RECORD OF DECISION
Declaration

Site Name and Location

Sixty-One Industrial Park Site

Memphis, Shelby County, Tennessee

TND 987790300

Statement of Basis and Purpose

This decision document presents the selected remedial action for the Sixty-One Industrial Park Site (the, "Site") in Memphis, Tennessee, which was chosen in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision is based on the Administrative Record file for this Site.

The State of Tennessee, as represented by the Tennessee Department of Environment and Conservation (TDEC), has reviewed the reports which are included in the administrative record for the Site. In accordance with 40 Code of Federal Regulation (CFR) Sec. 300.430, as the support agency, TDEC has provided EPA with input on those reports. The TDEC agrees that enhanced reductive dechlorination (ERD) with monitored natural attenuation (MNA) for the groundwater is an appropriate remedy for the Site.

Assessment of Site

The response action selected in this Record of Decision is necessary to protect human health and the environment from actual or threatened releases of hazardous substances, pollutants or contaminants into the environment.

Description of Selected Remedy

This remedy addresses the potential human exposure to contaminants in groundwater associated with the Site.

The major components of the remedy include:

- Institutional Controls including groundwater use restrictions (enforced by the Memphis and Shelby County Health Department [MSCHD]) and restrictive covenants to maintain and limit use of the Site to heavy industrial for the period of time that the site contaminants exceed the remediation goals noted in Table 4;
- A treatment approach to impacted groundwater consisting of Enhanced Reductive Dechlorination (ERD) to address high COC concentrations in groundwater that have a high potential for further migration; and
- Monitored Natural Attenuation (MNA) for the groundwater downgradient of the high COC concentrations until remedial goals are achieved throughout the groundwater plume.

Statutory Determinations

The Selected Remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, is cost effective, and utilizes permanent solutions to the maximum extent practicable. This remedy also satisfies the statutory preference for treatment as a principal element of the remedy (i.e., reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element through treatment). Groundwater at and near the site that is contaminated with chlorinated volatile organic compounds (CVOC's) at concentrations greater than 1,000 milligrams /liter (ug/l) is considered principal threats to human health or the environment at the Site. The selected remedy for this site will treat and remediate these CVOCs through a combination of ERD and MNA. This remedy will not result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, but will take more than five years to attain remedial action objectives and cleanup levels. Therefore, a policy review will be conducted within five years of construction completion for the site to ensure that the remedy is or will be protective of human health and the environment.

ROD Data Certification Checklist

The following information is included in the Decision Summary section of this Record of Decision. Additional information can be found in the Administrative Record file for this Site.

- Chemicals of Concern (COCs) and their respective concentrations.
- Baseline risk represented by the COCs.
- Cleanup levels established for COCs and the basis for these levels.
- How source materials constituting principal threats are addressed.
- Current and future land use and groundwater use assumptions used in the baseline risk assessment and the ROD.
- Potential land and groundwater use that will be available at the Site as a result of the Selected Remedy.
- 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.
- Key factors that led to selecting the remedy.

Authorizing Signature

Franklin E. Hill, Director
Superfund Division

9/26/08
Date

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LIST OF ACRONYMS and ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Regulations
ATV	Alternate Toxicity Value
BDL	Below the laboratory Detection Limit
BHHRA	Baseline Human Health Risk Assessment
bls	below land surface
bgs	below ground surface
CAR	Corrective Action Report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	Contaminant (or Chemical) of Concern
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSF	Carcinogenic Slope Factor
CYS	cubic yards (also see yd3)
DQO	Data Quality Objectives
EPA	United States Environmental Protection Agency
EPA-OTS	EPA Region 4 Office of Technical Services
EPS	Exposure Pathway Scenarios
ERA	Ecological Risk Assessment
EPC	Exposure Point Concentration
ESD	Explanation of Significant Differences
ESI	Expanded Site Inspection
ESV	Ecological screening values
FDEP	Florida Department of Environmental Protection

HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
LOAEL	Lowest Observed Adverse Effects Level
MCL	Maximum Contaminant Level
MEP	Maximum Extent Practicable
mg/kg	milligrams per kilogram or parts per million (ppm)
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effects Level
NPL	National Priority List
OU1	Operable Unit 1
O&M	Operation and Maintenance
PA	Preliminary Assessment
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCOPEC	Preliminary Contaminant of Potential Ecological Concern
ppb	parts per billion
PRP	Potentially Responsible Party
ppm	parts per million
PRG	EPA Region 9 Preliminary Remediation Goals
RAO	Remedial Action Objectives
RBCA	Risk Based Corrective Action
RCRA	Resource Conservation and Recovery Act

RI/FS	Remedial Investigation/Feasibility Study
RG	Remedial Goals (i.e., cleanup levels)
ROD	Record of Decision
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act of 1986
SAS	Superfund Alternative Site
SDWA	Safe Drinking Water Act
SESD	EPA Region 4 Science and Ecosystem Support Division
SI	Site Inspection
SQL	Sample Quantification Limit
SVOCs	Semi-Volatile Organic Compounds
TAL	Target Analyte List
TAT	Technical Assistance Team
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxicity Equivalence Quotient
ug/kg	micrograms per kilogram
ug/L	micrograms per Liter
US	United States
US FWS	United States Fish and Wildlife Service
VOCs	Volatile Organic Compounds
yd3	cubic yards
XRF	X-ray fluorescence

1.0 Site Location and Description

The Sixty-One Industrial Park Site (the Site) is located within the limits of the City of Memphis in the extreme southwestern corner of Shelby County, Tennessee, just north of and abutting the Mississippi State line (Figure 1). The EPA Site Identification Number is TND987790300. The Site consists of approximately 78 acres of previously developed land primarily used for industrial purposes. Site access is limited to a gravel road entering the property from the south, at US Highway 61, connecting to a series of gravel and dirt roads that cross the Site. An "out parcel" bounds the Site to the south and abuts Highway 61. This out parcel (approximately 15 acres) was part of the Site until 2001. A small commercial building was constructed on this out parcel.

2.0 Site History and Enforcement Activities

2.1 History of Site Operations

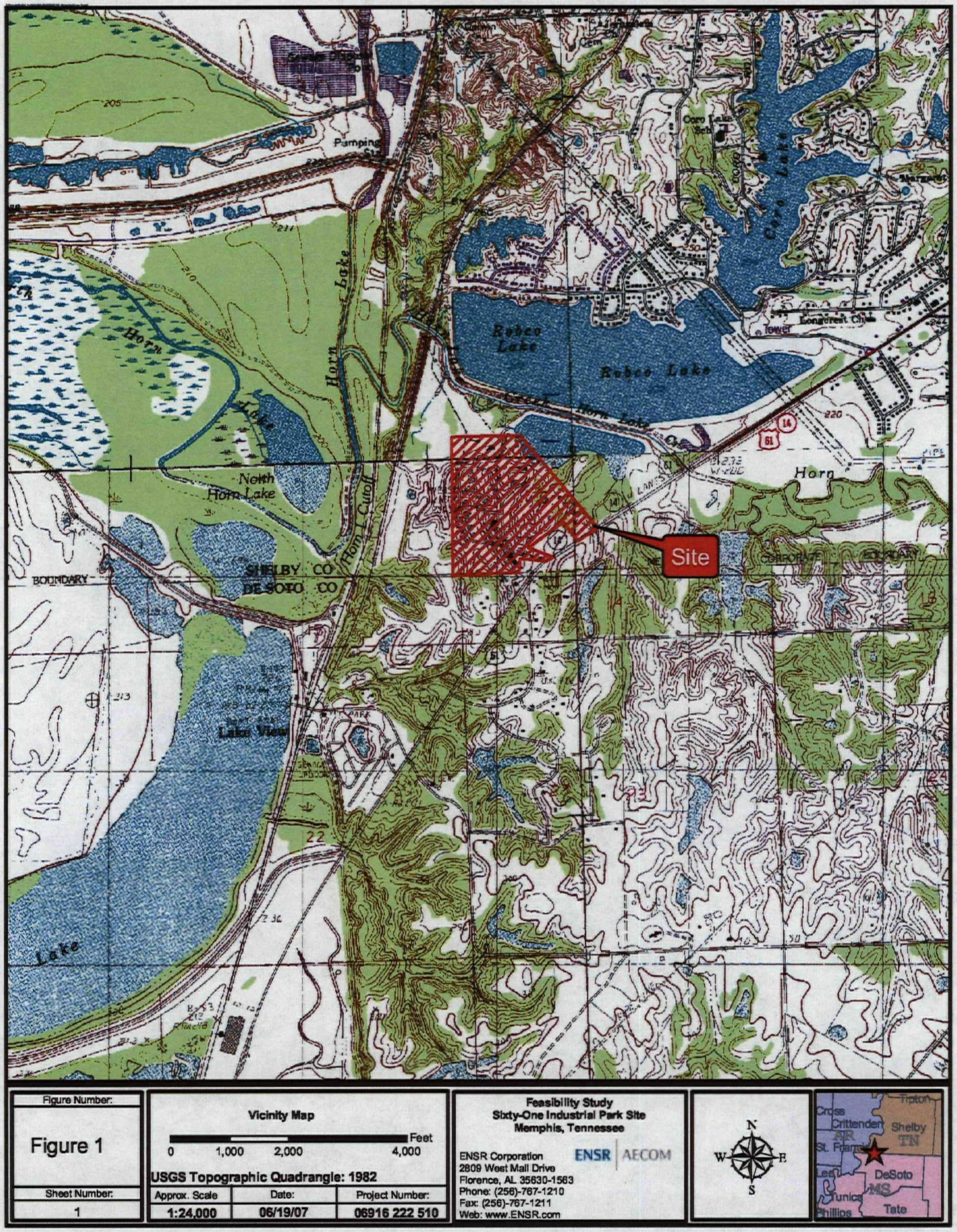
The Site was undeveloped woodland until sometime in 1956 when Pace Caribe, Inc. (Pace) acquired the land and moved to the Site. Over time, approximately 140 buildings/structures were constructed on 93 acres that formerly comprised the facility. From 1957 until 1972, Pace operated a pyrotechnic and ordnance production facility on the Site. Specific activities included:

> Fabrication and assembly of a variety of ordnance items such as hand held signals, artillery fuses, primers and various components of ammunition except small arms. Processes involved in the manufacture of these items consisted of mixing, blending, curing, screening and pressing pyrotechnic compositions, metal fabrication, assembly, product testing and packaging. Machining and electroplating are documented to have taken place on-site as part of the product preparation (ENSR, 2002a).

In 1967 and 1968, a second plating line was built at the Site for the purpose of electroplating steel with zinc and cadmium for metal parts that went into manufactured fuses. These plated parts were then dipped into a chromium solution and tested with an illuminating salt spray. The salt spray compound consisted of aluminum, magnesium, sodium nitrate, potassium and perchloride. The rinse water and any other plating solutions were discharged through seven in-series, unlined industrial lagoons for oxidation. Sewage from on-site activities was also discharged into the lagoon system. The dipped metals were set to dry in the various small empty buildings scattered throughout the Site. Ambac, a successor corporation to Mid-South Metal Products Company, Inc., purchased the Site from Pace in 1968. As a division of Ambac Industries, Pace continued pyrotechnic and ordnance production on the Site, as well as metal plating operations.

On April 10, 1973, Mr. Bennie Lazarov, as nominee for Sixty-One Industrial Park, Ltd., (the Partnership), purchased the Site from Ambac. By June of 1973 Ambac, ceased operation and removed all of its equipment and materials from the Site with the exception of salvageable material, such as an unknown number of 55-gallon drums of cyanide, pursuant to the agreement with the new owner to purchase this material. After the Partnership's purchase of the Site, the Lazarov Brothers Tin Compress Company and Lazarov Brothers Surplus Sales used the Site for storage and salvage operations. Materials brought to, stored and processed on-site included military automotive and industrial storage batteries, scrap metal, among other materials. Lazarov Brothers Tin Compress Company also operated a magnesium coating process and other processes that involved the melting of metals on-site. In 1978, UT Automotive, Inc. (then known as United Technology Automotive Corporation) merged with Ambac Industries, Inc., and conducted business as a subsidiary of UTC (United

Figure 1 Vicinity Map



Technologies Corporation). Pursuant to the Plan of Merger, UT Automotive, Inc. acquired all of the assets and liabilities of Ambac Industries, Inc. UTC was not involved in any of the former site operations.

The Partnership also leased portions of the Site to other tenants who participated in various activities. These tenants included Kerr Brothers (stockpiled automobile parts), W.C. Barnes, Downhill Diesel Shop; West Tennessee Printed Circuitry Co. (prepared printed circuit boards); and Warzone, Inc. (paint-ball war games). The Partnership also sold portions of the property that fronted Highway 61, reducing the area of the Site to 78 acres. The Lazarovs ceased operations at the Site in the early 1990s.

2.2 Prior Site Investigations and Removal Actions

Several site investigations and two removal actions have been conducted at the Site by the EPA and United Technnology Corporation (UTC), the potential responsible parties (PRPs) in order to determine the nature and extent of contamination and to mitigate eminent threats to human health and the environment. During these investigations, soil, sediment, surface water and groundwater samples were collected and numerous permanent groundwater monitoring wells were installed.

In November 1993, the EPA conducted sediment sampling from three of the seven lagoons at the Site and submitted a Preliminary Assessment (PA), dated December 1993. In November 1994, additional multi-media sampling was completed by the EPA. The Site Investigation (SI), dated July 1995, indicated the presence of heavy metal and organic compounds in the soils, sediments, groundwater, and surface water at concentrations that warranted additional investigative activities at the Site.

In January 1995, the EPA issued a Unilateral Administrative Order (UAO) requiring immediate removal of materials potentially hazardous to human health and the environment. In 1995 and 1996, the removal of hazardous materials (drums, tanker trucks, underground storage tanks, batteries, asbestos containing materials, impacted soils and sludge) was conducted at the Site with confirmation sample collection and chemical testing indicating that soils were removed to achieve the UAO cleanup goals.

Because of the concentrations of cadmium and chromium in the lagoon sludge, the lagoons were drained, the sludge from lagoons 1 through 6 was stabilized (mixed with lime kiln dust and Portland cement), excavated and transported off-site for disposal. Constituent concentrations of site-related compounds in lagoon 7 were not of concern. Confirmation sampling of the floors and sidewalls of the lagoons confirmed removal of the impacted sludges. A total of 47,052 tons of solidified/stabilized sludge was excavated and transported off-site for disposal. Although two of the dikes between the lagoons were removed, the remaining dikes detained water, recreating three lagoons (one large lagoon, lagoon 123, and lagoons 4 and 5).

The EPA conducted an aerial photographic analysis of the Site to document landscape morphology, patterns of waste disposal, and other conditions of environmental significance for the time periods of 1957 to 1998. Following the 1995-1996 removal actions, few environmentally significant features were evident at the Site (EPA, 2000).

The EPA completed an Expanded Site Inspection (ESI) in April 2001 (EPA, 2001). The primary purpose of this investigation was to address areas of potential concern (APCs) with regard to the presence of heavy metals and organic compounds in each media type across the Site.

In October 2001, the EPA again collected samples from the various media types across the Site in preparation for preliminary hazard ranking system (HRS) scoring of the Site and completion of a Screening-Level Ecological Risk Assessment (SLERA). Results of the testing confirmed the presence of heavy metals and organic compounds above the screening levels for the various media.

In January 2002, UTC and the EPA agreed to a strategy which included developing a Conceptual Site Exposure Model (CSEM), conducting background sampling and analysis, developing risk-based Preliminary Remediation Goals (PRGs), and refining the Chemicals of Potential Concern (COPCs) in order to focus the RI/FS on the areas, media and chemicals that exceed the Region 9 PRGs and background concentrations (ENSR, 2002a). This strategy identified five Areas of Concern (AOCs) and identified COPCs to be addressed by the Remedial Investigation/Feasibility Study (RI/FS).

A SLERA (Decker and Lewis, 2003) was conducted at the Site to evaluate the potential ecological risks due to exposure. Data used for the ecological COPC refinement presented in the Ecological Risk Assessment Problem Formulation Statement (PFS) was obtained from the SLERA and a variety of other sources, including the following:

- Roy F. Weston, Inc.'s July 1995 Site Investigation Report;
- EnSAFE's May 1997 On-Scene Coordinator Report;
- ENSR's March 1997 Removal Action under the Administrative Order on Consent Final Report;
- EPA Aerial Photographic Analysis (May, 2000);
- ENSR's May 2002 Background Field Sampling and Analysis Report; and
- United States Geological Survey (USGS) groundwater data from background locations (http://nwis.waterdata.usgs.gov/nwis).

2.2.1 Remedial Investigation

An RI/FS Work Plan was developed to outline activities for the investigation, feasibility study and the human health and ecological risk assessments. A Revised RI/FS Work Plan was submitted to the EPA in February 2005 and in March 2005.

In January 2005, EPA assessed whether the Site should be listed on the Superfund National Priorities List (NPL) because of detections of metals and organic substances, pollutants or contaminants in the sediment, soil and groundwater. EPA determined that the site is an NPL-Equivalent site. The NPL is a list of priority releases for long-term evaluation and remedial response, and was promulgated pursuant to section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended,. The NPL list is found in the NCP (Appendix B of 40 CFR part 300).

From 2005 to 2007 under EPA oversight, the PRPs conducted the RI and risk assessments, which delineated the horizontal and vertical extent of contamination to soil, sediment, surface water and groundwater, and evaluated the human health and ecological risk associated with the contaminants. The RI was conducted in three phases with Phase I completed in June 2005 and Phase 2 completed in January 2006. A Groundwater Monitoring Plan was implemented in October 2006 and was implemented along with the final phase of the RI. The final RI was submitted to the EPA in July 2007 (ENSR, 2007) and approved in October 2007.

In order to evaluate the chemicals of potential concern (COPCs) and refine the list of chemicals of concern (COCs), a Human Health Risk Assessment (HHRA) was conducted. The HHRA was submitted to EPA in December 2006 (ENSR, 2006) and approved in October 2007. In order to evaluate the potential ecological risk due to exposure, and refine the list of COCs, a Baseline Ecological Risk Assessment (BERA) was conducted. The BERA was submitted to EPA in May 2007 and was approved by EPA with the approval of the FS in December 2007.

Five areas of concern (AOCs) were evaluated and addressed in the RI and are briefly described below. Two areas were found to pose a risk to human health and the environment (AOCs 1 and 5). The other AOCs evaluated did not pose a risk to human health or the environment.

AOC 1

AOC 1 consists of a small tributary, Tributary 1, which receives most of the Site runoff and discharge from the onsite lagoons, the lagoons were formerly used to treat wastewater from the electroplating process facility. AOC 1 includes Tributary 1 from its discharge at the northern end of the Site to its confluence with Horn Lake Creek. AOC 1 also includes the wetland areas that Tributary 1 traverses, north and northwest of the Site. Cadmium was the COC in the sediment most frequently detected above remedial goals (RGs). In the AOC 1 surface water samples, cadmium and manganese were detected above ecological screening values. These exceedances are being addressed by an additional removal action.

AOC 2

AOC 2 is located at the southeast corner of Lagoon 123 (formerly three lagoons that were structurally connected to form one larger lagoon). It covers approximately one acre, and includes monitoring well MW-03R, the remnants of Building 2 and several other small buildings just east of the lagoon. The RI investigation concluded that the Chemicals of Potential Concern (COPC) were not present above human health or ecological screening values.

AOC 3

AOC 3 is located in the central portion of the Site, along the center ridge road. It encompasses approximately 1.5 acres at the highest topographic area of the Site. AOC 3 includes the former location of several buildings; the former location of a pile of small electrical capacitors and the former location of a pile of light fixtures. The PCB Aroclor 1248 was detected above the human health screening levels in the vicinity of one soil sample. However, the Human Health Risk Assessment (HHRA) determined that the concentrations do not pose an unacceptable risk of exposure.

AOC 4

AOC 4 is located near the southeast border of the Site. It consists of a former silo test structure and several other small buildings and covers approximately one acre. AOC 4 slopes to the north towards Tributary 3, which receives runoff from the south eastern portion of the Site. The RI indicated that COPCs are not present above human health and/or ecological screening values in surface soils.

AOC 5

AOC 5 includes the groundwater beneath the Site. Results obtained during the RI have required this AOC to be expanded. Chlorinated volatile organic compounds (CVOCs) are the main COCs detected in the groundwater at the Site. The source of the organic COCs was located near the west-central side of the current Lagoon 123. This area was excavated during the 1995-1996 removal action. Although the source soils were removed, concentrations of CVOCs remain above the remedial goals (RGs) noted in Table 4 for groundwater.

2.2.2 Groundwater Monitoring Program

In October 2006, a groundwater monitoring program (the Program) was implemented at the Site to establish baseline conditions and collect data for the remedial design. The Program proposed monitoring on a quarterly basis for one year followed by one year of sampling on a semi-annual basis. The initial quarterly sampling event was performed in October 2006 in conjunction with Phase 3 of the RI; therefore, the results of the first quarterly sampling event were discussed in the RI Report. Monitoring reports have been submitted for the subsequent quarterly sampling events.

Of the metals considered COCs in the Feasibility Study (FS), only arsenic and barium have consistently been detected above the RGs noted in Table 4. Arsenic has been detected above the RG only in MW-19 and barium has been detected above the RG only in MW-02. Based on this data, the other four COC metals (antimony, iron, manganese and thallium) are no longer considered COCs and are no longer part of the Program.

The monitoring of CVOCs and the remaining COC metals (arsenic and barium) will continue, to further evaluate the fate and transport of the COCs. Natural attenuation parameters will continue to be monitored to evaluate the physical and biological processes occurring at the Site.

3.0 Community Participation

The RI/FS Report and Proposed Plan for the Sixty-One Industrial Park Site in Memphis, Tennessee, were made available to the public in March 18, 2008. They can be found in the Administrative Record file and the information repository maintained at the EPA Docket Room in Region 4 and at the Levi Library, 3676 Southbird Drive, Memphis, Tennessee. The notice of the availability of these two documents was published in the Memphis Daily News on March 18, 2008. A public comment period was held from March 18, 2008 to April 18, 2008. In addition, a public meeting was held on March 27, 2008 to present the Proposed Plan to the local community in Memphis. At this meeting, representatives from EPA and TDEC were present to answer questions about the Site and the preferred remedial alternative. However, no one from the community attended the meeting. No comments were received during the comment period.

4.0 Scope and Role of Response Action

EPA has elected to use only one Operable Unit (OU) for the Site. The primary subject of this ROD is the impacted groundwater (AOC 5). Due to the limited volume, sediments and soils in AOC 1 are being addressed through a follow-up removal action (RA) which is currently underway. The action involves: excavating sediments and hydric soil above the remediation goal of 100 parts per million of cadmium; transportation and disposal to an off-site location; backfilling with clean soils and restoring the wetland vegetation. In addition, the follow-up RA will include draining the lagoons and grading the area around the lagoons to facilitate runoff. The levels of COCs in AOC 2, 3, and 4 in soils and sediment do not exceed the remedition goals.

In-situ enhanced reductive dechlorination (ERD) will be used to treat the areas with elevated chlorinated volatile organic compounds (CVOCs) in groundwater and monitored natural attenuation (MNA) will degrade the downgradient contamination through natural processes. As described in the HHRA, contact with COCs in groundwater in certain areas of the Site pose a risk to human health because concentrations are above applicable and relevant and appropriate requirements (ARARs) or are above EPA's acceptable level of risk ($1x10^{-4}$). The purpose of this final action is to prevent current or future exposure to contamination. The response action addresses the principal threat at the Site through the treatment of impacted groundwater with CVOCs concentration greater than 1,000 micrograms/liter (ug/L) and monitored natural attenuation for the remaining impacted groundwater.

5.0 Site Characteristics

5.1 Site Features, Topography, Surface Water and Drainage

The topography of the Site consists of rolling hills and drainage features that are dominated by a fork-shaped ridge that bisects the Site. Proceeding away from the ridge towards the north, east or the west, the topography slopes downward, as elevation drops from a high of approximately 250 feet along the divide to a low of approximately 200 feet near the northern property boundary.

Prior to 1996, seven industrial lagoons were present on the Site along the western portion of the property. After completion of removal activities in 1996, three lagoons were joined to form one larger lagoon (Lagoon 123). The dike of the sixth lagoon was removed to drain the contents. Presently, three separate lagoons remain on the western part of the Site, along with remnants of numerous buildings/structures in various states of disrepair. The majority of the structures are on the western portion of the Site's topographic divide. Each lagoon and building area is surrounded with access roads that interconnect and ultimately join with the primary access road entering the Site from the southeast. A drainage ditch extends from the northern most lagoon (former Lagoon 5), continues under the adjoining access road, combines with a small usually dry tributary (Tributary 2) and forms Tributary 1 that flows north into a seasonal wetland area located in the northwest portion of the Site. These tributaries drain the northern portion of the Site. The lagoons, tributaries and other pertinent physical features are depicted on Figure 2.

The eastern portion of the Site is mostly wooded with areas of debris, remnants of dilapidated buildings and access roads, and the usually dry creek bed of Tributary 3 that intermittently flows to Tomco Lake (Figure 2). A power line right-of-way extends along the eastern border of the Site. Overgrown grasses and weeds dominate the landscape in the right-of-way. A firewater pond was recently constructed on the southeast portion of the Site, to service the abutting property (the out parcel).

The Site is bordered to the north and northwest by an area of wetlands. Tomco Lake and the larger Robco Lake are to the north/northeast of the property boundary. Horn Lake Creek, which flows from east to west between Robco Lake and Tomco Lake is located about 1,000 feet due north of the Site and receives runoff from the Site from Tributary 1 and the discharge from Tomco Lake. Due west of the Site are undeveloped, seasonal wetlands and wooded areas and two active railroad tracks.

Site hydrology is controlled by three lagoons that line the western side of the property and three tributaries that drain portions of the Site, and a firewater pond located in the southeast corner of the Site, upgradient of Tributary 3. The tributaries drain to surface water bodies; Tributary 1 and 2 to the wetlands north and northwest of the Site and Tributary 3 to Tomco Lake. The lagoons receive surface water runoff from the western portion of the Site and drain to the north. The surface water levels in the lagoons appear to be controlled mainly by run-off after rainfall events. Three tributaries are present at the Site. Tributary 1 is a small intermittent stream that drains the lagoons and the northwestern portion of the Site. Tributary 1 traverses AOC 1 (wetlands north of the Site) and discharges to Horn Lake Creek. Tributary 2 is an intermittent stream that drains the northern portion of the Site during wet periods of the year. Tributary 2 combines with Tributary 1 north of Lagoon 5. Tributary 3 is an intermittent stream that drains the east-central portion of the Site and the firewater pond. Tributary 3 discharges to Tomco Lake, which discharges to Horn Lake Creek. Horn Lake Cutoff is hydraulically connected to North Horn Lake. North Horn Lake, on its northern side, discharges into Horn Lake Creek. Horn Lake Creek ultimately discharges to the Mississippi River.

Figure 2 Site Map

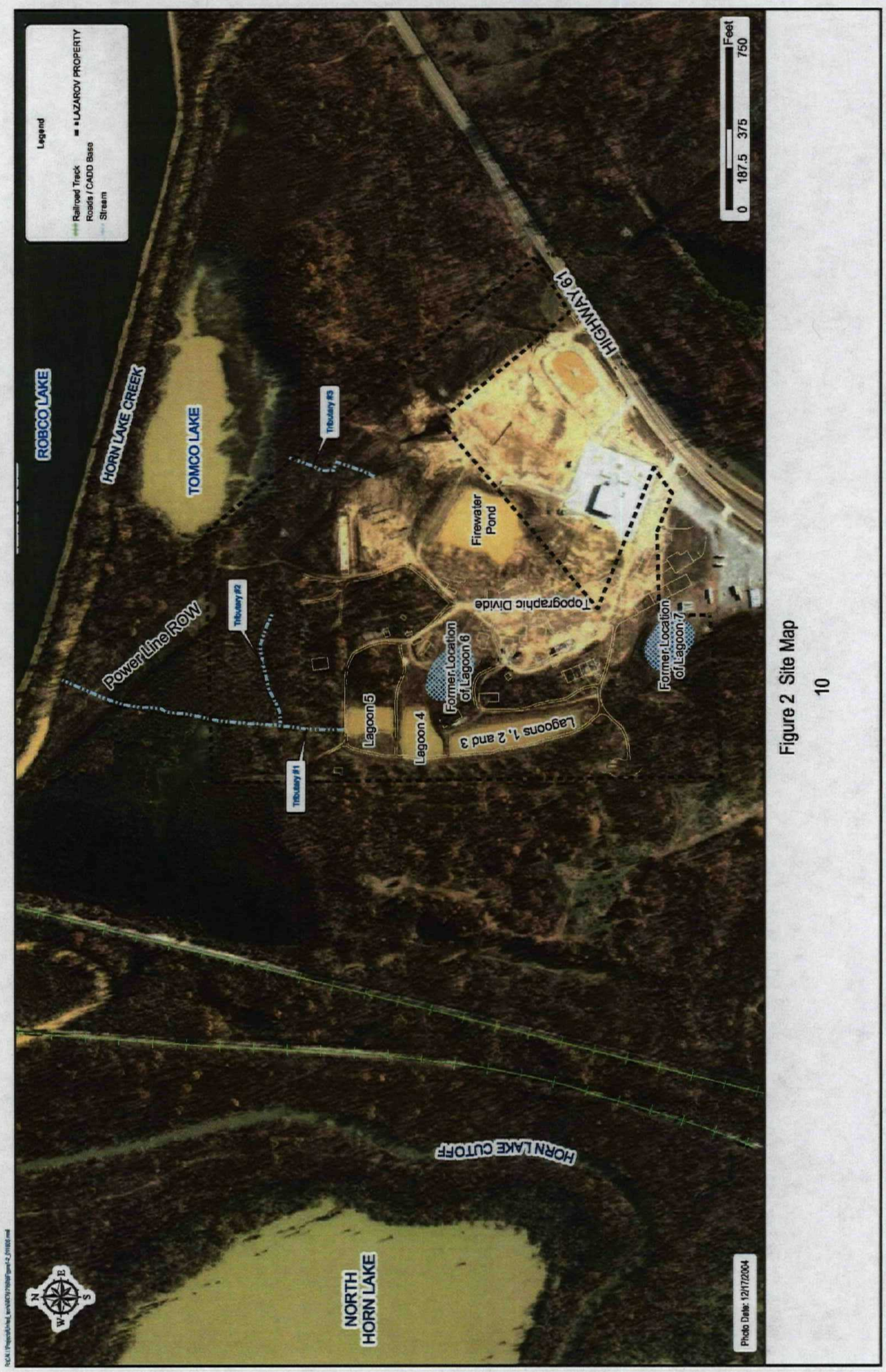


Figure 2 Site Map

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Site Geology and Hydrogeology

Soils encountered beneath the Site range from silts and silty clays to sands and gravelly sands. The uppermost soils consisted of pale brown to brown silts and silty clays ranging in thickness extending from approximately 18 feet below ground surface (bgs) in the areas of lower elevation around the lagoons to over 50 feet bgs along the ridges of higher elevation. The surficial silt is underlain predominantly by a yellowish brown to reddish brown sand zone. This sand zone contains varying percentages of silts to gravels, and ranges in thickness from approximately 25 feet near the lagoons to approximately 40 feet beneath the south-central portion of the Site. A layer of dark-gray to black silt with intermittent, very thin (1/16 inch to 1/4 inch) to thin (2 inch to 4 inch) layers of gray silty sand was encountered below the sand zone, at depths ranging between 43 feet bgs near the lagoons to 78 feet bgs in the south-central portion of the Site. This grades to a very dense, dark gray to olive-gray to dark-brown silty sand. The dense silty sand is underlain by very stiff clay. The sediments encountered to this depth are considered to be part of the Alluvial Terrace deposits. The sediments beneath this clay unit are the uppermost portion of the Jackson formation. Beneath this clay unit lies another 10 to 12 feet of dense silty sand which is underlain by dense, dry, silty clay.

There are two zones of groundwater beneath the Site, the surface water table, and the Memphis Sand aquifer of the Clairborne geological formation. The Jackson Formation confines the surface water table from the Memphis sand aquifer. The water table was encountered in the silts and sands of the surficial Alluvial Terrace deposits. The water table was measured at depths from 5 to 10 feet bgs in the lower elevations to approximately 20 to 35 feet bgs in wells installed on ridges towards the southern end on the Site. The shallow monitoring wells installed at the Site are screened in the water table aquifer encountered within the Alluvial Terrace deposits. One deep monitoring well is screened in the upper portion of the Jackson Formation. The Jackson Formation was encountered at approximately 75 feet bgs. The Jackson Formation is reportedly 60 feet thick in the Site vicinity. This formation is the upper confining unit for the Claiborne Formation. The Memphis Sand aquifer, of the Claiborne Formation, provides the majority of the municipal and industrial water supply in the Memphis area.

Groundwater flow is generally to the north-northwest towards the Horn Lake Cutoff (Figure 3). Aquifer characterization tests indicate that the hydraulic conductivity of the water table aquifer averaged 1.65 ft/year. Based on the average hydraulic conductivity, the hydraulic gradient as determined from the two RI water level measurements, the average groundwater flow rate in the water table aquifer is 0.01 feet/day or 36.5 ft/year.

The surface water bodies provide recharge to groundwater that seasonally influences groundwater flow direction. Vertical seepage from these ponds also appears to cause mounding of the water table. This mounding effect alters the groundwater flow direction more to the west past the west side of the lagoons.

5.2 Nature and Extent of Contamination

Two groups of chemical compounds have been identified in the groundwater at the Site. Examples of COCs belonging to each group are identified below, with their associated potential health effects and routes of possible exposure.

Volatile Organic Compounds (VOCs): Organic solvents are the group of volatile compounds or mixtures found at the Site. They are relatively stable chemically and exist in the liquid state at temperatures of approximately 32° to 82°F. Organic solvents are used for extracting, dissolving, or suspending materials such as fats, waxes, and resins that are not soluble in water. Solvents are used in paints, adhesives, glues, coatings, and degreasing/ cleaning agents.

Inhalation and skin absorption are the primary routes of solvent uptake into the peripheral blood, which begins within minutes of the onset of exposure. Organic solvents undergo biotransformation or they accumulate in the lipid-rich tissues such as those of the nervous system.

Solvent inhalation may cause effects ranging from an alcohol-like intoxication to narcosis and death from respiratory failure, with a spectrum of intermediate symptoms that include drowsiness, headache, dizziness, dyspepsia, and nausea. Examples of VOCs that are COCs on-site are Tetrachloroethene (PCE), trichloroethene (TCE) and vinyl chloride. The International Agency for Research on Cancer (IARC) has classified PCE and TCE as Group 2A: Probable human carcinogen, based on sufficient evidence in animals and limited evidence in humans. EPA is currently reviewing the carcinogen classification of TCE. The IARC has classified vinyl chloride as Group 1: Human carcinogen based on sufficient evidence of carcinogenity in both humans and animals. EPA has classified vinyl chloride as Group A: Human carcinogen.

Metals: Metals that are COCs at the Site are arsenic and barium used in the formulation of dispersants and chelating agents; solvents; emulsifiers; spray oils; and wetting agents. Metals can enter the body by ingestion, inhalation, or direct dermal contact.

Most arsenic that is absorbed into the body is converted by the liver to a less-toxic form that is efficiently excreted in the urine. Consequently, arsenic does not have a strong tendency to accumulate in the body except at high exposure levels. Inorganic arsenic has been recognized as a human poison since ancient times, and large doses can produce death. Lower levels of exposure may produce injury in a number of different body tissues or systems: these are called "systemic" effects.

Barium compounds, especially soluble forms such as barium hydroxide and barium oxide, are strongly alkaline and can be injurious to the eyes and skin. Insoluble dusts containing barium may cause local irritation without systemic toxicity. The barium ion interferes with potassium ion utilization and muscular function. This may lead to muscle stimulation, followed by paralysis with tingling in the extremities. Nausea, vomiting, colic, and diarrhea may also occur. In severe cases, loss of tendon reflexes and general muscular paralysis may precede respiratory arrest or ventricular fibrillation.

5.2.1 Conceptual Site Model

Historical operations at the Site have resulted in groundwater contamination caused by the discharges of contaminants to the surface soils. Contaminated soil was removed during the1995 removal action. Groundwater contamination is also attributed to poor storage and management of lead-acid batteries and other salvage materials stored at the Site.

Available data indicate that COCs (primarily CVOCs and metals) have migrated through the shallow soils and have impacted the surficial aquifer. The data indicates that impacts to groundwater are limited to the surficial aquifer zone, and that an aquitard prevents site-related contaminants from reaching the underlying Memphis Sand Aquifer System. COCs which have been detected in groundwater above their respective screening values are listed below along with their current maximum concentrations (ENSR, October 2007).

- Arsenic [20 μg/L]
- Barium [2,820 μg/L]
- Tetrachlorethylene [less than 200 μg/L]
- Trichloroethylene [9,300 μg/L]

- Vinyl Chloride [13.9 μg/L]

The following sections briefly discuss the COCs found and the extent of impacts to groundwater at the Site.

VOC Distributions

Figure 4 presents the distribution of TCE in groundwater. TCE is the most widespread of the chlorinated compounds detected in the groundwater. The highest concentrations are found in proximity to Lagoon 123. The area of TCE impacted groundwater extends semi-radially from this area to the north beyond the lagoons, but predominantly to the northeast towards Tomco Lake and west to the railroad tracks. This distribution of TCE appears to be consistent with groundwater flow direction which is generally to the northwest. However, surface water recharge from the seasonal wetlands north and northwest of the Site appears to significantly effect the elevations of the water table aquifer and flow direction. This may be the cause of the bifurcation of the TCE plume to the east, toward Tomco Lake and west, toward the railroad tracks.

Elevated vinyl chloride concentrations are generally located around the lagoons in areas with the highest TCE concentrations. PCE is only detected in wells where elevated concentrations of TCE are present.

Metal Distribution

The metals considered COCs, are arsenic and barium. They have been limited to detections primarily in MW-19 and MW-02, respectively. Antimony has been detected above the laboratory reporting limit once in 2001 which was due to the inadequate development and/or turbidity in the samples collected prior to the implementation of the groundwater program. Thallium has been detected sporadically during historical sampling events. It is suspected that inadequate development and/or turbidity in samples collected prior to the implementation of the groundwater monitoring program may have also resulted in the historic detections of thallium. Thallium has not been detected above screening levels except at MW-02 using low-flow sampling procedures and has not been detected above the laboratory reporting limit since the implementation of the groundwater program. Antimony and thallium are not considered COCs.

Iron is an essential nutrient; however it was previously retained as a COPC because it failed background and toxicity screens. More background data has been obtained since the HHRA and the iron detected in various locations at the Site would fall within the ranges of background iron concentrations. Monitoring wells such as MW-17, MW-18 and MW-19 are both on- and off-site wells which are not impacted by CVOCs and the iron concentrations in these wells have ranged from 2,910 to 20,700 ug/L. These wells are outside of the CVOC groundwater plume and are significantly higher than the single background location (MW-06) concentration of 573 ug/L that was used for screening in the HHRA. Also, the toxicity value used in the HHRA is considered extremely conservative. The reference dose for iron is below and more stringent than the Recommended Daily Allowances (RDAs) for young children. This would confirm the iron present is naturally occurring nutrient and will not pose a human risk. Therefore, iron is not considered a COC.

Manganese has been sporadically detected above the background levels in MW-02, MW-04 and MW-19. Manganese was not considered to pose a threat to human health and the environment as an onsite COC. Manganese was previously retained as a COC due to the hazard index being greater than one for off-site residents using the groundwater as a drinking water source. Manganese was detected above the background levels in one off-site well (MW-19) which is not impacted with CVOCs; therefore, manganese is not considered a COC.

Figure 3 Water Level Contour Map - July 2007

Figure 3 Water Level Contour Map - July 2007

Figure 4 Trichloroethylene (TCE) Concentrations in Groundwater - July 2007

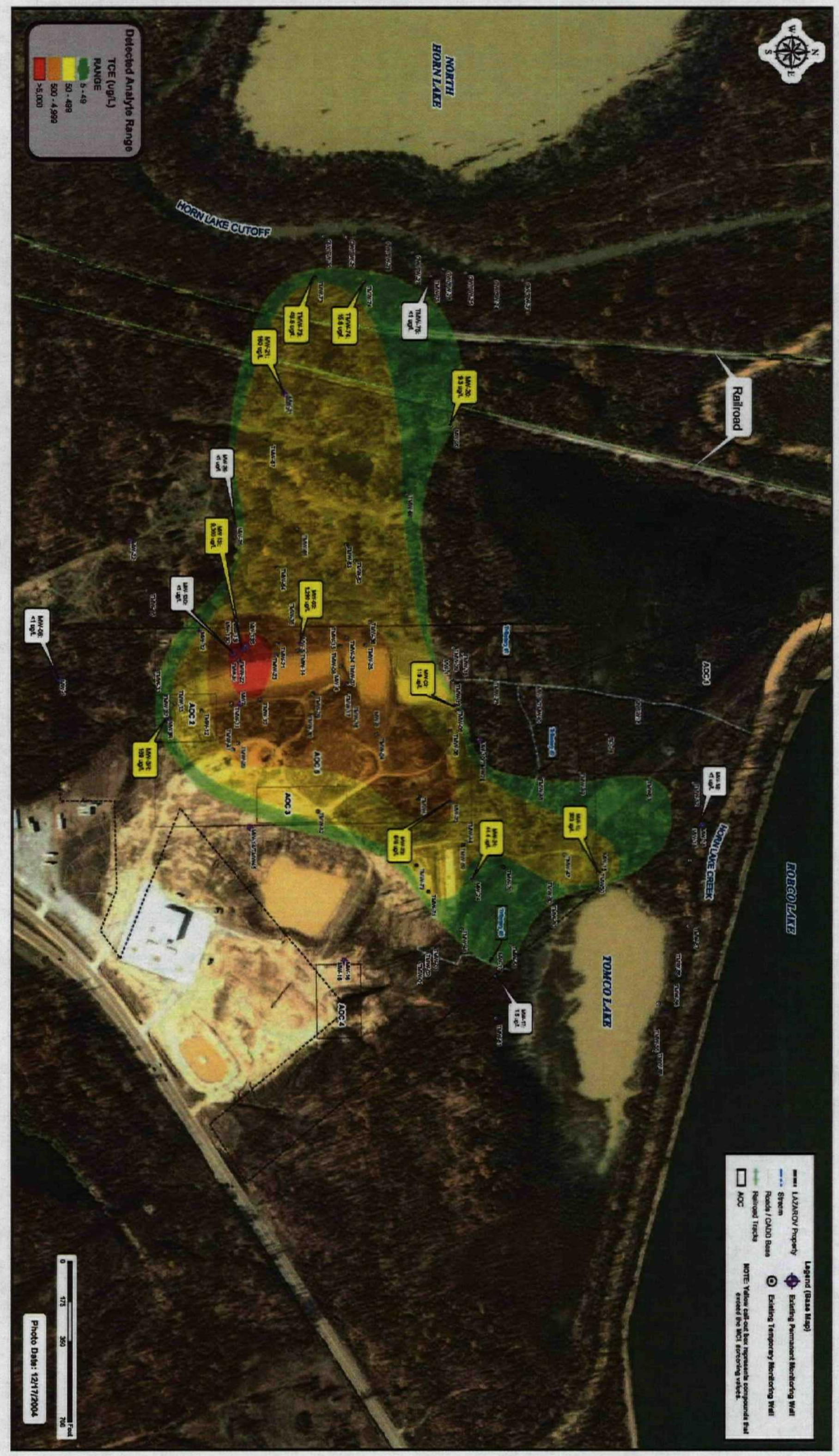

Figure 4 Trichloroethylene (TCE) Concentrations in Groundwater - July 2007

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6.0 Current and Potential Future Land and Resource Use

The Site was previously developed and primarily used for industrial purposes. The Site is currently unoccupied and zoned for heavy industrial use. The former industrial wastewater lagoons are along the western border of the Site. The eastern portion of the Site is mostly wooded with areas of debris, remnants of dilapidated buildings and access roads, and the usually dry creek bed of Tributary 3 that intermittently flows to Tomco Lake. A power line right-of-way extends along the eastern border of the Site. Overgrown grass and weeds dominate the landscape in the right-of-way. A firewater pond was constructed on the southeast portion of the Site, abutting the out parcel.

The Site is bordered to the north and northwest by an area of wetlands. Due west of the Site are undeveloped seasonal wetlands, wooded areas and two active railroad tracks. An out parcel bounds the Site to the south and abuts Highway 61. A small commercial building was constructed on this out parcel. The surrounding areas of the Site are also zoned heavy industrial.

The Site will remain zoned heavy industrial because of restrictive local zoning. If the property owner desired to change the current or future zoning classification, a petition would be submitted to the Memphis Shelby County Planning and Development Department. As part of the zoning change petition, the property owner must secure the approval from Memphis and Shelby County Health Department (MSCHD) that requirements have been successfully met proving that no adverse ecological or human effects would result from the changes in the proposed property use. With the documented status of the Site as a CERCLIS NPL-Equivalent site, the MSCHD would not concur with a zoning change without a demonstration that the Site is safe for use other than heavy industrial. Therefore, the conceptual site exposure model indicating current and future use of the Site as an industrial site is supported by current zoning and regulatory processes (i.e., institutional controls).

Groundwater beneath the Site and the surrounding area is not used as a drinking water supply. The water supply for the surrounding area is provided by the City of Memphis and is drawn from deep Memphis Sand Aquifer wells, with the nearest public well field north and northeast of the Site. Access to impacted groundwater on and surrounding the Site is restricted. MSCHD has statutory authority to deny well applications based on health, safety, and general welfare considerations in accordance with Rules and Regulations of Wells in Shelby County (hereafter referred to as Well Regulations). Well Regulations specifically require that MSCHD deny a permit application to construct a water well if use of the well would increase the potential for harm to public health safety and welfare, or if the proposed well would enhance the movement of contaminated groundwater or material into the shallow or deep aquifer. The rules more specifically require that a water well cannot be sited or placed in service within a half-mile of the designated boundaries of a listed federal or state Superfund site or RCRA corrective action site (Section 4.01-C, Well Regulations). MSCHD has been, and will continue to be, supplied copies of all investigative and monitoring reports to assist the MSCHD hydrogeologist with determining areas where water wells should not be installed or placed in service.

7.0 Summary of Site Risks

The purpose of the baseline risk assessment is to estimate human health risks posed by the Site if no action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the ROD summarizes the results of the baseline risk assessment and the process used for selection of cleanup goals for the COCs at the Site.

7.1 Summary of Human Health Risk Assessment

In 2006, a Human Health Risk Assessment (HHRA) was conducted to evaluate potential risks to human health and the environment associated with chemicals detected in soil, groundwater, surface water, and sediment samples collected from the Site and neighboring off-site locations.

The HHRA found that potential risk associated with the future use of groundwater as a drinking water source by a future on-site worker and a future off-site resident exceeded the 1×10^{-4} risk level and the hazard index of one, thereby triggering further action under Superfund.

7.1.1 Chemicals of Concern

Chemicals in groundwater were compared to groundwater screening criteria. Groundwater screening criteria were defined as the lower of the Tennessee or Federal maximum contaminant levels (MCLs). U. S. EPA Region 9 preliminary remediation goals (PRGs)s for tap water using a hazard index of 0.1 for non-carcinogens, were used for chemicals where neither Tennessee nor Federal MCLs were available.

The chemical of potential concern (COPCs) in the HHRA were later refined in the RI/FS based on exceedances of the Applicable or Relevant and Appropriate Regulations (ARARs). Table 1 presents the minimum and maximum detected concentrations, frequency of detection, and maximum exposure point concentrations for the final groundwater COCs after refinement in the FS.

EPA anticipates no further chemicals of concern to be present in the soils or sediments as a result of the ongoing follow-up Removal Action in AOC 1, and AOC 2, 3 and 4 were found to be within the acceptable risk range of 1 x10-4.

7.1.2 Exposure Assessment

The HHRA evaluated potential exposure through a number of exposure scenarios, including current and potential future exposure scenarios. The receptors evaluated for the Site include a future outdoor industrial worker, future construction worker, current and future trespasser, current and future recreational angler, and future off-site resident. The conceptual site model, Figure 5, presents the potential exposure pathways.

For each route of exposure, a reasonable maximum exposure (RME) scenario was developed based on EPA's Risk Assessment Guidance for Superfund (RAGS) and EPA Region 4 Human Health Risk Assessment Bulletins – Supplement to RAGS. Values used for the scenarios are presented in Tables 4.1 through 4.12 provided in the HHRA.

The potential exposure pathways were evaluated for surface soils, sediments and surface water; however, these media will be removed as potential exposure pathways as a result of the follow-on removal action that is currently underway. Therefore, only the potential exposure pathways for groundwater were used for refining the COCs.

- Future Outdoor Industrial Worker - The outdoor industrial worker was evaluated for potential exposure to COPCs in on-site groundwater used as a source of drinking water.

- Future Construction/Utility Worker - Groundwater is not a medium of concern for the construction/utility worker, because depth to shallow groundwater at the Site is 15 to 20 feet bgs (beyond typical excavation depths).

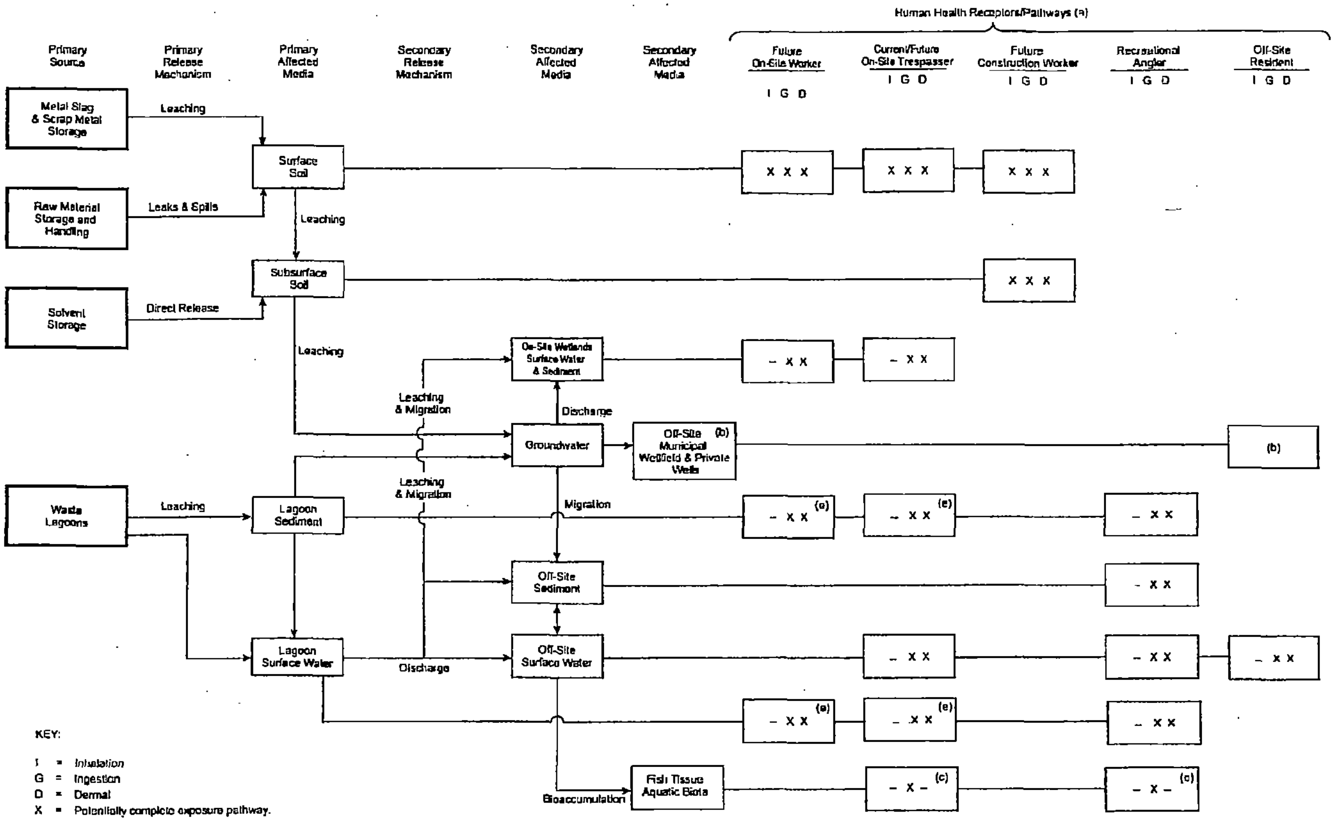
- Current/Future Trespasser - Groundwater is not a medium of concern for the trespasser since on-site groundwater is not used as a source of drinking water.

Current/Future Recreational Angler – It was assumed that a recreational angler has the potential to be exposed to certain site-related COPCs through ingestion of fish. The recreational angler is assumed to ingest fish primarily from the closest off-site surface water body, Tomco Lake.

- Future Off-site Resident - On-site groundwater is flowing to the north away from the residential area located southeast of the Site. Thus, consumption of groundwater as drinking water by off-site residents to the southeast is not a complete exposure pathway at the Site. The City of Memphis operates well fields North and Northeast of the Site, but these extraction wells are screened in the underlying aquifer at great depths. Two private wells are located to the north across Robco Lake, representing the only potentially complete pathways to drinking water. Therefore, an off-site resident is evaluated for potential exposure to COPCs in groundwater in these two wells via drinking water ingestion. The off-site resident is also assumed to swim in Tomco Lake, and is therefore potentially exposed to surface water via incidental ingestion. Both adult and child residents were evaluated.

There are no homes located on the Site above or near the groundwater plume of contamination, or any homes off site within 100 feet of the plume. For that reason, vapor intrusion is not a complete pathway and does not pose an unacceptable risk to human health

Figure 5 Conceptual Site Model



KEY:

I = Inhalation
G = Ingestion
D = Dermal
X = Potentially complete exposure pathway.
-- = Not applicable
(a) = Absence of exposure pathway box indicates that receptor is not exposed to that medium.
(b) = Groundwater for the off-site resident is conservatively evaluated using two property boundary wells (MW-8 and MW-12).
(c) = Limited fishing assumed to occur in on-site lagoons due to limited site access.
(d) = Recreational fishing assumed to occur primarily off-site (i.e., Tomco Lake). Evaluation of recreational fishing in on-site water bodies will be limited to where there is evidence of fishing activity.
(e) = Under future presumptive remedy, lagoon dikes will be cut, the lagoons drained, and the dikes and sediments graded to match existing topography, eliminating potential future exposure to lagoon sediment and surface water.

M060039

Figure 5

Conceptual Site Model
61 Industrial Park Site, Memphis, TN

7.1.3 Toxicity Assessment

The purpose of the toxicity assessment is to identify the types of adverse health effects a chemical may potentially cause, and to define the relationship between the dose of a chemical and the likelihood or magnitude of an adverse effect (response). Adverse effects are classified by EPA as potentially carcinogenic or non-carcinogenic (i.e., potential affects other than cancer). Dose-response relationships are defined by EPA for oral exposure and for exposure by inhalation. Oral toxicity values are also used to assess dermal exposures, with appropriate adjustments, because EPA has not yet developed values for this route of exposure. Combining the results of the toxicity assessment with information on the magnitude of potential human exposure provides an estimate of potential risk.

Sources of the published toxicity values in the risk assessment include U.S. EPA's Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST), and the EPA National Center for Environmental Assessment (NCEA) in Cincinnati, Ohio.

A summary of carcinogenic and non-carcinogenic toxicity data for the COCs are presented in Tables 2 and 3. Detailed toxicity data for COCs are provided in Appendix A of the HHRA.

7.1.4 Risk Characterization

For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

Risk = CDI x SF

where: risk = a unitless probability (e.g., $2x10^{-5}$) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
SF = slope factor, expressed as (mg/kg-day)-1.

These risks are probabilities that usually are expressed in scientific notation (e.g., $1x10^{-6}$). An excess lifetime cancer risk of $1x10^{-6}$ indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer that individuals face from other causes such as smoking or exposure to too much sun. The chance of an individual developing cancer from all other causes has been estimated to be as high as one in four. EPA's generally acceptable risk range for site-related exposures is $1x10^{-4}$ to $1x10^{-6}$.

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., life-time) with a reference dose (RfD) derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An HQ<1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic non-carcinogenic effects from that chemical are unlikely. The Hazard Index (HI) is generated by adding the HQs for all COPCs that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An HI<1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic non-carcinogenic effects from all contaminants are unlikely. An HI>1 indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

Non-cancer HQ = CDI/RfD

where: CDI = chronic daily intake
RfD = reference dose.

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or short-term).

The target cancer risk and hazard index (HI) levels used for the identification of COCs are based on EPA and EPA Region 4 guidance. The results of the risk characterization show that chemicals detected in the in surface soil, subsurface soil, sediment and surface water do not pose unacceptable risks. The predicted cancer risk levels are all below $1x10^{-4}$, and the non-carcinogenic HIs are all below 1.

Potential risks and HI for the future construction worker and the current/future trespasser before and after the follow-on removal action are within EPA's target risk range of 10^{-4} to 10^{-6} and an HI of one. Potential risks for the recreational angler before and after the follow-on RA are also within EPA's target risk range of 10^{-4} to 10^{-6} and an HI of one, with the exception of potential risks associated with fish ingestion in Tomco Lake. There is a high degree of uncertainty associated with this risk estimate, which is based on the results of one surface water sample collected in 1994 and a BCF for arsenic. Therefore, no RG was derived for arsenic in fish tissue.

Potential risks associated with the future use of groundwater as a drinking water source exceed the acceptable risk benchmarks for both the future on-site worker and the future off-site resident. Groundwater is not currently used as an on-site drinking water source. On-site groundwater is flowing to the north away from the residential area located southeast of the Site. Thus, consumption of groundwater as drinking water by off-site residents to the southeast is not a complete exposure pathway at the Site. The City of Memphis operates well fields North and Northeast of the Site, but these extraction wells are screened in the underlying aquifer at great depths. Two private wells are located to the north across Robco Lake, representing the only potentially complete future pathways to drinking water. Institutional controls will be used to prohibit use of groundwater from the Site as a drinking water source. Risk based remedial goals were derived for the following COCs in groundwater:

Future On-Site Outdoor Worker
Antimony
Arsenic
Barium
Iron
PCE
TCE
Thallium
Vinyl Chloride

Future Off-Site Resident
Arsenic
Manganese
Iron
PCE
TCE

The risk estimates and HIs (risk based RGs) calculated for the COCs are presented in Table 4 as well as the MCLs (used as RGs). However, antimony, iron, manganese and thallium have not been detected above the respective RGs since implementation of the groundwater monitoring program in October 2006.

7.1.5 Uncertainty

Within any of the four steps of the risk assessment process, assumptions were made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. Every assumption introduces some degree of uncertainty into the risk assessment process. Regulatory risk assessment methodology requires that conservative assumptions be made throughout the risk assessment to ensure that public health is protected. Therefore, when all of the assumptions are combined, it is much more likely that risks are overestimated rather than underestimated.

The assumptions that introduce the greatest amount of uncertainty in this risk assessment are discussed in this section. They are discussed in qualitative terms, because for most of the assumptions there is not enough information to assign a numerical value to the uncertainty that can be factored into the calculation of risk.

7.1.5.1 Uncertainty Associated with Data Evaluation

The chemicals detected in various Site media were screened against background concentrations and risk-based screening levels. Chemicals exceeding these concentrations were selected as COPCs for quantitative evaluation in the risk assessment. A subset of chemicals detected at a site is generally selected for quantitative analysis for several reasons. Some chemicals detected at a site may be naturally occurring and not related to site use. Other chemicals may be present at concentrations that can be assumed with reasonable assurance not to pose a risk to human health. A review of the results of risk assessments demonstrate that in most cases, risks are attributable only to one or a few chemicals, and that many of the chemicals quantitatively evaluated do not contribute significantly to total risk estimates. The screening process is conducted to identify the COPCs that may contribute the greatest to potential risk. The screening process used here is conservative. Although the excluded chemicals may pose a finite level of risk, that risk would contribute negligibly to the total site risk. Therefore, not evaluating the excluded chemicals does not measurably affect the numerical estimates of hazard or risk, and does not affect remedial decision-making at the Site.

7.1.5.2 Uncertainty Associated with Dose-Response Assessment

The purpose of the dose-response assessment is to identify the types of adverse health effects a chemical may potentially cause and to define the relationship between the dose of a chemical and the likelihood or magnitude of an adverse effect (response). Risk assessment methodologies typically divide potential health effects of concern into two general categories: effects with a threshold (noncarcinogenic) and effects assumed to be without a threshold (potentially carcinogenic). Toxicity assessments for both of these types of effects share many of the same sources of uncertainty. To compensate for these uncertainties, EPA's RfDs and CSFs are biased to overestimate rather than underestimate human health risks. Several of the more important sources of uncertainty and the resulting biases are discussed below.

<u>Animal-to-Human Extrapolation in Noncarcinogenic Dose-Response Evaluation</u>

For many chemicals, animal studies provide the only reliable information on which to base an estimate of adverse human health effects. Extrapolation from animals to humans introduces a great deal of uncertainty into the risk characterization. In most instances, it is not known how differently a human may react to the chemical compared to the animal species used to test the chemical. If a chemical's fate and the mechanisms by which it causes adverse effects are known in both animals and humans, uncertainty is reduced. When the fate and mechanism for the chemical are unknown, uncertainty increases.

TABLE 1
Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations

Scenario Timeframes: Current and Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Concern	Concentration Detected		Units	Frequency of Detection	Exposure Point Concentration	Exposure Point Concentration Units	Statistical Measure
		Min	Max					
Groundwater-Central Plume - ingestion	PCE	8.45	20.1	ppb	3/5	15.62	ppb	Average (a)
	TCE	1089.5	11000	ppb	5/5	6353.9	ppb	Average (a)
	Vinyl Chloride	2	4.4	ppb	3/5	3.22	ppb	Average (a)
Groundwater-Sitewide-ingestion	Antimony	4.6	4.6	ppb	1/6	4.6	ppb	MAX (b)
	Arsenic	4	26.1	ppb	9/24	10.1	ppb	UCL
	Barium	79.3	9525	ppb	24/24	4456	ppb	UCL
	Iron	61	20700	ppb	16/24	5555	ppb	UCL
	Manganese	2.25	11375	ppb	24/24	2324	ppb	UCL
	Thallium	4.8	11.5	ppb	4/24	11.5	ppb	MAX (b)

ppb: Parts per billion
UCL Upper Confidence Limit
MAX Maxium Concentration
(a) Plume wells: MW-4, MW-5, MW-7, MW-13I, MW-13S. Statistics calculated using 2005 data. EPC is the average.
(b) Due to low frequencey of detection, the maximum detecred concentration is selected as the EPC.

TABLE 2
Carcinogenic Toxicity Data Summary

Pathway: Ingestion

Chemical of Concern	Oral Cancer Slope Factor	Slope Factor Units	Weight of Evidence/ Cancer Guidelines Description	Source	Date (MM/DD/YYYY)
Antimony	NA	(mg/kg/day)	D	USEPA	2005
Arsenic	1.50E+00	(mg/kg/day)	A	IRIS	4/10/1998
Barium	NA	(mg/kg/day)	D	USEPA	2005
Iron	NA	(mg/kg/day)	NA	HSDB	2005
Manganese	NA	(mg/kg/day)	D	USEPA	2005
PCE	5.40E-01	(mg/kg/day)	2A	USEPA, OEHHA	2005
TCE	2.00E-02	(mg/kg/day)	2A	USEPA	6/23/1905
TCE	1.30E-02	(mg/kg/day)	2A	OEHHA	1995
Thallium	NA	(mg/kg/day)	D	USEPA	--
Vinyl chloride	7.50E-01	(mg/kg/day)	A	USEPA*	--

NA: No information is available
A: Human Carcinogen
B2: Probable human carcinogen- indicated sufficient evidence in animals and inadequate or no evidence in humans
D: Not classifiable as a human carcinogen
USEPA: United States Environmental Protection Agency
Hazardous Substance Databank
IARC: Internation Agency for Research on Cancer
OEHHA: California Office of Environmental Health Hazard Assessment
* Value under review, it was not used

TABLE 3
Non-Carcinogenic Toxicity Data Summary

Pathway: Ingestion							
Chemical of Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Primary Target Organ	Combined Uncertainty/ Modification	Sources of RfD Target Organ	Date of RfD Target Organ (MM/DD/YYYY)
Antimony		0.0004	(mg/kg/day)	Blood, Decreased longevity	–	IRIS	2/1/1991
Arsenic		3.00×10^{-4}	(mg/kg/day)	Skin, gastroinstestinal, kidney, Liver	–	IRIS	2/1/1993
Barium		0.2	(mg/kg/day)	Muscle	–	IRIS	1/21/1999
Iron		0.3	(mg/kg/day)	Blood and Liver	1/1	NCEA	2001
Manganese		0.14	(mg/kg/day)	CNS	/3	IRIS	5/1/1996
PCE		0.01	(mg/kg/day)	Liver, CNS, Kidney	–	IRIS	3/1/1988
TCE		0.0003	(mg/kg/day)	CNS, Liver, Kidney	–	USEPA	2001
Thallium		6.67E-05	(mg/kg/day)	CNS, Lungs, Heart, Liver, Kidney	3000/1	USEPA	1998
Vinyl chlori	Subchronic	3×10^{-3}	(mg/kg/day)	CNS, Liver	–	USEPA	2005

IRIS: Intergrated Risk Information System
USEPA: United States Environmental Protection Agency NCEA:
USEPA National Center for Environmental Assessment

TABLE 4
Remedial Goals for COCs in Groundwater

Chemical	EPA/TDEC MCL	2X Background Levels	Proposed Remedial Goals	On-Site		Off-Site	
				RG for Risk 1×10^{-4}	RG for HI=1	RG for Risk 1×10^{-4}	RG for HI=1
Arsenic	0.01	0.006	**0.01**	0.0191	0.0307	0.00448	0.00469
Barium (1)	2	0.186	**2**	NC	20.4	NA	NA
PCE	0.005	0.004	**0.005**	0.053	1.02	0.0125	NC
TCE	0.005	0.004	**0.005**	0.0715	0.0307	0.0168	0.00469
Vinyl Chloride	0.002	0.002	**0.002**	0.0382	NC	NA	NA

Notes:
All units are milligrams per liter (mg/L) MCL = Maximum Contaminant LevelNA = Not Available
NC = Not Calculated or RG not needed for noncarcinogenic effects
HI = Hazard Index
MCLs for EPA and TDEC were the same for the COCs
Background levels based on Table 4-1 of the RI Report dated June 2007
(1) = Risk based COC for on-site only
(2) = Risk based COC for off-site only

The procedures used to extrapolate from animals to humans involve conservative assumptions and incorporate uncertainty factors such that overestimation of effects in humans is more likely than underestimation. When data are available from several species, the lowest dose that elicits effects in the most sensitive species is used for the calculation of the RfD. To this dose are applied uncertainty factors, generally of 1 to 10 each, to account for intraspecies variability, interspecies variability, study duration, and/or extrapolation of a low effect level to a no effect level. Thus, most RfDs used in risk assessment are 100- to 10,000-fold lower than the lowest effect level found in laboratory animals.

Nevertheless, because the fate of a chemical can differ in animals and humans, it is possible that animal experiments will not reveal an adverse effect that would manifest itself in humans. This can result in an underestimation of the effects in humans. The opposite may also be true: effects observed in animals may not be observed in humans, resulting in an overestimation of potential adverse human health effects.

Evaluation of Carcinogenic Dose-Response

Significant uncertainties exist in estimating dose-response relationships for potential carcinogens. These are due to experimental and epidemiologic variability, as well as uncertainty in extrapolating both from animals to humans and from high to low doses. Three major issues affect the validity of toxicity assessments used to estimate potential excess lifetime cancer risks: (1) the selection of a study (i.e., data set, animal species, matrix the chemical is administered in) upon which to base the calculations, (2) the conversion of the animal dose used to an equivalent human dose, and (3) the mathematical model used to extrapolate from experimental observations at high doses to the very low doses potentially encountered at the Site.

Study Selection

Study selection involves the identification of a data set (experimental species and specific study) that provides sufficient, well-documented dose-response information to enable the derivation of a valid cancer slope factor (CSF). Human data (e.g., from epidemiological studies) are preferable to animal data, although adequate human data sets are relatively uncommon. Therefore, it is often necessary to seek dose-response information from a laboratory species, ideally one that biologically resembles humans (e.g., with respect to metabolism, physiology, and pharmacokinetics), and where the route of administration is similar to the expected mode of human exposure (e.g., inhalation and ingestion). When multiple valid studies are available, the EPA generally bases CSFs on the one study and site that show the most significant increase in tumor incidence with increasing dose. In some cases this selection is done in spite of significant decreases with increasing dose of tumor incidence in other organs and total tumor incidence. Consequently, the current study selection criteria are likely to lead to overestimation of potential cancer risks in humans.

Interspecies Dose Conversion

The U.S. EPA derivation of human equivalent doses by conversion of doses administered to experimental animals requires the assumption that humans and animals are equally sensitive to the toxic effects of a substance, if the same dose per unit body surface area is absorbed by each species. Although such an assumption may hold for direct-acting genotoxicants, it is not necessarily applicable to many indirect acting carcinogens and likely overestimates potential risk by a factor of 6 to 12 depending on the study species. Further assumptions for dose conversions involve standardized scaling factors to account for differences between humans and experimental animals with respect to life span, body size, breathing rates, and other physiological parameters. In addition, evaluation of risks associated with one route of administration (e.g., inhalation) when tests in animals involve a different route (e.g., ingestion) requires additional assumptions with corresponding additional uncertainties.

High-to-Low Dose Extrapolation

The concentration of chemicals to which people are potentially exposed at industrial sites is usually much lower than the levels used in the studies from which dose-response relationships are developed. Estimating potential health effects at such sites, therefore, requires the use of models that allow extrapolation of health effects from high experimental doses in animals to low environmental doses. These models are generally statistical in character and have little or no biological basis. Thus the use of a model for dose extrapolation introduces uncertainty in the dose-response estimate. In addition, these models contain assumptions that may also introduce a large amount of uncertainty. Generally the models have been developed to err on the side of over-estimating rather than under-estimating potential health risks.

The EPA CSFs are derived using the upper 95% confidence limit of the slope predicted by the linearized multi-stage (LMS) model used to extrapolate low dose risk from high dose experimental data. EPA recognizes that this method produces very conservative risk estimates, and that other mathematical models exist. EPA states that the upper-bound estimate generated by the LMS model leads to a plausible upper limit to the risk that is consistent with some of the proposed mechanisms of carcinogenesis. The true risk, however, is unknown and may be as low as zero. The LMS model is very conservative as it assumes strict linearity between the lowest dose that produced an effect and zero dose. However, the body has many mechanisms to detoxify chemicals, especially at low doses, and many mechanisms to repair damages if they should occur. Therefore, many scientists believe that most chemicals can cause cancer only above a "threshold" dose.

Uncertainty in TCE Toxicity Value

To account for some of the uncertainty and likely overconservatism in the CSF for TCE, risks were calculated two ways. For TCE, the upper end of the range of EPA's provisional CSFs was used, as well as the California Environmental Protection Agency (CalEPA) CSF. Because of uncertainty and concern that the upper end of the provisional EPA CSF range for TCE is overly stringent, the CalEPA CSF for TCE has been adopted by some states (e.g., Ohio) and EPA regions (e.g., Region 8) until EPA's Health Assessment for TCE is finalized. Both risk estimates were presented in the HHRA to provide upper and lower bounding estimates of potential TCE cancer risk. It should be noted that risk based RGs for TCE were derived using only the more stringent CSF.

Uncertainty in Iron Toxicity Value

Iron is an essential nutrient and there is considerable uncertainty in the oral toxicity value provided by EPA and used in the HHRA. It is a provisional value with a medium level of confidence assigned by the agency. The reference dose is below (more stringent than) the Recommended Daily Allowances (RDAs) for young children (the receptor group evaluated for noncarcinogenic effects from drinking water exposure) (Institute of Medicine, 2001). In addition, the provisional RfD for iron of 0.3 mg/kg-day is based on the upper bound value in the range of mean dietary (including supplemental) iron intakes. Repeated oral-dose studies in experimental animals found no significant effect from treatment with inorganic iron compounds. Human studies showing minimal effects contained "confounding factors, inadequate endpoint assessment, and too short a duration or too few subjects" according to NCEA.

7.1.5.3 Uncertainty Associated with Exposure Assessment

Exposure Scenarios

Exposure scenarios in a risk assessment are selected to be representative of potential exposures to COPCs in media that may be experienced by human receptors based on current and reasonably foreseeable land use. These exposure scenarios were developed for a hypothetical receptor, but one that would represent the reasonable maximal exposure (RME) scenario for the Site. Therefore, exposure levels assumed for these receptors are much greater than expected to occur in an actual population. Two future scenarios were evaluated for the Site, one assuming that there is potential exposure in the lagoons (prior to follow-on RA), and one assuming the follow-on RA will eliminate exposure in the lagoons.

Estimation of Exposure Point Concentrations (EPCs)

Sample Statistics. Exposure to COPCs at the Site is best estimated by the use of the arithmetic mean concentration of a COPC in each medium. Because of the uncertainty associated with estimating the true average concentration at a site, the EPA has required the use of the 95% UCL on the arithmetic mean as the EPC. Therefore, this is a very conservative estimate of the true arithmetic mean. EPCs in this risk assessment represent the lower of the maximum detected concentration or the 95% UCL on the mean. UCLs were calculated using EPA's ProUCL Version 3.0 software. Uncertainty can arise if the test results show the data set to be normally distributed when it is actually lognormally distributed, or vice-versa. This source of uncertainty, however, is unlikely to lead to large differences in the calculated dose for a given receptor.

Sample Location. In addition, the data used to calculate the EPCs was assumed to be representative of specific exposure areas and general site conditions. Sample locations in the various exposure areas were identified to be as representative of site conditions as possible. In the HHRA, it was assumed that sediments in the lagoons are present as surface soils after the follow-on RA. This is a conservative assumption in that some of these sediments will be under fill and therefore will be considered subsurface soils with less potential for human contact.

Environmental Degradation. The EPCs calculated in the risk assessment were based on current site conditions remaining constant for the assumed exposure duration – for an industrial or residential scenario this is a period of 25 to 30 years. However, it is well known in the scientific community that chemicals in the environment are subject to natural attenuation and biodegradation processes. Organic chemicals are naturally degraded in the environment by a variety of processes (i.e., photodegradation, microbial activity, hydrolysis, etc.). Environmental half-lives vary for specific chemicals based on environmental conditions (i.e., presence of bacteria, pH, exposures to sunlight and oxygen), and there are respected literature sources of such information. However, environmental degradation is not typically accounted for in the calculation of risks for a site. This has likely resulted in an over-estimation of Site risks.

Exposure Assumptions

When estimating potential human doses (i.e., intakes) from potential exposure to various media containing COPCs, several assumptions were made. Uncertainty may exist, for example, in assumptions concerning rates of ingestion, frequency and duration of exposure, and bioavailability of the chemicals in the medium. Typically, when limited information is available to establish these assumptions, a conservative (i.e., health-protective) estimate of potential exposure is employed. Default exposure assumptions recommended by the EPA are intended to be conservative and representative of an individual who consistently and frequently contacts environmental media at a site, a scenario that rarely occurs. Most individuals will contact media at non-site locations, while the risk assessment assumes that all exposure to environmental media will occur at the Site. Moreover, it is often assumed that contact with environmental media occurs in the areas having the highest chemical concentrations for the entire exposure frequency/duration used in the risk assessment, due to both statistical handling of the data and the original sampling plan.

The assumptions regarding exposure frequency and duration are very conservative. For example, while the agency default for working tenure is 25 years, the average occupational tenure for an industrial/commercial worker is 4.2 years. The use of conservative assumptions is likely to lead to an overestimate of potential risk.

7.1.5.4 Uncertainty Associated with Risk Characterization

The potential risk of adverse human health effects is characterized based on estimated potential exposures and potential dose-response relationships. Three areas of uncertainty are introduced in this phase of the risk assessment: the evaluation of potential exposure to multiple chemicals, the combination of upper-bound exposure estimates with upper-bound toxicity estimates, and the risk to sensitive populations.

Risk from Multiple Chemicals

Once potential exposure to and potential risk from each COPC is estimated, the total upper-bound potential risk posed by the Site is determined by combining the estimated potential health risk from each of the COPCs. Presently, potential carcinogenic effects are added unless evidence exists indicating that the COPCs interact synergistically (a combined effect that is greater than a simple addition of potential individual effects) or antagonistically (a combined effect that is less than a simple addition of potential individual effects) with each other. For most combinations of chemicals, little if any evidence of interaction is available. Therefore, additivity is assumed.

For noncarcinogenic effects, the HI should only be summed for chemicals that have the same or similar toxic endpoints. The toxic endpoint is defined as the most sensitive noncarcinogenic health effect used to derive the RfD or other suitable toxicity value. Again, there is little evidence to suggest whether those COPCs associated with a common toxicity endpoint are additive, synergistic, antagonistic, or independent in terms of mechanism of action. Whether assuming additivity leads to an underestimation or overestimation of risk is unknown.

Combination of Several Upper-Bound Assumptions

Generally, the goal of a risk assessment is to estimate an upper-bound, but reasonable, potential exposure and risk. Most of the assumptions about exposure and toxicity used in this evaluation are representative of statistical upper-bounds or even maxima for each parameter. The result of combining several such upper-bound assumptions is that the final estimate of potential exposure or potential risk is extremely conservative (health-protective).

This is best illustrated by a simple example. Assume that potential risk depends upon three variables (soil consumption rate, COPC concentration in soil and CSF). The mean, upper 95% bound and maximum are available for each variable.

One way to generate a conservative estimate of potential risk is to multiply the upper 95% bounds of the three parameters in this example. Doing so assumes that the 5% of the people who are most sensitive to the potential carcinogenic effects of a COPC will also ingest soil at a rate that exceeds the rate for 95% of the population, and that all the soil these people eat will have a chemical concentration that exceeds the concentration in 95% of the soil on Site. The consequence of these assumptions is that the estimated potential risk is representative of 0.0125% of the population (0.05 x 0.05 x 0.05 = 0.000125 x 100 = 0.0125%).

The risk assessment approach used here employed upper 95% bounds or maxima for most RME exposure and toxicity assumptions. Thus, it produces estimates of potential risk two to three orders of magnitude greater than the risk experienced by the average member of the potentially exposed populations.

Risk to Sensitive Populations

The health risks estimated in the risk characterization generally apply to the receptors whose activities and locations were described in the exposure assessment. Some people will always be more sensitive than the average person and, therefore, will be at greater risk. Dose-response values used to calculate risk, however, are frequently derived to account for additional sensitivity of subpopulations (e.g., the uncertainty factor of 10 used to account for intraspecies differences). Therefore, it is unlikely that this source of uncertainty contributes significantly to the overall uncertainty of the risk assessment.

Central Tendency Exposure Risk Estimates

The RME scenario presented in the HHRA represents a very conservative scenario in which both upper-bound exposure assumptions as well as upper-bound EPCs were used. For RME scenarios where estimated risks are within or below the EPA acceptable levels, confidence is high that there are no unacceptable risks due to the conservative nature of the scenario. However, where unacceptable risks are identified under the RME scenario, these risks may be overestimated. Therefore, a second scenario is considered to evaluate the potential risks under an average scenario, the Central Tendency Exposure (CTE). Under this scenario, exposure assumptions are meant to reflect more typical exposures rather than upper-bound. In addition, the CTE scenario assumes average EPCs rather than upper-bound. Three RME receptor scenarios resulted in estimated risks above EPA levels for before and after the follow-on RA scenarios. The three scenarios that were evaluated using CTE assumptions are:

- Future On-site Worker Drinking Water Scenario;
- Future Off-Site Resident Drinking Water Scenario; and
- Current/Future Recreational Angler Ingestion of Fish from Tomco Lake.

7.1.5.5 Summary of Sources of Uncertainty in Human Health Risk Assessment

The large number of assumptions made in the risk characterization introduces uncertainty in the results. Any one person's potential exposure and subsequent risk are influenced by all the parameters used in the HHRA and will vary on a case-by-case basis The results of the risk assessment must be carefully interpreted considering the uncertainty and conservatism associated with the analysis, especially where site management decisions are made.

7.2 Summary of Ecological Risk Assessment

7.2.1 Screening Level Ecological Risk Assessment (SLERA)

The SLERA (Decker and Lewis, 2003) was conducted by the EPA in 2003 and consisted of a preliminary ecological risk evaluation based largely on readily available site information and sampling data. In the SLERA, a preliminary conceptual site model (CSM) was developed for the Site, preliminary data quality objectives (DQOs) were established, available data were screened against ecotoxicological benchmarks and standards, and data gaps were identified. Since the results of the SLERA indicated that a conclusion of "no significant risk" could not be reached for ecological receptors potentially exposed to media at the Site, a Problem Formulation Statement (PFS; Step 3) was prepared and submitted to EPA (ENSR, 2004b).

The PFS was prepared to refine the COPCs identified in the SLERA, initiate the problem formulation phase of the baseline ecological risk assessment (BERA) at the Site, and help establish the goals, breadth, and focus of the BERA. The results of the SLERA and PFS Refinement of COPCs were used to scope the BERA.

7.2.2 Baseline Ecological Risk Assessment (BERA)

The BERA was conducted in accordance with the EPA Ecological Risk Assessment Guidance for Superfund and was preceded by a series of Work Plans and Technical Memoranda. The Final BERA Work Plan was submitted to EPA in 2005. In early 2006, an update to the BERA Work Plan was submitted which superseded the original Work Plan. The update was necessary to incorporate the results of the 2005 site investigations into the problem formulation process and to refine the scope of work. The Work Plan was further revised in 2006 based on changing conditions observed at the Site. Hydrological conditions had shifted from an aquatic system (characterized by standing water) to a drier, palustrine wetland system. A series of technical memoranda and discussions with EPA culminated in modifications to the Work Plan that more appropriately reflected the new hydrological conditions at the Site. Specifically, the focus of the BERA shifted to assessing potential risks to wetland receptors (soil invertebrates, wetland plants, and amphibians) associated with exposure to hydric soils in the tributary channels and associated palustrine wetlands located in the northerly portion of the Site.

Sampling and analysis conducted in support of the BERA consisted of hydric soil collection for bulk chemical analysis, laboratory toxicity testing, and tissue residue analyses. Whenever possible, samples evaluated in the BERA were collected synoptically to support a weight-of-evidence analysis of the results. The specific data evaluated in the BERA included:

- Cadmium and manganese concentrations in hydric soils,
- Selective sequential extraction (SSE) analysis for cadmium in hydric soils,
- Toxicity bioassays for early life stage amphibians exposed to hydric soils,
- Toxicity bioassays for wetland vegetation exposed to hydric soils,
- Cadmium concentrations in earthworms reared on hydric soil from the Site, and
- Analysis of field-collected amphibian tissue for cadmium and manganese.

The results of these analyses were incorporated into a risk characterization framework to assess the potential ecological risks to the selected wetland receptors. This framework included a summary of assumptions and associated uncertainties, an assessment of the strengths and weaknesses of the various analyses, and presentation of conclusions regarding the ecological significance of the estimated risks identified in the BERA.

The results of the chemical and biological testing program indicate that lower trophic level receptors (represented by amphibians, wetland plants, and soil invertebrates) are not at risk of lethal, or acute, harm due to exposure to cadmium and manganese in the hydric soils assessed at the Site. However, at several sampling locations representing the upper bound range of cadmium concentrations evaluated in the BERA, limited sub-lethal effects on plants and amphibians were observed and no amphibian or invertebrate tissue samples were available for tissue residue analysis from these sampling locations. Sub-lethal effects on growth were observed in both the amphibian and wetland plant toxicity tests. Although there was no toxic effect on plant root growth, there was an apparent, negative relationship between plant shoot growth and cadmium concentrations. There was no indication that unacceptable levels of manganese are present at the Site.

Relative to the presence of cadmium in hydric soil, the following preliminary Remedial Action Objectives (RAOs) have been established:

- Implement measures that restore concentrations of cadmium in hydric soils to RGs that are protective of sub-lethal effects on amphibian ecological receptors such as larval (early life stage) frogs; and
- Implement measures that restore concentrations of cadmium in hydric soils to RGs that are protective of sub-lethal effects on hydrophytic plant ecological receptors.
- Implement measures that restore concentrations of cadmium in hydric soils to RGs that are protective of sub-lethal effects on soil invertebrates such as the earthworm.

Based on the results of the BERA, there is potential for sub-lethal ecological risk due to exposure to hydric soils. While no lethal effects were observed or predicted from exposure to inorganic constituents in hydric soil, it is possible that sub-lethal impacts (i.e., growth impacts) may occur on plants and early life stage amphibians at cadmium concentrations ranging from 100 to approximately 160 mg/kg. Therefore, an RG of 100 mg/kg cadmium was established to be protective of these hydric soil receptors.

7.2.3 Uncertainty

7.2.3.1 Uncertainties Associated with Natural System Variability

Numerous factors may influence the bioavailability of constituents in the environment. Relative to the soil evaluated in the BERA, factors such as pH, redox potential, various biological processes, texture, and dissolved organic carbon concentrations may affect COPC bioavailability. With the exception of SSE analysis, COPCs were conservatively assumed to be bioavilable in the BERA. The variation in distribution of COPCs across soil and habitat types also introduced uncertainty into the tissue analysis results. Soils with the highest cadmium concentrations did not occur in habitat suitable for amphibians, for example, and therefore could not be included in the amphibian bioaccumulation assessment.

7.2.3.2 Uncertainties Associated with Benchmark Evaluations

The screening values used in the BERA do not generally account for possible synergistic, antagonistic, or additive effects of contaminant mixtures. These factors may result in an under-estimate or over-estimate of potential risks.

The screening values used in the BERA are based on direct or indirect toxicity, and do not consider bioaccumulation or bioavailability. This limitation may result in an under-estimate of potential risks.

The surface soil screening values have inherent uncertainty because they are based on a limited data set. Additionally, these values were developed primarily using terrestrial crop plant species and earthworms. The sensitivity of wetland plant and invertebrate species relative to terrestrial plants and invertebrates is not known. These screening values may be based on receptors other than earthworms and plants and may over or under-estimate risk.

7.2.3.3 Uncertainties Associated with Toxicity Testing Program and Bioaccumulation Study

Species used for testing in the laboratory are assumed to be equally sensitive to COPC as those found on-site. Laboratory toxicity tests are normally conducted with species that are highly sensitive to contaminants in the media of exposure. Guidance manuals from regulatory agencies contain lists of these organisms that they consider to be sensitive enough to be protective of naturally occurring organisms at a site. However, reaction of all species to COPC is not known, and species found within the site might be more or less sensitive than those used in the laboratory toxicity testing. The toxicity tests are considered to be short-term assays so there is some uncertainty in predicting long-term population- or community-level impacts from these assays.

In addition, species introduced to test media have not been acclimated to site conditions. Species found at a site have usually been naturally acclimated to certain physical and chemical conditions and potential stressors. When organisms from a controlled laboratory environment are introduced to media collected from the site, they are often susceptible to these stressors, and may have adverse reactions that are not indicative of site conditions.

Field and laboratory manipulation of soil prior to the introduction of laboratory test organisms may alter the bioavailability of COPCs. Soils in their native state are often at some degree of chemical equilibrium. When samples are collected, they are homogenized, sieved, and otherwise handled prior to testing. This can alter the bioavailability of COPCs, making them more or less available to test organism exposure.

If a toxic impact is observed in a toxicity test, there may not be a casual relationship between the toxic effect and measured chemical concentrations in the sediment. Physical properties of the sediment (e.g., TOC content, grain size) may also impact the ability of test organisms to survive and grow. Alternatively unidentified and unmeasured chemicals may also be present in the sediments. Lastly, as identified elsewhere in the BERA, tissue samples were not collected from areas with the highest soil cadmium concentrations. This has the potential to result in an under-estimate of potential exposure relative to the tissue residue analyses considered in the evaluation.

7.2.3.4 Uncertainties Associated with the Selective Sequential (SSE) Extraction Process

The main uncertainty associated with the SSE process lies in the relationship between mobile cadmium and bioavailable cadmium. Part of the SSE results includes the relative amount of mobile cadmium present in the soil sample. While it can be assumed that some portion of mobile cadmium is bioavailable, there are significant uncertainties associated with determining the exact amount of bioavailable cadmium within the mobile fraction. Based on the results of the toxicity testing program at this Site, it appears that the SSE results may over-estimate potential risks related to cadmium bioavailability at this Site. However,the data evaluated in the BERA suggested that at least some of the cadmium is indeed bioavailable.

8.0 Remedial Action Objectives

Remedial Action Objectives (RAOs) for the Site were developed based on a review of the results of the Site sampling data, site-specific risk and fate and transport evaluations, and review of ARARs. RAOs are statements that specify site remedial action goals at the Site. The RAOs further identify which COCs, media and exposure pathways that will be addressed by the remedial actions. Remedial Action Goals establish exposure levels that are protective of human health and the environment. RAOs for the Site were developed and presented in the RI report. The RAOs for groundwater at the Site are as follows:

- Implement measures to prevent the ingestion of, and direct contact with, groundwater containing constituents at concentrations in excess of cleanup goals noted in Table 4. Table 4 is based on current federal regulatory drinking water standards (MCLs), current TDEC MCLs. Total HI's greater than 1, and a cumulative excess lifetime cancer risk greater than 1 E-04.
- Prevent or minimize further migration of the contaminant plume by reducing the concentrations of groundwater contamination in the areas of highest site–related groundwater concentrations above drinking water standards found in Table 4

9.0 Description of Alternatives

The purpose of this section is to briefly summarize the remedial alternatives that were evaluated in the FS for groundwater at the Site. The following groundwater alternatives were evaluated during the FS.

- Alternative GW1 – No Action
- Alternative GW2 – Monitored Natural Attenuation (MNA)
- Alternative GW3 – Enhanced Reductive Dechlorination (ERD) with MNA
- Alternative GW4 – In-Situ Chemical Oxidation (ISCO) with MNA
- Alternative GW5 – In-Situ Nano-scale Zero Valent Iron (NZVI) with MNA
- Alternative GW6 – Groundwater Recovery and Treatment with MNA
- Alternative GW7 – Phytoremediation with MNA

9.1 Common Elements for Alternatives GW2 through GW7

Alternatives GW2 through GW7 have two components in common (use of institutional controls and groundwater MNA). Alternative GW2 is MNA and is used in conjunction with active remedies. For this reason, MNA will only be described in detail for Alternative GW2. Although the description of the institutional controls and MNA are not repeated in the discussions of each alternative, differences in their planned implementation are identified where appropriate.

Institutional Controls: Institutional controls to be implemented at the Site in conjunction with the active remedies are restrictive covenants that are deed recorded to 1) maintain and limit use of the Site to heavy industrial and 2) prevent any use of the surficial aquifer where groundwater has been contaminated from the site above RG's. The restriction of use of on-site and off- site groundwater shall continue until the RGs are met.

Use of the property has already been limited to heavy industrial through zoning since the ealy 1970's. If a property owner desired to change the current or future zoning classification, a petition would be submitted to the Memphis Shelby County Planning and Development Department. As part of the zoning change petition, the property owner must secure approval from Memphis and Shelby County Health Department (MSCHD) that shows requirements have been successfully met proving that no adverse ecological or human effects would result from the changes in the proposed property use. With the documented status of the Site as a CERCLIS NPL-Equivalent site, the MSCHD is unlikely to concur with a zoning change without a demonstration that the Site is safe for use other than heavy industrial. Therefore, the conceptual site exposure model indicating current and future use of the Site as an industrial site is supported by current zoning and will be supported through regulatory processes (i.e., institutional controls) (ENSR, 2004a).

The primary groundwater institutional control will be strict prohibition of drilling of wells and use of groundwater in the impacted area pursuant to MSCHD water well regulatory program. MSCHD has statutory authority to deny well applications based on health, safety, and general welfare considerations in accordance with Rules and Regulations of Wells in Shelby County (hereafter referred to as Well Regulations). Well Regulations specifically require that MSCHD deny a permit application to construct a water well if use of the well would increase the potential for harm to public health safety and welfare, or if the proposed well would enhance the movement of contaminated groundwater or material into the shallow or deep aquifer. The rules more specifically require that a water well cannot be sited or placed in service within a half-mile of the designated boundaries of a listed federal or state Superfund site or RCRA corrective action site. (Section 4.01-C, Well Regulations). MSCHD has been, and will continue to be, supplied copies of all investigative and monitoring reports to assist the MSCHD hydrogeologist with determining areas where water wells should not be installed or placed in service.

Institutional controls may be used as the principal tool for preventing human exposure to contaminated groundwater downgradient of the Site. Maintenance of institutional controls is an essential component of the selected remedy and is necessary to prevent future risk resulting from consumption of contaminated groundwater.

Five Year Reviews

Each of the seven alternatives (GW1 through GW7) require five-year reviews. This requirement shall remain as long as there are hazardous substances, pollutants, or contaminants present on or off site that do not allow for unlimited use and unrestricted exposure

9.2 Alternative GW1: No action

The no action alternative was developed as required by the NCP, which regulates implementation of the Superfund law. No action is used as a baseline for comparing other alternatives. Under this alternative, EPA would take no action to remedy any contaminated media at the Site. The potential risks associated with the contamination would not be minimized by this action. The only activity assumed to be involved in this alternative is the 5-year review mandated by CERLCA.

The following are estimated costs for implementing Alternative GW1 (using a 7% discount rate):

- Estimated design costs: $31,500
- Estimated O&M costs: $0
- Total present worth cost: $129,200

9.3 Alternative GW2: Monitored natural attenuation (MNA)

Alternative GW2 consists of the following components:

- Institutional controls;
- Natural attenuation of groundwater contaminants, and;
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

Natural attenuation depends on existing inherent processes, including adsorption, desorption, dilution, dispersion, volatilization, hydrolysis and biodegradation, to attenuate the COCs in groundwater to levels that achieve the RGs. Initial evaluation of key geochemical parameters and the ratio of VOCs present to their degradation products at the Site, indicates that biologically assisted reductive dechlorination is reducing concentrations of VOCs in groundwater at the Site. This conclusion is supported by both field and laboratory data collected during the RI and the groundwater monitoring plan (GMP). Also, a declining and consistent trend is evident downgradient of Lagoon 123. However, available data is limited and further monitoring to determine if natural attenuation processes are sufficiently reducing the mass of CVOCs in the plume is required. Typically, MNA demonstration involves implementing the following tasks: (1) collecting field and laboratory biogeochemical indicators (electron acceptors and degradation products); (2) long-term monitoring to document reduction in contaminant concentrations (declining trends); and (3) groundwater modeling. Using the existing data and a BIOCHLOR model, the estimated time required to achieve the RGs by means of naturally attenuation is 75 years.

Institutional controls shall be implemented in the form of zoning classification (Heavy Industrial) for the Site along with well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the impacted groundwater resulting from the release of on-site contaminants until the RGs have been reached.

The following are estimated costs for implementing Alternative GW2 (using a 7% discount rate):

- Estimated design costs: $286,800
- Estimated monitoring costs: $1,955,400
- Total present worth cost: $ 2,837,200
- Estimated Construction Timeframe: 6 months
- Estimated Time to Achieve RAOs: 75 years

9.4 Alternative GW3: Enhanced reductive dechlorination (ERD) with MNA

Alternative GW3 consists of the following components:

- Institutional controls;
- Installation of injection wells;
- ERD injections in treatment area;
- Natural attenuation of groundwater contaminants; and
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

Enhanced reductive dechlorination (ERD) would be implemented to remediate areas with elevated CVOC groundwater concentrations and the remaining untreated portions of the groundwater plume shall be allowed to attenuate by natural processes. This alternative involves injection of a biodegradable electron donor/carbohydrate solution (e.g., HRC, vegetable oil, corn syrup, sodium lactate etc.) through wells to enhance in-situ anaerobic treatment zones conducive to the reductive dechlorination of elevated CVOCs.

Treatment shall target areas of impacted groundwater that exceed TCE concentrations greater than 1,000 ug/l. The actual detailed components of the treatment system shall be determined during design, however the following assumptions were made to provide a basis for comparison and to aid in a general costing of this remedial alternative. A Geoprobe™ rig will be used to inject the electron donor solution, using approximately 310,900 gallons of a 15 percentage solution. Injections will be conducted at approximately 292 locations with a spacing of approximately 40-feet on center. Approximately 500 to 1500 gallons of solution shall be injected per location across the groundwater plume's thickness (thickness ranges from 10 to 35 feet). Monitoring of CVOCs and anaerobic biodegradation parameters will be conducted on an estimated 26 wells on a quarterly basis for the first year and semi-annual basis for years 2 and 3.

MNA will be used in conjunction with the ERD remedy to address dissolved contaminants in groundwater downgradient of Lagoon 123. The scope of the MNA effort is similar to that described above for GW2. MNA is estimated to take 40 years to achieve RGs after ERD has reduced TCE concentrations to 1,000 ug/l (estimate is based on natural decay of TCE using the Biochlor model). Given time required for ERD to reduce contaminant levels to 1,000 ug/l, the total time required by this option to achieve RGs is 45 years.

Institutional controls shall be implemented in the form of the existing heavy industrial zoning classification for the Site along with well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the impacted groundwater resulting from the release of on-site contaminants until the RGs have been reached.

The following are estimated costs for implementing Alternative GW3 (using a 7% discount rate):

- Estimated capital costs: $1,259,700
- Estimated O&M costs: $1,811,800
- Total present worth cost: $3,518,600
- Estimated Construction Timeframe: 8 weeks
- Estimated Time to Achieve RAOs: 40 years

9.5 Alternative GW4: In-situ chemical oxidation (ISCO) with MNA

Alternative GW4 consists of the following components:

- Institutional controls;
- Installation of injections wells;
- Chemical oxidation injections in treatment area;
- Natural attenuation of groundwater contaminants; and
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

This alternative involves manual injection of a reagent (oxidant - electron acceptor) solution through wells into the subsurface where reagents will oxidize COCs in the treatment area. The chemical oxidant (e.g., permanganate, persulfate, peroxide, ozone, etc.) will react with the contaminants and degrade to carbon dioxide, water, and inorganic chloride. Generally, metals may be oxidized by the application of ISCO. .

Presence of high organic carbon and inorganic species in soil and groundwater can act as oxidant sinks, limiting the affectiveness of the remedy. Therefore, a field pilot study would be required to estimate the oxidant requirements and to evaluate effectiveness of the treatment process prior to full-scale implementation.

For the purpose of costing, the treatment area will be where the groundwater plume TCE concentrations exceed 1,000 ug/l. A Geoprobe™ rig will be used to inject the electron acceptor solution, using approximately 1,900,000 gallons of a 30 percentage solution. Four injections will be conducted at approximately 292 locations with a spacing of approximately 40-feet on center to allow for the optimum contact time between the oxidant and the contaminant which is affected by the amount of organics in the soil and groundwater. The injections will involve injecting 1,000 to 2,000 gallons of solution at each location at 5-foot depth increments across the groundwater plume thickness (10 to 35 feet depending on location). The duration of the injections will be one year. Monitoring of CVOCs and anaerobic biodegradation parameters will be conducted on an estimated 26 wells on a quarterly basis for the first year, semi-annual basis for years 2 and 3.

MNA will be used in conjunction with the active remedy to address dissolved contaminants in groundwater downgradient of Lagoon 123. The scope of the MNA effort is similar to that described above for GW2. MNA is estimated to take 50 years to achieve RGs after ISCO has reduced TCE concentrations to 1,000 ug/l (estimate is based on natural decay of TCE using the Biochlor model

Institutional controls shall be implemented in the form of the existing heavy industrial zoning classification for the Site along with well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the impacted groundwater resulting from the release of on-site contaminants until the RGs have been reached.

The following are estimated costs for implementing Alternative GW4 (using a 7% discount rate):

- Estimated capital costs: $11,076,700
- Estimated O&M costs: $1,884,900
- Total present worth cost: $13,478,200
- Estimated Construction Timeframe: 1 year
- Estimated Time to Achieve RAOs: 50 years

9.6 Alternative GW5: In-situ nano-scale zero valent iron (NZVI) with MNA

Alternative GW5 consists of the following components:

- Institutional controls;
- Installation of injections wells;
- NZVI injections in treatment area;
- Natural attenuation of groundwater contaminants; and
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

This alternative involves injection of a nanoscale zero valent iron (NZVI) solution through wells into the subsurface to abiotically reduce chlorinated solvents in the treatment area where the groundwater plume TCE concentrations exceed 1,000 ug/l. The NZVI serves as an electron donor in the abiotic dechlorinating process. Nanoscale iron (abiotic) technologies can also reduce metals, if present in the treatment area groundwater.

NZVI has a smaller size and greater surface area. It is thought to be more effective technology for remediation of areas with elevated CVOC concentrations than the iron substrate used in permeable reactive barriers. The greater surface area allows the NZVI particles to react at a much higher rate with the CVOCs. This potentially makes NZVI more suitable for high concentrations of CVOCs. The small particle size provides more mobility into the soil pores and is more easily injected into shallow and deep aquifers. The NZVI would be injected into the treatment area allowing MNA to continue the dechlorination process downgradient.

A Geoprobe™ rig will be used to inject the NZVI solution, using approximately 66,000 pounds of NZVI. Injections will be conducted at approximately 1,098 locations. The injections will be conducted across the groundwater plume thickness (10 to 35 feet depending on location). Monitoring of CVOCs and anaerobic biodegradation parameters will be conducted on an estimated 26 wells on a quarterly basis for the first year, semi-annual basis for years 2 and 3.

MNA will be used in conjunction with the active remedy to address dissolved contaminants in groundwater downgradient of Lagoon 123. The scope of the MNA effort is similar to that described above for GW2. The time that it takes for natural attenuation to achieve RGs can be estimated from the natural decay of TCE, and is estimated using the Biochlor model after NZVI reduced TCE concentrations to 1,000 ug/L. 50 years is the estimated time it shall take for the plume downgradient of lagoon 123 to achieve RGs by means of natural attenuation.

Institutional controls shall be implemented in the form of the existing heavy industrial zoning classification for the Site along with well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the impacted groundwater resulting from the release of on-site contaminants until the RGs have been reached.

The following are estimated costs for implementing Alternative GW5 (using a 7% discount rate):

- Estimated capital costs: $5,326,400
- Estimated O&M costs: $1,889,900
- Total present worth cost: $7,570,100
- Estimated Construction Timeframe: 1 year
- Estimated Time to Achieve RAOs: 50 years

9.7 Alternative GW6: Groundwater recovery and treatment with MNA

Alternative GW6 consists of the following components:

- Institutional controls;
- Installation of recovery wells in treatment area;
- Installation of on-site recovery and treatment systems;
- Natural attenuation of groundwater contaminants; and
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

Groundwater recovery and treatment (also known as pump and treat) is a remedial technology designed to hydraulically control and treat affected groundwater. Groundwater extracted from recovery wells would be treated on-site and/or discharged under the appropriate permit. Discharge of the treated groundwater would require a National Pollutant Discharge Elimination System (NPDES) permit or approval to discharge to a publicly owned treatment works (POTW).

MNA will be used in conjunction with the active remedy to address dissolved contaminants in groundwater downgradient of the treatment area. The treatment area will be where the groundwater plume TCE concentrations exceed 1,000 ug/l. Installation of recovery wells in the areas with elevated CVOC concentration would contain these concentrations, allowing the downgradient plume to naturally attenuate. The scope of the MNA effort is similar to that described above for GW2. If the TCE concentrations of greater than 1,000 ug/L are contained, then downgradient natural attenuation would take 50 years. However, a batch flushing model indicates that a pump and treat system operating at 10 gallons per minute would take 82 years to restore the treatment area to 1,000 ug/L.

Approximately 15 recovery wells would be installed to effectively contain the treatment area. The extracted groundwater would be piped to a treatment system. An air stripper would be used to separate phases. Granular activated carbon would be used to treat the vapor phase. Liquid phase carbon would be used to treat the groundwater prior to discharge. Sampling of the effluent for VOCs would be conducted monthly. Monitoring of CVOCs and anaerobic biodegradation parameters will be conducted on an estimated 26 wells on a quarterly basis for the first year, semi-annual basis for years 2 through 15 and annual basis for years 16 through 82.

Institutional controls in the form of the existing zoning classification of heavy industrial for the Site and well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the impacted groundwater resulting from the release of on-site contaminants until the RGs have been reached.

The following are estimated costs for implementing Alternative GW6 (using a 7% discount rate):

- Estimated capital costs: $1,704,300
- Estimated O&M costs: $6,669,800
- Total present worth cost: $8,082,400
- Estimated Construction Timeframe: 6 months
- Estimated Time to Achieve RAOs: 82 years

9.8 Alternative GW7: Phytoremediation with MNA

Alternative GW7 consists of the following components:

- Institutional controls;
- Installation of stands of trees in treatment area;
- Natural attenuation of groundwater contaminants; and
- Development of a performance monitoring plan to monitor and evaluate the effectiveness of the natural attenuation remedy.

Phytoremediation is the use of stands of deep-rooted trees to control the migration of groundwater contaminant plumes. This technology is an innovative approach that is becoming increasingly popular because these systems are cost effective, especially for operation and maintenance. Special cultural practices have been developed to train roots to extend through a relatively thick vadose zone to the interface between saturated and unsaturated soils. Plant uptake of moisture from the capillary fringe and shallow groundwater thus creates a capture zone. The capture zone is a specific thickness of the saturated zone in which groundwater that passes beneath the root-zone and within the area of their hydraulic influence is used by the trees.

Organic chemical contaminants dissolved in the groundwater that enter the capture zone are transferred to the unsaturated root-zone where, depending on the chemical class, they would be removed by various treatment processes. The fate of chlorinated aliphatic compounds involves plant uptake and release into the atmosphere (phytovolatilization) followed by photo-oxidation. For this class of compounds, a competing treatment process is mineralization by bacteria residing in the rhizosphere around the plant roots.

A recent computer modeling study was performed to investigate the development of capture zones as a result of the interactions between the transpiring trees and the groundwater (Thibodeau and Ferro, 2007). The study focused on how the thickness of the capture zone varied as a function of the number of rows of trees and the hydraulic conductivity of the aquifer. The study suggested that for an aquifer with a hydraulic conductivity of less than 5 ft/day (such as at the Site), eight rows of trees can create a capture zone that is approximately 23 ft thick. CVOC concentrations deeper than 23 feet into the aquifer and laterally beyond the treatment area would be monitored to demonstrate natural attenuation.

The groundwater phytoremediation system would be designed to hydraulically control the migration of the most contaminated portion of the contaminant plume. The phytoremediation system would consist of two dense zones of deep-rooted willow trees (*Salix alba*), 1,000 trees total on approximately 2.3 acres.

TCE concentrations in the treatment zone are between 1,000 to 10,000 ug/L (and the concentrations of total CVOCs are in about this same range of concentrations). Phytotoxicity would not be expected to be a limiting factor. CVOCs are only minimally toxic to willow trees in these concentration ranges (Newman, 1997).

Special planting methods would be used to produce deep-rooted willow trees (*Salix alba*) that use groundwater as a source of moisture. At each planting location, boreholes (e.g. 8 inch diameter) would be drilled down to the water table, and the boreholes backfilled with a mixture of sand and compost (60% sand; 40% compost). Drilling waste would be containerized and disposed of properly. The planting stocks would be long hardwood cuttings (8 ft long "poles"). The poles would be planted deeply in the backfill, ideally with the bottom end of the pole at the level of the saturated zone, and with only a few inches of the cutting above ground-surface. The poles would develop roots along sections of the pole that are exposed to moist soil and would use water from the saturated zone as soon as the first growing season. Therefore no irrigation system would be necessary.

The treatment area will be where the groundwater plume TCE concentrations exceed 1,000 ug/l to a depth of 23 feet below the water table. MNA will be used in conjunction with this remedy to address dissolved contaminants in groundwater downgradient of the treatment area. Elevated levels of TCE shall remain at depth due to the limitation of the effective range of this alternative. Because elevated TCE contamination at depth shall be address by MNA alone,the estimated time for the alternative to meet RGs is 75 years. Monitoring will be conducted on a quarterly basis for the first year, semi-annual basis for years 2 through 15 and annual basis for years 16 through 30.

Institutional controls shall be implemented in the form of the existing heavy industrial zoning classification for the Site along with well permitting restrictions. Additionally, covenants will be placed on the property deeds to restrict the use of the on-site groundwater until the RGs have been reached.

The following are estimated costs for implementing Alternative GW7 (using a 7% discount rate):

- Estimated capital costs: $319,700

- Estimated O&M costs: $1,946,600
- Total present worth cost: $2,703,400
- Estimated Construction Timeframe: 10 weeks
- Estimated Time to Achieve RAOs: 75 years

10.0 Summary of Comparative Analysis of Alternatives

The alternatives are evaluated against one another by using the following nine criteria:

- Overall protection of human health and the environment;
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs);
- Long term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short term effectiveness;
- Implementability;
- Costs;
- State acceptance; and

  Community acceptance.

The NCP categorized the nine criteria into three groups:

- **Threshold criteria:** the first two criteria, overall protection of human health and the environment and compliance with ARARs (or invoking a waiver), are the minimum criteria that must be met in order for an alternative to be eligible for selection.
- **Primary balancing criteria:** the next five criteria are considered primary balancing criteria that are used to weigh major trade-offs among alternative cleanup methods.
- **Modifying criteria:** state and community acceptance are modifying criteria that are formally taken into account after public comment is received on the Proposed Plan. Community acceptance is addressed in the responsiveness summary of the ROD.

10.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls.

With the existing groundwater restrictions, Alternative GW1 is expected to be protective of human health, but may not be protective of the environment as it does not include active measures that would reduce or monitor contaminant migration. Alternative GW2 is expected to be protective of human health and environment as natural processes are expected to provide a reduction in mobility, toxicity and volume and a monitoring program will be instituted to ensure these processes are occurring.

Alternatives GW3 through GW6 are expected to reach RGs much sooner than Alternatives GW1 GW2, and GW7 thereby providing increased protection to human health and the environment. Alternatives GW3, GW4 and GW5 are expected to significantly reduce COC concentrations within a shorter timeframe in the treatment areas of the Site. However, the overall protection of Alternative GW4 is minimized due to the potential to oxidize any metals that are present and temporarily increase their mobility. Alternatives GW 3 through GW7 will reduce the migration and concentrations of the contaminated groundwater. Alternatives

GW6 and GW7 provide an extra measure of protection by means of hydraulic control/containment of the treatment areas. The resulting reduction of key COCs in treatment areas in Alternatives GW3 through GW7 will enhance MNA of residual COCs. Due to active treatment of groundwater and institutional controls, Alternatives GW3, GW4, GW5, GW6 and GW7 will provide better protection of human health and the environment compared to Alternatives GW1, and GW2 .

10.2 Compliance with ARARs

Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and 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, remedial action, 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, remedial action, 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. To Be Considered (TBC) Criteria are non-promulgated advisories or guidance documents issued by federal or state governments. They do not have the status of ARARs but can be considered in determining the necessary level of cleanup for the protection of human health or the environment. Compliance with ARARs addresses whether a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for invoking a waiver.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances to the conduct of activities solely on the basis of location. EPA considers the applicable or relevant and appropriate provisions of the statutes, rules, regulations, and requirements contained in Table 5 as location specific ARARs.

Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. EPA considers the applicable or relevant and appropriate provisions of the statutes, rules, regulations, and requirements contained in Table 6 as action specific ARARs.

Chemical-specific ARARs are specific numerical quantity restrictions on individually-listed contaminants in specific media. Examples of chemical-specific ARARs include drinking water standards and ambient air quality standards. Because there are usually numerous contaminants of potential concern for any remedial site, various numerical requirements can be ARARs. In most cases for this remedy, EPA has chosen to incorporate TDEC groundwater cleanup standards found in Tennessee statutes when they existed for Site COCs, where they were developed based on health based criteria, and were derived using currently accepted risk assessment assumptions and processes utilized by the CERCLA program. EPA considers the applicable or relevant and appropriate provisions of the statutes, rules, regulations, and requirements contained in Table 7 as chemical specific ARARs.

Alternative GW1 is not expected to meet ARARs as no active remedy, monitoring, or controls would be involved. Alternatives GW2 through GW7 are expected to meet chemical-specific ARARs. Although it is difficult to predict the exact duration of time required to meet the ARARs with the limited data, Alternative

GW2 is anticipated to require a longer timeframe since active treatment would not be implemented to reduce or contain elevated COC concentrations.

Alternatives GW1, GW2 and GW7 comply with location-specific ARARs. If flooding occurs in the floodplain, migration of the contaminated groundwater and groundwater flow direction may be altered. Alternatives GW3, GW4, GW5 and GW6 will comply with the location-specific ARARs providing proper precautions are taken if portions of the treatment area are in the floodplain.

Alternative GW1 would not meet action-specific ARARs since no action or controls will be involved. Alternative GW2 would comply with ARARs. Alternatives GW3, GW4 and GW5 would comply with OSHA and UIC requirements; however, these alternatives require injection wells to be installed which are not allowed under Shelby County Rules and Regulations of Wells. Injection wells may be considered by Shelby County after a lengthy appeal process. Alternative GW6 would comply with OSHA, NPDES and air quality requirements. Alternative GW7 would comply with all action-specific ARARs.

10.3 Long Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to the expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup 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.

Alternative GW1 is not expected to reduce residual risk. The residual risk is expected to be reduced for Alternative GW2 through natural processes and institutional controls (groundwater use restrictions). The residual risk for Alternatives GW3 through GW5 would be low due to active treatment of groundwater with elevated COC concentrations. Alternatives GW6 and GW7 may take longer to reduce elevated concentrations, however, the elevated concentrations will be contained from further migration. Further, the risks would be minimal for untreated residuals due to groundwater use restrictions for on-site areas and adjacent properties. The active treatment technologies in Alternatives GW3 through GW7 have been successfully used for remediation of organic constituents. Alternatives GW3, GW6 and GW7 have been successful for assisting in remediation of inorganic constituents, if present , through adsorption processes. Since the effectiveness of in-situ treatment alternatives are controlled by the biogeochemical conditions and hydrogeology at the Site, pilot studies would be required to develop design criteria for Alternatives GW3 through GW7. Since limited data is currently available to evaluate degradation rates in groundwater (2 to 3 data sets), long-term data collection is being implemented to better evaluate trends for Alternatives GW2 through GW7. Due to active treatment and mass reduction, the duration of long-term monitoring is expected to be shorter for Alternatives GW3 through GW7 than that of Alternative GW2.

TABLE 5
Identification of Location-Specific ARARs

Location	Requirements	Prerequisites for Applicability	Citation
Within 100-year Floodplain	Remedial actions meeting requisite requirements must be designed, constructed, operated and maintained to avoid washout.	Remedial action includes treatment, storage, or disposal of a hazardous waste.	40 CFR 264.18(b)
Within Floodplain	Remedial actions meeting requisite requirements must be conducted so as to minimize potential harm, restore and preserve natural and beneficial values of the floodplain. (Floodplain defined as lowland and relatively flat areas adjoining inland and coastal waters and other floodprone areas such as offshore islands, including areas subject to a one percent chance of flooding in any given year (100-year floodplain).	Any activity occurring in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood prone areas.	40 CFR 6 Appendix A (Protection of Floodplains) 16 USC 661 et seq. (Fish and Wildlife Coordination Act) 40 CFR 6.302
Stream or River	Measures must be taken to prevent, mitigate, or compensate for project-related losses of fish and wildlife resources. The U.S. Fish and Wildlife Service and analogous state agency must be consulted.	Diversion, channeling or other activity as part of the remedial action modifies a stream or river and affects fish or wildlife.	16 USC 1271 et seq. (Fish and Wildlife Coordination Act)
River or Canal	Disposal or discharge of refuse into a navigable waterway is generally prohibited. Excavation or filling in a canal or channel of a navigable waterway must be "recommended by the Chief of Engineers and authorized by the secretary of the Army."	Activities adjacent to a river or harbor.	Rivers and Harbors Act of 1899; 33 U.S.C. 403,407.
Wetlands	Actions to prohibit discharge of dredged or fill material into wetlands without a permit. Actions to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands to the extent possible.	Wetland as defined in U.S. Army Corps of Engineers regulations. Action involves construction of facilities or management of properties in wetlands, as defined by 40 CFR 6, Appendix A, Section 4(j).	Clean Water Act Section 404; 40 CFR 230, 33 CFR 320-330. 40 CFR 6, Appendix A.

TABLE 6
Identification of Action-Specific ARARs

Federal Groundwater			
Action	**Requirement**	**Prerequisite for Applicability**	**Citation**
Recharge of Treated Groundwater	May need to meet the substantive requirements of an Underground Injection Control (UIC) permit. UIC program prohibits: • Injection activities that allow movement of contaminants into underground sources of drinking water that may result in violations of MCLs or adversely affects health. • Construction of new Class IV wells, and operation and maintenance of existing wells. Class IV wells are banned except for reinjection of treated groundwater into the same formation from which it was withdrawn, as part of a CERCLA cleanup or RCRA corrective action. The Director of the UIC program in a state may lessen the stringency of 40 CFR 144.52 construction, operation, and manifesting requirements for a well if injection does not occur into, through, or above a USDW or if the radius of endangering influence (see 40 CFR 146.06(c)) is less than or equal to the radius of the well. • Report non-compliance orally within 24 hours. • Prepare, maintain, and comply with plugging and abandonment plan. Monitor Class I wells by: • frequent analysis of injection fluid; • continuous monitoring of injection pressure, flow rate, and volume; and • installation and monitoring of ground-water monitoring wells. Applicants for Class I permits must: • Identify all injection wells within the area of review.	Approved UIC program is required in states listed under SDWA section 1422. (All states have been listed.) Class I wells and Class IV wells are the relevant classifications for CERCLA sites. Class I wells are used to inject hazardous waste, beneath the lowermost formation containing, within one quarter mile, an underground source of drinking water (USDW). Class IV wells are used to inject hazardous or radioactive waste into or above a formation which contains, within one quarter mile of the well, an underground source of drinking water. The State of Tennessee has primacy for the enforcement of UIC regulations. Class I wells. Class I wells are used to inject hazardous waste, beneath the lowermost formation containing, within one quarter mile, an underground source of drinking water (USDW).	40 CFR 144.12 40 CFR 144.13 40 CFR 144.13(c) 40 CFR 144.16 40 CFR 144.28(b) 40 CFR 144.51(b) 40 CFR 144.28(g)(1) 40 CFR 144.55

TABLE 6
Identification of Action-Specific ARARs

Federal Groundwater			
Action	**Requirement**	**Prerequisite for Applicability**	**Citation**
Recharge of Treated Groundwater (Continued	Task action as necessary to ensure that such wells areproperly sealed, completed, or abandoned to prevent contamination of USDW.		
	Criteria for determining whether an aquifer may be determined to be an exempted aquifer included current and future use, yield, and water quality characteristics.		40 CFR 146.4
	USDW, taking into consideration well depth, injection pressure, hole size, composition of injected waste, and other factors.		
	Conduct appropriate geologic drilling logs and other tests during construction.		40 CFR 146.12(d)
	Injection pressure may not exceed a maximum level designed to ensure that injection does not initiate new fractures or propagate existing ones and cause the movement of fluids into a USDW.		
	Continuous monitoring of injection pressure, flow rate, and volumes, and annual pressure, flow rate, volume and annual pressure, if required.		
	Demonstration of mechanical integrity is required every 5 years.		
	Reporting and monitoring requirements are on a case-by-case basis as required by TDEC.		
	Comply with state underground injection requirements.		40 CFR 147
	Treat groundwater to Maximum Contaminant Levels (MCLs) and comply with all analytical methods, reporting, and recordkeeping requirements.	All groundwater in Tennessee.	40 CFR 141
	Regulation states that all public water must meet the established primary and secondary drinking water standards unless a variance is issued by the State.	Groundwater at the site must be classified by the State of Tennessee as a drinking water source.	40 CFR 142 and 143

TABLE 6
Identification of Action-Specific ARARs

State Groundwater			
Action	**Requirements**	**Prerequisites for Applicability**	**Citation**
All Remedial Actions	Groundwater will not have a default classification. The classification of groundwater will be determined based on annual well yield, total dissolved solids, and current and future use. If groundwater is determined to be polluted, then aerial extent (vertical and horizontal) of the pollution will be determined.	All groundwater in the state of Tennessee.	TDEC Water Quality Control Board Rules and Regulations for the Classification of Groundwater
Groundwater Extraction	The Tennessee Department of Environment and Conservation-Water Supply Division and the Rules and Regulations for Wells In Shelby County regulate the placement, depth and construction of wells that extract groundwater. Tennessee Environmental Assessment Guidelines and Rules and Regulations of Wells in Shelby County outline requirements for installation, abandonment and approvals for extraction wells for site remediation. Permits and fees are required to install any well in Shelby Co.	A well that extracts groundwater for consumption and domestic public use.- **relevant and appropriate** Remedial action includes construction of groundwater extraction wells.	TDEC-Water Supply Division. Rule 1200-4-9. Rules and Regulations of Wells in Shelby Co. TDEC Environmental Assessment Guidelines. Rules and Regulations of Wells in Shelby Co.
Recharge of Treated Groundwater/	Wells used to reinject treated groundwater in site remediation are considered Class V wells under the Tennessee Underground Injection Control Regulations. Construction, use, or operation of a Class V well requires a permit, and in an aquifer which is an "Underground Source of Drinking Water", may not cause a violation of a drinking water standard or "otherwise adversely affect the health of persons". The regulations also specify criteria for construction, operation, monitoring and abandonment of Class V wells. **Injection wells for the improvement of groundwater quality may be considered under Section 14.02 for approval** Regulation states that all public water must meet the established primary and secondary drinking water standards unless a variance is issued by the State.	Reinjection of treated groundwater into an aquifer. Groundwater at the site must be classified by the State of Tennessee as a drinking water source.	TDEC-Division of Water Supply, Rules of Water Quality Control Board-Underground Injection Control. Rule 1200-4-6 Rules and Regulations of Wells in Shelby County.
	Except for naturally occurring levels, shall not contain constituents in excess of the concentrations listed in Table 1. Inorganic Criteria for General Use Ground Water Except for naturally occurring levels, shall not contain constituents exceeding those in TDEC 1200-4-3-.03 except that the criteria for Fish and Aquatic Life and Recreational Use shall not apply		TDEC 1200-4-3-.08(2)(a) TDEC 1200-4-3-.08(2)(b)
Installation and maintenance of groundwater monitoring well(s)	All well shall be constructed in a manner that will guard against contamination of the groundwater aquifer underlying Shelby County Shall be performed in accordance with the substantive provisions of Siting and Section 6.02 for Sanitary Protection at Section 6.03 for Construction Materials and Other Requirements at Section 6.04 for Protection and Maintenance at Section 6.05 and .06 respectively.	Construction, modification, and repair of groundwater monitoring well(s) --- **relevant and appropriate**	TDEC 1200-4-6-.14(1)(b) TDEC 1200-4-6-.14(7)(b) and (8)(a)

Closure of groundwater monitoring well(s)	Well shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing groundwater classified pursuant to Rules of the TDEC Chap. 1200-4-6-.6.05(1) through the borehole is not allowed.	Permanent plugging and abandonment of a well---**relevant and appropriate**	TDEC 1200-4-6-.09(6)(d)
Injection of nutrients (or other treatments) into groundwater	Wells shall be designed , constructed, and operated in such a manner that does not present a hazard to existing or future use of groundwater and may not cause a violation of water quality standards	Class V injection well for innovative or experimental technologies ---**relevant and appropriate**	TDCE 1200-4-6-.12

ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
TBC = to be considered
TCA = *Tennessee Code Annotated*
TDEC = Rules of the Tennessee Department of Environment and Conservation, Chapter as noted

TABLE 7
Identification of Chemical Specific ARARs

Media	Requirements	Prerequisites	Citation
Groundwater	Remedial actions meeting requisite requirements must be designed, constructed, to meet MCLs or alternative standards	All groundwater in state of Tennessee	Federal Safe Drinking Water Act (40 CFR Part 141) Primary Maximum Contaminant Limits (MCLs) Tennessee Department of Environment and Conservation (TDEC) – Groundwater Protection Rules and Regulations 1200-4-10
Sediment	Remedial actions must be designed to meet site specific risk based remediation goals	Impacted sediment in lagoons and Tributaries 1,2, and 3 on site and Tributary 1 off site.	USEPA Risk Assessment Guidance for Superfund: "Environmental Evaluation Manual" TDEC Environmental Assessment Guidelines.
Surface Water	Remedial actions must be designed to meet Federal and State Water Quality Criteria	Impacted surface water in lagoons and tributaries on site and Tributary 1 offsite.	Federal Water Quality Criteria Documents Tennessee Water Quality Control Act – 69-3-101

10.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of the remedy.

Alternative GW1 has no reduction in toxicity, mobility, or volume. With Alternative GW2, reduction of toxicity, mobility and volume would be through natural processes that are actively monitored. Reduction of toxicity, mobility and volume would be highest for Alternatives GW3 through GW5 and GW7 due to treatment of areas with elevated CVOC concentrations. Alternative GW6 will contain the elevated CVOC concentrations and reduce toxicity and mobility through treatment; however, the reduction in volume would be somewhat less due to the disposal, not destruction, of spent carbon as a waste. Alternative GW4 would reduce toxicity and volume of CVOCs through treatment; however, mobility of metals may be increased if metals are oxidized. The reduction of toxicity, mobility and volume of constituents in the rest of the groundwater plume will be largely dependent on naturally occurring processes.

10.5 Short Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the 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.

Alternative GW1 requires no construction or intrusive activities but does not remedy the groundwater. All other alternatives require the installation of groundwater monitoring and/or injection wells, which can be accomplished by a local driller. Risk of exposure to impacted groundwater during implementation of Alternatives GW2 through GW7 would be eliminated by implementing institutional controls. Risk of exposure of chemicals to workers is greatest for Alternative GW4 due to the exothermic reaction during ISCO, this risk would be reduced through implementation of proper procedures and the use of appropriate health and safety measures. Risk of exposure of impacted groundwater to workers is greatest for Alternative GW6 due to above ground treatment of recovered groundwater. This risk would be reduced through implementation of proper procedures and the use of appropriate health and safety measures.

The duration of the remedial alternative is the greatest for Alternative GW1. Implementation of groundwater use restrictions will achieve RAOs. However, to achieve RGs, Alternatives GW2 through GW7 will require long-term monitoring of natural attenuation with Alternatives GW2 and GW6 requiring the longest duration of monitoring. Alternatives GW3 through GW5 have the greatest potential for demonstrating short-term effectiveness due to a sudden reduction of the highest concentration (greatest mass) of groundwater COCs with active treatment.

10.6 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 government entities are also considered.

All alternatives are easily implementable. Alternative GW1 has no construction or monitoring activities other than that required for the five year review and is easiest to implement. It is easy to implement Alternative GW2 as it involves routine groundwater monitoring. Groundwater monitoring in Alternatives GW3 through GW5 is not labor intensive, however the respective solution injections could be relatively labor intensive, but easily implementable. Construction and groundwater monitoring in Alternative GW6 are not labor intensive while operation and maintenance of the system is the most labor intensive and most difficult to implement.

Construction in Alternative GW7 is probably the most labor intensive alternative due to the special installation of plants, but post initial construction the intensity level is equivalent to the rest of the alternatives for groundwater monitoring.

The installation of Alternatives GW3 through GW7 can be implemented using standard construction equipment and techniques. Vendors and contractors for Alternatives GW2 through GW7 are readily available.

10.7 Costs

Costs estimates for each alternative were calculated based on conceptual engineering and design. The type of costs that were assessed included:

- capital costs, including both direct and indirect costs;
- annual O&M; and
- total present worth costs.

The present worth cost for each alternative provides the basis for the cost comparison. Total present worth cost was calculated by combining the capital cost plus the present worth of the annual O&M costs, as well as a contingency cost. Capital cost includes engineering and design, mobilization, site development, equipment, construction, demobilization, utilities, and sampling/analyses. Operating costs were calculated for activities that continue after completion of construction, such as routine operation and maintenance of treatment equipment, and groundwater monitoring. The present worth of an alternative is the amount of capital required to be deposited at the present time at a given interest rate to yield the total amount necessary to pay for initial construction costs and future expenditures, including O&M and future replacement of capital equipment. The total present worth cost was developed using a discount rate of 7 percent. Present worth costs needed to meet performance standards are within the range of +50% to -30% accuracy. If the area that is to be treated with active treatment changes from current estimates, the cost estimate associated with these remedial components would change.

Alternative GW1 has the lowest for probable cost while Alternative GW4 has the highest. Potential costs for Alternatives GW7, GW2 and GW3 would be moderate. Potential costs for Alternatives GW6 and GW5 are approximately twice the cost of Alternatives GW7, GW2, and GW3. Long-term monitoring may be shortened in alternatives consisting of active treatment in areas with elevated CVOC concentrations.

10.8 State Acceptance

The State of Tennessee, as represented by the Tennessee Department of Environmental and Conservation (TDEC), has been the support agency during the Remedial Investigation and Feasibility Study (RI/FS) process for the Sixty-One Industrial Park Site. In accordance with 40 C.F.R. § 300.430, TDEC as the support agency, has provided input during this process by reviewing major documents in the Administrative Record. TDEC concurs with the selected remedy.

10.9 Community Acceptance

EPA held a public meeting to discuss the proposed remedy on March 27, 2008. During the public comment period, no objection to the implementation of Alternative GW3 as the selected remedy was received from the community.

11.0 Principal Threat Wastes

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (NCP §300.430(a)(1)(iii)(A)). The "principal threat" concept is applied to the characterization of "source materials" at a Superfund site. A source material is material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contaminants to ground water, surface water or air, or acts as a source for direct exposure. Contaminated ground water generally is not considered to be a source material. Principal threat wastes are those source materials considered highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to human health or the environment should exposure occur. The principal threat wastes that were present at the Site in surface and subsurface soils were removed during the previous removal actions. No principal threat wastes remain on-site.

12.0 Summary of Selected Remedy

12.1 Summary of Rationale for the Selected Remedy

Based upon consideration of the requirements of CERCLA, the NCP, State regulations, the detailed analysis of alternatives and public and state comments, EPA has selected Groundwater Alternative GW3 Enhanced Reductive Dechlorination (ERD) with Monitored Natural Attenuation (MNA) as the final action for groundwater contamination along with implementation of various institutional controls to ensure future protectiveness. Alternatives GW3 and GW5 require shorter durations to achieve RGs than Alternatives GW4, GW 6 and GW7; however, Alternative GW 3 has a comparative advantage over the other alternatives in that it requires less solution to be injected and is implemented in a much shorter timeframe making Alternative GW3 more cost effective than the other alternatives. Alternative GW3 also uses a solution that is safer to inject than Alternative GW4. Alternatives GW6 and GW7 provide slight hydraulic control of the migration of the elevated concentrations in the plume; however, Alternative GW6 involves extensive O&M and Alternative GW7 would not contain or treat elevated concentration at depths greater than 23 feet allowing CVOCs to migrate. Alternative GW3 complies with all ARARs; however, similar to Alternatives GW4 and GW5, approval for injection wells from Shelby County may be difficult to obtain. Alternative GW3 will have minimal residual risks and will reduce toxicity, mobility, and volume of COCs. The present worth cost of Groundwater Alternative GW3 is $3,518,600.

12.2 Description of the Selected Remedy

12.2.1 Selected Groundwater Remedy

12.2.1.1 Institutional controls

Institutional Controls are non-engineering instruments such as administrative or legal controls that eliminate or minimize the potential human exposure to contaminants and chemicals of concern and to protect the integrity of the remedy by limiting land or resource utilization. The specific Institutional Controls for the Site will be established as part of the Remedial Design. During Remedial Design, an Institutional Control Implementation Plan will be developed to more clearly detail and describe the objective, mechanism, timing, and responsibility for the Institutional Controls to be implemented at the Site. The Institutional Controls will eliminate potential exposure at the Site property to impacted groundwater and to the impacted groundwater at other properties.

Use of the property has already been limited to heavy industrial through zoning since the ealy 1970's If a new property owner desired to change the current or future zoning classification, the petition would be submitted to the Memphis Shelby County Planning and Development Department. As part of the zoning change petition, the property owner must secure a approval from Memphis and Shelby County Health Department (MSCHD) that show requirements have been successfully met, which include proving that no adverse ecological or human health effects would result from the changes in the proposed property use. With the documented status of the Site as a CERCLIS NPL-Equivalent site, the MSCHD would not concur with a zoning change without a demonstration that the Site is safe for use other than heavy industrial. Therefore, the conceptual site exposure model indicating current and future use of the Site as an industrial site is supported by current zoning and regulatory processes (i.e., institutional controls).

The primary groundwater institutional control will be strict prohibition of drilling of wells and use of groundwater in the impacted area pursuant to MSCHD water well regulatory program. Restrictive covenants will be placed on the deeds for properties where groundwater has been contaminated from the site above RG's, The restriction shall remain enforce until the contaminant levels are below the RG's noted in Table 4. MSCHD has statutory authority to deny well applications based on health, safety, and general welfare considerations in accordance with Rules and Regulations of Wells in Shelby County (hereafter referred to as Well Regulations). Well Regulations specifically require that MSCHD deny a permit application to construct a water well if use of the well would increase the potential for harm to public health safety and welfare, or if the proposed well would enhance the movement of contaminated groundwater or material into the shallow or deep aquifer. The rules more specifically require that a water well cannot be sited or placed in service within a half-mile of the designated boundaries of a listed federal or state Superfund site or RCRA corrective action site. (Section 4.01-C, Well Regulations). MSCHD has been, and will continue to be, supplied copies of all investigative and monitoring reports to assist the MSCHD hydrogeologist with determining areas where water wells should not be installed or placed in service.

12.2.1.2 In-situ ERD injections

In-situ ERD will be implemented to address areas with elevated groundwater CVOC concentrations (TCE concentrations exceeding 1,000 ug/L) at the Site. Figure 4 presents the July 2007 TCE groundwater concentrations. This alternative involves injection of a biodegradable electron donor/carbohydrate solution (e.g., HRC, vegetable oil, corn syrup, sodium lactate, etc.) through wells to enhance in-situ anaerobic treatment zones conducive to reductively dechlorinate elevated CVOCs at the Site. Injections may be conducted manually or using an automated system. Injection wells will be properly spaced to allow establishment of an anaerobic zone to allow dechlorination of CVOCs.

Actual components of the remedy shall be determined during remedial design (RD), For the purpose of costing and evaluation, the remedy shall include the following. The treatment area will consist of the groundwater plume where TCE concentrations exceed 1,000 ug/l. A Geoprobe™ rig will be used to inject the electron donor solution, using approximately 310,900 gallons of a 15 percent solution of corn syrup and water. Injections will be conducted at approximately 292 locations with a spacing of approximately 40-feet on center. The injections will involve injecting 500 to 1500 gallons of solution across the groundwater plume thickness (10 to 35 feet depending on location). The duration of the fieldwork to complete the injections is estimated to be four months. Monitoring of CVOCs and anaerobic biodegradation parameters will be conducted on an estimated 26 wells on a quarterly basis for the first year and semi-annual basis for years 2 and 3.

12.2.1.3 Monitored Natural Attenuation

The MNA alternative involves demonstrating that natural attenuation of COCs in groundwater will achieve RGs. Natural attenuation makes use of natural processes to reduce the concentration and amount of pollutants at a site. Natural attenuation depends on existing inherent processes, including adsorption, desorption, dilution, dispersion, volatilization, hydrolysis and biodegradation. Initial evaluation of natural attenuation processes (review of key geochemical parameters and the ratio of VOCs present to their degradation products at the Site) indicates that biologically assisted reductive dechlorination (intrinsic anaerobic bioremediation) is a process that is currently reducing concentrations of VOCs in groundwater at the Site. This conclusion is supported by both field and laboratory data collected during the RI and the groundwater monitoring plan (GMP). Also, a declining and consistent trend is evident downgradient of Lagoon 123. . However, available data is limited and further monitoring to determine if natural attenuation processes are sufficiently reducing the mass of CVOCs in the plume is required Typically, MNA demonstration involves implementing the following tasks: (1) collecting field and laboratory biogeochemical indicators (electron acceptors and degradation products); (2) long-term monitoring to document reduction in contaminant concentrations (declining trends); and (3) groundwater modeling.

As part of the MNA approach, groundwater monitoring would be performed to evaluate the attenuation of the dissolved contaminants. The time that it takes for natural attenuation to achieve RGs can be estimated from the natural decay of TCE, and is estimated using the Biochlor model after ERD reduced TCE concentrations to 1,000 ug/L and stimulated downgradient natural attenuation to take 40 years.

12.2.1.4 Performance Monitoring Plan

Groundwater monitoring will be performed to determine the effectiveness of the ERD and evaluate the attenuation of the dissolved contaminants. For the purposes of developing a cost estimate, it is anticipated that groundwater monitoring will involve the sampling of 26 wells, which will be analyzed for CVOCs and MNA parameters semi-annually for 15 years, and then annually thereafter until RGs are met. Groundwater modeling will be conducted to demonstrate degradation is occurring at the Site and to establish a timeframe to ultimately achieve RGs. Groundwater elevations and gradients will be compiled and evaluated along with the concentration data in order to track contaminant movement and fate.

Evaluation of the monitoring data will be conducted on a yearly basis and at the five-year review timeframe. It is anticipated that the first five year review will include an evaluation of the effectiveness of the selected remedial action.

12.3 Summary of the Estimated Remedy Costs

The cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternatives. Major changes in the remedial approach may be documented in the form of a memorandum in the Administrative Record file, an ESD, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost. The total present worth cost of selected remedy is $3,518,600 (Table 8).

All of the assumptions made, including the number of injection wells, the number of wells included in the performance monitoring plan and the frequency of sampling are based on the current data available at the Site. Actual costs to successfully implement these remedies may vary based on new Site data and/or changing Site conditions.

12.4 Expected Outcomes of the Selected Remedy

The purpose of this response action is to control the risk associated with human exposure to contaminated groundwater at the Site and surrounding areas. The groundwater at the Site will be restored to the EPA and TDEC MCLs or two-times the established background level. Table 4 presents the final cleanup levels for groundwater.

The Site is currently available for heavy industrial use and it is anticipated that these activities will not be restricted during the implementation of the selected remedy. Institutional controls consisting of restrictive covenants and current groundwater use restrictions will ensure future protectiveness until the cleanup goals are attained. A policy review will be conducted every five years to evaluate and assess the effectiveness of the remedy.

The selected groundwater remedy will reduce the elevated CVOC concentrations and naturally attenuate the impacted groundwater until the remedial goals are achieved throughout the groundwater plume. The ERD injections will be delivered within a timeframe of four months. The timeframe estimated to restore the groundwater to concentrations below the remedial goals is approximately 45years; however, due to the multiple variables in the attenuation process, this timeframe is only an estimate. Monitoring of the remedy will continue until contaminant concentrations either reaches remediation goals or asymptotic levels. If contaminant concentrations reach asymptotic levels, the remedy will be re-evaluated.

DESCRIPTION	NOTES	UNITS	QTY	UNIT COST ($)	TOTAL COST ($)
I. Predesign Services	a/	ls	1	$6,700	$6,700
1.Project Management/Coordination					
2.Groundwater Sampling (labor and lab)	b/	ls	1	$26,400	$26,400
3.Remedial Design Work Plan (Groundwater)		ls	1	$40,700	$40,700
Subtotal Predesign Services Costs					$73,800
4.Contingency (20% of Predesign Services Costs)					$14,800
Total Predesign Services Costs					$88,600
Present Worth (PW) of Total Predesign Costs	c/				**$82,800**
Payment Year 1					
II. Design Services					
1.Project Management/Coordination	a/	ls	1	$20,600	$20,600
2.Remedial Design Reports (Groundwater - 30%, 60% & 100%)		ls	1	$124,900	$124,900
3.Fate and Transport Modeling		ls	1	$50,700	$50,700
4.Field Scale Pilot Study	d/	ls	1	$95,500	$95,500
5.Design/Contract Documents Preparation/HASP	e/	ls	1	$7,800	$7,800
6.Regulatory Negotiations/Meetings		ls	1	$5,500	$5,500
7.UIC Permitting	f/	ls	1	$10,300	$10,300
8.Pre-bid Meeting/Contractor Selection/Contracting		ls	1	$7,100	$7,100
Design Services Costs					$322,400
9. Contingency (20% of Design Services Costs)					$64,500
Total Design Services Costs					$386,900
PW of Total Design Costs	c/				**$361,800**
Payment Year 1					
III. Capital Costs					
1. Construction Costs		ls	1	$18,000	$18,000
a Mobilization/Demobilization					
b Site Clearance/Temporary Road Construction	g/	ls	1	$20,000	$20,000
c Electron Donor	h/	lbs	457,500	$1.4	$640,500
d Injections (labor/portable mixing tank/storage/pumps/piping)	i/	days	119	$3,300	$392,700
e Project Management (injection subcontractor)		ea	1	$25,000	$25,000
f Additional Groundwater Monitoring Wells Installation	j/	ea	1	$5,100	$5,100
g IDW disposal		cy	10	$55	$550
Subtotal Construction Costs					$1,101,850
2. Baseline Sampling and System Startup	a/	ls	1	$2,600	$2,600
a.Project Management/Coordination					
b.Labor - sampling wells		ls	1	$10,100	$10,100
c.Analyticals: EPA 8260 (26 Wells+ QA/QC)	k/	ea	39	$96	$3,740
d.Analyticals: Biogeochemical Parameters (20 samples)	k/	ea	20	$420	$8,400
d. Equipment rental/Reimbursable		ea	1	$3,700	$3,700
Subtotal Baseline Sampling & Startup					$28,500

3. Engineering Services a.Record Drawings/Construction Report/O&M Manual		ls	1	$26,300	$26,300
b.Engineering Oversight (labor and expenses)	l/	ls	1	$39,200	$39,200
c. Project Management/Coordination	a/	ls	1	$6,600	$6,600
Subtotal Engineering Services Costs					$72,100
4. Contingency (20% of Installation Costs)					$240,490
Total Construction and Startup Cost					$1,442,940
PW of Construction and Startup Cost	c/				**$1,259,700**
(Payment year 2)					

DESCRIPTION	NOTES	UNITS	QTY	UNIT COST ($)	TOTAL COST ($)
IV. MNA Monitoring Costs					
Year 1 Monitoring 1. Quarterly Groundwater Monitoring (26 monitoring wells + 5 QA/QC samples) a. Project Management/Coordination	a/	ls	1	$18,200	$18,200
b. Additional Groundwater Monitoring Wells Installation	m/	ea	6	$4,900	$29,400
c.IDW Disposal (drilling cuttings/non-hazardous - 5 drums/well)		ea	30	$125	$3,750
d.Labor - sampling wells (quarterly)	n/	ea	4	$10,100	$40,400
e.Analyticals: EPA 8260 (26 monitoring wells)	o/	ea	156	$96	$14,980
f.Analyticals: Biogeochemical Parameters (20 samples)	o/	ea	112	$420	$47,040
e.Equipment rental/Reimbursable		ea	4	$3,700	$14,800
f.Monitoring report to Agency (semi-annually)		ea	2	$14,000	$28,000
g Regulatory Negotiations/Meetings		ls	1	$3,700	$3,700
Subtotal Annual Quarterly Monitoring Cost (Year 1)					$200,300
2. Contingency (20% of Annual Monitoring Costs)					$40,100
Total Annual Monitoring Cost (Year 1)					$240,400
PW of Quarterly Monitoring Costs (Year 1)	c/				**$209,900**
(Payment Year 2)					
Years 2 through 15 (Semi-Annual Natural Attenuation Monitoring)					
3. a. Project Management/Coordination	a/	ls/yr	1	$9,000	$9,000
b. Labor - sampling wells	n/	ea	2	$10,100	$20,200
c. Analyticals: EPA 8260 (monitoring wells)	o/	ea	78	$96	$7,490
d.Analyticals: Biogeochemical Parameters (20 samples)	o/	ea	56	$420	$23,520
e.Equipment rental /Reimbursable		ea	2	$3,700	$7,400
f.Monitoring report to Agency (semi-annually)		ls	2	$14,000	$28,000
g.Regulatory Negotiations/Meetings		ls	1	$3,700	$3,700
Subtotal Annual Monitoring Costs					$99,300
4. Contingency (20% of Annual Monitoring Costs)					$19,860
Total Annual Monitoring Costs					$119,200
PW of Semi-Annual Monitoring Costs (Years 2-15)	c/				**$996,300**
(Payment Years 3-16)					
Years 16 through 40 (Annual Natural Attenuation Monitoring)					
5. a. Project Management/Coordination	a/	ls/yr	1	$4,000	$4,000
b.Labor - sampling wells	n/	ea	1	$10,100	$10,100
c.Analyticals: EPA 8260 (monitoring wells)	o/	ea	39	$96	$3,740
d.Analyticals: Biogeochemical Parameters (20 samples annual)	o/	ea	28	$420	$11,760

e.Equipment rental /Reimbursable		ea	1	$3,700	$3,700
f.Monitoring report to Agency (annual)		ls	1	$7,000	$7,000
g.Regulatory Negotiations/Meetings		ls	1	$3,700	$3,700
Subtotal Annual Monitoring Costs					$44,000
6. Contingency (20% of Annual Monitoring Costs)					$8,800
Total Annual Monitoring Costs					$52,800
PW of Annual Monitoring Costs (Years 16-40) (Payment Years 17- 41)	c/				**$605,600**

DESCRIPTION	NOTES	UNITS	QTY	UNIT COST ($)	TOTAL COST ($)
V. Decommissioning Costs					
1. a. Project Management/Coordination	a/	ls	1	$3,300	$3,300
b.Abandon Monitoring Wells	p/	lf	1437	$8	$11,210
c.Labor/expenses		ls	1	$3,700	$3,700
d.Regulatory Negotiations/Meetings		ls	1	$5,800	$5,800
e.Closure Report		ls	1	$12,200	$12,200
Subtotal Closure Costs					$36,200
2. Contingency (20% of Decommission Costs)					$7,240
Total Annual Monitoring Costs					$43,440
PW of Decommissioning Costs (Year 40) (distribution in Yr. 42)	c/				**$2,500**
PW OF TOTAL PROBABLE COSTS	c/				**$3,518,600**

Notes/Assumptions:

a/ Project management and coordinating all project related activities.
b/ Groundwater sampling prior to assess groundwater conditions (20 monitoring wells) during remedial design work plan preparation.
c/ Present worth costs were estimated based on a net annual discount rate of 7%, assuming year-end distribution.
d/ A field scale ERD pilot study to develop design criteria (area of influence, electron donor injection rate, etc.).
e/ Finalizing design and preparation of contract documents for bidding.
f/ Underground injection control permit.
g/ Site clearance (tree clearance and temporary gravel road for drill rig mobilization).
h/ Materials cost for Anaerobic Biochem Plus (Redox-Tech, LLC).
i/ Installation of 2-inch diameter PVC injection wells to cover the treatment area.
j/ Assumes 6 additional monitoring wells installation for performance monitoring.
k/ Baseline sampling prior to injection system assumes 26 MWs and QA/QC samples for VOCs; 20 samples will be analyzed for select biogeochemical parameters.
l/ Assumes 8 weeks for injection.
m/ Installation of 6 additional monitoring wells for performance monitoring.
n/ Assumes 4 days to sample by 2 fulltime technicians and includes travel expenses.
o/ Sampling of 26 MWs plus 5 QA/QC samples for VOCs EPA Method 8260; 20 samples will be analyzed for selected biogeochemical parameters.
p/ Assumes in-place abandonment of 26 existing monitoring wells and 6 new wells (grouting).
- Costs are based on vendor information, contractors' estimate, cost estimation manuals, and past experience.
-Abbreviations: ea = each; ls = lump sum; hr = hours; CY = cubic yards; LF = linear feet; Gal - gallons; wk = week.

13.0 Statutory Determinations

Under CERCLA §121 and the NCP, the lead agency must select remedies that are protective of human health and the environment, comply with applicable or relevant and appropriate requirements (ARARs)(unless a statutory waiver is justified), are cost-effective, and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as a principal element and a bias against off-site disposal of untreated wastes. The following sections discuss how the Selected Remedy meets these statutory requirements.

13.1 Protection of Human Health and the Environment

The selected remedy will protect human health by eliminating or controlling risks associated with human exposure to contaminated groundwater at the Site and surrounding areas. Groundwater will be actively treated to reduce elevated COC concentrations and stimulate attenuation to below the MCLs. Institutional controls will be implemented to restrict the use of groundwater for potable water and retain the heavy industrial use for the Site and surrounding areas. The selected remedy is expected to reduce contaminant concentrations to the remedial goals within approximately 45 years.

13.2 Compliance with ARARs

The selected remedy complies with all of the ARARs presented in Tables 5 through 7.

13.3 Cost Effectiveness

The selected remedy is cost effective and represents a reasonable value. According to the National Contingency Plan (NCP) "A remedy shall be cost effective if its costs are proportional to its overall effectiveness." (40 CFR §300.430(f)(1)(ii)(D)). The "overall effectiveness" of the selected remedy was compared to those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment and compliant with ARARs). Overall effectiveness was determined by assessing three of the five balancing criteria in combination: long-term effectiveness and permanence, reduction in toxicity, mobility, and volume through treatment, and short-term effectiveness. The relationship of the overall effectiveness of these remedial alternatives was determined to be proportional to the costs and hence represent a reasonable value.

The selected Groundwater Alternative GW3 has a comparative advantage over the other groundwater alternatives including lower residual risk, requires less solution to be injected and is implemented in a much shorter timeframe. Groundwater Alternatives GW3 through GW7 are protective of human health and the environment than the other alternatives; however, Alternative GW3 has a significantly shorter duration to achieve the RGs. Alternative GW3 also uses a solution that is safer to inject than Alternative GW4. Although Alternative GW3 relies on the natural attenuation mechanisms for the impacted downgradient groundwater following the active treatment in the elevated CVOC concentration area, the active treatment is expected to stimulate natural attenuation and shorten the duration for the COCs to attenuate below RGs.

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

The selected alternative makes use of permanent solution to restore the groundwater to below RGs and to levels protective of human health. The selected remedy will use ERD in areas with elevated CVOC concentrations which will also enhance the natural attenuation of the contaminants, permanently reducing the toxicity, mobility and volume of COCs.

13.5 Preference for Treatment as a Principal Element

The selected groundwater remedy satisfies the preference for treatment. The remedy will use ERD in area with elevated CVOC concentrations which will also enhance the natural attenuation of the contaminants, reducing the toxicity, mobility and volume of COCs.

13.6 Five-Year Review Requirements

This remedy will not result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, but will take more than five years to attain remedial action objectives and cleanup levels. Therefore, a policy review will be conducted within five years of construction completion for the site to ensure that the remedy is or will be protective of human health and the environment.

14.0 Documentation of Significant Changes

The Proposed Plan for the Site was released for public comment on March 18, 2008. The Proposed Plan identified Groundwater Alternative GW3, enhanced reductive dechlorination with MNA, as the Preferred Alternative for groundwater remediation.