwater through physical processes such as air stripping and adsorption through activated carbon is a component of this alternative.
4	Monitored Natural Attenuation (MNA)	Natural biotic or abiotic degradation for contaminant reduction as a supplemental alternative used in conjunction with treatment of source areas. Long-term monitoring is a component of this alternative.

Alternative DP #1: No Action – This alternative would not expend funds for control, isolation, or remediation of contaminated soil or groundwater, and the Site would remain in its present condition. This alternative, required by the NCP and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. The O&M costs are for periodic groundwater monitoring and reporting every five years to confirm Site conditions.

Alternative DP #2: EISB Biobarrier – This alternative involves injection of amendments such as an emulsified oil substrate potentially supplemented with bioaugmentation and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater. The emulsified oil carbon substrate would potentially provide a long-term source of carbon (electron donor); from 2 to 5 years are anticipated for

the treatment of COCs in groundwater flowing through the area. BiRD amendments (see alternative SSZ #5) could also be added, if deemed necessary for downgradient treatment. This alternative assumed installation of a row of 16, 2-inch permanent injection wells across the DP at the toe of the SSZ. The injection wells were assumed to be screened in the transition zone and bedrock aquifer. The injection well spacing was assumed to be relatively close, with a 10-ft radius on influence, to provide overlapping coverage along the barrier. In addition, a zone of reduced conditions should develop downgradient from the barriers. The injections would use a temporary manifold delivery system and associated equipment. The EISB solution make-up water would need to be conditioned to lower the ORP and adjust the pH.

The FS assumed an injection period of approximately 3 weeks, with approximately 117,500 pounds of emulsified oil injected at up to 6 wells simultaneously. Injection was estimated at 1.25 gpm/well. A pH buffer would be required to offset the production of acid from the reaction and to raise the natural pH to optimal levels for biodegradation. The remedy also assumes that bioaugmentation of the formation would be required. A secondary injection of emulsified oil at 25% of the original dose was incorporated as follow-up injection during the first five years of operation. A total operation of 20 years was assumed, this period being contingent upon the effectiveness of upgradient source reduction. Performance monitoring and installation of performance monitoring wells was included in the FS.

The addition of colloidal (micro-scale) activated carbon was considered as an augmentation to the DP #2 biobarrier option. Colloidal carbon can be injected in the same injection wells and would provide *in situ* carbon adsorption and a potential zone for aggregation of halorespiring bacteria. This supplemental approach would conceptually improve the biobarrier performance and could extend its useful life if the COCs adsorbed on the carbon are biodegraded *in situ*. Colloidal carbon may not be compatible with emulsified oils as they may coat the carbon. This patented technology would require specialized testing and design and cannot be adequately costed at this stage. The incremental cost should consist of the colloidal carbon itself and the preparation and injection of the mixture. The formal evaluation of this Alternative did not include colloidal activated carbon. However, if selected as the recommended alternative, this variation will be considered a viable expansion of the remedy.

Alternative DP #3: Hydraulic Capture/Containment – This alternative involves the use of hydraulic containment using groundwater recovery wells to provide limited COC mass removal and prevent the lateral transport of contaminated groundwater. Recovered groundwater would be treated with air stripping and activated carbon and either returned to the aquifer via injection wells, or discharged to the sanitary sewer. This alternative would include installing deep groundwater recovery wells to capture the groundwater flux at the well and to capture a significant downgradient portion of the undefined dissolved plume. This alternative assumed installation of a row of recovery wells just beyond the extent of the SSZ. The recovery wells were assumed to be screened in the transition zone and bedrock aquifer. The FS preliminarily estimated that an extraction rate of 4 to 15 gpm per well would produce a downgradient capture distance of 145-ft without excessive drawdown induced at the extraction wells. Although, the formation may be capable of yielding higher flowrates. Confirmation of the transition zone and bedrock aquifer hydraulic conductivity are critical data gaps for this alternative. Groundwater flow modeling would be required to determine the optimal well design.

In the absence of source reduction, this alternative may result in the spreading of dissolved COCs away from the source areas to the recovery wells and may result in taking a significant amount of time to capture all contamination. Thus, this remedy is most suitable when combined into a Site-wide alternative. This remedy can provide substantial containment of the dissolved COCs in the DP, but may smear contamination within the containment area. System operation for 15 years was assumed, this period being contingent upon the effectiveness of upgradient source reduction. Performance monitoring was included in the FS.

Alternative DP #4: MNA – This alternative is similar to Alternative 1 except the groundwater monitoring efforts will include the necessary analytical parameters to assess natural attenuation. MNA uses analyses of COCs

and natural attenuation parameters from monitoring wells to gauge the effectiveness of natural biotic and abiotic degradation mechanisms. The difference between this remedy and an active EISB remedy is that carbon and nutrient levels are not enhanced and there is no effort made to stimulate or augment the existing dechlorinating bacteria. Due to the largely aerobic groundwater conditions onsite, natural biodegradation may be limited. However, the presence of PCE/TCE daughter products implies at least a marginal degree of anaerobic reductive dehalogenation. Natural abiotic degradation is assumed to also be a limited but active degradation mechanism.

MNA is a viable supplemental alternative for the DP zone when used in conjunction with treatment of source areas/higher concentration areas. This remedy will be ineffective without source area treatment and will require an extended time for Site restoration (estimated at 30 years) even if source area remedies are not treated aggressively.

EVALUATION OF ALTERNATIVES

The selection of the preferred alternatives for the Site, as described in this Proposed Plan, is the result of a comprehensive screening and evaluation process. The 2016 FS identified and analyzed appropriate remediation technologies/alternatives for addressing contamination at the Site.

EPA uses the following nine criteria to evaluate the identified alternatives. The remedial alternative selected for a Superfund site must achieve the two threshold criteria as well as attain the best balance among the five evaluation criteria. EPA's Preferred Alternative may be altered or changed based on the two modifying criteria.

EVALUATION CRITERIA FOR SUPERFUND REMEDIAL ALTERNATIVES

THRESHOLD CRITERIA

Overall Protectiveness of Human Health and the Environment determines whether an alternative eliminates, reduces, or controls threats to public health and the environment through institutional controls, engineering controls, or treatment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) evaluates whether the alternative meets Federal and State environmental statutes, regulations, and other requirements that pertain to the site, or whether a waiver is justified.

EVALUATION CRITERIA

Long-term Effectiveness and Permanence considers the ability of an alternative to maintain protection of human health and the environment over time.

Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present.

Short-term Effectiveness considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation.

Implementability considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services.

Cost includes estimated capital and annual operations and maintenance costs, as well as present worth cost. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent.

MODIFYING CRITERIA

State/Support Agency Acceptance considers whether the State agrees with the EPA's analyses and recommendations, as described in the RI/FS and Proposed Plan.

EVALUATION CRITERIA FOR SUPERFUND REMEDIAL ALTERNATIVES

Community Acceptance considers whether the local community agrees with EPA's analyses and preferred alternative. Comments received on this Proposed Plan are an important indicator of community acceptance.

A detailed analysis of the remedial alternatives was presented in the 2017 FS document. This analysis compared each remedial alternative for each CMZ to the Threshold and Evaluation Criteria highlighted in the table above. The analysis was conducted by individually evaluating the CERCLA FS guidance sub-criteria for the Threshold and Evaluation Criteria. Each group of sub-criteria was individually evaluated and given a subjective rating and score against the context of the Site RAOs. Scores for the primary Threshold and Evaluation Criteria were developed by averaging sub-criteria scores. Cost was not assigned a score, but the relative cost between remedial alternatives was considered in the comparison. The scores were developed for the threshold and/or primary balancing criteria with "5" being the highest score and "1" being the lowest score. The scores were summed to provide a total (out of 30 points) for each alternative. The tables below summarize the primary criterion scores from this analysis for each CMZ.

Unsaturated Zone (UZ)

SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR THE UNSATURATED ZONE								
		Overall Protection	Compliance with ARARs	Long-Term Effectiveness	Reduction in Toxicity, Mobility, & Volume	Short-Term Effectiveness	Implementability	**Total Score**
UZ ALTERNATIVE								
1	No Action	1.00	1.00	1.00	1.00	4.00	4.50	**12.50**
2	Soil Vapor Extraction (SVE)	4.00	3.75	4.00	3.40	3.63	4.36	**23.14**
3	Soil Excavation	4.50	3.83	4.25	4.30	3.75	4.31	**25.94**
4	*In Situ* Chemical Oxidation (ISCO) with Shallow Soil Mixing	4.50	4.00	4.25	4.10	3.75	4.21	**24.81**

Saturated Source Zone (SSZ)

SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR THE SATURATED SOURCE ZONE								
		Overall Protection	Compliance with ARARs	Long-Term Effectiveness	Reduction in Toxicity, Mobility, & Volume	Short-Term Effectiveness	Implementability	**Total Score**
SSZ ALTERNATIVE								
1	No Action	1.00	1.00	1.00	1.00	4.00	4.50	**12.50**
2	Enhanced *In Situ* Bioremediation (EISB) with Chemical Reduction	3.50	3.75	3.50	3.80	3.67	3.93	**22.15**
3	Electrokinetics-*In Situ* Chemical Oxidation (EK-ISCO) with	4.50	4.00	3.83	4.10	3.88	4.07	**24.38**

	Biobarriers							
4	Electrokinetics-Enhanced *In Situ* Bioremediation (EK-BIO) with Biobarriers	4.00	4.25	3.83	4.00	3.75	4.07	**23.90**
5	Biochemical Reductive Dechlorination (BiRD) with Recirculation	4.00	4.00	3.67	3.90	3.63	3.93	**23.13**

Dilute Plume (DP)

SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR THE DILUTE PLUME								
		Overall Protection	Compliance with ARARs	Long-Term Effectiveness	Reduction in Toxicity, Mobility, & Volume	Short-Term Effectiveness	Implementability	**Total Score**
DP ALTERNATIVE								
1	No Action	1.00	1.00	1.00	1.00	4.00	4.50	**12.50**
2	Enhanced *In Situ* Bioremediation (EISB) Biobarrier	3.00	3.75	4.00	4.00	4.25	4.21	**23.21**
3	Hydraulic Capture/Containment	3.50	4.00	4.00	4.00	4.00	4.29	**23.79**
4	Monitored Natural Attenuation (MNA)	2.00	2.00	3.00	2.90	4.38	4.14	**18.42**

OVERALL PROTECTIVENESS OF HUMAN HEALTH AND THE ENVIRONMENT

UZ → All of the alternatives, with exception of UZ #1 - No Action, scored well for protection of Human Health and the Environment (HH&E). Alternatives UZ #3 and UZ #4, Soil Excavation and ISCO with Shallow Soil Mixing, respectively, were tied with the highest ranking for relative overall protection of HH&E as they both offer complete destruction or removal of COCs. However, excavation of the contamination is a more assured technology as the success of any ISCO application depends on contact and thorough mixing of the soils with the oxidant. Alternative UZ #2, SVE, also provides strong overall protection of HH&E with little differentiation between this and the top two scoring alternatives.

SSZ → All SSZ alternatives scored well for protection of HH&E with little significant differentiation between them. Although each alternative would conceptually reduce the contaminant mass, they vary most in the expected efficiency and surety of successful remediation. Alternative SSZ #3, EK-ISCO is the most aggressive of the approaches and is projected to achieve effective mass reduction in a timeframe of 2 years. Each of the three remaining active approaches relies on a biological or chemical reduction process to achieve mass reduction and are, therefore, somewhat less aggressive than achieving mass reduction via chemical oxidation. Alternatives SSZ #2 (EISB with Chemical Reduction) and SSZ #5 (BiRD) would provide slightly less protection for HH&E due to their reliance on reducing geochemical conditions and their potentially longer treatment timeframes. Alternative SSZ #2 scored the lowest as it relies on direct injection only for amendment distribution and could be less effective. The No Action alternative was not deemed protective.

DP → Alternative DP #3 (Hydraulic Capture/Containment) is expected to provide the highest level of protection for HH&E as it provides both hydraulic containment and long-term mass reduction.. Alternative DP #2 (EISB Biobarrier) was subjectively scored next as it creates a passive treatment wall that will treat groundwater as it continues to flow downgradient. DP #2 will effectively limit any significant dissolved phase contamination from migrating past the barrier, but will not accelerate the mass recovery and subsequent treatment to the extent that the hydraulic capture/containment option will do. DP #4 (MNA) is the least protective of the three active approaches evaluated as it provides only for monitoring of the plume and evaluation of conditions favorable to Monitored Natural Attenuation. The No Action alternative was deemed non-protective as it would allow continued migration of the contaminants downgradient.

COMPLIANCE WITH ARARS

Remedial actions must comply with Applicable or Relevant and Appropriate Requirements (ARARs) of federal and state laws, statutes, and regulations. ARARs are determined by applying a two-tiered test to determine first whether the requirement is applicable and second to determine whether the requirement is relevant and appropriate. Applicable requirements are those cleanup standards, controls, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, or contaminant, remedial action, location, or other circumstance at a Superfund site. Relevant and appropriate requirements are those cleanup standards, standards of control, or other substantive environmental provisions that do not directly and fully address site conditions but address similar situations or problems to those encountered at a Superfund site. Whether or not a requirement is appropriate (in addition to being relevant) will vary depending on factors such as the duration of the response action, the form or concentration of the chemicals present, the nature of the release, the availability of other standards that more directly match the circumstances at the site, and other factors.

In addition, non-promulgated advisories or guidance documents issued by federal or state governments, referred to as To Be Considered (TBC), also are identified. TBCs are not considered legally enforceable and, therefore, are not considered to be applicable for the site, but they are evaluated along with ARARs as part of the risk assessment to set protective cleanup goal targets.

There are three types of ARARs: chemical-specific, action-specific, and location-specific. Chemical-specific ARARs are usually health or risk-based restrictions on the amount or concentration of a chemical that may be found in or discharged to the environment. Action-specific ARARs establish controls or restrictions on the remedial activities which are part of the remedial solution. Action-specific ARARs are triggered by the specific activity rather than the chemicals present. Location-specific ARARs prevent damage to unique or sensitive areas, such as floodplains, historic places, wetlands, and fragile ecosystems, and restrict other activities that are potentially harmful because of where they take place. Chemical- specific, action-specific, and location-specific ARARs including TBCs for the Site have been identified and are listed in the 2016 FS.

UZ → Alternative UZ #4, ISCO with Shallow Soil Mixing, is projected to be the most aggressive treatment alternative and is expected to have the most comprehensive successes at reducing the mass and concentration of contaminants, and should do so in a short timeframe (less than six months). The soil excavation remedy (UZ #3) offers an incremental advantage too as it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. However, it does not ultimately meet chemical ARARs but instead transfers contaminants to a more secure location. Alternative UZ #2, SVE, scored lower on chemical-specific ARARs due to it being the least robust of the active remedies at removing or destroying contaminant mass in the subsurface. The No Action alternative (UZ #1) was scored low based upon the lack of treatment.

The action-specific ARARs provided some differentiation between the alternatives as alternative UZ #3, soil excavation, provides a greater exposure risk to workers and the community than the other alternatives. All of the alternatives provide reasonable assurances of meeting the location- and action-specific ARARs.

SSZ → Alternatives SSZ #3 and SSZ #4, EK-ISCO and EK-BIO, respectively, each have a projected remedial timeframe of only 2 years and have a more aggressive method for achieving contact between COCs and amendments. EK-ISCO has a few more operational and permitting concerns related to U.S. Department of Homeland Security Chemical Facility Anti-Terrorism Standard for specific oxidants. Alternative SSZ #5 is dependent on formation of iron sulfide complexes under specific biogeochemical conditions. The minerology to further support this treatment approach has not been completed; hence this alternative has a less rigorous design basis. Alternative SSZ #2 is the least reliable approach for meeting chemical-specific ARARs since it has more uncertainty for amendment distribution and may be more reliant on COC desorption and natural transport within the saprolite. The No Action alternative (UZ #1) was scored low based upon the lack of

treatment. All of the alternatives provide reasonable assurances of meeting the location- and action-specific ARARs.

DP → Compliance with chemical-specific ARARs is best afforded by Alternatives DP #3 (Hydraulic Capture/Containment) and DP #2 (EISB Biobarrier). Both of these options provide a good level of treatment or capture of COCs in the DP to preclude offsite migration and contact with COCs in groundwater above RGOs. DP #2 provides better overall surety as the positive hydraulic control will prevent excursions. DP #3 is expected to have the most comprehensive success at reducing the contiguous adsorbed phase mass at and immediately downgradient of the barrier. The MNA alternative (DP #4) and the No Action Alternative were scored low based upon the lack of treatment. All of the alternatives provide reasonable assurances of meeting the location- and action-specific ARARs.

LONG-TERM EFFECTIVENESS AND PERMANENCE

UZ → Alternatives that physically remove contaminants from the Site media provide the most protection for the longest period, which all three active remedial alternatives offer. The Soil Excavation alternative (UZ #3) would provide a guaranteed successful outcome and eliminate all COCs from the source area. While it scored the same as ISCO with Shallow Soil Mixing (UZ #4), the soil excavation remedy offers an incremental advantage as it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. SVE (UZ #2) was ranked slightly lower than the other alternatives as it is it more likely to leave residual COCs due to the heterogeneous, low permeability soils. The likelihood of all alternatives to meet performance specifications in the near term is high.

SSZ → All of the remedies evaluated (excluding the No Action alternative) will achieve similar outcomes with successful long-term results. Alternatives SSZ #3 and SSZ #4, EK-ISCO and EK-BIO, respectively, are the highest rated as they should have the fewest post-remediation risks and provide a dynamic control mechanism for real time adjustments in amendment distribution. The success of the EK-ISCO alternative is sensitive to the oxidant dosing, although the remedy allows for continued oxidant inputs as needed. EK-ISCO and EK-BIO have relative tradeoffs for overall effectiveness: EK-ISCO is a more robust remedy, while EK-BIO is more compatible with the reduced chemistry of the middle downgradient biobarrier. The comparatively innovative status of EK lowered the overall scoring for SSZ #3 and SSZ #4 as this supplemental technology is less proven. The BiRD and EISB with Chemical Reduction remedies had slightly lower rankings due to the added concern of changing the Site geochemistry to a reduced state for these remedies to be effective.

DP → Alternatives DP #3 (Hydraulic Capture/Containment) and DP #2 (EISB Biobarrier), offer containment and COC removal and have adequate and reliable controls, but will require the same long-term monitoring as required for DP #4 (MNA). Functionally, remedies DP #2 and DP #3 are similar; both will treat the groundwater flux and contain a portion of the dissolved plume. These alternatives should have no significant issues with residual risks, reliability, or treatment irreversibility. Both remedies are susceptible to long-term O&M costs events if SSZ remediation does not adequately limit the incoming flux of COCs; DP #2 through continued operating costs, and DP #3 through reinjections of substrate. Alternative DP #2 is dependent upon direct hydraulic contact that could be limited in the heterogeneous lithology. DP # 3 (Hydraulic Capture/Containment) relies on long-term back diffusion of COCs from transition zone soil.

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

UZ → Alternative UZ #3, Soil Excavation has been ranked slightly higher because it provides complete removal of the contaminant mass and the shortest timeframe of all remedies. The ISCO remedy (UZ #4) may have technical limitations getting sufficient mixture in the saprolitic clays which could result in some pockets of long-term desorption and a potential for continued Toxicity, mobility, and volume (T/M/V). The remaining alternative, SVE (UZ #2), has comparable reductions in T/M/V as it provides reduction of T/M/V through mass

destruction, but has the longest timeframe for success (five years) and may also be limited by inadequate air-phase contact in the saprolite. The No Action alternative offers no T/M/V reduction.

SSZ → All of the remedies evaluated (excluding the No Action alternative) will achieve a similar reduction in T/M/V with a projection for successful long-term results. The biobarrier and BiRD recirculation layouts all provide good downgradient mobility restrictions in the saprolite and Transition Zone. With proper engineering, all alternatives are capable of complete reductions in toxicity and volume. Alternative SSZ #3 (EK-ISCO), was rated marginally higher for being the most aggressive option. Alternative SSZ #5 (BiRD) was ranked slightly lower than the other two active treatment approaches due to uncertainty with the overall effectiveness of the phased biogeochemical treatment approach and lack of bench scale testing. However, the recirculation approach with the BiRD remedy will remediate marginal levels of dissolved contamination around the SSZ as an ancillary benefit. The No Action alternative offers no T/M/V reduction.

DP → DP #3 (Hydraulic Capture/Containment) and DP #2 (EISB Biobarrier) have the equivalent rankings for reduction of T/M/V. DP #2 is an active treatment approach that destroys contaminants; hence it is expected to effectively reduce toxicity and mobility and ultimately reduce the plume volume. The EISB barrier wall will require complete sequential degradation through vinyl chloride to prevent residual risks. Bioaugmentation should provide the engineering control to meet this goal. Alternative DP #3 provides greater reductions in mobility and volume, but would be less effective at lowering adsorbed phase COCs in the short-term. MNA, alternative DP #4, scored lower as it lacks active treatment. The No Action alternative offers no T/M/V reduction.

SHORT TERM EFFECTIVENESS

UZ → The No Action alternative was ranked the highest as it is the fastest to implement and does not provide COC exposure to workers or the community. Alternative UZ #4 (ISCO with Shallow Soil Mixing) and UZ #3 (Soil Excavation) have equivalent rankings because either alternative has minimal environmental impacts with prudent safeguards, and a relatively short implementation timeframe. The excavation alternative (UZ #3) increases the potential for impacts to the community and workers, although these issues can be effectively managed. The use of oxidants for UZ #4 always carries the potential for spills and chemical injuries. Alternative UZ #2 (SVE) is limited by non-uniform air contact with soils and would have the longest timeframe for meeting RAOs. SVE has few construction concerns, but does have the potential for excursions of untreated air upon vapor phase carbon breakthrough.

SSZ → All four active alternatives provide good short-term effectiveness. They are all equally protective of workers and the community during remedial action and have no anticipated environmental impacts. EK-ISCO (SSZ #3) has a marginal advantage over EK-EISB (SSZ #4) in that the more aggressive approach should obtain RAOs faster. The No Action alternative was ranked the highest as it is the fastest to implement, does not impact the environment and is protective of workers. The electrokinetic enhanced alternatives ranked best as they are projected to have shorter remedial timeframes with EK-ISCO (SSZ #3) having a slight edge due to being the more aggressive of the two treatments.

DP → None of the active remedies will have a distinguishable difference in community impacts or worker protection. All options are generally protective of the local community, though MNA (DP #4) has the greatest uncertainty regarding the overall remedial timeframe. The two active alternatives EISB Biobarrier (DP #2) and Hydraulic Capture/Containment (DP #3) provide good short-term effectiveness and are protective of workers and the community during remediation. An EISB biobarrier should be more effective at meeting RAOs in a shorter timeframe. This benefit is offset though by the potentially longer operational timeframe and ongoing emission of treated exhaust.

IMPLEMENTABILITY

UZ → The No Action alternative is the simplest alternative to implement. All three active alternatives are considered to have good implementability with little differentiation. Alternative UZ #2, SVE, was scored the second highest because it will be simplest to construct and easier to monitor for remedial effectiveness and to make remedial modifications to with minor Site disruption. However, this alternative has the longest implementation timeframe (5 years). Alternative UZ #3 (Soil Excavation) will be easy to implement and monitor for remedial effectiveness, but may require more significant structural mitigations for the building or expanded removal of the building. UZ #4 (ISCO with Shallow Soil Mixing) should be easy to implement to depth, but may have uncertainties related to clumping of clayey soils in the saprolite.

SSZ → All of the alternatives evaluated for the SSZ are implementable with only minor issues and have equivalent ratings. SSZ #5 (BiRD) was scored lowest due to the higher complexity of the geochemical reactions. Alternatives SSZ #3 (EK-ISCO) and SSZ #4 (EK-BIO) could have implementation issues related to their complexity and the innovative nature of EK; but counter this with potentially higher remedial effectiveness. All of the remedies depend on reliable technology that is easy to construct and implement. The two options using electrokinetics, SSZ #3 and SSZ #4, utilize a patented technology that relies on limited vendors, which could present scheduling issues during implementation.

DP → All of the alternatives evaluated for the DP zone are implementable with only minor issues and have similar cumulative ranks. The MNA alternative (DP #4) was scored lower since natural attenuation may not be a reliable treatment method based on Site geochemical conditions. DP #2 (EISB Biobarrier) offers more complexity due to the reliance on establishing and maintaining reduced conditions. The No Action alternative is the most easily implemented option and was afforded the highest score. All remedies offer reliable and proven technology that is easy to implement, though the capture/containment system (DP #3) is more easily modified.

COST

Cost estimates are summarized in the tables below including the following pertinent information for each alternative: Estimated Capital Cost, Estimated Annual Operation and Maintenance (O&M) Costs, Net Present Value, Estimated Construction Timeframe, and Estimated Time to Achieve RAOs. Net Present Values were calculated using a 7 percent discount rate with -30/+50% cost estimate reliability and costs were rounded-off to the nearest hundredth dollar amount. Costs for the implementation of Five-Year-Reviews and groundwater monitoring are included as the Site-Wide Costs. These O&M costs were estimated separately as they apply to all remedy alternatives since waste will remain in place at the Site. They are not included in the tables below but are included in the costs for the preferred remedial alternatives.

ESTIMATED COSTS FOR CONTAMINATED SOIL REMEDIAL ALTERNATIVES IN THE UNSATURATED ZONE				
Alternative	**UZ #1**	**UZ #2**	**UZ #3**	**UZ #4**
Estimated Capital Cost	$0	$846,400	$1,873,000	$1,332,700
Estimated Annual O&M Costs	$14,200	$135,900	$0	$29,800
Net Present Value	$42,000	$1,607,400	$1,873,000	$1,370,800
Estimated Construction Timeframe	0 months	6 months	3 months	less than 6 months
Estimated Time to Achieve RAOs	greater than 30 years	5 years	3 months	less than 1 year

ESTIMATED COSTS FOR CONTAMINATED SATURATED SOIL AND GROUNDWATER REMEDIAL ALTERNATIVES IN THE SATURATED SOURCE ZONE					
Alternative	**SSZ #1**	**SSZ #2**	**SSZ #3**	**SSZ #4**	**SSZ #5**
Estimated Capital Cost	$0	$2,749,800	$3,710,700	$3,192,800	$3,651,000
Estimated Annual O&M Costs	$14,200	$143,600	$272,100	$285,800	$581,500
Net Present Value	$42,000	$3,554,300	$4,609,700	$4,409,100	$4,054,900
Estimated Construction Timeframe	0 months	1 year	1 year	9 months	6 months
Estimated Time to Achieve RAOs	greater than 30 years	5 years	2 years	2 years	4 years

ESTIMATED COSTS FOR CONTAMINATED GROUNDWATER AND CONTIGUOUS SOIL REMEDIAL ALTERNATIVES IN THE DILUTE PLUME				
Alternative	**DP #1**	**DP #2**	**DP #3**	**DP #4**
Estimated Capital Cost	$0	$1,201,400	$594,100	$0
Estimated Annual O&M Costs	$14,200	$78,200	$124,500	$26,500
Net Present Value	$42,000	$2,264,500	$1,757,500	$189,100
Estimated Construction Timeframe	0 months	6 months	3 months	0 months
Estimated Time to Achieve RAOs	greater than 30 years	20 years	20 years	greater than 30 years

SUMMARY OF PREFERRED ALTERNATIVE

Using the above information and assumptions, the EPA's preferred remedial alternative for the Site is the combination of the following alternatives:

- The preferred remedial alternative for contaminated soil in the UZ is Alternative UZ #3 – Soil Excavation;
- The preferred remedial alternative for contaminated saturated soil and groundwater in the SSZ is Alternative SSZ #3 – EK-ISCO with biobarriers;
- The preferred remedial alternative for contaminated groundwater and contiguous soils/partially weathered bedrock in the DP is Alternative DP #2 –EISB Biobarriers; and
- Site-wide activities including long-term groundwater monitoring, five-year reviews, placement of institutional controls on the Site to provide increased public awareness of the Site's hazards and to minimize the potential for exposure to contaminated groundwater.

The ICs will: 1) prohibit the use of contaminated groundwater, 2) prohibit contact with contaminated soil/sediments or surface water, and 3) restrict intrusive activities or access to some portions of the facility where contaminated soil may remain in place.

This Preferred Remedial Alternative also includes the following actions:

- Demolition of the former drum storage pad and a portion of the Site building (and slab) to accommodate work in the soils below;
- ISCO/EISB performance monitoring to assess soil contamination around the treated SSZ area and quarterly groundwater sampling of the SSZ for five years; and
- EISB performance monitoring to assess the treated DP groundwater for up to 20 years.

Figure 8 shows the locations of the UZ, SSZ, and DP treatment areas.

The estimated total cost of this preferred remedial alternative is $8,798,235.

TOTAL COST OF PREFERRED REMEDIAL ALTERNATIVE		
Contaminated Media Zone	**Alternative Name**	**Net Present Value**
UZ	UZ #3 - Soil Excavation	$873,035
SSZ	SSZ #3 - EK-ISCO with Biobarriers	$4,609,700
DP	DP #2 –EISB Biobarriers	$2,264,500
Site-Wide Costs (5-Year Sampling and Reviews, ICs, etc.)		$51,000
Total		**$8,798,235**

PUBLIC PARTICIPATION

The public meeting for the Proposed Plan will begin at 6:00 p.m. on Tuesday June 27, 2017, at the NC Cooperative Extension, Granville County, 125 Oxford Loop Road, Oxford, NC.

EPA and NCDEQ have provided information regarding the cleanup of the Site to the public through Fact Sheets, public meetings, announcements in Oxford Public Ledger, and the Administrative Record file. In addition to reading this Proposed Plan, EPA and NCDEQ encourage the public to gain a more comprehensive understanding of the Site and the Superfund activities that have been conducted at the Site by reviewing the documents contained in the Administrative Record/Information Repository.

For further information on the Site, please contact:

Beverly Hudson-Stepter, Remedial Project Manager
US EPA Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-8960
(404) 562-8816 or (800) 435-9233
E-mail: Stepter.beverly@epa.gov

or

Abena Ajanaku, Community Involvement Coordinator
US EPA Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-8960
(404) 562-8834 or (800) 435-9233
E-mail: ajanaku.abena@epa.gov

DOCUMENT INFORMATION

The Administrative Record contains all the information used by the EPA to select a Remedial Action. Copies of the Administrative Record are kept at:

Richard H Thornton Library
210 Main Street
Oxford, NC 27565
Phone: 919-693-1121
Hours: Monday – Thursday 10 a.m. – 8 p.m.
Fri, Sat 10 a.m. – 5 p.m.
Sunday 1 p.m. – 5 p.m.

U.S. Environmental Protection Agency Region IV - Records Center
61 Forsyth Street, SW Atlanta, Georgia 30303-3104
Phone: 404-562-8816
Hours: Monday - Friday 8 a.m. - 5 p.m.

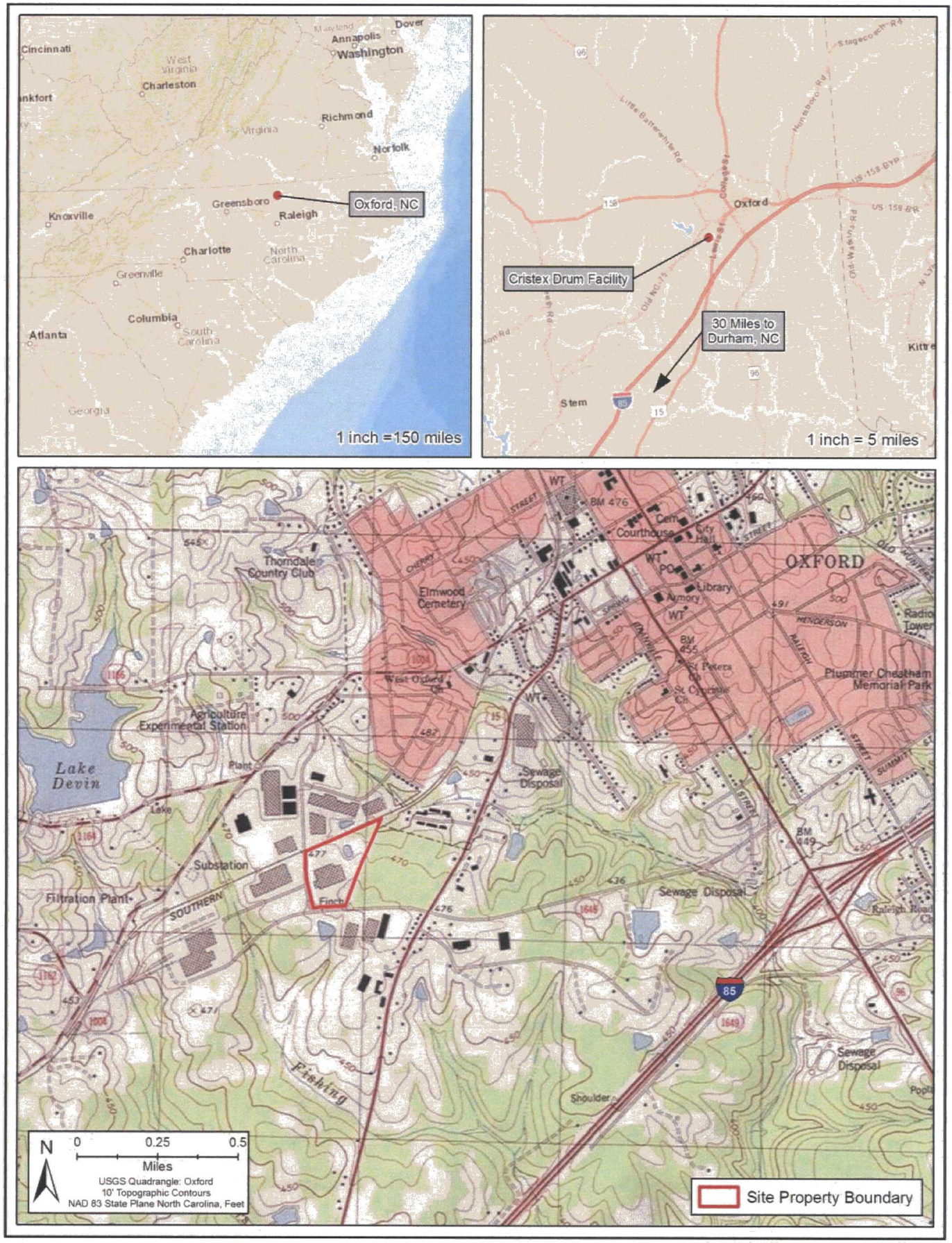


Figure 1: Location of Site

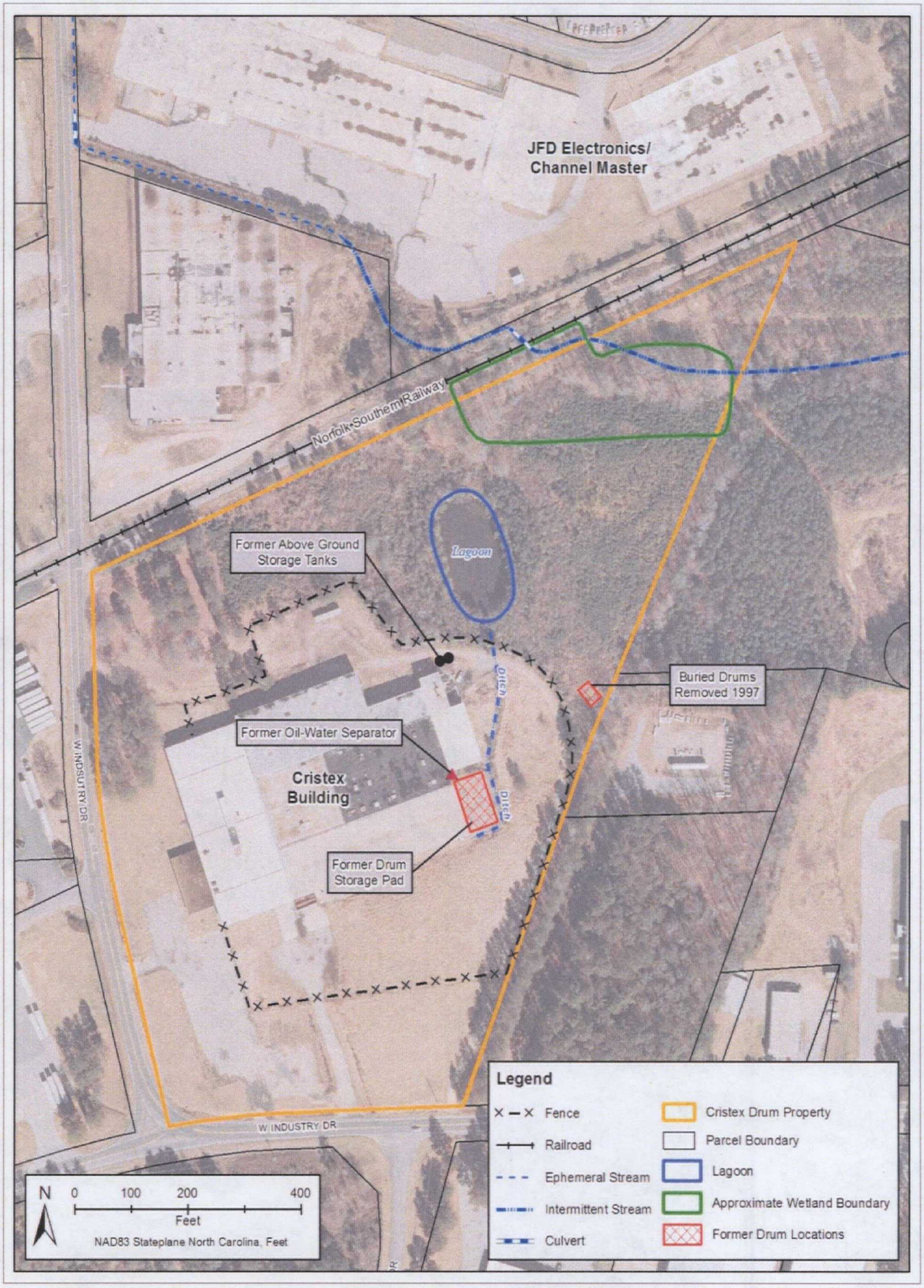


Figure 2: Site Layout

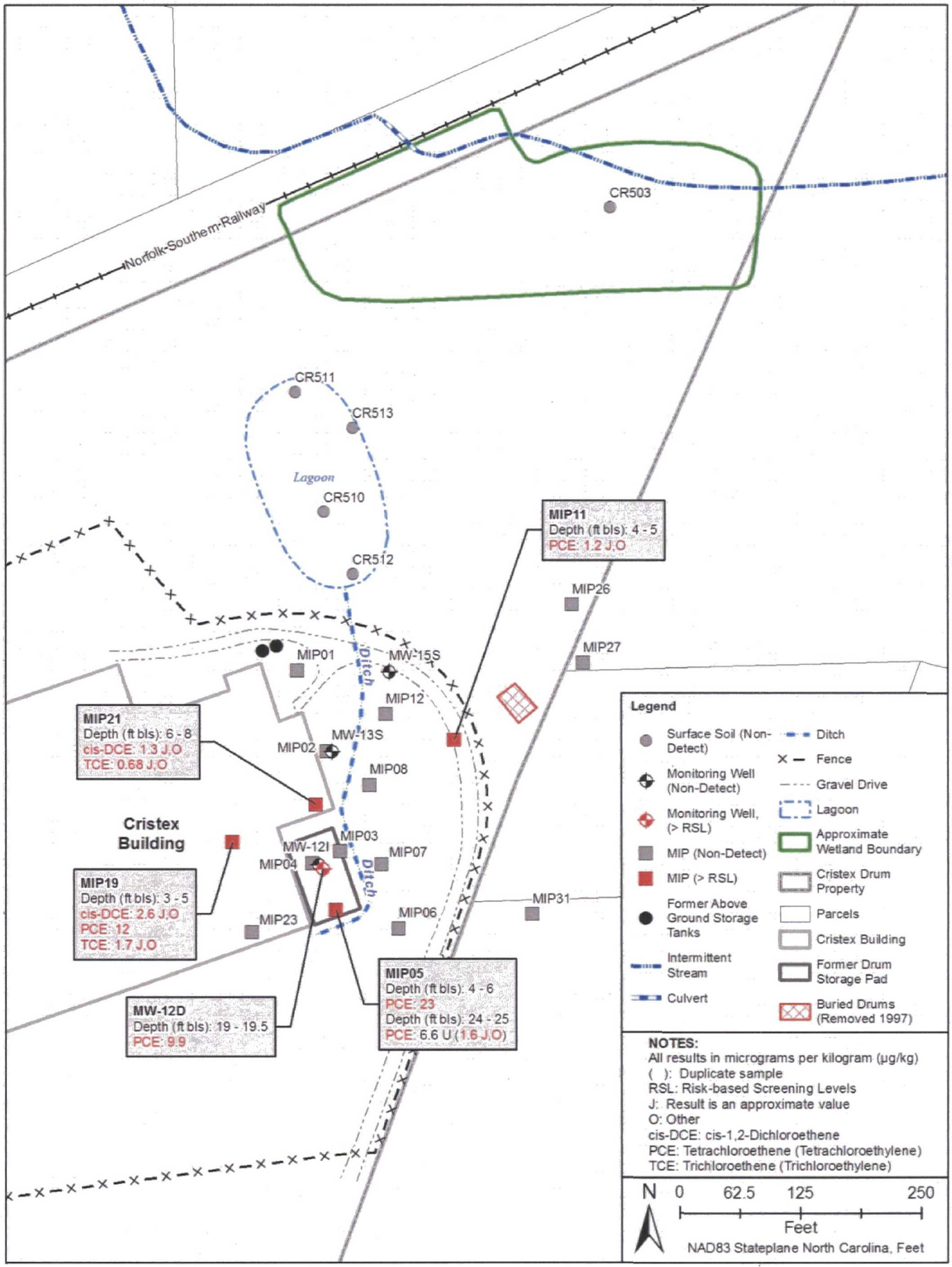


Figure 3: Soil VOC Exceedances

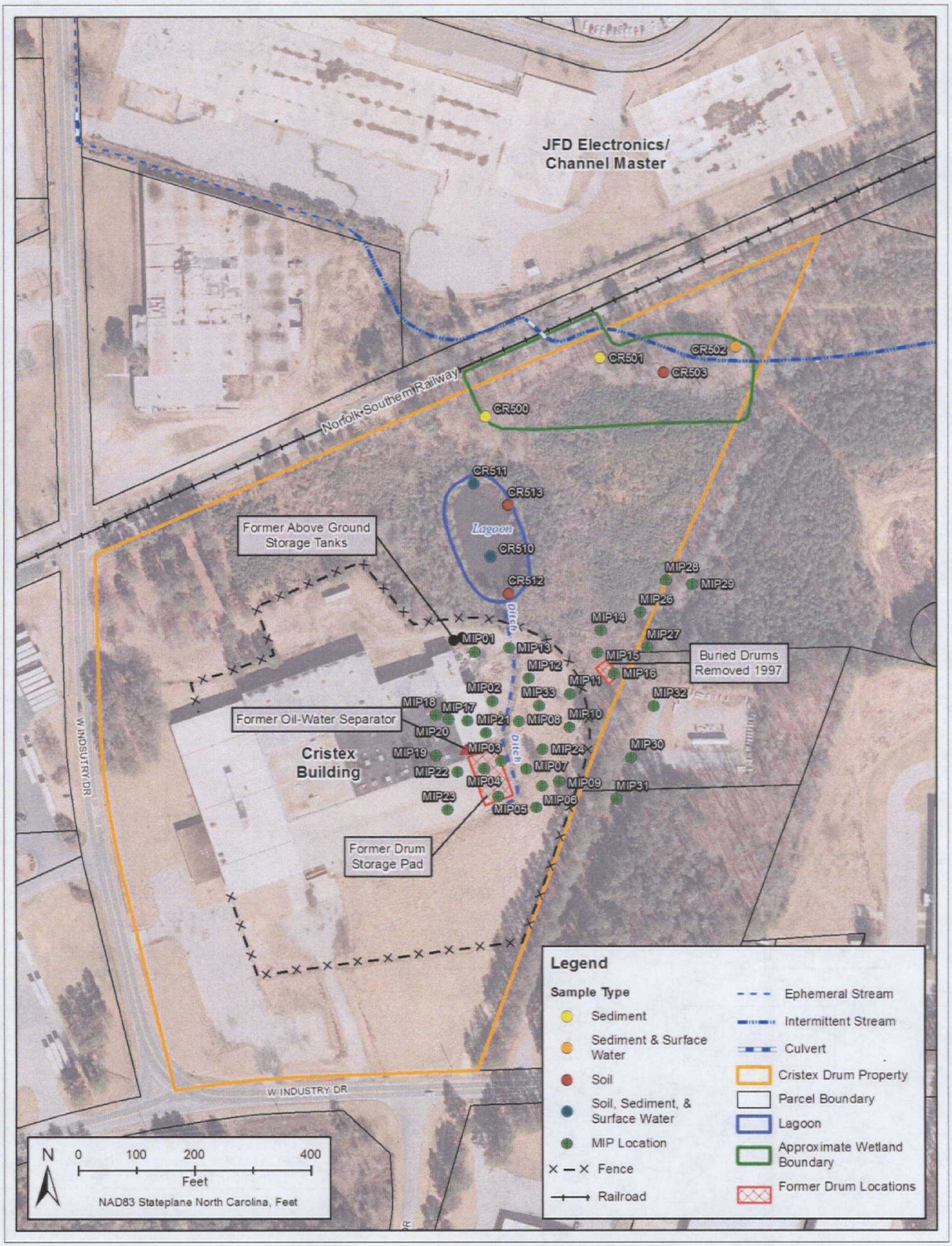


Figure 4: RI Soil, Sediment, and Surface Water Sampling Locations

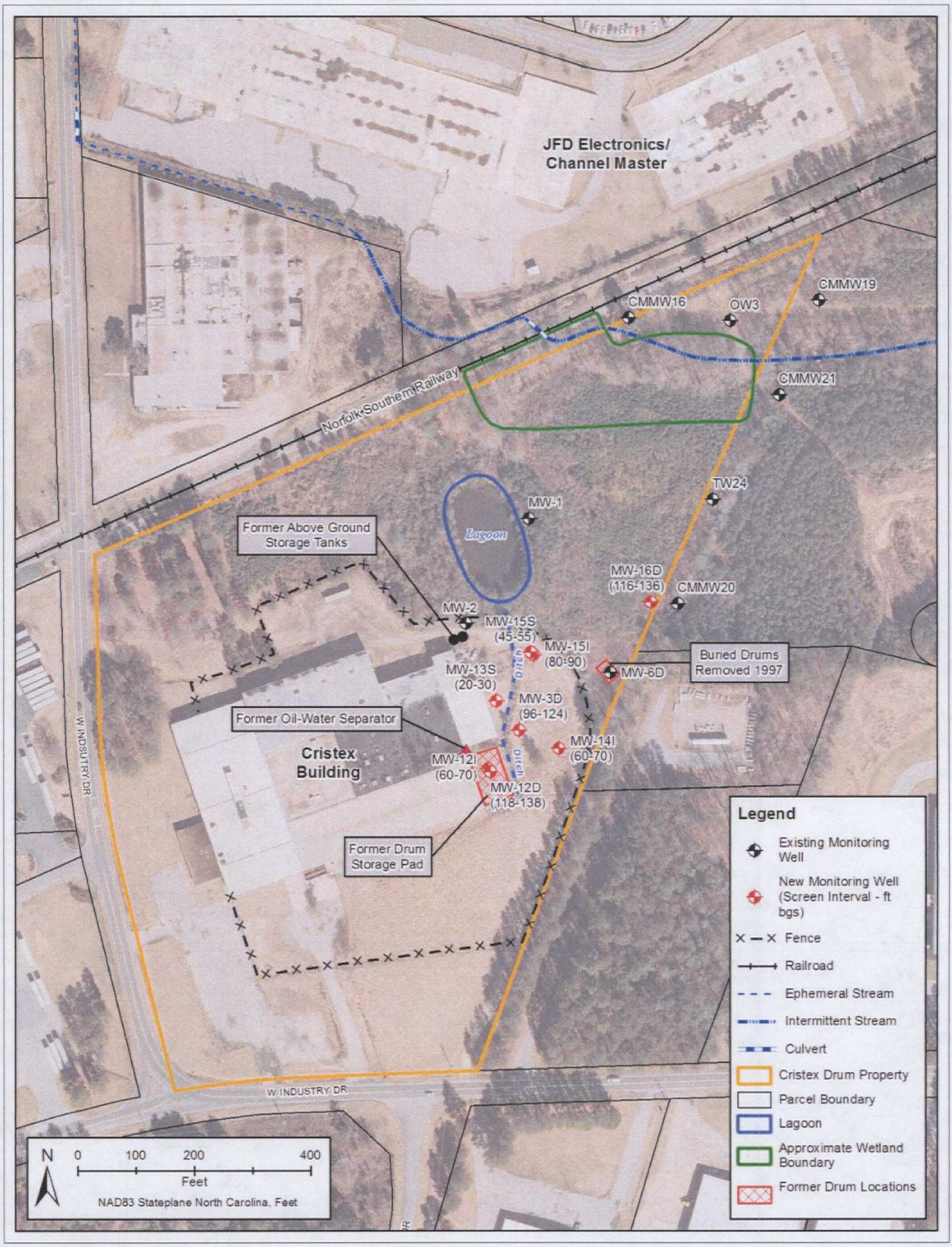
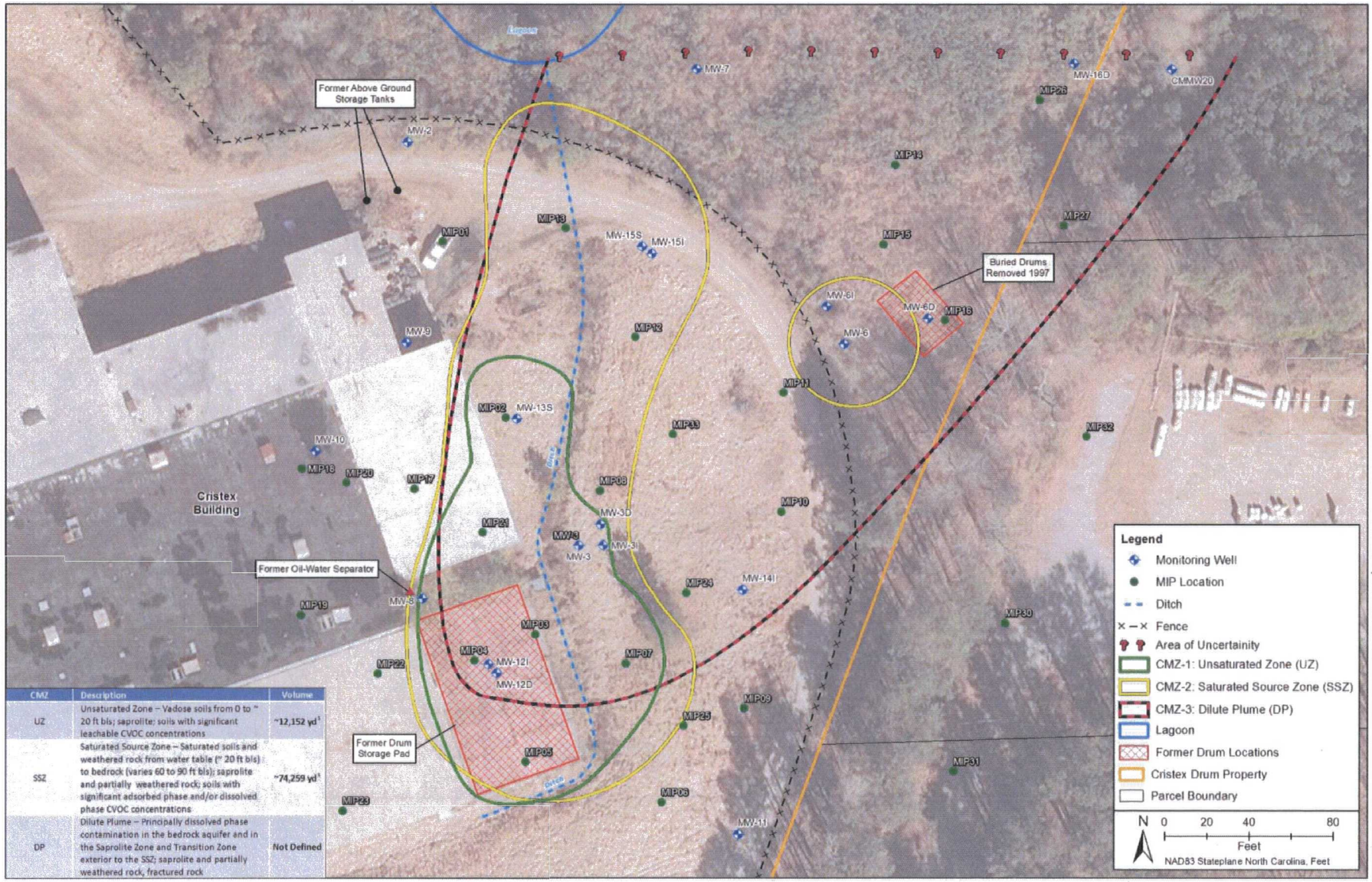


Figure 5: RI Groundwater Sampling Locations

Figure 6: PCE Concentrations in Groundwater

Figure 7: TCE Concentrations in Groundwater



CMZ	Description	Volume
UZ	Unsaturated Zone – Vadose soils from 0 to ~ 20 ft bls; saprolite; soils with significant leachable CVOC concentrations	~12,152 yd[1]
SSZ	Saturated Source Zone – Saturated soils and weathered rock from water table (~ 20 ft bls) to bedrock (varies 60 to 90 ft bls); saprolite and partially weathered rock; soils with significant adsorbed phase and/or dissolved phase CVOC concentrations	~74,259 yd[1]
DP	Dilute Plume – Principally dissolved phase contamination in the bedrock aquifer and in the Saprolite Zone and Transition Zone exterior to the SSZ; saprolite and partially weathered rock, fractured rock	Not Defined

Figure 8: Contaminated Media Zone Designations

Table 1: Summary of Reasonable Maximum Exposure

Location	Receptor	Cancer Risk	Hazard Index (HI)
On Site (Without indoor vapor intrusion pathway)	Future Lifetime Resident	2E-03	228
	Future Industrial Worker	3E-04	39
	Current/Future Trespasser	1E-05	0.1
	Future Construction Worker	5E-06	19
	Future Utility Worker	1E-04	18
On Site (With indoor vapor intrusion pathway)	Future Lifetime Resident	3E-03	426
	Future Industrial Worker	5E-04	86

Notes: Shading indicates unacceptable cancer risk or non-cancer hazard (cancer risk greater than 1x10-4 and HI greater than 1).

Table 2: Human Health Risks in Sediment and Identified Chemicals of Concern

HHRA COC	EPA RSL (mg/kg)		HHRA Risk-Based Sediment RGOs (mg/kg)					
	Residential Soil	Industrial Soil	Residential Cancer Risk Levels			Industrial Cancer Risk Levels		
			$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$
BaP TEQ	0.016	0.29	1.1E-01	1.1E+00	1.1E+01	1.4E+00	1.4E+01	1.4E+02

Notes: BaP TEQ - benzo(a)pyrene toxicity equivalent; COC – chemicals of concern; mg/kg – milligrams per kilogram; EPA RSL – U.S. Environmental Protection Agency Regional Screening Level; HHRA – Human Health Risk Assessment

Table 3: Human Health Risks in Surface Soil and Identified Chemicals of Concern

HHRA COC	EPA RSL (mg/kg)		HHRA Risk-Based Surface Soil RGOs (mg/kg)												North Carolina (mg/kg)		
	Res. Soil	Ind. Soil	Res. Cancer Risk Levels			Res. Non-Cancer Hazard Levels			Ind. Cancer Risk Levels			Ind. Non-Cancer Hazard Levels			Ind. PSRG	Res. PSRG	Protection of GW PSRG
			$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	HQ=0.1	HQ=1	HQ=3	$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	HQ=0.1	HQ=1	HQ=3			
As	0.68	3	6.8E-01	6.8E+00	***6.8E+01***	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.0E+00	6.8E-01	5.8E+00
PCE	0.0018	39	2.6E+01	2.6E+02	2.6E+03	1.0E+01	***1.0E+02***	3.0E+02	NA	NA	NA	4.2E+01	***4.2E+02***	1.3E+03	7.8E+01	1.62E+01	5.0E-03

Notes: BaP TEQ - benzo(a)pyrene toxicity equivalent; COC – chemicals of concern; mg/kg – milligrams per kilogram; EPA RSL – U.S. Environmental Protection Agency Regional Screening Level; HHRA – Human Health Risk Assessment; ***Bold Italics*** = HHRA Risk-Based RGO Used to Evaluate Exposure Pathway Risk (Cancer Risk greater than 1x10-4, or HQ greater than 1)

Table 4: Human Health Risks in Subsurface Soil and Identified Chemicals of Concern

HHRA COC	EPA RSL (mg/kg)			HHRA Risk-Based Subsurface Soil RGOs (mg/kg)			North Carolina (mg/kg)		
	Industrial Soil	Protection of Groundwater SSL		Construction Worker Non-Cancer Hazard Levels			Industrial PSRG	Residential PSRG	Protection of Groundwater PSRG
		MCL-Based	Risk-Based	HQ=0.1	HQ=1	HQ=3			
Aluminum	110,000	NA	3,000	3.5E+03	***3.5E+04***	1.1E+05	1.0E+05	1.54E+04	NA
Manganese	2,600	NA	***2.8***	3.7E+01	3.7E+02	1.1E+03	5.2E+03	3.6E+02	NA
Tetrachloroethene	39	0.0023	***0.0018***	4.3E+01	4.3E+02	1.3E+03	7.8E+01	1.62E+01	5.0E-03

Notes: BaP TEQ - benzo(a)pyrene toxicity equivalent; COC – chemicals of concern; mg/kg – milligrams per kilogram; EPA U.S. Environmental Protection Agency; RGO – Regional Goal Options; RSL – Regional Screening Level; HHRA – Human Health Risk Assessment; HQ – hazard quotient; MCL – Maximum Contaminant Level; ***Bold Italics*** = HHRA Risk-Based RGO Used to Evaluate Exposure Pathway Risk (Cancer Risk greater than 1x10-4, or HQ greater than 1). Yellow highlight = Selected cleanup level.

Table 5: Human Health Risks in Groundwater and Identified Chemicals of Concern

HHRA COC	MCL (µg/L)	NCAC 2L (µg/L)	HHRA Risk-Based Groundwater RGOs (µg/L)					
			Residential Cancer Risk Levels			Residential Non-Cancer Hazard Levels		
			$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	HQ=0.1	HQ=1	HQ=3
BaP TEQ	0.2	0.005	4.4E-03	4.4E-02	***4.4E-01***	NA	NA	NA
Pentachlorophenol	1	0.3	1.6E-02	1.6E-01	***1.6E+00***	NA	NA	NA
1,4-Dichlorobenzene	75	6	2.0E+00	2.0E+01	***2.0E+02***	NA	NA	NA
Benzene	5	1	9.2E-01	9.2E+00	***9.2E+01***	NA	NA	NA
cis-1,2-Dichloroethene	70	70	NA	NA	NA	5.2E+00	***5.2E+01***	1.6E+02
Tetrachloroethene (Tetrachloroethylene)	5	0.7	1.9E+01	1.9E+02	1.9E+03	8.8E+00	***8.8E+01***	2.6E+02
Trichloroethene (Trichloroethylene)	5	3	9.4E-01	9.4E+00	9.4E+01	7.8E-01	***7.8E+00***	2.3E+01
Vinyl chloride	2	0.03	5.1E-02	5.1E-01	***5.1E+00***	NA	NA	NA

Notes: BaP TEQ - benzo(a)pyrene toxicity equivalent; COC – chemicals of concern; HHRA – Human Health Risk Assessment; MCL – Maximum Contaminant Level; µg/L – micrograms per liter; NCAC 2L - North Carolina 2L Class GA Water Quality Standard (15A NCAC 02L); RGO –Remedial Goal Options; Yellow Highlight = Selected cleanup level; ***Bold Italics*** = HHRA Risk-Based RGO Used to Evaluate Exposure Pathway Risk (Cancer Risk greater than 1x10-4, or HQ greater than 1)

Table 6: Human Health Risks in Indoor Air and Identified Chemicals of Concern

HHRA COC	EPA RSL ($\mu g/m^3$)		HHRA Risk-Based Indoor Air RGOs ($\mu g/m^3$)											
	Res. Air	Ind. Air	Res Cancer Risk Levels			Res Non-Cancer Hazard Levels			Ind. Cancer Risk Levels			Ind. Non-Cancer Hazard Levels		
			$1X10^{-6}$	$1X10^{-5}$	$1X10^{-4}$	HQ=0.1	HQ=1	HQ=3	$1X10^{-6}$	$1X10^{-5}$	$1X10^{-4}$	HQ=0.1	HQ=1	HQ=3
1,4-Dichlorobenzene	2.6E-01	NA	***2.6E-01***	2.6E+00	2.6E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	3.6E-01	1.6E+00	***3.6E-01***	3.6E+00	3.6E+01	NA	NA	NA	1.6E+00	1.6E+01	1.6E+02	NA	NA	NA
Carbon Tetrachloride	4.7E-01	NA	***4.7E-01***	4.7E+00	4.7E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCE	4.2E+00	1.8E+01	1.1E+01	1.1E+02	1.1E+03	***4.2E+00***	4.2E+01	1.3E+02	4.7E+01	4.7E+02	4.7E+03	1.8E+01	1.8E+02	5.3E+02
TCE	2.1E-01	8.8E-01	5.5E-01	5.5E+00	5.5E+01	***2.1E-01***	2.1E+00	6.3E+00	3.0E+00	3.0E+01	3.0E+02	8.8E-01	8.8E+00	2.6E+01
Vinyl Chloride	3.2E-01	2.8E+00	***3.2E-01***	3.2E+00	3.2E+01	NA	NA	NA	2.8E+00	2.8E+01	2.8E+02	NA	NA	NA

Notes: BaP TEQ - benzo(a)pyrene toxicity equivalent; COC – chemicals of concern; $\mu g/m^3$ - micrograms per cubic meter; HHRA – Human Health Risk Assessment; RGO – Remedial Goal Options; ***Bold Italics*** = HHRA Risk-Based RGO Used to Evaluate Exposure Pathway Risk (Cancer Risk greater than 1x10-4, or HQ greater than 1). Yellow highlight = Selected cleanup level.

U.S. Environmental Protection Agency
61 Forsyth Street, SW
Atlanta, Georgia 30303

North Site Management Branch
Abena Ajanaku, Community Involvement Coordinator
Beverly Stepter, Remedial Project Manager

Official Business

Penalty for Private Use $300

U.S. Environmental Protection Agency

Cristex Drum Site

Oxford, North Carolina

June 2017

Public meeting scheduled to discuss the Proposed Plan

Tuesday, June 27, 2017 at 6:00pm at the NC Cooperative Extension 125 Oxford Loop Road Oxford, NC

Introduction

The U.S. Environmental Protection Agency (EPA) invites the public to comment on a Proposed Plan (Plan) to clean up the Cristex Drum Superfund Site (Site), located in Oxford, NC. This fact sheet discusses EPA's Proposed Plan to address the adverse environmental impacts resulting from Site-related contamination. The public is encouraged to comment on the Plan during the comment period. The Plan and associated documents related to the Site activities are available in the Administrative Record of the Information Repository housed at the Richard H. Thornton Library in Oxford, NC.

Background

The 22-acre Cristex Drum Superfund Site is a former textile plant that operated from 1966 until 1986 (Figure 1). The Site is located in a predominantly industrial area. During operations, the plant used an above-ground storage tank, oil-water separator, and a drum storage pad. A small lagoon was used for wastewater storage and treatment discharged into the city's wastewater treatment plant. The lagoon represents a secondary source which received wastewater and spills by a surface water ditch. Spills at the Site were identified during regulatory inspections and were self-reported by the facility. Primary sources of soil, sediment, surface water and groundwater contamination include spills, leaks, and facility operations.

NPL and Remedial Investigation

The Site was listed on the National Priorities List (NPL) in 2013. EPA began the Remedial Investigation in 2014 to determine the nature and extent of the contamination. Soil, groundwater, surface water and sediment samples were collected as part of the investigation. Contaminants of concern (COCs) were found in soil and groundwater, and these could potentially affect indoor air; no COCs were identified in surface water or sediment.

We want your comments!

The EPA relies on public input to ensure the concerns of the community are considered in selecting an effective remedy for each Superfund Site. The public is encouraged to comment on the documents from:

June 20, 2017, to July 20, 2017

EPA'S Preferred Cleanup Remedy

Based on the conclusions of a 2016 Remedial Investigation report, which included baseline human health and ecological risk assessments, the EPA determined that remedial actions were required. EPA's preferred cleanup plan is based on a Feasibility Study also prepared in 2016. Soil and groundwater contamination at the Site were classified into three contaminated media zones (Figure 2). The unsaturated zone (UZ) encompasses significantly contaminated surface and subsurface soil from 0 to about 20 feet below ground with significant concentrations of chlorinated volatile organic compounds. The saturated source zone (SSZ) encompasses contaminated soil beneath the former drum storage pad and groundwater extending down-gradient toward the lagoon and vertically from the water table at approximately 20 feet below ground to bedrock at a depth ranging from 60 to 90 feet. The dissolved plume (DP) encompasses a wider band of dissolved contamination in the fractured bedrock aquifer and in material adjacent to the SSZ.

The preferred cleanup plan for the UZ is soil excavation. Approximately 11,500 cubic yards of soil would be excavated to a depth of approximately 20 feet and removed from the Site to a landfill. The excavation would be backfilled with clean fill.

The preferred cleanup plan for the SSZ is electrokinetic-*in situ* chemical oxidation (EK-ISCO) with biobarriers. In the most highly contaminated parts of the SSZ, this remedy would inject chemicals from wells into the subsurface to permanently destroy chlorinated volatile organic compounds by chemical oxidation; a direct current would be applied to ensure an even distribution of the oxidants to improve effectiveness. In less contaminated parts of the SSZ, two biobarriers would be installed across the mid-point and toe of the SSZ to limit migration of contaminants by permanently destroying contaminants flowing through the barriers by chemical reduction. Each passive barrier would consist of two rows of injection wells. The injection wells would be injected with emulsified oil substrate potentially supplemented with a bacteria consortium and pH adjustment to accelerate biodegradation via direct anaerobic reductive dechlorination of CVOCs in groundwater.

The preferred cleanup plan for the DP is enhanced *in situ* bioremediation (EISB) biobarriers. Similar to the remedy for the outlying parts of the SSZ, this remedy would use chemical reduction to permanently destroy contaminants passing through the barriers. The barriers would be created by injecting emulsified oil from wells into the bedrock. Institutional controls (i.e. limits to land and groundwater use) will be placed on the property to reduce the likelihood that people would be exposed to contaminants in the future.

Public Comment

EPA relies on public input to ensure the concerns of the community are considered in selecting an effective remedy for each Superfund Site. **The public comment period runs from June 20, 2017, through July 20, 2017 (extended one day due to July 4th holiday)**. The Administrative Record and Information Repository for the Cristex Drum Superfund Site, which includes the Remedial Investigation and Feasibility Study Reports, are located at the Richard H. Thornton Library, 210 Main Street in Oxford, NC.

EPA will host a public meeting on **Tuesday, June 27, 2017, at 6:00p.m.** at the NC Cooperative Extension, Granville County, 125 Oxford Loop Road in Oxford, NC. Representatives from EPA will present the details of the Plan to address the environmental impacts at the Cristex Drum Superfund Site, and answer any questions the public may have regarding the preferred cleanup remedy. You may email your comments to stepter.beverly@epa.gov or, if you prefer to submit written comments, please mail them, postmarked no later than **July 20, 2017** to Beverly Stepter at US EPA, 61 Forsyth Street, SW, 11th Floor, Atlanta GA 30303.

After EPA has received comments and questions during the public comment period, EPA will summarize the comments and provide responses in the Responsiveness Summary which will be part of the Record of Decision (ROD). The ROD will select the final remedial action and will provide the rationale of EPA'sselection.

FOR MORE INFORMATION

EPA Remedial ProjectManager
Beverly Stepter (404) 562-8816
stepter.beverly@epa.gov

EPA Community Involvement Coordinator
Abena Ajanaku (404) 562-8834
ajanaku.abena@epa.gov

www.epa.gov/superfund/cristexdrum

Information Repositories
Richard H. Thornton Library
210 Main Street
Oxford, NC 27565

U.S. EPA Region 4 Office Records Center
61 Forsyth St, SW
Atlanta, GA 30303

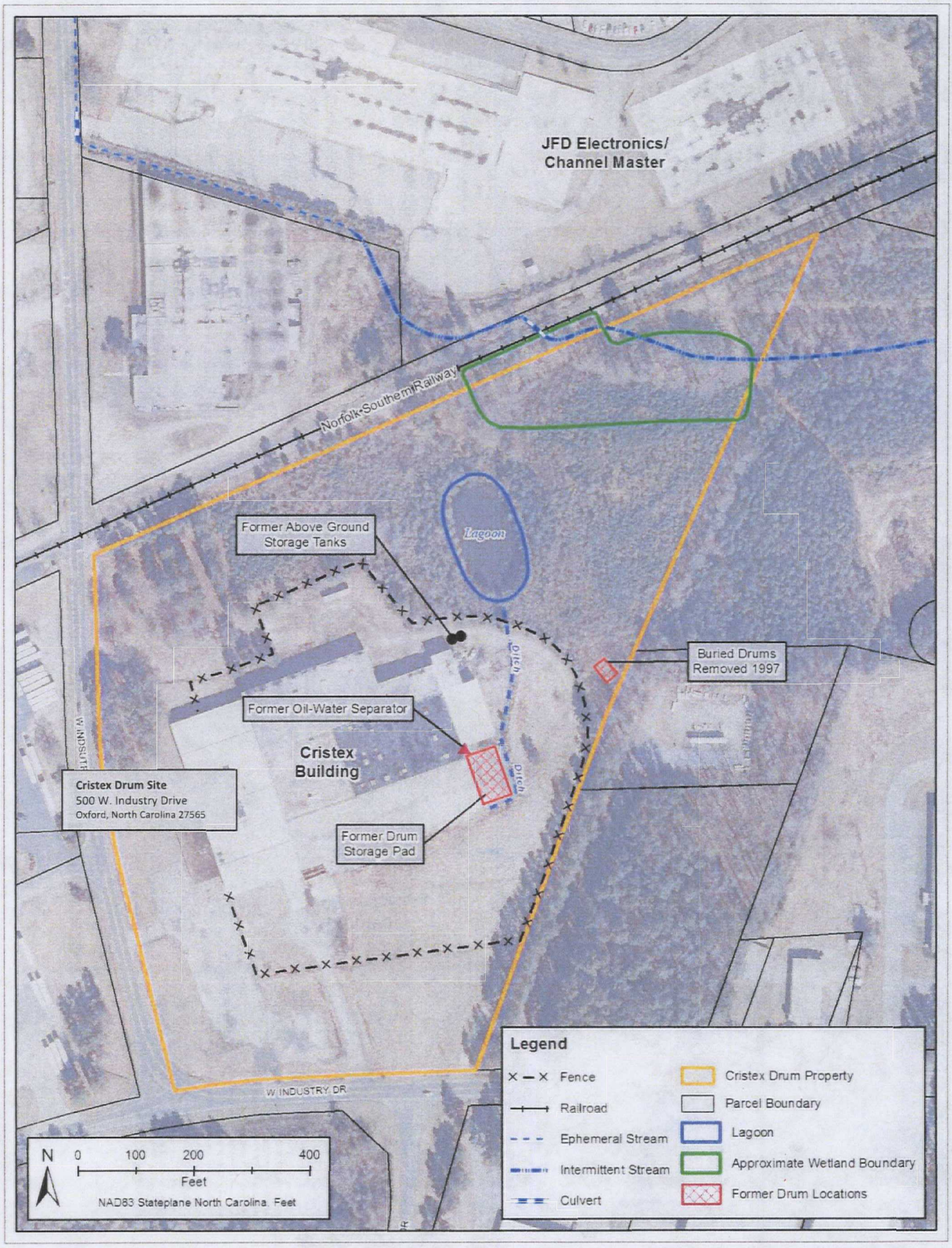
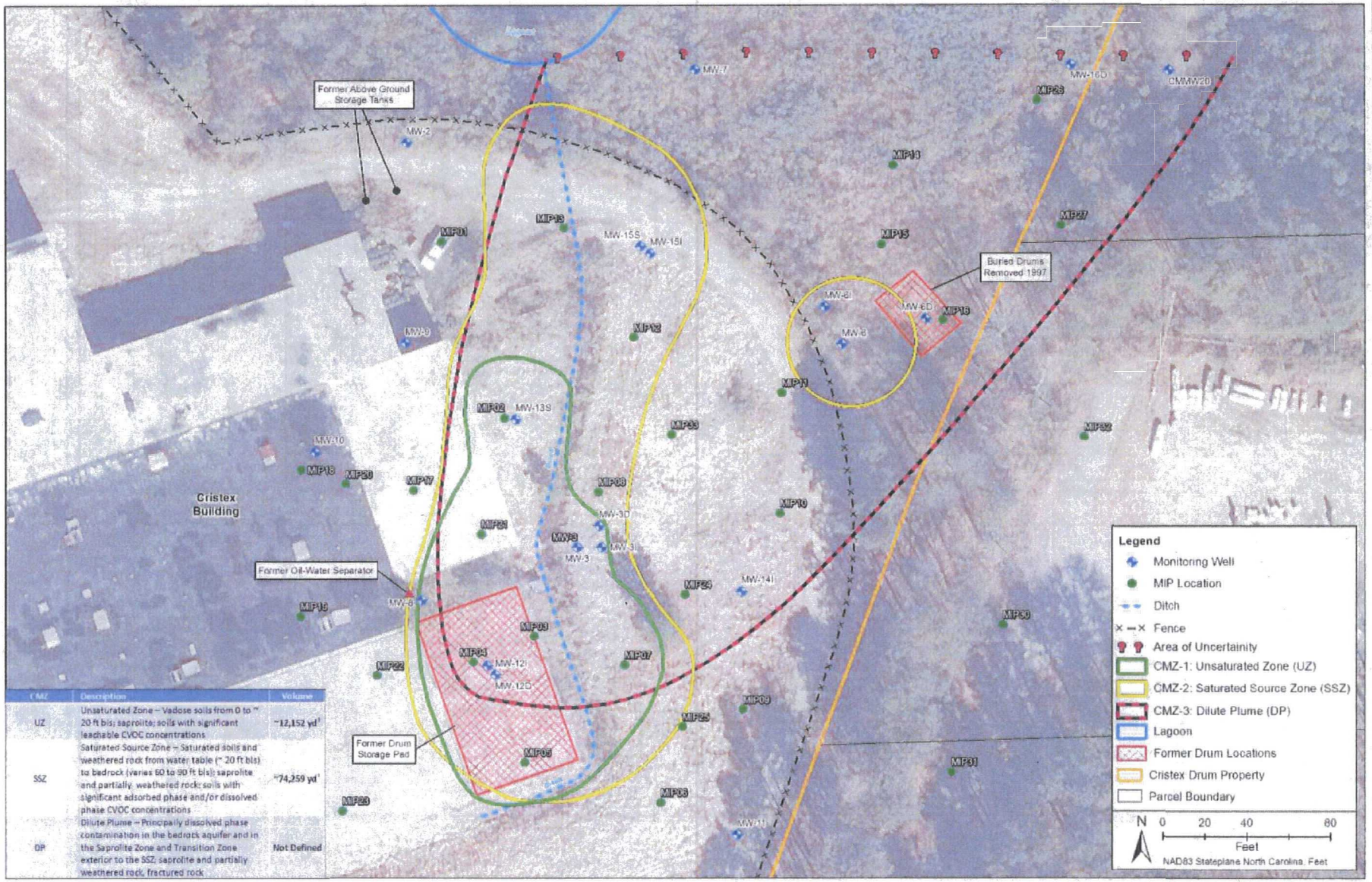


Figure 1: Site Layout for Cristex Drum Superfund Site



CMZ	Description	Volume
UZ	Unsaturated Zone – Vadose soils from 0 to ~ 20 ft bls; saprolite; soils with significant leachable CVOC concentrations	~12,152 yd³
SSZ	Saturated Source Zone – Saturated soils and weathered rock from water table (~ 20 ft bls) to bedrock (varies 60 to 90 ft bls); saprolite and partially weathered rock; soils with significant adsorbed phase and/or dissolved phase CVOC concentrations	~74,259 yd³
DP	Dilute Plume – Principally dissolved phase contamination in the bedrock aquifer and in the Saprolite Zone and Transition Zone exterior to the SSZ; saprolite and partially weathered rock, fractured rock	Not Defined

Figure 2: Contaminated Media Zone Designations for Cristex Drum Superfund Site

APPENDIX B
COMMENTS RECEIVED ON THE PROPOSED PLAN

Feasibility Study Report Comments

Unsaturated Zone (UZ)

A statement in the FS regarding the results of the membrane interface probe investigation (Section 7.3 of the FS report), and the depiction of residual DNAPL in the vadose zone on the site conceptual model illustration (Figure 3-1 of the FS report) suggest that residual dense non-aqueous phase liquid (DNAPL) impacts may be present in the UZ. If residual DNAPL is suspected to be present in the UZ, then these impacts may not be adequately addressed by the proposed remedy and could result in ongoing concerns for the downstream dilute plume. For example, an excavation remedy combined with targeted source area injection approach might be more appropriate and could better "dovetail" with the Saturated Source Zone (SSZ) approach.

Dilute Plume (DP)

Because the RI failed to determine the full extent of groundwater contamination, the FS incorrectly evaluates remedial alternatives for the DP. Remediation Alternative DP#2, enhanced *in situ* bioremediation biobarrier, may address the first 340 feet of Cristex dilute plume but ignores the remaining 1,660 feet of comingled plume. For Alternative DP#2 to address the entire dissolved plume from Cristex sources would require several additional rows of injection wells across the plume and multiple injections and would result in significant escalation in cost. The addition of two to three additional barriers using the costs listed in Appendix E of the FS for containment through biobarrier at the Cristex property boundary would result in a total alternative cost escalation in excess of approximate $1,400,000. Adding additional injections or additional rows of biobarrer in the comingled plume would make this alternative significantly more expensive than hydraulic containment.

The FS also indicates that DP#2 Alternative "will effectively limit *any* significant dissolved phase contamination from migrating past the barrier." This statement is inaccurate. The reliability of precluding dissolved plume migrating off site with biobarrier is lower than the hydraulic containment option. Further, the FS incorrectly states, "both hydraulic containment and biobarriers should have no significant issues with residual risk, reliability, or treatment irreversibility." There will be residual risk with one row of biobarrier as the parent product or degradation products (e.g., cis-1,2-dichloroethene or vinyl chloride) may continue to migrate down-gradient further comingling with the JFD/CM plume.

The FS inaccurately evaluated Alternative DP#3, hydraulic capture/containment. Since the hydraulic capture/containment system installed and operated at the JFD/CM site already captures/contains nearly all of the Cristex site dissolved plume, a remedy is already in place. The JFD/CM hydraulic capture/containment system has adequate capacity and with the addition of one or two extraction wells could be modified to complete capture of the Cristex DP at a fraction of the costs presented in the FS. DP#2 Alternative is thus not cost-effective compared to Alternative DP#3 when a joint remedy is considered (assuming an appropriate cost-sharing approach for the joint remedy can be agreed to by EPA and JFD/CM). In addition, significant uncertainty exists for Alternative DP#2 due to unknown nature of fractures and their orientation resulting in ineffective distribution of reagents and an ineffective barrier. Although the cost for DP#3 Alternative is lower than that of DP#2 Alternative, the FS selects DP#2 Alternative without proper justification.

SSZ

The FS eliminates hydraulic containment as a remedial technology for SSZ without providing any rationale. Cost for containment of SSZ plume can be significantly lower than Alternative SSZ#3 Electrokinetic Enhanced *In Situ* Chemical Oxidation (EK-ISCO). In fact, the FS estimates total net present worth cost for Alternative SSZ#3 to be $4,609,700, which is the most costly of the evaluated alternatives. Of that cost, approximately $1,000,000 was attributable to installation of the electrokinetic enhancements, which although innovative, are relatively unproven and specialized, and therefore transfer relatively more risk for underperformance to the EPA than does a lower cost or more conventional technology.

AECOM Imagine it. Delivered.

AECOM
1600 Perimeter Park
Morrisville, NC 27560
USA
T: 919.461.1100
F: 919.464.1415
aecom.com

July 20, 2017

Ms. Beverly Stepter
Remedial Project Manager
United States Environmental Protection Agency, Region IV
61 Forsyth Street, SW
Atlanta, GA 30303-8960

Subject: Cristex Drum NPL Site, Oxford, North Carolina
Remedial Investigation Report – Revision 1 (December 2016),
Feasibility Study Report – Revision 1 (March 2017) and
Proposed Plan (June 2017)
Project No. 60545654

Dear Ms. Stepter,

On behalf of JFD Electronics Corporation and CMSS, Inc., AECOM is submitting comments, recorded herein, concerning the above referenced documents for the Cristex Drum NPL Site (Cristex site). Our comments are directed at the Black & Veatch Remedial Investigation (RI) and Feasibility Study (FS) and the United States Environmental Protection Agency (EPA) Proposed Plan referenced above.

Remedial Investigation Report Comments

The Cristex investigation is substantially incomplete. As you are aware, dissolved groundwater contamination from the Cristex Drum Site comingles with groundwater contamination from the JFD Electronics/Channel Master NPL Site (JFD/CM site) in an area south and east of the railway that separates the properties. The RI fails to delimit the down-gradient lateral extent of groundwater contamination from Cristex sources. Figure 8 from the Proposed Plan indicates that the lateral extent of the groundwater contamination is at least 340 feet. Beyond that distance the RI concludes the extent is uncertain. We disagree.

Our analysis, combining data from Cristex and JFD/CM, demonstrates that Cristex groundwater contamination extends laterally as far down-gradient as does the JFD/CM groundwater contamination a distance of more than 2,000 feet from Cristex sources. Figures 1, 2, and 3 (attached) are simulations (models) of contaminated groundwater transport from Cristex sources described in the RI. We used the same model for simulating transport from sources at the JFD/CM site for calibration. A large portion of the comingled plumes is shown to be attributed to sources at the Cristex site.

In addition, we tracked the concentration proportions (molarity) of chlorinated compounds on JFD/CM and Cristex properties at wells within the comingled plume as shown in Figure 4. The Cristex contamination, predominantly tetrachloroethene, occupies the southern and eastern portion of the comingled plume. JFD/CM contamination, predominantly trichloroethene, occupies the northern and western portions of the comingled plume.

These results fundamentally should change the focus of the FS and Proposed Plan.

AECOM Imagine it. Delivered.

Furthermore, strategic use of EK-ISCO is somewhat incongruent with selection of Alternative DP#2 because the two strategies affect dissimilar and even competing groundwater chemistries. In comparison, selection of either SSZ#4 Alternative, or a hydraulic containment strategy (not currently considered), would be more chemically congruent. In the case of hydraulic containment, costs for installing two to four extraction wells and on-site treatment and disposal is far less expensive than SSZ#3 or SSZ#4 Alternative. Although hydraulic containment may have to be maintained over 30+ years, there could be a significant cost savings and effective control to limit/prevent further comingling of the Cristex plume with the JFD/CM plume. AECOM believes that a more rigorous consideration of hydraulic containment as a remedy for the SSZ is warranted based on the potential cost savings.

- The EPA should address the DP first (combined with JFD/CM) because the EPA is not likely to be able to fund the source area remedies for many years. Capture the plume first. Hydraulic containment for the SSZ should be considered as the Cristex site's saprolite and partially weathered rock zone plume is likely to be comingled with JFD/CM plume.
- FS costs are mainly for comparing alternatives and the actual cost of implementation typically are higher than the FS costs. Currently, the FS selected the most expensive alternatives for all media of concern with insufficient justification. Actual implementation of these alternatives will be higher than those estimated in the FS report.

We request a meeting to discuss a combined dissolved phase groundwater remedy option at your earliest opportunity. Should you have questions or require additional information, please contact Nanjun Shetty at (919) 461-1426 or William Doucette at (919) 780-8058.

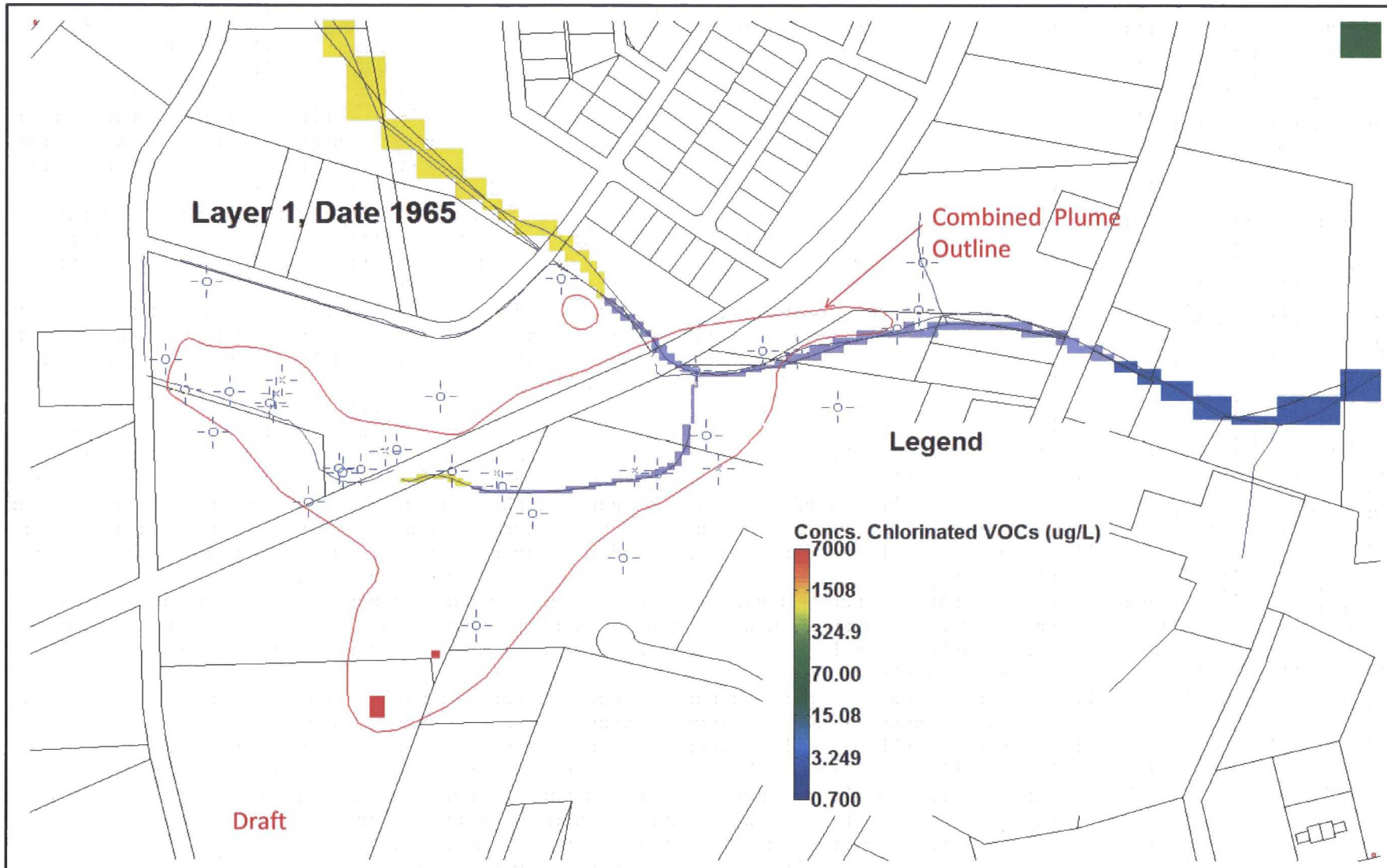
Yours sincerely,

Nanjun V. Shetty, P.E.
Project Manager

William H. Doucette, Jr., Ph.D., L.G.
Project Coordinator for the Responsible Parties

Attachments

cc: Steve Kempf – The Unimax Corporation
Darrel Jackson – Avnet, Inc.
Steve Earp – Smith Moore, LLP
David Mattison – NCDEQ
File



Note: Volatile organic compounds source concentration of 7,000 micrograms per liter.

AECOM
1600 Perimeter Park Drive, Suite 400
Morrisville, North Carolina
T: +1.919.461.1100
F: +1.919.461.1415
www.aecom.com

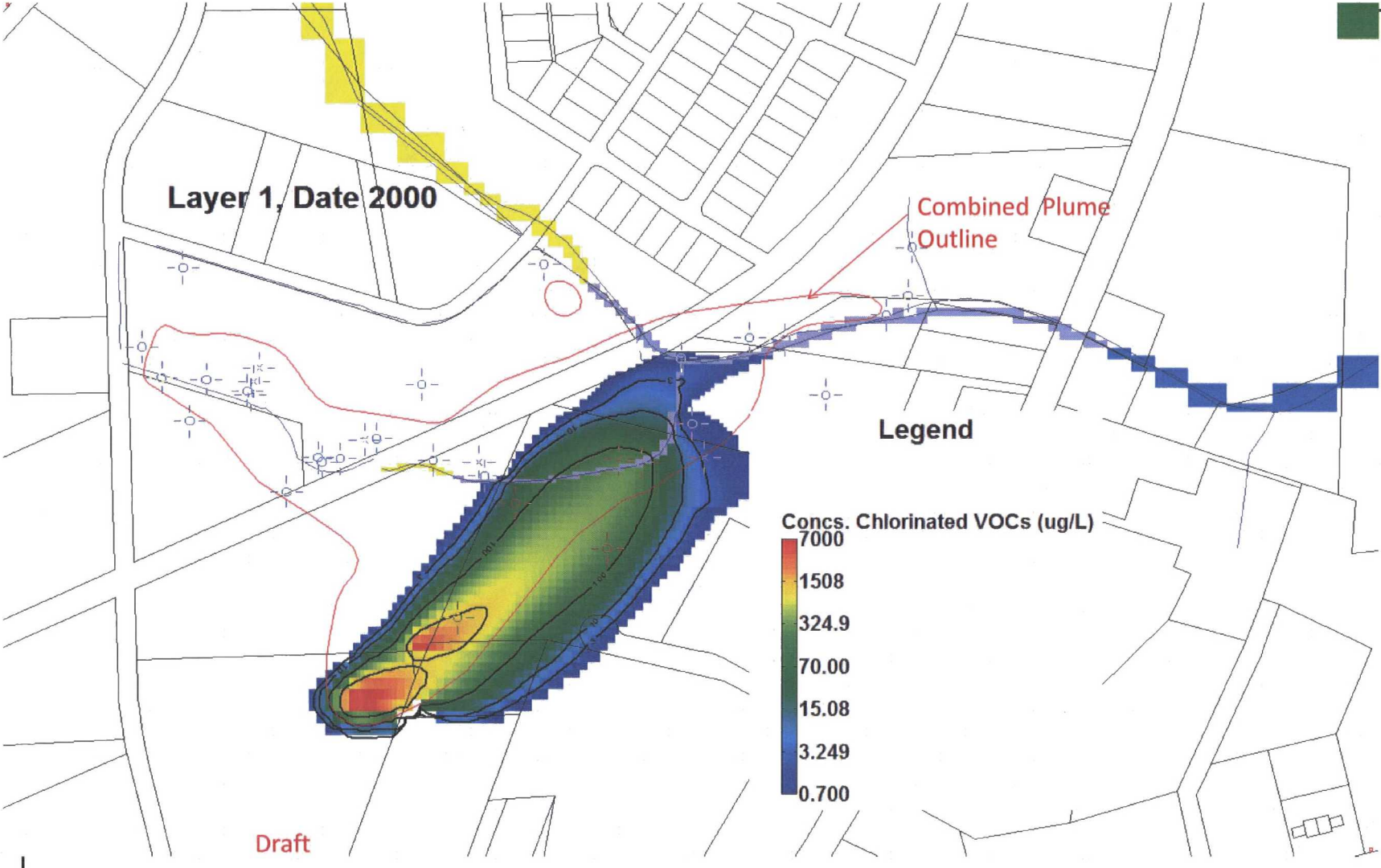
CRISTEX SOURCE, NO PUMPING

Cristex Site
Oxford, North Carolina

Approx. Scale	Date:	Project Number:
	6/2016	60323537

Figure Number:

1



Note: Volatile organic compounds source concentration of 7,000 micrograms per liter.

AECOM
1600 Perimeter Park Drive, Suite 400
Morrisville, North Carolina
T: +1.919.461.1100
F: +1.919.461.1415
www.aecom.com

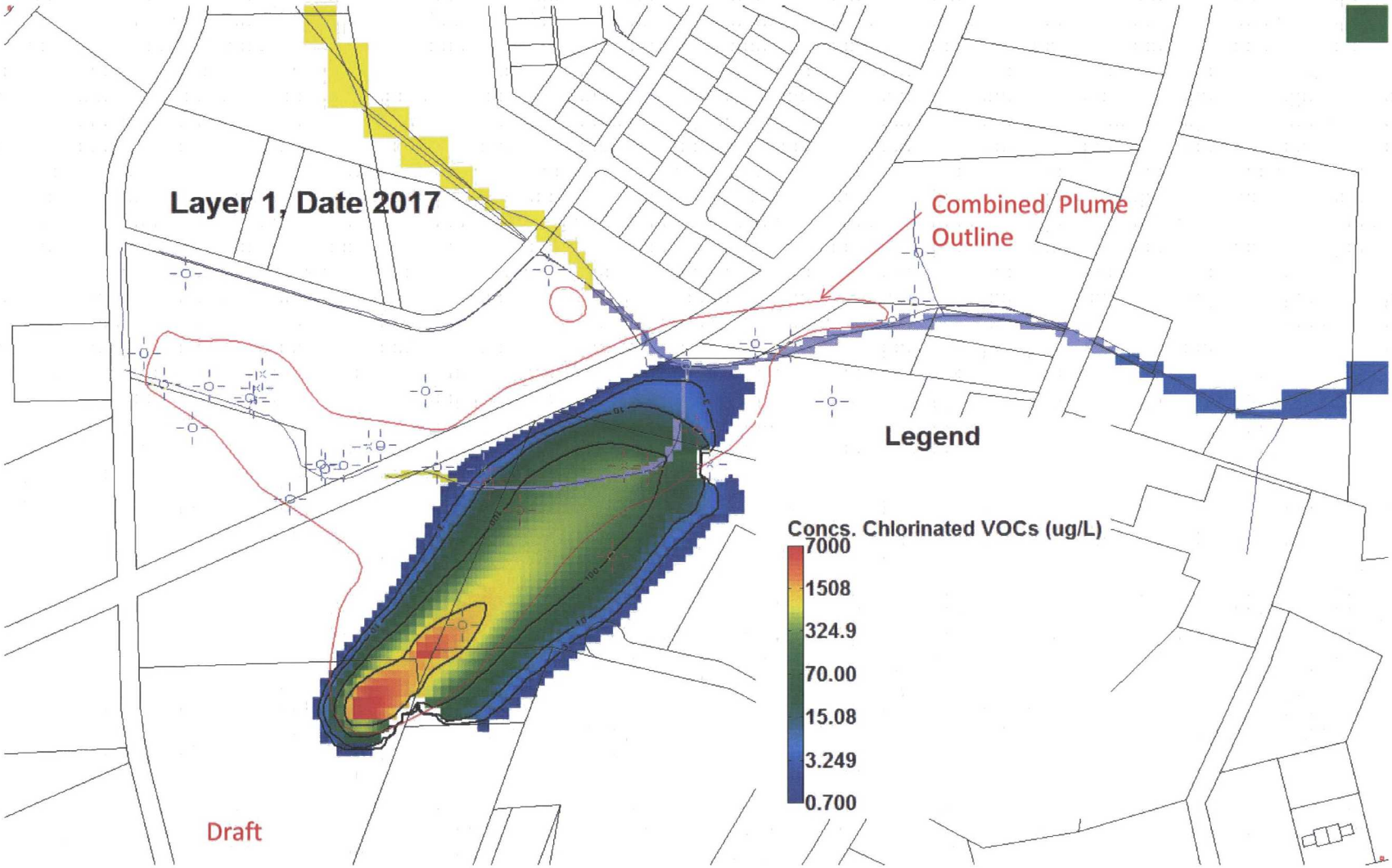
CRISSTES SOURCE ONLY , NO PUMPING

Cristex Site
Oxford, North Carolina

Approx. Scale	Date:	Project Number:
	6/2016	60323537

Figure Number:

2



Note: Volatile organic compounds source concentration of 7,000 micrograms per liter.

AECOM
1600 Perimeter Park Drive, Suite 400
Morrisville, North Carolina
T: +1.919.461.1100
F: +1.919.461.1415
www.aecom.com

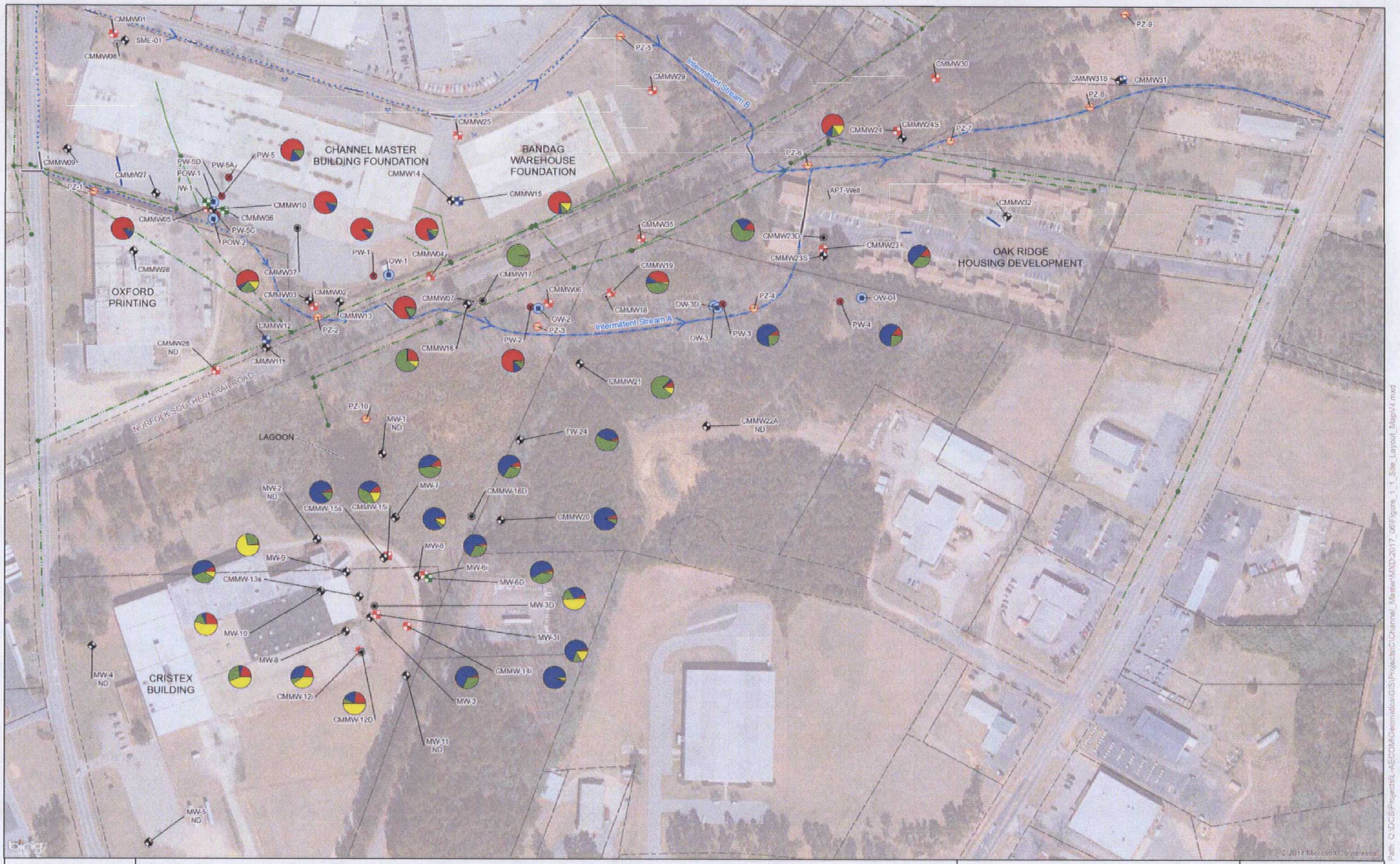
CRISTEX SOURCE ONLY, PUMPING SINCE 2000

Cristex Site
Oxford, North Carolina

Approx. Scale	Date:	Project Number:
	6/2016	60323537

Figure Number:

3


CHANNEL MASTER BUILDING FOUNDATION
BANDAG WAREHOUSE FOUNDATION
OXFORD PRINTING
OAK RIDGE HOUSING DEVELOPMENT
CRISTEX BUILDING
LAGOON
NORFOLK SOUTHERN RAILROAD
Intermittent Stream A
Intermittent Stream B
CMMW01
SME-01
CMMW08
CMMW09
CMMW27
PZ-1
PW-5D
POW-1
IW-1
PW-5A
PW-5
PW-5C
POW-2
CMMW05
CMMW36
CMMW10
CMMW28
CMMW37
CMMW03
CMMW02
CMMW13
CMMW12
PZ-2
CMMW26 ND
CMMW11
PW-1
OW-1
CMMW04
CMMW07
CMMW14
CMMW15
CMMW25
CMMW17
CMMW16
CMMW06
OW-2
PZ-3
PW-2
CMMW35
CMMW19
CMMW18
OW-3D
OW-3
PW-3
PZ-4
CMMW21
PZ-5
CMMW29
CMMW23D
CMMW23S
CMMW23
APT-Well
CMMW24
CMMW24S
PZ-6
PZ-7
CMMW30
CMMW31S
CMMW31
PZ-8
PZ-9
CMMW32
OW-04
PW-4
PZ-10
MW-1 ND
TW-24
CMMW22A ND
MW-2 ND
CMMW-15s
CMMW-15i
MW-7
CMMW-16D
CMMW20
MW-9
MW-6
MW-6i
MW-6D
CMMW-13s
MW-3D
MW-10
MW-3I
MW-8
CMMW-14i
MW-4 ND
CMMW-12i
CMMW-12D
MW-3
MW-11 ND
MW-5 ND
N
Index Map
OH
PA
NJ
MD
DE
WV
KY
VA
TN
NC
SC
GA
Wells / Sample Locations
Deep Bedrock Well
Deep PWR Well
Intermediate Well
Observation Well
Piezometer
Pumping Well
Shallow Bedrock Well
Shallow Well
Top of Rock Well
Utilities
Sanitary Sewer Manhole (Surveyed)
Water - Fire Hydrant (Surveyed)
Sanitary Sewer Line (Data from City of Oxford)
Approximate Sanitary Sewer Location (Field Verified)
Storm Sewer Line (Surveyed)
Sanitary Sewer Line (Surveyed)
Site Features
Ephemeral Stream
Intermittent Stream
Culvert
Parcels
Molarity Graphs
TCE
PCE
cCDE
VC
1 inch equals 150 feet
0 75 150 225 300 Feet
Note:
Cristex wells sampled in April 2016 and August 2015. JFD Electronics wells sampled in April 2016.
Molarity Map
JFD Electronics/Channel Master
620 West Industry Drive
Oxford, North Carolina
July 2017
AECOM
Figure 4

EPA's Response to AECOM

AECOM commented on EPA's proposed plan during the public comment period. AECOM states that its groundwater transport modeling show that the Cristex plume extends more than 200 feet offsite. Based on their model, AECOM concludes that EPA failed to delineate the scope and extent of the dilute plume and that any remedies considered are inherently flawed because of this data gap. However, AECOM has not provided data and analysis to substantiate their claim. Without data to support this baseline assumption, AECOM's conclusion about the adequacy of EPA's proposed remedy is not justifiable. With respect to the SSZ plume, EPA's remedy includes treatment which is preferred under the CERCLA statute as opposed to the containment remedy proposed by AECOM. Finally, AECOM claims that EPA's remedy failed to address DNAPL, however, no DNAPL was detected and NAPL is only expected.

In summary, AECOM has provided no information that would support changing the remedies proposed in the ROD.

APPENDIX C
TRANSCRIPT OF APRIL 2017 PUBLIC MEETING

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
SUPERFUND DIVISION

In the Matter of:

CRISTEX DRUM SITE
Superfund Site
Oxford, North Carolina

PROPOSED PLAN

PUBLIC MEETING

Present:

Ms. Abena Ajanaku
Community Involvement Coordinator
Enforcement & Community Engagement Branch
Superfund Division
Ms. Beverly Hudson-Stepter
Civil Engineer, Superfund Division
Restoration & Site Evaluation Branch
Mr. James Ferreira
Hydrogeologist
Scientific Support Section
MS. Kerisa Coleman
Community Involvement Coordinator
USEPA

Also Present:

Mr. David B. Mattison
Environmental Engineer
Superfund Section
State of North Carolina
Division of Waste Management

Date: Tuesday, June 27, 2017

Location: North Carolina Cooperative
Granville County Center
125 Loop Road
Oxford, North Carolina 27612

On Tuesday, June 27, 2017, the United States Environmental Protection Agency, Region 4, Superfund Division, held a public meeting in the matter of the proposed plan for the Cristex Drum Site, Superfund Site, in Oxford, North Carolina, beginning at 6:00 p.m.

The Hearing was held in the Offices of the North Carolina Cooperative, Granville County Center, located at 125 Loop Road, in Oxford, North Carolina.

Ms. Abena Ajanaku, Community Involvement Coordinator for EPA, presided, and the following EPA representatives were present: Ms. Beverly Hudson-Stepter, Civil Engineer, Superfund Division; and Mr. James Ferreira, Hydrologist, Scientific Support Section; and Kerisa Coleman, Community Involvement Coordinator for EPA.

Also present was Mr. David B. Mattison, Environmental Engineer, Superfund Section, North Carolina Division of Waste Management. The meeting proceeded as follows:

MS. AJANAKU: Good evening, everybody. Thank you all so, so much for coming out this evening. I know that you could've been somewhere else, visiting with family and other things, but we really appreciate you taking the time to come to this meeting this evening.

I want to go over a little bit of housekeeping before I get started. So cell phones, if you could put those on vibrate or silent, that would be great. And please be sure to sign in. I think everybody did that.

Bathrooms are down the hall to the right. Bathrooms are down there. And again, welcome. And next I want to go into--I did the housekeeping, so introductions. I wanted to introduce my other co-workers that are here with me this evening.

So we have Beverly Hudson-Stepter. She is the remedial project engineer in Superfund, and she's the lead on this site among several others that she handles the remedial process for.

And we have James Ferreira. He is the hydrologist on this project for EPA. We have Kerisa Coleman. She's another community involvement coordinator for EPA and myself. My name is Abena Ajanaku, and I am also a community involvement coordinator for EPA.

And we also have David Mattison. He's right here. He's an environmental engineer, and he's in the

Superfund section, Division of Waste, for the North Carolina Department of Environmental Quality, and his office is in Raleigh.

And some other people I'd like to recognize that are here is Mayor Jackie Sergent. She is the mayor of the City of Oxford, and we have Mr. Alan Thornton who is the city manager for Oxford. There you are back there. Okay.

And the county manager, Mr. Michael Felts, is in the back. He is the county manager for the County of Granville, and I have to thank Mr. Felts. He put the ad--many people know about this meeting--on the city's website so that we could really get the word out about this meeting. So I really appreciate that. Thank you for doing that.

So this evening, a little of the welcome and introduction, this is going to be our agenda for this evening. I just wanted you to get an opportunity to see that, and I wanted to talk a little bit about community participation and the purpose of why we're here tonight.

We're going to provide information about the Cristex site. Beverly is going to come up and talk about the Superfund process and some other things that are on the agenda and answer questions for you at the end of the meeting. So if you could hold your questions till the end, that would be great. Okay?

Also we're going to exchange information. We're not just here to throw a lot of information out at you, but we want you to give us your concerns or questions that you may have. We're here for that, and we're going to provide you with answers, and if we don't know the answer, we'll make sure and get that back to you.

Another purpose for this meeting is to discuss the proposed plan. That's going to cover the process by which they're going to clean up the Cristex site, and Beverly will go into detail with that, but that proposed plan is located in the site repository. The repository is in the Richard Thornton Library along with other documents that were used to come up with the cleanup process for the Cristex site.

So all those documents, all those key documents are in that repository. The administrative record is located at the EPA in Atlanta, GA. It holds all those technical documents that were used in order to help come up with this cleanup remedy.

During the proposed plan, there is a comment period, where you have 30 days to comment on the proposed plan. Now, I added a day because during the 30 day period is the 4th of July, and so I don't think that you're going to spend your 4th reading this proposed plan, so I decided to go ahead and add an extra day to give you time to look

at that document.

So from this point I'm just going to hand it over to Beverly so that she can come up and give you guys some really good information. Okay.

MS. HUDSON-STEPTER: Thank you, Abena.

MS. AJANAKU: You're welcome. One more thing before she takes over, we have a court reporter here this evening, and she is going to be documenting all the--she's going to be providing a transcript for this meeting, and it is required by the EPA that we do this for this particular type of meeting, proposed plan, where we're talking about that.

So she is going to be documenting it, and if you would, when you ask a question, if you would give your name before you ask a question, that would be great. Okay? Thank you.

MS. HUDSON-STEPTER: Good evening. My name is Beverly Hudson-Stepter and I am the remedial project manager for the Cristex site. First, I would like to talk to you about Superfund. I know a lot of you may know something about the Superfund Program, but what does it mean today?

Superfund is a federal government program that's designed to fund the cleanup of sites that's contaminated with hazardous substances and pollutants. It was

established as the Comprehensive Environmental Response Compensation and Liability Act of 1980, and it's called CERCLA, which is administered by the EPA.

The next slide I want to show you is the Superfund process. First, a site is discovered, and then it goes through a site evaluation which consists of a preliminary assessment and a site inspection. The site inspection sometimes is conducted by the states, and this one was conducted by North Carolina.

After a site is evaluated, EPA will score the site. A site needs to score greater than 28.5 to become a Superfund site. The Cristex site was scored and was placed on the National Priorities List (NPL).

The next phase is the remedial investigation. This phase is where we determine what the contaminants are at the site and what the risks from those contaminants are to the community, workers or trespassers.

Afterwards, we proceed to the feasibility study, This phase is where we determine the nature and extent of contamination to develop a proposed plan. We are at this point now.

The proposed plan basically explains what we found at the site and how we want to go about cleaning it up. As Abena stated, you have 30 days to comment on the proposed plan. Comments can we sent to me. I'll provide

you my address at the end of the presentation.

Once we receive your comments, EPA will address the issues in the Responsiveness Summary of the Record of Decision (ROD). The ROD is a final document that contains explanations of the site cleanup activities. This is the main part of the Superfund program.

Now I want to talk about the Cristex site. The Cristex Drum site is located at 500 West Industry Drive, in Oxford, Granville County, NC. The site was a former textile manufacturing plant that knitted and dyed fabrics. The facility was in operation from 1966 to 1986.

The site is about 22 acres, and it was purchased by Steinfield Mills in 1965. They constructed a 150,000 square-foot building with several gravel driveways, a parking lot, asphalt pad in the back, and a small lagoon that's located on the northeast part of the property.

The lagoon discharged to the city wastewater treatment plant, and was used for storage and treatment. Today, the property is vacant but it's fenced to prevent unauthorized access.

Due to illegal operations and practices, the result was contamination to the soils and groundwater which could possibly affect the indoor air. There are no contaminants of concerns that are identified in the surface water or sediments above EPA's water quality

standards.

EPA is very familiar with the site. In 1996, we conducted a removal action. We removed approximately 26 contaminated drums, 137 carcasses, and three roll off containers of contaminated soil in the western part of the building.

Now this slide shows you the site location map. The site is shown in the red figure above. Located directly to the east and south of the site is an Industrial park. Located to the north of the site is the Norfolk Railroad, and the JFD Electronics/Channel Master site. Located to the east of the site are parcels and an apartment complex.

During the remedial investigation, our objective is to define the nature and extent of contamination and to assess potential risks from exposure to the contamination.

For approximately three years, EPA's contractors characterized the site with the state overseeing the process. We conducted a sampling analysis, and sampled five soil samples, 57 surface soil samples, 49 ground water samples, six surface water samples, and five sediment samples.

We conducted a hydrogeological investigation by studying the geology and the hydrogeology of the site. In

addition, we conducted a human health risk assessment and an ecological risk assessment.

This slide shows you the nature and extent of contamination. This is what we found at the site. In the surface soil, we found 38 milligrams per kilogram of tetrachloroethane (PCE), and previously we found 180 milligrams per kilogram PCE around the drum storage area located in the subsurface soil.

In the groundwater, the maximum concentration we found is 13,000 micrograms per liter of tetrachloroethane. We also found other contaminants such as trichloroethane, vinyl chlorides, cis 1,2-dichloroethane and benzene. We also noted that there is an indoor air problem, and basically we developed concentrations from our EPA's Vapor Intrusion Screening Level Calculations which are our numbers for indoor air.

As part of the remedial investigation, we conducted a baseline risk assessment. However, there's no ecological risk at the site. This table summarizes the cumulative cancer and noncancer risks at the site as well as the location of the contamination and who is affected.

An unacceptable cancer risk is identified when the site-related cumulative cancer risk is above EPA's risk management limit of one times ten to the minus four. There is an unacceptable risk. For a noncancer risk

identified when Site-related cumulative hazard quotients in a Hazard Index is greater than one. As you can see, all these numbers are greater than one.

The next couple of slides shows you the proposed remedial goals for the media of concern, and basically the proposed remedial goals are numbers that we use to clean up to as well as a rationale as to why we should clean up to those proposed standards.

Now, the next phase is the feasibility study phase. As part of the study, we looked at remedial options or remedial alternatives for the site. We grouped them into five main categories: institutional controls, monitoring, removal, containment or isolation, ex situ, and in situ treatment.

As required by the Superfund law, all the alternatives developed were compared side by side with nine different criteria as follows: The first criteria is protection of human health and environment. We want to determine whether the alternative eliminates, reduces, or controls threat to the public health.

The second criteria is compliance with ARARs (federal, state, and local regulations). The next criteria is long term effectiveness. We want to make sure that we maintain protection over time.

The next criteria is reduction of mobility and

toxicity volume by treatment. We want to evaluate whether alternatives reduce harmful effects. The next criteria is short term effectiveness for community, site workers impact and again we want to make sure that we consider the length of time required.

The next criteria is implementability, and this is the ability to construct and operate the technology. The next criteria is costs. We determined the capital cost, annual cost, as well as maintenance cost.

The last two criteria are state and community acceptance. Community acceptance is very important, and that's why we're here today, to get community acceptance and to allow you the opportunity to comment on our alternatives.

Now, this slide shows you the boundaries of the contamination at this site. There are two areas located on the property. One is located right here and the other one is located here.

For the groundwater, we separated the area into contaminated media zones. So why did we do that? We did that because portion of the site has a particular characteristic or lithology, contaminant of concern or even depth. There is an unsaturated zone area. Let me show you where its located.

If you look at the green boundary line, this

represents the unsaturated zone where the contamination ranges from zero to 20 feet in depth.

If you look at the yellow boundary line, the saturated source zone represents where contamination ranges from 20 to 80 feet deep. The red boundary line represents the dilute plume area, where contamination can possibly range from 80 feet to 300 feet deep.

We're proposing to clean up the site in the unsaturated, saturated and dilute areas. We have three alternatives that we are proposing: The soil excavation for the unsaturated zone, electrokinetics in situ chemical oxidation with biobarriers for the saturated source zone, and enhanced in situ bioremediation with biobarriers for the dilute plume.

This map shows you the first alternative we're proposing for soil. We want to excavate the soil approximately 12,000 cubic yards at the two source areas here, and we want to transport it to an EPA approved facility. We will backfill the area with clean soil. We have to assume that part of the building will be demolished and may have to remove the slab.

The next alternative describes the saturated source zone. The technology is electrokinetics and with in situ chemical oxidation and biobarriers. This technology uses a direct current to enhance the transport and oxidant

in the injection wells, all the injection wells will facilitate a direct chemical oxidation in that area.

Basically, it uses a passive barrier which is located along the top of the northern part of the site. This technology will use emulsified oils to clean up the groundwater more efficiently.

There is no above ground treatment. It's a very innovative technology that we're proposing.

The last technology describes the dilute plume area. This technology consists of injections of amendments, possibly a consortium into the groundwater through a row of injection wells, right here, to create a barrier for accelerating biodegradation in the ground water.

These are the three alternatives that we are proposing. There are other alternatives that are outlined in your proposed plan, but these are ones that ranked the highest and met all criteria.

Next, we want to look at the cost. For the first alternative, soil excavation, we're looking at 1.8 million dollars. The second alternative is electrokinetic in situ chemical oxidation with biobarriers at a cost of 4.6 million dollars.

And the last alternative is enhanced in situ bioremediation which cost 2.2 million dollars. There are

other costs for five year reviews, sampling, institutional controls, at $51,000. The total is 8.7 million dollars to clean up the Cristex site.

As Abena previously stated, you have 30 days beginning June 20th to July 20th to comment on these three proposed technologies.

You may submit your comments via e-mail or mail. You can also call me with your comments. We will respond to all of your in the Responsiveness Summary section of the Record of Decision.

If you require additional information, please visit the site repository located at the Richard H. Thornton Library. This is my contact number, and I have some cards on the table.

Now, before we get into questions and answers, I would like to introduce my colleague, Mr. James Ferreira. He's the hydrogeologist for my site. He's spent hours on this new technology and studying the ground water at the site. I would like for him to add some additional comments. Thank you.

MR. FERREIRA: Okay. Electrokinetics. I'll talk a little bit more about this. Electrokinetics. The reason why we're going this direction, the geology of the site, the formations are somewhat tight. The flow of water is slow moving.

So getting amendments or a way of handling the contaminants in the ground is very difficult. Normally we do pump and treat or we add bio or we add amendments into the ground to gobble up the contaminants or get them to move, and then we'll extract them out of the ground.

We don't think we're going to be able to do it at this site because the ground water flow is kind of slow and the contaminant is also contained within the formation, within the silts and clays.

So with electrokinetics, how it works, I'll just talk about that in a minute, but how it works, it actually will pull it out of the formation by its charge, by the positive and negative charge with the rods that Beverly was talking about earlier.

As you can see here, the circles, the dark blue represents the rods, and what we do is we have a banking system. We'll have a positive and negative charge. Opposites attract. And the yellow circles represent injection wells.

In this particular case, we're going to be injecting an amendment, permanganate, and the injection--the rods themselves, we have a charge going to it. It's going to be a low electrical current, probably in a range that will probably power your coffee pot, toaster, in that idea. If you really wanted to, you could probably run the

system off solar power.

The idea of adding the injection wells with the amendment is an additive to help the system run better. You probably could run the system with just the rods, but it would take a lot longer, and you might not get everything you want out of it.

By the injection of the permanganate into the system, it will help free up the contaminant out of the formation. It will be attracted towards the opposite charge within the rod.

At some point we stop the charge, we reverse the charge polarity within the rods, and we call it a washing action. So you let it flow back and forth between the rods. It's a bonus, because we're not adding any more solution into the formation. It actually helps clean the formation out.

That goes for a while, three or four months, six months. After that, we turn the charge to a different direction, and then we lock in that direction, and then we continue there for the charge to go in that one direction, and then we run that--run its course until the contaminant reaches the rod, say in a year's time.

Why I'm just making up these duration times, we haven't run the pilot test yet because every site will be different depending on the formation. The pilot test will

tell us how long it will take to go from point A to point B. At this point we believe it's going to take two to three centimeters per day for ground water flow being attracted by the charge. Also, the spacing of the rods, the injection amounts into the formation will be dictated by the pilot test. And the pilot test will be run prior to actual installation of all--this whole entire system.

This test has been run--or this system has been run; Electrokinetics has been used a lot over in Europe. It's been used down in Florida. This is a new technology being used in the United States. We feel that it would be promising within formations similar to what we have here at this site that are tight formations.

Any questions? I'm not sure how far to take it before it gets really kind of technical. Yes, sir.

MR. THORNTON: I'm Alan Thornton, with the City of Oxford. The site in Florida, how long has this method been being utilized at that site? Do you have any test results?

MR. FERREIRA: Yeah. The site in Florida, it was a pilot test. It was similar in size, a different kind of--I mean different kind of sediment but same porosity, which is how the water moves from point A to point B.

It was a chlorinated solvent which is a dry

cleaner facility. It was on a Navy base. The test was very successful. They put on expanding, and what they did is they--the reason why they only did a smaller pilot test, because the Navy, well, the military or the government, they took it and they had the giant dry cleaning facility, demo'd it, built warehouses on it. So now there's a parking lot there. So they wanted to run the pilot test in the parking lot because it was easy to do.

And once the pilot test was completed and everything was successful, then they'll actually go inside the warehouses and drill inside of them and take care of the plume inside the structures themselves.

That's why they didn't do the whole entire project at once. You know, I'm not sure what's in the warehouses. They wouldn't tell me that, but it's--the test was very successful, and they do plan on moving forward. Right now the final documents are being written up.

And in Europe they did a--their sites were a lot bigger than ours. Geology was very similar. They were probably on the size of a football field that they ran their projects in. They might not have run all the rods at the same time. Might've done, say, half a football field, done it there, and then pulled the rods out and

used them on the second half of the football field, in that aspect. Might not have done the whole thing at once, because it's cheaper to do it that way, if that makes sense to you.

MR. THORNTON: My question's about the ** soils in Florida might not (unintelligible) sand based.

MR. FERREIRA: It was a clay base. It was below the--it was below the sand layer. It was--

MR. THORNTON: Was it as deep as this site? You said 300 feet contamination.

MR. FERREIRA: The depth doesn't really--the depth--no, the depth was down probably about 30 feet or so. The depth doesn't have much to do with it in setting these up because the rods here will be continuous down to about 85 feet while you've got the top 20 feet you're going to pull off. This does have to be in a wet zone. It cannot be in a dry zone because it won't work. You need conductivity to be connected.

And when you actually set this up, if you have a high permeability, which it can flow from point A to point B very rapidly, you wouldn't use this because it wouldn't cost effective.

If it goes from point A to point B very slowly, this is a great setup. That being said, it did do this in Florida. That depth has no relevance here, and if you

wanted, you could actually set these rods up in a banking system. They don't have to be continuous. You could actually hang them. Whatever the reason may be, your plume might be at certain elevations where we are in the country.

So you don't actually have to have continuous rod 90 feet. It could be 20 feet and then down 30 feet, then another 20 feet of rod, if that answers your question.

And these rods are not big. They're only like an inch and a quarter diameter. They're not--they're graphite. They're higher end material, so they don't break down in the ground, so they are reusable. They could be used at a different site, I guess, in the future.

MS. HUDSON-STEPTER: So are there questions.

MS. OVERTON: Mine is more, I guess, before the cleanup. But, you know, obviously I have a house and it was important enough for you to send me a letter to let me know about the meeting, and so for me, I probably got a call 10 or 15 years ago, just a survey saying, "Did you know that there's a Superfund site near your home?"

So we live in the community across the road in Thorndale section. So what risk does that site pose to me and my community?

MS. HUDSON-STEPTER: There are two source areas on site. The groundwater plume is pretty much on site as well. The goundwater plume has not migrated to your property. It's localized right now.

MS. OVERTON: I didn't expect it to travel, but I didn't--I don't know if their rule was you had to send the notice to homeowners within a certain radius and we were in that radius and so--

MS. HUDSON-STEPTER: Yes.

MS. OVERTON: --it just caused concern, you know, was it--was there anything that--I'm sorry, Julie Overton--you know, that was affecting--

MS. HUDSON-STEPTER: No, we like to keep the residents informed about the site and the cleanup process.

MS. OVERTON: --us and the community?

MS. HUDSON-STEPTER: In order to keep the community informed of activities at the site, we usually mail out fact sheets to all residents within a quarter mile of the site. It appears that no one is affected, we just like to keep you informed of the process.

MS. OVERTON: We just didn't know.

MS. HUDSON-STEPTER: Oh, okay.

MS. OVERTON: And will that site, once the treatment's done, be considered a clean site? Will it ever be used for anything else or will it always be

unusable?

MS. HUDSON-STEPTER: We like to clean the site to its productive use. We want to clean up the site so that it can be reused. That's our ultimate goal. Basically, after the site meet our cleanup goals, it can be reused. It depends on how the owner or buyer wants to redevelop the property.

MS. OVERTON: Thank you.

MS. SERGENT: Jackie Sergent. I have a couple of questions also related to Julie Overton's. How long do you expect the process to take?

MS. HUDSON-STEPTER: Well, for the soil excavation--

MS. SERGENT: Well, to get from starting work--

MS. HUDSON-STEPTER: To the end?

MS. SERGENT: --to this is a usable site.

MS. HUDSON-STEPTER: Well, like I said, we separated the cleanup into phases. First, we are going to excavate the soil which may take up to six months, very quick, to get the soil out of there.

The next phase is the groundwater which could possibly take up to two years for the saturated source area. The last phase of the groundwater is the dilute plume area. This area is the deeper area which may take

longer, up to 20 years. But we're going to move the soil out first and there will not be any exposure there.

MS. SERGENT: So while you're still working on the dilute plume, is there potential for that site to be used again or do we have to wait till everything's done with the dilute plume section?

MS. HUDSON-STEPTER: No, you don't have to.

MS. SERGENT: And you mentioned air contamination which I am assuming is in the interior of the building.

MS. HUDSON-STEPTER: In the building only.

MS. SERGENT: And you had mentioned there might need to be some destruction of the building to manage, I guess, the--some of the soil excavation at the very beginning.

MS. HUDSON-STEPTER: Right.

MS. SERGENT: So has there not been a recommendation to just remove the building and then wouldn't that release the air, and you would be done with that piece?

MS. HUDSON-STEPTER: I was told that the owner wanted to remove the building. That would be a perfect scenario. We hope that would happen. Any more questions?

MR. THORNTON: Yes. This is Alan Thornton again. The owner, what is their responsibility for

something such as this ultimately with the price tag associated with this, six or seven million? Is there anything that--seven million, eight million--that the government does in regards to that in a situation like this?

MS. HUDSON-STEPTER: Well, the site is going to be cleaned up under the Superfund program. That means that the site is fund-lead. EPA considers enforcement first, and an opportunity to find potentially responsible parties. However, our discovery revealed that there are were no viable potentially responsible parties at this time.

MR. THORNTON: Ultimately is there a situation where there's a lien, lien type obligation placed on the property that would prohibit the property in the future from potentially being utilized for another purpose?

MS. HUDSON-STEPTER: I'm not sure if there's a lien on the property. I could find out. I'm not sure, do you know, David?

MR. MATTISON: I don't believe there is--

MS. HUDSON-STEPTER: I don't believe it's one on the property.

MR. MATTISON: --or some other type of device that may inhibit the potential use of that 22 acre

site.

MS. HUDSON-STEPTER: Right. Well, if there is a person that wants to purchase the property, they would have to go through a process at the EPA as a bona fide prospective purchaser, (BFPP).

They would contact the EPA, and let us know their intentions or plans to develop the property. At some Superfund sites, there may be interest to purchase sites.

MR. THORNTON: Do you become the owner; does the government become the owner of the property?

MS. HUDSON-STEPTER: No.

MS. OVERTON: Julie Overton. I understand what you're saying. We spend--the government spends nine million dollars. They get a clean piece of land and they sell it. There should be some kind of recovery on that, for the costs, to have title.

MS. HUDSON-STEPTER: There is a process where the government may recover funding. But that's a different area at the EPA. One would have to work with the enforcement program or attorneys.

I understand exactly where you're coming from, but it's a process. What would normally happen is that a conference call would be scheduled with a prospective buyer and a site attorney and the RPM. The attorney would explain the process and discuss liability issues. A buyer

would know exactly what their role and responsibilities are once they purchase it.

MS. SERGENT: Jackie Sergent. The bigger issue is the tremendous amount of taxpayer dollars are being invested into this for which we are very grateful, but if there is a private entity that is able--that isn't investing their own dollars in cleaning it up and then is able to take advantage of the fact that somebody else paid for clean up, there seems to be a disconnect.

MS. HUDSON-STEPTER: At the EPA, we always consider enforcement first, before cleaning up a site. If someone is liable, we would attempt recovery by normal procedures. This is in the enforcement section of the EPA.

MR. THORNTON: This is Alan Thornton. I'm assuming by "other parties," you're also bringing into account potentially anyone that did business with this business such as the Ward Transformer site situation where a number municipalities that had transformers there were being billed after that in conjunction with that situation. Is this similar to that as far as potential options for--

MS. HUDSON-STEPTER: Yes, often we are looking for operators and transporters, but not companies that used or leased the property. For example, at the Cristex site there were some companies such as Revlon Inc., and

the tire company that leased the property. They were not responsible for illegal operations. They used a portion of the property for business purposes.

MR. THORNTON: That's a different position than was taken on the Ward Transformer site. I can't remember the community that received a pretty large bill because they sent a couple of transformers to the site, and then it became basically their property, but we were still found liable.

MS. HUDSON-STEPTER: Yes, that's a different scenario.

MR. THORNTON: My question is--you recovered so many containers. Could they all be traced back to Cristex or to another customer who potentially--

MR. HUDSON-STEPTER: We have an enforcement division or department that track potentially responsible parties and also conducts PRP searches.

MR. THORNTON: The point I'm really making is when you get that involved and that into the weeds, it extends the whole issue for years and years and years which would further reduce the likelihood of the ability for someone else to utilize this property because it's still tied up in legal proceedings.

MS. HUDSON-STEPTER: I understand what you're

saying, but that's a legal answer, and basically, I could get my attorney to call you to discuss legal concerns regarding the site. Her name is Susan Capel, however, she couldn't be here tonight.

MR. THORNTON: Thank you.

MS. HUDSON-STEPTER I'll take your number and have her call you. Any other questions?

(No response from the audience)

MS. AJANAKU: Okay. Well, Beverly, thank you. Appreciate it. Thank you, James, and thank you all for coming out this evening. Again, all your comments and everything have been taken down, and they will--they have been responded to, but they will also be in our--a part of the ROD. This transcript will be a part of the ROD.

So I also wanted to thank Paul for allowing us to use the facility this evening. I really appreciate it. Really appreciate it. And we're going to be around for a few more minutes after the meeting, so if something pops in your head that you need to talk to us about before you leave, please feel free to do that. But right now I'm going to call this meeting closed. Thank you.

(The meeting concluded at 6:45 p.m.)

Date: 6/27/17

APPENDIX D
STATE OF NORTH CAROLINA CONCURRENCE

Waste Management
ENVIRONMENTAL QUALITY

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

MICHAEL SCOTT
Director

September 28, 2017

Ms. Beverly Hudson-Stepter
Remedial Project Manager
Superfund Division
United States Environmental Protection Agency, Region 4
Sam Nunn – Atlanta Federal Center
61 Forsyth Street, SW
Atlanta GA 30303-8960

RE: State Concurrence with the Record of Decision
Cristex Drum NPL Site
Oxford, Granville County, North Carolina
NC0001606250

Dear Ms. Hudson-Stepter:

The State of North Carolina has reviewed the attached *Record of Decision* ("ROD") at the Cristex Drum National Priorities List ("NPL") Site ("Site"). The State of North Carolina concurs with the *Record of Decision*, subject to the following conditions:

1. **The remedy is to address all the soil contamination in the Unsaturated Zone (UZ) originating from the Former Drum Storage Pad adjacent to the Cristex building. The State acknowledges the estimated additional costs of $849,600 for building demolition and excavation that may be needed to achieve complete removal of all contaminated soils.**

The *Remedial Investigation Report, Version 1* (Black & Veatch, December 2016), the *Final Feasibility Study Report, Version 1* (Black & Veatch, March 2017) and Figures 3 – Contaminated Media Zone (CMZ) Designations and Figure 12 – *Selected Remedy of the Record of Decision* each acknowledge the presence of soil contamination in the Unsaturated Zone (UZ), originating from the Former Drum Storage Pad adjacent to the Cristex building, necessitating building demolition in order to achieve complete excavation and removal of all contaminated soils.

The fifth through ninth sentences of the first paragraph of Section 9.1.3 – *UZ Alternative 3: Soil Excavation* of the *Record of Decision* state:

"A sampling plan will be developed as part of the Remedial Design to determine if additional building demolition and soil excavation is warranted. Expanded (or complete)

demolition of the Cristex building would allow for full excavation of the presumed area of soil contamination. Under this scenario, an additional 4,812 bank cubic yard (bcy) of soil plus 765 bcy of sidewall slopes would be excavated. This would add $849,600 to the cost of Alternative UZ #3 (total NPW cost of $2,722,600). Soil excavation is expected to remove the majority of the suspected source area and any NAPL present in the UZ." Section 12.2.1 – Unsaturated Zone of Section 12.2 – Description of the Selected Remedy of the Record of Decision does not provide for expanded (or complete) demolition of the Cristex building, allowing for full excavation of the presumed area of soil contamination, but acknowledges in the second sentence of the third paragraph of Section 12.2.1 that "Expanded building demolition and excavation would increase the capital cost by $849,600. "

The NC DEQ has reviewed the Remedial Investigation Report, Version 1, Final Feasibility Study Report, Version 1 and the Record of Decision for the Cristex Drum NPL Site and support building demolition and complete excavation of contaminated soils located in the Unsaturated Zone (UZ) for the following reasons:

a) Conducting complete source removal will shorten the duration of remedial activities by removing the source and lessening the volume of contaminated material requiring treatment in the Saturated Source Zone (SSZ) and Dilute Plume (DP) as the contaminated materials migrate down and away from their original location.

b) Conducting complete source removal will shorten the overall cost of remedial activities by removing the source and lessening the volume of contaminated material requiring treatment in the SSZ and DP.

c) Conducting complete source removal will provide a permanent remedy, lessening the overall long-term site operation and maintenance requirements.

d) Conducting complete source removal and lessening the volume of contaminated material requiring treatment in the SSZ and DP will have the added effect of reducing issues related to the comingling of contaminated plumes from the Cristex Drum NPL Site and the adjacent JFD Electronics/Channel Master NPL Site.

Again, State concurrence is conditioned on the expanded (or complete) demolition of the Cristex building, allowing for full excavation of the presumed area of soil contamination. Under this scenario, an additional 4,812 bcy of soil plus 765 bcy of sidewall slopes would be excavated adding $849,600 to the cost of Alternative UZ #3 (total NPW cost of $2,722,600).

2. **State concurrence on the *Record of Decision* and the selected remedy for the Site is based solely on the information contained in the subject *Record of Decision*. Should the State receive new or additional information that significantly affects the conclusions or remedy selection contained in the *Record of Decision*, it may modify or withdraw this concurrence with written notice to the United States Environmental Protection Agency (US EPA) Region IV.**

3. **State concurrence on this *Record of Decision* in no way binds the State to concur in future decisions or commits the State to participate, financially or otherwise, in the cleanup of the Site. The State reserves the right to review, overview, comment, and make independent assessment of all future work relating to this Site.**

The State of North Carolina appreciates the opportunity to comment on the *Record of Decision* for the Cristex Drum NPL Site and looks forward to working with the US EPA on the final remedy. If you have any questions or comments, please feel free to contact David Mattison at (919) 707-8336 or at david.mattison@ncdenr.gov.

Sincerely,

Jim Bateson
Chief, Superfund Section
Division of Waste Management

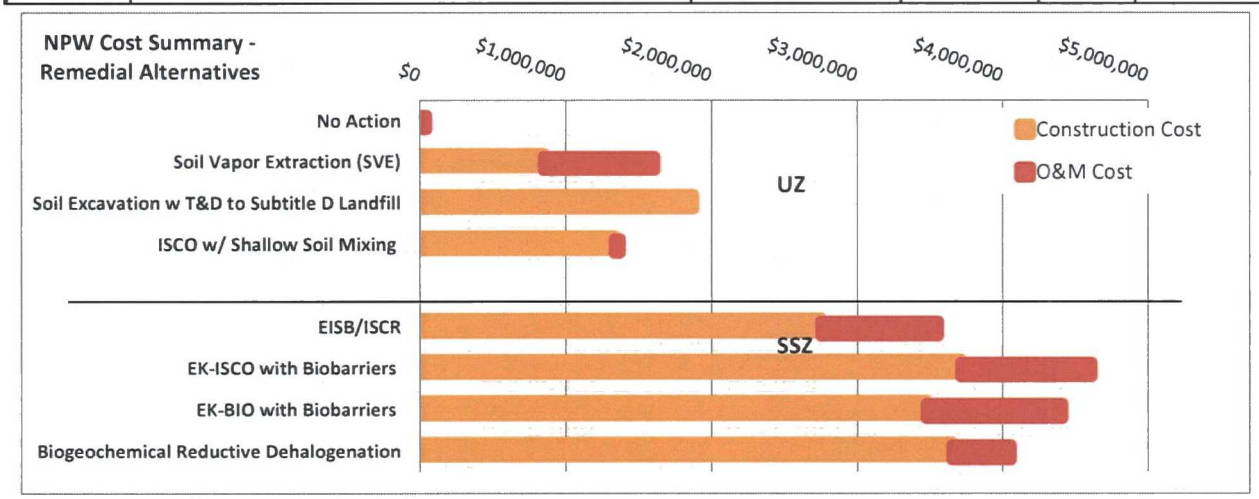
Attachment

APPENDIX E
SELECTED REMEDY DETAILED COST ESTIMATE SHEETS

Feasibility Study Cost Estimate Summary

Project:	Cristex Drum	Report:	Feasibility Study Cost Estimate		
Location:	Oxford, NC	Project Number:	49073	Revision:	0
Project Phase:	FS	Date:	10/6/2016	Stage:	
Operable Unit:	N/A	Estimated By:	EMS, WW, MS	Checked By:	CEM

Alternative	Description	Construction Cost	O&M Cost	Yrs	NPW Total
Unsaturated Zone Alternatives					
UZ #1	No Action	$0	$41,978	30	$42,000
UZ #2	Soil Vapor Extraction (SVE)	$846,381	$761,054	5	$1,607,400
UZ #3	Soil Excavation w T&D to Subtitle D Landfill	$1,873,035	$0	0	$1,873,035
UZ #4	ISCO w/ Shallow Soil Mixing	$1,332,693	$38,060	1	$1,370,800
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
Saturated Zone Alternatives					
SSZ #2	EISB/ISCR	$2,749,823	$804,473	5	$3,554,300
SSZ #3	EK-ISCO with Biobarriers	$3,710,720	$898,998	2	$4,609,700
SSZ #4	EK-BIO with Biobarriers	$3,474,333	$934,756	2	$4,409,100
SSZ #5	Biogeochemical Reductive Dehalogenation	$3,651,044	$403,875	4	$4,054,900
-	-	-	-	-	-
-	-	-	-	-	-
Dilute Plume Alternatives					
DP #2	EISB Passive Barrier	$1,201,418	$1,063,045	20	$2,264,500
DP #3	GR&T/Hydraulic Containment	$594,088	$1,163,434	20	$1,757,500
DP #4	Monitored Natural Attenuation	$0	$189,054	20	$189,100
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-



Feasibility Study Cost Estimate

Total NPW Cost: $51,000

		Alternative #:			
Project:	Cristex Drum	Title:	*Sitewide Costs*		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	0

Task Description: Sitewide costs applicable to each remedial alternative. Includes costs for 5YRs, maintenance of land use restrictions, site inspections.

Cost Basis: Detailed estimate

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
			Subtotal - Capital Costs:		$ -
Capital Contingency	20%	of Capital Cost			$ -
Legal Fees, Licenses & Permits[1]	0.5%				$ -
Engineering & Administrative[1]	8%				$ -
Contractor Fee[2]	10%	of Capital Cost			$ -
			Total Capital Cost:		$ -

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

O&M Costs

O&M Period	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

Site-Wide O&M Costs — **Annual Cost**

Gauge 8 wells for SVOCs every 5 years for 30 years (6 events); 9 hour day - 1 day effort, 8 hr travel, 6 hr prep; Prepare 5YR report, Site visits

Labor	30	yr	1	total	$	12,780	$ 12,780
Travel	30		1	total	$	470	$ 470
Materials/Equipment/Subcontractors	30		1	total	$	2,815	$ 2,815
Analytical - Water	30		1	total	$	1,219	$ 1,219
							$ 17,284

Frequency of Periodic Annual Cost: 6 events

Net Present Worth (NPW) Subtotal: $ 37,296

O&M Contingency	15%	of NPW Cost	$ 5,594.46
Engineering & Administrative[1]	8%		$ 3,431.27
Contractor Fee[2]	10%		$ 4,632

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

Net Present Worth derived from summation of Modified Uniform Present Value

Subtotal - O&M Costs: $ 50,954

Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Total NPW Cost Estimate: $ 51,000

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

				Total NPW Cost:	$42,000
		Alternative #:	UZ #1	UZ Alternative #1	
Project:	Cristex Drum	Title:	*No Action*		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	0
Task Description:	No Action remedial alternative. Only includes LTM costs for sampling CVOCs for 30 years on 6 yr intervals.				
Cost Basis:	Detailed estimate				

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
			Subtotal - Capital Costs:		$ -
Capital Contingency	15%	of Capital Cost			$ -
Legal Fees, Licenses & Permits[1]	0.5%				$ -
Engineering & Administrative[1]	8%				$ -
Contractor Fee[2]	10%	of Capital Cost			$ -
			Total Capital Cost:		$ -

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

O&M Costs

	O&M Period			
7.00%	Discount Rate			
0.00%	Constant Escalation Factor			

Sampling O&M							**Annual Cost**
Gauge 10 wells for VOCs every 5 years for 30 years (6 events); 9 hour day - 2 day effort, 8 hr travel, 12 hr prep							
Labor	30	yr	1	total	$ 11,288		$ 11,288
Travel	30		1	total	$ 1,374		$ 1,374
Materials/Equipment/Subcontractors	30		1	total	$ 755		$ 755
Analytical - Water	30		1	total	$ 822		$ 822
							$ 14,239
Frequency of Periodic Annual Cost:	6	events					
					Net Present Worth (NPW) Subtotal:		**$ 30,726**
O&M Contingency			15%	of NPW Cost			$ 4,608.92
Engineering & Administrative[1]			8%				$ 2,826.81
Contractor Fee[2]			10%				$ 3,816
					Subtotal - O&M Costs:		**$ 41,978**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A
Net Present Worth derived from summation of Modified Uniform Present Value

Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Total NPW Cost Estimate: **$ 42,000**

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $1,607,400

Alternative #: UZ #2 — UZ Alternative #2

Project: Cristex Drum
Location: Oxford, NC
Project Phase: FS

Title: Soil Vapor Extraction (SVE)
Project Number: 49073
Date: 10/6/2016
Base Year: 2016
Revision: 0

Task Description: Installation of ~31 permanent soil vapor extraction (SVE) wells on ~27-ft spacings (~15-ft overlapped radius of influence assumed) for direct extraction of CVOCs/VOCs/SVOCs. Recovered gasses treated with air/fluid separation and vapor phase carbon.

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Volume of Impacted Media to be Treated w/SVE:	12,444	yd^3		Unit Cost ($/yd3):	$ 129
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 22,459		$ 22,459
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ 15,000		$ 15,000
Pilot Scale Testing	1	ls	$ -		$ -
				Design/Bench/Pilot Testing Subtotal:	**$ 38,829**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 27,404		$ 27,404
Travel	1	ls	$ 6,053		$ 6,053
Materials/Equipment/ Subcontractors	1	ls	$ 11,280		$ 11,280
				Mobilization Subtotal:	**$ 44,737**
3.0 Site Preparation					
Utility protection, grubbing, clearing, onsite meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 14,972		$ 14,972
				Site Preparation Subtotal:	**$ 14,972**
4.0 Install Extraction Wells					
Drilling of (31) 4-inch SVE wells. Drilling to 20 bls with 15-feet screens. Flush Mount. Assumes 4 wells drilled/day. Use 1 rig/day. 9 hr day (8 days). Well development not required.					
Labor	1	ls	$ 25,306		$ 25,306
Travel	1	ls	$ 4,897		$ 4,897
Drilling Subcontractor Rate	620	ft	$ 60		$ 37,200
Drilling Subcontractor - Other	1	ls	$ 20,481		$ 20,481
Well Materials	1	ls	$ 19,604		$ 19,604
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 7,960		$ 7,960
				Extraction Well Subtotal:	**$ 115,448**
5.0 Install Recovery System Piping/Wellheads					
Installation of 31 wellheads, headers, lines, aboveground piping					
Labor	1	ls	$ 32,472		$ 32,472
Travel	1	ls	$ 8,991		$ 8,991
Materials/Equipment/Subcontractors	1	ls	$ 62,575		$ 62,575
				Install Piping/Wellheads Subtotal:	**$ 104,038**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: UZ #2 UZ Alternative #2
Title: Soil Vapor Extraction (SVE)

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Construct/Install SVE Equipment Enclosure/System					
Install SVE system and enclosure (moisture seperator, exhaust blower, vapor phase carbon, appurtenances). Assume (1) Trailered mobile units in fenced compound. Five day installation assumed.					
Labor	1	ls	$ 46,488		$ 46,488
Travel	1	ls	$ 7,137		$ 7,137
Site Preparation	1	ls	$ 17,500		$ 17,500
Extraction Wells Main Header	1	ls	$ 5,872		$ 5,872
Equipment Enclosure/SVE Treatment System	1	ls	$ 120,800		$ 120,800
SVE Manifold	1	ls	$ 13,508		$ 13,508
SVE Wellhead Assembly	1	ls	$ -		$ -
				SVE Equipment Enclosure System Subtotal:	**$ 211,304**
7.0 Install Air Entry Wells					
Drilling of (22) 2-inch diameter air entry wells. Drilling to 20-ft bls with 15-feet screen and 20-slot. Flush Mount. Assumes 4 wells drilled/day. Use 1 rig/day. 9 hr day (~6 days total).					
Labor	1	ls	$ 10,123		$ 10,123
Travel	1	ls	$ 2,789		$ 2,789
Drilling Subcontractor	1	ls	$ 35,123		$ 35,123
Well Materials	1	ls	$ 12,074		$ 12,074
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 1,930		$ 1,930
				Install Air Entry Well Subtotal:	**$ 62,037**
8.0 Install Performance Monitoring Wells					
Drilling of (6) 2-inch diameter vadose zone PMWs for chemical and vacuum readings. Drilling to 25-ft bls with 20-feet screen and 20-slot. Flush Mount. Assumes 4 wells drilled/day. Use 1 rig/day. 9 hr day (~1.5 days total).					
Labor	1	ls	$ 5,360		$ 5,360
Travel	1	ls	$ 1,552		$ 1,552
Drilling Subcontractor Rate	150	lf	$ 56		$ 8,400
Drilling Subcontractor - Other	1	ls	$ 4,083		$ 4,083
Well Materials	1	ls	$ 3,893		$ 3,893
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 2,007		$ 2,007
				Install PMW Subtotal:	**$ 25,294**

1)
2)
3)

		Subtotal - Capital Costs:	**$ 616,660**
Capital Contingency	15%	of Capital Cost	$ 92,499
Legal Fees, Licenses & Permits[1]	0.5%		$ 3,546
Engineering & Administrative[1]	8%		$ 56,733
Contractor Fee[2]	10%	of Capital Cost	$ 76,944
		Total Capital Cost:	**$ 846,381**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: UZ #2 — UZ Alternative #2
Title: Soil Vapor Extraction (SVE)

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
9.0 SVE O&M Costs							**Annual Cost**
Operation of SVE system for 5 years. Preparation of equipment, materials, and labor for operation. Assumes (1) staff full-time (8 hrs/day) for 80 hrs month then 16 hrs/month thereafter, plus (1) supplemental staff as needed (~120 hr/year).							
Labor	5	yr	1	total	$ 33,094		$ 33,094
Travel	5	yr	1	total	$ 10,293		$ 10,293
Materials/Equipment/Subcontractors	5	yr	1	total	$ 24,815		$ 24,815
Analytical - Soil	5	yr	1	total	$ -		$ -
Analytical - Air Phase	5	yr	1		$ -		$ -
							$ 68,202
10.0 Performance Sampling O&M Costs							
Monitor system performance for VOCs and SVOCs (influent and effluent, each manifold [quarterly]) weekly first two months, bimonthly for 10 months, monthly thereafter (76 events); 8 hour day - 2 day effort, 4 hr travel, 4 hr prep.							
Labor	5	yr	1	total	$ 35,672		$ 35,672
Travel	5	yr	1	total	$ 9,400		$ 9,400
Materials/Equipment	5	yr	1	total	$ 3,600		$ 3,600
Analytical	5	yr	1	total	$ 18,988		$ 18,988
							$ 67,660
						Net Present Worth (NPW) Subtotal:	**$ 557,059**
O&M Contingency			15%	of NPW Cost			$ 83,559
Engineering & Administrative[1]			8%				$ 51,249
Contractor Fee[2]			10%				$ 69,187
						Subtotal - O&M Costs:	**$ 761,054**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

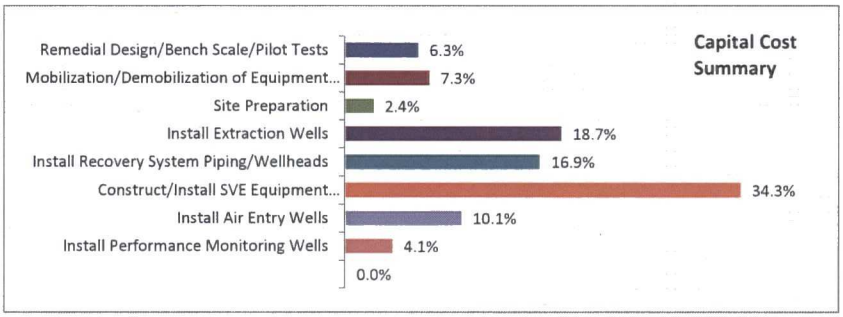
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 1,607,400



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $1,873,035

Alternative #:	UZ #3	UZ Alternative #3			
Project:	Cristex Drum	Title:	Soil Excavation w T&D to Subtitle D Landfill		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	0

Task Description: Excavation of 11,275 bcy of contaminated soils with dispsoal at a Subtitle D Hazardous Waste Landfill. Installation of ~9 laterals (440-ft total) within excavation as a contingency for future amendment addition. Cover with clean sand and liner, backfill with clean compacted fill.

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Volume of Impacted Media to be Excavated:	11,275	yd^3	Unit Cost ($/yd3):	$	103
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 21,488	$	21,488
Remedial Design Travel	1	ls	$ 870	$	870
Materials/Equipment/Subcontractors	1	ls	$ 500	$	500
Bench Scale Testing	1	ls	$ -	$	-
Pilot Scale Testing	1	ls	$ -	$	-
			Design/Bench/Pilot Testing Subtotal:	**$**	**22,858**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 39,809	$	39,809
Travel	1	ls	$ 6,053	$	6,053
Materials/Equipment/ Subcontractors	1	ls	$ 16,350	$	16,350
			Mobilization Subtotal:	**$**	**62,212**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -	$	-
Travel	1	ls	$ -	$	-
Materials/Equipment/ Subcontractors	1	ls	$ 20,873	$	20,873
Building Demoilition	1	ls	$ 103,000	$	103,000
			Site Preparation Subtotal:	**$**	**123,873**
4.0 Soil Excavation and Staging					
Excavation of 17,100 bcy of soils and sidewalls; staging of soils; transport and disposal at Subtitle D Hazardous Waste Landfill; backfill; site restoration; assumes 60% of soils are deemed contaminated					
Labor	1	ls	$ 16,455	$	16,455
Travel	1	ls	$ 4,666	$	4,666
Excavation Subcontractor Costs	1	ls	$ 90,200	$	90,200
Haul Impacted Soil and Sidewall Soils	8,456	lcy	$ 29.0	$	245,231
Subtitle D Landfill Disposal	8,456	lcy	$ 64.8	$	547,965
Lateral/Riser Installation Subcontractor Costs	1	ls	$ 104,457	$	104,457
Backfill Subcontractor Costs	1	ls	$ 139,539	$	139,539
Site Restoration	1	ls	$ 7,208	$	7,208
				$	**1,155,720**

Notes:

1)

2)

		Subtotal - Capital Costs:	**$**	**1,364,664**
Capital Contingency	15%	of Capital Cost	$	204,700
Legal Fees, Licenses & Permits[1]	0.5%		$	7,847
Engineering & Administrative[1]	8%		$	125,549
Contractor Fee[2]	10%	of Capital Cost	$	170,276
		Total Capital Cost:	**$**	**1,873,035**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: UZ #3 — UZ Alternative #3
Title: Soil Excavation w T&D to Subtitle D Landfill

Item		Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs						
	O&M Period	7.00%	Discount Rate			
		0.00%	Constant Escalation Factor			
10.0						**Annual Cost**
None						
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1			$	-
					$	-
				Net Present Worth (NPW) Subtotal:	$	-
O&M Contingency		15%	of NPW Cost		$	-
Engineering & Administrative[1]		8%			$	-
Contractor Fee[2]		10%			$	-
				Subtotal - O&M Costs:	$	-

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

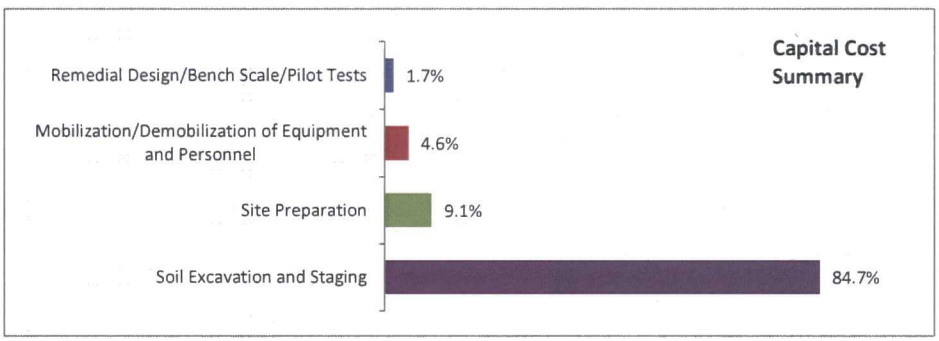
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 1,873,000



General Assumptions
1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Excavation Worksheet

Manually transfer costs to summary sheet

S = Subcontractor; L = Labor; M = Material; R = Rental; O = Other Direct Charge; PD = Per Diem; T = Travel

Item	Basis	Code	Cat.	#	Qty.	Unit	Unit Cost	Note	Subtotal ($)
Volume Calculations									
Total Soil Volume to Excavate (Exclusive of Sidewalls		7,340	bcy		includes contaminated and clean lifts				
Total Area to be Cleared:		15,221	ft^2		0.35	acres			
Nominal Width of Excavation:		95	ft		Area Check				
Nominal Length of Excavation:		160	ft		15,200	ft^2			
Average Depth to Water:		20	ft				**12152**		
Average Depth of Excavation:		20	ft bls						
Deepest Excavation:		20	ft bls				**4,812**		
Depth of Clean Overburden:		0	ft						
Number of Track Excavators:		2							
Excavator Bucket Size:		0.95	cy				Sidewall Length:		
Angle of Repose for Excavation Sidewalls:		45	degrees (to horizontal)				20.00	ft	
Percent Over-Excavation of Contaminated Soil:		100%							
Volume of Slope Cuts:		3,935	bcy				Approximate Sidewall Area:		
Total Volume Excavated:		11,275	bcy				15,748	ft^2	
Percent of Excavated Soils Contamainted:		60%							
Estimated Volume of Contaminated Soil:		6,765	bcy						
Soil Swell Factor:	Clay	1.25							
Safety Factor for Timeframe:		1.25							
Hours of Excavation/Day		8.00	hrs						
Estimated Timeframe for Excavation:		4.8	days	@	183.21	bcy/hr/excavator			
Hazardous Soil Disposal:		8,456	lcy						
Estimated Timeframe for Backfill:		6	days	@	183.00	bcy/hr/excavator			
Estimated Work Timeframe:		14	days		2.0	wks			

Feasibility Study Cost Estimate

				Total NPW Cost:	$2,722,680
		Alternative #:	UZ #3	UZ Alternative #3B	
Project:	Cristex Drum	Title:	Soil Excavation w T&D to Subtitle D Landfill		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	0

Task Description: Excavation of 11,275 bcy of contaminated soils with dispsoal at a Subtitle D Hazardous Waste Landfill. Installation of ~9 laterals (440-ft total) within excavation as a contingency for future amendment addition. Cover with clean sand and liner, backfill with clean compacted fill.

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Volume of Impacted Media to be Excavated:	16,087	yd^3		Unit Cost ($/yd3):	$ 100
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 21,488		$ 21,488
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ -		$ -
Pilot Scale Testing	1	ls	$ -		$ -
				Design/Bench/Pilot Testing Subtotal:	**$ 22,858**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 39,809		$ 39,809
Travel	1	ls	$ 6,053		$ 6,053
Materials/Equipment/ Subcontractors	1	ls	$ 16,350		$ 16,350
				Mobilization Subtotal:	**$ 62,212**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 21,490		$ 21,490
Building Demoilition	1	ls	$ 268,000		$ 268,000
				Site Preparation Subtotal:	**$ 289,490**
4.0 Soil Excavation and Staging					
Excavation of 17,100 bcy of soils and sidewalls; staging of soils; transport and disposal at Subtitle D Hazardous Waste Landfill; backfill; site restoration; assumes 60% of soils are deemed contaminated					
Labor	1	ls	$ 16,455		$ 16,455
Travel	1	ls	$ 4,666		$ 4,666
Excavation Subcontractor Costs	1	ls	$ 128,696		$ 128,696
Haul Impacted Soil and Sidewall Soils	12,065	lcy	$ 29.0		$ 349,892
Subtitle D Landfill Disposal	12,065	lcy	$ 64.8		$ 781,828
Lateral/Riser Installation Subcontractor Costs	1	ls	$ 114,140		$ 114,140
Backfill Subcontractor Costs	1	ls	$ 206,028		$ 206,028
Site Restoration	1	ls	$ 7,437		$ 7,437
					$ 1,609,141

Notes:

1)

2)

		Subtotal - Capital Costs:	**$ 1,983,701**
Capital Contingency	15%	of Capital Cost	$ 297,555
Legal Fees, Licenses & Permits[1]	0.5%		$ 11,406
Engineering & Administrative[1]	8%		$ 182,501
Contractor Fee[2]	10%	of Capital Cost	$ 247,516
		Total Capital Cost:	**$ 2,722,680**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project:	Cristex Drum	Alternative #:	UZ #3 — UZ Alternative #3B
Location:	Oxford, NC	Title:	Soil Excavation w T&D to Subtitle D Landfill

Item		Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs						
	O&M Period	7.00%	Discount Rate			
		0.00%	Constant Escalation Factor			
10.0						**Annual Cost**
None						
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1	total		$	-
	yr	1			$	-
					$	-
				Net Present Worth (NPW) Subtotal:	$	-
O&M Contingency		15%	of NPW Cost		$	-
Engineering & Administrative[1]		8%			$	-
Contractor Fee[2]		10%			$	-
				Subtotal - O&M Costs:	$	-

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

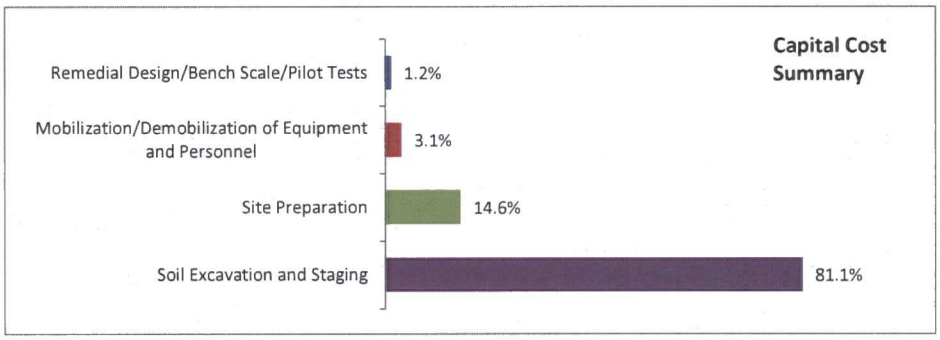
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 2,722,700



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Excavation Worksheet

Manually transfer costs to summary sheet

S = Subcontractor; L = Labor; M = Material; R = Rental; O = Other Direct Charge; PD = Per Diem; T = Travel

Item	Basis	Code	Cat.	#	Qty.	Unit	Unit Cost	Note	Subtotal ($)

Volume Calculations

Total Soil Volume to Excavate (Exclusive of Sidewalls		12,152	bcy		includes contaminated and clean lifts			
Total Area to be Cleared:		16,800	ft^2		0.39	acres		
Nominal Width of Excavation:		100	ft		Area Check			
Nominal Length of Excavation:		168	ft		16,800	ft^2		
Average Depth to Water:		20	ft					
Average Depth of Excavation:		20	ft bls					
Deepest Excavation:		20	ft bls					
Depth of Clean Overburden:		0	ft					
Number of Track Excavators:		2						
Excavator Bucket Size:		0.95	cy				Sidewall Length:	
Angle of Repose for Excavation Sidewalls:		45	degrees (to horizontal)				20.00	ft
Percent Over-Excavation of Contaminated Soil:		100%						
Volume of Slope Cuts:		3,935	bcy				Approximate Sidewall Area:	
Total Volume Excavated:		16,087	bcy				16,359	ft^2
Percent of Excavated Soils Contamainted:		60%						
Estimated Volume of Contaminated Soil:		9,652	bcy					
Soil Swell Factor:	Clay	1.25						
Safety Factor for Timeframe:		1.25						
Hours of Excavation/Day		8.00	hrs					
Estimated Timeframe for Excavation:		6.9	days	@	183.21	bcy/hr/excavator		
Hazardous Soil Disposal:		12,065	lcy					
Estimated Timeframe for Backfill:		9	days	@	183.00	bcy/hr/excavator		
Estimated Work Timeframe:		18	days		2.6	wks		

Feasibility Study Cost Estimate

Total NPW Cost: **$1,370,800**

Project:	Cristex Drum	Alternative #:	UZ #4	UZ Alternative #4	
Location:	Oxford, NC	Title:	ISCO w/ Shallow Soil Mixing		
Project Phase:	FS	Project Number:	49073	Base Year:	2016
		Date:	10/6/2016	Revision:	0

Task Description: Treatment of ~10,800 bcy of contaminated soils (~14,600 sf at a depth of 20') *in situ* with potassium permanganate using shallow soil mixing with a Lang or Allu tool on an excavator.

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Volume of Impacted Media to be treated w/ISCO:	10,800	yd^3		Unit Cost ($/yd3):	$ 127
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 26,611		$ 26,611
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ 8,000		$ 8,000
Pilot Scale Testing	1	ls	$ -		$ -
				Design/Bench/Pilot Testing Subtotal:	**$ 35,981**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 39,809		$ 39,809
Travel	1	ls	$ 6,533		$ 6,533
Materials/Equipment/ Subcontractors	1	ls	$ 11,030		$ 11,030
				Mobilization Subtotal:	**$ 57,372**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 19,538		$ 19,538
Building Demoilition	1	ls	$ 103,000		$ 103,000
				Site Preparation Subtotal:	**$ 122,538**
4.0 Shallow Soil Mixing and ISCO					
Preparation of potassium permanganate mixture, shallow soil mixing to 20-ft bls with simultaneous addition of oxidant. Assumes use of Land or Allu tool. Areas of clean surface soil (assume 80%) reused for cover soils.					
Labor	1	ls	$ 39,320		$ 39,320
Travel	1	ls	$ 15,782		$ 15,782
Oxidant Feed System	1	ls	$ 1,300		$ 1,300
Soil Mixing Contractor					
Mob/Demob	1	ls	$ 100,000		$ 100,000
Site Set-up	1	ls	$ 50,000		$ 50,000
Shallow Soil Mix Contractor	1	ls	$ 486,000		$ 486,000
Chemicals and Freight	1	ls	$ 60,136		$ 60,136
Materials/Equipment/Subcontractors	1	ls	$ 2,550		$ 2,550
Lateral Wellheads and Effluent Manifolds	1	ls			$ -
Injection Wells Main Header	1	ls	$ -		$ -
				Soil Mixing/ISCO Subtotal:	**$ 755,088**
				Subtotal - Capital Costs:	**$ 970,979**
Capital Contingency	15%	of Capital Cost			$ 145,647
Legal Fees, Licenses & Permits[1]	0.5%				$ 5,583
Engineering & Administrative[1]	8%				$ 89,330
Contractor Fee[2]	10%	of Capital Cost			$ 121,154
				Total Capital Cost:	**$ 1,332,693**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project:	Cristex Drum	Alternative #:	UZ #4 — UZ Alternative #4
Location:	Oxford, NC	Title:	ISCO w/ Shallow Soil Mixing

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
5.0 Performance Sampling O&M Costs							**Annual Cost**
Drill (DPT) 20 borings to confirm short and long-term effectiveness. Sample soils for VOCS. Assume 4 borings/day 9 hour day - 5 day effort, 8 hr travel, 12 hr prep. (5) Samples per location.							
Labor	1	yr	1	total	$ 16,907		$ 16,907
Travel	1	yr	1	total	$ 3,359		$ 3,358.89
Materials/Equipment	1	yr	1	total	$ 2,450		$ 2,450
Analytical	1	yr	1	total	$ 7,092		$ 7,092
							$ 29,809
					Net Present Worth (NPW) Subtotal:		**$ 27,858**
O&M Contingency			15%	of NPW Cost			$ 4,179
Engineering & Administrative[1]			8%				$ 2,563
Contractor Fee[2]			10%				$ 3,460
					Subtotal - O&M Costs:		**$ 38,060**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

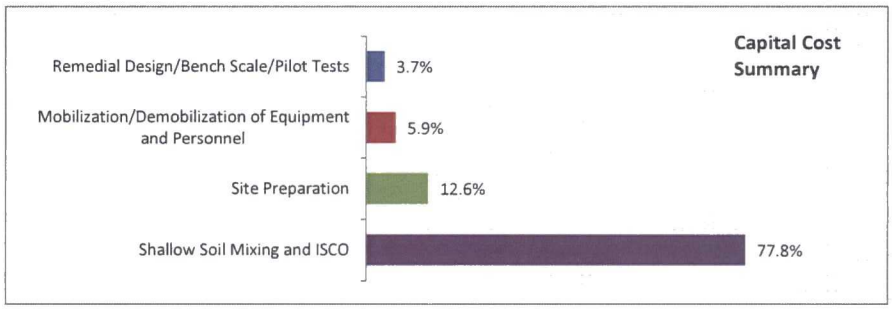
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 1,370,800



General Assumptions
1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

ISCO Worksheet

ISCO Calculations - Permanganate:

Parameters	Value	Units					
Length:	90	ft					
Width:	162	ft					
Area:	14,580	ft^2	0.33	acres			
Thickness:	20	ft					
Total Volume:	10,800	yd^3					
Porosity:	35%	%			5% Pore Volume		
Effective Porosity (not used):	20%						
Plume Total Pore Volume:	763,409	gal	lb soil	ft3	38,170	gal	ug cont
Avg. Contaminant Concentration:	2,000	µg/L		estimated			
Mass of Contaminant:	12.74	lb.					
Soil Density:	106	lb/ft^3					
$KMnO_4$ Soil Oxidant Demand (PSOD) :	1.45	g_{ox}/kg-soil		Sirem, 6-23-2016			
Effective PSOD %:	0.73	50 %					
PSOD :	2.07	lb/yd^3					
PSOD Oxidant Demand:	22,409	lb					
Avg. Stoichiometric Demand:	1.27	lb/lb					
Contaminant Oxidant Demand:	16.18	lb.					
Theoretical Oxidant Demand:	22,426	lb.					
Confidence Factor:	1.00						
Calculated Oxidant Demand:	**22,426**	lb.	See Carus Oxidant calculation sumamry below				

Injection Design	A	B	C	
Radius of Influence:				ft
Number of Injection Points:	#DIV/0!			
Injection Concentration:	2.00%			% wt/wt
Flow Rate - Per Injection Point:	1.50	4.00		gpm
Number of Wells per Phase:				
Total Injection Flow Rate:	0.0	0.0		gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:	#DIV/0!	#DIV/0!		gal
Injection Schedule				
Hours per Day:	8	8		hrs
Days Per Week:	6.00	6.00		days
Number of Days of Injection:	#DIV/0!	#DIV/0!		days
Number of Weeks of Injection:	#DIV/0!	#DIV/0!		weeks

Calculations modified from Carus (2009)

PSOD

g KMnO4	lb KMnO4	kg soil	454 g soil	(r) lb	27 ft^3 soil
kg soil	454 g KMnO4	1000 g soil	lb soil	ft^3 soil	yd^3 soil

40% $NaMnO_4$ Injection Options

Pounds of 40% NaMnO4 Solution	Gallons of 40% Solution	Number of Pails	Number of Drums	Number of Totes	Price per Lb of Solution	Total Cost of Chemical
49,897	4,377	875	91	19.90	$ 2.05	$ 102,289

Total Gallons of Dilution Water Required	Dilution Water Flow Rate - GPM	NaMnO4 40% Solution Flow Rate -
113,674	0.00	0.00

OR

Dilution Water Gals per Pail	Dilution Water Gals per Drum	Dilution Water Gals per Tote
130	1,247	5,714

Dry $KMnO_4$ Injection Options

Pounds of KMnO4 (Dry Crystals)	Number of Pails	Number of Drums	Number of SuperSacks	Number of Totes	Price per Lb (Dry)	Total Cost of Chemical
22,426	407.7	67.96	11.2	6.8	$ 2.40	$53,822

Total Gallons of Dilution Water Required	Dilution Water Flow Rate - GPM
131,757	0.00

OR

Dilution Water Gals per Pail	Dilution Water Gals per Drum	Dilution Water Gals per Tote
323	1,939	19,388

Feasibility Study Cost Estimate				Total NPW Cost:	$3,554,300
		Alternative #:	SSZ #2	SSZ Alternative #2	
Project:	Cristex Drum	Title:	EISB/ISCR		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	9/27/2016	Revision:	1
Task Description:	*In situ* treatment using injectable mixture of carbon substrate and microscale zero valent iron iron in an injection well array to facilitate direct chemical reducton of CVOCs in the solvent source area.				
Cost Basis:	Detailed estimate				

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 29,462		$ 29,462
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ 10,000		$ 10,000
Pilot Scale Testing	1	ls	$ 25,000		$ 25,000
			Design/Bench/Pilot Scale Subtotal:		**$ 65,832**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 44,000		$ 44,000
Travel	1	ls	$ 6,053		$ 6,053
Materials/Equipment/ Subcontractors	1	ls	$ 11,085		$ 11,085
			Mobilization Subtotal:		**$ 61,138**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 16,577		$ 16,577
			Site Preparation Subtotal:		**$ 16,577**
4.0 Install EISB/ISCR Injection Wells					
Drilling of (80) 2-inch injection wells for EISB/ISCR. Drilling to 75 ft bls with 55-feet of 10-slot screens. Flush Mount. Assumes 2 wells drilled/day/rig. Use 2 rig/day. 9 hr day (20 days total). Task includes well development.					
Labor	1	ls	$ 28,880		$ 28,880
Travel	1	ls	$ 7,345		$ 7,345
Drilling Subcontractor Per/Foot Rate	6000	ls	$ 56		$ 336,000
Drilling Subcontractor - Other	1	ls	$ 77,100		$ 77,100
Well Materials	1	ls	$ 98,068		$ 98,068
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 19,080		$ 19,080
			Install Injection Well Subtotal:		**$ 566,473**
5.0 Construct/Install EISB/ISCR Delivery System					
Install EISB/ISCR feed system. Eight (8) day installation assumed. Includes construction of aboveground or					
Labor	1	ls	$ 28,955		$ 28,955
Travel	1	ls	$ 6,861		$ 6,861
Site Preparation	1	ls	$ 19,701		$ 19,701
Extraction Wells Main Header	1	ls	$ -		$ -
Water Treatment System	1	ls	$ 19,000		$ 19,000
Injection Manifold	1	ls	$ 9,029		$ 9,029
Injection Wellhead Assembly	1	ls	$ 3,374		$ 3,374
			EISB/ISCR Delivery System Subtotal:		**$ 86,920**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #2 — SSZ Alternative #2
Title: EISB/ISCR

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Install Performance Monitoring Wells					
Drilling of (6) 2-inch diameter performance monitoring wells (PMWs). Drilling to 75 ft bls with 25-feet screen and 10-slot. Flush Mount. Assumes 2 wells drilled/day. Use 1 rig/day. 9 hr day (3 days total). Task includes well development.					
Labor	1	ls	$ 5,216		$ 5,216
Travel	1	ls	$ 1,495		$ 1,495
Drilling Subcontractor Per/Foot Rate	450	days	$ 56		$ 25,200
Drilling Subcontractor - Other	1	ls	$ 6,105		$ 6,105
Well Materials	1	ls	$ 4,945		$ 4,945
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 1,258		$ 1,258
			Install PMW Subtotal:		**$ 44,219**
7.0 EISB/ISCR Injection and Initial Startup					
Preparation of EISB/ISCR solution, equipment, materials , and labor for injection services. Assumes (23) weeks of injection. 2 days of setup/demobe.					
Labor	1	ls	$ 126,152		$ 126,152
Travel	1	ls	$ 31,776		$ 31,776
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 423,773		$ 423,773
DPT Injection Drilling Subcontractor	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs/Consumables	1	ls	$ -		$ -
Chemicals and Freight	1	ls	$ 580,617		$ 580,617
			EISB/ISCR Injection:		**$ 1,162,318**

Notes:

1)
2)
3)

		Subtotal - Capital Costs:	**$ 2,003,478**
Capital Contingency	15%	of Capital Cost	$ 300,522
Legal Fees, Licenses & Permits[1]	0.5%		$ 11,520
Engineering & Administrative[1]	8%		$ 184,320
Contractor Fee[2]	10%	of Capital Cost	$ 249,984
		Total Capital Cost:	**$ 2,749,823**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #2 — SSZ Alternative #2
Title: EISB/ISCR

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
8.0 EISB/ISCR Year 1-2 Operation	5						**Annual Cost**
Reinjection of amendments for rebound, monitoring. Assumes (25%) of original effort and time of operation during Year 5.							
Labor	5	yr	1	total	$ 9,597		$ 9,597
Travel	5	yr	1	total	$ 2,163		$ 2,163
Materials/Equipment/ Other Subs/Consumable	5	yr	1	total	$ 24,222		$ 24,222
DPT Injection Drilling Subcontractor	5				$ -		
DPT Vendor - Materials/Equipment/ Other Subs	5				$ -		
Chemicals and Freight	5	yr	1		$ 34,546		$ 34,546
							$ 70,529
9.0 Performance Sampling Costs							
Gauge ~14 wells for field parameters and substrate/amendments quarterly for 5 years (20 events); 9 hour day - 2 day effort, 4 hr travel, 4 hr prep. Four days of DPT soil sampling							
Labor	5	yr	1	total	$ 37,980		$ 37,980
Travel	5	yr	1	total	$ 5,902		$ 5,902
Materials/Equipment/Subcontractors	5	yr	1	total	$ 12,730		$ 12,730
Analytical - Groundwater	5	yr	1	total	$ 16,471		$ 16,471
							$ 73,083
						Net Present Worth (NPW) Subtotal:	**$ 588,840**
O&M Contingency			15%	of NPW Cost			$ 88,326
Engineering & Administrative[1]			8%				$ 54,173
Contractor Fee[2]			10%				$ 73,134
						Subtotal - O&M Costs:	**$ 804,473**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

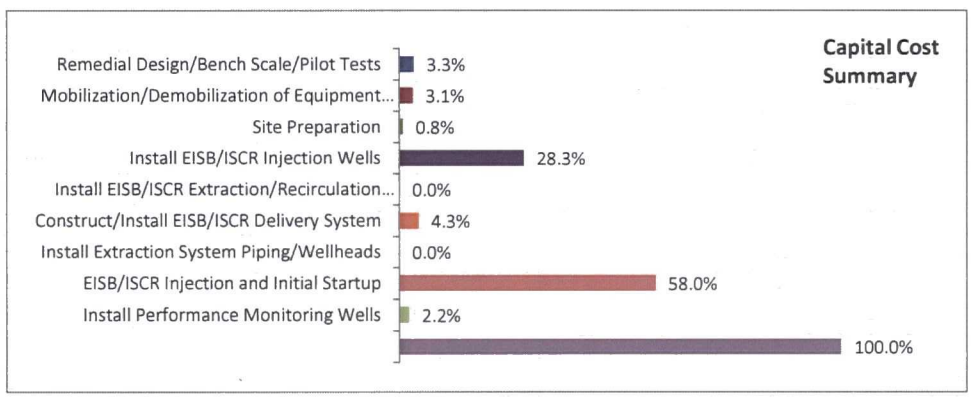
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($); Ao = Annual Amount ($); d = discount rate; e = escalation factor; n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 3,554,300



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	Injection Well	Extraction Well	PMW			
Total Soil Volume to be Treated:	-	bcy				
Total Area to be Treated:	36,455	ft^2				
Nominal Width of Treatment:	1,823	ft	Area Check			
Nominal Length of Treatment:	20	ft	36,455	ft^2	0.84	
Average Depth to Water:	20	ft			acres	
Vertical Treatment Interval:	55	ft				
Number of Injection Well Locations:	80	0	6			
Wells to Drill/Day:	2	2	2			
Work Days/Week:	6	days				
Work Hours/Day	9	hrs				
Number of Rigs/Day of Drilling:	2	1	1			
Injection Well Installation Period:	180	0	27	hrs		
Extraction Well Installation Period:	20.0	0.0	3.0	days		
	3.3	0.0	0.5	weeks		

ISCR Worksheet

ISCR Calculations - EHC-L, EOS-ZVI

Parameters	Value	Units		
Length:	100	ft		
Width:	125	ft		
Area:	12,500	ft^2	0.29	acres
Thickness:	55	ft		
Total Volume:	687,500	ft^3		
	25,463	yd^3		
Porosity:	40%	%		
Effective Porosity:	15%			
Plume Total Pore Volume:	2,057,000	gal	275,000	ft^3
Effective Porosity Pore Volume:	771,375	gal		
Avg. Contaminant Concentration:		µg/L		
Mass of Contaminant:	0.00	lb.		
Soil Density:	105	lb/ft^3		
Soil Mass:	72,187,500	lb	36,094	tons
	32,773,125	kg		
Effective Treatment Thickness:	25%		Adjustment for application dosing	
Net Soil Mass to Treat:	18,046,875	lb		
	8,193,281	kg		
Soil Natural Reductant Demand (NRD) :		g_{ox}/kg-soil		
			Based on EOS Remediation EOS-ZVI	
Emulsified Oil/ZVI			Presumes EOS 100 emulsified oil; 0.15% for EOS ZVI	
Emulsified Oil Target Concentration (wt%):	0.80%	w/w	0.5% to 1% (oil entrapment), applied to soil mass	
Mass of Emulsified Oil Required:	65,546	lb	EOS 100 Calculation	
Safety Factor:	2.0			
Drums of Emulsified Oil:	312	drums	~40% oil by weight%, 420 lbs/drum	
Drums of EOS-ZVI:	593	drums		
Water Needed for Dilution: 4-Fold	150	gal/drum		
Total Dilution Water:	88,932	gal		
Total Fluids Injected:	118,576	gal	18.2	6500-gallon poly
Percent of Effective Pore Volume:	15.4%			

Emulsified Oil/Soluble iron

			Presumes Peroxychem EHC-Liqud
Recommended EHC Dosage	3,500	mg/L	1K to 10K mg/L; Peroxychem recommendation
Mass of EHC-L Needed:	60,022	lb	
EHC-Liquid (ELS) Concentration:	100%		
Mass of ELS /Container:	460	lb	
Drums of EHC-L (ELS):	130	drums	from FMC EHC Mixing Guidelines (460 lb/drum)
Mass of EHC Liquid Mix (Fe Component):	14,063	lbs	100% concentrate
Mass of EHC-Liquid Mix (Fe)/Container:	24.5	lb	drum
Number of EHC-Liquid Mix (Fe) Containers:	574		asumes 100% concentrate
Volume of EHC-L	26,097	gal	asumes 100% concentrate
Concentration per Effective Porosity:	9,333	mg/L	
EHC-L Effective Porosity Target:	30.0%		Applied to effective porosity; 10% to 100%
Volume of Diluted EHC-L Needed:	231,413	gal	
Volume of Dilution Water Needed:	205,316	gal	

Innoculant

Target DHC Concentration:	1.E+06	cells/mL
Innoculant DHC Concentration:	5.E+10	cells/mL
Volume of Innoculant Required:	156	L

Buffer Needed

Mass of $KHCO_3$ to buffer ELS:	14,291	lbs	potassium bicarbonate @ 25 lbs/ELS drum
Additional Buffer Demand for Native Soils:	20,000	lbs	assumed

Base Design Cost on: Emulsified Oil/ZVI (EOS Remediation EOS ZVI)

Injection Design		Phase A	Phase B	Phase C	
Radius of Influence:		8.00			ft
Calculated Number of Injection Points:		62.2			
Actual Number of Injection Points:		80			
Injection Concentration:	4-Fold	25.00%			% wt/wt
Flow Rate - Per Injection Point:		0.40			gpm
Simultaneous Injections:		6			
Daily Injection Rate:		2.40			gpm
Estimated Injection Pressure (not used):					psig
Injection Volume/Hole:					gal
Injection Schedule					
Hours per Day:		9			hrs
Days Per Week:		5.50			days
Number of Days of Injection:		91.5			days
Number of Weeks of Injection:		16.6			weeks

Feasibility Study Cost Estimate				Total NPV Cost:	$4,609,700
		Alternative #:	SSZ #3	SSZ Alternative #3	
Project:	Cristex Drum	Title:	EK-ISCO with Biobarriers		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	9/27/2016	Revision:	0
Task Description:	*In situ* treatment using oxidant (e.g., potassium permanganate) in an injection well array to facilitate direct chemical oxidation of CVOCs in the solvent source area. Electrokinetics (EK) used to uniformly distribute oxidant.				
Cost Basis:	Detailed estimate				

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 29,462	$	29,462
Remedial Design Travel	1	ls	$ 870	$	870
Materials/Equipment/Subcontractors	1	ls	$ 30,500	$	30,500
Bench Scale Testing	1	ls	$ 25,000	$	25,000
Pilot Scale Testing	1	ls	$ 200,000	$	200,000
			Design/Bench/Pilot Scale Subtotal:	**$**	**285,832**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 44,000	$	44,000
Travel	1	ls	$ 6,053	$	6,053
Materials/Equipment/ Subcontractors	1	ls	$ 11,085	$	11,085
			Mobilization Subtotal:	**$**	**61,138**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -	$	-
Travel	1	ls	$ -	$	-
Materials/Equipment/ Subcontractors	1	ls	$ 13,096	$	13,096
			Site Preparation Subtotal:	**$**	**13,096**
4.0 Install EK-ISCO Supply Wells					
Drilling of (32) 4-inch PVC Electrode Wells and (28) Supply Wells for EK-ISCO. Drilling to 75 ft bls with 55-feet of 10-slot screens. Flush Mount. Assumes 2 wells drilled/day/rig. Use 2 rig/day. 9 hr day (15 days total). Task includes well development.					
Labor	1	ls	$ 24,471	$	24,471
Travel	1	ls	$ 5,897	$	5,897
Drilling Subcontractor Per/Foot Rate	4500	ls	$ 60	$	270,000
Drilling Subcontractor - Other	1	ls	$ 61,935	$	61,935
Well Materials	1	ls	$ 71,151	$	71,151
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 18,340	$	18,340
			Install Supply Well Subtotal:	**$**	**451,793**
5.0 Install EISB BioBarrier Wells					
Drilling of (27) 2-inch injection wells for EISB. Drilling to 75 ft bls with 55-feet of 10-slot screens. Flush Mount.					
Labor	1	ls	$ 21,381	$	21,381
Travel	1	ls	$ 5,584	$	5,584
Drilling Subcontractor Per/Foot Rate	2025	ls	$ 56	$	113,400
Drilling Subcontractor - Other	1	ls	$ 31,308	$	31,308
Well Materials	1	ls	$ 32,936	$	32,936
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 9,333	$	9,333
			Install EISB Biobarrier Well Subtotal:	**$**	**213,942**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #3 — SSZ Alternative #3
Title: EK-ISCO with Biobarriers

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Install Electrodes and EK Control System					
Installation of 60 EK electrodes and Wellheads; installation of EK control and amendment supply system; two					
Labor	1	ls	$ 32,512		$ 32,512
Travel	1	ls	$ 6,528		$ 6,528
Electrode Installation and Wellhead Components	32	ls	$ 2,219		$ 71,000
Trenching Contractor for Piping and Electrical	950	ft	$ 265		$ 252,000
EK Conrol & Amendment Supply System	1	ls	$ 225,000		$ 225,000
Construction Oversight, System Startup and Shakedown	1	ls	$ 77,000		$ 77,000
			Install EK System Subtotal:		**$ 664,040**
7.0 Construct/Install ISCO Delivery System					
Install ISCO feed system. Four (4) day installation assumed. Includes construction of aboveground or permanent					
Labor	1	ls	$ 23,039		$ 23,039
Travel	1	ls	$ 5,486		$ 5,486
Site Preparation	1	ls	$ 10,254		$ 10,254
Extraction Wells Main Header	1	ls	$ -		$ -
Effluent Manifold	1	ls	$ 9,029		$ 9,029
			ISCO Delivery System Subtotal:		**$ 47,808**
8.0 Construct/Install EISB Barrier Delivery System					
Install EISB feed system. Eight (6) day installation assumed. Includes construction of aboveground or permanent yard piping (4 days). Header by injection vendor.					
Labor	1	ls	$ 20,546		$ 20,546
Travel	1	ls	$ 3,509		$ 3,509
Site Preparation	1	ls	$ 10,986		$ 10,986
Water Treatment System	1	ls	$ 19,000		$ 19,000
Injection Manifold	1	ls	$ 9,029		$ 9,029
Injection Wellhead Assembly	1	ls	$ 2,049		$ 2,049
			EISB Delivery System Subtotal:		**$ 65,118**
9.0 Install Performance Monitoring Wells					
Drilling of (8) 2-inch diameter performance monitoring wells (PMWs). Drilling to 75 ft bls with 25-feet screen and 10-slot. Flush Mount. Assumes 2wells drilled/day. Use 1 rig/day. 9 hr day (3 days total). Task includes well development.					
Labor	1	ls	$ 6,390		$ 6,390
Travel	1	ls	$ 1,650		$ 1,650
Drilling Subcontractor Per/Foot Rate	600	days	$ 56		$ 33,600
Drilling Subcontractor - Other	1	ls	$ 7,780		$ 7,780
Well Materials	1	ls	$ 6,593		$ 6,593
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 6,014		$ 6,014
			Install PMW Subtotal:		**$ 62,027**
10.0 ISCO Injection and Initial Startup					
Preparation of ISCO solution, equipment, materials , and labor for injection services. Assumes (17) weeks (82 days) of injection. 2 days of setup/demobe. Assumes Injection Vendor Trailer/Feed system.					
Labor	1	ls	$ 66,373		$ 66,373
Travel	1	ls	$ 19,014		$ 19,014
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 114,528		$ 114,528
Chemicals and Freight	1	ls	$ 353,272		$ 353,272
			ISCO Injection:		**$ 553,187**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #3 — SSZ Alternative #3
Title: EK-ISCO with Biobarriers

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
11.0 EISB Injection and Initial Startup					
Preparation of EISB solution, equipment, materials , and labor for biobarriers. Assumes (3) weeks of injection.					
Labor	1	ls	$ 26,748		$ 26,748
Travel	1	ls	$ 6,394		$ 6,394
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 94,451		$ 94,451
DPT Injection Drilling Subcontractor	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs/Consumables	1	ls	$ -		$ -
Chemicals and Freight	1	ls	$ 157,999		$ 157,999
			EISB/ISCR Injection:		**$ 285,592**

Notes:

1)

		Subtotal - Capital Costs:	**$ 2,703,572**
Capital Contingency	15%	of Capital Cost	$ 405,536
Legal Fees, Licenses & Permits[1]	0.5%		$ 15,546
Engineering & Administrative[1]	8%		$ 248,729
Contractor Fee[2]	10%	of Capital Cost	$ 337,338
		Total Capital Cost:	**$ 3,710,720**

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #3 — SSZ Alternative #3
Title: EK-ISCO with Biobarriers

O&M Costs

	O&M Period	
	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
12.0 EISB/ISCO Year 1-2 Operation	2						**Annual Cost**
Reinjection of amendments for rebound, monitoring. Assumes (20%) of original chemical input on Year 2. Three (3) phases of operation: (24) field days per phase (72 total days); each vist is 1-day plus 4 hr travel							
Labor	2	yr	1	total	$ 106,170		$ 106,170
Travel	2	yr	1	total	$ 11,280		$ 11,280
Materials/Equipment/ Other Subs/Consumabl	2	yr	1	total	$ 11,014		$ 11,014
DPT Injection Drilling Subcontractor	2	yr	1	total	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Sub	2	yr	1	total	$ 800		$ 800
Chemicals and Freight	2	yr	1	total	$ 69,749		$ 69,749
							$ 199,013
13.0 Performance Sampling Costs							
Gauge ~14 wells for field parameters and substrate/amendments quarterly for 5 years (20 events); 9 hour day - 2 day effort, 4 hr travel, 4 hr prep. Four days of DPT soil sampling							
Labor	5	yr	1	total	$ 37,980		$ 37,980
Travel	5	yr	1	total	$ 5,902		$ 5,902
Materials/Equipment/Subcontractors	5	yr	1	total	$ 12,730		$ 12,730
Analytical - Groundwater	5	yr	1	total	$ 16,471		$ 16,471
							$ 73,083
						Net Present Worth (NPW) Subtotal:	**$ 658,028**
O&M Contingency			15%	of NPW Cost			$ 98,704
Engineering & Administrative[1]			8%				$ 60,539
Contractor Fee[2]			10%				$ 81,727
						Subtotal - O&M Costs:	**$ 898,998**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

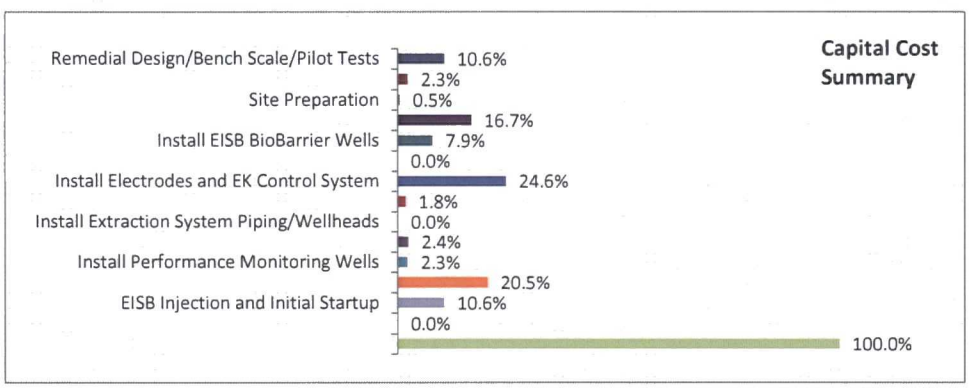
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($); Ao = Annual Amount ($); d = discount rate; e = escalation factor; n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 4,609,700



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	ISCO Supply Well	EISB Well	PMW			
Total Soil Volume to be Treated:	-	bcy				
Total Area to be Treated:	36,455	ft^2				
Nominal Width of Treatment:	1,823	ft	Area Check			
Nominal Length of Treatment:	20	ft	36,455	ft^2	0.84	
Average Depth to Water:	20	ft			acres	
Vertical Treatment Interval:	55	ft				
Number of Injection Well Locations:	60	27	8			
Wells to Drill/Day:	2	2	2			
Work Days/Week:	6	days				
Work Hours/Day	9	hrs				
Number of Rigs/Day of Drilling:	2	1	1			
Injection Well Installation Period:	135	122	36	hrs		
	15.0	13.5	4.0	days		
	2.5	2.3	0.7	weeks		

ISCO Worksheet

ISCO Calculations - Permanganate:

Parameters	Value	Units					
Length:	115	ft					
Width:	120	ft					
Area:	13,800	ft^2	0.32	acres			
Thickness:	55	ft					
Total Volume:	28,111	yd^3					
Porosity:	40%	%			5% Pore Volume		
Effective Porosity (not used):	15%						
Plume Total Pore Volume:	2,270,928	gal	lb soil	ft3	113,546	gal	ug cont
Plume Pore Volume (w/ Effective Porosity):	851,598	gal					
Avg. Contaminant Concentration:	2,000	µg/L		estimated			
Mass of Contaminant:	37.90	lb.					
Soil Density:	105	lb/ft^3					
$KMnO_4$ Soil Oxidant Demand (PSOD) :	1.45	g_{ox}/kg-soil		August 4, 2016 PNOD Result, Carus			
Effective PSOD %:	0.87	60 %					
PSOD :	2.47	lb/yd^3					
PSOD Oxidant Demand:	69,335	lb					
Avg. Stoichiometric Demand:	1.27	lb/lb					
Contaminant Oxidant Demand:	48.14	lb.					
Theoretical Oxidant Demand:	69,383	lb.					
Confidence Factor:	1.00						
Calculated Oxidant Demand:	**69,383**	lb.					

Injection Design	$KMnO_4$	$NaMnO_4$	C	
Radius of Influence:	8.00	8.00		ft
Number of Injection Points:	68.64	68.64		
Actual Injection Points:	60	60		
Injection Concentration:	2.00%	8.00%		% wt/wt
Flow Rate - Per Injection Point:	0.40	0.40		gpm
Number of Wells per Phase:	6	6		
Total Injection Flow Rate:	2.4	2.4		gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:	6,794	1,079		gal
Effective Pore Volumes Delivered:	48%	8%	0%	gal

Injection Schedule				
Hours per Day:	9	9		hrs
Days Per Week:	5.00	5.00		days
Number of Days of Injection:	314.54	57.13		days
Number of Weeks of Injection:	62.91	11.43		weeks

Calculations modified from Carus (2009)

PSOD

g KMnO4	lb KMnO4	kg soil	454 g soil	(r) lb	27 ft^3 soil
kg soil	454 g KMnO4	1000 g soil	lb soil	ft^3 soil	yd^3 soil

40% $NaMnO_4$ Injection Options

Pounds of 40% NaMnO4 Solution	Gallons of 40% Solution	Number of Pails	Number of Drums	Number of Totes	Price per Lb of Solution	Total Cost of Chemical
154,377	13,542	2708.4	282.1	61.6	$ 2.05	$ 316,472

Total Gallons of Dilution Water Required	Dilution Water Flow Rate - GPM	NaMnO4 40% Solution Flow Rate -
74,042	2.03	0.37

OR

Dilution Water Gals per Pail	Dilution Water Gals per Drum	Dilution Water Gals per Tote
27	262	1,203

Dry $KMnO_4$ Injection Options

Pounds of KMnO4 (Dry Crystals)	Number of Pails	Number of Drums	Number of SuperSacks	Number of Totes	Price per Lb (Dry)	Total Cost of Chemical
69,383	1,261.5	210.3	34.7	21.0	$ 2.40	$166,519

Total Gallons of Dilution Water Required	Dilution Water Flow Rate - GPM
407,645	2.40

OR

Dilution Water Gals per Pail	Dilution Water Gals per Drum	Dilution Water Gals per Tote
323.1	1,939	19,388

EISB Worksheet

EISB Calculations - EOS-100

Parameters	Value	Units		
Length:	432	ft		
Width:	16	ft		
Area:	6,912	ft^2	0.16	acres
Thickness:	55	ft		
Total Volume:	380,160	ft^3		
	14,080	yd^3		
Porosity:	40%	%		
Effective Porosity:	15%			
Plume Total Pore Volume:	1,137,439	gal	152,064	ft^3
Effective Porosity Pore Volume:	426,540	gal		
Avg. Contaminant Concentration:		µg/L		
Mass of Contaminant:	0.00	lb.		
Soil Density:	105	lb/ft^3		
Soil Mass:	39,916,800	lb	19,958	tons
	18,122,227	kg		
Effective Treatment Thickness:	25%		Adjustment for application dosing	
Net Soil Mass to Treat:	9,979,200	lb		
	4,530,557	kg		
Soil Natural Reductant Demand (NRD) :		g_{ox}/kg-soil		

Emulsified Oil			Presumes EOS 100 emulsified oil (85% oil)
Emulsified Oil Target Concentration (wt%):	0.50%	w/w	0.5% to 1% (oil entrapment), applied to soil mass
Mass of Emulsified Oil Required:	**22,653**	lb	EOS 100 Calculation
Safety Factor:	2.0		
Pounds of EOS/Drum:	420	lbs	
Drums of Emulsified Oil:	**108**	drums	~85% oil by weight%, 420 lbs/drum (Calx =)
Total Mass of Emulsified Oil Required:	**45,306**	lbs	
Water Needed for Dilution: 4-Fold	150	gal/drum	
Total Dilution Water:	16,181	gal	
Total Fluids Injected:	21,574	gal	3.3 6500-gallon poly
Percent of Effective Pore Volume:	5.1%		

Innoculant			
Target DHC Concentration:	1.E+06	cells/mL	
Innoculant DHC Concentration:	5.E+10	cells/mL	
Volume of Innoculant Required:	86	L	
Buffer Needed			
Mass of $KHCO_3$ to buffer ELS:	11,814	lbs	potassium bicarbonate @ 25 lbs/ELS drum
Additional Buffer Demand for Native Soils:	9,000	lbs	assumed

Base Design Cost on: Emulsified Oil (EOS Remediation EOS 100)

Injection Design	Phase A	Phase B	Phase C	
Radius of Influence:	8.00			ft
Calculated Number of Injection Points:	34.4			
Actual Number of Injection Points:	27			
Injection Concentration: 4-Fold	8.40%			% wt/wt
Flow Rate - Per Injection Point:	0.40			gpm
Simultaneous Injections:	6			
Daily Injection Rate:	2.40			gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:				gal
Injection Schedule				
Hours per Day:	9			hrs
Days Per Week:	5.00			days
Number of Days of Injection:	16.6			days
Number of Weeks of Injection:	3.3			weeks

Feasibility Study Cost Estimate

Total NPW Cost: $4,409,100

		Alternative #:	SSZ #4	SSZ Alternative #4	
Project:	Cristex Drum	Title:	EK-BIO with Biobarriers		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	9/27/2016	Revision:	0

Task Description: *In situ* treatment using injectable mixture of carbon substrate in an injection well array to facilitate direct biodegradation of CVOCs in the solvent source area. Electrokinetics (EK) used to uniformly distribute amendments.

Cost Basis: Detailed estimate

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Volume of Impacted Media to be Treated with ISCR:	74,260	yd^3	Unit Cost ($/$yd^3$):		$ 59
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 29,462		$ 29,462
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 30,500		$ 30,500
Bench Scale Testing	1	ls	$ 25,000		$ 25,000
Pilot Scale Testing	1	ls	$ 200,000		$ 200,000
			Design/Bench/Pilot Scale Subtotal:		**$ 285,832**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 44,000		$ 44,000
Travel	1	ls	$ 6,053		$ 6,053
Materials/Equipment/ Subcontractors	1	ls	$ 11,085		$ 11,085
			Mobilization Subtotal:		**$ 61,138**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 14,329		$ 14,329
			Site Preparation Subtotal:		**$ 14,329**
4.0 Install EK-BIO Supply Wells					
Drilling of (32) 4-inch PVC Electrode Wells and (28) Supply Wells for EK-BIO. Drilling to 75 ft bls with 55-feet of 10-slot screens. Flush Mount. Assumes 2 wells drilled/day/rig. Use 2 rig/day. 9 hr day (15 days total). Task includes well development.					
Labor	1	ls	$ 24,471		$ 24,471
Travel	1	ls	$ 5,897		$ 5,897
Drilling Subcontractor Per/Foot Rate	4500	ls	$ 60		$ 270,000
Drilling Subcontractor - Other	1	ls	$ 61,935		$ 61,935
Well Materials	1	ls	$ 71,151		$ 71,151
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 18,340		$ 18,340
			Install Supply Well Subtotal:		**$ 451,793**
5.0 Install EISB BioBarrier Wells					
Drilling of (27) 2-inch injection wells for EISB. Drilling to 75 ft bls with 55-feet of 10-slot screens. Flush Mount.					
Labor	1	ls	$ 21,381		$ 21,381
Travel	1	ls	$ 5,584		$ 5,584
Drilling Subcontractor Per/Foot Rate	2025	ls	$ 56		$ 113,400
Drilling Subcontractor - Other	1	ls	$ 31,308		$ 31,308
Well Materials	1	ls	$ 32,936		$ 32,936
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 9,333		$ 9,333
			Install EISB Biobarrier Well Subtotal:		**$ 213,942**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #4 — SSZ Alternative #4
Title: EK-BIO with Biobarriers

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Install Electrodes and EK Control System					
Installation of 60 EK electrodes and Wellheads; installation of EK control and amendment supply system; two					
Labor	1	ls	$ 32,512		$ 32,512
Travel	1	ls	$ 6,528		$ 6,528
Electrode Installation and Wellhead Components	32	ls	$ 2,219		$ 71,000
Trenching Contractor for Piping and Electrical	950	ft	$ 265		$ 252,000
EK Conrol & Amendment Supply System	1	ls	$ 225,000		$ 225,000
Construction Oversight, System Startup and Shakedown	1	ls	$ 77,000		$ 77,000
			Install EK System Subtotal:		**$ 664,040**
7.0 Construct/Install EISB Barrier Delivery System					
Install EISB feed system. Six (6) day installation assumed. Includes construction of aboveground or permanent yard					
Labor	1	ls	$ 20,546		$ 20,546
Travel	1	ls	$ 3,509		$ 3,509
Site Preparation	1	ls	$ 13,706		$ 13,706
Extraction Wells Main Header	1	ls	$ -		$ -
Water Treatment System	1	ls	$ 19,000		$ 19,000
Injection Manifold	1	ls	$ 9,029		$ 9,029
Injection Wellhead Assembly	1	ls	$ 2,049		$ 2,049
			EISB Delivery System Subtotal:		**$ 67,839**
8.0 Install Performance Monitoring Wells					
Drilling of (8) 2-inch diameter performance monitoring wells (PMWs). Drilling to 75 ft bls with 25-feet screen and 10-slot. Flush Mount. Assumes 2wells drilled/day. Use 1 rig/day. 9 hr day (3 days total). Task includes well development.					
Labor	1	ls	$ 6,390		$ 6,390
Travel	1	ls	$ 1,650		$ 1,650
Drilling Subcontractor Per/Foot Rate	600	days	$ 56		$ 33,600
Drilling Subcontractor - Other	1	ls	$ 7,780		$ 7,780
Well Materials	1	ls	$ 6,593		$ 6,593
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 6,014		$ 6,014
			Install PMW Subtotal:		**$ 62,027**
9.0 EISB Injection and Initial Startup					
Preparation of EISB solution, equipment, materials , and labor for injection services. Assumes (5) weeks of injection. 2 days of setup/demobe.					
Labor	1	ls	$ 50,484		$ 50,484
Travel	1	ls	$ 11,697		$ 11,697
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 197,238		$ 197,238
DPT Injection Drilling Subcontractor	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs/Consumables	1	ls	$ -		$ -
Chemicals and Freight	1	ls	$ 450,985		$ 450,985
			EISB/ISCR Injection:		**$ 710,404**

Notes:

1)

		Subtotal - Capital Costs:	**$ 2,531,344**
Capital Contingency	15%	of Capital Cost	$ 379,702
Legal Fees, Licenses & Permits[1]	0.5%		$ 14,555
Engineering & Administrative[1]	8%		$ 232,884
Contractor Fee[2]	10%	of Capital Cost	$ 315,848
		Total Capital Cost:	**$ 3,474,333**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #4 — SSZ Alternative #4
Title: EK-BIO with Biobarriers

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
10.0 EISB Year 1-2 Operation	2						**Annual Cost**
Reinjection of amendments for rebound, monitoring. Assumes (20%) of original chemical input on Year 2. Three (3) phases of operation: (24) field days per phase (72 total days); each vist is 1-day plus 4 hr travel and							
Labor	2	yr	1	total	$ 106,261		$ 106,261
Travel	2	yr	1	total	$ 11,280		$ 11,280
Materials/Equipment/ Other Subs/Consumable	2	yr	1	total	$ 27,092		$ 27,092
DPT Injection Drilling Subcontractor	2				$ -		
DPT Vendor - Materials/Equipment/ Other Subs	2				$ 800		
Chemicals and Freight	2	yr	1		$ 68,056		$ 68,056
							$ 212,689
11.0 Performance Sampling Costs							
Gauge ~14 wells for field parameters and substrate/amendments quarterly for 5 years (20 events); 9 hour day - 2 day effort, 4 hr travel, 4 hr prep. Four days of DPT soil sampling							
Labor	5	yr	1	total	$ 37,980		$ 37,980
Travel	5	yr	1	total	$ 5,902		$ 5,902
Materials/Equipment/Subcontractors	5	yr	1	total	$ 12,730		$ 12,730
Analytical - Groundwater	5	yr	1	total	$ 16,471		$ 16,471
							$ 73,083
						Net Present Worth (NPW) Subtotal:	**$ 684,201**
O&M Contingency			15%	of NPW Cost			$ 102,630
Engineering & Administrative[1]			8%				$ 62,947
Contractor Fee[2]			10%				$ 84,978
						Subtotal - O&M Costs:	**$ 934,756**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

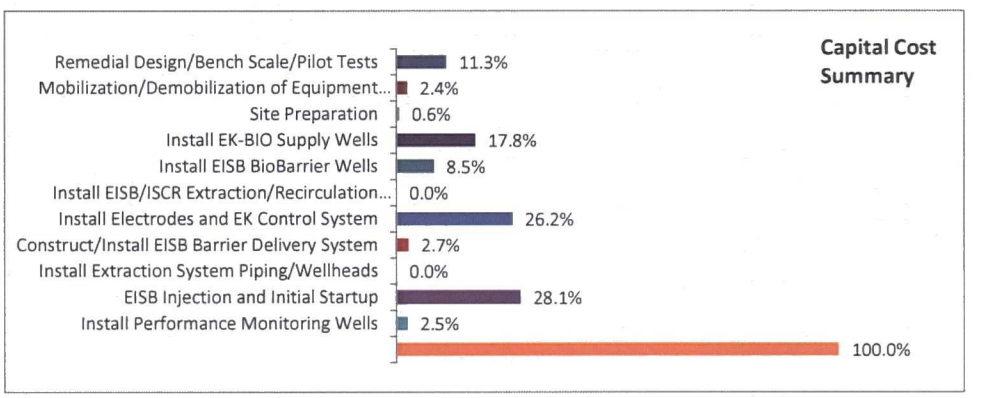
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($); Ao = Annual Amount ($); d = discount rate; e = escalation factor; n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 4,409,100



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	Supply Well	EISB Well	PMW			
Total Soil Volume to be Treated:	74,260	bcy				
Total Area to be Treated:	36,455	ft^2				
Nominal Width of Treatment:	1,823	ft	Area Check			
Nominal Length of Treatment:	20	ft	36,455	ft^2	0.84	
Average Depth to Water:	20	ft			acres	
Vertical Treatment Interval:	55	ft				
Number of Injection Well Locations:	60	27	8			
Wells to Drill/Day:	2	2	2			
Work Days/Week:	6	days				
Work Hours/Day	9	hrs				
Number of Rigs/Day of Drilling:	2	1	1			
Injection Well Installation Period:	135	122	36	hrs		
	15.0	13.5	4.0	days		
	2.5	2.3	0.7	weeks		

EISB Worksheet

EISB Calculations - EOS-100

Parameters	Value	Units					
Length:	115	ft	includes EK-Bio and Barrier areas				
Width:	120	ft					
Area:	20,712	ft^2	0.48	acres	13,800	ft^2	main area
Thickness:	55	ft			6,912	ft^2	biobarrier
Total Volume:	1,139,160	ft^3					
	42,191	yd^3					
Porosity:	40%	%					
Effective Porosity:	15%						
Plume Total Pore Volume:	3,408,367	gal	455,664	ft^3			
Effective Porosity Pore Volume:	1,278,138	gal					
Avg. Contaminant Concentration:		µg/L					
Mass of Contaminant:	0.00	lb.					
Soil Density:	105	lb/ft^3					
Soil Mass:	119,611,800	lb	59,806	tons			
	54,303,757	kg					
Effective Treatment Thickness:	25%		Adjustment for application dosing				
Net Soil Mass to Treat:	29,902,950	lb					
	13,575,939	kg					
Soil Natural Reductant Demand (NRD) :		g_{ox}/kg-soil					
Emulsified Oil			Presumes EOS 100 emulsified oil (85% oil)				
Emulsified Oil Target Concentration (wt%):	0.50%	w/w	0.5% to 1% (oil entrapment), applied to soil mass				
Mass of Emulsified Oil Required:	**67,880**	lb	EOS 100 Calculation				
Safety Factor:	2.0						
Pounds of EOS/Drum:	420.0	lbs					
Drums of Emulsified Oil:	**323**	drums	~85% oil by weight%, 420 lbs/drum (Calx =)				
Total Mass of Emulsified Oil Re 3-Fold	**135,759**	lbs					
Water Needed for Dilution:	100	gal/drum					
Total Dilution Water:	32,324	gal					
Total Fluids Injected:	48,485	gal	7.5	6500-gallon poly			
Percent of Effective Pore Volume:	3.8%						
Innoculant							
Target DHC Concentration:	1.E+06	cells/mL					
Innoculant DHC Concentration:	5.E+10	cells/mL					
Volume of Innoculant Required:	258	L					
Buffer Needed							
Mass of $KHCO_3$ to buffer ELS:	35,402	lbs	potassium bicarbonate @ 25 lbs/ELS drum				
Additional Buffer Demand for Native Soils:	20,000	lbs	assumed				

Emulsified Oil (EOS Remediation EOS 100)

Base Design Cost on:

Injection Design	Phase A	Phase B	Phase C	
Radius of Influence:	8.00			ft
Calculated Number of Injection 3-Fold	103.0			
Actual Number of Injection Points:	87			
Injection Concentration:	18.20%			% wt/wt
Flow Rate - Per Injection Point:	0.40			gpm
Simultaneous Injections:	6			
Daily Injection Rate:	2.40			gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:				gal
Injection Schedule				
Hours per Day:	9			hrs
Days Per Week:	5.00			days
Number of Days of Injection:	37.4			days
Number of Weeks of Injection:	7.5			weeks

Feasibility Study Cost Estimate

Total NPW Cost: $4,054,900

		Alternative #:	SSZ #5	SSZ Alternative #5	
Project:	Cristex Drum	Title:	Biogeochemical Reductive Dehalogenation		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	1

Task Description: *In situ* treatment using naturally occurring divalent minerals along with supplemental injectable carbon substrate, sulfate, and soluble ferrous iron. Applied via an injection well array with groundwater recirculation. Facilitates direct chemical reduction of CVOCs in the solvent source area using iron sulfides.

Cost Basis: Detailed estimate

Volume of Impacted Media to be Treated with ISCR: 104,436 yd^3 **Unit Cost ($/$yd^3$):** $ 39

Capital Costs

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 29,543		$ 29,543
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 13,000		$ 13,000
Bench Scale Testing	1	ls	$ 18,000		$ 18,000
Pilot Scale Testing	1	ls	$ 35,000		$ 35,000
			Design/Bench/Pilot Scale Subtotal:		**$ 96,413**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 42,876		$ 42,876
Travel	1	ls	$ 6,053		$ 6,053
Materials/Equipment/ Subcontractors	1	ls	$ 124,575		$ 124,575
			Mobilization Subtotal:		**$ 173,505**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 15,669		$ 15,669
			Site Preparation Subtotal:		**$ 15,669**
4.0 Install BiRD Injection Wells					
Drilling of (34) 4-inch injection wells for BiRD. Drilling to 75-ft bls with 55-feet screens. Flush Mount. Assumes 2 wells drilled/day. Use 1 rig/day. 9 hr day (17 days total). Task includes well development.					
Labor	1	ls	$ 26,520		$ 26,520
Travel	1	ls	$ 6,192		$ 6,192
Drilling Subcontractor Per/Foot Rate	2550	ls	$ 60		$ 153,000
Drilling Subcontractor - Other	1	ls	$ 27,165		$ 27,165
Well Materials	1	ls	$ 71,346		$ 71,346
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 10,624		$ 10,624
			Install Injection Well Subtotal:		**$ 294,846**
5.0 Install EISB/ISCR Extraction/Recirculation Wells					
Drilling of (18) 4-inch Extraction Wells for BiRD. Drilling to 75 ft bls with 55-feet screens. Flush Mount. Assumes 2 wells drilled/day. Use 1 rig/day. 9 hr day (9 days total). Task includes well development.					
Labor	1	ls	$ 18,596		$ 18,596
Travel	1	ls	$ 4,242		$ 4,242
Drilling Subcontractor Day Rate	1350	ls	$ 60		$ 81,000
Drilling Subcontractor - Other	1	ls	$ 17,510		$ 17,510
Well Materials	1	ls	$ 36,539		$ 36,539
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 9,438		$ 9,438
			Install Extraction Well Subtotal:		**$ 167,325**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #5 — SSZ Alternative #5
Title: Biogeochemical Reductive Dehalogenation

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Install Extraction System Piping/Wellheads					
Installation of 18 extraction well wellheads					
Labor	1	ls	$ 28,024		$ 28,024
Travel	1	ls	$ 6,275		$ 6,275
Materials Equipment/Subcontractor	1	ls	$ 79,824		$ 79,824
			Install Piping/Wellheads Subtotal:		**$ 114,123**
7.0 Construct/Install BiRD Delivery System					
Install BiRD system. Twelve (12) day installation assumed. Includes construction of aboveground or permanent yard					
Labor	1	ls	$ 43,775		$ 43,775
Travel	1	ls	$ 10,060		$ 10,060
Site Preparation	1	ls	$ 53,480		$ 53,480
Extraction Wells Main Header	1	ls	$ 2,164		$ 2,164
Water Treatment System	1	ls	$ 118,200		$ 118,200
Injection Main Header	1	ls	$ 2,164		$ 2,164
Injection Manifold	1	ls	$ 57,024		$ 57,024
Injection Wellhead Assembly	1	ls	$ 17,816		$ 17,816
			BiRD Delivery System Subtotal:		**$ 304,683**
8.0 Install Performance Monitoring Wells					
Drilling of (6) 2-inch diameter performance monitoring wells (PMWs). Drilling to 70 ft bls with 20-feet screen and 10-slot. Flush Mount. Assumes 3 wells drilled/day. Use 1 rig/day. 9 hr day (2 days total). Task includes well development.					
Labor	1	ls	$ 4,983		$ 4,983
Travel	1	ls	$ 1,409		$ 1,409
Drilling Subcontractor Per/Foot Rate	420	days	$ 56		$ 23,520
Drilling Subcontractor - Other	1	ls	$ 5,430		$ 5,430
Well Materials	1	ls	$ 4,345		$ 4,345
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 1,168		$ 1,168
			Install PMW Subtotal:		**$ 40,855**
9.0 Construct Infiltration Gallery					
Install infiltration gallery; assume 5 days; assume 40-ft by 75-ft by 3-feet deep					
Labor	1	ls	$ 22,917		$ 22,917
Travel	1	ls	$ 7,112		$ 7,112
General Subcontractor Costs	1	ls	$ 10,532		$ 10,532
			Infiltration Gallery Subtotal:		**$ 40,561**
10.0 BiRD Injection and Initial Startup					
Preparation of EISB/ISCR solution, equipment, materials , and labor for injection services. Assumes (1 months) of injection. Two weeks of manned operation followed by 2 additional days/month (108 hrs); 9-hr days; All chemical costs.					
Labor	1	ls	$ 40,051		$ 40,051
Travel	1	ls	$ 11,453		$ 11,453
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 12,463		$ 12,463
DPT Injection Drilling Subcontractor	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs/Consumables	1	ls	$ -		$ -
Chemicals and Freight	1	ls	$ 1,348,148		$ 1,348,148
			BiRD Startup/Injection:		**$ 1,412,114**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #5 — SSZ Alternative #5
Title: Biogeochemical Reductive Dehalogenation

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Notes:					
1)					
2)					
3)					
			Subtotal - Capital Costs:		**$ 2,660,093**
Capital Contingency	15%	of Capital Cost			$ 399,014
Legal Fees, Licenses & Permits[1]	0.5%				$ 15,296
Engineering & Administrative[1]	8%				$ 244,729
Contractor Fee[2]	10%	of Capital Cost			$ 331,913
			Total Capital Cost:		**$ 3,651,044**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: SSZ #5 — SSZ Alternative #5
Title: Biogeochemical Reductive Dehalogenation

O&M Costs

	O&M Period		
	4	7.00%	Discount Rate
		0.00%	Constant Escalation Factor

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
11.0 BiRD Year 1-4 Operation							**Annual Cost**
Recirculation/Injection of amendments for BiRD; monitoring. Assumes (48 months) of injection. Manned operation of 4 days/month for 2 years (252 hrs); 9-hr days; assumes 25% more chemicals.							
Labor	3	yr	1	total	$ 81,288		$ 81,288
Travel	3	yr	1	total	$ 24,971		$ 24,971
Materials/Equipment/ Other Subs/Consumable	3	yr	1	total	$ 6,388		$ 6,388
DPT Injection Drilling Subcontractor	3	yr	1	total	$ -		$ -
DPT Vendor - Materials/Equipment/ Other	3	yr	1	total	$ -		$ -
Chemicals and Freight	3	yr	1	total	$ 408,129		$ 408,129
					BiRD Startup/Injection:		**$ 520,775**
12.0 Performance Sampling Costs							
Gauge ~14 wells for field parameters and substrate/amendments weekly first month, quarterly for 4 years (20							
Labor	4	yr	1	ls	$ 38,011		$ 38,011
Travel	4	yr	1	ls	$ 5,100		$ 5,100
Materials/Equipment/Subcontractors	4	yr	1	ls	$ 12,910		$ 12,910
Analytical	4	yr	1	ls	$ 4,729		$ 4,729
					Sampling Subtotal:		**$ 60,750**
					Net Present Worth (NPW) Subtotal:		**$ 295,619**
O&M Contingency			15%	of NPW Cost			$ 44,343
Engineering & Administrative[1]			8%				$ 27,197
Contractor Fee[2]			10%				$ 36,716
					Subtotal - O&M Costs:		**$ 403,875**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

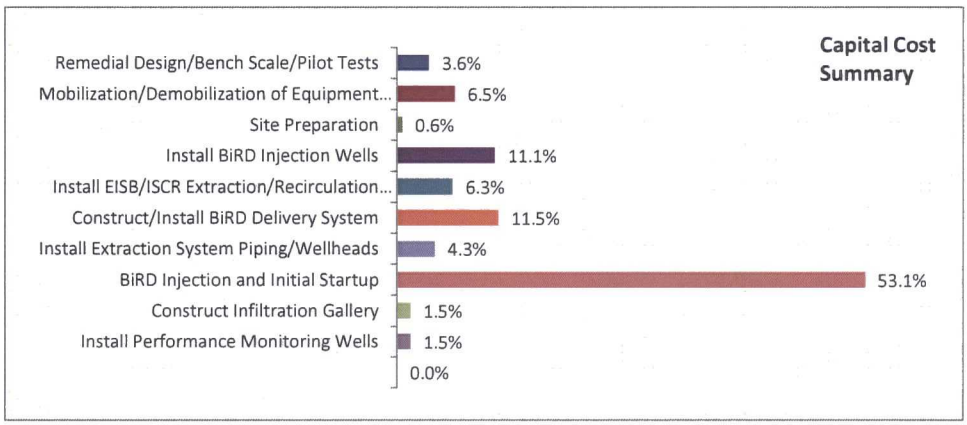
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 4,054,900



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	Injection Well	Extraction Well	PMW			
Total Soil Volume to be Treated:	104,436	bcy				
Total Area to be Treated:	51,268	ft^2				
Nominal Width of Treatment:	354	ft	Area Check			
Nominal Length of Treatment:	145	ft	51,268	ft^2	1.18	
Average Depth to Water:	50	ft			acres	
Vertical Treatment Interval:	55	ft				
Number of Injection Well Locations:	34	18	6			
Wells to Drill/Day:	2	2	3			
Work Days/Week:	6	days				
Work Hours/Day	9	hrs				
Number of Rigs/Day of Drilling:	1	1	1			
Injection Well Installation Period:	153	81	18	hrs		
Extraction Well Installation Period:	17.0	9.0	2.0	days		
	2.8	1.5	0.3	weeks		

ISCR Worksheet

BiRD Calculations

Parameters	Value	Units		
Length:	320	ft		
Width:	180	ft		
Area:	57,600	ft^2	1.32	acres
Thickness:	55	ft		
Total Volume:	3,168,000	ft^3		
	117,333	yd^3		
Porosity:	40%	%		
Effective Porosity:	15%			
Plume Total Pore Volume:	9,478,656	gal	1,267,200	ft^3
Effective Porosity Pore Volume:	3,554,496	gal		
Avg. Contaminant Concentration:		µg/L		
Mass of Contaminant:	0.00	lb.		
Soil Density:	105	lb/ft^3		
Soil Mass:	332,640,000	lb	166,320	tons
	151,018,560	kg		
Effective Treatment Thickness:	25%		Adjustment for application dosing	
Net Soil Mass to Treat:	83,160,000	lb		
	37,754,640	kg		
Soil Natural Reductant Demand (NRD) :		g_{ox}/kg-soil		
			Based on EOS Remediation EOS-ZVI	
Emulsified Oil/ZVI			Presumes EOS 100 emulsified oil; 0.15% for EOS ZVI	
Emulsified Oil Target Concentration (wt%):	0.50%	w/w	0.5% to 1% (oil entrapment), applied to soil mass	
Mass of Emulsified Oil Required:	188,773	lb	EOS 100 Calculation	
Safety Factor:	2.0			
Drums of Emulsified Oil: 4-Fold	899	drums	~40% oil by weight%, 420 lbs/drum	
Drums of EOS-ZVI:	**1,707**	drums		
Water Needed for Dilution:	150	gal/drum		
Total Dilution Water:	256,124	gal		
Total Fluids Injected:	341,499	gal		
Percent of Effective Pore Volume:	9.6%			
Emulsified Oil/Soluble iron			Presumes EHC-Liquid	
Recommended EHC Dosage	3,500	mg/L	1K to 10K mg/L; Peroxychem recommendation	
Mass of EHC-L Needed:	276,583	lb		
EHC-Liquid (ELS) Concentration:				
Mass of ELS /Container: 100%	460	lb		
Drums of EHC-L (ELS):	**601**	drums	from FMC EHC Mixing Guidelines (460 lb/drum)	
Mass of EHC Liquid Mix (Fe Component):	64,803	lbs	100% concentrate	
Mass of EHC-Liquid Mix (Fe)/Container:	24.5	lb	drum	
Number of EHC-Liquid Mix (Fe) Containers:	**2,645**		assumes 100% concentrate	
Volume of EHC-L	120,253	gal	assumes 100% concentrate	
Concentration per Effective Porosity:	9,333	mg/L		
EHC-L Effective Porosity Target:	30.0%		Applied to effective porosity; 10% to 100%	
Volume of Diluted EHC-L Needed:	1,066,349	gal		
Volume of Dilution Water Needed:	946,096	gal		

Inoculant

Target DHC Concentration:	1.E+06	cells/mL	
Inoculant DHC Concentration:	5.E+10	cells/mL	
Volume of Inoculant Required:	718	L	

Buffer Needed

Mass of $KHCO_3$ to buffer ELS:	65,853	lbs	potassium bicarbonate @ 25 lbs/ELS drum
Additional Buffer Demand for Native Soils:	20,000	lbs	assumed

Sulfate Needed

Target Sulfate Concentration:	1,000	mg/L	per NAVFAC Tech Report, EV-1601 (1000 - 1500)
	29,634	lbs	based on effective porosity
Iron Sulfate to Add:	46,874	lbs	
Added Iron:	17,240	lbs	
	582	mg/L	

Emulsified Oil/Soluble iron (Peroxychem EHC-L)

Base Design Cost on:

Injection Design	Phase A	Phase B	Phase C	
Radius of Influence:	8.00			ft
Calculated Number of Injection Points:	286.5			
Actual Number of Injection Points:	34			
Injection Concentration: 6-Fold	5.30%			% wt/wt
Flow Rate - Per Injection Point:	0.40			gpm
Simultaneous Injections:	34			
Daily Injection Rate:	13.60			gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:				gal
Injection Schedule				
Hours per Day:	9			hrs
Days Per Week:	6.00			days
Number of Days of Injection:	145.2			days
Number of Weeks of Injection:	24.2			weeks

Feasibility Study Cost Estimate					Total NPW Cost:	$2,264,500
		Alternative #:	DP #2	DP Alternative #2		
Project:	Cristex Drum	Title:	EISB Passive Barrier			
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016	
Project Phase:	FS	Date:	10/6/2016	Revision:	0	
Task Description:	Installation of 16 downgradient wells for an enhanced *in situ* bioremediation (EISB) biobarrier using vegetable oil.					
Cost Basis:	Detailed estimate					

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 23,178		$ 23,178
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ -		$ -
Pilot Scale Testing	1	ls	$ 25,000		$ 25,000
			Design/Bench/Pilot Scale Subtotal:		**$ 49,548**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days)					
Labor	1	ls	$ 21,756		$ 21,756
Travel	1	ls	$ 3,543		$ 3,543
Materials/Equipment/ Subcontractors	1	ls	$ 3,585		$ 3,585
			Mobilization Subtotal:		**$ 28,884**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ -		$ -
Travel	1	ls	$ -		$ -
Materials/Equipment/ Subcontractors	1	ls	$ 12,553		$ 12,553
			Site Preparation Subtotal:		**$ 12,553**
4.0 Install EISB Injection Wells					
Drilling of (16) 2-inch barrier injection wells for EISB. Drilling to 140 ft bls with 70-feet 10-slot screens. Flush Mount. Assumes 2 wells drilled/day. Use 1 rig/day. 9 hr day (8 days total). Task includes well development.					
Labor	1	ls	$ 17,266		$ 17,266
Travel	1	ls	$ 3,820		$ 3,820
Drilling Subcontractor Per/Foot Rate	2240	feet	$ 56		$ 125,440
Drilling Subcontractor - Other	1	ls	$ 18,340		$ 18,340
Well Materials	1	ls	$ 25,714		$ 25,714
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 9,936		$ 9,936
			Install Injection Well Subtotal:		**$ 200,516**

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: DP #2 DP Alternative #2
Title: EISB Passive Barrier

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
5.0 Construct/Install EISB Delivery System					
Install EISB feed system. Eight (8) day installation assumed. Includes construction of aboveground or permanent					
Labor	1	ls	$ 30,930		$ 30,930
Travel	1	ls	$ 7,171		$ 7,171
Site Preparation	1	ls	$ 10,501		$ 10,501
Extraction Wells Main Header	1	ls	$ -		$ -
Water Treatment System	1	ls	$ 14,000		$ 14,000
Injection Manifold	1	ls	$ 9,029		$ 9,029
Injection Wellhead Assembly	1	ls	$ 2,814		$ 2,814
			EISB Delivery System Subtotal:		**$ 74,446**
6.0 Install Performance Monitoring Wells					
Drilling of (4) 2-inch diameter performance monitoring wells (PMWs). Drilling to 140 ft bls with 70-feet screen and 10-slot. Flush Mount. Assumes 2 wells drilled/day. Use 1 rig/day. 9 hr day (2 days total). Task includes well development.					
Labor	1	ls	$ 4,568		$ 4,568
Travel	1	ls	$ 1,340		$ 1,340
Drilling Subcontractor Per/Foot Rate	560	feet	$ 56		$ 31,360
Drilling Subcontractor - Other	1	ls	$ 4,280		$ 4,280
Well Materials	1	ls	$ 7,026		$ 7,026
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 1,255		$ 1,255
			Install PMW Subtotal:		**$ 49,829**
7.0 EISB Injection and Initial Startup					
Preparation of EISB solution, equipment, materials , and labor for injection services. Assumes (2) weeks of injection. 2 days of setup/demobe.					
Labor	1	ls	$ 29,672		$ 29,672
Travel	1	ls	$ 10,644		$ 10,644
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 86,620		$ 86,620
DPT Injection Drilling Subcontractor	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs/Consumables	1	ls	$ -		$ -
Chemicals and Freight	1	ls	$ 254,385		$ 254,385
			EISB Injection:		**$ 381,321**

Notes:

1)
2)
3)

			Subtotal - Capital Costs:	**$ 875,334**
Capital Contingency	15%	of Capital Cost	$	131,300
Legal Fees, Licenses & Permits[1]	0.5%		$	5,033
Engineering & Administrative[1]	8%		$	80,531
Contractor Fee[2]	10%	of Capital Cost	$	109,220
			Total Capital Cost:	**$ 1,201,418**

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: DP #2 — DP Alternative #2
Title: EISB Passive Barrier

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
8.0 EISB Year 1-5 Operation							**Annual Cost**
Reinjection of amendments for rebound, monitoring at 5-yr intervals for 20 years. Assumes (30%) of original effort and time of operation.							
Labor	15	yr	1	ls	$ 1,766		$ 1,766
Travel	15	yr	1	ls	$ 686		$ 686
Materials/Equipment/ Other Subs/Consumable	15	yr	1	ls	$ 6,158		$ 6,158
DPT Injection Drilling Subcontractor	15	yr	1	ls	$ -		$ -
DPT Vendor - Materials/Equipment/ Other Subs	15	yr	1	ls	$ -		$ -
Chemicals and Freight	15	yr	1	ls	$ 25,539		$ 25,539
						Year 1 to 5 EISB Operation:	**$ 34,149**
9.0 Performance Sampling Costs							
Gauge ~8 wells for field parameters and substrate/amendments quarterly each year (4 events); 9 hour day - 2 day effort, 4 hr travel, 4 hr prep.							
Labor	20		1	ls	$ 35,154		$ 35,154
Travel	20		1	ls	$ 4,622		$ 4,622
Materials/Equipment/Subcontractors	20		1	ls	$ 1,410		$ 1,410
Analytical	20		1	ls	$ 2,902		$ 2,902
						Sampling Subtotal:	**$ 44,088**
						Net Present Worth (NPW) Subtotal:	**$ 778,104**
O&M Contingency			15%	of NPW Cost			$ 116,716
Engineering & Administrative[1]			8%				$ 71,586
Contractor Fee[2]			10%				$ 96,640
						Subtotal - O&M Costs:	**$ 1,063,045**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

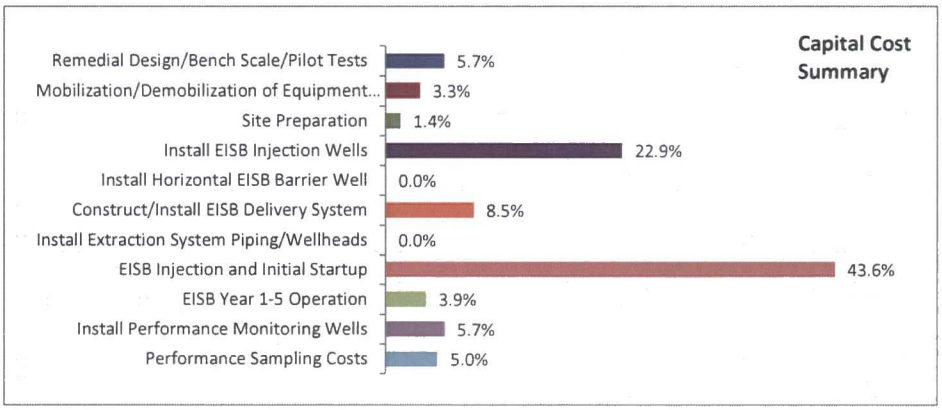
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 2,264,500



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	Injection Well	Extraction Well	PMW		
Total Soil Volume to be Treated:	-	bcy			
Total Area to be Treated:	13,750	ft^2			
Nominal Width of Treatment:	550	ft	Area Check		
Nominal Length of Treatment:	25	ft	13,750	ft^2	0.32
Average Depth to Water:	50	ft			acres
Vertical Treatment Interval:	70	ft			
Number of Injection Well Locations:	16	0	4		
Wells to Drill/Day:	2	2	2		
Work Days/Week:	6	days			
Work Hours/Day	9	hrs			
Number of Rigs/Day of Drilling:	1	1	1		
Injection Well Installation Period:	72	0	18	hrs	
Extraction Well Installation Period:	8.0	0.0	2.0	days	
	1.3	0.0	0.3	weeks	

EISB Worksheet

EISB Calculations - EOS-100

Parameters	Value	Units		
Length:	550	ft		
Width:	16	ft		
Area:	8,800	ft^2	0.20	acres
Thickness:	70	ft		
Total Volume:	616,000	ft^3		
	22,815	yd^3		
Porosity:	10%	%		hydrologic conductivity of the fractured bedrock is generally 0.001 to 3 ft/ day; primary porosity ranges from about 0.01 to 2 percent (Harned, 1989).
Effective Porosity:	5%			
Gradient (not used in direct calculation):	0.01			0.00974026
Plume Total Pore Volume:	460,768	gal	61,600	ft^3
Effective Porosity Pore Volume:	230,384	gal		
Avg. Contaminant Concentration:	1,000	µg/L		
Mass of Contaminant:	3.85	lb.		
Soil Density:	105	lb/ft^3	1.68	g/cm^3
Soil Mass:	64,680,000	lb	32,340	tons
	29,364,720	kg		
Effective Treatment Thickness:	40%		Adjustment for application dosing	
Net Soil Mass to Treat:	25,872,000	lb		
	11,745,888	kg		
Soil Natural Reductant Demand (NRD) :		g_{ox}/kg-soil		

Emulsified Oil

			Presumes EOS 100 emulsified oil (85% oil)
Emulsified Oil Target Concentration (wt%):	0.50%	w/w	0.5% to 1% (oil entrapment), applied to soil mass (0.3 by calx)
Mass of Emulsified Oil Required:	**58,729**	lbs	EOS 100 Calculation
Safety Factor:	2.0		
Pounds of EOS/Drum:	420.0	lbs	
Drums of Emulsified Oil:	**280**	drums	~85% oil by weight%, 420 lbs/drum (Calx = 363)
Total Mass of Emulsified Oil Required:	**117,459**	lbs	
4-Fold			
Water Needed for Dilution:	150	gal/drum	
Total Dilution Water:	41,950	gal	
Total Fluids Injected:	55,933	gal	8.6 6500-gallon poly
Percent of Effective Pore Volume:	24.3%		

Inoculant

Target DHC Concentration:	1.E+06	cells/mL	
Inoculant DHC Concentration:	5.E+10	cells/mL	
Volume of Inoculant Required:	35	L	

Buffer Needed

Mass of $KHCO_3$ to buffer ELS:	7,500	lbs	potassium bicarbonate @ 25 lbs/ELS drum
Additional Buffer Demand for Native Soils:	5,000	lbs	assumed

Base Design Cost on: Emulsified Oil (EOS Remediation EOS 100)

Injection Design	Phase A	Phase B	Phase C	
Radius of Influence:	8.00			ft
Calculated Number of Injection Points:	43.8			
Actual Number of Injection Points:	16			
Injection Concentration:				% wt/wt
Flow Rate - Per Injection Point:	1.25			gpm
Simultaneous Injections:	6			
Daily Injection Rate:	7.50			gpm
Estimated Injection Pressure (not used):				psig
Injection Volume/Hole:				gal
Injection Schedule				
Hours per Day:	8			hrs
Days Per Week:	6.00			days
Number of Days of Injection:	15.5			days
Number of Weeks of Injection:	2.6			weeks

Feasibility Study Cost Estimate

Total NPW Cost: $1,757,500

Alternative #:	DP #3	DP Alternative #3			
Project:	Cristex Drum	Title:	GR&T/Hydraulic Containment		
Location:	Oxford, NC	Project Number:	49073	Base Year:	2016
Project Phase:	FS	Date:	10/6/2016	Revision:	0

Task Description: Installation of four (4) groundwater recovery wells for capture and hydraulic containment of the CVOC plume in the bedrock zone. Assumes treatment with air stripping and GAC with discharge to infiltration gallery or sanitary sewer.

Cost Basis: Detailed estimate

Capital Costs

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design Professional Labor	1	ls	$ 31,413		$ 31,413
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Bench Scale Testing	1	ls	$ -		$ -
Pilot Scale Testing	1	ls	$ 15,000		$ 15,000
			Design/Bench/Pilot Scale Subtotal:		**$ 47,783**
2.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days);					
Labor	1	ls	$ 8,584		$ 8,584
Travel	1	ls	$ 2,580		$ 2,580
Materials/Equipment/ Subcontractors	1	ls	$ 9,100		$ 9,100
			Site Preparation Subtotal:		**$ 20,264**
3.0 Install GR&T Extraction Wells					
Drilling of (4) 4-inch injection wells for GR&T. Drilling to 140 ft bls with 70-feet screens. Flush Mount in concrete vaults. Assumes 1 wells drilled/day. Use 1 rig/day. 9 hr day (4 days). Task includes well development.					
Labor	1	ls	$ 16,117		$ 16,117
Travel	1	ls	$ 3,096		$ 3,096
Drilling Subcontractor Well Install	300	ft	$ 60		$ 18,000
Drilling Subcontractor - Other	1	ls	$ 13,130		$ 13,130
Well Materials	1	ls	$ 11,090		$ 11,090
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 9,355		$ 9,355
			Install Well Subtotal:		**$ 70,787**
4.0 Install Extraction System Piping/Wellheads					
Installation of 4 wellheads, lateral lines, below ground piping; Approximatley 550-feet of trenching for					
Labor	1	ls	$ 7,491		$ 7,491
Travel	1	ls	$ 2,360		$ 2,360
Materials Equipment/Subcontractor	1	ls	$ 30,222		$ 30,222
			Install Piping/Wellheads Subtotal:		**$ 40,073**
5.0 Construct/Install Groundwater Treatment System					
Install GW Treatment system. Trailer enclosed equipment. Ten day installation assumed. Includes construction of					
Labor	1	ls	$ 39,370		$ 39,370
Travel	1	ls	$ 8,650		$ 8,650
Extraction Wells Main Header	1	ls	$ 3,664		$ 3,664
Water Treatment System	1	ls	$ 128,700		$ 128,700
Effluent Manifold	1	ls	$ 2,928		$ 2,928
			Delivery System Subtotal:		**$ 183,312**
6.0 Construct Infiltration Gallery					
Install infiltration gallery; assume 8 days; assume two (2) 40-ft by 75-ft by 3-feet deep infiltration galleries					
Labor	1	ls	$ 35,118		$ 35,118
Travel	1	ls	$ 9,442		$ 9,442
General Subcontractor Costs	1	ls	$ 26,064		$ 26,064
			Gallery Construction Subtotal:		**$ 70,624**

Feasibility Study Cost Estimate

Project:	Cristex Drum	Alternative #:	DP #3 — DP Alternative #3
Location:	Oxford, NC	Title:	GR&T/Hydraulic Containment

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Notes:					
1)					
2)					
3)					
			Subtotal - Capital Costs:		**$ 432,843**
Capital Contingency	15%	of Capital Cost		$	64,926
Legal Fees, Licenses & Permits[1]	0.5%			$	2,489
Engineering & Administrative[1]	8%			$	39,822
Contractor Fee[2]	10%	of Capital Cost		$	54,008
			Total Capital Cost:		**$ 594,088**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Cristex Drum
Location: Oxford, NC

Alternative #: DP #3 — DP Alternative #3
Title: GR&T/Hydraulic Containment

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
7.0 GR&T Operation							**Annual Cost**
System operation for 15 years; carbon changeouts; refurbishments; 2 visits per month							
Labor	15	yr	1	total	$ 55,319		$ 55,319
Travel	15	yr	1	total	$ 17,331		$ 17,331
Materials/Equipment	15	yr	1	total	$ 20,850		$ 20,850
							$ 93,499
8.0 Performance Sampling Costs							
Monitor system performance for CVOCs (influent and effluent, each RW) weekly first month, quarterly for Year 1 (8 events), quarterly through year 20 (76 events); 85 hr effort, 2 hr travel, 2 hr prep							
Labor	20	yr	1	ls	$ 24,402		$ 24,402
Travel	20	yr	1	ls	$ 2,765		$ 2,765
Materials/Equipment/Subcontractors	20	yr	1	ls	$ 953		$ 953
Analytical - Water	20	yr	1	ls	$ 2,849		$ 2,849
						Sampling Subtotal:	**$ 30,969**
						Net Present Worth (NPW) Subtotal:	**$ 851,584**
O&M Contingency			15%	of NPW Cost			$ 127,738
Engineering & Administrative[1]			8%				$ 78,346
Contractor Fee[2]			10%				$ 105,767
						Subtotal - O&M Costs:	**$ 1,163,434**

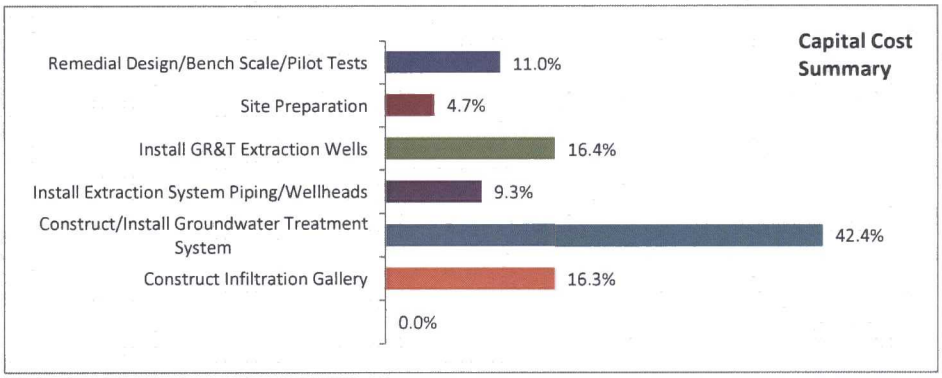
[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

Net Present Worth Formula

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 1,757,500



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Drilling Worksheet

Drilling Calculations	Extraction Well	Extraction Well	PMW			
Total Soil Volume to be Treated:	-	bcy				
Total Area to be Treated:	13,750	ft^2				
Nominal Width of Treatment:	550	ft	Area Check			
Nominal Length of Treatment:	25	ft	13,750	ft^2	0.32	
Average Depth to Water:	50	ft			acres	
Vertical Treatment Interval:	70	ft				
Number of Well Locations:	4	0	4			
Wells to Drill/Day:	1	2	2			
Work Days/Week:	6	days				
Work Hours/Day	9	hrs				
Number of Rigs/Day of Drilling:	1	1	1			
Well Installation Period:	36	0	0	hrs		
	4.0	0.0	0.0	days		
	0.67	0.0	0.0	weeks		

GR&T Worksheet

Duration of Installation of Wells and Equipment:	2	weeks
Duration of GR&T:	15	yrs
	780	weeks