Patrick Air Force Base
Cape Canaveral Air Force Station

FINAL

SECURITY POLICE CONFIDENCE COURSE (FACILITY 18003)
SOLID WASTE MANAGEMENT UNIT C091
CAPE CANAVERAL AIR FORCE STATION, FLORIDA

Corrective Measures Implementation Report
Volume I

Revision 0 – May 2007

Prepared for:

U.S. Air Force Space Command
45th CES/CEVR
Patrick Air Force Base, Florida 32925-3343

Air Force Center for Environmental Excellence
Space Command Division
HQ AFCEE/ICS
3300 Sidney Brooks
Brooks City - Base, Texas 78235-5112

Prepared by:

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USAF Contract No. FA8903-04-D-8677, Delivery Order No. 0031

FINAL

INSTALLATION RESTORATION PROGRAM
45th SPACE WING FACILITIES AT
CAPE CANAVERAL AIR FORCE STATION, FLORIDA

SECURITY POLICE CONFIDENCE COURSE (FACILITY 18003)
SOLID WASTE MANAGEMENT UNIT C091
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Corrective Measures Implementation Report
Security Police Confidence Course (Facility 18003)
Solid Waste Management Unit C091
Cape Canaveral Air Force Station, Florida

By:

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May 2007

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PREFACE

This document is a Corrective Measures Implementation Report for Security Police Confidence Course (Facility 18003), Solid Waste Management Unit (SWMU) C091, at Cape Canaveral Air Force Station (CCAFS), Florida. Tetra Tech, Inc. conducted the work under contract with the Air Force Center for Environmental Excellence (AFCEE), Brooks City-Base, Texas, for the 45th Space Wing Facilities. John King was the AFCEE Contracting Officer (CO) and Judith Keith was the AFCEE Contracting Officer's Representative (COR). The Tetra Tech, Inc.'s AFCEE WERC Contract Program Manager was Scott Vick and Tetra Tech, Inc.'s Project Manager was Michael Higgins, P.E. Mark Kershner and John Matthews, P.E. (45th CES/CEVR), provided coordination for the 45th Space Wing Facilities at CCAFS, Florida.

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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AFCEE	Air Force Center for Environmental Excellence
AHA	Activity Hazard Analysis
AL	Action Level
ANSI	American National Standards Institute
APEX	Apex Environmental Engineering & Compliance, Inc.
bgs	below ground surface
bhp	brake horsepower
BTU	British Thermal Unit
CAMP	Corrective Action Management Plan
CAP	Corrective Action Plan
CCAFS	Cape Canaveral Air Force Station
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CES/CEVR	Civil Engineering Squadron/Restoration Division
CFR	*Code of Federal Regulations*
CMD	Corrective Measures Design
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CO	Contracting Officer
COC	contaminant of concern
COR	Contracting Officer's Representative
CPT	cone penetrometer test
CRZ	contamination reduction zone
DAS	Data Acquisition System
DCA	1,1-dichloroethylene
DCE	dichloroethylene
DPT	direct push technology
DNAPL	dense non-aqueous phase liquid
EZ	exclusion zone
FAA	Federal Aviation Administration
F.A.C.	*Florida Administrative Code*
FDEP	Florida Department of Environmental Protection
FID	flame ionization detector
FTO	flameless thermal oxidizer
GAC	granular activated carbon
GC	gas chromatograph
GCTL	groundwater cleanup target level
GPR	ground penetrating radar
H&S	Health and Safety
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HCl	hydrochloric acid
HF	hydrofluoric acid
HTRW	Hazardous, Toxic and Radioactive Waste
IM	Interim Measure
IRP	Installation Restoration Program
KO	knock-out
KSC	Kennedy Space Center
LDA	large diameter auger

MBTU	million British Thermal Unit
MIP	membrane interface probe
msl	mean sea level
NaOH	sodium hydroxide
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NSC	National Safety Council
ODC	other direct cost
OSHA	Occupational Safety and Health Administration
P&ID	piping and instrumentation diagram
Partnering Team	Cape Canaveral and Patrick Environmental Restoration Partnering Team
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PFD	process flow diagram
PFM	passive flux meter
PLC	Programmable Logic Controller
PPE	personal protective equipment
psig	pounds per square inch gauge
PWQ	Process Waste Questionnaire
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCADA	Supervisory Control and Data Acquisition
SCTL	Soil Cleanup Target Level
SJRWMD	Saint Johns River Water Management District
SPCC	Security Police Confidence Course
SSHO	Site Safety and Health Officer
SWPPP	Storm Water Pollution Prevention Plan
SWMU	Solid Waste Management Unit
TCA	trichloroethane
TCE	trichloroethylene
TDEM	time domain electromagnetics
TRP	Technical Response Package
UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
VCS	vapor conditioning system
VFD	Variable Frequency Drive
VOC	volatile organic compound
VPN	virtual private network
ZVI	zero valent iron

EXECUTIVE SUMMARY

Background

This document is a Corrective Measures Implementation (CMI) Report for Security Police Confidence Course (SPCC) (Facility 18003), at Cape Canaveral Air Force Station (CCAFS), Florida. Facility 18003 is designated as Solid Waste Management Unit (SWMU) C091 in the Corrective Action Management Plan (CAMP) for the 45th Space Wing. This CMI Report has been prepared in accordance with the Resource Conservation and Recovery Act (RCRA) Corrective Action Plan (CAP) guidance. Tetra Tech, Inc. has prepared this CMI Report for the Installation Restoration Program (IRP) of the 45th Space Wing Civil Engineering Squadron/Restoration Division (45th CES/CEVR) in accordance with the approved Final Corrective Measures Designs (CMDs) prepared by Jacobs Engineering Group, Inc. and the approved CMI Work Plan prepared by Tetra Tech, Inc. This report was prepared under contract with the Air Force Center for Environmental Excellence (AFCEE), Brooks-City Base, Texas (Contract FA8903-04-D-8677, Delivery Order 0031).

Facility 18003 encompasses approximately 10 acres on the southeast portion of CCAFS, approximately 0.5 miles west of the Atlantic Ocean and 2.5 miles east of the Banana River located along Pier Road. Conditions at Facility 18003 were previously assessed with regard to the quality of groundwater, soil, sediment, and surface water and the results were presented in the Corrective Measures Study (CMS) (BEM, 2003) and the CMD (Jacobs, 2005b). Potential release mechanisms at Facility 18003 included discharges and spills associated with the chemical cleaning lab and the potential disposal of chemicals through the sanitary latrine. The primary contaminants in groundwater at Facility 18003 included the volatile organic compounds (VOCs) tetrachloroethylene (PCE), trichloroethylene (TCE), and cis-1,2-dichloroethylene (cis-1,2-DCE).

The purpose and objective of this report are to present all CMI activities and the results of the remedial action that addressed the chlorinated solvent source area in the surficial aquifer at Facility 18003. The objective of the CMI was to remove and/or destroy significant contaminant mass [including dissolved, sorbed constituents, and dense non-aqueous phase liquids (DNAPL)] in the identified source area in order to achieve cleanup goals within a reasonable time frame for the site. The objective of source treatment at the site was the significant reduction of the contaminant mass via in-situ soil mixing with steam, hot air, and zero valent iron (ZVI).

Several lines of evidence are used in indicating effective contamination removal efficiencies using the in-situ soil mixing technology with injection of steam, hot air, and ZVI. The lines of evidence include: 1) Comparing baseline and post-remediation concentrations of contaminants in soil and groundwater samples from the performance monitoring locations; 2) Comparing baseline and post- remediation groundwater mass flux results; 3) The mass removed for each VOC at SPCC and its percent of total mass removed for SPCC;

4) Treatment of cell BC04 (approximately 27 days later) located between BC14, BC16, and BB15 in the highest contaminated area determined at the site; and 5) Estimating the percent reduction in TCE concentration in each cell by comparing the maximum concentration of TCE detected during the early passes of the large diameter auger (LDA) with the maximum concentration detected in the last pass for a given treatment cell.

The source area was defined as the horizontal extent of TCE concentrations in groundwater greater than 10 milligrams per liter (mg/L), resulting in an estimated horizontal area of approximately 7,300 ft^2. The proposed number of cells required to treat the area were 145 cells with an 8 foot auger utilizing a 6% overlap. The footprint of each treatment cell is 50.24 ft^2 (without overlap). The data indicated that the thickness of the source area varied vertically across the site. Based upon this evidence, the source area was divided into two treatment zones with different target treatment depths, as follows:

Treatment Zone	**Area (ft^2)**	**Treatment Depth (ft)**	**Volume (yd^3)**	**No. of Proposed Treatment Cells**[1]
Zone 1	3,160	10 - 55	5,267	61
Zone 2	4,140	10 - 25	2,300	84

[1] Slight variations were made in the field based on the treatment protocol.

Treatment System

In-situ soil mixing using an LDA combined with the injection of hot air/steam followed by the injection of ZVI was the remedial technology used for the treatment of soil and groundwater contaminated with high concentrations of VOCs or DNAPL in the source area. This technology, as constructed at the SPCC site, consisted of the following major elements: a mixing and vapor collection system (i.e., the LDA and ancillary equipment), the VOC treatment system (thermal oxidizer and/or granulated activated carbon), and the Supervisory Control and Data Acquisition (SCADA) system. The treatment system utilized a process control and data acquisition system for real time evaluation that assisted in controlling the process parameters to maximize the VOC removal and supported instant decision making for operation (i.e., depth and duration) of the LDA.

The mixing system was equipped with an LDA (8 feet in diameter) that sheared and mixed the soil as the auger advanced below the ground surface while concurrently injecting steam and hot air. This action caused thermal desorption and volatilization of the VOCs from soil particles and interstitial spaces. The steam and hot air raised the temperature of the soil mass above 160°F, increasing the vapor pressure of the contaminants, volatilizing the compounds from the soil particles, and allowed them to be transported to the soil surface where they were collected in a shroud maintained under vacuum (vapor collection system) covering the active treatment area. The shroud was 12 feet in diameter that provided the ability to capture off-gases beyond the 8-foot diameter drilling blades, minimizing fugitive emissions. The vapors were transported from the shroud through the vapor conditioning system (VCS) to the VOC treatment system by the blower. VOC treatment was succeeded by placement of ZVI to enhance reductive dechlorination of VOCs to facilitate the achievement of cleanup target levels in an estimated reasonable time frame.

The VOC treatment system consisted of a conditioning system and vapor treatment system. Vapor collected in the LDA shroud contained air, water, VOC contaminants, and particulates. The conditioning system was required to remove water and particulates from the vapor before being processed in the vapor treatment system. The VCS consisted of a knockout tank, chiller, reheater, and particulate filter. The vapor from the conditioning system was then processed in the vapor treatment system consisting of thermal oxidation and/or a vapor phase carbon adsorption to remove VOC contaminants. The thermal oxidation system was capable of destroying 99.9% of VOCs. The vapor phase carbon adsorption system was generally used as a backup during thermal oxidation system shutdown.

Real-time data acquisition was an integral part of the in-situ soil mixing that allowed the operator to determine the efficiency of treatment and maximize the results within the treatment protocols established for the site. The data acquisition system and gas chromatographs (GCs) allow effective coordination and control of various process parameters in the treatment train. The SCADA system also helps in making real-time decisions related to expanding the area of treatment and focusing the interval of treatment.

Data Collection and Evaluation

A SCADA system was used to monitor field instruments and process equipment associated with the in situ soil treatment system. The SCADA system collected and stored data for reporting, trending, and analysis as well as provided process information for operator control. Standard reports were generated and published on the web so that authorized users can access reports using a web browser over the Internet. Analytical instruments that were integrated with the SCADA system provided data that allowed real-time evaluation and instant decision making, as follows:

- Three flame ionization detectors (FIDs) were used to continuously monitor the effluents (total hydrocarbons) produced by the treatment process. The FIDs were used to measure total VOCs in three sample streams given below:
  - Off-gas from the treatment process.
  - Influent to the thermal oxidizer.
  - Either the stack effluent thermal oxidizer when the unit was on-line, or the stack at the exit of the carbon bed if the carbon bed was being used.

- Four GCs were used to detect, speciate, and quantify target analytes from the treatment process off-gas. Three GCs were cycled at 2 minute intervals throughout the treatment process with one GC being operated when a maximum VOC as measured by the FID was detected. The GCs were computer controlled with the vendor-supplied software that allowed chromatographic analysis of the contaminants of concern, quantitation of analytes, and reporting of concentrations from each sample.

Data from the FIDs and GCs were utilized to determine trends in depth, concentration, and location of contamination requiring treatment. Identified data trends in contamination enabled on-site field personnel and managers to perform real-time decision making on depth placement and treatment times needed for effective and efficient LDA operation and to aid in a real-time determination for adding or deleting treatment cells. Mass removal information was not available in real time but was provided within one or two days, thus allowing field decisions on treatment or no treatment while the LDA was positioned near the area in question. A total of 27 treatment cells were thermally treated as expansion cells due to either elevated TCE concentrations (greater than 100 ppm) and elevated FID concentrations (greater than 400 ppm), or based on mass removal of greater than one pound of TCE mass in the adjacent cells, per treatment protocols. A total of 15 cells were deleted due to a combination of low FID (less than 400 ppm) and low TCE (less than 60 ppm) in adjacent cells.

Results

Treatment of Facility 18003 started in March 2006 and was completed in May 2006; 157 8-foot diameter cells were treated over a period of 1.5 months to maximum depths of 55 feet below ground surface. Approximately 388 pounds of VOCs were removed and destroyed. Cis-1,2-DCE, TCE and PCE accounted for 99% of the total mass removed in relative amounts of 45, 44 and 10 percent, respectively. Baseline and post-remediation soil and groundwater samples collected from identical locations and depths within the source area demonstrate that maximum concentrations of the target VOCs were reduced between one to four orders of magnitude, or a reduction range of > 99% to 87%. None of the post-remediation soil samples showed concentrations that exceeded the industrial soil cleanup target levels for the target VOCs, and the concentration of TCE in groundwater did not exceed 0.18 mg/L in any post-remediation sample collected from the treatment zone.

1.0 INTRODUCTION

This Corrective Measures Implementation (CMI) Report was prepared by Tetra Tech, Inc. for the Security Police Confidence Course (SPCC) (Facility 18003) at Cape Canaveral Air Force Station (CCAFS), Florida. Facility 18003 is designated as Solid Waste Management Unit (SWMU) C091 in the Corrective Action Management Plan (CAMP) for the 45th Space Wing. This CMI Report has been prepared in accordance with the Resource Conservation and Recovery Act (RCRA) Corrective Action Plan (CAP) guidance. Tetra Tech has prepared this CMI Report for the Installation Restoration Program (IRP) of the 45th Space Wing Civil Engineering Squadron/Restoration Division (45th CES/CEVR) in accordance with the approved Final Corrective Measures Designs (CMDs) prepared by Jacobs Engineering Group, Inc. and the approved CMI Work Plan prepared by Tetra Tech, Inc. This report was prepared under contract with the Air Force Center for Environmental Excellence (AFCEE), Brooks-City Base, Texas (Contract FA8903-04-D-8677, Delivery Order 0031).

1.1 OBJECTIVE

This CMI Report is intended to present all the implementation activities including site preparations, mobilization, system startup and testing, system operation, and data acquisition. The report also presents the results of the treatment of contaminated saturated subsurface through in-situ soil mixing with steam, hot air, and zero valent iron (ZVI) injection.

1.2 BACKGROUND

CCAFS is located in Brevard County on the east-central coast of Florida. Facility 18003 is now the SPCC, an obstacle course consisting of trails and various apparatus for physical training. Past storage and manufacturing operations at the site led to its investigation by the IRP and subsequent SWMU listing. Three investigations identified and described contamination impacts at Facility 18003:

- Preliminary Assessment #3 (Parsons, 1995)
- Confirmation Sampling Summary and RFI/CMS Recommendations, Facility 18003-SPCC (18003), SWMU 91 (Parsons, 1996)
- RCRA Facility Investigation (RFI) Report and Interim Measures (IM) Work Plan (BEM, 2001)

These investigations identified areas of soil and groundwater contamination that presented potential risk to human and/or ecological receptors. An IM for excavation of polychlorinated biphenyl (PCB) and inorganics (chromium and vanadium) contaminated soil was conducted by BEM Systems, Inc. in 2002 to address soil impacts at the site. Consequently, supplemental investigations were undertaken and a Corrective Measures Study (CMS) was performed by BEM Systems, Inc. The CMS Report (BEM, 2003) concluded that soil no longer presents a risk to human health following the IM, though some residual ecological risk may persist. There is a plume of dissolved groundwater contamination emanating from Facility 18003 that consists primarily of chlorinated volatile organic compounds (VOCs). Within that plume, trichloroethylene (TCE), cis-1,2-dichloroethylene (DCE), and vinyl chloride are present in concentrations which exceed the Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (GCTLs). BEM ascertained that there is an area on the northeast side of Facility 18003 with very high dissolved concentrations of TCE and, based upon the solubility of TCE, the concentrations are suggestive of the presence of TCE in the form of dense non-aqueous phase liquid (DNAPL). This area is presumed to be the source of continuing groundwater VOC contamination. The CMS recommended that the source area be addressed to substantially reduce the mass of DNAPL, and presented several alternatives to achieve that objective.

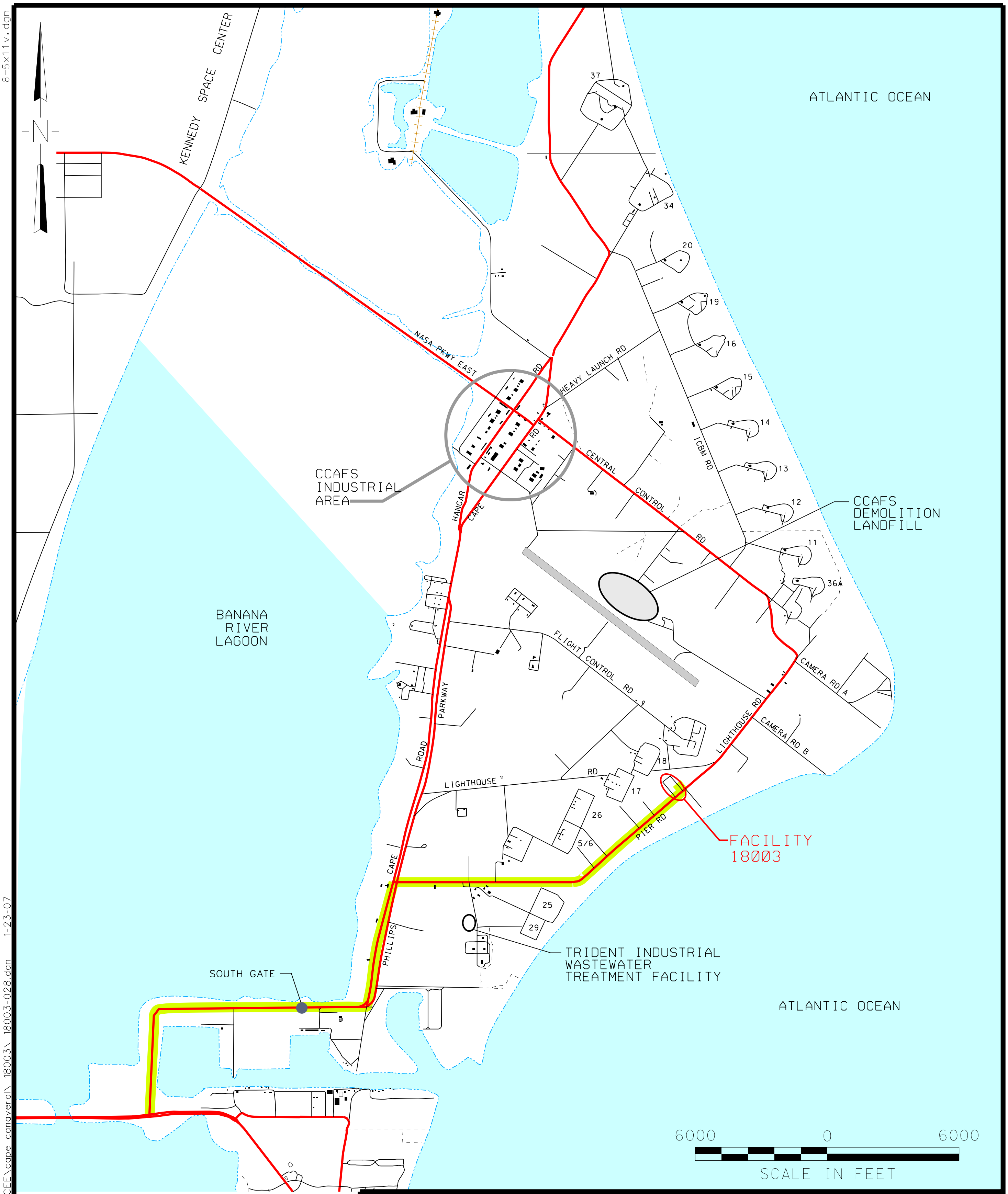
The CMS for Facility 18003 was approved by Cape Canaveral and Patrick Environmental Restoration Partnering Team (Partnering Team), which was established to facilitate restoration of SWMUs at 45th Space Wing facilities. The Partnering Team includes representatives of the 45th Space Wing IRP Office, AFCEE, the U.S. Environmental Protection Agency (USEPA), the FDEP, the U.S. Army Corps of Engineers (USACE), and environmental contractors. The recommended alternative for corrective action comprises several steps:

1. Treatment of the source area (defined as the area where the TCE concentration in groundwater is 10 mg/L or greater) through in-situ soil mixing with steam, hot air, and ZVI injection via large diameter auger (LDA);
2. Natural attenuation of groundwater contamination to FDEP GCTLs for the non-source area, documented by continued monitoring; and
3. Land use control at the site to prevent exposure to contaminants until cleanup targets are achieved.

The recommended alternative was presented to the U.S. Air Force Command Peer Review in June 2003. The U.S. Air Force Command Peer Review Committee endorsed this approach as the environmentally responsible and cost-effective remedial strategy for source area contamination at Facility 18003.

1.2.1 Site Location and Operational History

Facility 18003 encompasses approximately 10 acres on the southeast portion of CCAFS, approximately 0.5 miles west of the Atlantic Ocean and approximately 2.5 miles east of the Banana River located along Pier Road (Figure 1-1). Also known as the SPCC, Facility 18003 is located along Pier Road on CCAFS (Figure 1-2). Previous investigations have determined that the site is safe for its current use as an outdoor law enforcement physical training area. No structures, other than man-made obstacles for the course, currently exist on the site. Two concrete pads, which historically served as foundations for two storage sheds known as former facilities 1250 and 1251, were identified on the southwest and northeast sides of the facility.



LEGEND

🟩 CONTRACTOR ACCESS ROUTE TO FACILITY 18003

PRIMARY HIGHWAY

IMPROVED ROADS

UNIMPROVED ROAD

RAILROAD

◆ BUILDING/STRUCTURE

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 1-1
SITE LOCATION MAP

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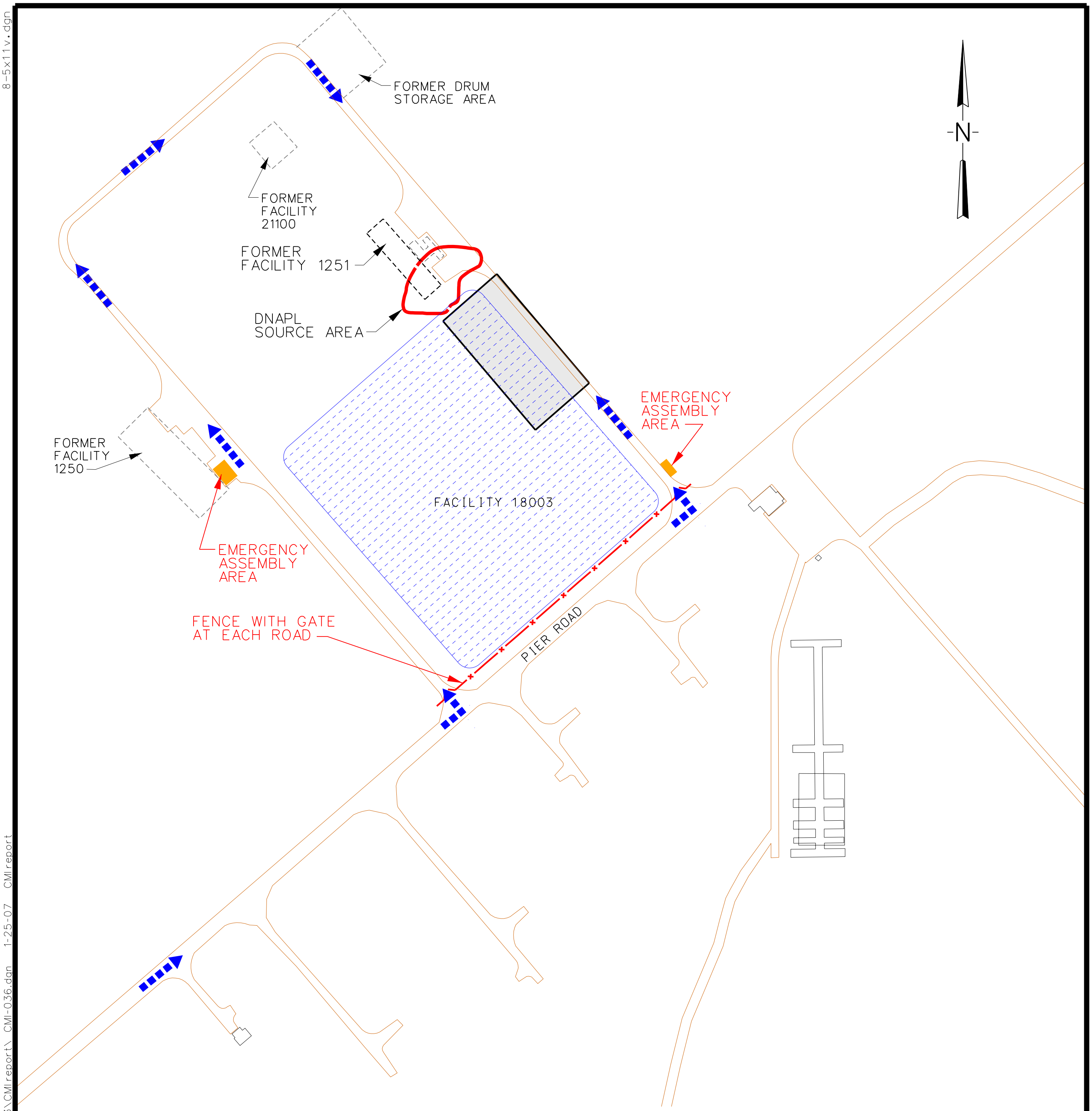

LEGEND

▭ CONTRACTOR LAYDOWN AND STORAGE

▨ CONFIDENCE COURSE AREA

▪▪▪▪▶ ACCESS ROUTE INDICATOR

200 0 200
SCALE IN FEET

SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003,
JACOBS ENGINEERING, MAY 2005

SOME BASEMAP INFORMATION FROM BEM SYSTEMS INC.

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 1-2
SITE MAP

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8-5x11v.dgn

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In the early 1950s, two open-air type facilities (1250 and 1251) were constructed to store liquid rocket propellant. The sites for these former facilities are now within the footprint of Facility 18003, SPCC. Former Facility 1250, on the west side of Facility 18003, was originally used as an alcohol and aniline storage shed. Former Facility 1251, on the east side of the site, was used as an acid storage shed. The shed foundations were sloped inward and included a drainage trench.

In the early 1960s, former Facility 1250 was used to assemble small, solid-fuel meteorological rockets. Former Facility 1251 was utilized as a chemical cleaning lab for the cleansing of Atlas rocket hoses and other lines with solvents. During the routine cleaning process, several buckets of solvents were reportedly released directly to the ground along the edges of the concrete pad. Solvents were also flushed from the pad onto the ground or into the drainage trench.

Spill collection systems were built for both facilities. Former Facility 1250 was drained through a discharge trench into a 1500-gallon steel collection tank. Former Facility 1251 also drained through a discharge trench into a 540-gallon stainless steel neutralizing tank, then into a concrete collection pit, and finally into a leaching bed. The drainage trenches were, at some point, filled with concrete. There is no current evidence of any remaining underground collection systems for either building.

In 1963, several deteriorated underground storage tanks (USTs) around CCAFS were pumped dry of the gasoline they contained. The gasoline was stored in approximately 100 55-gallon drums and placed in the north corner of Facility 18003. The final disposition of these drums is unknown. A sanitary latrine (Facility 21100) was built in 1964 approximately 100 feet off the northwest edge of the acids storage shed foundation (Facility 1251). Facilities 1250, 1251, and 21100 were demolished in 1970. The SPCC was constructed at Facility 18003 in 1983 to train CCAFS security personnel and is still used as an active training facility. Previous reports indicate the current use does not have the potential for any unacceptable exposure to site contaminants. Remaining contaminants are below the ground surface, and there is no route for exposure.

1.2.2 Existing Site Conditions

This section describes an overview of the physical attributes of Facility 18003 including physiography and hydrogeology. A complete discussion of geology, hydrology, and historical events leading to developing the conceptual site model at Facility 18003 is included in the CMS Report (BEM, 2003).

1.2.2.1 Physiography

The natural ground surface elevations at Facility 18003 range from approximately 5 to 10 feet above mean sea level (msl). Facility 18003 encompasses approximately 10 acres containing no structures other than the physical conditioning apparatuses and concrete pads described in previous sections. The area surrounding the facility is predominantly natural vegetation. There are no drainage canals within or adjacent to the site.

1.2.2.2 Hydrogeology

During the RFI, the geology at Facility 18003 was evaluated to 80 feet below ground surface (bgs) using data collected from soil borings and cone penetrometer test (CPT) logs. The surficial geology was described as consisting of recent, unconsolidated deposits of fine- to medium-grain sand, with little to some shell fragments. Layers and lenses of silt, fine sand and silt, and clay occurred sporadically within this interval, and were difficult to correlate from one location to another. It is expected that the layers and lenses are discontinuous. The lower permeability clays, silts, and marls of the Hawthorn Group were not encountered in any of the borings during the RFI. Based on regional information, the top of this unit is anticipated to be at approximately 100 - 150 feet below msl. This low permeability zone represents the first major aquitard below Facility 18003. It is substantially deeper than the lowest portion of the surficial aquifer believed to have source material (DNAPL).

Groundwater at CCAFS occurs under both unconfined (non-artesian) and confined (artesian) conditions. The surficial aquifer contains groundwater under both non-artesian and artesian conditions, starting at approximately 4 feet bgs. Water enters the aquifer through direct infiltration as a result of percolation of rainwater. Water in the saturation zone of the surficial aquifer moves laterally toward the regional drainage canal, the Banana River or the Atlantic Ocean. During the site remedial investigations, groundwater flow in the shallow, intermediate, and deep intervals was observed to be generally to the north, which is consistent with the direction of plume migration. Although the northward groundwater flow direction appears to be inconsistent with regional eastward flow, toward the Atlantic ocean from the central portions of the Cape, this localized change in flow direction is frequently observed along the western margins of the costal dune ridge and is attributed to the local change in topography.

1.2.3 DNAPL Source Area

The RFI and CMS activities conducted at Facility 18003 focused on areas related to the historical storage, management and disposal of acids, solvents, and petroleum products at the site. There are no other known activities at the site, nor on surrounding grounds, that would account for the contamination observed. Four potential sources of contamination were identified at Facility 18003:

- Former rocket assembly facility (Facility 1250)
- Foundation of the former chemical cleaning lab (Facility 1251)
- Vicinity of the collection/treatment system associated with former Facility 1251
- North corner of Facility 18003, where drums of gasoline were once stored.

Potential release mechanisms at Facility 18003 included discharges and spills associated with the chemical cleaning lab and rocket assembly operations, storage and use of gasoline in the drums on the north corner of the site, and the potential disposal of chemicals through the sanitary latrine. The mechanisms that appeared to have transported these contaminants were runoff and seepage. The RFI indicated that these contaminants migrated into groundwater and potentially discharged into surface water (drainage canals) located downgradient of Facility 18003. The study area for the Facility 18003 dissolved plume encompassed 475 acres. There is presumptive evidence that DNAPL is present because of the very high concentrations of dissolved TCE. A dissolved concentration of 10 mg/L of TCE (about 1% of solubility for TCE) is accepted by the IRP Partnering Team for presumptive identification and delineation of a DNAPL source area. For Facility 18003, the CMS determined that the DNAPL source area was located under the foundation of the former chemical cleaning lab (Facility 1251). At the conclusion of the CMS, the source area was estimated to have a footprint of approximately 6,000 ft^2, and to extend vertically from about 15 to 50 feet bgs. However, resources necessary to delineate the extensive dissolved plume limited the effort to discretely delineate the source area.

To provide more information to the CMS and to support development of the CMD, some additional investigatory work was performed at the Facility 18003 source area. In February 2004, groundwater samples were collected by Jacobs Engineering, Inc. from 18 locations on a 25-foot grid in and around the suspected source area. TCE detections ranged from 1.7 to 140,000 µg/L (0.0017 to 140 mg/L). The February 2004 sampling event expanded the extent of the Facility 18003 source area, but did not totally define its boundaries based upon the delineation criteria of 10 mg/L of TCE.

Additional sampling was performed by Apex Environmental Engineering & Compliance, Inc. (APEX) in May 2005, to close the boundaries, both horizontally and vertically. Samples collected during this event identified TCE concentrations at or exceeding 10 mg/L and tetrachloroethylene (PCE) concentrations at or exceeding 15 mg/L (approximately 1% solubility of PCE). The highest concentrations along the north corner of the site and beneath the slab of Facility 1251 were detected at the 20 feet bgs interval. In the southeasterly sample locations, the highest concentrations were at 40 to 55 feet bgs. This sampling event defined the extent of the source area covering an area of approximately 7,300 ft^2 to a depth of 55 feet bgs. The 10 mg/L TCE source area contour based on February 2004 and May 2005 data is depicted on Figure 1-3.

1.3 PURPOSE AND OBJECTIVE

Conditions at Facility 18003 were previously assessed with regard to the quality of groundwater, soil, sediment, and surface water. The primary contaminants of concern (COCs) in groundwater are VOCs, specifically chlorinated solvents. These VOCs include PCE, TCE, cis-1,2-DCE, and vinyl chloride. The VOC source area is defined in the CMS (BEM, 2003) and CMD (Jacobs, 2005B) based upon dissolved concentrations of TCE in groundwater equal to or greater than 10 mg/L.

1.3.1 Remedial Action Objectives

Without active cleanup, it is anticipated that significantly more than 150 years will be required in order to achieve cleanup target levels for groundwater. However, the Facility 18003 CMS indicated that plume size and cleanup times could be reduced significantly if at least 70% reduction in contaminant mass could be

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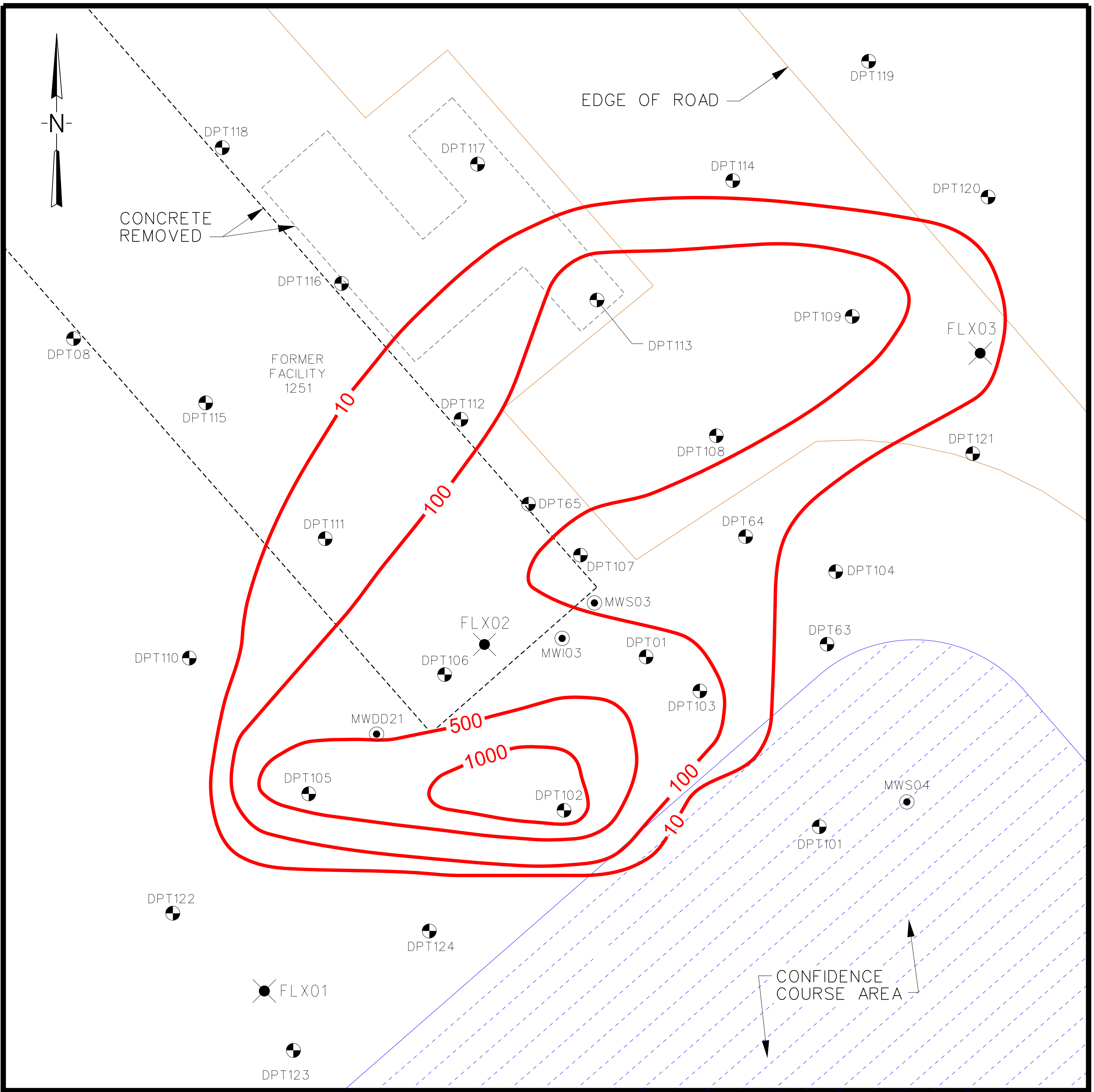

20 0 20
SCALE IN FEET

LEGEND

TCE PLUME (ppm)

DIRECT PUSH TECHNOLOGY SAMPLING POINT 2004

MONITORING WELL

FLUX WELL

NOTE

MWS02 AND MWD02 ARE LOCATED APPROXIMATELY 400' SOUTHWEST OF SITE. SEE FIGURE 2-6 FOR ACTUAL LOCATION.

SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003, JACOBS ENGINEERING, MAY 2005

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FIGURE 1-3
TCE SOURCE AREA

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achieved. Therefore, the remedial action objectives as per Statement of Basis for Facility 18003 (IRP, 2005) are as follows:

1. Through an active remedy, remove a significant percentage of solvent source material that remains in the subsurface aquifer (TCE concentration > 10 mg/L is considered “source”).
2. Implement a remedy on the residual groundwater contamination upon termination of the source area treatment action.
3. Achieve final remedial goals for groundwater within 150 years of active remedy implementation. Since this is such a long time frame, interim goals shall be established based on reduction in plume mass:
    - 50% mass reduction in 30 years
    - 75% mass reduction in 80 years
    - 90% mass reduction in 120 years
    - 100% mass reduction in 150 years
4. Continue monitoring of surface water protective measures, until several rounds of sampling data indicate that the groundwater plume no longer intersects or discharges into the canals, thus remaining compliant with State surface water standards for the Banana River Lagoon (F.A.C. 62-302.700).
5. Protect humans from exposure to residual groundwater contamination and prevent consumption of groundwater from the shallow aquifer [while COCs remain above health-based standards for unrestricted (residential) use].

1.3.2 Report Objectives

The objective of the CMI is to remove and/or destroy significant contaminant mass (including dissolved, sorbed constituents, and DNAPL) in the identified source areas. The purpose and objective of this report are to present all implementation activities and results of a remedial action that address groundwater impacts at Facility 18003.

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2.0 DESIGN AND CONSTRUCTION

2.1 DESIGN SUMMARY

This section details the remedial equipment that was used for the source area remediation via in-situ soil mixing with injection of steam, hot air, and ZVI at Facility 18003. The process flow diagram (PFD) and piping and instrumentation diagram (P&ID) are illustrated in Figure 2-1 and Figure 2-2, respectively.

2.1.1 Injection Equipment and Materials

The following section describes the method and equipment/materials that were utilized to inject steam, hot air, and ZVI slurry during operation.

2.1.1.1 Hot Air/Steam Equipment

Hot air was generated using ambient air from two electrically powered air compressors each with a maximum volumetric flow rate of 600 cfm at an operating pressure 150 pounds per square inch gauge (psig). A filter bank was utilized in line prior to the manifold and was utilized to remove any oil from the generated air flow. Air exited the compressors at a temperature of approximately 150^{o}F and was controlled remotely by the operator. Injection pressure, temperature, and flow were electronically transmitted and recorded in a database. The photographs of the equipment are presented in Appendix A.

The steam generating equipment consisted of two steam boilers with power ratings of 400 hp and 250 hp, both operating at 135 psig at a temperature of 385°F. The boilers were fired using #2 diesel fuel. Base supplied potable water entering the boiler units was conditioned by a water softening ion exchange unit to prevent scaling of the units. At the maximum operating capacity, the boilers' output exceeded 10.5 million British Thermal Units (MBTUs) per hour [BTU/hr]. Utilizing sufficiently sized hose from the boiler to the manifold and a 4-inch hose from the manifold to the drill stem (Kelly Bar), the maximum flow rate obtainable was approximately 13,500 pounds of saturated steam per hour. Steam injection flow rate was controlled remotely by the operator. Steam injection pressure, temperature, and flow were electronically transmitted and recorded in a database.

2.1.1.2 Zero Valent Iron Injection Equipment and Slurry

Thermal treatment using in-situ soil mixing with steam and hot air injection has been shown to follow pseudo-first order kinetics (BEM, 2005). This indicates that as treatment time increases, the amount of material removed will continue decreasing exponentially. Therefore, in order to remove as much contaminant mass from each cell and yet keep thermal treatment time and costs in check, ZVI slurry was injected throughout the treatment volume after thermal treatment. The ZVI slurry components consist of ZVI powder, water, and guar that were mixed in the batch plant and pumped down hole through associated piping. Details of the batch plant, ZVI slurry, and associated pipes and pumps are discussed further.

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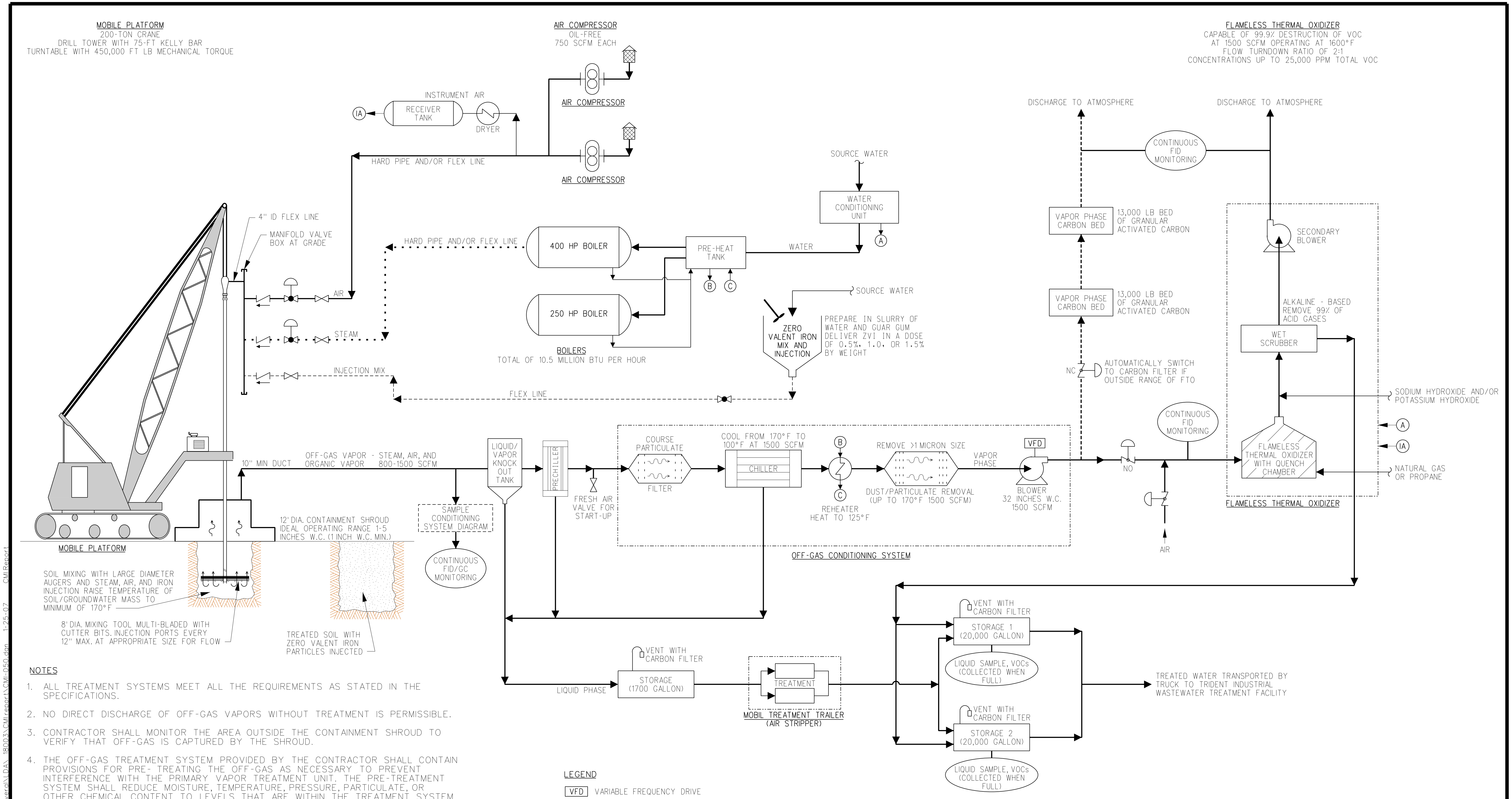

NOTES

1. ALL TREATMENT SYSTEMS MEET ALL THE REQUIREMENTS AS STATED IN THE SPECIFICATIONS.
2. NO DIRECT DISCHARGE OF OFF-GAS VAPORS WITHOUT TREATMENT IS PERMISSIBLE.
3. CONTRACTOR SHALL MONITOR THE AREA OUTSIDE THE CONTAINMENT SHROUD TO VERIFY THAT OFF-GAS IS CAPTURED BY THE SHROUD.
4. THE OFF-GAS TREATMENT SYSTEM PROVIDED BY THE CONTRACTOR SHALL CONTAIN PROVISIONS FOR PRE- TREATING THE OFF-GAS AS NECESSARY TO PREVENT INTERFERENCE WITH THE PRIMARY VAPOR TREATMENT UNIT. THE PRE-TREATMENT SYSTEM SHALL REDUCE MOISTURE, TEMPERATURE, PRESSURE, PARTICULATE, OR OTHER CHEMICAL CONTENT TO LEVELS THAT ARE WITHIN THE TREATMENT SYSTEM MANUFACTURER'S SPECIFICATIONS FOR TREATING CONTAMINANTS ENCOUNTERED AT THE SITE.
5. THE CONTRACTOR SHALL PROVIDE AND OPERATE AN INTEGRATED DATA ACQUISITION SYSTEM (DAS) CAPABLE OF CONTINUOUS MONITORING AND RECORDING ALL PROCESS CONTROL PARAMETERS AT A CENTRAL LOCATION.
6. DAS SHALL BE CAPABLE OF PROVIDING DATA, AS INDICATED, IN REAL TIME FOR PROCESS CONTROL.
7. THE STORAGE TANKS SHOULD INCLUDE VENTS CONNECTED TO CARBON FILTERS TO CAPTURE FUGITIVE EMISSIONS.
8. THE CONTRACTOR WILL HAVE THE OPTION OF TREATING THE CONDENSATE WATER OR STORING AND DISPOSING OF IT THROUGH THE BASE WASTEWATER TREATMENT SYSTEM, DEPENDING ON THE CONCENTRATION OF THE CONTAMINANTS OR OTHER CONSTITUENTS IN THE CONDENSATE.

LEGEND

VFD	VARIABLE FREQUENCY DRIVE
⋈	GATE VALVE
⧓	BALL VALVE
⋈	CHECK VALVE
⋈	BUTTERFLY VALVE
⏉	PNEUMATIC ACTUATED
NC	NORMALLY CLOSED
NO	NORMALLY OPEN
Ⓘ IA	INSTRUMENT AIR
Ⓐ	FROM WATER CONDITIONING UNIT
Ⓑ	FROM BOILER PRE-HEAT WATER TANK (180°F)
Ⓒ	TO BOILER PRE-HEAT WATER TANK (170°F)

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FIGURE 2-1
PROCESS FLOW DIAGRAM

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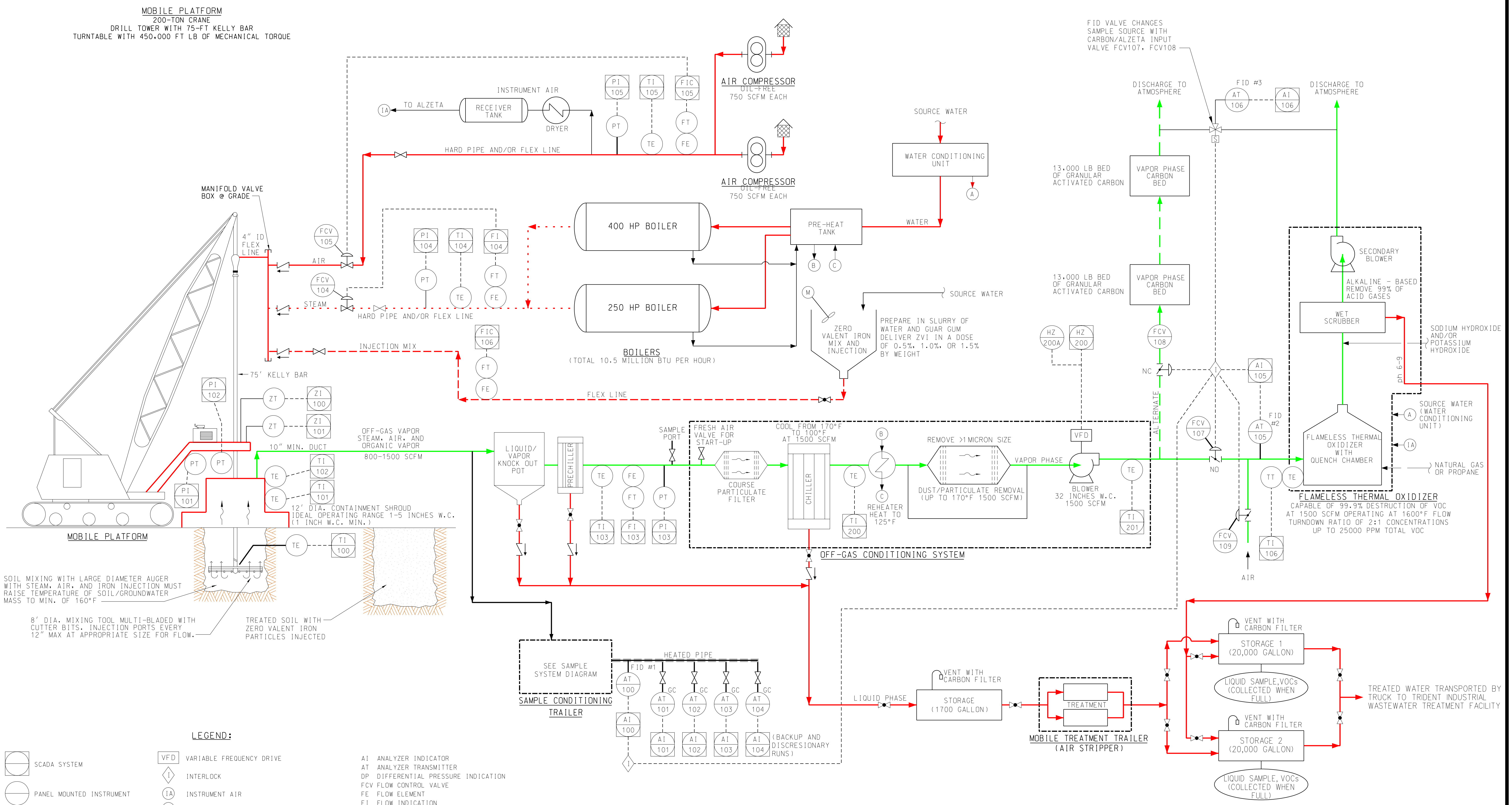

LEGEND:

⊟	SCADA SYSTEM	VFD	VARIABLE FREQUENCY DRIVE	AI	ANALYZER INDICATOR
⊖	PANEL MOUNTED INSTRUMENT	◇ I	INTERLOCK	AT	ANALYZER TRANSMITTER
○	LOCAL INSTRUMENT	(IA)	INSTRUMENT AIR	DP	DIFFERENTIAL PRESSURE INDICATION
⋈	GATE VALVE	(A)	FROM WATER CONDITIONING UNIT	FCV	FLOW CONTROL VALVE
⊿	CHECK VALVE	(B)	FROM BOILER PRE-HEAT WATER TANK (180°F)	FE	FLOW ELEMENT
⋈	BALL VALVE	(C)	TO BOILER PRE-HEAT WATER TANK (170°F)	FI	FLOW INDICATION
⧵	BUTTERFLY VALVE	NC	NORMALLY CLOSED	FIC	FLOW INDICATION CONTROLLER
⊤	PNEUMATIC ACTUATED	NO	NORMALLY OPEN	FID	FLAME IONIZATION DETECTOR
S	3-WAY SOLENOID VALVE			FQI	FLOW TOTALIZING INDICATION
				FT	FLOW TRANSMITTER
				GC	GAS CHROMATOGRAPH
				HZ	FREQUENCY INDICATION AND CONTROL
				PI	PRESSURE INDICATION
				PT	PRESSURE TRANSMITTER
				RH	RELATIVE HUMITY
				RT	RUN TIME
				TE	TEMPERATURE ELEMENT
				TI	TEMPERATURE INDICATION
				TT	TEMPERATURE TRANSMITTER
				VI	VERTICALITY INDICATION
				ZI	POSITION INDICATION

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FIGURE 2-2
PIPING AND INSTRUMENTATION DIAGRAM

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The ZVI slurry was prepared in two 600-gallon mixing tanks. The required quantity of ZVI-guar slurry mixture for each cell was transferred to the soil mixing auger by a progressive cavity pump. The slurry traveled down a 4-inch flexible hose to a 4-inch pipe connected to the crane. The slurry traveled up the 4-inch pipe then into another 4-inch flex hose and into the swivel. The slurry then traveled down the Kelly Bar and was injected into the subsurface through the rotating auger to distribute the iron throughout the column. Water was used to flush the iron-guar slurry from the injection plumbing into the column during the final pass to ensure that the entire quantity of iron required was injected into the column.

The amount of ZVI injected was determined by reading the maximum flame ionization detector (FID) concentration in the treatment cell during operation. ZVI slurry injection of 0.5%, 1.0%, or 1.5% was used depending upon FID following the treatment protocol. The ZVI used was Connelly CC-1021 or Peerless P1 with less than a -50 mesh grain size, and was prepared in a slurry of water and guar gum in two 600-gallon mixers. ZVI powder was suspended in the slurry at a rate of approximately 5-7 lbs of ZVI per gallon of water. Guar gum was mixed at a rate of 70 lbs per 1000 gallons of water. The actual quantity of guar and water was adjusted to adequately suspend the ZVI and achieve optimal pumping viscosity. The batching mass ratios were approximately 0.5:1 ZVI:water and 0.008:1 guar gum:water. Table 2-1 details the ZVI quantities per treatment cells by zones at Facility 18003.

Table 2-1. ZVI Quantities per Treatment Cell by Zones

Zone	Depth (ft)	ZVI Proposed (lbs)			
		0.5%	1.0%	1.5%	2%
SPCC Perimeter Cells		--	2250	--	
SPCC Zone 1	10-55	1150	2250	3400	4500
SPCC Zone 2	10-25	400	750	1100	1500

Note – ZVI quantities may vary slightly due to availability of on-site bag sizes.

2.1.1.3 Mixing Equipment and Tools

Equipment and tools that were utilized for soil mixing included the crane, swivel, mixing blade, Kelly Bar, drill platform, and timber mats. The crane that was used for drilling is a Manitowoc 777 series crane. The swivel was attached to the end of the crane boom cables that serves as the connection point for the Kelly Bar, allowing the bar to rotate freely while drilling. In addition, the swivel (2-inch ID) serves as the injection point of material from the 4-inch diameter flexible hose to the Kelly Bar. The Kelly Bar was 75 feet long with a 13.5 inch x 13.5 inch cross-sectional area. The interior of the hollow Kelly Bar consisted of a 3-inch diameter pipe that transferred the injection material to the subsurface.

The mixing tool was a multi-bladed 8-foot diameter auger with ½-inch injection ports along both blades for a total of 14 ports. A spare mixing tool of the same diameter was maintained on-site. The Kelly Bar and mixing tool were supported by a high-torque transmission platform attached to the crane. The range of torque exerted by the drill transmission for normal operations was between 100,000 and 453,000 foot-pounds. The crane and mixing equipment traversed the site upon 1 foot high by 4 foot wide by 21 foot long hardwood timber mats. Auger depth was determined through the use of a wire-guided position indicator. This measurement was electronically transmitted and recorded in a database during treatment.

2.1.2 Vapor Extraction Equipment

The following section describes the method and equipment that were utilized in extracting and conditioning volatilized contaminants.

2.1.2.1 Vapor Extraction and Conditioning Equipment

As the mixing blade rotates and hot air and steam were injected in the soils, volatilized contaminants escaped to the surface through the annulus created by the rotating square Kelly Bar. The contaminants were collected through a shroud maintained under 1-5 inches of water vacuum that covers the active treatment area. The containment shroud is 12 feet in diameter that provides the ability to capture off-gases beyond the 8-foot diameter drilling blades, minimizing fugitive emissions.

The vapors were removed from the shroud by the blower that is a component of the trailer-mounted vapor conditioning system (VCS). The blower provides for the transport of vapor from the shroud to the VCS and through the treatment system. Vapors generated during the soil mixing process were captured inside the shroud and drawn by the vacuum through 10-inch diameter flexible hose with 10-inch diameter steel pipe connected ahead of the VCS. Sections of the flexible hose were either added or taken away as treatment progressed throughout the site.

The VCS consisted of the knock-out (KO)/demister tank, the chiller, the reheater, and the particulate filters. The vapor entering the shroud from the annulus is saturated with water. The vapors initially flow through a liquid vapor KO tank to remove large dirt particles and the condensed moisture. The vapors then flow from the KO tank into a pre-chiller and then through 10 to 20 micron filter and into the chiller unit used to cool the gas temperature from approximately 170^{o}F to less than 100^{o}F at a flow rate of 1,500 cfm. Condensate water generated by the KO tank, pre-chiller and chiller were stored in a temporary 1,755 gallon holding tank for air-stripping treatment by the mobile treatment system. Cooled vapor then enters the re-heater (housed in the same unit as the chilling elements) to raise the temperature by 10 to 12^{o}F to reduce the relative humidity to 80%. Vapor then flows through a 1 micron filter to remove the fine particulates. The vapor then enters a Y junction at the end of the VCS controlled by two pneumatically controlled valves diverting the flow either to the vapor phase granular activated carbon (GAC) beds or the flameless thermal oxidizer (FTO) treatment systems. Control of the equipment was performed remotely by the operator through interface with the VCS Programmable Logic Controller (PLC) located on the trailer. Data that were recorded from instruments on the VCS include pressure drop over the chiller/heat exchange unit, vapor temperature after chiller, vapor temperature and relative humidity after reheater, blower frequency, and open/closed status of the valves. The following information provides detailed VCS equipment sizes, models, and specifications.

- **KO Tank** - The KO tank was 44 inches in diameter by 72 inches in height with a 12 inch slip hose connection for processing air in and out. Included on the unit were a 4 inch sludge drain port with a gate valve, 1 inch connection for feeding to a transfer pump, 2 ¼ inch gauge taps, liquid transfer gear pump with ½ hp 115/1/60 motor, and three float switches for pump on/off control and high water alarm. The KO tank was equipped with a demister pad to remove additional water droplets and dust particles.
- **Pre-Chiller Unit –** The pre-chiller unit was designed in an independent housing constructed of 14 gauge galvanized steel. The pre-chiller unit utilized the same air cooled chiller described below for the primary chiller. The chiller unit was designed to cool the incoming air from 170°F to the VCS operating temperature of 160°F.
- **Course Particulate Filter** – A 25 inch by 16 inch by 2 inch 10 – 20 micron filter was included in the chiller/heat exchanger housing.
- **Chiller/Heat Exchange Unit** – The chiller elements and heat exchange coils were designed in the same housing along with a particulate filter. The housing for mounting the elements and coils, inlet filters, inlet and outlet (12 inches round) connections was 14 gauge galvanized steel. The chiller unit was a Trane™ 70 ton (840,000 BTU/hr) air cooled water chiller using Freon 22 as the cooling agent with chilled water entering the cooling elements at 40°F and exiting at 60°F. The heat exchanger was an Aerofin Type Rf coil 34.9 inch by 25 inch 6 row with copper fins on 5/8 inch copper tubing with a galvanized steel case. The drain pan was 304 stainless steel, 14 guage, with a ¾ inch drain connection. The heat exchanger was designed to produce 150,000 BTU/hr using 180°F from the boiler preheat tank. A hand valve on the upstream side of the reheater controlled the water flow and subsequent heating capacity.
- **Fine Particulate Filter** - The final filter prior to entering the vapor treatment unit was a 24 inch square by 4 inch thick 1 micron fiberglass mesh filter housed in 16 gauge galvanized steel.
- **Blower** – The blower used to provide the vacuum was rated for 1,800 cfm at 31 inches total static pressure at 13.4 brake horsepower (bhp) using a 15 hp 230-460/3/60 VAC TEFC premium efficiency motor. A National Electrical Manufacturers Association (NEMA) 4 rated Variable Frequency Drive (VFD) motor speed control rated for a 15 hp motor and 460 VAC/3 phase input from a generator.
- **Pneumatic Control Valves** – Two pneumatically air-actuated valves directed the vapor flow to the FTO or to the GAC beds. The valve in-line with the FTO was normally open (spring loaded open) and the valve to the GAC bed was normally closed (spring loaded closed). A 30-gallon air receiver tank was maintained at a pressure of 100 psig to provide air to the valves for control.

2.1.3 Vapor Treatment Equipment

The following section describes the primary and secondary equipment/materials that were utilized to treat the conditioned contaminant vapor stream.

2.1.3.1 Primary Treatment - Flameless Thermal Oxidizer

The conditioned vapor stream was primarily treated by the FTO model Edge QR™ unit designed by Alzeta Corporation. The FTO is trailer mounted and includes the oxidizer, integral quench chamber, acid gas scrubber, and a PLC. An air bleed valve was placed ahead of the reheater on the VCS trailer to ensure that the air flow to the thermal oxidizer unit is controlled. After the off-gas is burned in the flameless reactor at 1700ºF, it goes to a quench chamber where it is cooled to 180°F before being neutralized in the acid gas scrubber. The gas from the quench chamber is driven by a secondary blower through the 25-foot packed scrubber column before venting to the atmosphere. Fuel for the FTO was provided by three 1000-gallon propane tanks. The unit that was used offers a quick response (2 to 5 seconds) oxidizer startup and shutdown time and is rated at 1500 cfm, 25,000 ppm input of VOCs, and 99% destruction with a 50% turndown.

The FTO burning process generated acid gases from the destruction of TCE, Freon 113, and other chlorinated VOCs. The destruction of TCE and its daughter products (DCE and vinyl chloride) produced hydrochloric acid (HCl). Freon 113 contained both chlorine and fluorine atoms. Its destruction generated both HCl and hydrofluoric acid (HF). As mentioned above, the FTO was equipped with an acid gas scrubber to remove the HCl and HF gases from the vapor stream effluent prior to discharge into the atmosphere. The acid gas scrubber used water for the scrubbing which subsequently became acidic. Sodium hydroxide (NaOH) was metered into the re-circulating tank to raise the pH above 6. The amount of VOC material emitted to the atmosphere from the FTO was less than 1 pound total per day and no more than 0.2 pound per hour. Water generated from the scrubber blowdown was stored on-site in two 20,000-gallon frac tanks connected in parallel and tested to satisfy pre-treatment requirements and discharge parameters established by the Process Waste Questionnaire (PWQ). The water stored in the frac tank was discharged at the Trident Industrial Wastewater Treatment Facility.

2.1.3.2 Secondary Treatment – Granular Activated Carbon

GAC absorption vessels were used for backup treatment purposes when the FTO shut down. The GAC unit consists of two vessels connected in series; each vessel has the capacity for 13,000 pounds of carbon. An FID was connected to the exhaust stack of the lag carbon vessel as well as connected to the exhaust stack of the FTO to analyze potential organic material exhaust.

2.1.4 Mobile Water Treatment System

A mobile treatment system consisting of a 925-gallon temporary holding tank and a three-tray air stripper was used to treat the condensate water from the VCS unit. Condensate water was treated for a minimum of 12 hours in a closed loop system as part of the off-gas treatment process. Once treated, the water was discharged into the on-site 20,000-gallon frac tanks.

2.1.5 Process Monitoring and Control System

A Supervisory Control and Data Acquisition (SCADA) system was used to monitor field instruments and process equipment associated with the in-situ soil treatment system at the CCAFS Facility 18003. The SCADA system collected data for trending and reporting, as well as provided process information for operator control. The system integrated existing PLCs with new workstations, servers and Iconics Genesis SCADA software. The SCADA/PLC network diagram is illustrated on Figure 2-3.

2.1.5.1 General Description

This SCADA system was utilized for data acquisition and historical collection for available devices utilized in the treatment process for the following systems:

- LDA for mixing the soil and injecting steam and hot air,
- Steam generators (10.5 MBTU/hr),
- Air compressors (750 scfm each),
- Vapor extraction and conditioning system,
- Vapor treatment system,
- ZVI slurry injection system,
- Sample conditioning system, and
- Analytical measurement system [gas chromatograph (GCs) and FID].

2.1.5.2 System Description

The system:

- Provided an interactive illustration of the treatment system process for operator information and process control,
- Provided equipment status and monitoring functionality,
- Acquired process data for real-time and historical analysis for decision making capabilities,
- Tailored procedural control of the process via parameter modification, and
- Provided advanced reporting, charting, and data analysis capability.

The SCADA system collected process data, as transmitted from process instrumentation, and made the process data available for the following:

- Display to system users,
- Historical data collection, and
- Reporting, charting, and analysis.

User Interface graphic screens were designed to facilitate both general process awareness and specific process control tasks. Interface to PLCs and other control systems was over Ethernet network connections. Interface to local instruments and control devices was analog and/or digital process control loops.

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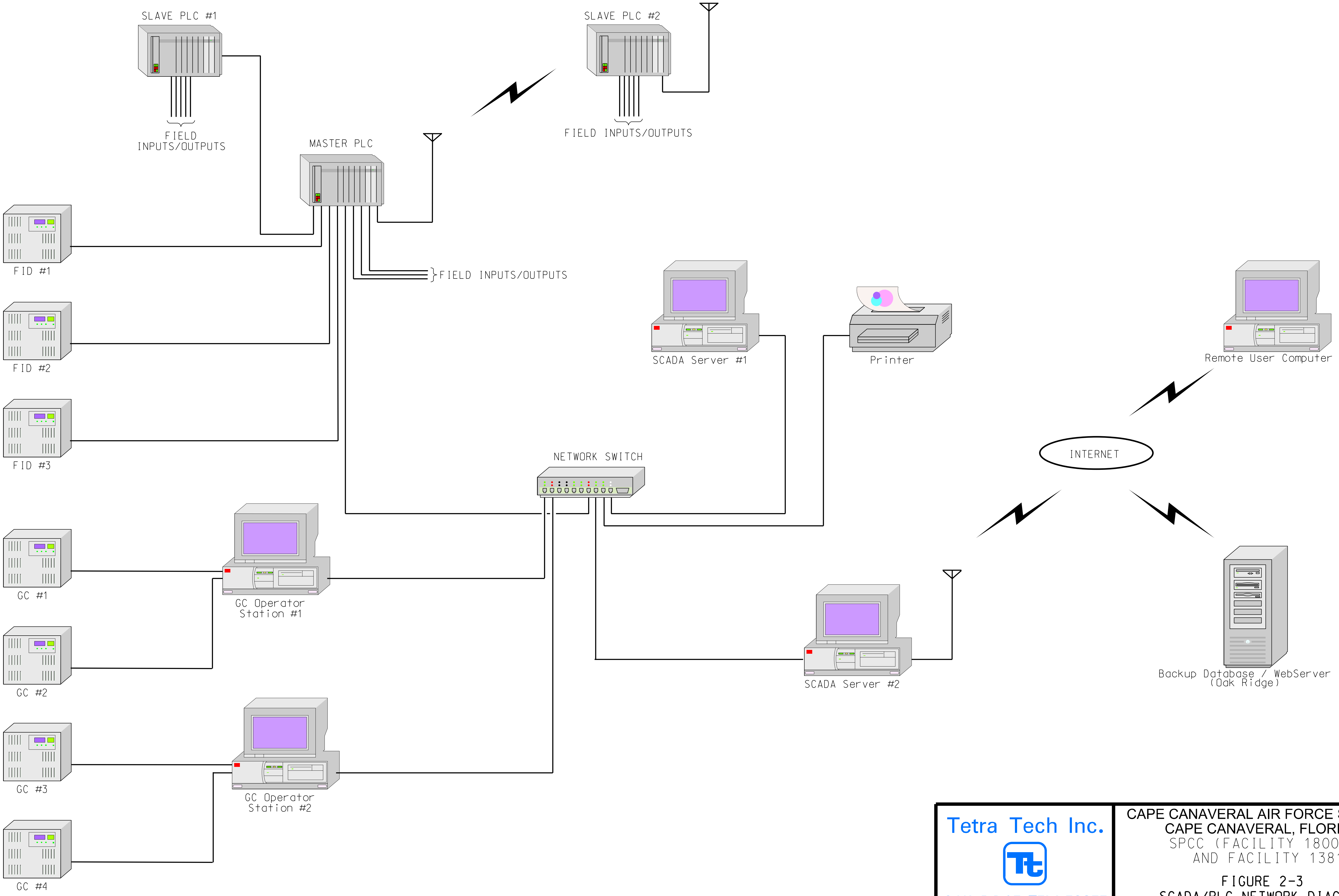

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FIGURE 2-3
SCADA/PLC NETWORK DIAGRAM

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The SCADA/HMI system software (Iconics Genesis32) consisted of the following modules:

- GraphWorx,
- TrendWorx,
- AlarmWorx,
- DataWorx,
- ReportWorx, and
- Web HMI.

The SCADA system utilized Microsoft SQL 2000 to store historical data.

2.1.5.3 System Functions and Capabilities

Navigation

A menu system allowed the operator to change screens to the primary operational areas. Additional menus and pop-ups gave access to the monitoring screens and trending screens.

Monitoring Screens

Each operational screen consisted of an overview screen. It detailed the values of all instruments. Easy access to historical and real-time trending data was available.

Trending

All analog data were trended in the system. The data were viewed in chart format, which was trended versus time. Historical data were kept in circular files on each local workstation. The process data were collected and stored every second. Data were copied to a network drive. Archived data were stored for display via a web interface.

Database

The monitored process variables were written to a Microsoft SQL database.

2.1.5.4 USER Interface

The SCADA servers ran Windows Server 2003 with SQL 2000.

2.1.5.5 Server Locations

The SCADA servers were located one each in the Data Acquisition System (DAS) trailer as well as Tetra Tech trailer. SCADA server 1 was connected via a network switch to the redundant SCADA server 2.

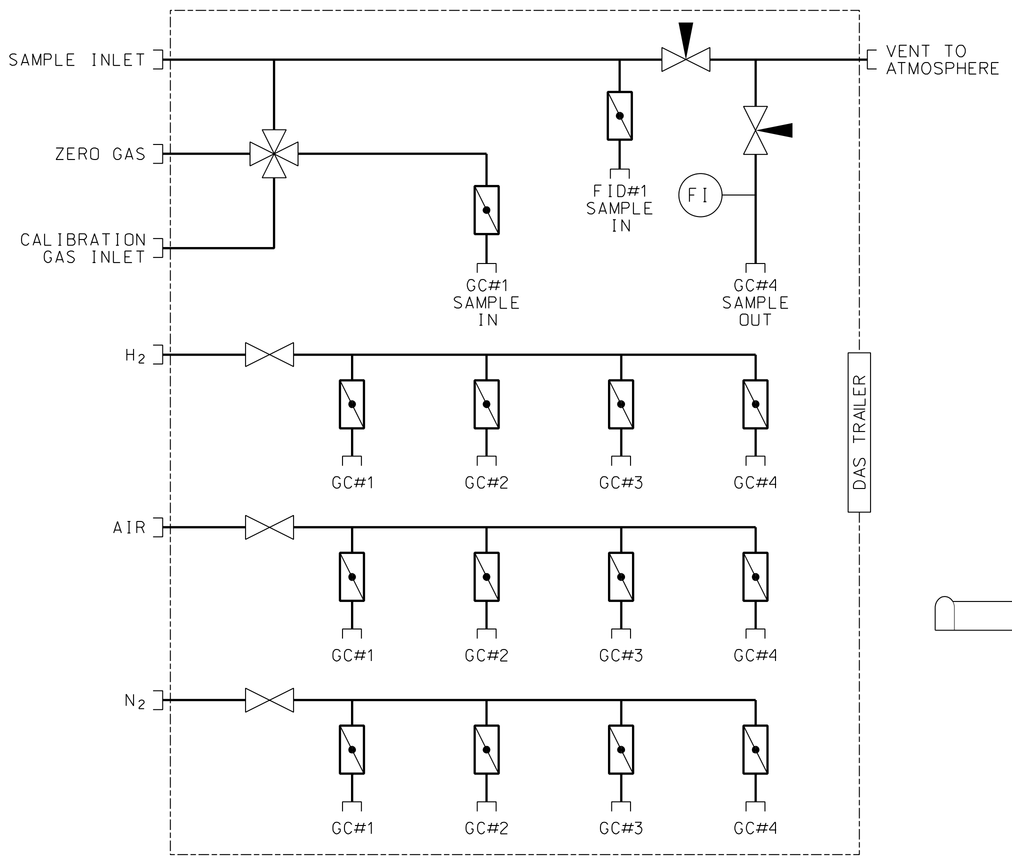
The Webserver runs Windows Server 2003 with SQL 2000 and the Iconics web modules. The webserver is located at the Tetra Tech facility in Oak Ridge. Installed on the webserver are ReportWorX and WebHMI utilized for processing data.

Standard reports are generated and published on the web so that authorized users can access reports using a web browser over the Internet.

2.1.6 Sample Handling and Conditioning System

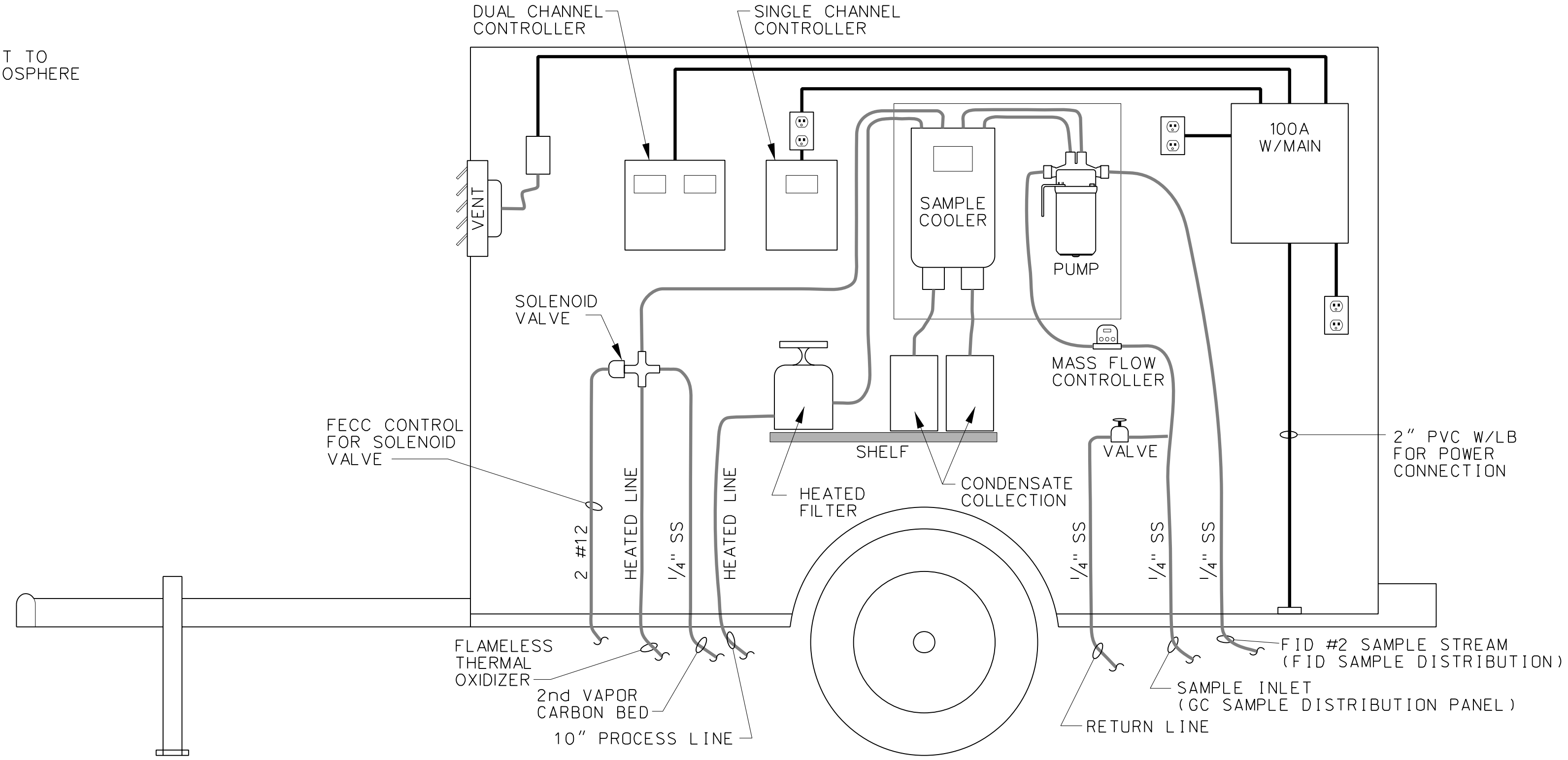
Gas samples from the process streams were collected at four different points for analysis by either FID or GC (Figures 2-1 and 2-2). GCs were used to detect, speciate, and quantify target analytes from the treatment process off-gas. FIDs were used to continuously monitor the effluents produced by the treatment process. Data from the FIDs and GCs were utilized to determine trends in depth, concentration, and location of contamination requiring treatment. Identified data trends in contamination enabled on-site field personnel and managers to perform real-time decisions on treating contamination. The sample extraction points included (1) the 10-inch off-gas line from shroud to the VCS, (2) inlet of the FTO, (3) the stack of the FTO, and (4) effluent from the stack of the lag vessel of the vapor phase carbon system. Due to the high moisture content expected in the sample streams of (1) and (2) above, these streams were conditioned and cooled prior to reaching the analytical units as presented in Figure 2-4.

Temperature controlled, heated sample lines carried the sample to the cooling unit to restrict condensation in the lines. The water content in the sample stream was removed in two independent parallel paths. Two dual stage heat exchange systems were provided. The first stage cooled each path at ambient temperature. The second stage was cooled thermoelectrically and controlled with independent temperature sensors and control circuitry. The goal was to condense the water from a wet gas sample with a minimal loss of the contaminant gas fraction. The separation occurred in a classical impinger which has a highly polished cylindrical surface cooled to the desired dew point temperature. The gas sample is brought to the bottom of the cylinder through an insulated tube and allowed to rise through a narrow annular area at a relatively high Reynolds number to insure the entire sample is influenced by the cold surface. The condensate falls down the cold polished surface in the form of a sheet (as opposed to droplets or the bubbling of the gas sample through the condensate) which minimizes the surface area in contact with the gas sample. The temperature of the cylindrical condensation surface of the heat exchangers is maintained through intimate contact with aluminum heat transfer blocks. The first of the heat transfer blocks in each line is cooled by direct contact with the fan cooled heat sink. The temperature of the first of the two heat exchangers was about 18°F above the temperature of the air passing through the heat sink when under full load conditions. (The temperature differential depends on the amount of heat that is being extracted from the sample, which is a function of the water content of the sample.) The second heat exchanger in each line is cooled by the use of thermoelectric elements to a controlled temperature of 5°C. Once the stream was cooled, it delivered a clean, dry sample stream to the FID and GC for analysis.



GC SAMPLE DISTRIBUTION PANEL

19" RACK MOUNTABLE



SAMPLE CONDITIONING TRAILER EQUIPMENT LAYOUT

LEGEND

METER VALVE USED TO MAINTAIN 1 TO 2 PSI ON PRESSURE INDICATOR (PI) AND 100 mL/min ON FLOW INDICATOR (FI)

SHUT-OFF VALVE

FOUR-WAY VALVE

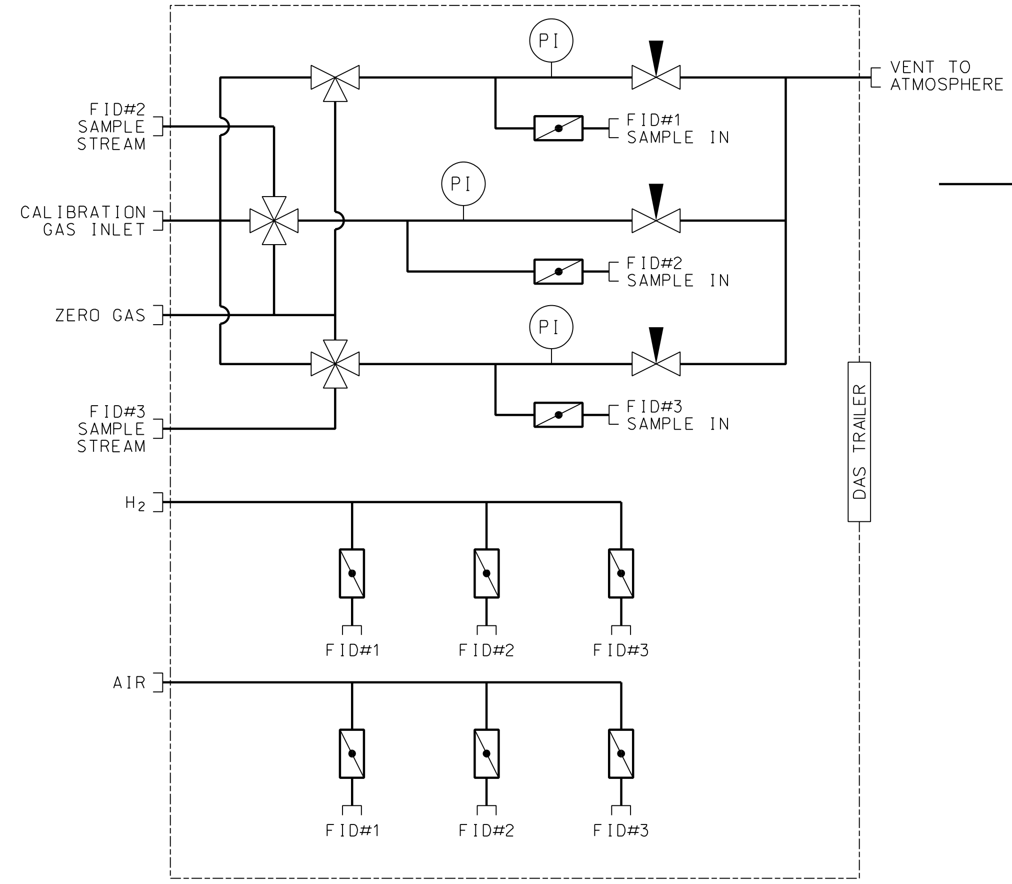
TOGGLE VALVE

[1/16" LINE CONNECTION

FID•1 --- OFF-GAS

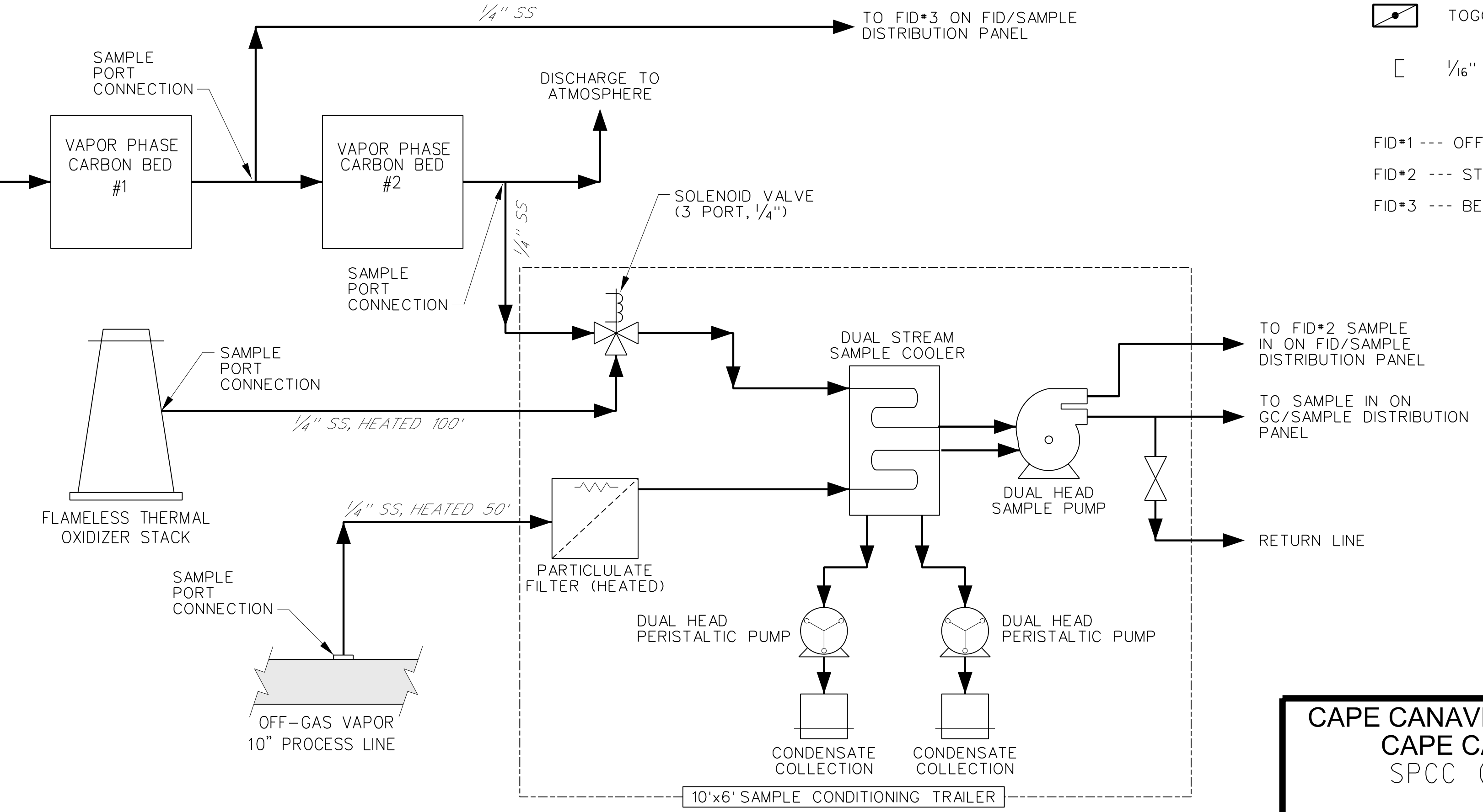
FID•2 --- STACK/BED•2

FID•3 --- BED•1



FID SAMPLE DISTRIBUTION PANEL

19" RACK MOUNTABLE



SAMPLE COLLECTION/CONDITIONING SYSTEM FLOW DIAGRAM

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CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 2-4
SAMPLE CONDITIONING SYSTEM DIAGRAM

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2.2 CONSTRUCTION AND IMPLEMENTATION

2.2.1 Treatment Cell/Zone Configuration and Pre-Treatment Cell Assessment

The following section details the proposed treatment cell and treatment zone configuration based on data collected for previous reports (RFI and CMS) and the CMD (Jacobs, 2005a, 2005b). Due to the varying vertical nature of the contamination, treatment zones were established to most effectively target the level of contamination in the subsurface. The treatment zones were based on 10 mg/L TCE contour.

2.2.1.1 Facility 18003 Treatment Cell/Zone Configuration

The source area, illustrated in Figure 1-3, was defined as the horizontal extent of TCE concentrations in groundwater greater than 10 mg/L, resulting in an estimated horizontal area of approximately 7,300 ft^2. The proposed amount of cells required to treat the area were 145 cells with an 8 foot auger utilizing a 6% overlap. The footprint of each treatment cell is 50.24 ft^2 (without overlap). Figure 2-5 illustrates the proposed treatment cell configuration.

Existing data indicated that the thickness of the source area varies vertically across the site. Based upon this evidence, the source area was divided into two treatment zones (Figure 2-5). The planned treatment thickness for each zone is shown in Table 2-2. Slight variations made in the field were based on the treatment protocol.

Table 2-2. Facility 18003 Treatment Zone Configuration

Treatment Zone	Area (ft^2)	Treatment Depth (ft)	Volume (yd^3)	No. of Proposed Treatment Cells[1]
Zone 1	3,160	10 - 55	5,267	61
Zone 2	4,140	10 - 25	2,300	84

[1] The total estimated remediation volume was 7,567 yd^3.

2.2.2 Permits

The following permits were obtained for Facility 18003 prior to beginning any work at the site.

2.2.2.1 Excavation and Block Dig Permits

An Excavation Permit was obtained to facilitate well installation and sampling activities, trenching for Block Dig Waiver Permit, trenching for electrical conduit lines and electrical vault installation. The Excavation Permit activities included a utility locate performed by base personnel, followed by “no impact” approval from various base entities. After approval and Excavation Permit package submittal, the Excavation Permit was issued for the duration of the project.

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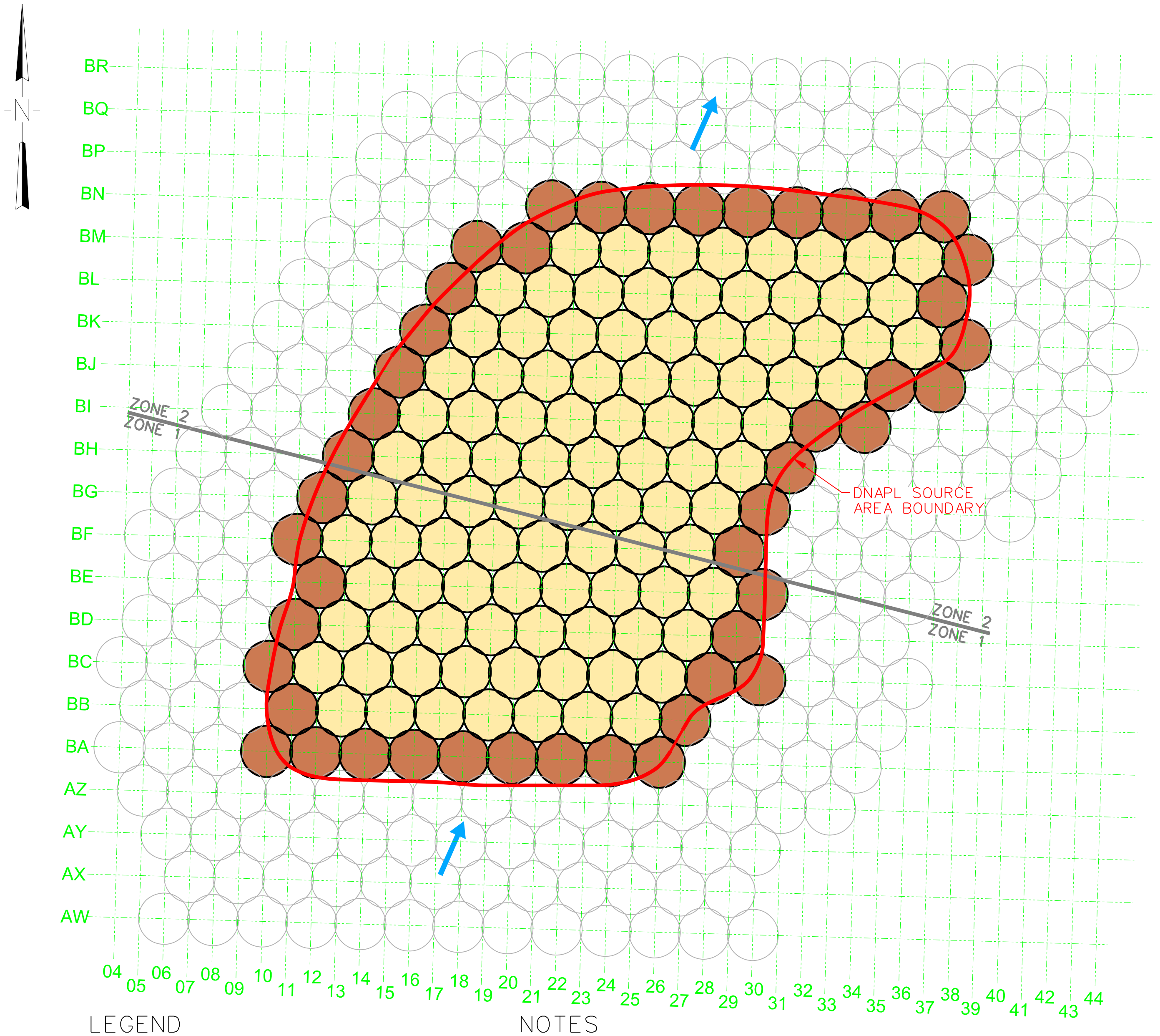
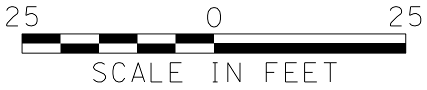


LEGEND

○	8' DIA BORING LOCATION
●	PERIMETER CELLS (46 IRON INJECTION AUGER BORINGS) SEE NOTE 4
●	INNER CELLS 99 AUGER BORINGS
○	POTENTIAL EXPANSION CELLS (SEE NOTE 5)
→	GROUNDWATER FLOW DIRECTION

NOTES

1. THE SURVEY GRID SHALL BE TIED TO A PERMANENT BENCHMARK ESTABLISHED AT THE FACILITY 18003 SITE.
2. 145 MIXING BORING CELLS IN PROPOSED TREATMENT AREA.
3. APPROXIMATE SURFACE AREA IS 7,300 SQ. FT.
4. THE PERIMETER CELLS OF THE SOURCE AREA SHALL BE TREATED BEFORE PROGRESSING TO THE INNER CELLS OF THE SOURCE AREA. INNER CELL AUGERING SHALL START ON THE UPGRADIENT SIDE OF THE PLUME SO THAT CONTAMINANTS RELEASED TO THE FREE LIQUID PHASE WILL PROCEED INTO THE PLUME RATHER THAN DOWNGRADIENT FROM IT.
5. EXPANSION CELLS AS SHOWN ARE OUTSIDE THE PREDICTED DNAPL SOURCE AREA AND ARE PROVIDED AS AN OPTION WHERE THE CONTAMINATION MAY EXCEED EXPECTED LIMITS.
6. ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.



SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003,
JACOBS ENGINEERING, MAY 2005.

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
FACILITY 18003

FIGURE 2-5
TREATMENT CELL/ZONE
CONFIGURATION MAP

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A Block Dig Waiver Permit was established around the source treatment areas to minimize the amount of down days due to range critical and launch days. Base personnel initiated an Operational Risk Management determination which in-turn facilitated the granting of the Block Dig Waiver. The Block Dig Waiver Permit activities included a utility locate performed by Base personnel, followed by trenching around the proposed area to a minimum distance and depth of 50 feet and 5 feet, respectively, to ensure utilities are not encroaching on the proposed area. Upon completion of the trench, visual inspections by the Cape Superintendent and Site Supervisor were performed. Finally, a package was submitted to the appropriate Base authority briefly describing the project activities and schedule, utility locate results, trenching activities results (including a photo log), and site maps. After the locations were cleared, the Block Dig Waiver Permit was signed by the appropriate Base authorities prior to issuance. Issuance of the Block Dig Waiver Permit did not exempt drilling operation during launch days or shuttle landing days. The Block Dig Waiver Permit is attached in Appendix B.

2.2.2.2 Federal Aviation Administration Notification

The Federal Aviation Administration (FAA) requires notification for any construction or alteration up to 20,000 feet from an airport that is operated by an armed force of the United States. A Notice of Proposed Construction or Alteration was submitted to the FAA at least 30 days prior to the erection of the LDA crane at the site. The distance of the LDA rig at Facility 18003 from the skid strip on CCAFS is approximately 4,065 feet. At this distance, the FAA requires a notice to be filed if the construction or alteration exceeds a height greater than an imaginary surface extending outward and upward at 100 to 1 from the nearest point of the runway. At the maximum height, the crane reached approximately 140 feet above ground surface. The maximum allowable height (41 feet for Facility 18003) was exceeded and required notification. The FAA notification and approval documentation are attached in Appendix C.

2.2.2.3 Publicly Owned Treatment Work Discharge

A significant amount of process wastewater was generated and stored on-site requiring disposal. Process wastewater was disposed of at the Trident Industrial Wastewater Treatment Facility. The administrative requirements of the 45th Space Wing and the specific requirements of the permit, the installation's wastewater pre-treatment plants have specific applicability to discharge of scrubber water. Pre-treatment requirements and discharge parameters were established through the PWQ and Technical Review Package process provided in Appendix D.

2.2.2.4 Surface Water Runoff

Surface water runoff from the project was controlled via a 1-foot soil berm around the soil mixing area that enclosed an area of approximately 30,149 square feet. The berm was adequate to contain storm water and any spoils from migrating out of the work areas. Since the majority of the soil mixing and steam injection occurs in-situ, additional surface water management and erosion control measures were not deemed necessary. Due to the implementation of these measures, a National Pollutant Discharge Elimination System (NPDES) Storm Water Permit was not required. Additional details are presented in Appendix E.

2.2.2.5 Flux Well Construction

Permits for the construction and installation of flux wells at Facility 18003 were secured by a driller licensed in the State of Florida. All appropriate information was submitted to the Saint Johns River Water Management District (SJRWMD) to obtain the necessary well construction permits prior to construction and installation of the flux wells.

2.2.2.6 Hot Work Permit

A hot work permit was obtained prior to performing any welding activities at the site. The Contractor contacted the Cape Fire Prevention Scheduler to make an appointment for a Fire Inspector at least 24 hours in advance of the work being performed. The Fire Inspector viewed the proposed work and completed the permit on-site and called it into the Fire Prevention Office.

2.2.2.7 Underground Injection Control

FDEP does not require an Underground Injection Control (UIC) permit for the injection of iron into the subsurface if the remediation is being implemented under a remedial action plan or other enforceable mechanism approved by the FDEP. Remediation of Facility 18003 is being conducted under the RCRA CAP and in accordance with FDEP-approved CMD. Therefore, UIC permit is not required for this site.

2.2.3 Site Preparations

Several site activities were implemented prior to mobilization of treatment equipment. These activities included:

- Site Surveying
- Utility Locating and Dig Clearance
- Well Abandonment
- Demolition and Clearing
- Geophysical Survey and Removal
- Site Filling, Grading, and Leveling
- Electrical Vault Installation

2.2.3.1 Site Surveying

An initial site survey of Facility 18003 was completed prior to any site disturbance. The survey established locations of pertinent site features (structures, utilities, wells, and drainage features) as well as establishing baseline site elevations. Three permanent survey monuments were established and used throughout the implementation to provide consistent control.

The survey was used to establish and confirm the location of the source area along with laying out individual treatment cell locations and performance sample locations. Because the planned depth of treatment was all based upon below ground surface elevations, and the understanding that the site will be re-graded prior to set-up of treatment equipment, the elevation survey was also used to correct final depths of treatment to be consistent with the design depth intervals.

2.2.3.2 Utility Locating

Utilities across the site were located and marked to support the upcoming mobilization of treatment equipment, including initial site preparations, along with supporting the acquisition of dig permits/waivers. No “live” utilities were found within the area planned for treatment or within a 50 foot perimeter of the planned treatment area. Utilities around the site were all marked.

2.2.3.3 Well Abandonment

Subsurface obstructions could be detrimental to the operation of the subsurface mixing equipment. The location of eight monitoring wells fall either within the footprint of the planned treatment area, or within 30 feet of the planned treatment area. Based upon these locations and the potential of being an obstruction to the mixing equipment, these eight wells were abandoned. The abandoned wells included MWS02, MWS03, MWS04, MWI03, MWDD21, FLX01, FLX02, and FLX03, with their former locations shown on Figure 1-3. The wells were abandoned by pulling the casing from the subsurface. Well abandonment was completed by a licensed water well contractor. Upon completion of the well abandonment, the licensed water well contractor notified Brevard County/SJRWMD, the details of well abandonment.

2.2.3.4 Demolition and Clearing

Demolition and clearing of the source area including adjacent perimeter, was completed by Spec Pro, Inc. (base environmental support contractor). The demolition included the removal and disposal of the remaining concrete slabs and loading ramp from former facilities 1250 and 1251. The concrete from the slabs and ramp was disposed of in the CCAFS construction and demolition debris landfill. Starting beneath the concrete slabs and running under the slabs then out to the northwest was a series of pipes (4-inch diameter, grey cast iron sanitary pipe) used as a liquid collection and disposal system of some kind. The pipes ran through a concrete collection box/sump then out to what appeared to be a drain field. All the piping was removed and disposed of in the CCAFS landfill and the concrete collection box/sump was left in place. A portion of the perimeter road was also removed, the top surface (asphalt) of the road was disposed of in the landfill, and the second surface or sub-foundation of limestone was stockpiled on-site to be used for backfilling, leveling, and grading to support treatment equipment.

An area approximately 200 by 400 feet was cleared and grubbed to provided ample area for equipment lay-down and adjacent site operations. Clearing this area also included the removal of three obstacle course apparatuses. It is planned that these apparatuses be replaced by a Base-supplied contractor.

Figure 2-6 identifies the areas that were cleared and concrete which was removed and disposed of.

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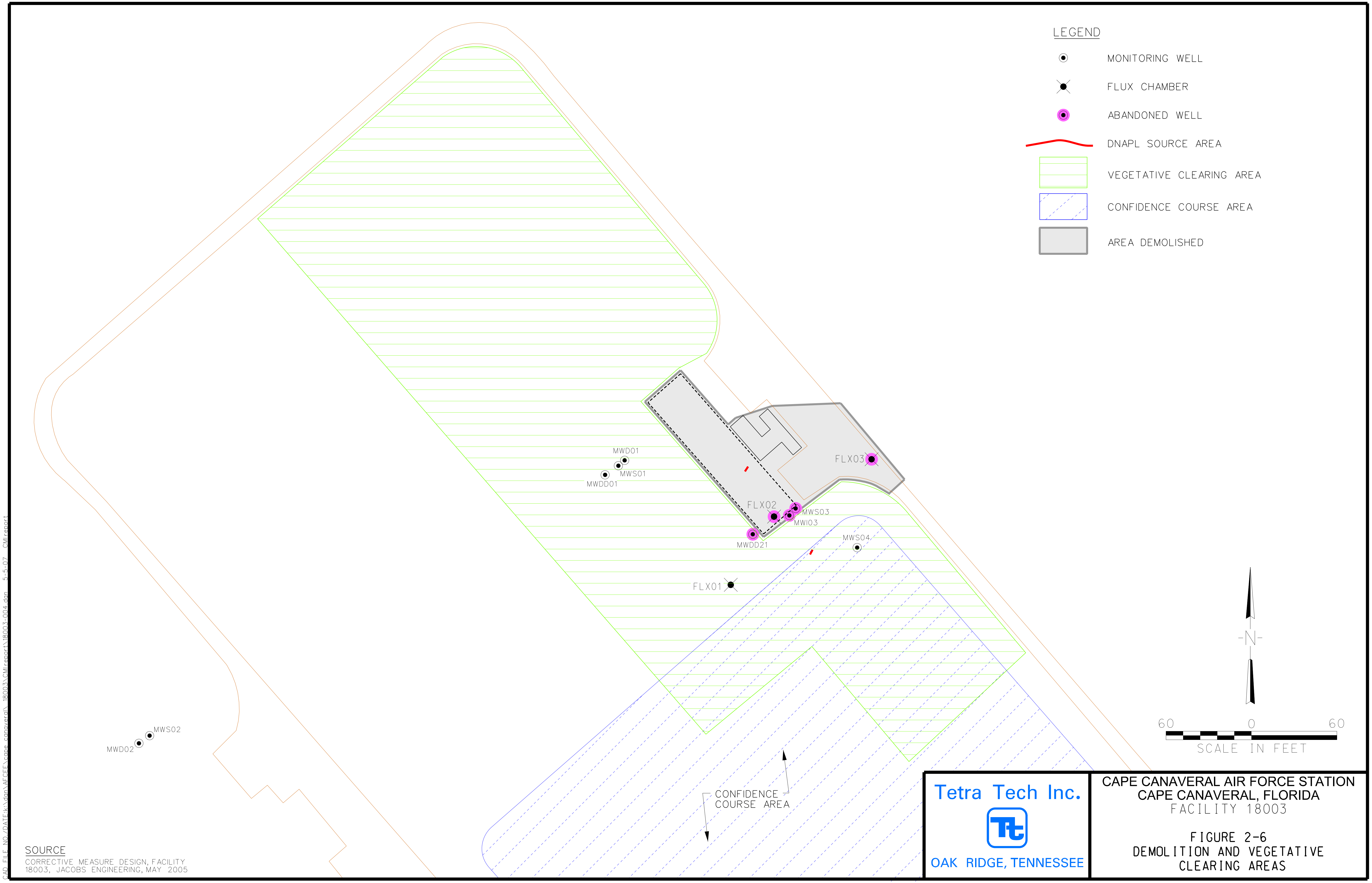

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CAPE CANAVERAL, FLORIDA
FACILITY 18003

FIGURE 2-6
DEMOLITION AND VEGETATIVE
CLEARING AREAS

SOURCE
CORRECTIVE MEASURE DESIGN, FACILITY
18003, JACOBS ENGINEERING, MAY 2005

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2.2.3.5 Geophysical Surveying and Removal

Again, subsurface obstructions could be detrimental to the operation of the subsurface mixing equipment. In order to provide additional assurance the subsurface is clear, a geophysical investigation was conducted across the source area including some additional perimeter area. The geophysical investigation area was a plot approximately 145 by 190 feet. Of continued concern was the possible presence of construction debris, building sub-foundations, foundation supports, etc., buried within the boundaries planned for treatment which would impact the mixing equipment. The investigation used time domain electromagnetics (TDEM) via an EM-61 Buried Metal Detector (EM-61) and ground penetrating radar (GPR).

The EM-61 survey was conducted along parallel lines spaced 5 feet apart collecting readings every 0.62 feet. A total of 8,992 data readings were collected and contoured, shown on Figure 2-7. The GPR survey was conducted along a series of perpendicular transects spaced 5 feet apart. Figure 2-8 shows the GPR transects as well as anomalies identified via both GPR and EM-61.

All suspected debris identified across the surveyed area (illustrated on Figure 2-8) was investigated either by hand digging or the use of a mini excavator. Debris including concrete rubble, rebar, wire mesh, guide wire tie downs, and general trash, was excavated and removed from the area and disposed of in accordance with Base waste disposal regulations.

2.2.3.6 Gopher Tortoise Relocation

On 12 July 2004 during site preparation activities at SPCC, an active Gopher Tortoise burrow was discovered in the immediate area of the preparation activities. Immediately upon discovery, CCAFS authorities were contacted and visited the SPCC site. CCAFS authorities confirmed the Gopher Tortoise burrow as active and removed and relocated a male Gopher Tortoise from the site. An additional five inactive burrows were identified in the site preparation area which were left undisturbed. All appropriate paperwork was completed and filed by CCAFS authorities. Appendix F contains the Report Form for Gopher Tortoise Relocations completed by and obtained from CCAFS authorities.

2.2.3.7 Little Midden Site (8 BR 1933)

The Little Midden Site is a 50 m x 40 m black earth coquina shell midden oriented northeast to southwest along a relict dune located adjacent to the SPCC. It is bordered on the west and south by man-made sand berms, on the north by southern road bordering the confidence course, and on the east by a paved road and concrete loading ramp. The site was discovered in February 2006 while conducting a prescribed burn of the area for scrub jay habitat restoration.

A Phase I Archaeological Survey was conducted of the site in April 2006 through January 2007. The resulting survey determined the site has been partially destroyed by the construction of a facility at the site in the 1960s along with monitoring well installation prior to or during RFI. Additional damage to the site was the result of the prescribed burn. Though the site was first thought to have been impacted to the point that the site would not be considered significant, testing indicated otherwise.

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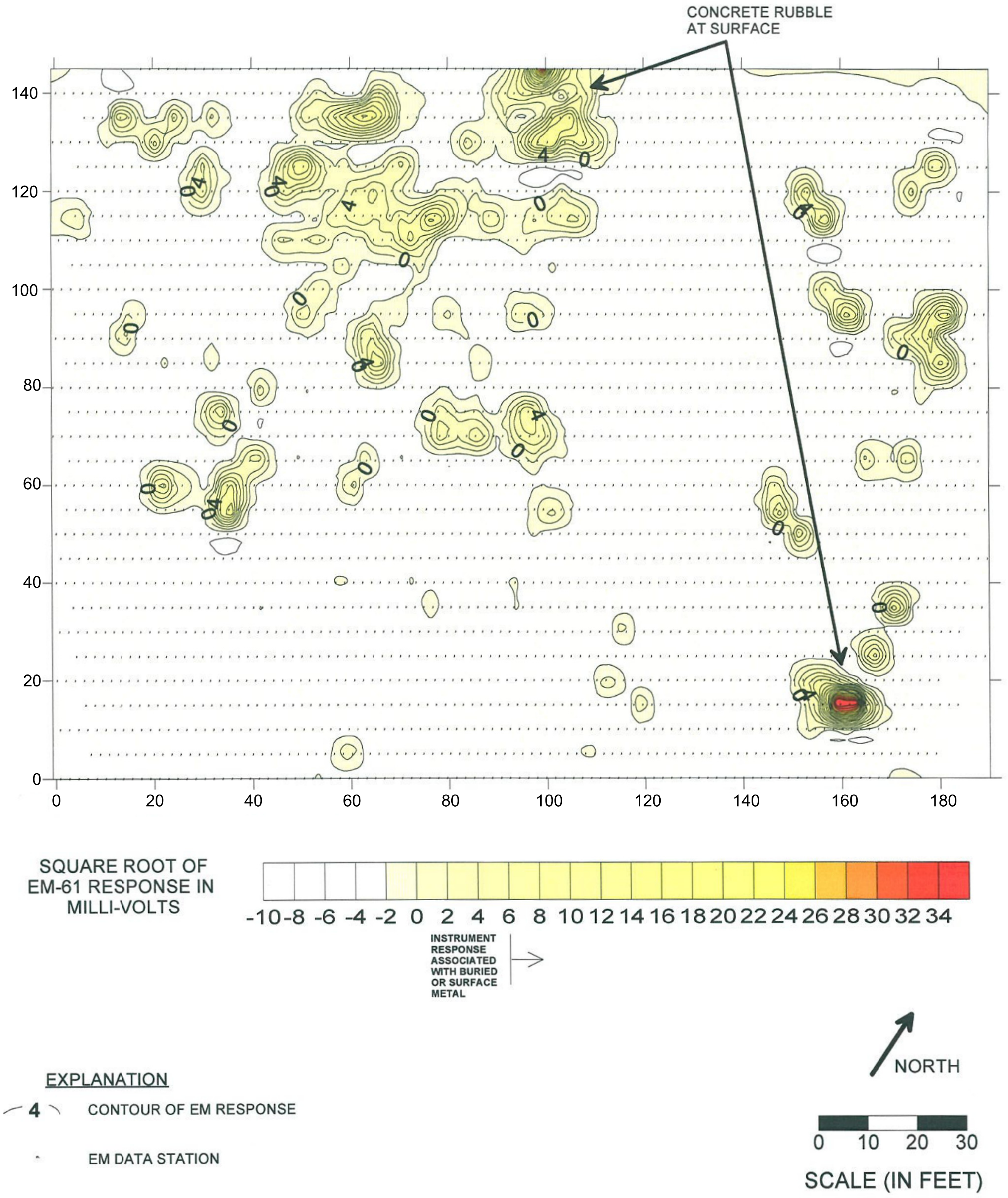

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SOURCE:
TAKEN FROM CORE ENGINEERING AND CONSTRUCTION, INC.
PROJECT 2875 DATED 11-28-05

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 2-7
CONTOUR MAP OF EMI RESPONSE

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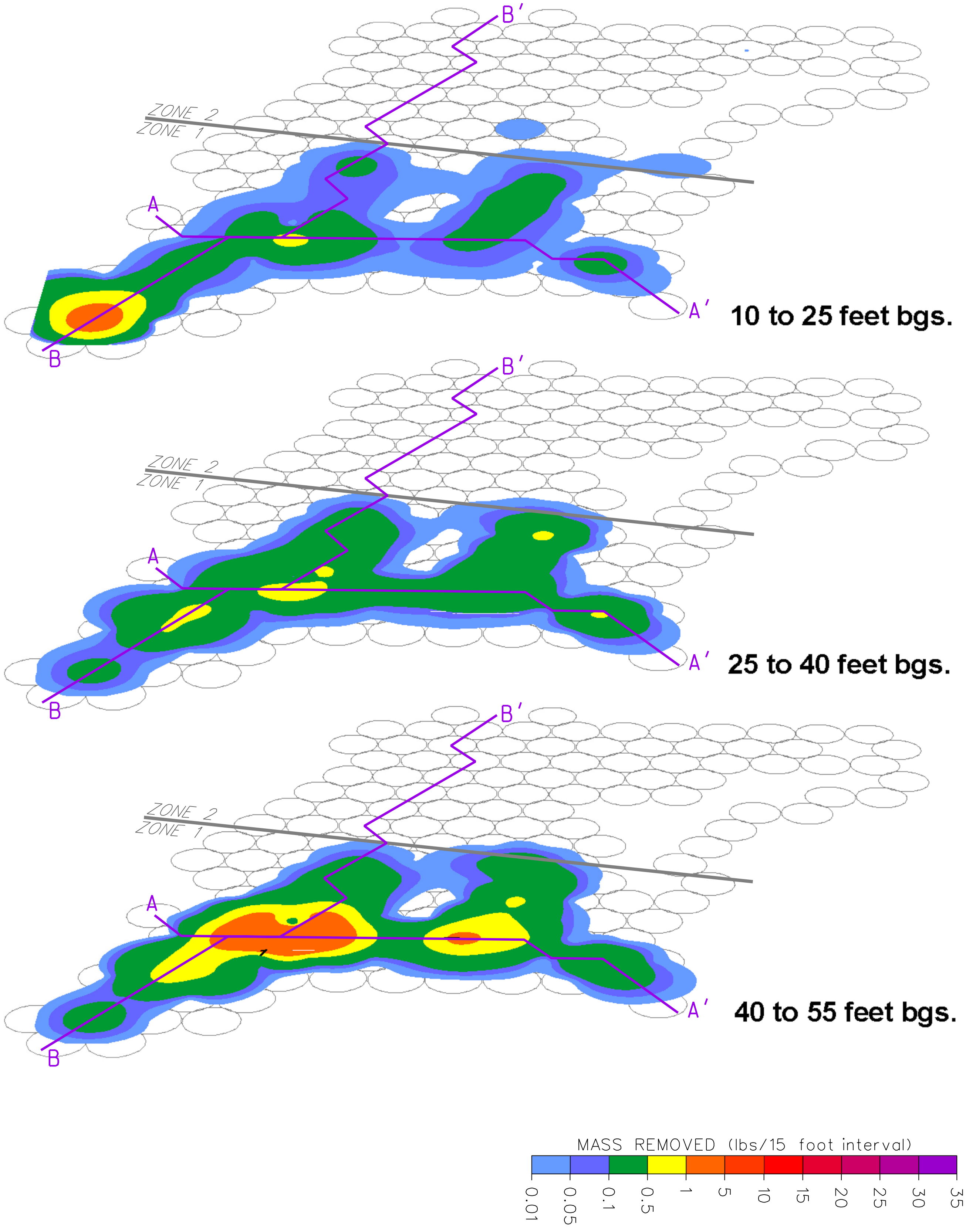

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CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 3-16
TETRACHLOROETHENE (PCE)
MASS REMOVED PER SITE
SHOWN IN 15′ INTERVALS

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Testing of the site consisted of 42 shovel tests at 5 meter intervals on a grid pattern across the site. Each test was 0.5 x 0.5 x 1.0 meter in size. A total of 21 shovel tests were positive for cultural material. An intact cultural stratum was identified from 20-50 centimeters thick with the thickest deposit located around the groundwater monitoring wells. Artifacts recovered from the site include prehistoric ceramic sherds (typical for this area of Florida), a projectile point and lithic debitage (extremely rare for this area of Florida), and a high density of faunal material. The artifacts suggest this site, though partially destroyed, is eligible to the National Register of Historic Places and is likely to provide additional useful scientific information. It was concluded that the impacts to the Little Midden Site (8 BR 1933) site should be avoided.

2.2.3.8 Site Filling, Grading, and Leveling

Prior to the initiation of equipment mobilization and treatment, the source area and adjacent lay-down areas had to be backfilled and leveled. Backfilling was needed in the lower lying portions of the source area, to the west, in order to raise the grade establishing a vadose zone of approximately 5 feet. An ample vadose zone is required to safely and adequately transfer and capture steam at the surface during treatment operations. Leveling of the site was needed to provide verticality of operational treatment equipment (mixing/augering) during operation and to provide an even foundation for all of the support equipment.

Approximately 800 yd^3 of backfill was transferred to the site from a certified clean outside borrow source to be used to support initial backfilling and leveling. Additional fill material used for initial backfill and leveling was borrowed or sculpted from “higher” areas immediately adjacent to the source area.

2.2.4 Mobilization

The following section describes the activities associated with mobilization and setup of the remedial equipment at the site.

2.2.4.1 Site Equipment and Materials Lay-down Areas

Site grading and leveling of the equipment and material lay-down and source treatment areas were performed prior to equipment being mobilized to the site. The equipment was positioned in pre-determined areas. Figure 2-9 illustrates the locations of the pre-determined equipment lay-down areas for Facility 18003. In addition, equipment and material storage areas, vehicle parking areas, and utility locations are also illustrated on Figure 2-9.

2.2.4.2 Equipment Setup

All equipment was inspected for damage prior to being assembled and integrated. Equipment requiring electrical connections was connected by an electrician licensed in the State of Florida. Connection lines (electrical, propane, water) were buried, wherever possible, to minimize the amount of ground clutter around the equipment and to prevent trip hazards. Boiler connections were performed by a licensed boiler operator. All trailer-mounted equipment were securely anchored to the ground to prevent movement during elevated wind events. Material storage areas were covered or sheltered from the elements to provide adequate protection prior to being used.

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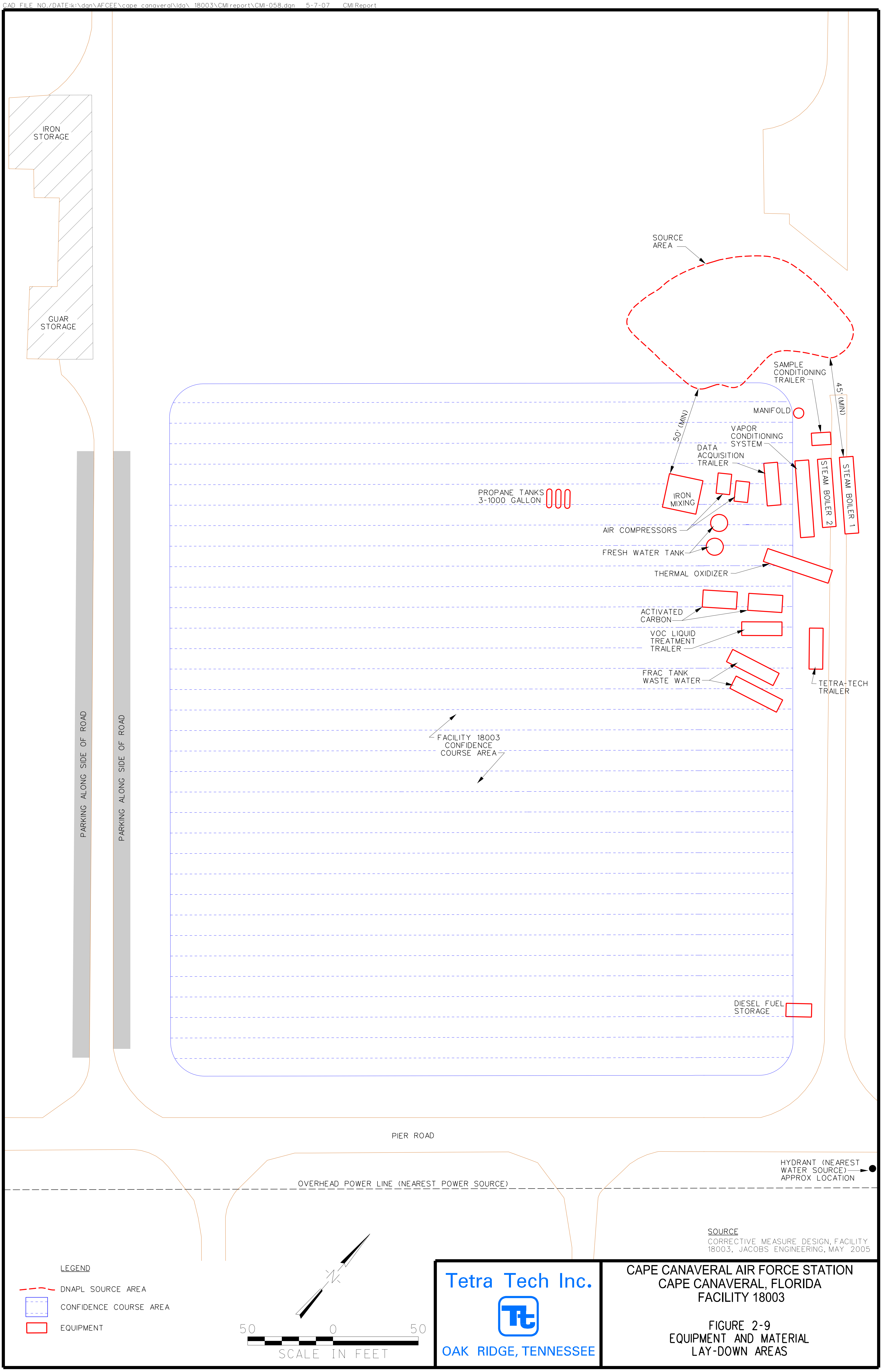

SOURCE
CORRECTIVE MEASURE DESIGN, FACILITY 18003, JACOBS ENGINEERING, MAY 2005

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
FACILITY 18003

FIGURE 2-9
EQUIPMENT AND MATERIAL
LAY-DOWN AREAS

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2.2.4.3 Utilities

At Facility 18003, high voltage lines are located due east of the site across Pier Road. In order to provide power to the site, an electrical vault was installed to route the power grid under Pier Road. Three powerpoles were also installed to provide power to the site transformer. All electrical high voltage connections were performed by the Base High Voltage Department.

Water was provided through a connection with the Base's fire water system available on the west side of Pier Road.. Pre-conditioning of the water supply was performed on water entering the boilers and quench system associated with the oxidizer.

2.2.4.4 Site Zones

Work zones, support zones, contamination reduction zones (CRZs), and exclusion zones (EZs) were established at the site to minimize the potential human exposure to VOCs during the remedial activities (Figure 2-10). Temporary fencing was constructed around the work zones and signs posted to keep unauthorized personnel from entering the work zones. Daily sign-in sheets (Volume IV) were posted at the entrances of the work zones, and all personnel were required to sign in prior to entering or leaving the areas. Support zones were established containing the remedial and supporting construction equipment (excavators, man-lifts, loaders, etc.), safety and medical materials (eye wash stations, first aid kits, towels, fire extinguishers and decontamination supplies), and materials storing areas. EZs were established at the areas directly related to the soil mixing above the source treatment area. The EZs were delineated through the use of barrier fencing, signage, and caution tape. Access to this area was limited to essential operational personnel involved in the mixing operation. Personnel entering this area were required to wear required personal protective equipment (PPE). Access to the EZ by foot was through the CRZs. This zone served as area for proper disposal and/or cleaning of PPE.

2.2.4.5 Dust Control and Decontamination Procedures

Dust control was implemented to minimize the amount of airborne dust particles due to the movement of equipment. Dust control was performed by water spraying of high traffic areas on an as-needed basis. Decontamination of equipment and personnel was required during various work phases. Gravel beds were installed (when necessary) to minimize soil movement from the treatment areas. All equipment was sprayed down prior to leaving the work zone. Personnel exiting the EZ removed and disposed the required PPE in the CRZ prior to entering the support zone.

2.2.5 Site Closure

The following section describes the activities associated with demobilization and breakdown of the remedial equipment to each site.

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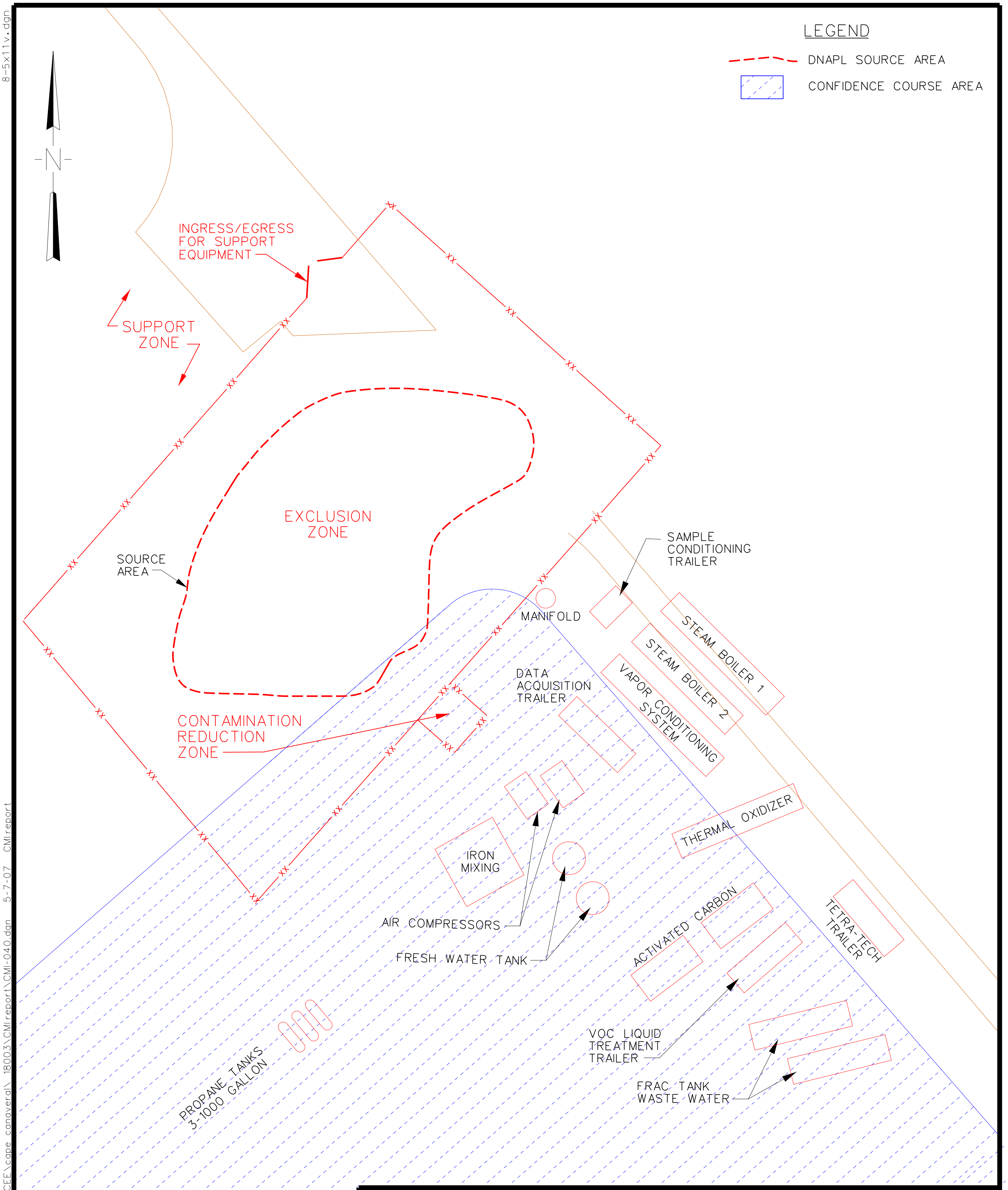

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SCALE IN FEET

SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003, JACOBS ENGINEERING, MAY 2005

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 2-10
WORK ZONES

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2.2.5.1 Site Cleanup and Demobilization

Upon the completion of source area treatment at Facility 18003, electrical disconnections from the CCAFS power grid were performed by the Base High Voltage Department prior to performing any demobilization activities. Equipment disassembly and disconnections commenced once the electricity was shut off. Once power was off, equipment was disconnected, disassembled and mobilized to Facility 1381 for treatment. All construction debris, waste materials, and packaging material were containerized in dumpsters for off-site transportation and disposal. A Base-supplied contractor removed the waste from the provided dumpsters. Once all material and equipment were mobilized off-site, an orange safety fence was installed at a distance of 15 feet from the perimeter of the source area and signage were posted at the access roads to limit entry into the area.

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3.0 SYSTEM OPERATION AND EVALUATION

This section details the system operation and evaluation of the in-situ soil mixing with steam, hot air, and ZVI injection by LDA during remedial efforts at SPCC.

3.1 STARTUP AND TESTING

3.1.1 Full System Startup and Checkout

Full system startup and checkout were performed once setup was complete and prior to treating any cells at SPCC. The purpose of these activities was to ensure all mechanical, electrical, and electronic equipment/instrumentation/software were connected and communicating properly for effective remediation. Activities performed included:

- Ensuring all mechanical and electrical equipment/devices were properly erected, installed, connected and sealed according to manufacturers' design specifications;
- Ensuring all electronic signals being received in the three PLCs (located on the Crane, VCS, and DAS) were checked and scaled appropriately in the SCADA software;
- Ensuring all sampling equipment was properly connected and calibrated to produce accurate data;
- Performing a steam and air test with the auger above surface to ensure adequate flow and appropriate instrument response;
- Ensuring the FTO was fully operational and relaying proper instrument response;
- Ensuring data were being collected and stored properly on-site and performing several simulated data package transmissions to the Oak Ridge server via wireless broadband connection; and
- Properly batching and preparing ZVI slurry in iron batch plants.

Once all the electrical connections were made, a licensed electrician visited the site and inspected all connections. Upon receiving notice from the licensed electrician that connections were adequate and ensuring all the above activities were completed, Tetra Tech authorized the drilling of test cells to simulate active treatment.

3.1.2 Test Cell Treatment

Treatment of test cells was performed to simulate active remediation, to ensure the entire system was functioning as designed, and to troubleshoot any problems or issues that developed prior to active remediation. The test cells were identified adjacent to but outside the 10 ppm TCE contour line for the purposes of obtaining low-level contaminant data to determine off-gas sample collection proficiency to analyze, store, and display results as well as to validate off-gas treatment by the FTO.

Figure 3-1 illustrates the location of six test cells performed prior to active treatment. The test cells on Figure 3-1 are identified as BP22, BP26, BQ25, BQ27, BQ33, and BR26. Test cells were also useful in determining the proper water/guar/ZVI batching ratio and preparation procedures for injection. Upon satisfactorily demonstrating the integrity of the entire system (thermal treatment, iron treatment, data collection, and data transmission) at the completion of the six test cells, Tetra Tech approved the commencement of active treatment on cell BN23 on 22 March 2006.

Test Cell #1 (BR26)

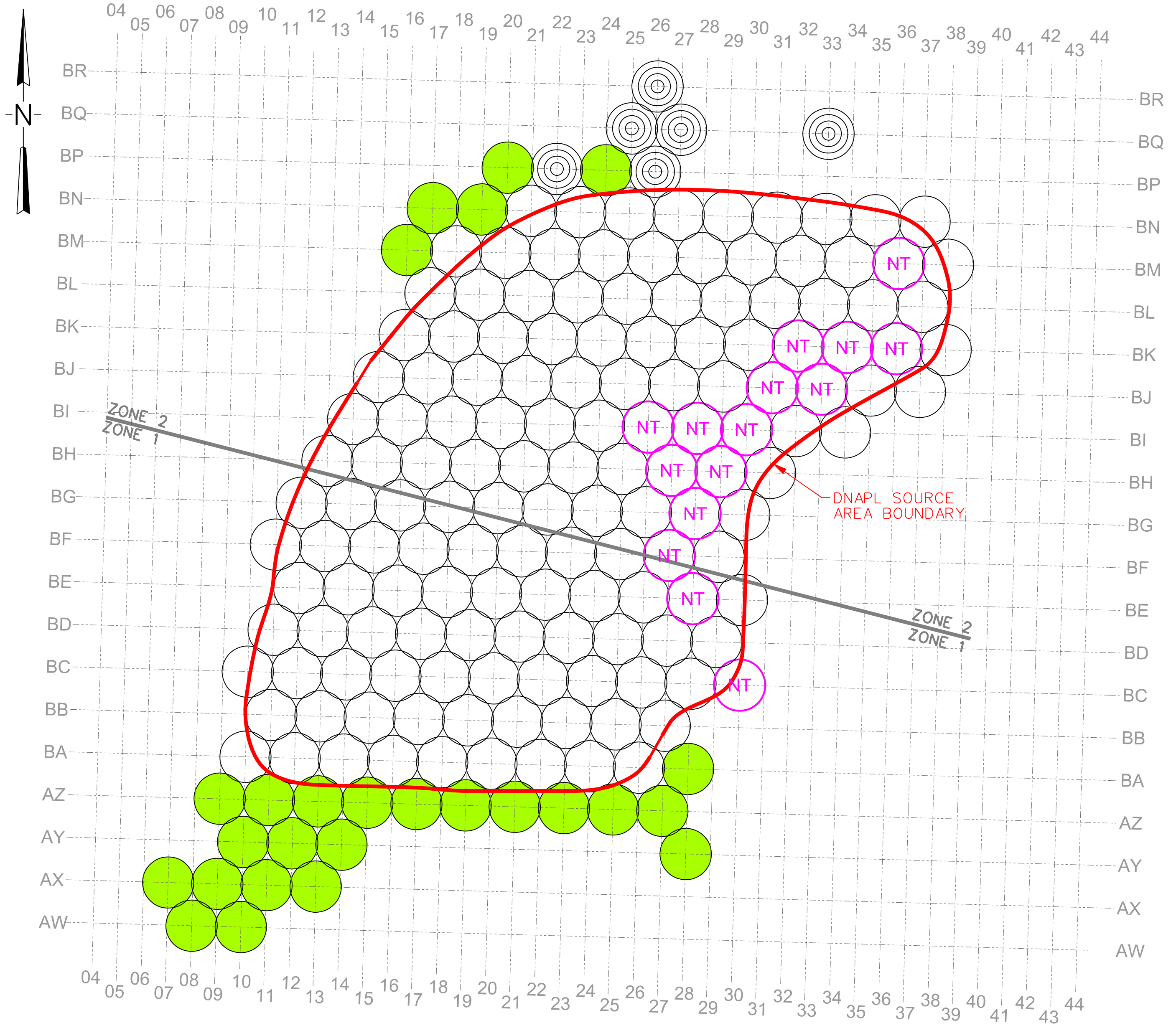
On 13 March 2006 the first of six test cells was performed to verify adequate drilling ability to 55 feet bgs with hot air and steam and proper FTO. Data collection, analysis, and processing were undergoing programming and setup and were not fully operational at the time of this test cell. Testing commenced and drilled to 28 feet bgs with hot air and steam. At approximately 25 feet bgs the FTO shut down due to low inlet air flow. It was determined that the fresh air valve on the VCS must remain partly open to allow for adequate air into the unit. Upon shutdown of the FTO, the auger was removed from the ground and the test was completed for the day.

Test Cell #2 (BQ33)

On 14 March 2006 testing commenced on test cell BQ33 after startup and checkout of the FTO. During testing a large amount of steam entered the shroud and traveled through the system, shutting down the FTO during the test. The auger was returned to the surface for FTO re-start and drilling commenced on the test cell. Drilling was successfully achieved through 55 feet bgs with hot air, steam, and the FTO being fully operational during entirety of test; however, it was determined that steam flow did not attain desired levels. While ascending from 55 feet bgs, steam pressure was lost due to a leak in the steam line. Steam was shut off and air remained on to aid in drilling. In addition, a hydraulic line in the platform became detached, causing hydraulic oil to spill on the platform. It was determined that a seal on the filter cap on the platform was too tight and caused the line to become detached. The spill was cleaned with absorbent pads and disposed of properly. The auger was removed from the test cell and the test cell completed. The steam leak and platform were repaired. It was also determined that steam flow was not adequate due to the nozzles on the auger bit being cut because of the amount of steam energy passing through the nozzles. The auger was replaced with the backup auger prior to drilling test cell #3.

Test Cell #3 (BQ27)

On 16 March 2006 the third of six test cells was performed to verify adequate drilling ability to 55 feet bgs with hot air and steam, proper FTO operation, proper batching and injection of 2250 pounds of ZVI, and data collection. Prior to testing on test cell BQ27, the first iron slurry batching was unsuccessful due to the improper timing of guar and iron addition which caused the batch plant mixers to seize. In addition, the FTO was unable to start up, and the manufacturer was contacted for maintenance/operation instructions (problem was later determined to be a PLC programming issue). Drilling commenced without testing the ZVI injection and FTO was not operational (carbon was used for off-gas treatment). Data collection, analysis and



LEGEND

○ 8' DIA BORING LOCATION

◎ TEST CELL LOCATION

🟩 CELL TREATED BEYOND ORIGINAL TREATMENT BOUNDARY

NT CELL NOT TREATED BECAUSE OF LOW CONTAMINATION VALUE

25 0 25

SCALE IN FEET

SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003,
JACOBS ENGINEERING, MAY 2005.

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 3-1
CELL TREATMENT LOCATIONS

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processing were available for this test cell. During the first pass down to 55 feet bgs on the test treatment, the auger was lodged at approximately 15 feet bgs due to the operator descending too fast. The auger was retracted and the test cell was re-started. The auger was successfully drilled to 55 feet bgs with steam and hot air and the peak FID was obtained of 180 ppm, demonstrating successful attainment and processing of data. The auger was removed from the soil completing the test cell. The iron batch plant was repaired and batching procedures were re-worked.

Test Cell #4 (BQ25)

On 17 March 2006 the fourth of the six test cells was performed to verify adequate ZVI batching and injection of 2250 pounds of iron and demonstrate that the FTO was properly repaired and fully functional. The FTO was started but shut down due to low air flow. The FTO was re-started and then remained operational throughout the rest of the test cell. The 2250 pounds of iron were successfully batched with guar and water due to modified batching procedures; however, the mixers were stopped due to the long delay time in re-starting the FTO. Stopping the mixing blades resulted in another seizing of the blades and the units again had to be washed out. Therefore, the iron batching procedures were determined to be successful but ZVI slurry injection was not verified. Treatment testing to 55 feet bgs with steam and hot air was again verified and data were processed accordingly. The auger was removed from the soil and the test cell was completed.

Test Cell #5 (BP22)

On 20 March 2006 the fifth of the six test cells was performed to verify adequate ZVI batching and injection of 2250 pounds of iron and to demonstrate that the FTO was properly repaired and fully functional. The FTO was started and then remained operational throughout the entirety of the test cell. The 2250 pounds of iron were successfully batched with guar and water. Treatment testing commenced to 55 feet bgs with hot air and steam. It was discovered that the delta pressure instrument was not operating correctly and required inspection and repair. The auger was removed from the soil and repairs were completed on the delta pressure instrument. ZVI injection was not completed on this test cell.

Test Cell #6 (BP26)

On 20 March 2006 the final test cell was performed to verify full system checkout and adequate ZVI batching and injection of 2250 pounds of iron. Drilling commenced on the test cell with the FTO being fully operational. ZVI slurry was batched with 2250 pounds of iron and adequately suspended for injection. A shroud temperature of 170°F was attained during the test and the ZVI slurry was successfully injected to 55 feet bgs. It was discovered during the injection that the iron slurry flow meter was not operating correctly; therefore, either a repair or replacement was needed. Because a proper flow meter could not be obtained, it was determined that drafting of a treatment operational procedure for iron injection was required to ensure homogenous distribution of the ZVI. Total run time for the test was approximately 94 minutes. Data were adequately processed and recorded. The entire system checkout was complete and successfully demonstrated all systems operational and procedures sound for active remediation. The auger was removed from the soil and the test cell was completed.

3.2 SYSTEM OPERATION

3.2.1 Operational Parameters

Treatment of the source area at SPCC was performed in accordance with the established site treatment protocol (Section 3.4). During treatment, equipment parameters were adjusted to optimal operating ranges for efficient removal of VOCs. Table 3-1 lists the standard operating ranges for the major remedial equipment during treatment.

Table 3-1. Major Equipment Operating Ranges

Major Remedial Equipment	Cell Location	Target First Pass	Range First Pass	Target Successive Passes	Range Successive Passes	Iron Pass
Steam Flow (pph)	Perimeter	9,500	9,500–13,500	9,500 until 160°F attained in shroud then varied to maintain temp	9,500–13,500; 0–5000 when shroud temperature of 160°F attained	NA
	Inner	13,500	9,500–13,500	9,500 until 160°F attained in shroud then varied to maintain temp	9,500–13,500; 0–5000 when shroud temperature of 160°F attained	NA
Air Flow (acfm)	Perimeter	200	200-400	400	300-500; 100-200 when shroud temperature of 160°F attained	100
	Inner	400	300-500	400	300-500; 100-200 when shroud temperature of 160°F attained	100
Shroud Pressure (inches H_2O)	All Cells	2	1-5	2	1-5	1-5
Off-Gas Air Flow (scfm)	All Cells	600	200-1500	600	200-1500	600
LDA Descent Rate (feet per minute)	All Cells	1-3	2	1-3	2	2
LDA Rotation per minute	All Cells	8	6-10	8	6-10	6-10
FTO Temperature	All Cells	1700° F	1700°F	1700°F	1700°F	1700°F
Iron Flow (gpm)	All Cells	NA	NA	NA	NA	~25

NA – Not applicable
~ - Approximately

3.2.2 Mechanical Issues

Operational maintenance was performed on a daily and monthly basis to prevent any major mechanical equipment failures during treatment at SPCC. Despite the preventative maintenance, several mechanical issues still arose during treatment. Table 3-2 describes the mechanical issues faced and repaired during treatment at SPCC.

Table 3-2. Mechanical Issues

Date	Cell	Mechanical Issue
3/22/06	BN27	400 hp boiler relay switch burnt out and resulted in loss of 400 hp operation until 3/25/06. Operated on 250 hp boiler with maximum output of approximately 5500 – 6000 pph.
Week of 04/01/06	-	Grout tube cut due to steam energy and iron application also bushings on ports wearing at a very fast rate. Welding performed on tube and jets were replaced with stainless steel bushings. An additional 4 ports were installed on each auger.
Week of 04/01/06	-	Iron flow meter did not perform well due to varying density of mixture. Removed from line and established injection protocol for slurry without flow meter.
4/2/06	BA10	Approximately 20 gallons of bio-degradable hydraulic oil was released to the ground below due to a broken hose and coupling joint from the platform to the shroud. Repairs were made the same day and fully operational
Week of 04/08/06	-	Baffle in shroud was crushed when operator lowered shroud with mixing tool off ground; repair complete same day and fully operational
Week of 04/15/06	-	Elevated FID concentrations seen from FTO stack due to one of the two heated line sections not operating which generated water vapor in line. Elevated FID remained until remainder of project when line was fixed by manufacturer.
Week of 04/15/06	BL21	Leak in gasket on FTO formed and returned to surface for repair. Repair complete and continued drilling
Week of 04/22/06	-	Master Data file uploading issues to Oak Ridge, Tennessee, throughout the week. Transfer issue corrected and data transfer completed successfully.
Week of 04/29/06	BB21	At the completion of treatment on the cell it was discovered that a grout tube was broken off and remained in the cell. A new grout tube was welded on the bit.
Week of 05/13/06	-	Kink in main crane spool was discovered and un-reeled cable at the end of the day to relieve kink. Kink was fixed that night and operational next day.
Week of 05/13/06	-	During QA/QC check on database it was discovered that the formula to calculate mass was entered incorrectly due to typographical error and also there were several redundant records which inflated mass removal numbers. The formula to calculate mass was corrected and redundant records were removed to correct the calculated mass.

3.3 DATA ACQUISITION

3.3.1 Data Collection

3.3.1.1 Gas Chromatograph Data

Description

Four GCs were used to detect, speciate, and quantify target analytes from the treatment process off-gas. Three GCs were cycled at 2 minute intervals throughout the treatment process with one GC being operated when a maximum of the FID was detected. The 4th GC was also used as a backup in the event that one of the three primary GCs did not work.

The sample was delivered to the GCs via a stainless steel sample line. Each GC was equipped with a 1 mL sample loop that was continuously swept with the sample stream except for the injection of the sample. The lag time between the sampling point (off-gas) and the point of analysis was approximately 20 seconds

The GCs were computer controlled with the vendor-supplied software program called “Peak Simple.” The program controls all aspects of the GC control as well as allowing for the chromatography analysis, quantitation of analytes, and reporting of concentrations from each sample. Two computers operated the four GCs. The software was in two different directories, each associated with a unique COM port. Therefore, each GC was operated independently with each data file being assigned a unique ID for each analytical run.

The GC data were synchronized with the off-gas process data to calculate/estimate the mass removed of each contaminant species.

GC Specifications

- SRI Model 8610C equipped with an FID
- Electronic pressure controls for gases
- Heated oven for the sample loop/valve
- Column: RTX 624 30M x 0.53mm, 3 µm film. Head Pressure setting 11(nominal)
- Detector : FID, 225°C, medium gain, 10 Hz sampling rate
- Oven: 65°C/1.8 min -> 145°C @ 40°C/min
- Sample Loop: 1 mL, on @ 0.05 min., off @ 0.50 min 105°C
- Data System: Peak Simple 3.36

Analytes Tested

The following analytes were reported in ppm (v/v):

- Vinyl chloride
- Freon 113 (1,1,2-Trichloro-2,2,1-trifluoroethane)
- trans-1,2-Dichloroethylene
- 1,1-Dichloroethane
- cis-1,2-Dichloroethylene
- 1,1,1-Trichloroethane
- Benzene
- Trichloroethylene
- Toluene
- Tetrachloroethylene
- Ethyl benzene

GC Calibration

Each analyte was calibrated by injecting known quantities of each compound into Tedlar bags to generate calibration curves. The calibration samples were introduced to the GCs by filling the injection loop of each GC and analyzing the contents of the loop. The responses versus concentration were plotted to generate calibration curves. Analyte concentrations were calculated using these calibration curves. The calibration curves were generated using Table 3-3. The table was calculated from the equation:

$$ppm(v/v)=(\mu g/m^3)(24.43/MW)$$

Where MW is the molecular weight of the analyte.

Table 3-3. Calibration Curve Data

Concentration of analyte in ppm (v/v)	**50**	**100**	**500**	**1000**	**5000**	**10000**	**20000**
TCE	2.5 mL of 20,000 ppm	5 mL of 20,000 ppm	1.8	3.7	18.4	36.8	73.6
c-1,2-DCE			1.5	3.1	15.5	30.9	61.9
PCE			2.1	4.2	20.9	41.8	83.6
Freon 113			2.4	4.9	24.4	48.8	97.6
1,1-DCA			1.7	3.4	16.9	33.7	67.4
1,1,1-TCA			2.0	4.1	20.3	40.7	81.3
t-1,2-DCE			1.5	3.1	15.5	30.9	61.9
Benzene			1.8	3.6	18.2	36.5	72.9
Toluene			2.1	4.2	21.0	42.0	84.0
Ethyl Benzene			2.5	5.0	25.0	50.1	100.1

Notes: (1) All values of neat compounds in μL/1 liter of air.
(2) 50 and 100 ppm (v/v) use the high standard (20,000) as an intermediate stock.

Due to the toxicity and difficulty in handling vinyl chloride, the concentration of vinyl chloride was calculated from a single point using the certified calibration gas concentration of 2080 ppm.

After prepping each bag the standards were analyzed by filling the sample loops of each GC and analyzing the standards. The response vs concentration is then entered into each analyte's calibration table. After calibration the certified reference gas is analyzed with the vinyl chloride, Freon 113, and TCE concentrations calculated. The concentrations should be within 15%.

The elution order (retention time) of the analyte on the GCs is given in Table 3-4.

Table 3-4. Retention Time of Analyte

Analyte	RT, min.
Methane	0.59
Vinyl Chloride	0.69
Freon 113	0.89
t-1,2-DCE	1.09
1,1-DCA	1.20
cis-1,2-DCE	1.43
1,1,1-TCA	1.59
Benzene	1.79
TCE	2.13
Toluene	2.77
PCE	2.94
Ethyl Benzene	3.39

3.3.1.2 Flame Ionization Detector

Description

Three total hydrocarbon analyzers manufactured by VIG Industries FID Model 20-S were used to continuously monitor the effluents produced by the treatment process. The FIDs were used to measure total VOCs in three sample streams given below:

1. Off-gas from the treatment process.
2. Influent to the FTO.
3. One of two possible sample streams depending on which treatment process was actively being utilized. If the Alzeta was on-line the stack effluent from the Alzeta was monitored. If the carbon bed was being used then the stack at the exit of the carbon bed was monitored. The effluent selection was made via a solenoid valve that was connected to the PLC that diverts the off-gas to either the Alzeta or the carbon bed. The valve diverted the off-gas from the Alzeta to the carbon bed when the total FID measurement was greater than 20,000 ppm or the Alzeta was off-line.

The samples were transferred via ¼-inch stainless steel lines to the analyzers. The lag time between the sampling points and the point of analysis was as follows:

- Process off-gas: 20 seconds
- FTO influent: 7 seconds
- Stack effluent: 25 seconds

Calibration

The analyzers were calibrated with a certified calibration gas. The calibration gas was 6,000 ppm propane in air. The FIDs were calibrated and verified daily or as deemed necessary using the calibration gas. A zero gas was also plumbed into the system to verify system cleanliness.

3.3.2 Data Management

The data measured by the instruments were recorded in the SQL Server database installed on the SCADA servers (SCADA1 and SCADA2) at the site. The frequency of data recording for various instruments is given below:

- FID: one second (FID1, FID2, and FID3)
- GC: approximately every two minutes (either from GC1, GC2, GC3, or GC4)
- Process data: one second

The sequence of data processing is described below.

The measured data were first stored to the SQL Server in ICONICS' proprietary data format and were stored in the **LDATREND** database. Once the measured data have been stored, the ICONICS Report Configurator application runs to transfer the measured data into a readable format. Several internal SQL Server scripts are executed in addition to those generated and controlled by ICONICS to save the data into a logical format by cell in three tables: **GCData**, **HoleCompleteSummaries**, and **MasterData**. The **GCData** table contains information obtained from GCs including contaminant concentrations. The **HoleCompleteSummaries** table contains summary information about each hole including coordinates, dates of treatment, depth of treatment, etc. The **MasterData** table contains information that is summarized by cell every second including process data and GC data. At approximately 11:00 pm, all of the data for the day that is organized by cell from the **GCData**, **HoleCompleteSummaries**, and **MasterData** tables is extracted and exported to *CSV* files within the **D:\SQL Data Sync** directory. The final SQL Server script executes at 11:30 pm and makes a copy of the files stored within the **D:\SQL Data Sync** in the **D:\SQL Data Backup** directory with the current date added to the end of each file. These files are not modified, moved, or deleted after creation and serve as a permanent record for all data for each day. The last task to be executed copies all of the current day's data from the job site to the **LDAWEB** server in Oak Ridge. Once the files are copied to the Oak Ridge server, the **LDAWEB** server appends all of the data located in the *CSV* files to its own tables (**GCData**, **HoleCompleteSummaries**, and **MasterData)** and is made available for reports.

3.4 COMPLETION CRITERIA AND PROTOCOL

The treatment protocol was established to provide the operator and site supervisor the treatment methodology for all perimeter and interior treatment cells at SPCC. The treatment protocol was generated to maximize contaminant mass removal while minimizing the treatment time. The protocol was also generated to allow for in the field decisions based on real-time contaminant data and trends during treatment. Real-time decisions will be discussed in Section 3.7 of this CMI Report.

3.4.1 Thermal and Iron Treatment Sequence

3.4.1.1 Treatment Cell Setup

Survey equipment was used to locate the anticipated day's treatment cells using the cell coordinates provided in Appendix G for SPCC. All the perimeter cells were treated first before treating interior cells. Once the treatment cells were located, the auger center was positioned over the stake and the auger was drilled into the soil until the top of the auger blade was at ground level. At this point the depth indicators were zeroed and the blower used to generate a vacuum in the shroud was activated to a flow rate of approximately 1000 acfm. The shroud was then lowered to the ground surface and monitored to ensure a vacuum pressure of approximately 1 to 5 inches of water. If the desired shroud pressure was not obtained initially, the auger was advanced approximately 3 feet and backfill was applied around the shroud.

3.4.1.2 First Treatment Pass

During the first thermal treatment pass (a pass is considered a movement of auger in one direction, up or down), the steam and hot air initiated the mass transfer. The FIDs and GCs were monitored to aid in real-time decision making process and to determine treatment criteria, completion criteria, and iron dosage quantities.

The auger drilled from the surface of soil to the starting thermal treatment depth for the zone at a descent rate of 1 to 3 feet per minute and 6 to 10 revolutions per minute. The three GCs processed samples approximately every 2 minutes for analysis. The fourth GC was also inline to collect samples during peak FID readings and was not in the cycled rotation. Hot air was delivered during the drilling at the following target and operating ranges:

Location	Target First Pass Air Flow (acfm)	Range of First Pass Air Flow (acfm)
Perimeter	200	200-400
Interior	400	300-500

Once the auger reached the target starting depth, the steam valve was opened and steam entered the treatment column. Thermal treatment commenced with the following steam target and operating ranges:

Location	Target First Pass Steam Energy (pph)*	Range of First Pass Steam Energy (pph)*
Perimeter	9,500	9,500 – 13,500
Interior	13,500	9,500 – 13,500

*Air and steam flow rates were varied at shallow levels, if needed, due to health and safety concerns, shroud movement, near surface thermal treatment, and/or to improve operational performance.

Once the peak off-gas FID and TCE values were determined, the cell treatment criteria (based on cell type), completion criteria, and iron dosages were determined according to Table 3-5 and Table 3-6, respectively. The minimum number of passes required was determined based on previous experience of the technology at SLC 15 at CCAFS for effective removal of VOC's at certain depths. Treatment cells were characterized into any of four types: Shallow low concentration cells, Deep low concentration cells, Shallow high concentration cells, and Deep high concentration cells.

Shallow Low Concentration Cells

These cells were characterized as cells with a maximum depth of 25 feet or less, FID values less than 400 ppm, and TCE values less than 60 ppm. Completion criteria for these cells required a minimum of two complete thermal passes and a minimum shroud temperature of 160^{o}F.

Deep Low Concentration Cells

These cells were characterized as cells with maximum depth between 25 and 55 feet, FID values less than 400 ppm, and TCE values less than 60 ppm. Completion criteria for these cells required a minimum of two complete thermal passes and a minimum shroud temperature of 160^{o}F.

Shallow High Concentration Cells

These cells were characterized as cells with maximum depth of 25 feet or less and which contained FID values greater than 400 ppm or TCE values greater than 60 ppm. These cells required a minimum of two complete thermal passes and a minimum shroud temperature of 160^{o}F. Completion criteria for this type of cell required reduction of peak FID value by 80% and reduction of TCE below 60 ppm or a maximum thermal treatment time of 90 minutes.

Deep High Concentration Cells

These cells were characterized as cells with maximum depth between 25 and 55 feet and which contained FID values greater than 400 ppm or TCE values greater than 60 ppm. These cells required a minimum of four complete thermal passes and a minimum shroud temperature of 160^{o}F. Completion criteria for this type of cell required reduction of peak FID value by 80% and reduction of TCE below 60 ppm or a maximum thermal treatment time of 120 minutes.

3.4.1.3 Successive Thermal Treatment Passes

The goal of the successive thermal treatment passes was to obtain a shroud temperature of greater than 160^{o}F and to remediate contaminant levels to the identified completion criteria provided in Table 3-5. The successive thermal passes consisted of either full interval treatment or focused thermal treatment. Focused thermal treatment was defined as treatment passes not returning to the starting thermal treatment depth but rather aimed at focusing on the interval of highest contamination. The typical target and operating air and steam flow rates on the successive thermal treatment passes were as follows (prior to obtaining 160°F+ in the shroud):

Location	Target Successive Pass Air Flow (acfm)	Range of Successive Pass Air Flow (acfm)	Target Successive Pass Steam Energy (pph)	Range of Successive Pass Steam Energy (pph)
Perimeter	400	300-500	9,500	9,500–13,500
Interior	400	300-500	9,500	9,500–13,500

Hot air and steam operating parameters were adjusted to maintain shroud temperature of 160°F or greater during the successive thermal treatment passes. Typical target and operating air and steam flow rates once 160°F was obtained in the shroud were:

Location	Target Successive Pass Air Flow (acfm)	Range of Successive Pass Air Flow (acfm)	Target Successive Pass Steam Energy (pph)	Range of Successive Pass Steam Energy (pph)
Perimeter	Varied	100-200	Varied	0-5000
Interior	Varied	100-200	Varied	0-5000

Upon satisfying all completion parameters identified in Table 3-5 per the cell type, the auger was drilled to the maximum treatment depth and retracted to the initial starting treatment depth in order to complete one full pass at 160°F or greater in the shroud to complete thermal treatment.

3.4.1.4 Iron Treatment

The iron dosage was determined once the peak FID value was obtained in accordance with Table 3-6 on the first/second pass. Preparation of the iron slurry was performed during the sequential thermal treatment passes in order to adequately suspend the iron in the guar and water mixture. The iron preparation procedures for ZVI slurry preparation were as follows:

1. In guar preparation tank begin with approximately 200 gallons of water and re-circulate.
2. Add approximately 30 pounds of guar in to the tank with another 200 gallons of water.
3. Begin mixing guar preparation tank and fill to approximately 600 gallons.
4. Re-circulate for approximately 30 to 40 minutes at approximately 300 gpm for adequate guar thickening.
5. Complete re-circulation and continue mixing in guar preparation tank until ready for iron preparation.
6. Once ZVI dosage is determined, add approximately 500 gallons to ZVI agitator tank and commence re-circulation and mixing.
7. Begin adding desired iron quantity slowly to ZVI agitator tank.
8. ZVI preparation of approximately 600 gallons of ZVI slurry complete and ready for injection.

Table 3-5. Treatment Protocol and Completion Criteria

Type	Treatment Cell Depth	First Pass Off-Gas Peak FID and TCE Concentration	Thermal Treatment Passes[1, 2]	Thermal Treatment Completion Criteria[2]	Iron Treatment Passes[2]
Shallow Low Concentration Cells	SPCC <= 25 ft	FID < 400 ppm AND TCE < 60 ppm	• Minimum of 2 complete thermal treatment passes • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	• Minimum of 2 complete thermal treatment passes • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	Minimum of 2 passes to inject and mix iron after thermal treatment
Deep Low Concentration Cells	SPCC > 25 ft	FID < 400 ppm AND TCE < 60 ppm	• Minimum of 2 complete thermal treatment passes • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	• Minimum of 2 complete thermal treatment passes • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	Minimum of 2 passes to inject and mix iron after thermal treatment
Shallow High Concentration Cells	SPCC <= 25 ft	FID >= 400 ppm OR TCE >= 60 ppm	• Minimum of 2 complete thermal treatment passes • Focused interval treatment may be implemented at operator's discretion on or after 2nd pass • Final focused thermal treatment pass must be completed to maximum treatment depth prior to ascending for final complete thermal treatment pass • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	Shroud temperature must be at least 160°F, TCE concentrations from GC must remain below 60 ppm, and off-gas FID reading must remain below 80% of the first pass peak reading throughout entire final thermal treatment pass OR Complete a maximum 90 minutes of thermal treatment (start of steam injection to start of iron injection)	Minimum of 2 passes to inject and mix iron after thermal treatment
Deep High Concentration Cells	SPCC > 25 ft	FID >= 400 ppm OR TCE >= 60 ppm	• Minimum of 4 complete thermal treatment passes • Focused interval treatment may be implemented at operator's discretion on or after 3rd pass • Final focused thermal treatment pass must be completed to maximum treatment depth prior to ascending for final complete thermal treatment pass • Maintain temperature of 160°F or greater as measured in shroud throughout entire final thermal treatment pass	Shroud temperature must be at least 160°F, TCE concentrations from GC must remain below 60 ppm, and off-gas FID reading must remain below 80% of the first pass peak reading throughout entire final thermal treatment pass OR Complete a maximum 120 minutes of thermal treatment (start of steam injection to start of iron injection)	Minimum of 2 passes to inject and mix iron after thermal treatment

Notes:

(1) A pass is considered a movement of auger in one direction (up or down) from either top to bottom (or bottom to top) of target treatment zone. Thermal treatment consists of injection of steam between 9,500-13,500 lbs/hr and air between 200 – 500 acfm until temperature of 160°F is attained in the shroud. The steam and air injection rate may be varied at the operator's discretion to maintain the temperature of 160°F in shroud. The auger descend/ascend rate shall be between 1-3 ft/min with the rotational speed of 6-10 rev/min. The detail operational parameters during each pass are presented in Section 3.2.1.

(2) The minimum number of passes required was determined based on previous experience of the technology at SLC 15 at CCAFS for effective removal of VOCs at certain depths.

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Table 3-6. ZVI Dose in Soil Column

Maximum FID in Off-Gas	<1000 ppm									1000-5000 ppm								
ZVI Dose	0.50%									1.00%								
	Req'd ZVI (lb)	Actual ZVI (lb)	# of Req'd Bags by Lb							Req'd ZVI (lb)	Actual ZVI (lb)	# of Req'd Bags by Lb						
			50	250	500	750	1000	1500	3000			50	250	500	750	1000	1500	3000
SPCC Perimeter Cells	1131	1150	3				1			2262	2250		1			2		
SPCC Zone 1	1131	1150	3				1			2262	2250		1			2		
SPCC Zone 2	377	400	3	1						754	750		3					

Maximum FID in Off-Gas	5000 - 10000 ppm									>10000 ppm								
ZVI Dose	1.50%									2.0%								
	Req'd ZVI (lb)	Actual ZVI (lb)	# of Req'd Bags by Lb							Req'd ZVI (lb)	Actual ZVI (lb)	# of Req'd Bags by Lb						
			50	250	500	750	1000	1500	3000			50	250	500	750	1000	1500	3000
SPCC Perimeter Cells	3393	3400	3	1					1	4524	4500						1	1
SPCC Zone 1	3393	3400	3	1					1	4524	4500						1	1
SPCC Zone 2	1131	1100	2				1			1508	1500						1	

Note – ZVI quantities and bag combination may vary slightly due to availability of onsite bag sizes.

Once the auger reached the starting thermal treatment depth, the ZVI slurry was pumped to the auger for injection at a rate of approximately 25 gpm and the air flow remained at a minimal 100 acfm to aid in drilling. Drilling commenced from the starting treatment depth to the finishing treatment depth at a descent rate of approximately 2 feet per minute and approximately 10 rpm. FID and GC samples were still collected during the iron treatment. Once the finishing treatment depth was reached and the 600 gallons of ZVI slurry was injected, water was introduced to the ZVI agitator tank for a washout of the lines on the way to the surface for cell completion. Figures 3-2, 3-3, and 3-4 were generated to illustrate the following discussion on the thermal and iron treatment sequence.

3.4.1.5 Treatment Cell Completion

At the completion of each cell, the auger was stopped just below the ground surface and the shroud was lifted. Once the shroud was lifted the auger was removed from the soil and spun several times to remove and loosen dirt from the blades. The crane was swung away from the treatment cell to allow for backfilling and compaction by an excavator. Approximately 3 to 5 yd^3 of soil was mixed with approximately 3 to 4 feet of recently treated cell soil to aid in soil stabilization. These activities were performed to stabilize the soil and bring it back to original grade.

3.4.2 Example Treatment Sequence on Treatment Cell BB13

Treatment cell BB13 located in Zone 1 at SPCC was treated on 19 April 2006 between starting time of 14:41 and ending time of 17:18. Figure 3-5 details the treatment sequence for cell BB13 and is provided to aid the description that follows. This cell was a Zone 1 cell which required thermal treatment from 10 to 55 feet bgs. The auger was advanced to 10 feet where thermal treatment commenced down to 55 feet bgs at a steam flow rate of 10,000 pph. FID contaminant levels increased near the bottom intervals and the peak was generated on the second pass. FID peak revealed a value of 7257 ppm. Peak FID value consisted of 5304 ppm TCE as determined from the GC samples collected during the spike. The peak also consisted of DCE of 1623 ppm and PCE of 796. These values characterized the cell as a Deep High Concentration Cell requiring a minimum of four thermal treatment passes, shroud temperature of 160°F minimum, and completion criteria of less then 60 ppm TCE and 80% FID reduction for completion. Figure 3-5 illustrates the contaminant response associated with the treatment of cell BB13.

Shroud temperature of 160°F was obtained on the third pass and several focused passes were implemented on the succeeding passes. On each successive thermal pass the contaminant levels were reduced, and 80% reduction of the FID was obtained on the 10th thermal pass (3 complete and 7 focused). TCE of less than 60 ppm was obtained on the 20th thermal treatment pass (3 complete and 17 focused). Prior to commencing the iron injection the highest FID value seen on the last pass was 150 ppm, which is 98% reduction from the peak FID value. TCE and PCE values on the final pass were reduced to 29 ppm and 10.65 ppm, respectively. Once thermal treatment was completed, the auger was drilled to 10 feet bgs and iron injection commenced for one pass to 55 feet bgs. Iron injection was completed at 55 feet bgs and the auger was returned to the surface for treatment cell completion.

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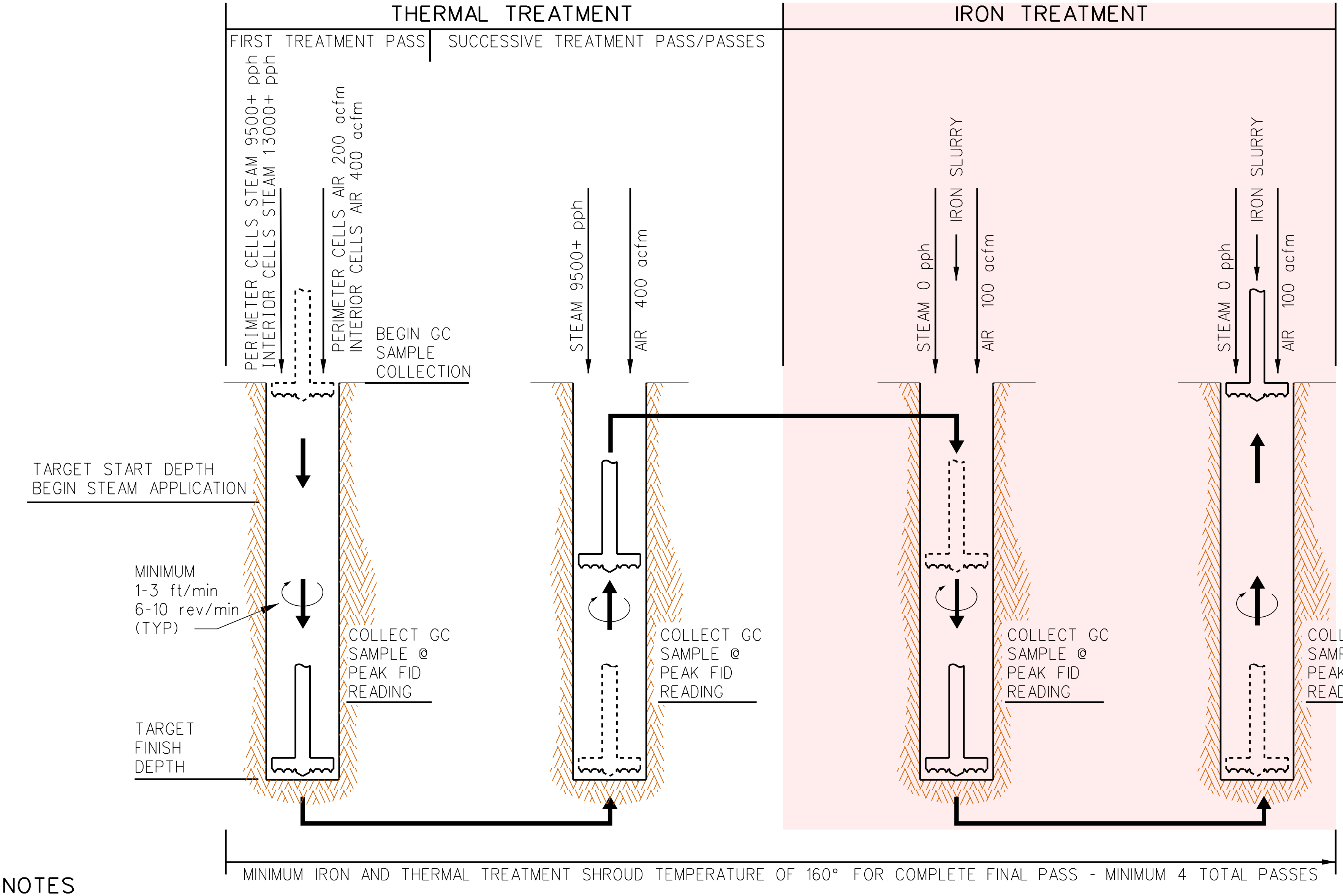

NOTES

1. AIR AND STEAM FLOW RATES MAY BE VARIED FOR:
   (1) HEALTH AND SAFETY REASONS
   (2) SHROUD LIFTING
   (3) MIXING NEAR SURFACE
   (4) IMPROVE OPERATIONAL PERFORMANCE
2. LOW CONCENTRATION CELLS ARE WHERE THE FIRST PASS PEAK FID IS LESS THAN 400ppm AND TCE CONCENTRATION IS LESS THAN 60ppm.
3. SHALLOW CELLS ARE LESS THAN OR EQUAL TO 25 FEET. DEEP CELLS ARE MORE THAN 25 FEET DEEP.

NOT TO SCALE

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FIGURE 3-2
CELL TREATMENT PROTOCOL
SHALLOW AND DEEP
LOW CONCENTRATION CELLS

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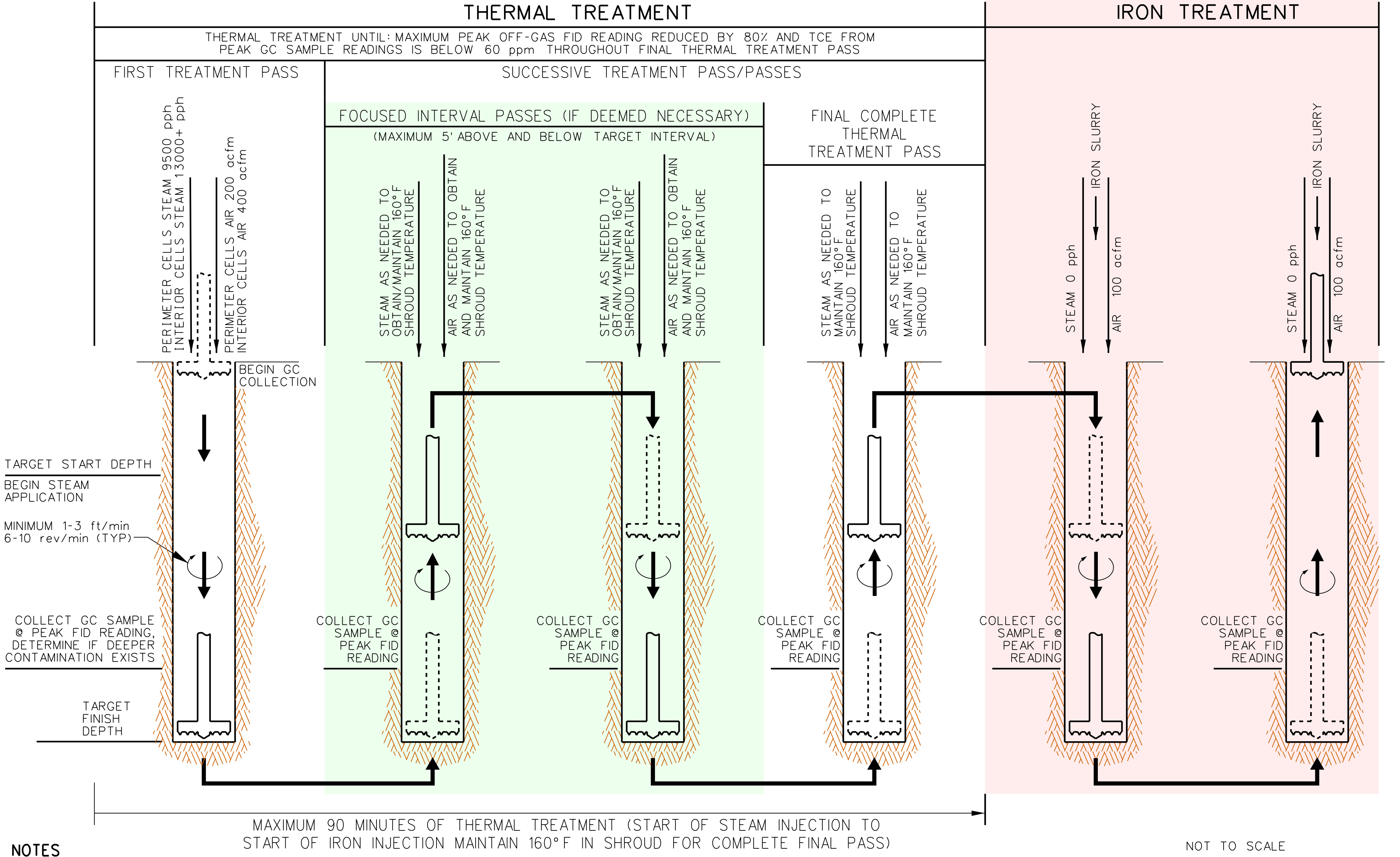

NOT TO SCALE

NOTES

1. AIR AND STEAM FLOW RATES MAY BE VARIED FOR:
   (1) HEALTH AND SAFETY REASONS
   (2) SHROUD LIFTING
   (3) MIXING NEAR SURFACE
   (4) IMPROVE OPERATIONAL PERFORMANCE
2. HIGH CONCENTRATION CELLS ARE WHERE THE FIRST PASS PEAK FID IS EQUAL TO OR GREATER THAN 400ppm OR TCE CONCENTRATION IS EQUAL TO OR GREATER THAN 60ppm.
3. SHALLOW CELLS ARE LESS THAN OR EQUAL TO 25 FEET DEEP.

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FIGURE 3-3
CELL TREATMENT PROTOCOL
SHALLOW HIGH CONCENTRATION CELLS

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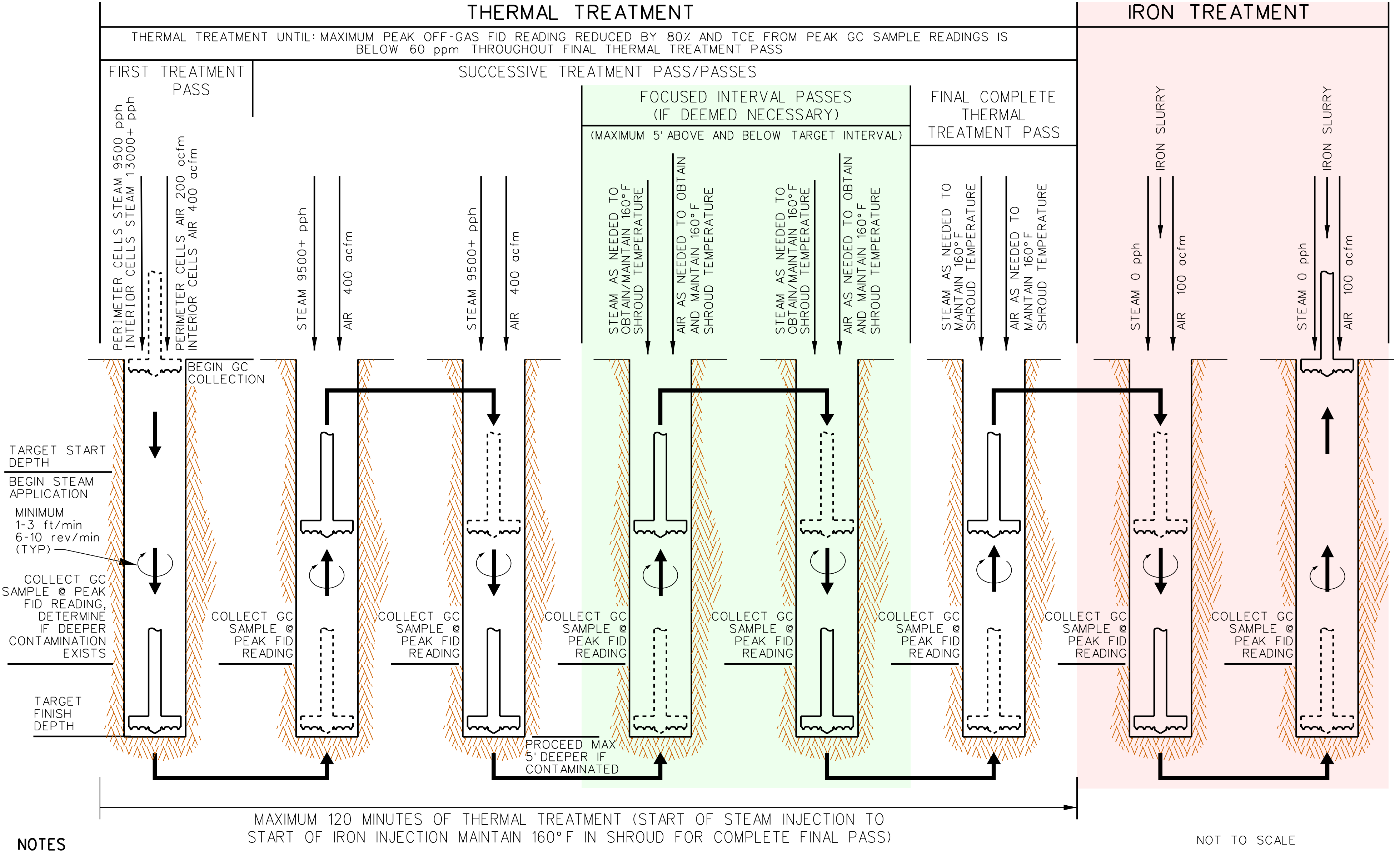

NOT TO SCALE

NOTES

1. AIR AND STEAM FLOW RATES MAY BE VARIED FOR:
   (1) HEALTH AND SAFETY REASONS
   (2) SHROUD LIFTING
   (3) MIXING NEAR SURFACE
   (4) IMPROVE OPERATIONAL PERFORMANCE
2. HIGH CONCENTRATION CELLS ARE WHERE THE FIRST PASS PEAK FID IS EQUAL TO OR GREATER THAN 400ppm OR TCE CONCENTRATION IS EQUAL TO OR GREATER THAN 60ppm.
3. DEEP CELLS ARE MORE THAN 25 FEET DEEP.

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FIGURE 3-4
CELL TREATMENT PROTOCOL
DEEP HIGH CONCENTRATION CELLS

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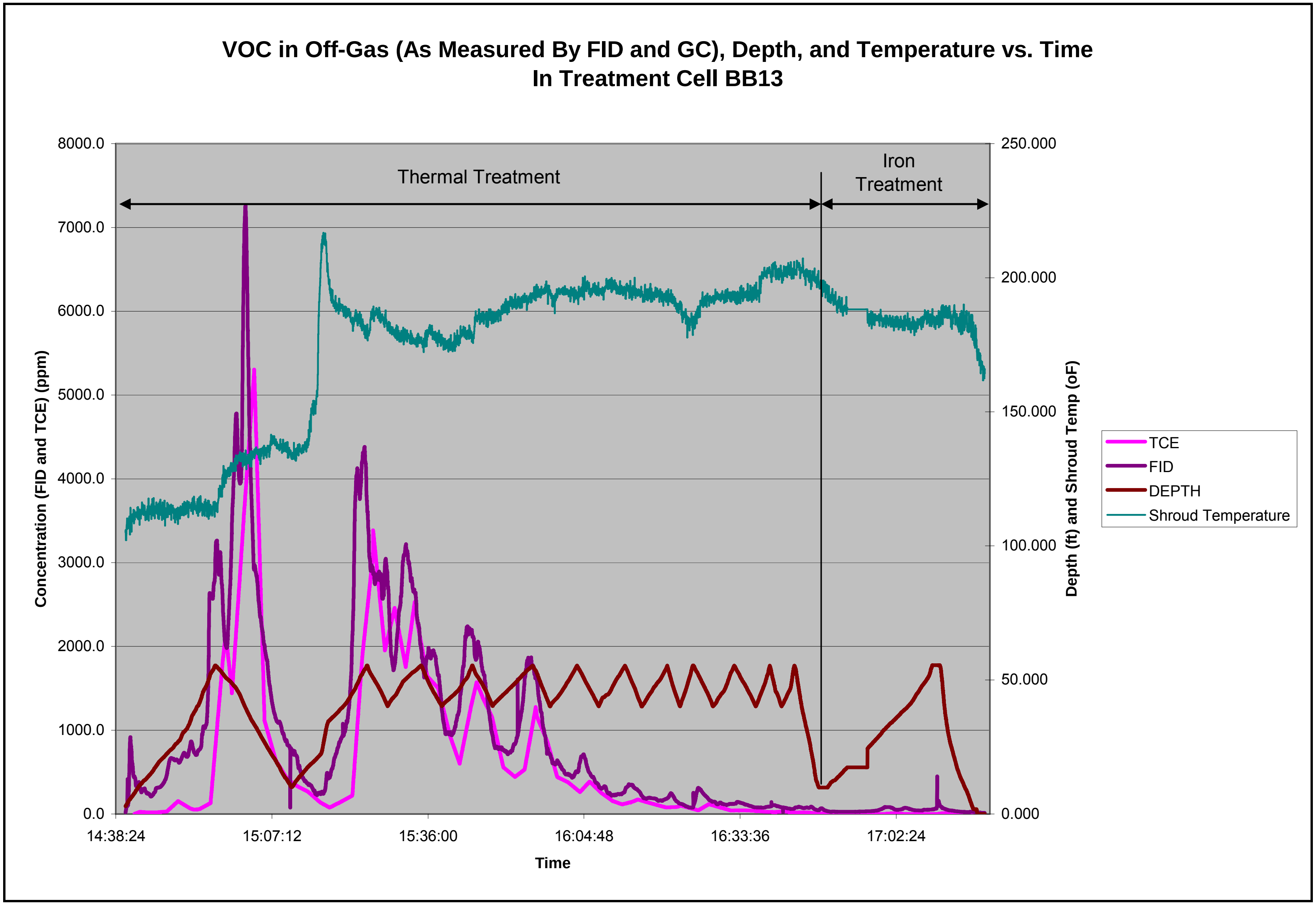


Figure 3-5. VOC in Off-gas, Depth, and Temperature versus Time in Treatment Cell BB13

3.5 DATA USE

3.5.1 Mass Calculations

The purpose of this calculation is to determine the estimated amount (mass) of VOCs extracted during the treatment of cells. The mass is calculated using the concentrations of the constituents detected by GC for the following compounds: PCE; TCE; cis-1,2-DCE; trans-1,2-DCE; vinyl chloride; 1,1,2-trichloro-1,2,2-trifluorethane (Freon 113); benzene; toluene; ethylbenzene; 1,1-DCA; and 1,1,1-TCA. The approach and the calculation to determine the mass of VOCs are given below.

Assumptions:

- The off-gas line is saturated with water at temperatures between 130 and 208°F.
- The amount of water vapor in the conditioned sample stream can be neglected.
- The mass of solids and liquid water in the bulk stream can be neglected.
- Some of the VOC mass removed may not be captured in the shroud and may emit into the atmosphere as a minor fugitive emission around the shroud.
- Ideal gas law applies
- Each analyte concentration measured by GC is constant for the 2 minute interval until the next GC concentration for each analyte is measured.

Approach:

F_m = Mole fraction of contaminant = μ–moles/mole * 10^{-6} moles/μ–mole.

C_w = Correction factor for water in the bulk stream is based on curve fit of steam tables data for saturated steam from 130 to 208°F.

C_m = Conversion from moles to mass = Molecular weight of contaminant: (grams/g-mole) * 0.00220462 lbs/gram.

M = Mass of contaminant

n = Total moles of a gas = PV/RT (Assuming ideal gas behavior applies)

P = absolute pressure = ambient pressure (P_a) – vacuum pressure (gage) (P_g)

V = volume of gas

R = Ideal gas constant: 0.654882 in-H_2O-ft^3/g-mole ^oR

T = Temperature degrees Rankin = degrees F + 459.4

Therefore, $M = F_m * n * C_w * C_m$

Applying the above approach, the expression to calculate total mass of the contaminant can be calculated by the following equation:

$$\mathbf{M_{ij} = [C_{ij} * MW_i * (4.01463E\text{-}1 * P_{Aj} - P_{1j}) * V_{1j} * 3.36635E\text{-}9/(T_{1j} + 459.4)] * [1\text{-}(4.64711E\text{-}7 * T_{1j}^3 - 1.45239E\text{-}4 * T_{1j}^2 + 1.84674E\text{-}2 * T_{1j} - 8.17509E\text{-}1)]}$$

Where:

b = GC sample interval (min.).(Extrapolated constant interval in minutes=1/60 min.)

C_{ij} = concentration of contaminant i at sample interval j

g_{1k} = incremental flow rate reading in the off-gas line (cfm)

MW_i = molecular weight of individual contaminant compound (g/g-mole)

P_{Aj} = ambient pressure at sample interval j (millibar absolute)

$$\mathbf{P_A\ (in\text{-}H_2O) = P_a(millibar)*0.401463\ (in\text{-}H_2O/millibar)}$$

P_{1j} = average vacuum reading in the off-gas line at sample interval j (in-H_2O gage)

T_{1j} = average temperature reading in the off-gas line at sample interval j (^oF)

V_{1j} = volume of gas at sample interval j (ft^3)

Also, $V_{1j}=b*g_{1k}$

M = Total mass of contaminant compounds (pounds)

M_i = Total mass of the individual contaminant compound i (pounds)

M_{ij} = mass of the individual contaminant compound i at sample interval j (pounds)

m = number of contaminant compounds detected by the GCs.

$$M_i = \sum_{j=1}^{n} M_{ij}$$

$$M = \sum_{i=1}^{m} M_i$$

3.5.2 Data Presentation

As cells were treated, the raw data were uploaded on the web server in Oak Ridge. The reports were then executed using ICONICS Reportworks software that used the custom template to generate the reports. During this project, four reports were generated:

- Mass removed for entire site,
- Mass removed for individual cell,
- Methane summary for individual cell, and
- Treatment summary for individual cell.

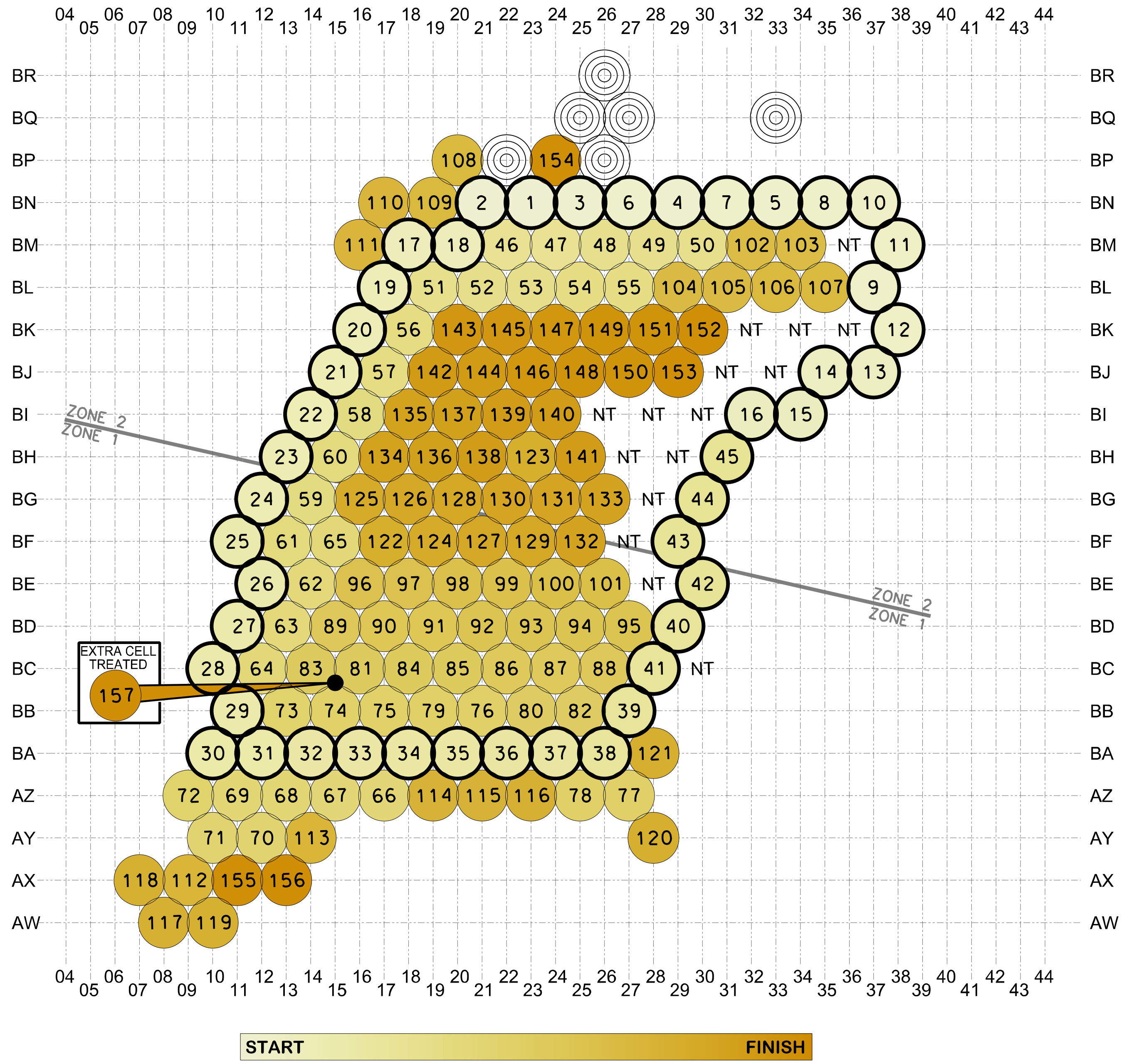
Mass removed for entire site presents the mass of contaminants removed from every cell. These contaminants include PCE; TCE; cis-1,2-DCE; trans-1,2-DCE; vinyl chloride; Freon 113; benzene; toluene; ethylbenzene; 1,1-DCA; and 1,1-TCA. This report also includes the total mass removed of each contaminant as well as the total mass removed from the site.

Mass removed for individual cell presents treatment cell information that includes coordinates, date and time of treatment, treatment depth, off gas VOC concentrations estimated by GC (ppm), process parameters used in the calculation of mass removal, and mass removed from cell. The report also presents the graph of VOCs in Off-Gas vs. Time. The graph presents the amount of VOC concentration in ppm removed from the cell with respect to time in seconds. It also represents the depth of auger in feet versus time in seconds.

Methane summary for individual cell report presents a graph of methane concentrations. The graph represents the amount of PCE; TCE; cis-1,2-DCE; methane and FID in ppm with respect to time in seconds. It also represents the depth of auger in feet versus time in seconds.

Treatment summary for individual cell report presents three graphs of the summarized data. The first graph is entitled VOCs in Off-Gas and Depth versus Time. This graph represents the total VOCs as measured by the FID with respect to time in seconds. It also represents the depth of auger in feet versus time in seconds. The second graph represents the air temperature, steam injection temperature, off-gas temperature, and shroud temperature, all in degrees Fahrenheit with respect to time. The third graph represents the air flow and off-gas flow in acfm with respect to time in seconds. In addition, it represents the steam injection rate in pph with respect to time in seconds. The individual cell reports are presented in Volume III.

From these reports, four figures were created and updated daily. Figure 3-6 shows the treatment sequence of the cells. The cells are numbers and shaded as to the order they were treated. The treatment progress for each cell is presented in Figure 3-7. In this figure the maximum FID and TCE values are shown for each cell. In addition, each cell is color coordinated depending upon the FID and TCE value (i.e., FID less than 400 ppm and TCE less than 60 ppm; FID greater than or equal to 400 ppm and less than 1000 ppm and/or TCE greater than or equal to 60 ppm and less than 120 ppm; FID greater than or equal to 1000 ppm or TCE greater than



LEGEND

○ 8' DIAMETER CELL LOCATION

◯ 8' DIAMETER INITIAL PERIMETER CELL LOCATION

◎ COMPLETED TEST CELL

NT NOT TREATED (LOW CONTAMINATION IN ADJACENT CELLS)

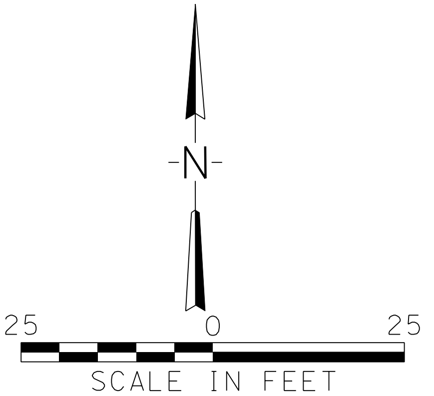


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FIGURE 3-6
TREATMENT SEQUENCE

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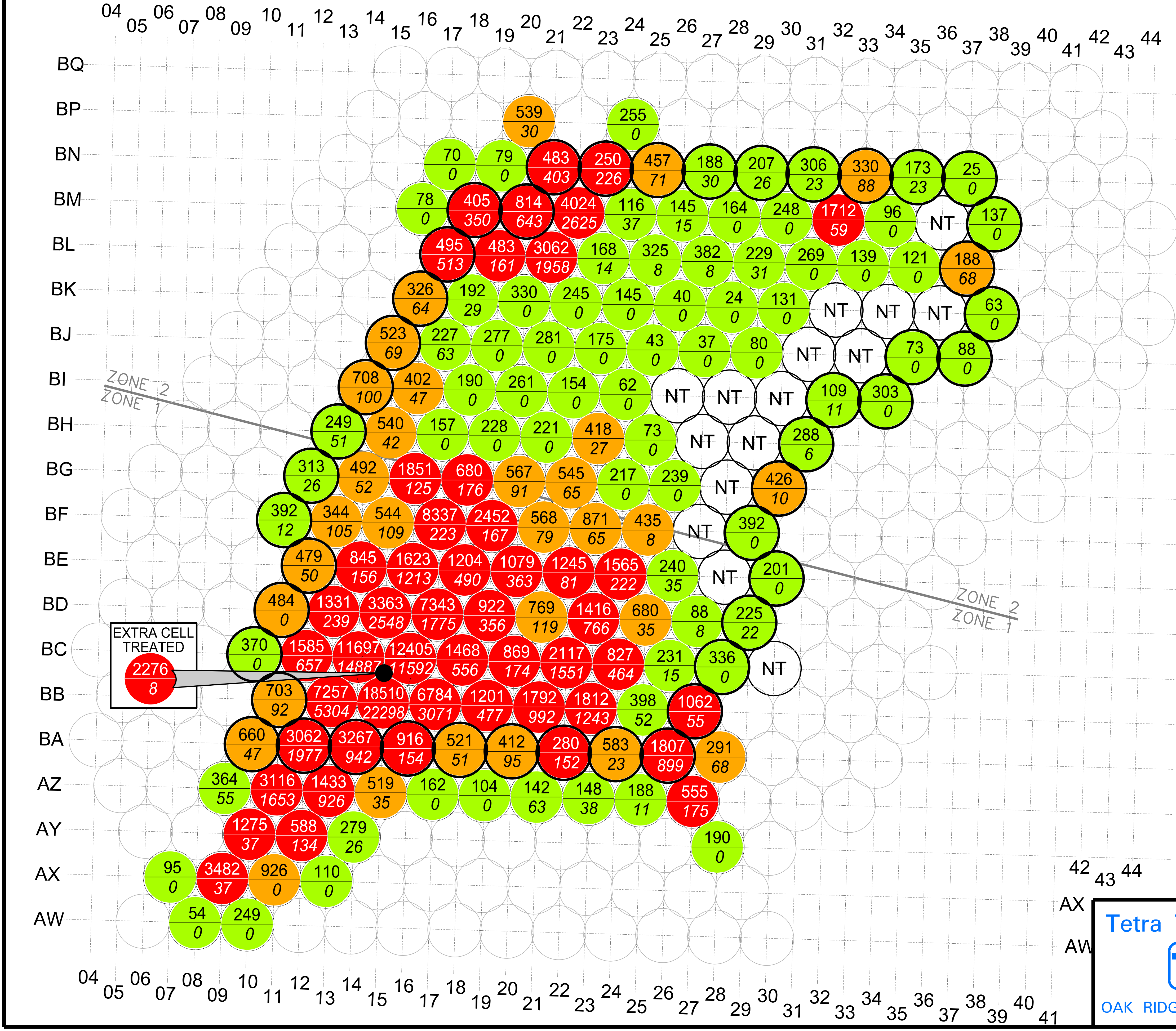

LEGEND

○ 8' DIAMETER CELL LOCATION

◯ 8' DIAMETER INITIAL PERIMETER CELL (SEE NOTES FOR ZONE DESCRIPTION)

🟢 207 / 26 — FID VALUE IN ppm (TYPICAL); TCE VALUE IN ppm (TYPICAL); FID <400ppm AND TCE <60ppm

🟠 326 / 105 — FID >=400ppm and <1000ppm AND/OR TCE >=60ppm and <120

🔴 3150 / 1977 — FID >=1000ppm OR TCE >=120ppm

NT — NOT TREATED (LOW CONTAMINATION IN ADJACENT CELLS)

NOTES

1. ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.
2. CELLS SHOWN OUTSIDE OF THE PERIMETER CELLS WERE NOT INCLUDED IN ORIGINAL TREATMENT AREA.
3. CELL AZ19 HAD A MAX FID OF 4864 THAT WAS A METHANE SPIKE.

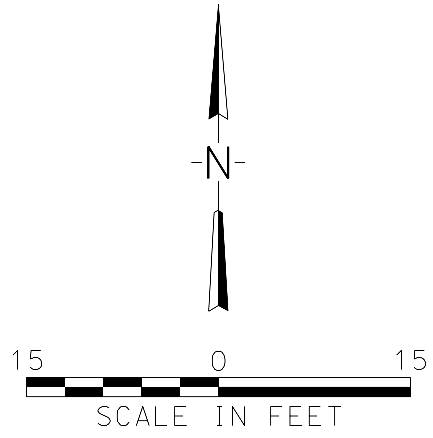

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FIGURE 3-7
TREATMENT PROGRESS
Progress as of 5-19-06

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or equal to 120 ppm). Figure 3-8 shows the TCE, DCE, PCE, and total VOC contamination mass for each cell. The iron injection percentage and mass for each cell are shown in Figure 3-9.

3.6 DATA EVALUATION

Each vertical penetration of the 8-foot diameter LDA represents the location of a treatment cell. The pounds of VOC chemical mass removed from each cell were calculated from the chemical concentrations measured in the off-gas that was sampled and analyzed using gas chromatography. The concentrations of VOCs in the off-gas were used to determine the chemical mass removed as described in Section 3.5.1. The total mass removed for each VOC represents all phases that were present in the subsurface (e.g., pure phase, sorbed, dissolved).

3.6.1 Total Mass Removed Per Cell

The total mass removed for each treatment cell location is represented in Figures 3-10 through 3-15 using isoconcentration contours for PCE, TCE, cis-DCE, trans-DCE, vinyl chloride, and Freon 113. These six VOCs represent 99.95% of the total mass removed during the remedial action, and the figures demonstrate where the bulk of the contamination was located and removed from the site. The incremental total mass removed per successive, 15-foot depth intervals is demonstrated in Figures 3-16 through 3-18 for only PCE, TCE, and cis-DCE, that comprised 99.6% of the VOC mass removed. These figures provide additional information on the vertical and horizontal distribution of the VOC mass that was encountered and removed from the site. The total mass removed for each treatment cell location is presented in Appendix H.

For all plots the mass removed per cell was assigned to a point representing the center of each treatment cell and the data were contoured using a kriging algorithm in the SURFER® software program. For all chemicals, with the exception of trans-DCE, the data show that the majority of the mass was located across the southern portion of the source area. PCE, TCE, and cis-DCE showed a similar vertical distribution with the largest mass present between depths of 40 to 55 feet bgs. Figures 3-16 through 3-18 also show a distinct increase in the size of the source area towards the north consistent with the reductive dechlorination pathway going from PCE (smallest area) to cis-DCE (largest area). The increase in the size of the source area to the north is consistent with the direction of groundwater flow which is to the north-northeast across the site. This observation suggests that downgradient advective flow of daughter products is at least partially responsible for the larger distribution of TCE and cis-DCE compared to PCE in the subsurface.

Vinyl chloride was only present in the southern portion of the site where relatively high concentrations of chlorinated solvents were present. This suggests that geochemical conditions in the mostly highly contaminated portion of the source area may have prevented further dechlorination of less oxidized daughter products, thus resulting in the accumulation of vinyl chloride in this area. Downgradient areas, to the north, where vinyl chloride was not detected may indicate where conditions were favorable for further dechlorination or even complete mineralization of the daughter products.

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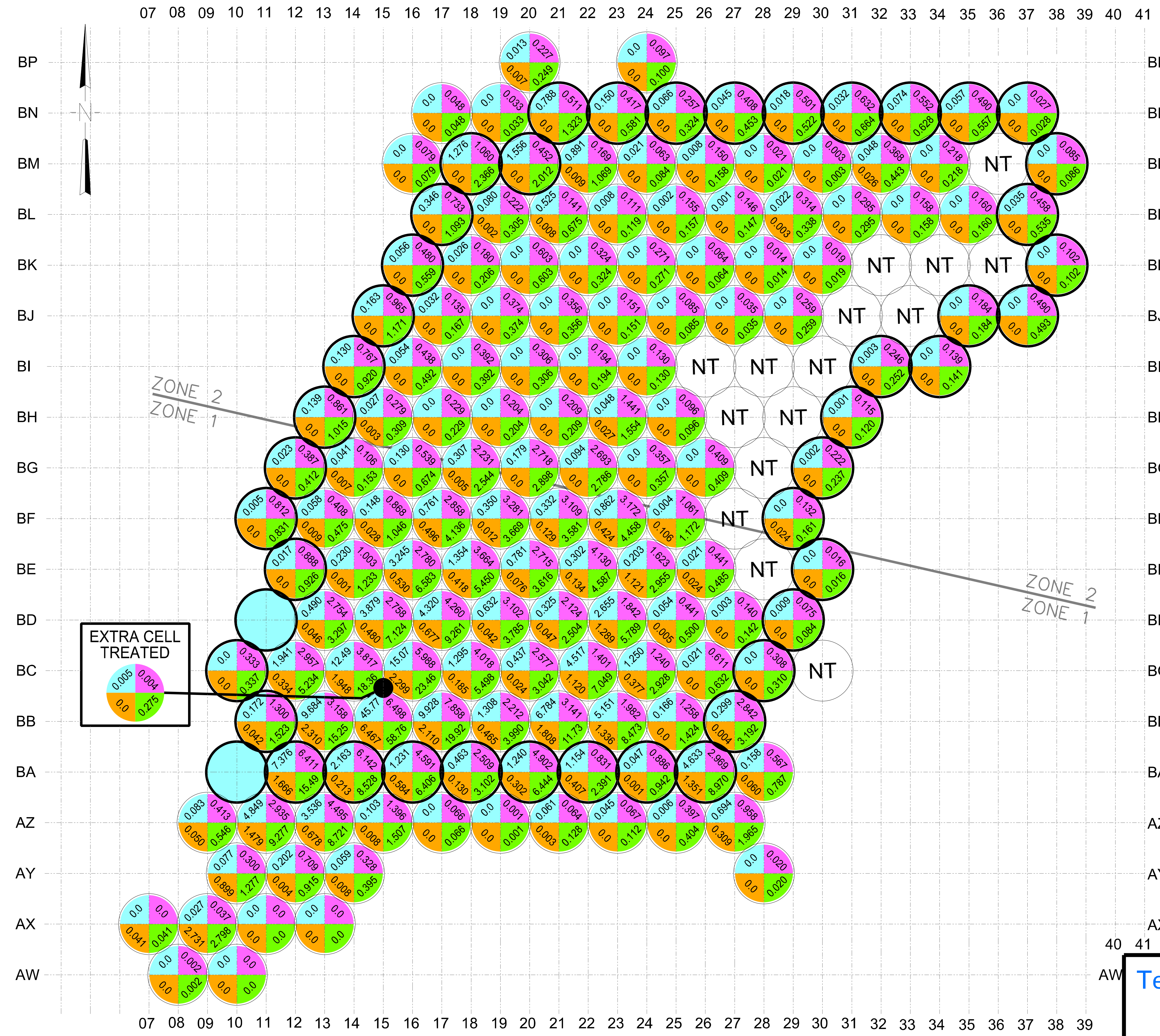

LEGEND

CONTAMINATION MASS
(LBS PER CELL)

TCE — CIS-1,2 DCE
PCE — TOTAL VOCs

8' DIAMETER CELL LOCATION

8' DIAMETER INITIAL PERIMETER CELL LOCATION (SEE NOTE)

NT — NOT TREATED (LOW CONTAMINATION IN ADJACENT CELLS)

DATA NOT RECORDED DUE TO SCADA SYSTEM ERROR

NOTE

ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.

14 0 14
SCALE IN FEET

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FIGURE 3-8
CONTAMINATION MASS DATA FOR
TCE, DCE, PCE AND TOTAL VOCs
UPDATED 6-27-06

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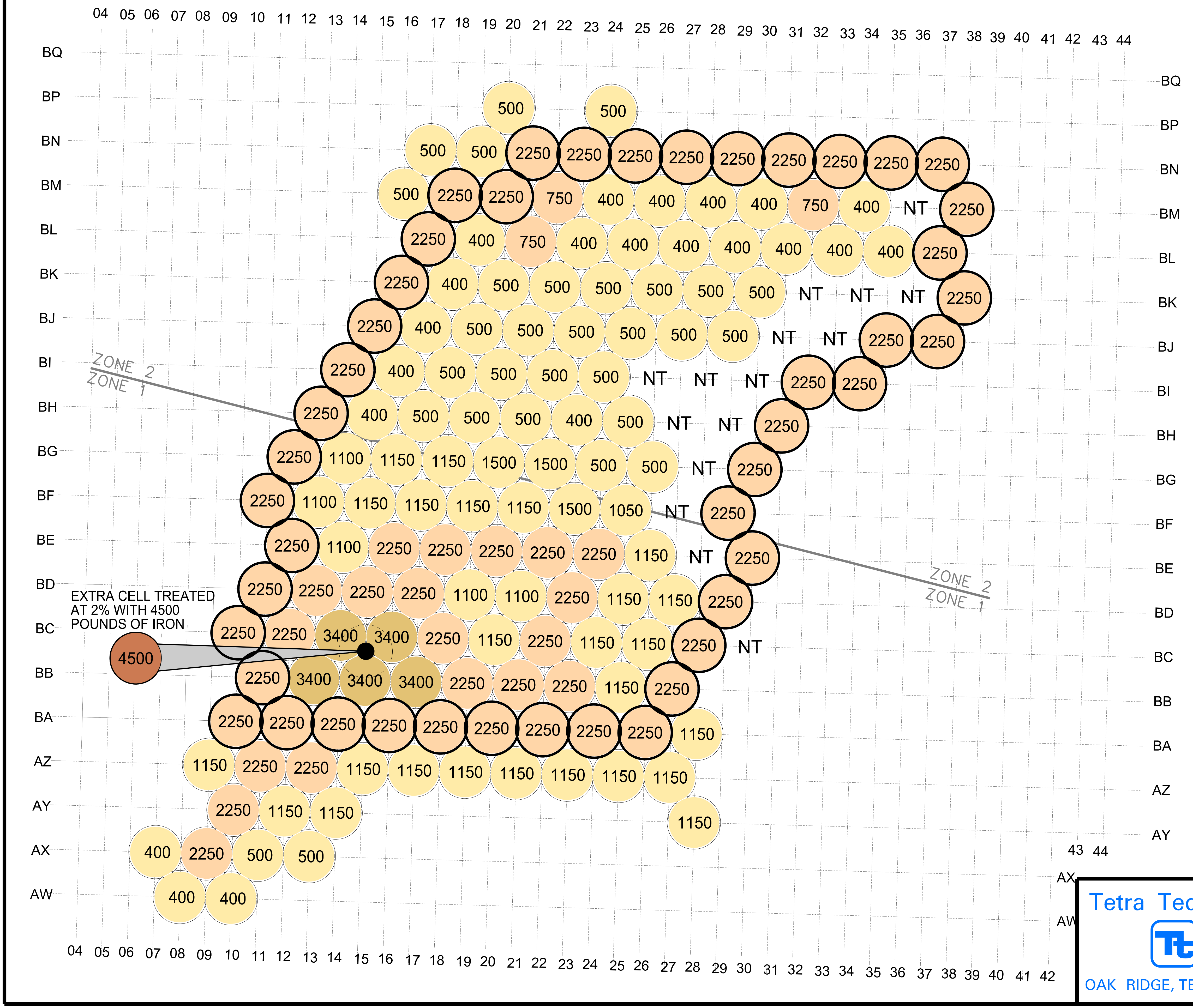

LEGEND

○	8' DIAMETER CELL LOCATION
◯	8' DIAMETER INITIAL PERIMETER CELL (SEE NOTE FOR ZONE DESCRIPTION)
400	POUNDS OF IRON PER CELL (TYPICAL) 0.5% OF IRON INJECTION
2250	1% OF IRON INJECTION
3400	1.5% OF IRON INJECTION
4500	2% OF IRON INJECTION (FOR SYSTEM CAPACITY TESTING)
NT	NOT TREATED (LOW CONTAMINATION IN ADJACENT CELLS)

NOTES

1. ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.
2. CELLS SHOWN OUTSIDE OF THE PERIMETER CELLS WERE NOT INCLUDED IN ORIGINAL TREATMENT AREA.

-N-

15 0 15
SCALE IN FEET

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FIGURE 3-9
IRON INJECTION
PERCENTAGE AND MASS
Progress as of 5-18-06

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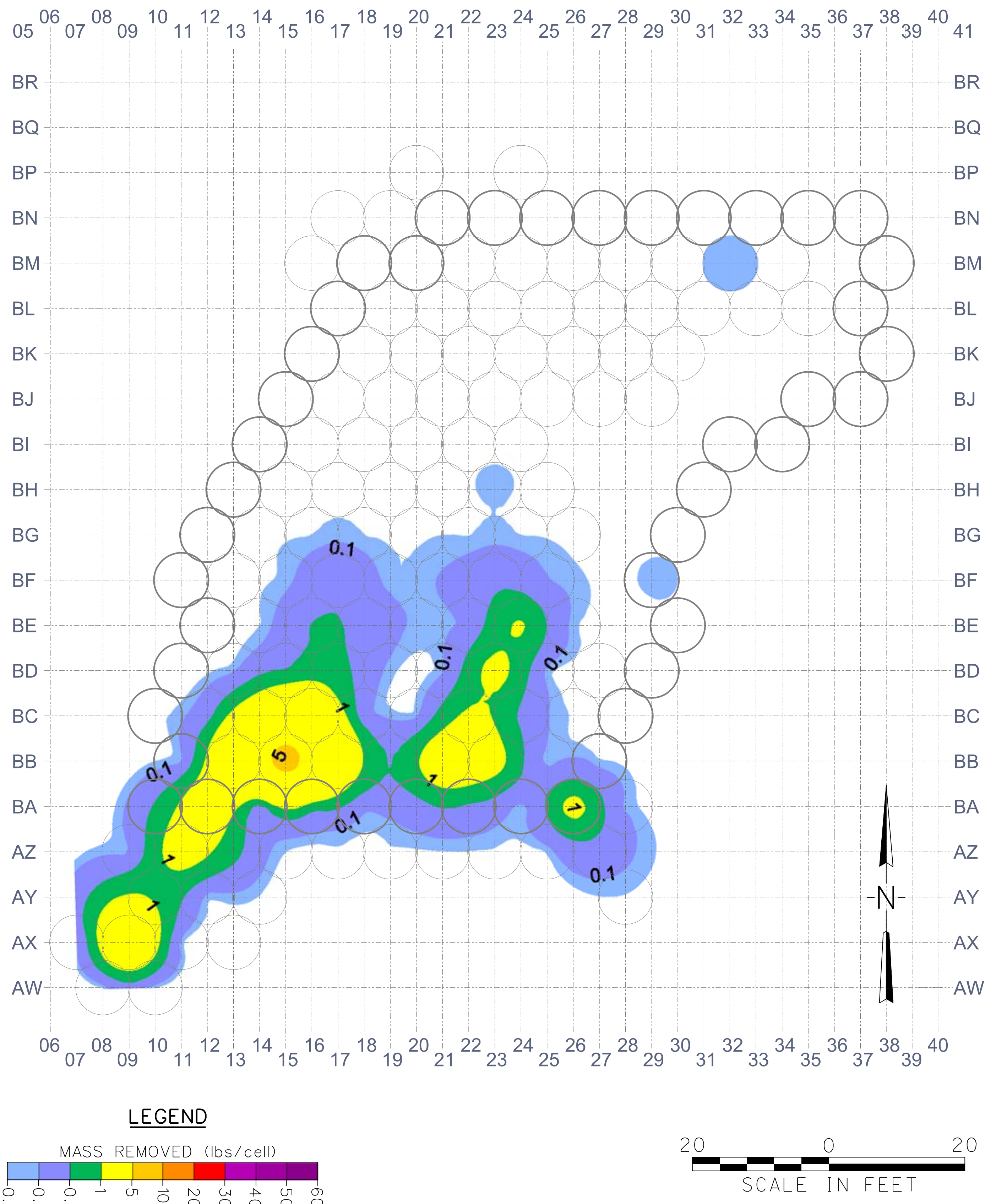

LEGEND

MASS REMOVED (lbs/cell)

0.01	0.1	0.5	1	5	10	20	30	40	50	60

○ 8' DIAMETER CELL LOCATION

◯ 8' DIAMETER PERIMETER CELL LOCATION AS PER WORK PLAN

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FIGURE 3-10
TETRACHLOROETHENE (PCE) MASS
REMOVED PER CELL

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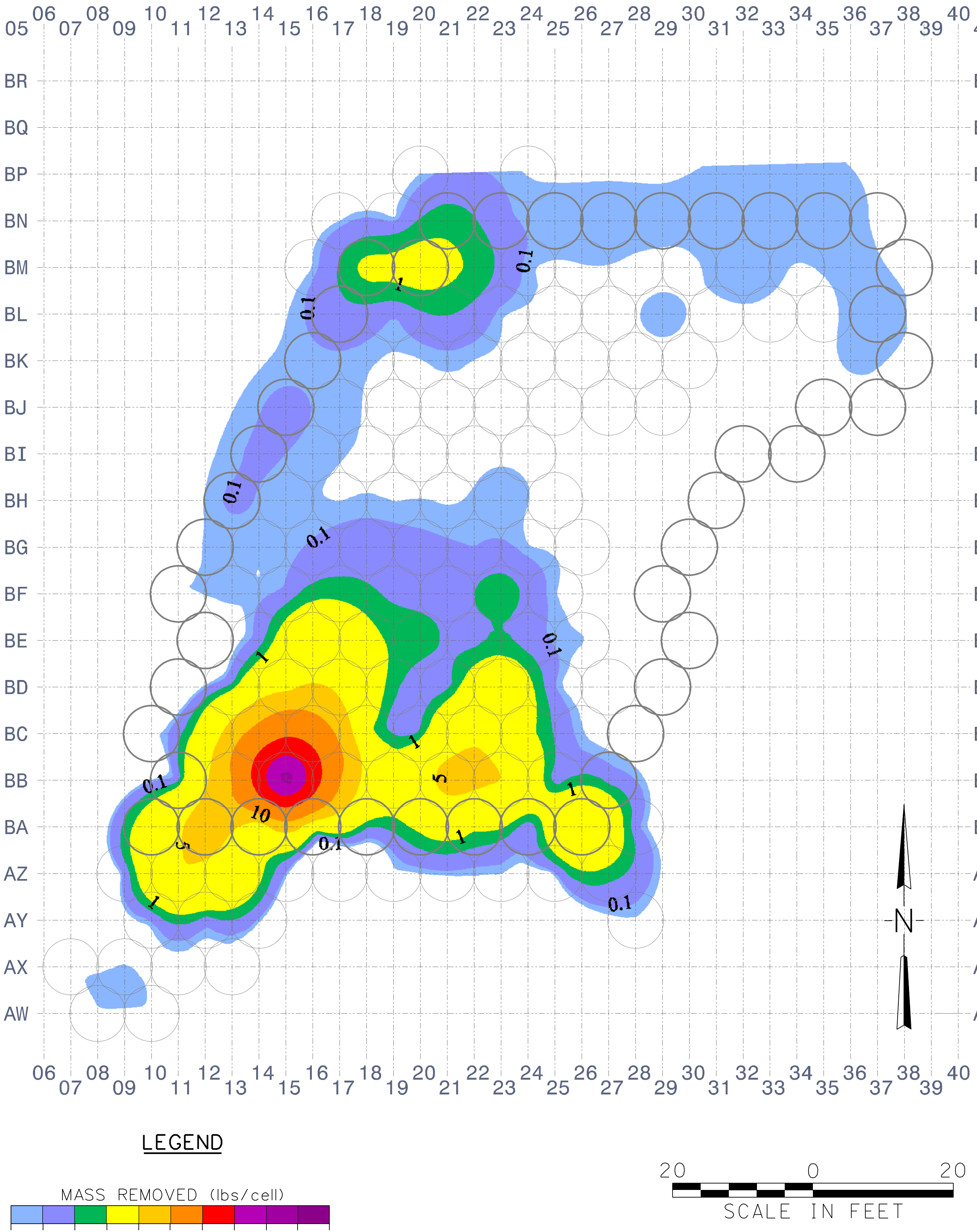

LEGEND

MASS REMOVED (lbs/cell)

0.01	0.1	0.5	1	5	10	20	30	40	50	60

○ 8' DIAMETER CELL LOCATION

○ 8' DIAMETER PERIMETER CELL LOCATION AS PER WORK PLAN

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FIGURE 3-11
TRICHLOROETHENE (TCE) MASS
REMOVED PER CELL

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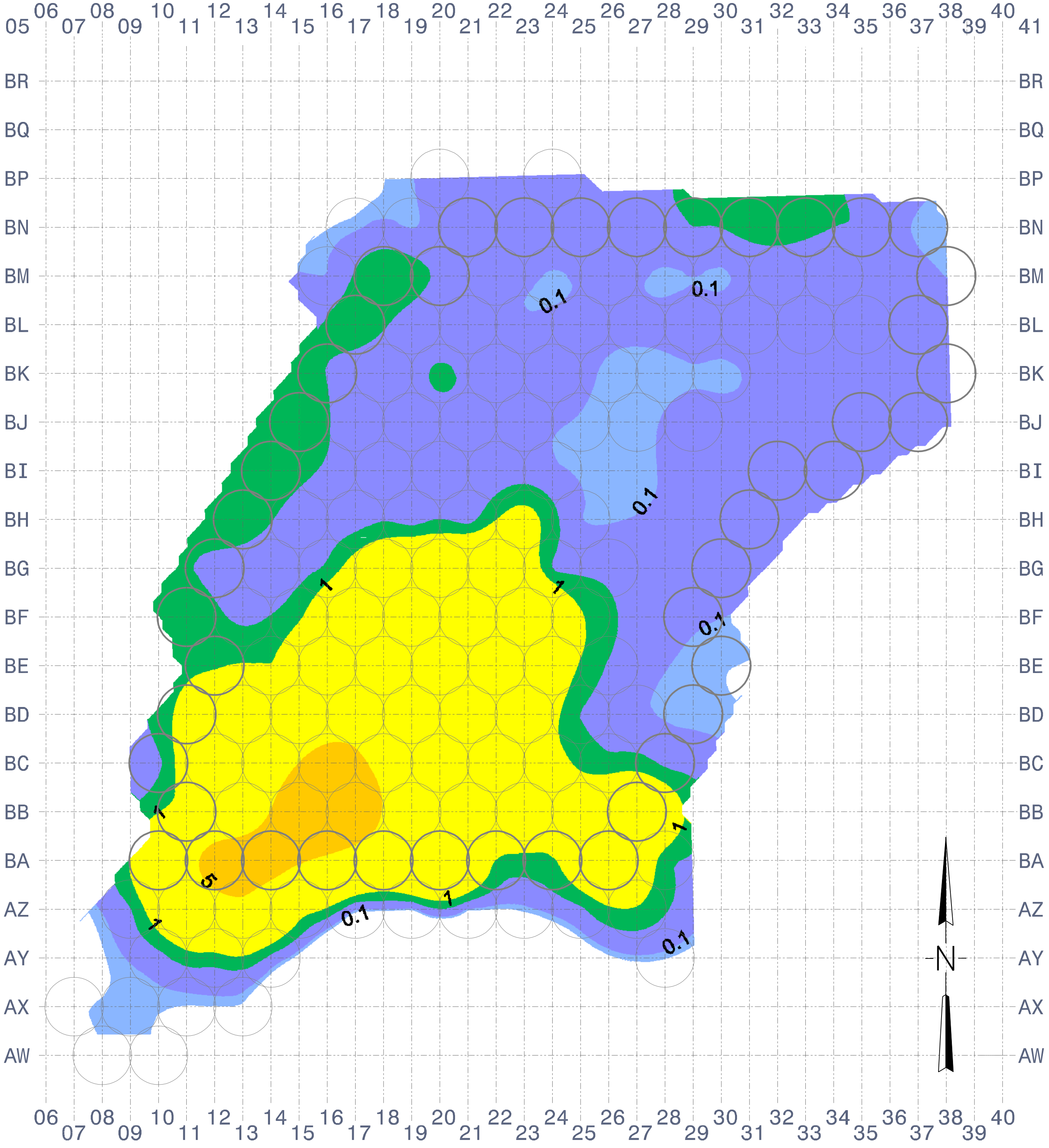

LEGEND

MASS REMOVED (lbs/cell)

🟦	🟦	🟩	🟨	🟨	🟧	🟥	🟪	🟪	🟪

0.01 0.1 0.5 1 5 10 20 30 40 50 60

○ 8' DIAMETER CELL LOCATION

◯ 8' DIAMETER PERIMETER CELL LOCATION AS PER WORK PLAN

20 0 20
SCALE IN FEET

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FIGURE 3-12
cis-1,2-DICHLOROETHENE MASS
REMOVED PER CELL

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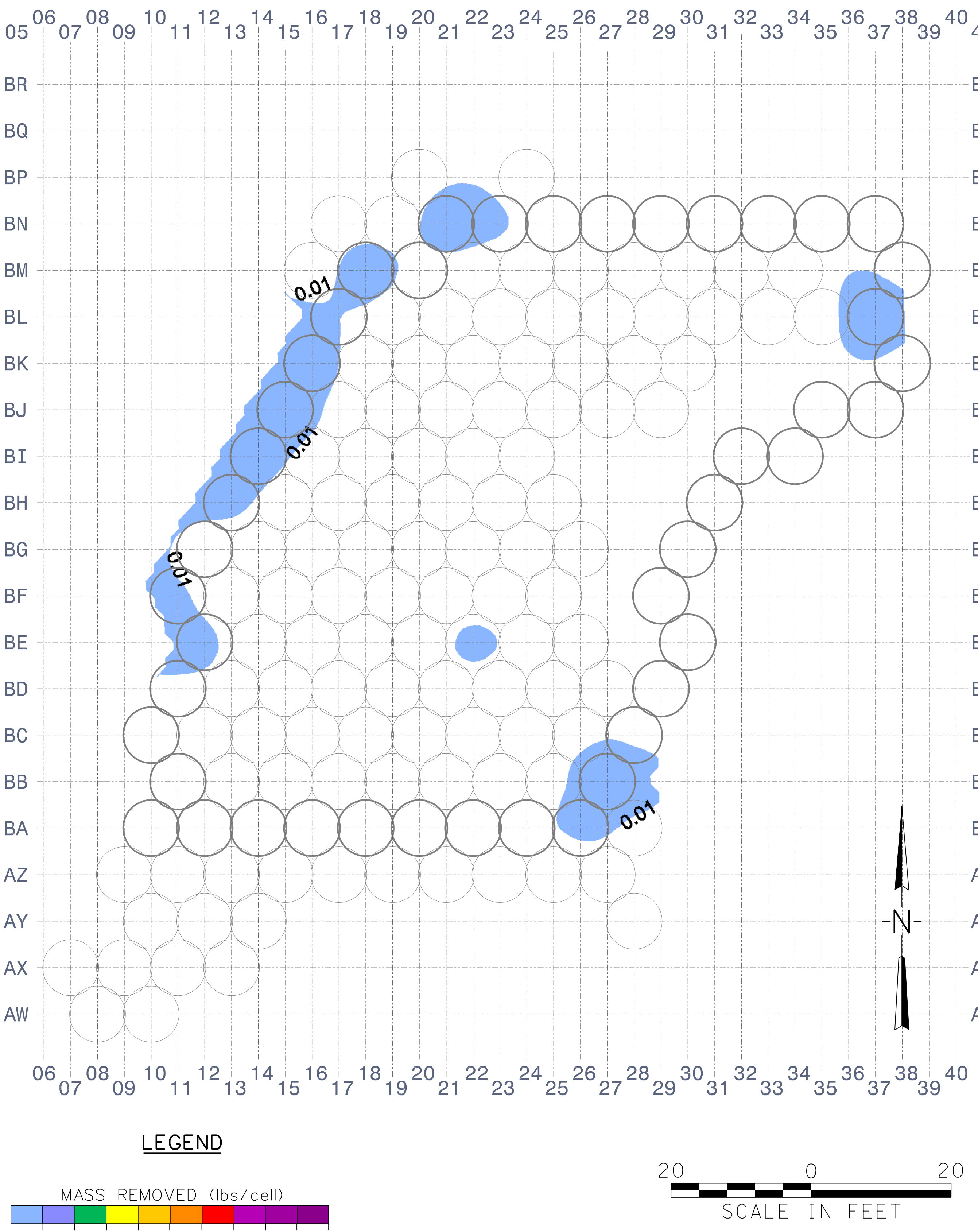

○ 8' DIAMETER CELL LOCATION

◯ 8' DIAMETER PERIMETER CELL LOCATION AS PER WORK PLAN

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FIGURE 3-13
trans-1,2-DICHLOROETHENE MASS
REMOVED PER CELL

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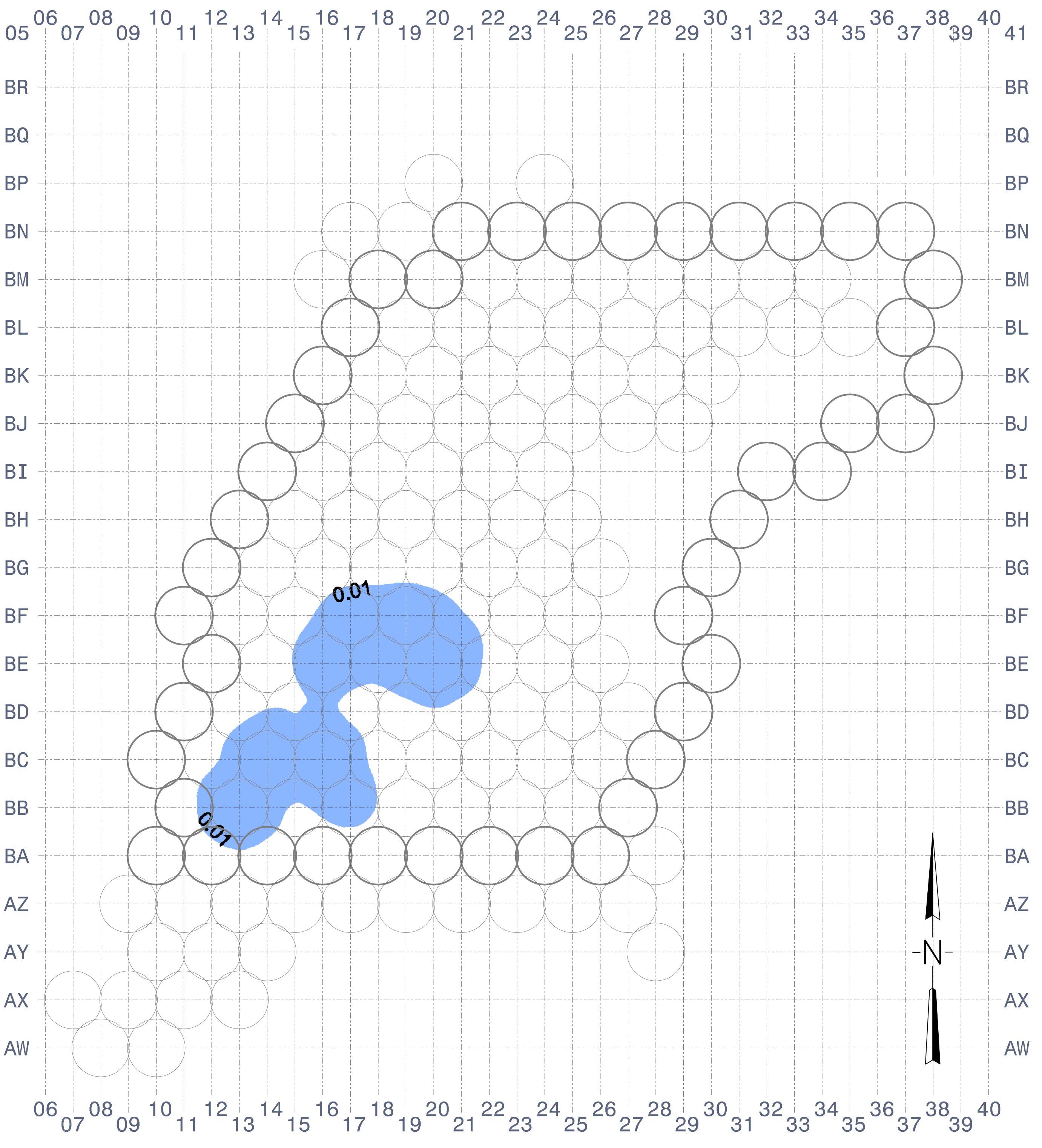

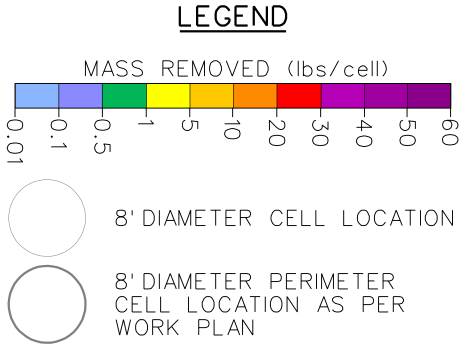

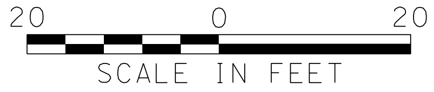

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FIGURE 3-14
VINYL CHLORIDE (VC) MASS
REMOVED PER CELL

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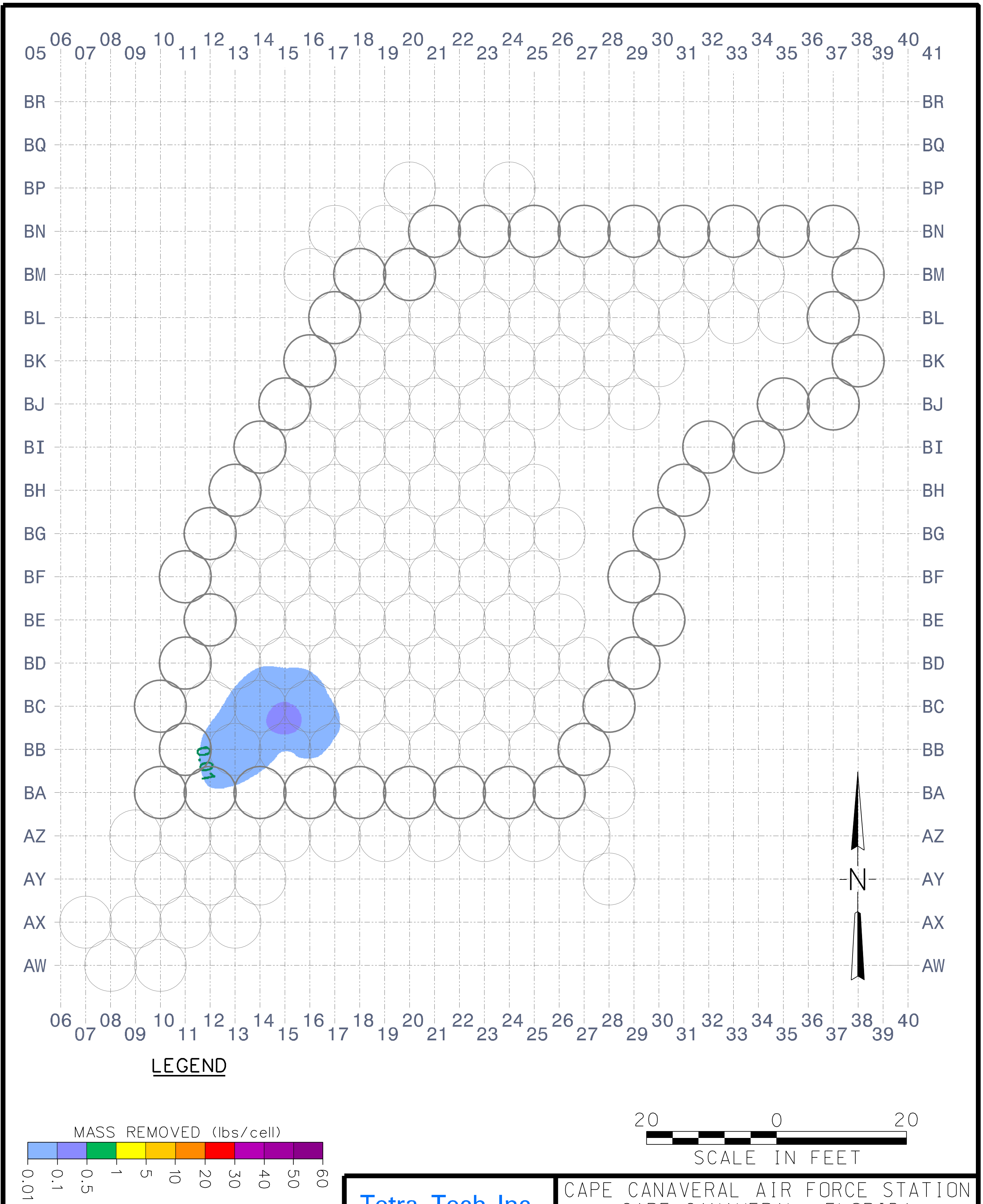

LEGEND

○ 8' DIAMETER CELL LOCATION

○ 8' DIAMETER PERIMETER CELL LOCATION AS PER WORK PLAN

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FIGURE 3-15
FREON 113 (F113) MASS
REMOVED PER CELL

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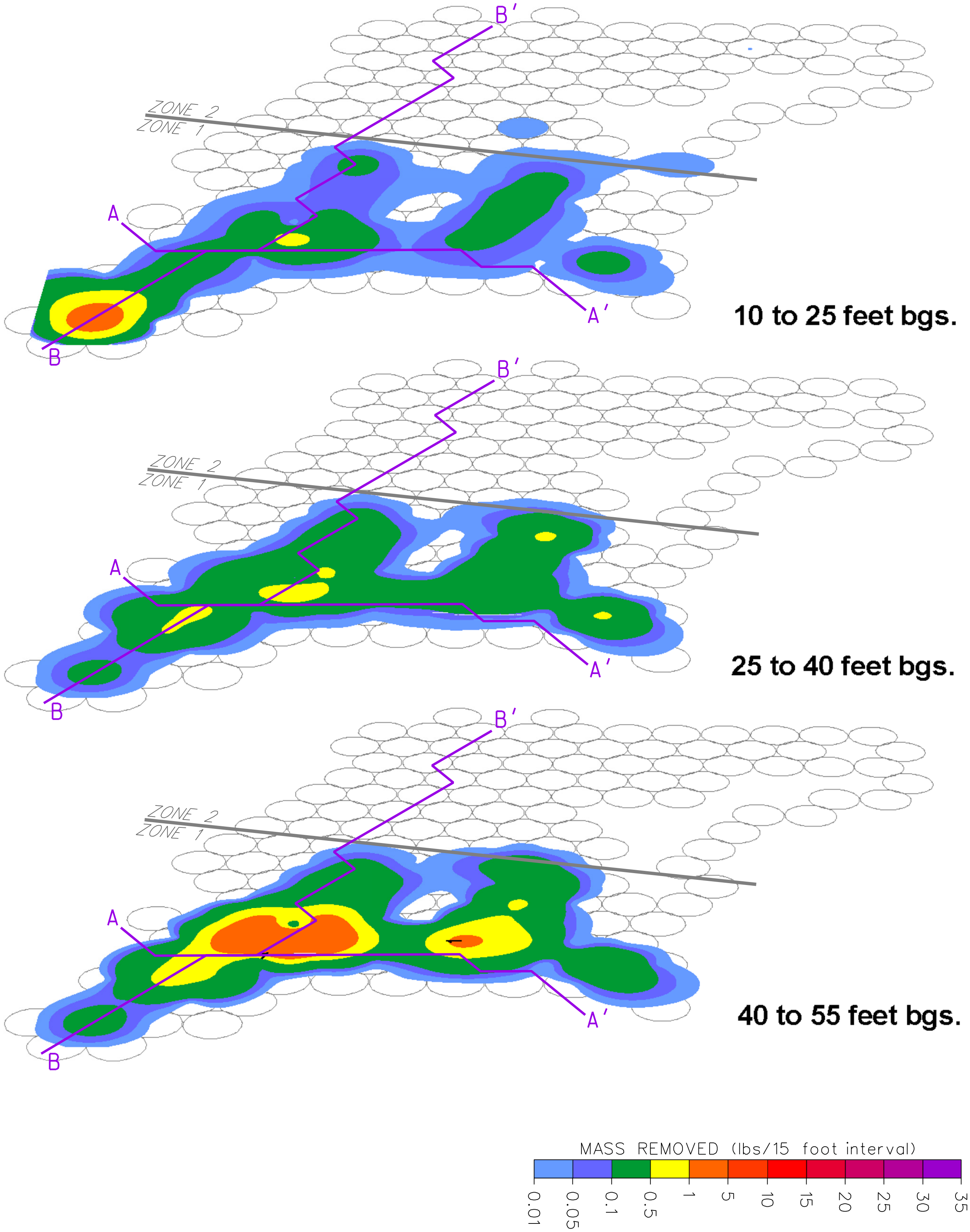

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FIGURE 3-16
TETRACHLOROETHENE (PCE)
MASS REMOVED PER SITE
SHOWN IN 15' INTERVALS

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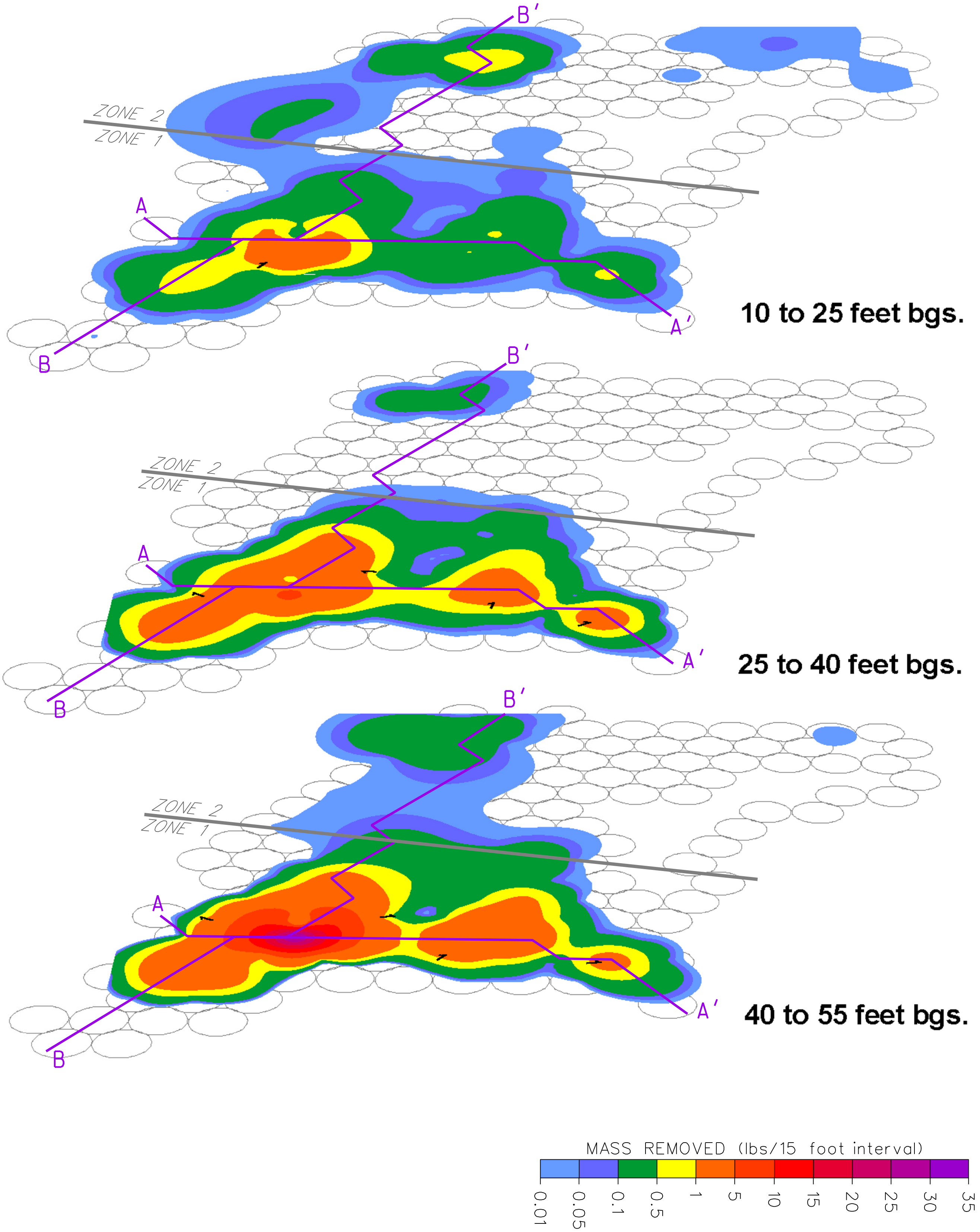

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FIGURE 3-17
TRICHLOROETHENE (TCE)
MASS REMOVED PER SITE
SHOWN IN 15' INTERVALS

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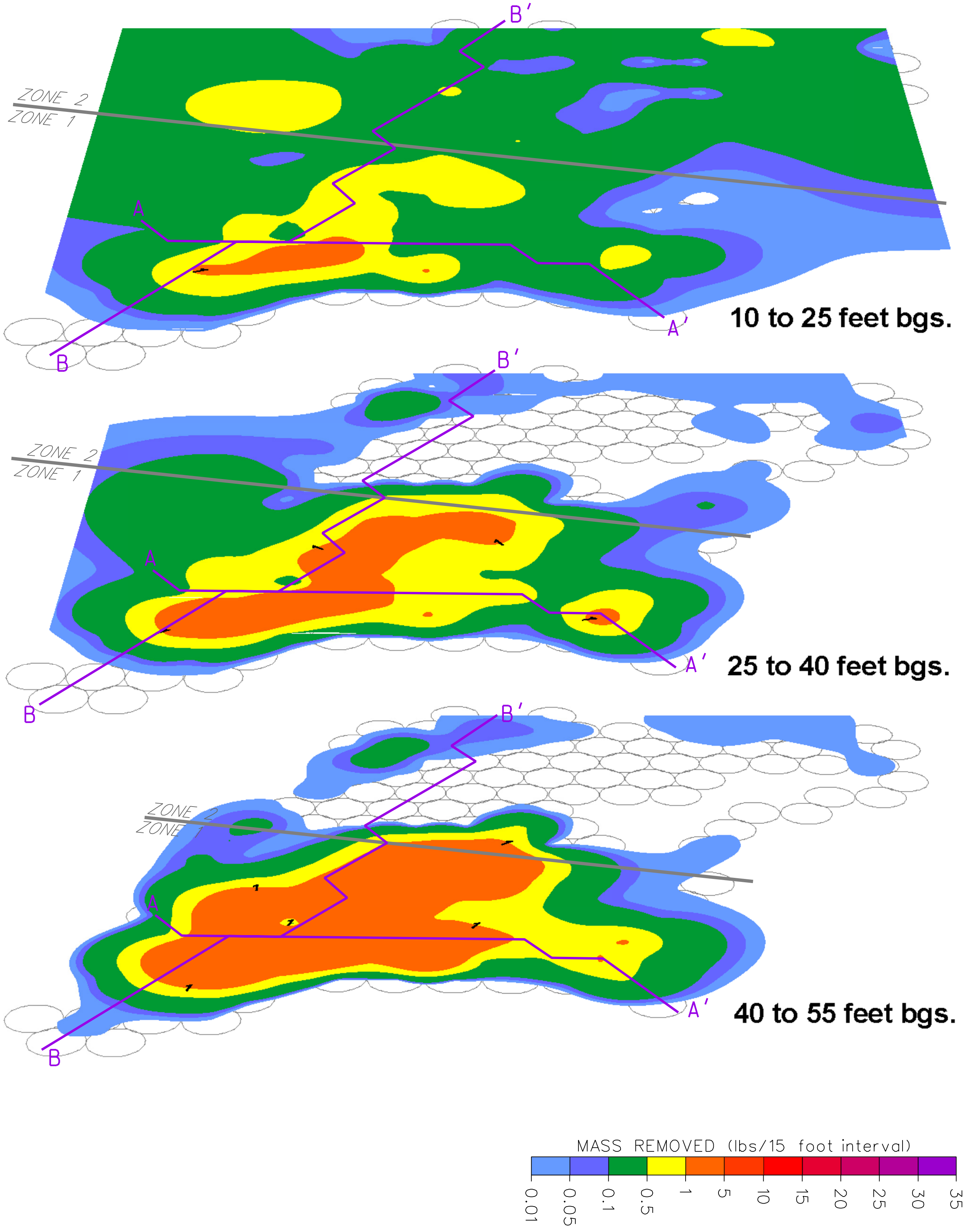

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FIGURE 3-18
cis-1,2-DICHLOROETHENE
MASS REMOVED PER SITE
SHOWN IN 15' INTERVALS

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3.6.2 Concentration and Mass Removed Profiles

Profile plots demonstrating the maximum concentrations of VOCs and the mass removed per foot of LDA penetration were prepared to further demonstrate the lateral and vertical distribution of the predominant VOCs encountered and removed in the source area. Two profiles, A-A' and B-B' as shown on Figure 3-19, were selected based on the horizontal and vertical distribution of the total mass of VOCs removed (see Section 3.6.1) that follow the track of the largest mass removed.

Figures 3-20 through 3-25 show the maximum concentrations of PCE, TCE, and cis-DCE that were detected per foot of LDA penetration along profiles A and B. The figures show that the highest concentrations were encountered in the immediate vicinity of cells BB15 and BC16. Concentrations of TCE were 6 to 10 times higher than PCE or cis-DCE, but the location of the highest concentrations and contaminant distribution were very similar for all three chemicals. The highest concentrations were detected between approximately 50 to 53 feet bgs at cell BB15. Cells BB15 and BC16 demonstrate an extensive vertical distribution of VOCs suggesting that a release may have occurred in this area of the site.

Figures 3-26 through 3-31 show the mass of PCE, TCE, and cis-DCE that was removed per foot of LDA penetration along profiles A and B. The pattern of high mass removal is consistent with the areas where the highest concentrations were detected, as expected. Although Figures 3-22 and 3-23 indicates that relatively high concentrations of TCE may extend below the depth of LDA penetration at cell BB15, the mass removal data shown in Figures 3-28 and 3-29, respectively, reveal that relatively little additional mass would be recovered by extending the depth of remediation at this location.

3.6.3 Steam Injection Profiles

Profiles A-A' and B-B' were utilized to demonstrate the duration (minutes/foot) and quantity (pounds/foot) of steam that was injected via the LDA, as shown in Figures 3-32 through 3-35. Both the duration and quantity of steam injected were proportional to the instantaneous operation parameters (temperature, pressure, flow volume of the steam generation system) and to the concentration of VOCs detected in the off-gas system (i.e., additional auger passes and time were applied to highly contaminated areas per protocols). Therefore, as can be seen in Figures 3-32 through 3-35, the areas of highest duration and quantity of steam injection generally coincide with the areas where the highest concentrations and greatest VOC mass were removed from the source area. Cell BA24 at a depth of approximately 52 feet bgs was an exception due to additional time of injection applied in response to reach the temperature goal.

3.7 REAL-TIME DECISIONS

Data from the FIDs and GCs were utilized to determine trends in depth, concentration, and location of contamination requiring treatment. Identified data trends in contamination enabled on-site field personnel and managers to perform real-time decisions on treating contamination. The following section describes the three forms of real-time decisions that were made during treatment at SPCC. The real-time decisions are:

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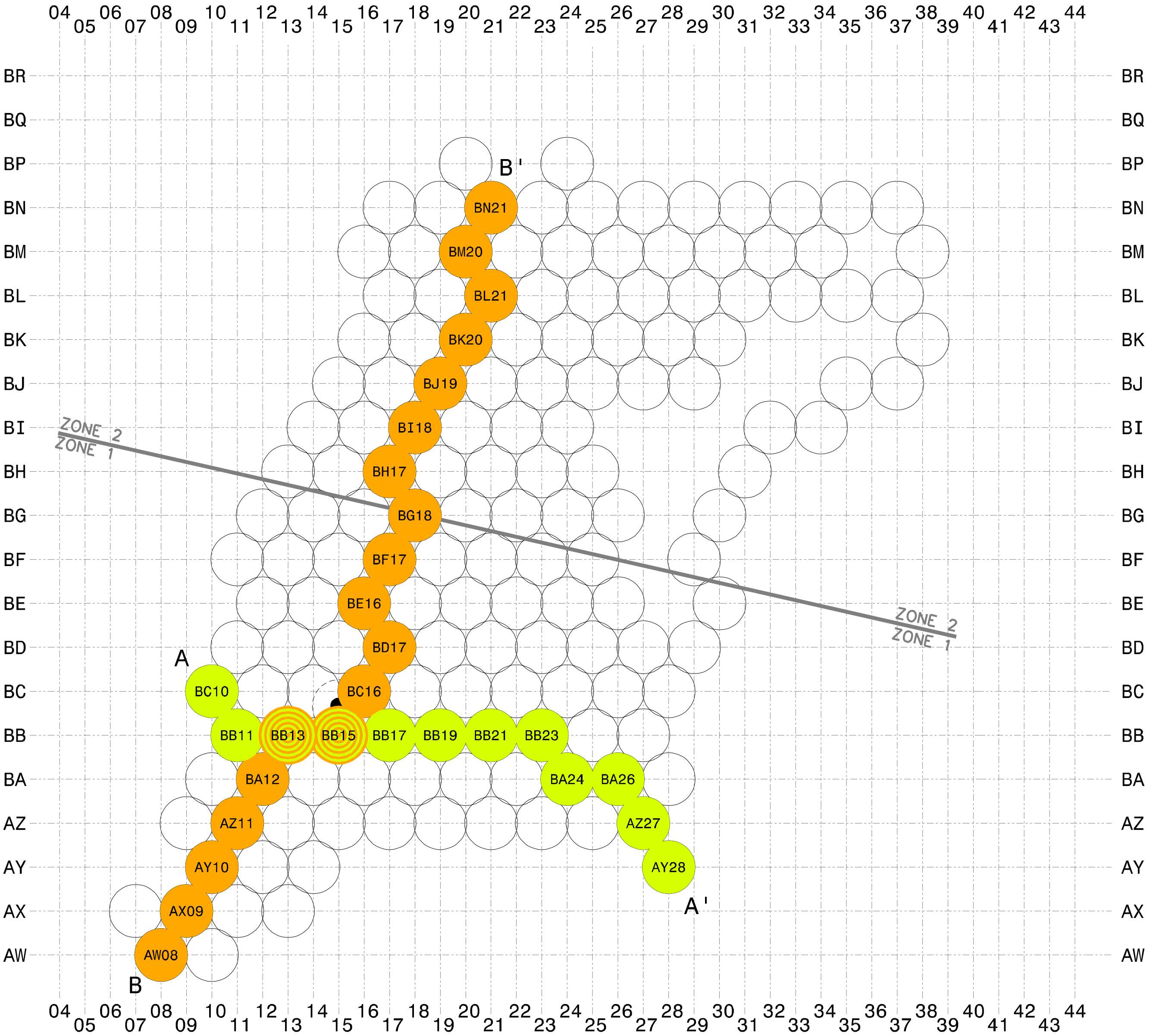

LEGEND

○ 8' DIAMETER CELL LOCATION

● CELLS ALONG SECTION A-A`

● CELLS ALONG SECTION B-B`

◎ CELLS WHERE SECTION A-A` AND SECTION B-B` OVERLAP

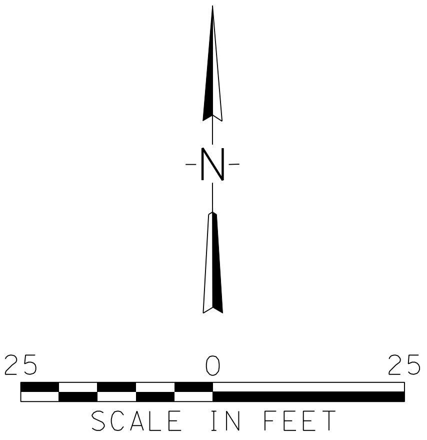

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FIGURE 3-19
PROFILE LOCATION MAP

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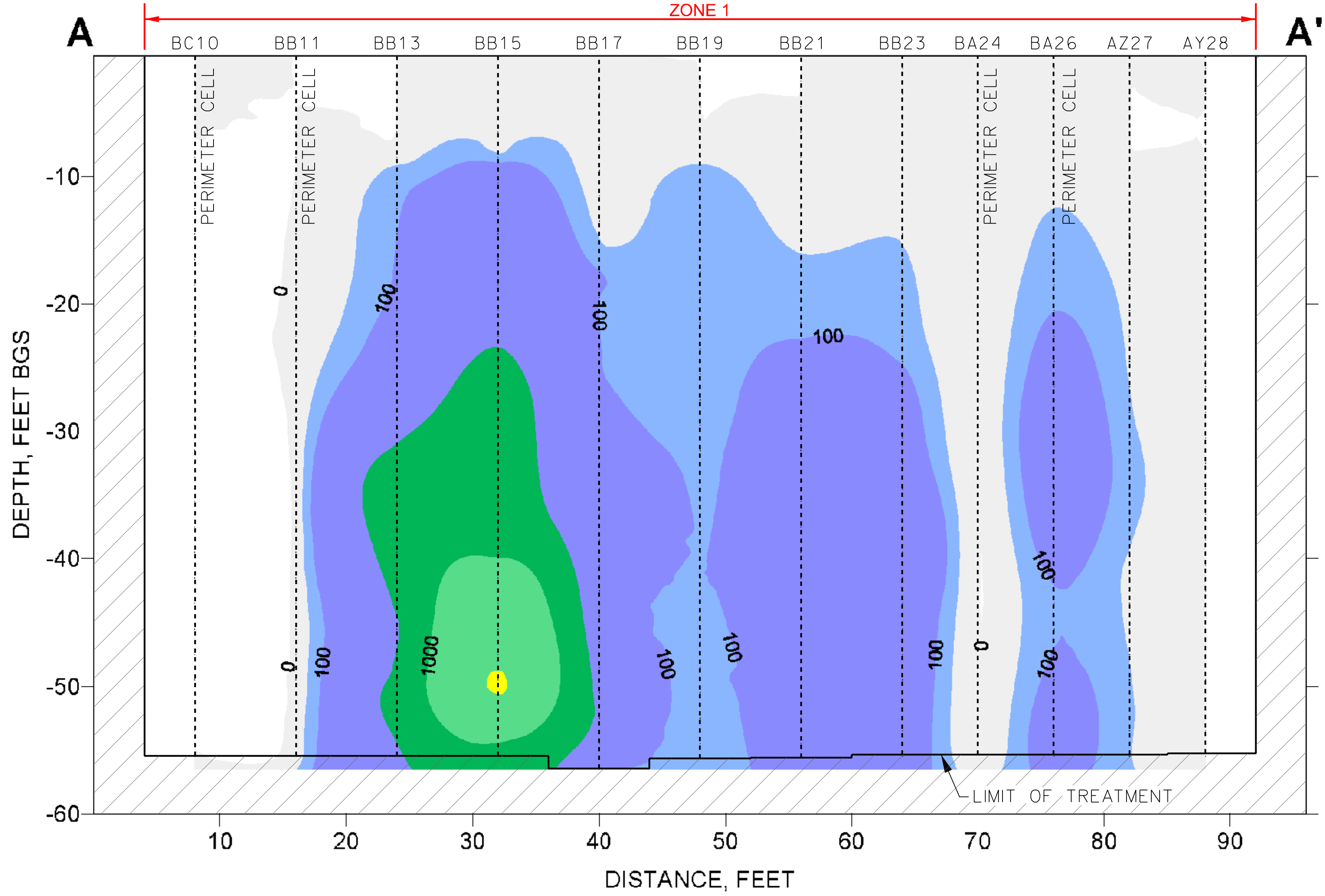

MAXIMUM CONCENTRATION PER FOOT, ppm

0	100	1000	4000	8000	12000	16000	20000

NOTES

1. ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.

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FIGURE 3-20
PCE MAXIMUM CONCENTRATION PER FOOT
CROSS SECTION A-A'

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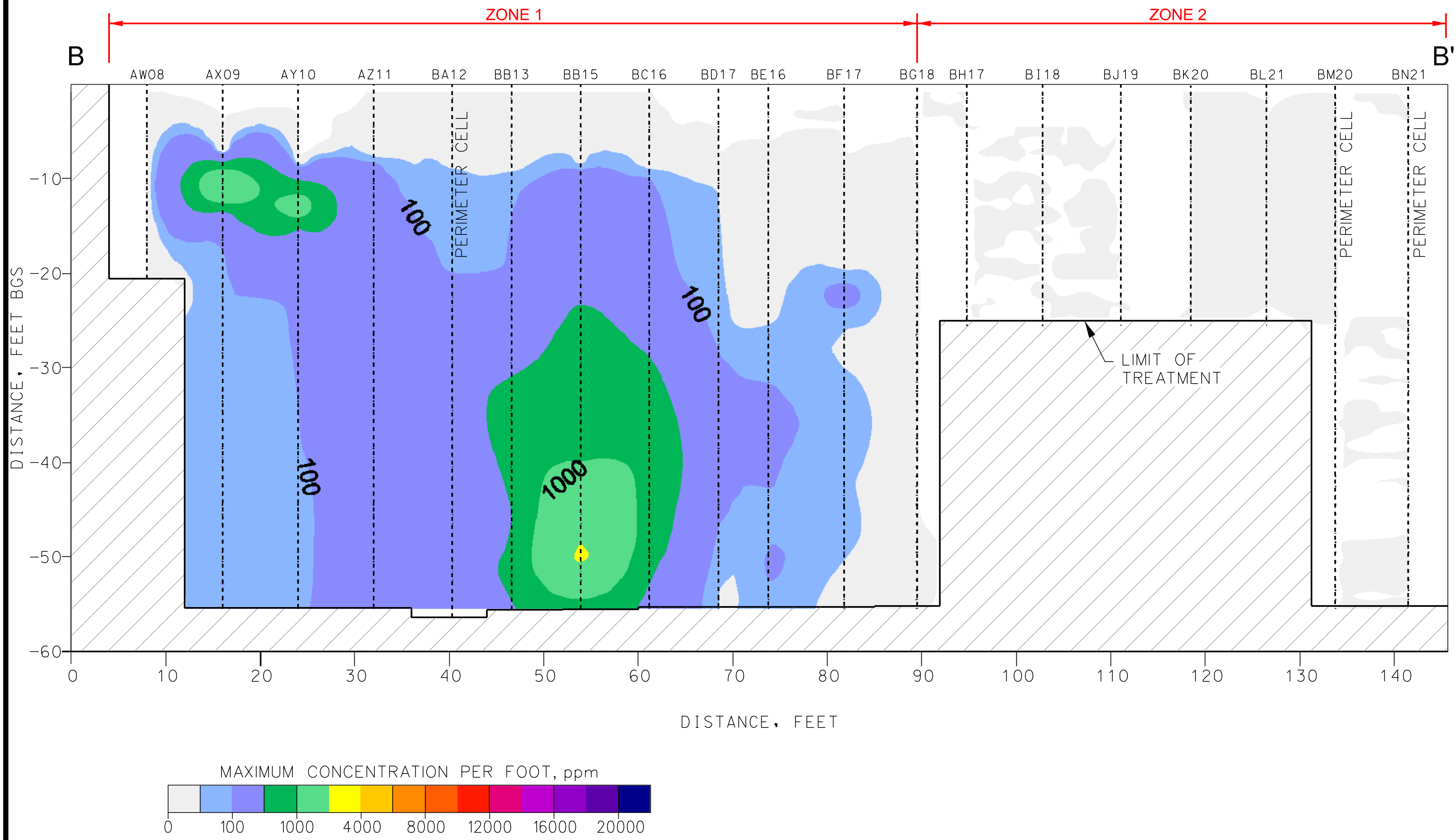

NOTES

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FIGURE 3-21
PCE MAXIMUM CONCENTRATION PER FOOT
CROSS SECTION B-B'

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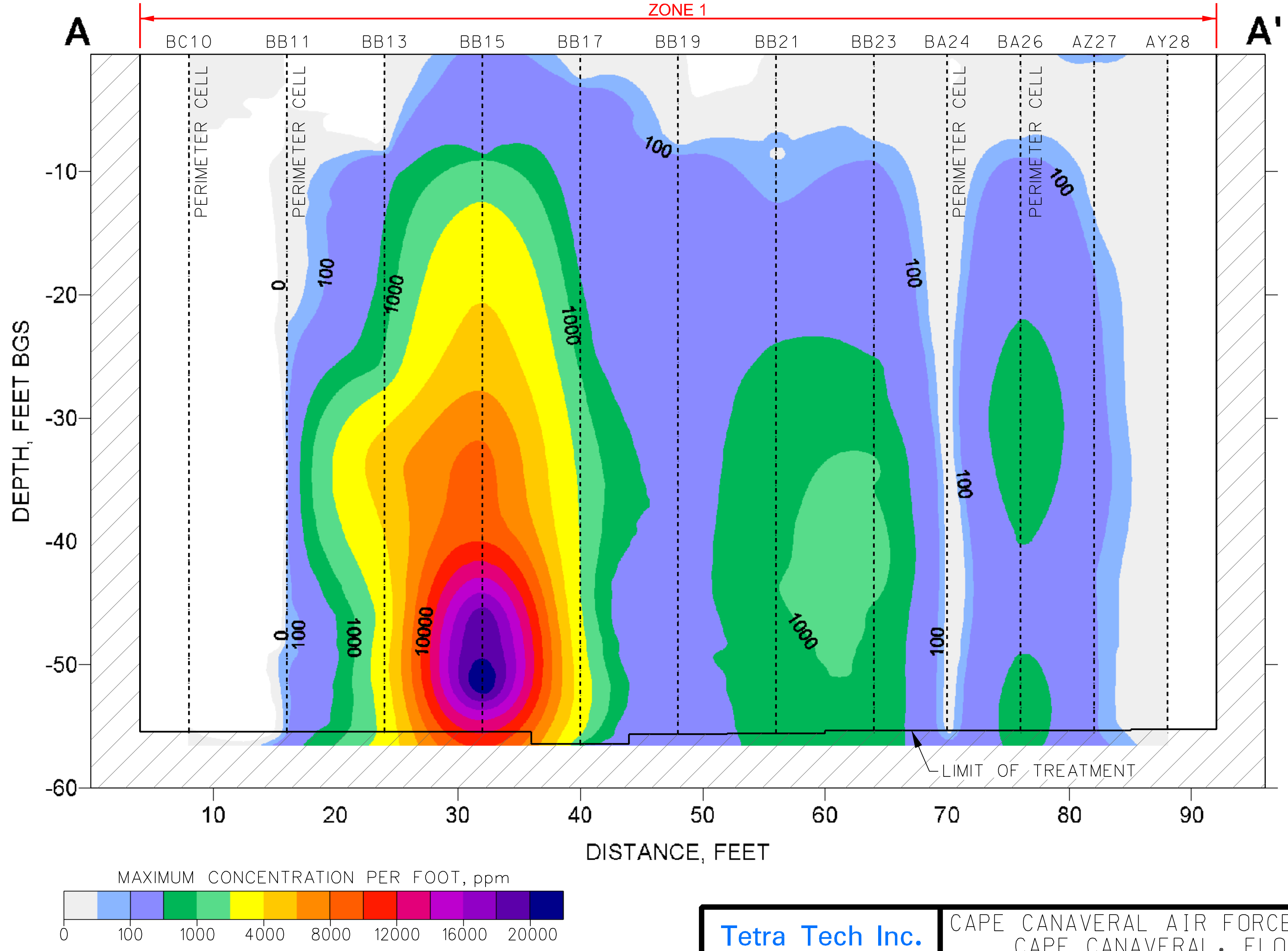

NOTE

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PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.

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FIGURE 3-22
TCE MAXIMUM CONCENTRATION PER FOOT
AT CROSS SECTION A-A'

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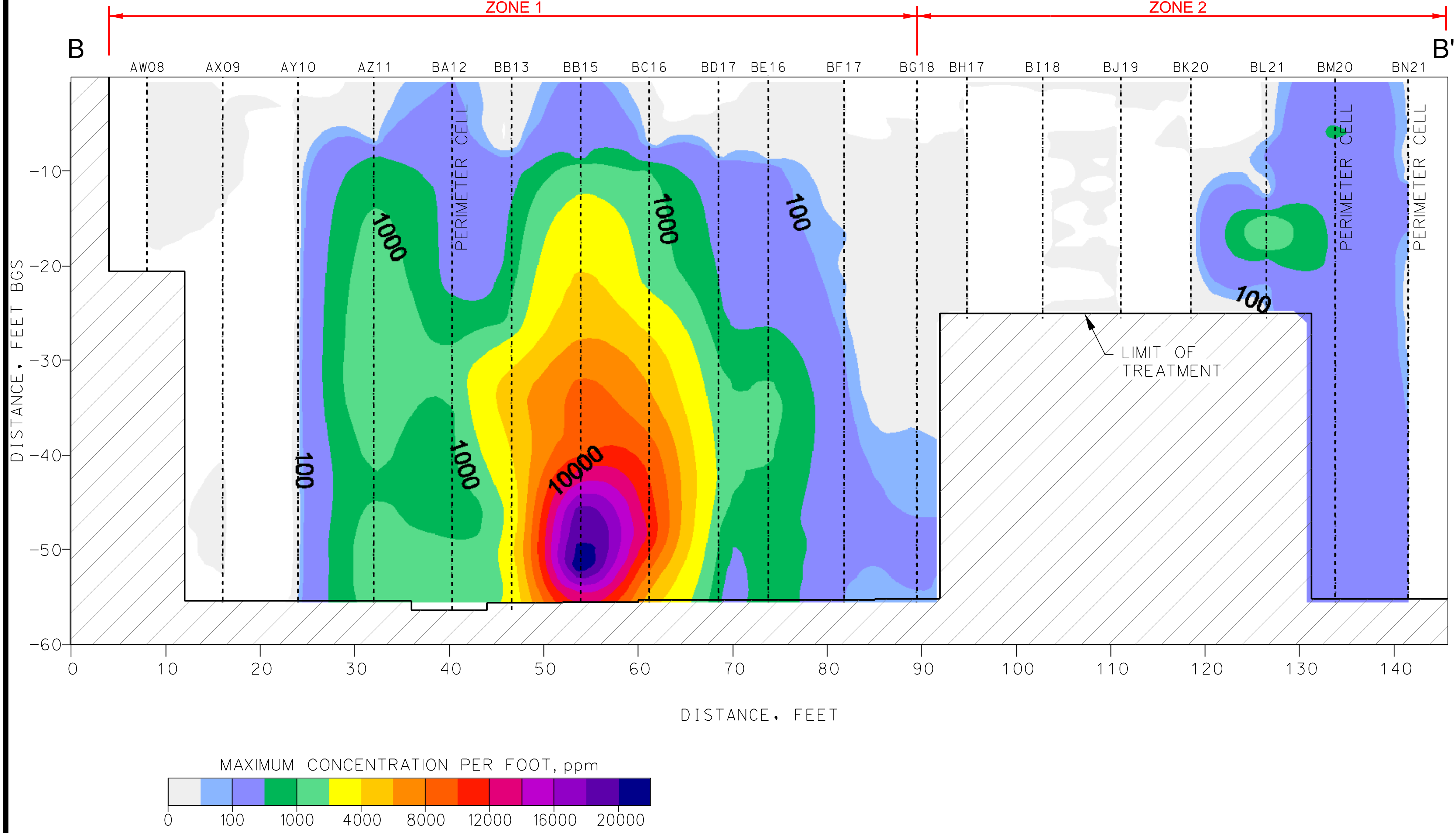

NOTE

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FIGURE 3-23
TCE MAXIMUM CONCENTRATION PER FOOT
CROSS SECTION B-B'

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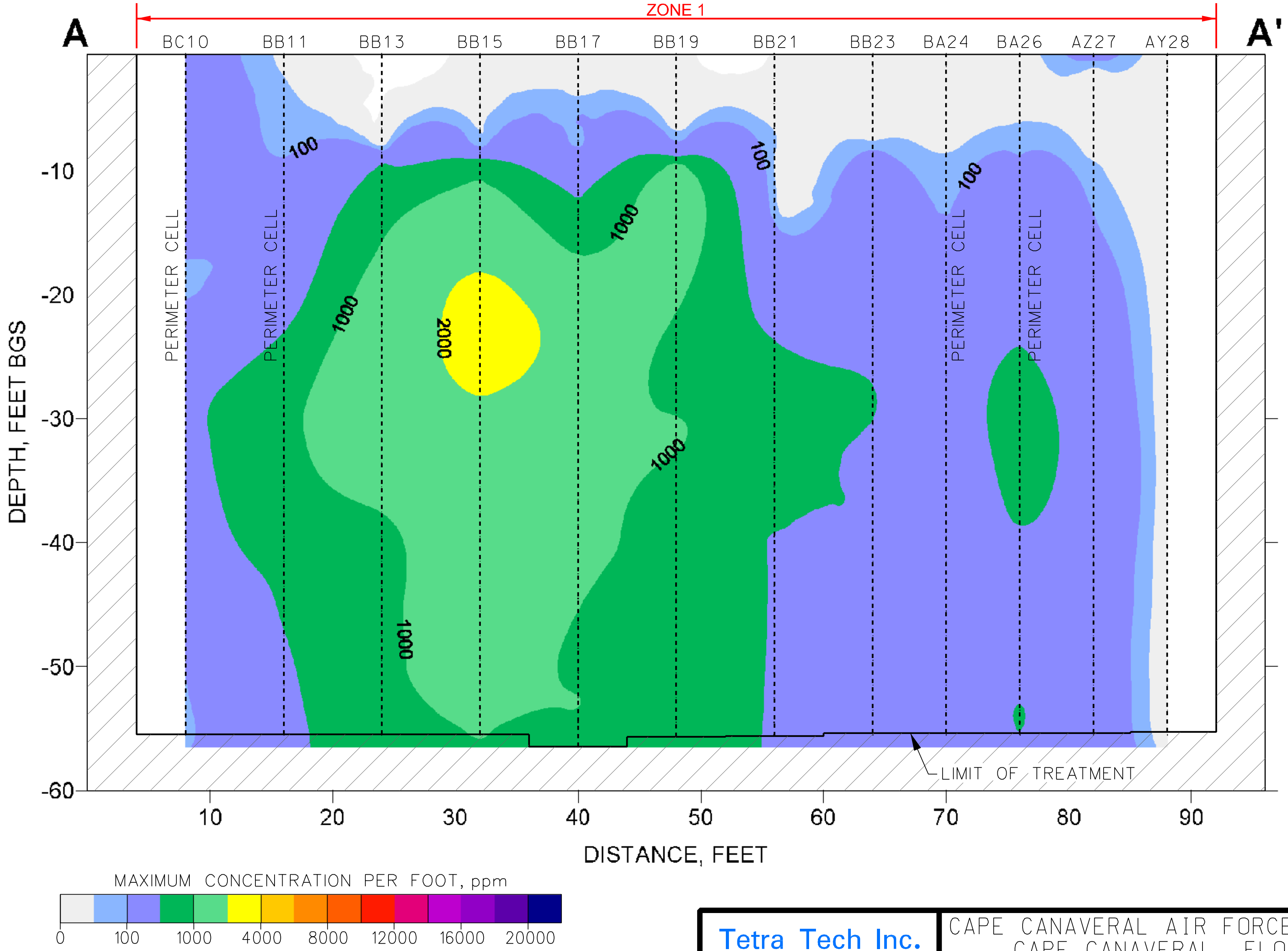

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FIGURE 3-24
cis-1,2-DCE
MAXIMUM CONCENTRATION PER FOOT
CROSS SECTION A-A'

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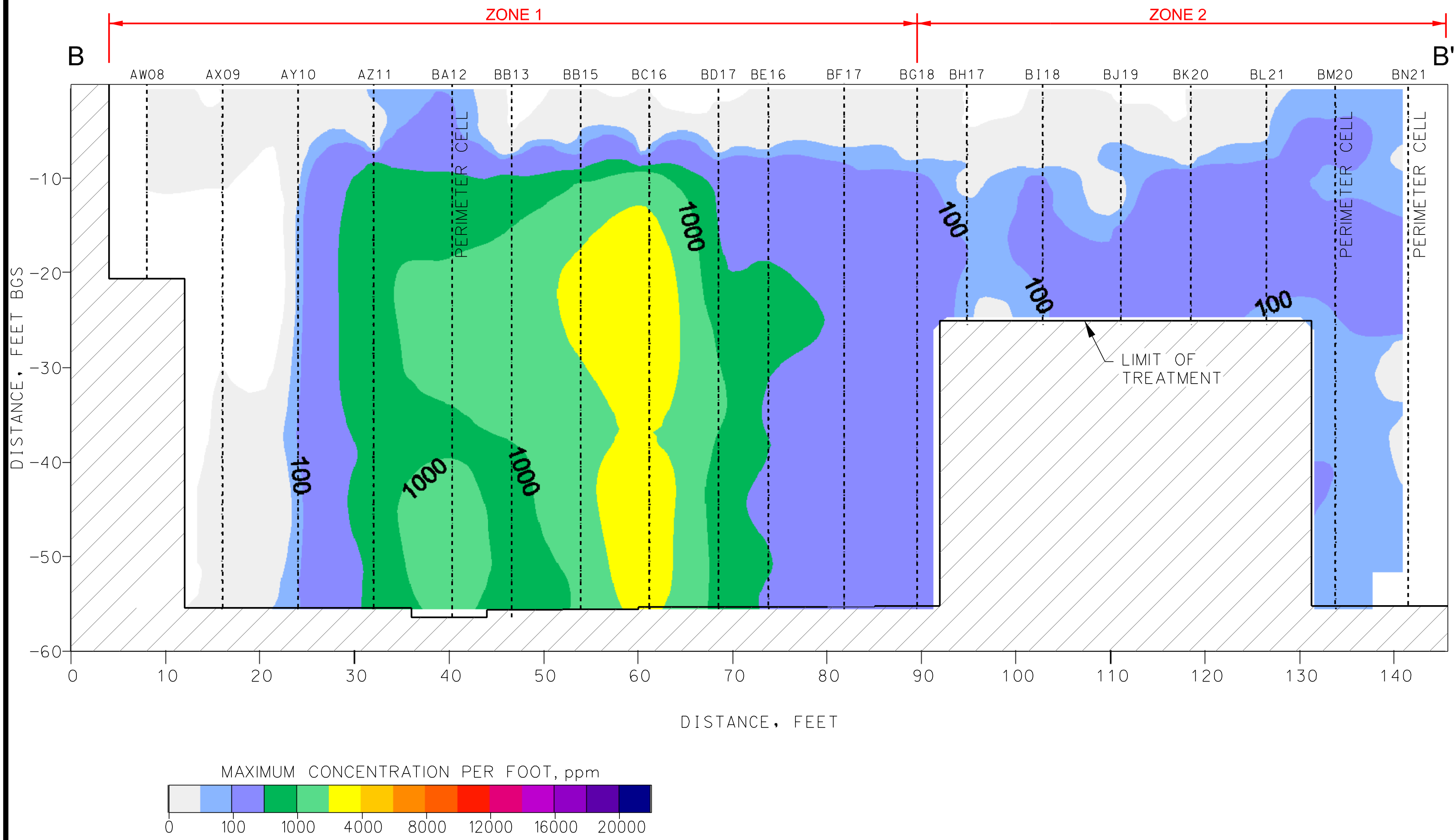

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FIGURE 3-25
cis-1,2-DCE
MAXIMUM CONCENTRATION PER FOOT
CROSS SECTION B-B'

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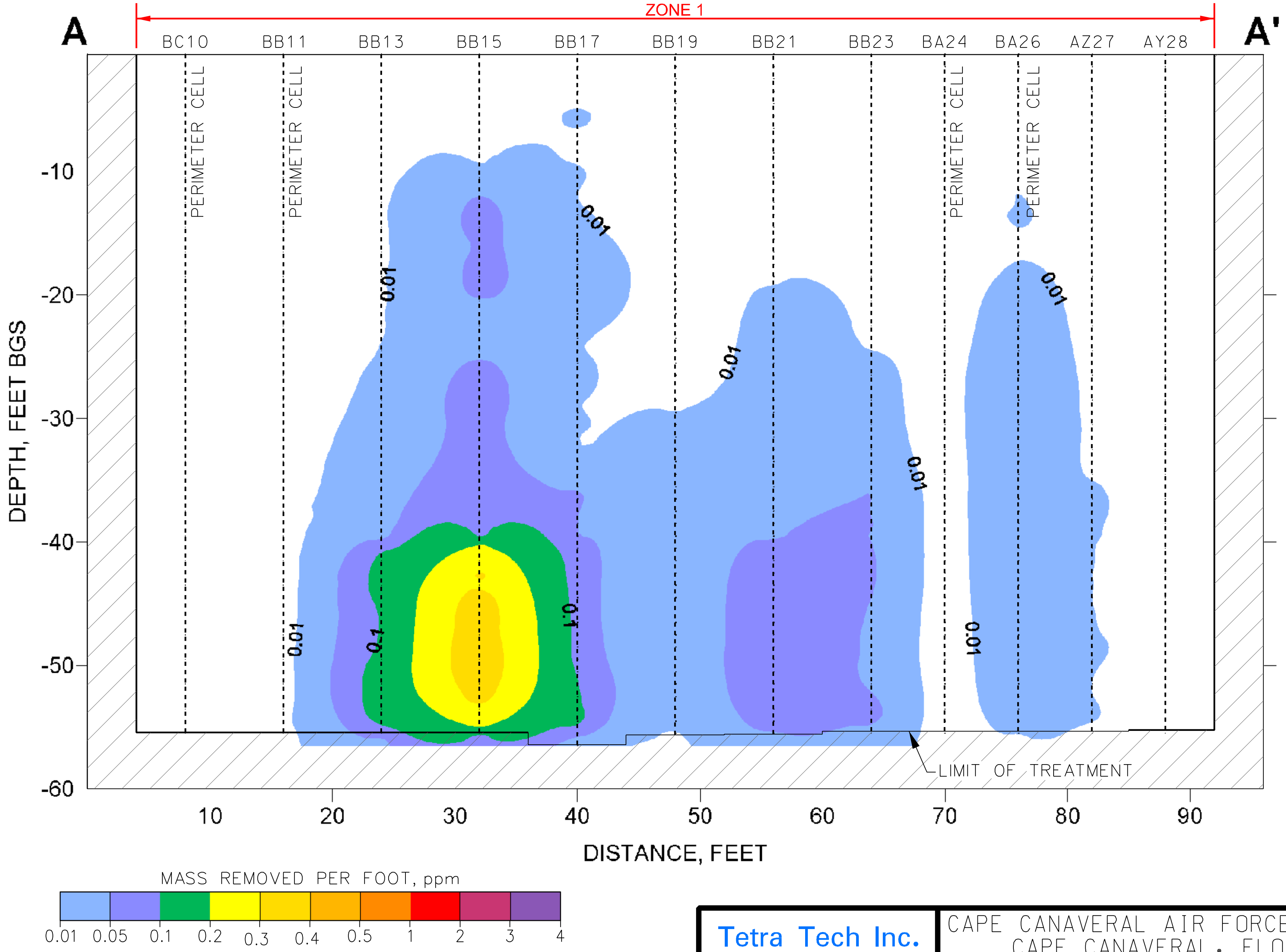

NOTES

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FIGURE 3-26
PCE MASS REMOVED PER FOOT
CROSS SECTION A-A'

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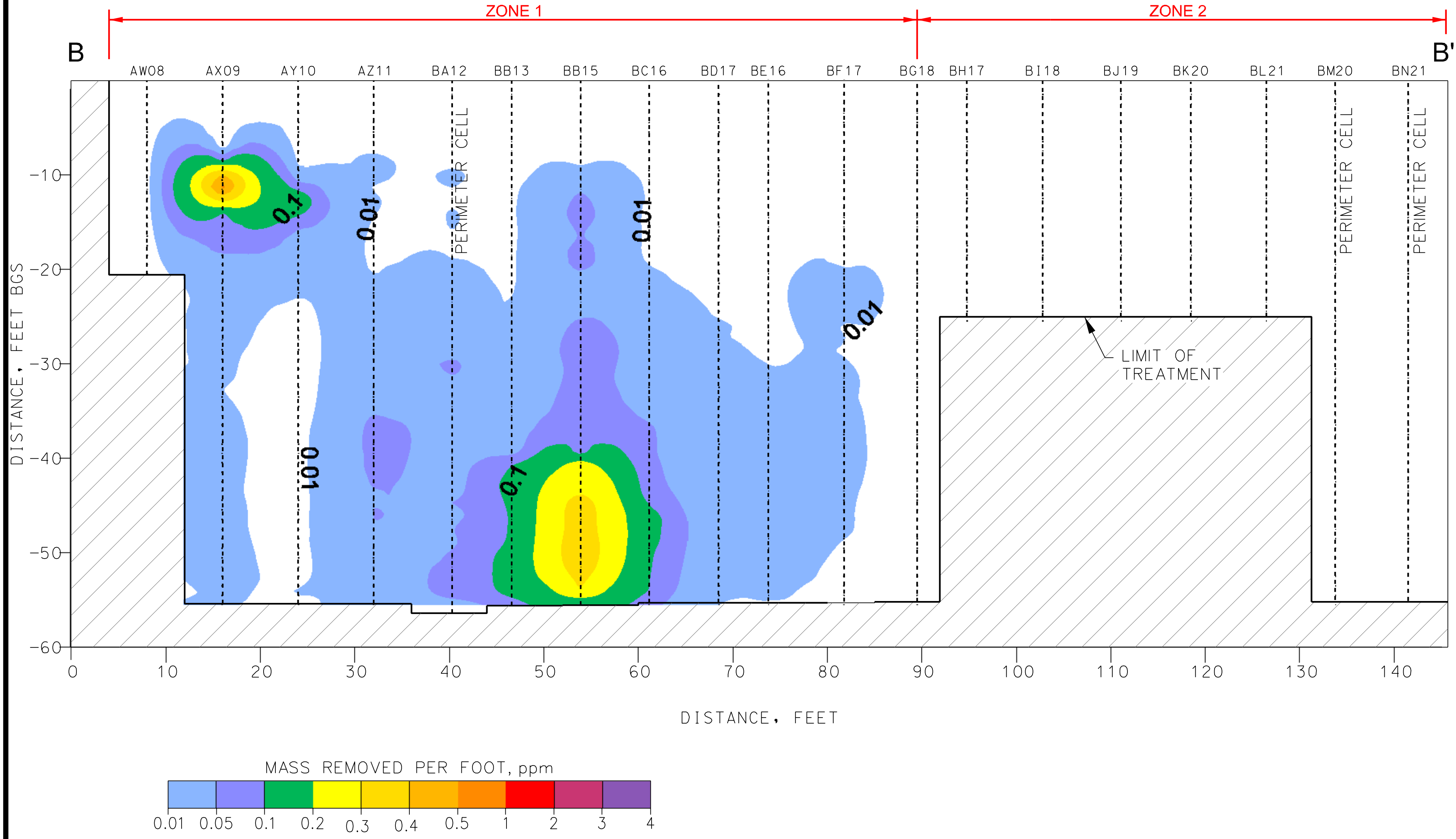

NOTE

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FIGURE 3-27
PCE MASS REMOVED PER FOOT
CROSS SECTION B-B'

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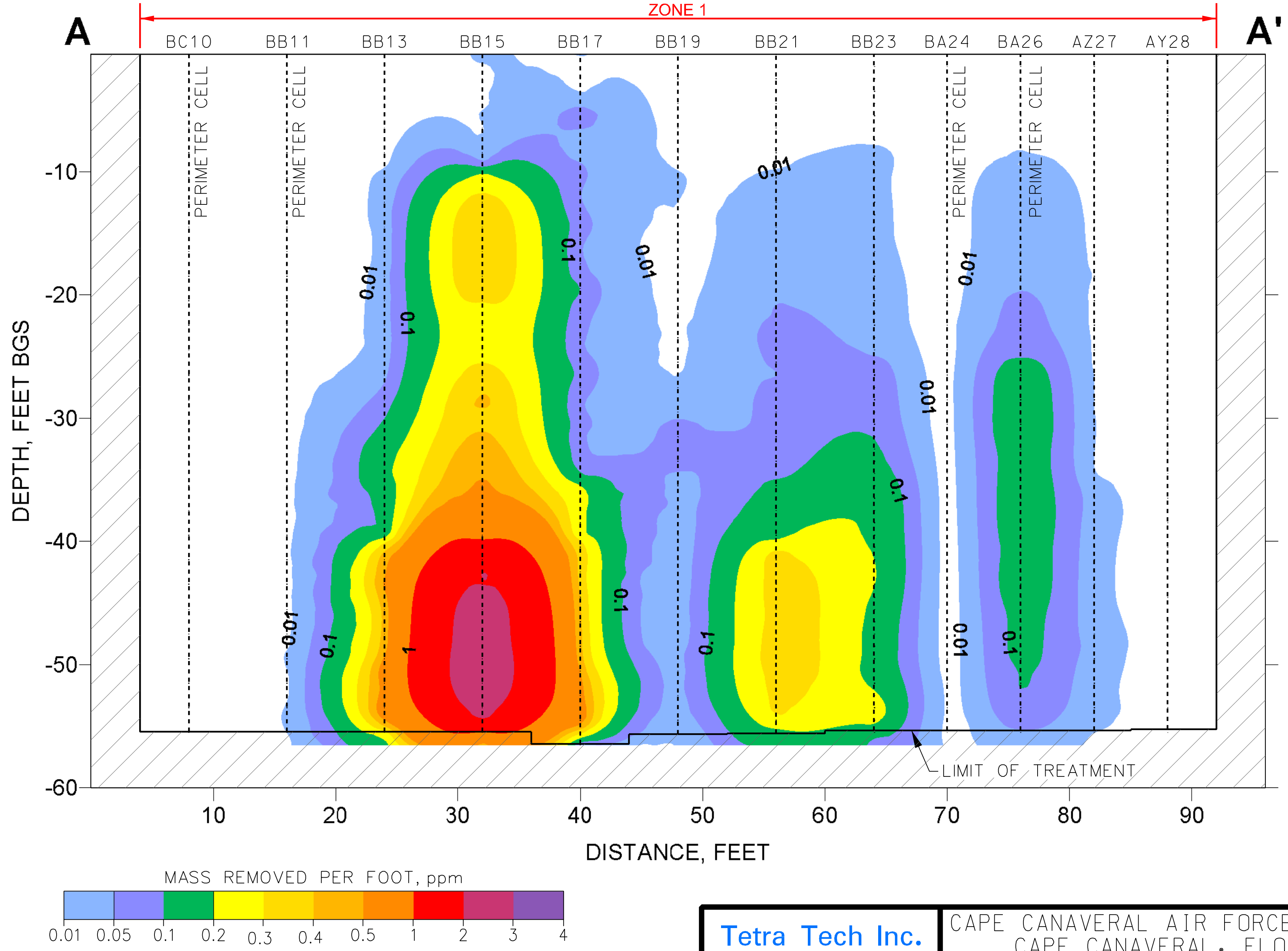

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FIGURE 3-28
TCE MASS REMOVED PER FOOT
CROSS SECTION A-A'

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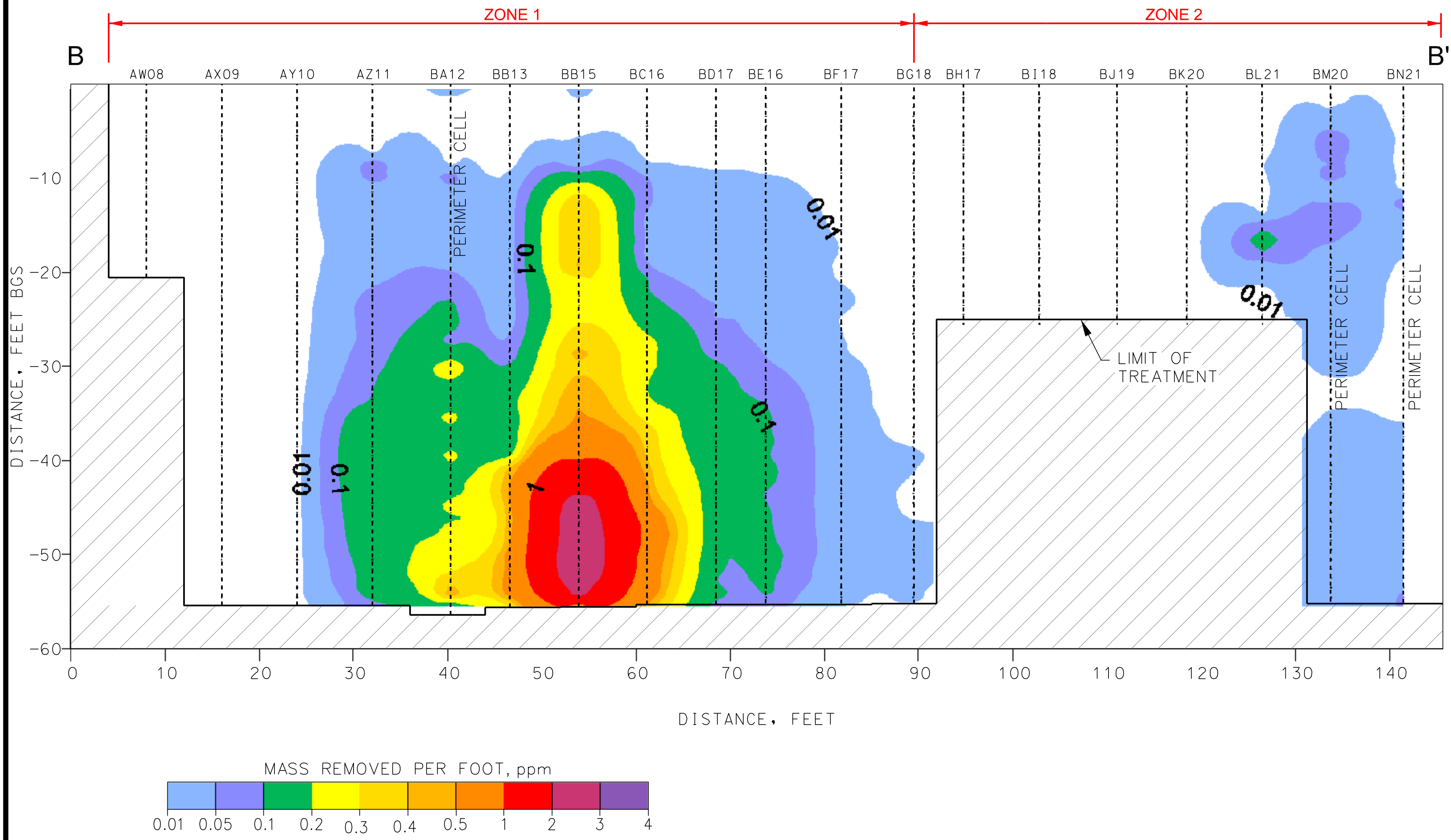

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FIGURE 3-29
TCE MASS REMOVED PER FOOT
CROSS SECTION B-B'

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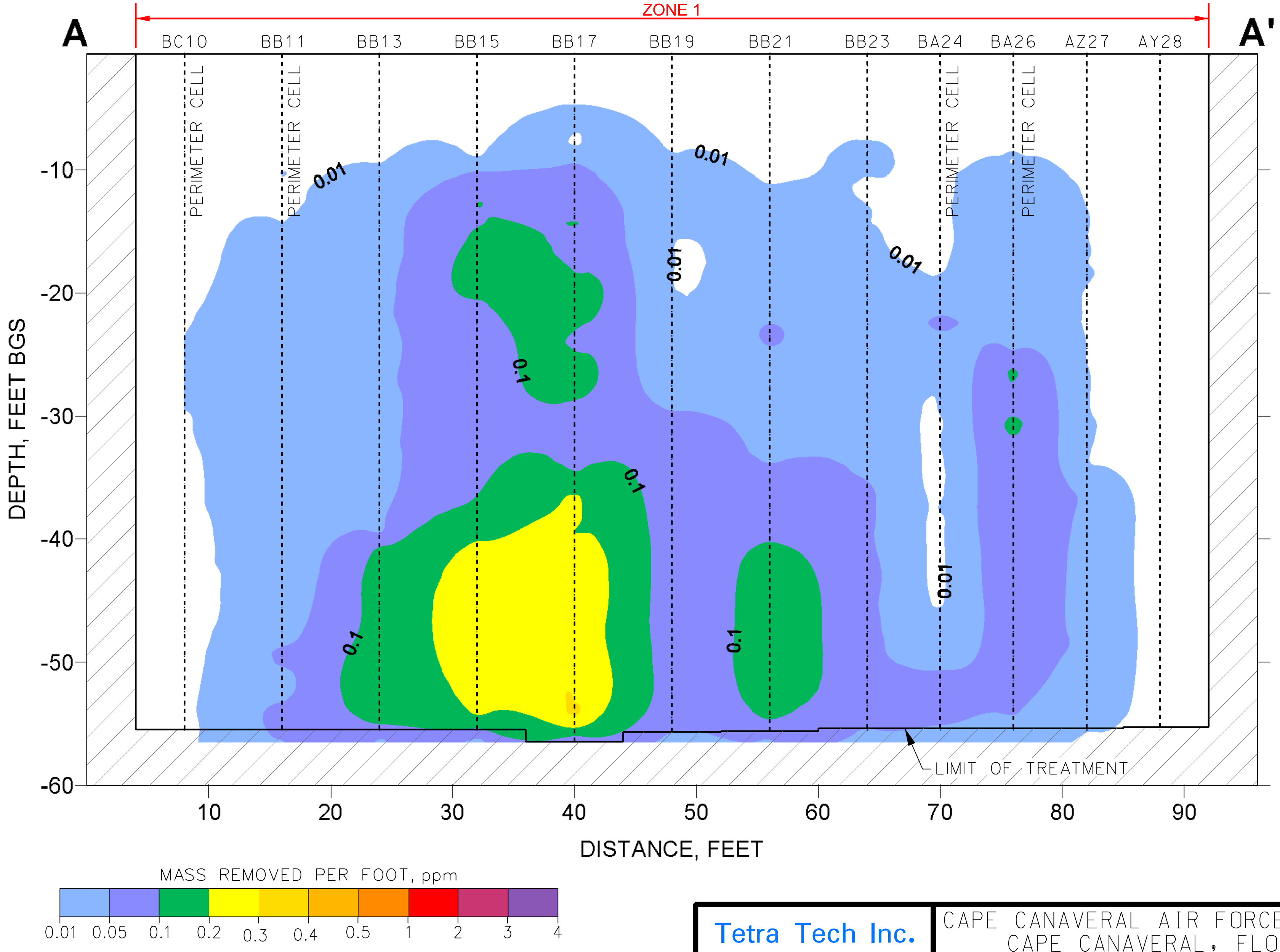

NOTE

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FIGURE 3-30
cis-1,2-DCE MASS REMOVED PER FOOT
CROSS SECTION A-A'

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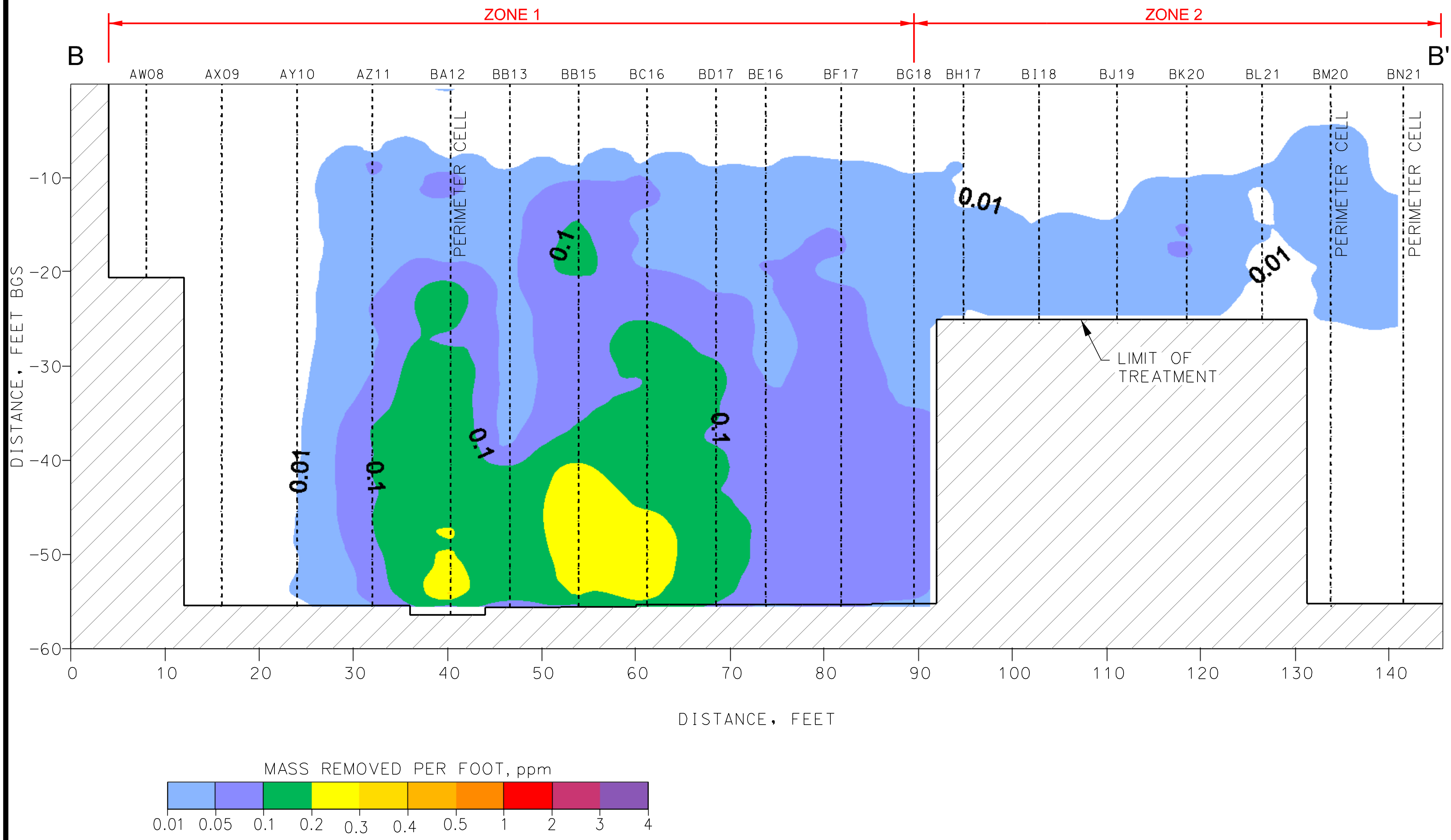

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FIGURE 3-31
cis-1,2-DCE MASS REMOVED PER FOOT
CROSS SECTION B-B'

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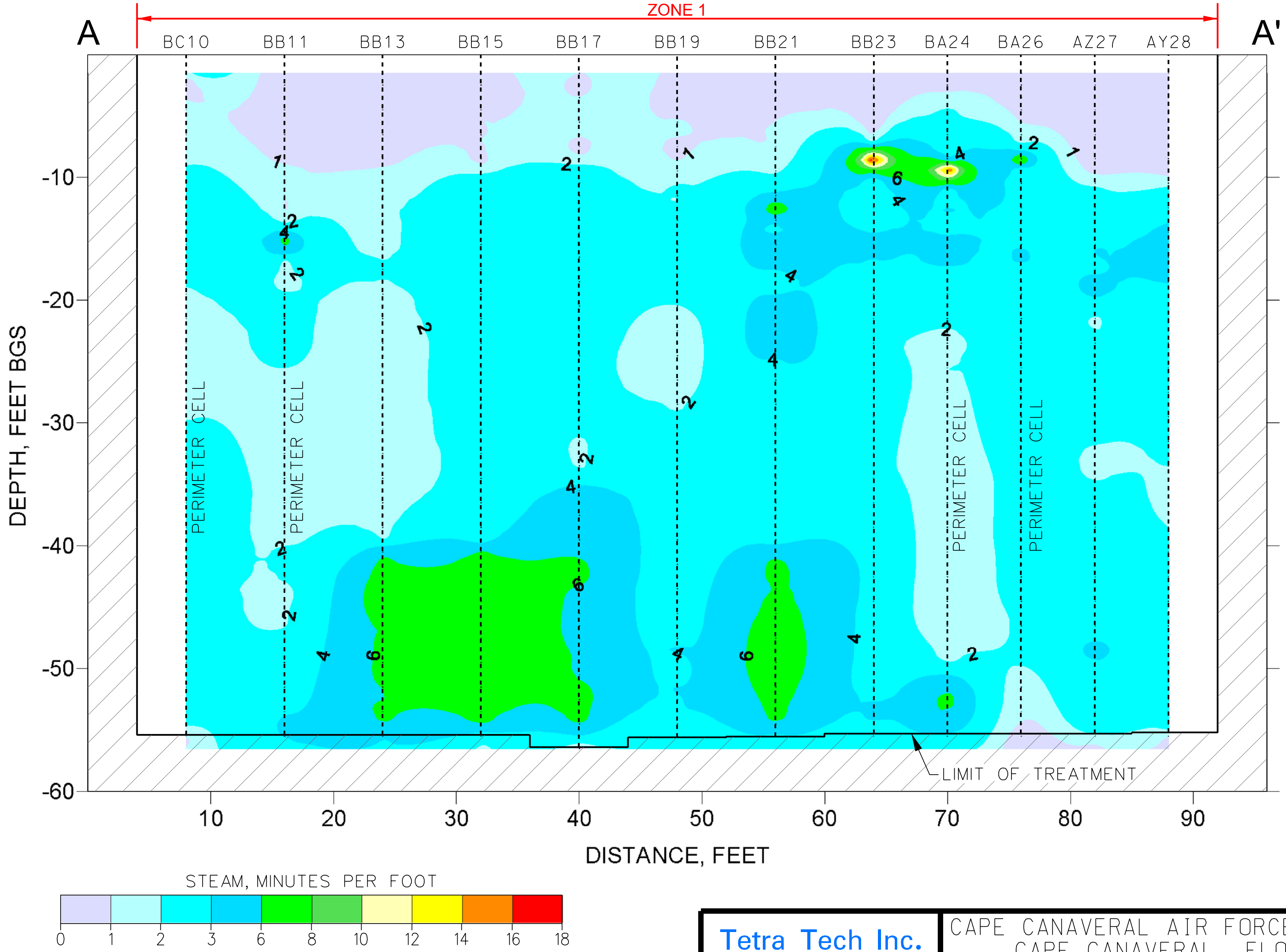

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FIGURE 3-32
STEAM INJECTION, MINUTES/FOOT
CROSS SECTION A-A'

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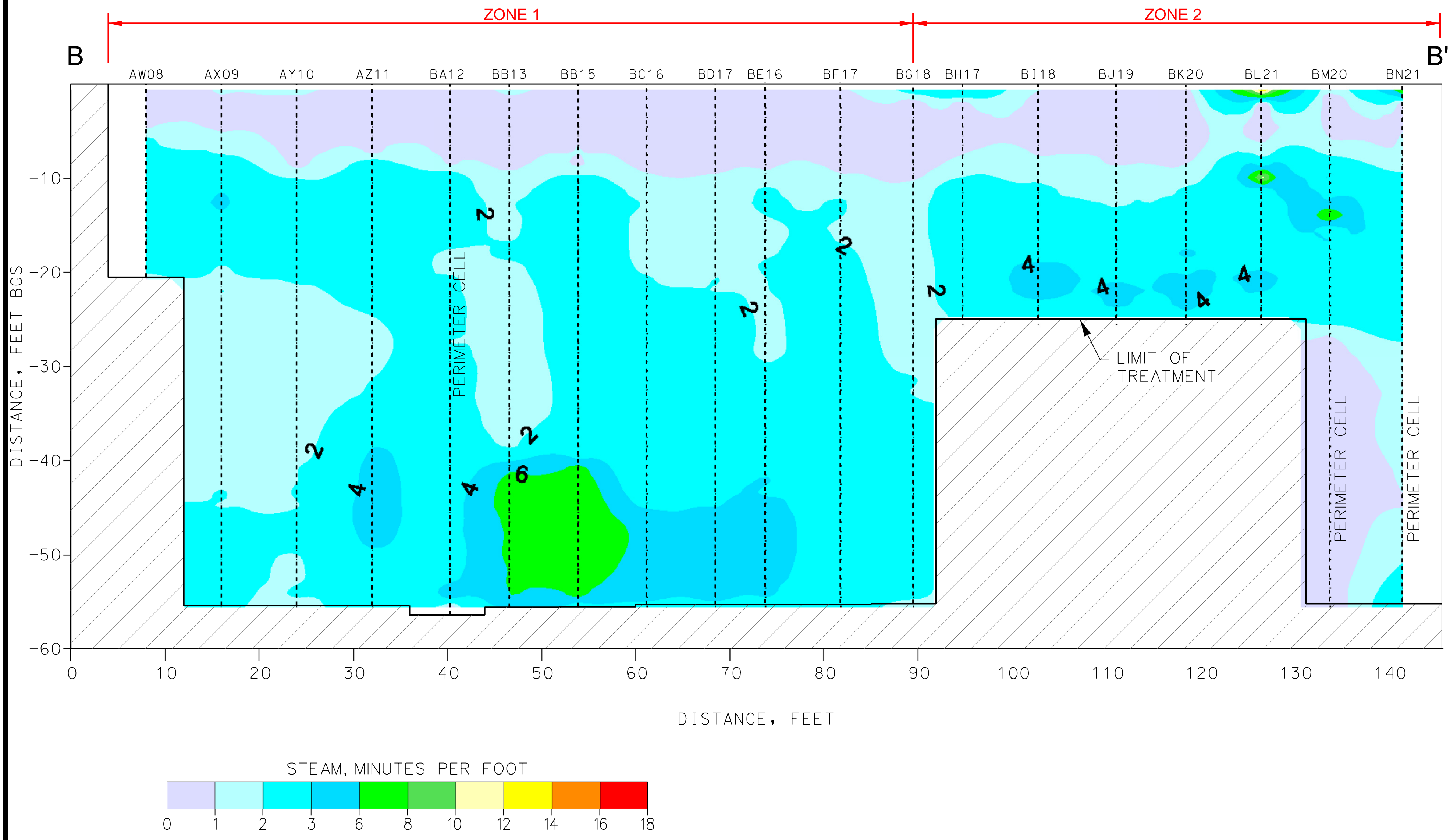

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FIGURE 3-33
STEAM INJECTION, MINUTES/FOOT
CROSS SECTION B-B'

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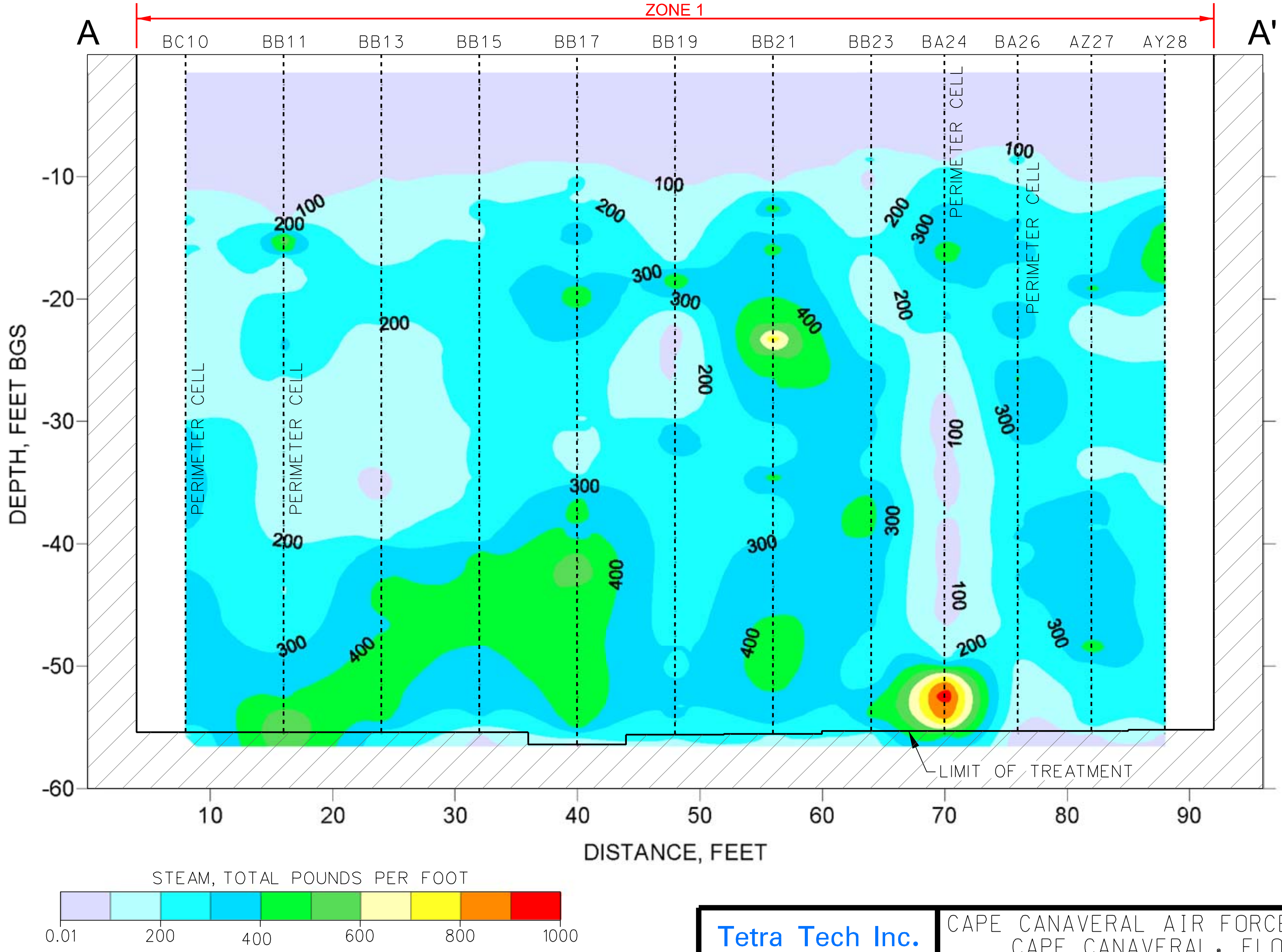

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FIGURE 3-34
STEAM INJECTION, TOTAL POUNDS/FOOT
CROSS SECTION A-A'

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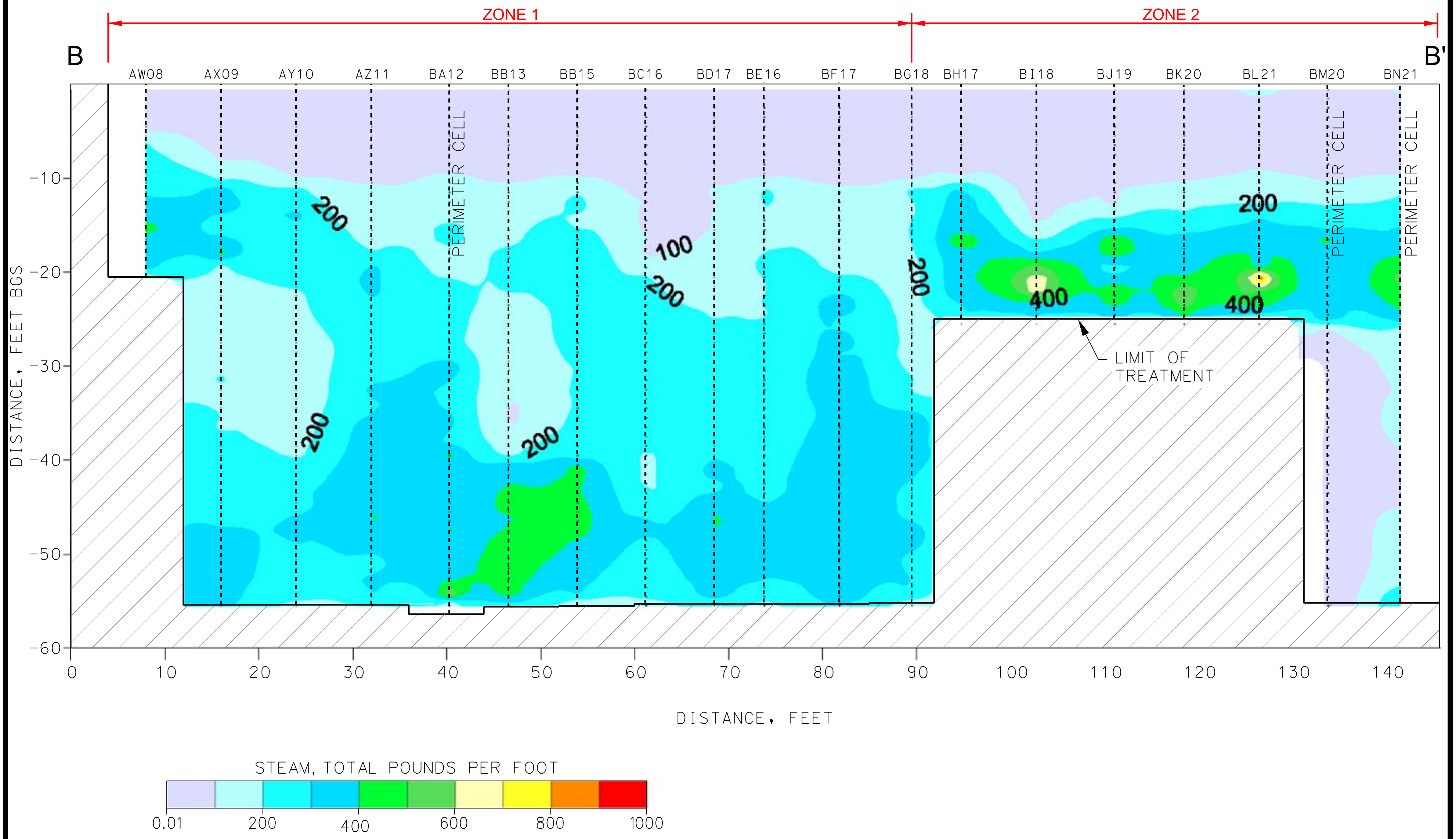

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FIGURE 3-35
STEAM INJECTION, TOTAL POUNDS/FOOT
CROSS SECTION B-B'

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- Deeper Contamination Treatment and Exploratory Treatment
- Expansion and Deletion of Cells, and
- Additional Thermal Treatment Time

The SCADA screen shots consisting of operator screen and trending graph for each cell are presented in Volume III. The documentation of real-time decisions is provided in field notes and presented in Volume IV.

3.7.1 Deeper Contamination Treatment and Exploratory Treatment

During active treatment on a cell, the off-gas FID was monitored to determine the approximate location of the highest level contamination in the treatment cell, and the GCs provided the chemical constituent breakdown of that contamination at that particular depth. If it was determined that FID values were rising near the planned maximum treatment depth and exceeded 400 ppm (with TCE concentration from GC greater than 60 ppm), then it was indicative that significant TCE contamination may be present below planned depth and an additional 5 feet of treatment was utilized to treat contamination on the third pass. Once the additional 5 feet of treatment was implemented, the maximum treatment depth for the cell was modified to the new depth. During treatment at SPCC there were no cells requiring the implementation of this decision; however, there were a few cells where exploratory treatment with hot air and steam were performed to determine if contamination existed at a deeper level than delineated. The exploratory treatment was implemented due to TCE readings (above 60 ppm) collected during iron injection to 55 feet bgs. The cells where exploratory treatment to 55 feet bgs was performed were BN21 (perimeter zone 2 treatment cell), and BM22 (inner zone 2 treatment cell). Both treatment cells BN21 and BM22 contained relatively low amounts of TCE below the planned treatment zone (208 ppm and 55 ppm, respectively).

3.7.2 Expansion and Deletion of Cells

Contaminant data were analyzed by on-site personnel and managers to determine areas where additional treatment may be required and areas where treatment may not be necessary. A combination of peak FID values, peak TCE values, and mass removal information was analyzed to aid in this determination of adding or deleting treatment cells. Mass removal information was not available in real time but was provided within one or two days after treatment to make adequate field decisions on treatment or no treatment while positioned near the area of question. Additionally, the available funding also influenced the decision in adding or deleting treatment cells by treating the high contaminated expansion cells in lieu of low contaminated inner cells. The addition or deletion of cells for treatment were discussed and approved by the Partnering Team.

A total of 27 treatment cells were thermally treated as expansion cells. Expansion cells were added adjacent to perimeter cells that contained approximately TCE of one pound of mass or greater and were expanded out until the TCE mass removal was less than one pound of TCE. Expansion cells AX07, AW08, and AW10 were thermally treated from 5 to 20 feet bgs due to elevated PCE concentrations seen in adjacent cells. Table 3-7 lists the expansion cells added for treatment at SPCC.

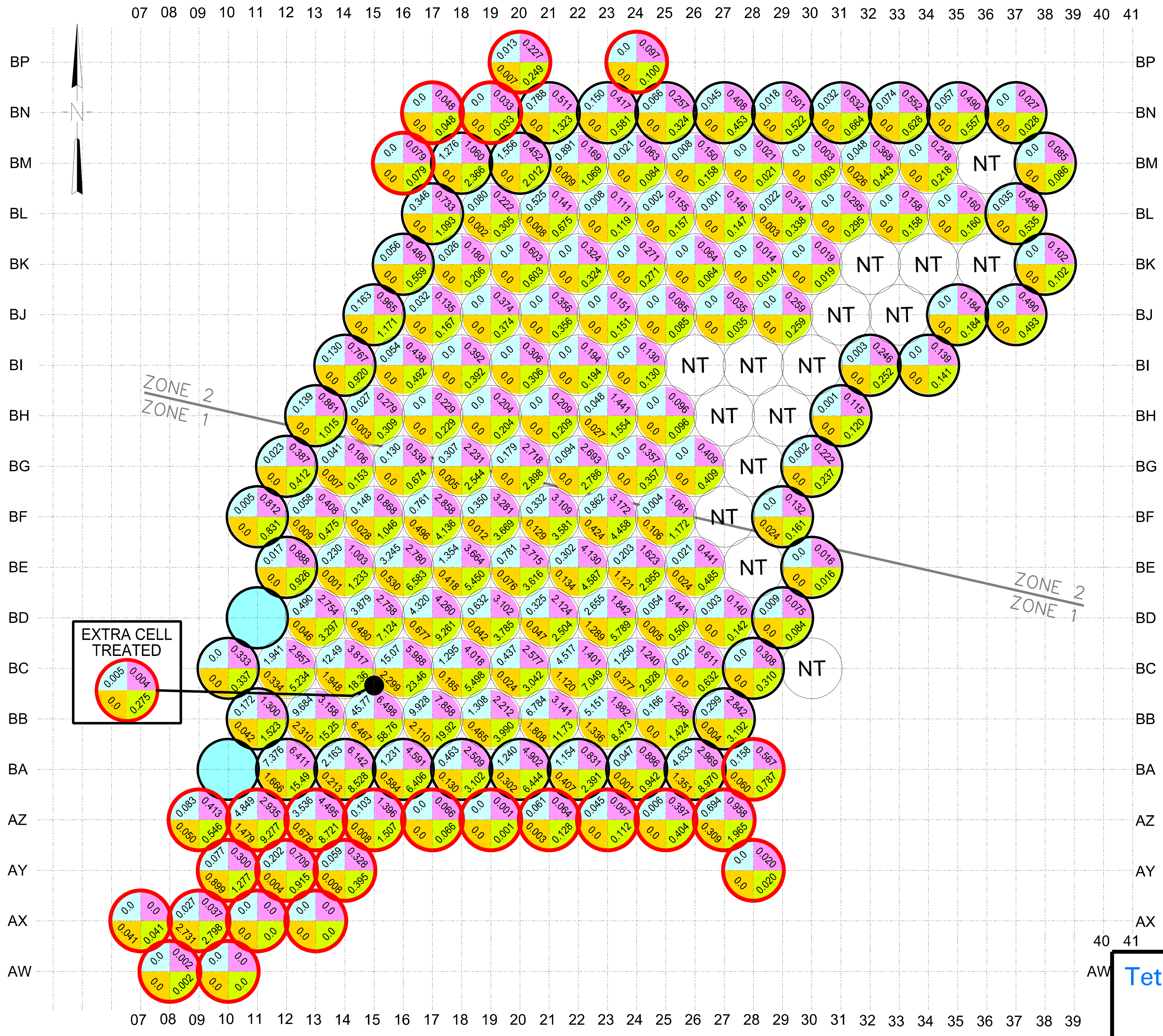
Table 3-7. Expansion Cells

Cell ID	Treatment Date	Zone
AZ17	4/17/2006	1
AZ15	4/18/2006	1
AZ13	4/18/2006	1
AZ11	4/18/2006	1
AY12	4/19/2006	1
AY10	4/19/2006	1
AZ09	4/19/2006	1
AZ27	4/25/2006	1
AZ25	4/25/2006	1
BP20	5/5/2006	2
BN19	5/5/2006	2
BN17	5/5/2006	2
BM16	5/5/2006	2
AX09	5/5/2006	1
AY14	5/5/2006	1
AZ19	5/8/2006	1
AZ21	5/8/2006	1
AZ23	5/8/2006	1
AW08	5/8/2006	1
AX07	5/8/2006	1
AW10	5/9/2006	1
AY28	5/9/2006	1
BA28	5/9/2006	1
BP24	5/18/2006	2
AX11	5/18/2006	1
AX13	5/18/2006	1
BC04	5/18/2006	1

Contaminant data were also analyzed to determine treatment cells that did not require treatment. A total of 15 cells were deleted from treatment due to a combination of low FID (less than 400 ppm) and low TCE (less than 60 ppm). The following cells were deleted from the treatment at SPCC:

BC30, BE28, BF27, BG28, BH27, BH29, BI25, BI27, BI29, BJ31, BJ33, BK32, BK34, BK36, and BM36.

Figure 3-36 illustrates the expansion and deletion of cells at SPCC.



LEGEND

CONTAMINATION MASS
(LBS PER CELL)

TCE
CIS-1,2 DCE
PCE
TOTAL VOCs

○ 8' DIAMETER INNER CELL LOCATION

○ 8' DIAMETER INITIAL PERIMETER CELL LOCATION

○ 8' DIAMETER EXPANSION CELL LOCATION

NT NOT TREATED (LOW CONTAMINATION IN ADJACENT CELLS)

● DATA NOT RECORDED DUE TO SCADA SYSTEM ERROR

NOTE

ZONE 1 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 55'. ZONE 2 THERMAL AND IRON TREATMENT DEPTH IS FROM 10' TO 25'. PERIMETER CELLS IN ZONE 2 RECEIVE IRON ONLY (NO THERMAL TREATMENT) FROM 25' TO 55'.

14 0 14
SCALE IN FEET

Tetra Tech Inc.
OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
FACILITY 18003

FIGURE 3-36
EXPANSION AND DELETION OF CELLS

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3.7.3 Additional Thermal Treatment Time

Another real-time decision that was made in the field was utilizing additional thermal treatment time to continue reduction of the chlorinated solvents. When nearing the end of the maximum thermal treatment time of 90 or 120 minutes for shallow or deep cells, respectively, the FIDs and GCs were monitored for contamination reduction trends over the entire thermal treatment. If it was determined that contamination remained at elevated levels (FID above 1000 ppm and TCE, as analyzed by GC, above 1000 ppm), 30 additional minutes of thermal treatment time were added until contamination levels were reduced to FID below 1000 ppm and TCE, as analyzed by GC, below 1000 ppm.

3.8 HEALTH AND SAFETY

The success of every project lies in the implementation of a thorough plan with health and safety in the forefront of every activity. The LDA CMI project was no exception to this principle. The CMI Work Plan and Health and Safety Plan (HASP) were source documents in providing a safe and operational effective remediation at Facility 18003, SPCC. The HASP (USAF Contract No. FA8903-04-D-8677, Delivery Order No. 0031) was prepared to provide health and safety procedures and guidelines for Tetra Tech employees and subcontractor personnel engaged in on-site activities.

The publications listed below were the basis of regulatory guidelines followed in preparation of the HASP.

- American Conference of Governmental Industrial Hygienists (ACGIH), 2005. Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices.
- American National Standards Institute (ANSI), 1998. Z358.1.
- National Institute for Occupational Safety and Health (NIOSH), 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.
- Occupational Safety and Health Administration (OSHA), *Safety and Health Regulations for General Industry,* Title 29 *Code of Federal Regulations* (CFR), Part 1910.
- OSHA, Safety and Health Regulations for Construction, 29 CFR 1926.
- U.S. Army Corps of Engineers (USACE), 2000. Safety and Occupational Health Requirements for Hazardous, Toxic, and Radioactive Waste (HTRW) Activities, ER 385-1-92.
- USACE, 2003. Safety and Health Requirements Manual, EM 385-1-1.

The HASP provided the framework for the Site Safety and Health Officer (SSHO) and Health and Safety (H&S) personnel to follow throughout the CMI activities. This section focuses on several key elements performed during CMI activities to ensure the health and safety for Tetra Tech employees, subcontractor personnel, and on-site visitors.

During the initial stages of the CMI activities, the SSHO met with subcontractor H&S personnel to review the HASP and discuss any pertinent health and safety concerns. Details on submission of employee training records, medical surveillance documentation, initial site-specific training and correspondence measures were discussed in a meeting held prior to commencing field activities. In this meeting the SSHO provided copies of the HASP and a training package was developed for initial site-specific training. In addition, the scope of tailgate topics was compiled specific to CMI activities.

CMI activities were categorized into five major activities:

- Groundwater Sampling
- Mobilization/Demobilization
- In-Situ Soil Mixing with Steam, Hot Air, and ZVI Injection by LDA
- Vapor Extraction, Conditioning, and Treatment
- Equipment and Personal Decontamination

The following elements detail actions monitored by the SSHO to ensure a safe and healthy work environment for all site personnel: training, tailgate safety meetings, monitoring, site access, injury/illness reporting, and equipment inspections.

3.8.1 Training

Prior to commencing field activities at Facility 18003, the SSHO compiled training documentation and certification records mandated in the OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) standard. All on-site workers were required to have the following HAZWOPER training:

- Initial General Site Worker Training (normally 40 hours off-site training) [29 CFR 1926.65 (e)(3)(i)]
- Three days of field experience under direct supervision of a trained, experienced supervisor [29 CFR 1926.65 (e)(3)(i)]
- Refresher Training (at least 8 hours on specific health and safety items) for all on-site workers, if it has been more than a year since completion of initial general site worker training [29 CFR 1926.65 (e)(8)]
- Supervisor Training for site supervisors in addition to the above requirements (an additional 8 hours of specialized training) [29 CFR 1926.65 (e)(4)]

A spreadsheet was developed to track all on-site workers' training information by their respective employer (Appendix I). The SSHO provided periodic updates to subcontractor supervision to ensure personnel maintained training competency.

All on-site workers were briefed by the SSHO on the HASP prior to commencing CMI activities. These sessions addressed pertinent areas under the HASP based on the respective major activity. Topics covered included:

- Names of personnel and alternates responsible for health and safety on-site and for the project.
- Site layout (Figure 2-8)
- Specific safety, health, and other hazards
- PPE requirements
- Work practices and restrictions, and personnel/equipment decontamination procedures
- Air monitoring program
- Spill containment and emergency procedures
- Accident and incident reporting

3.8.2 Tailgate Safety Meetings

Prior to the start of a workday, a tailgate safety meeting was held informing on-site workers of the potential hazards associated with planned daily activities (Volume IV). The meetings provided an open line of communication for supervisors and safety personnel to educate and increase workers' awareness on protective measures and hazards associated with each activity. In addition, the Activity Hazard Analysis (AHA) for a particular major site activity was reviewed prior to performing an activity during these sessions. These meetings were documented on Daily Tailgate Safety Meeting Forms (Volume IV). Topics included:

- Chemical hazards (hazard communication, material safety data sheets, exposure limits)
- Physical hazards (fall protection, heavy equipment pinch points, ladder safety)
- Environmental and biohazards (insects, snakes, poisonous plants)
- Air monitoring results (FID readings)
- Decontamination procedures (proper decontamination for sampling equipment)
- PPE (respirators, gloves, hard hats)
- Emergency procedures (emergency contact phone numbers, location of nearest hospital)
- Other pertinent information (use of hand-free devices when talking on cell phone while driving on base, lightning phase advisory)

During remediation treatment of Facility 18003, an AHA was developed prior to performing a thermal exploratory study (Appendix J). This study was not listed as an activity within the HASP. Therefore, the SSHO prepared the AHA to address all potential hazards associated with the planned event. The AHA was coordinated with all parties involved and a specific tailgate meeting for personnel performing the thermal exploratory study was held on the morning of the study (Appendix J). These actions were the key to a safe and successful study.

3.8.3 Monitoring

Monitoring workers' safety encompasses medical, heat strain, and air monitoring for all HAZWOPER-related activities.

3.8.3.1 Medical Monitoring

Medical monitoring involves the approval of a licensed physician certifying the employee fit-for-duty and able to wear any required PPE under normal work site conditions. All on-site workers required medical surveillance examinations prior to commencing work activities on site. The SSHO ensured all Tetra Tech personnel and subcontractor employees were fit-for-duty to perform their respective activities. The SSHO maintained the physician's written opinion on file at the site indicating the fit-for-duty status and individual worker limitation, if any. Examination dates and any limitations were noted and tracked on the Training Worksheet.

3.8.3.2 Heat Strain Monitoring

Heat stress is one of the health factors H&S personnel assessed during CMI activities. The National Safety Council (NSC) recognizes three significant risk factors that contribute towards heat stress: environment, work activity, and additional protective clothing. These stressors can greatly inhibit a worker's performance in conducting activities on a work site. Heat strain is the physiological effect of heat stress produced in the body.

There are three methods of evaluating heat strain in the workplace: body core temperature, heart rate, and sweating. During CMI activities, both body core temperature and heart rate methods were implemented to evaluate heat stress exposures. The body core temperature method involves measuring the oral temperature of a worker. Fifteen minutes prior to a worker eating or drinking, a thermometer is placed into the worker's mouth and, with the mouth closed, a measurement is taken. By adding 1^{o}F to the oral temperature, an equivalent body core temperature can be registered. NSC recommends not exceeding 102.2^{o}F for industrial exposure to heat stress.

The heart rate method uses the recovery heart rate after one minute to indicate whether protective heat stress measures are effective. This method focuses on the demand on the cardiovascular system to move blood from the body to the skin. As skin temperature increases, more blood is required to reach the skin to aid in the cooling of the body. Heart rate measurements are taken once the worker stops working in an environment, performs an activity, or wears protective clothing which may lead to heat strain. The worker is seated and a pulse rate after one minute recorded. NSC recommends the pulse rate after one minute be at or below 110 beats per minute.

As aforementioned, three risk factors contribute to heat stress. Workers were briefed during tailgate sessions on forecasted weather conditions and advised of preventive measures to take during elevated ambient temperatures. In addition, when ambient temperatures reached levels above 85^{o}F, H&S personnel increased vigilance of workers' performance. During CMI activities at SPCC, H&S personnel noted three days where significant heat stress factors were evident. Workers were monitored and all personnel were below the recommended guidelines indicating protective measures were functioning effectively.

3.8.3.3 Ambient Air Monitoring

A comprehensive Air Monitoring Program for the LDA project was developed during the initial mobilization phase of the project and added to the HASP. The program set forth the criteria necessary to conduct air monitoring as part of a comprehensive site evaluation that accomplishes the following:

- Identifies work areas and activities that require the use of engineering or work technique controls or require the use of PPE
- Provides data to confirm that levels of protection afforded by the assigned PPE and engineering or work technique controls are adequate to protect workers
- Provides data to ensure that all necessary controls and precautions are being taken to protect the public and the environment
- Complies with 29 CFR 1910.120(c)(6) and (h)

The program detailed the instruments available, instrument calibration procedures, monitoring locations, frequency of monitoring, and documentation of monitoring activities to adequately assess personal and ambient environmental conditions while performing CMI treatment activities as well as support activities.

3.8.3.4 Equipment Familiarization and Calibration

The SSHO ensured H&S personnel received training on the use, maintenance, limitations, and field operational testing of the specific direct reading instruments utilized on site. The SSHO or an H&S technician calibrated monitoring equipment in accordance with manufacturers' instructions. All direct reading instruments require calibration before use and after each use. A span gas check (bump test) using a Tedlar bag with a specific concentration of a known gas was used to ensure the instrument operated within manufacturer's calibration parameters. Methane gas of a known concentration was used for calibrating direct reading instruments.

Documentation of instrument calibration was performed using an Equipment Calibration Log worksheet (Appendix K). Each calibration event was noted on the worksheet. For portable monitoring instruments such as the hand-held FID, the information recorded included the following:

- Instrument type, brand, model, serial numbers, and other information such as lamp specifications
- Date of calibration
- Time of calibration
- Concentration and source of calibration gas standard
- Instrument scale range
- Name of person calibrating instrument

The primary means of ambient air monitoring during CMI activities was a direct reading instrument, hand-held FID. This instrument provided real-time measurements for designated H&S personnel to assess ambient air levels throughout the site. The FID was used to account for the total VOC in work zones.

Other devices were utilized to better indicate the presence of specific VOCs in the air. These devices included color-change detector tubes specific to a contaminant or a group of contaminants.

3.8.3.5 FID Functionality

FID functionality involves the response to any molecule with a carbon-hydrogen bond. Since the FID is mass sensitive, not concentration sensitive, changes in carrier gas flow rate have little effect on the detector response. It is preferred for general hydrocarbon analysis, with a detection range from 0.1 to 2000 ppm. This instrument is generally strong and easy to operate, but because it uses a hydrogen diffusion flame to ionize compounds for analysis, it destroys the sample in the process. The accuracy of detection for an FID can vary significantly from one organic substance to another. Also, an FID will not respond to inorganic substances, or to particulates in air. The instrument is designed to operate within a wide range of relative humidity, 5% to 95%. The FID is insensitive to water, inert gases, and inorganic compounds.

3.8.3.6 Initial Site Assessment

Background initial monitoring was performed prior to task initiation. The ambient levels indicated on the FID were documented on Direct Reading Instrument Log sheets (Appendix L). These levels provided reading adjustments, if necessary, to all ambient and breathing zone screening measurements. The initial site assessment indicated levels below 1 ppm under normal working conditions. Therefore, all measurements taken during the workday reflected this background reading.

3.8.3.7 Periodic Monitoring Activities

Any elevated readings for total VOCs lasting one minute or longer in the worker's breathing zone required site activities to be suspended and site personnel instructed to move upwind of the treatment area. Personnel would be instructed on where to assemble to ensure the safety of all site personnel. These procedures were briefed to all on-site workers during emergency response discussions in a tailgate forum. The Field Operations Supervisor is responsible for taking a roll call to ensure that all persons are accounted for and to stop all activities until the problem is resolved. The HASP indicates the action level triggering specific employee protection actions such as donning of respirators or evacuation of the work area. These levels are listed in Table 3-8.

Table 3-8. Action Levels

Potential Air Contaminant	Instrument 1*	Action Levels	Level of Respiratory Protection
Organic Vapors	FID	Continuous sustained readings of <5 ppm in the breathing zone	Level D
Organic Vapors	FID	Continuous sustained readings of >5 ppm but < 50 ppm above background in the breathing zone	Apply engineering controls and retest. If condition persists, employ Level C.
Organic Vapors	FID	Continuous sustained readings of > 50 ppm above background in the breathing zone	Apply engineering controls and retest. If condition persists, evacuate area.

*The H&S Manager or SSHO must approve an equivalent unit.

Periodic monitoring using the hand-held FID was performed during each hazardous, task-specific activity with 2-4 minute intervals at the worker's breathing zone area (4-5 feet in height). Periodic monitoring areas included support activity areas (batch plant, CRZs, and boilers), EZ fencing and inside the EZ. The periodic monitoring protocol used during CMI activities is listed in Table 3-9.

Table 3-9. Periodic Monitoring Guidelines

Personnel	Zones	Levels	Additional Guidelines
Crane operator and support personnel downwind from shroud	Inside EZ, EZ perimeter fence line and areas where personnel are working.	If 5 ppm FID sustained for more than 1 minute, upgrade PPE to Level C. If 50 ppm FID sustained for more than 1 minute, evaluate work area and re-assess operations.	Check on GC reading. If vinyl chloride is indicated, use colorimetric sampling device for confirmation of vinyl chloride concentration in the work areas.
Support personnel downwind and crosswind from shroud	Support areas and EZ perimeter fence line.	Same as above.	Same as above.
Crane operator is crosswind from shroud with wind speeds less than 10 knots	Inside EZ, EZ perimeter fence line and areas where personnel are working.	Same as above.	Same as above.
Crane operator and support personnel upwind from shroud with wind speeds greater than 10 knots	EZ perimeter fence line	Same as above.	Same as above.

The above monitoring is the minimal requirement. Additional monitoring based on process FID and GC measurements was added to better assess the airborne concentration of concerned contaminants. Table 3-10 lists the cell category color scheme used to indicate the probability of risk associated with ambient airborne contaminants.

Table 3-10. Cell Category Color Scheme

Color	Concentration Range	Risk
Green	FID: <400 ppm; and TCE: <60 ppm	Minimal to no risk for exceeding AL.
Orange	FID: ≥400 ppm ≤1000 ppm; or TCE: ≥ 60 ppm ≤120 ppm	Low risk for exceeding AL.
Red	FID: >1000 ppm <10000 ppm; or TCE: > 120 ppm <1000 ppm	Moderate risk for exceeding AL.
Pink	FID: ≥10000 ppm: or TCE: ≥1000 ppm	High risk for exceeding AL.

All periodic monitoring measurements, using a hand-held FID, were documented on Direct Reading Instrument Log sheets (Appendix L). Throughout the CMI treatment activities, there were only five recorded measurements exceeding the 5 ppm action level. The Periodic Measurements table (Table 3-11) lists dates, location of the elevated air monitoring levels, and action taken to reduce elevated levels.

Table 3-11. Periodic Measurements

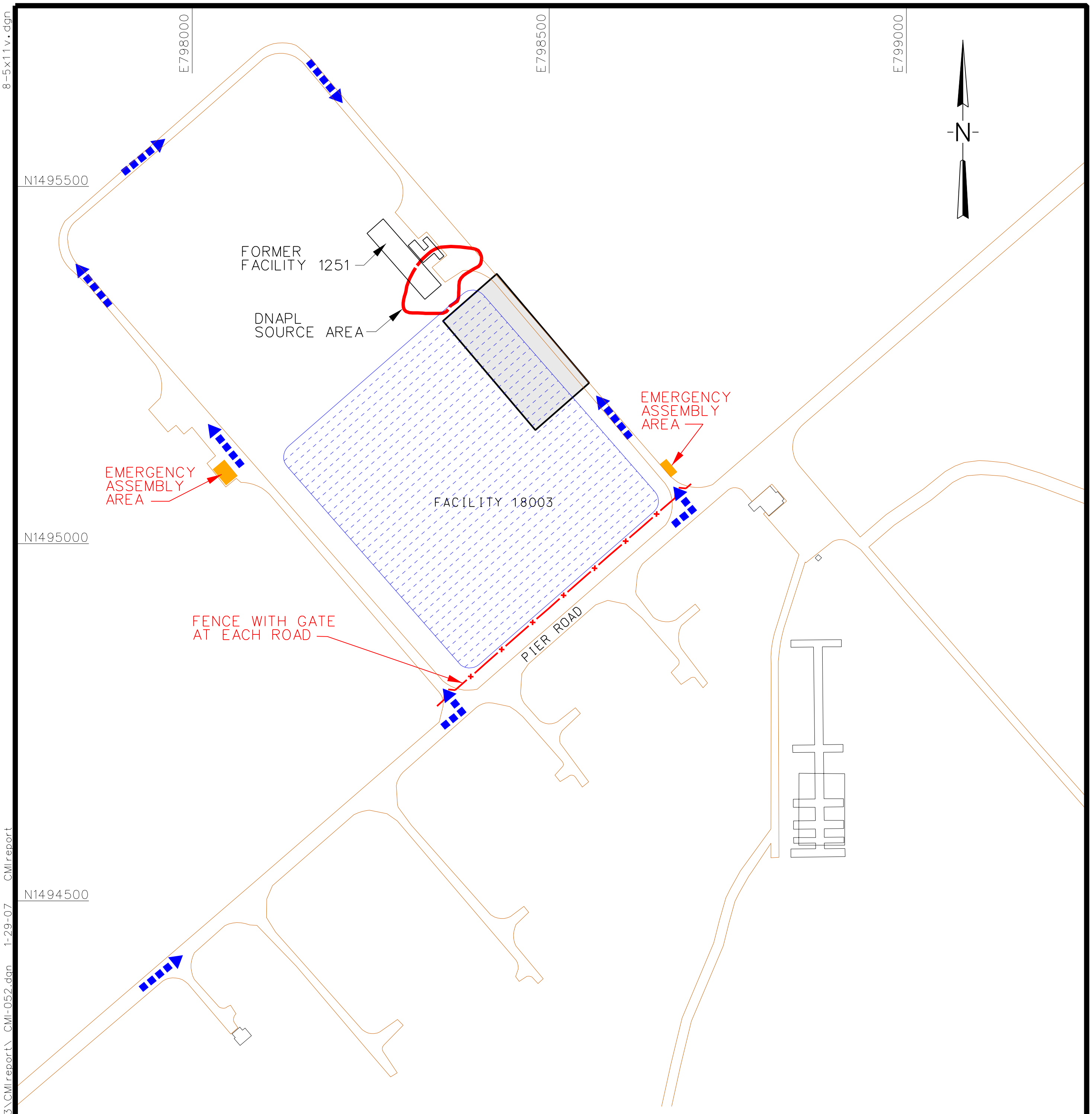
Dates	Cell	Location	Levels	Action Taken
Mar 22, 2006 1047 hrs	BN23	Background east of boilers	6.3	Moved upwind of boilers, meter reading corrected to <1 ppm.
Mar 23, 2006 1251 hrs	BN21	Near manifold valve	7.4	Measurement reduced to 4.7 ppm at one minute, then to <1 ppm after two minutes.
Mar 28, 2006 1525 hrs	BK38	Near manifold valve	5.0	Measurement lasted less than one minute, checked for leaks, none found.
Apr 7, 2006 1320 hrs	BA24	GC#3 Sample line approximately 5 feet from operator's position inside DAS trailer	46	Sample line fixed for GC#3, reading fell to <1 ppm after fix.
Apr 18, 2006 1045 hrs	AZ13	GC#2 Sample line approximately 5 feet from operator's position inside DAS trailer	73	Sample line fixed for GC#2, tightened fitting for all GC sample lines and implemented soap solution leak checks, reading fell to <1 ppm after fix. No more problems noted for the duration of the project.

3.8.4 Site Access

All personnel gained access to the SPCC grounds via a personal badge issued by the Pass and Identification offices after the Air Force IRP office approved badge request submittal. Access to the site was controlled using a fence line between the major roadway to the site, Pier Road, and the support zone (Figure 3-37). The fence line had two gates for accessing the site. The northern gate provided direct access to the support zone while the south gate area was used primarily for parking and storage of iron, guar, and other support supplies.

All personnel visiting the site were required to sign in at the northern gate. Tracking of personnel on-site was accomplished using Daily Sign-in Sheets (Volume IV). These sheets fulfilled two purposes: first, a record of personnel on site should an emergency occur and second, the source document for compiling worker's hours for illness or injury reporting.

Once inside the fence line, the site was partitioned into three zones: support zone, CRZ, and EZ. Visitors to the site were restricted to the support zone and escorted by a member of Tetra Tech or subcontractor supervision. Under no circumstance were visitors allowed into the CRZ or EZ during treatment activities. Only when treatment ceased and H&S personnel declared the area safe, were specialized workers (e.g., crane mechanic) allowed entry inside the EZ with appropriate supervision. No one was allowed to enter either the CRZ or EZ unless all the training requirements were met.



LEGEND

▭ CONTRACTOR LAYDOWN AND STORAGE

▨ CONFIDENCE COURSE AREA

▪▪▪▪▶ ACCESS ROUTE INDICATOR

200 0 200
SCALE IN FEET

SOURCE

CORRECTIVE MEASURE DESIGN, FACILITY 18003,
JACOBS ENGINEERING, MAY 2005

SOME BASEMAP INFORMATION FROM BEM SYSTEMS INC.

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 3-37
SITE ACCESS

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3.8.5 Injury/Illness Reporting

As stated in the beginning of this section, a thorough plan aids in the accomplishment of a successful project. Even though planning is accomplished and implemented, there is always the possibility for an incident to occur. The misfortune of an accident or incident diminishes workers' morale and reduces productivity. Every effort is made to minimize the risk factors of an accident or incident.

3.8.5.1 OSHA Recordkeeping Requirements

OSHA mandates recording of injuries or illnesses if the incident meets one or more of the general recording criteria listed in 29 CFR 1904.7 (b). First, the injury or illness must be work-related. The OSHA regulation, 29 CFR 1904.5, defines work environment as "the establishment and other locations where one or more employees are working or are present as a condition of their employment. The work environment includes not only physical locations, but also the equipment or materials used by the employee during the course of his or her work."

3.8.5.2 OSHA Injury or Illness Categories

Second, the injury or illness must have resulted in one or more of the following:

- Death.
- Days away from work.
- Restricted work or transfer to another job.
- Medical treatment beyond first aid.
- Loss of consciousness.
- A significant injury or illness diagnosed by a physician or other licensed health care professional.

3.8.5.3 On-Site Incident Information

During the CMI activities at SPCC, two OSHA recordable incidents occurred during the mobilization phase of the project. Both incidents involved subcontractor employees and were classified as OSHA recordables based on medical treatment performed on individuals as a result of the incident and restricted duty ordered by a licensed physician. Subcontractor H&S personnel investigated the incidents and reported findings to the SSHO. The SSHO in turn contacted the Tetra Tech Project Manager and Air Force personnel within the appropriate time limit, fulfilling notification requirements. The respective subcontractor H&S personnel provided the SSHO a written report with the OSHA Form 300 showing that the incidents were properly recorded. The completed incident report form is attached in Appendix M. The following information shows the total number of hours worked during the five major activities. This information is utilized to calculate incident ratings.

- Groundwater Sampling: 10 days totaling 90.5 hours
- Mobilization:
    - Grading Site: 8 days totaling 63.5 hours
    - Equipment/Electrical Set-up: 57 days totaling 535 hours

- In-Situ Soil Mixing with Steam, Hot Air, and ZVI Injection by LDA
- Vapor Extraction, Conditioning, and Treatment
- Equipment and Personal Decontamination
    - The above activities were comprised into one category
    - Treatment activities were divided into Perimeter and Interior cells
    - Perimeter cells: 17 days totaling 195.5 hours
    - Interior cells: 28 days totaling 321 hours
- Tear Down/Demobilization: 10 days totaling 80.5 hours

Both injuries occurred on Saturdays when minor maintenance activities were scheduled. The first injury occurred on Saturday, 4 March 2006. A worker lost his footing and balance while stepping off an excavator. The worker fell off the tracks and landed on his back on some wooden timbers. The timbers were used to provide support for the batch plant tanks. This resulted in the worker requiring medical assistance beyond first aid. The diagnosis was a slight fracture of the 1st and 2nd lumbar "outer" disc bones. H&S personnel investigated the incident and discovered that the worker was closing the excavator door at the same time of the dismounting of the excavator. During the following Daily Tailgate Safety meeting, all personnel were instructed to maintain three point contact (two hands and a foot or one hand and both feet) when mounting or dismounting of heavy equipment. In addition, personnel were briefed to perform one activity at a time to reduce the probability of an accident from occurring.

The second injury occurred on 8 April 2006. A pre-chiller unit was being installed after the knock-out tank. The unit measures 2.4 feet x 2.8 feet x 2.6 feet. A mechanical device was used to maneuver the unit in place for installation. After positioning the unit near the process line, the worker noticed that the unit was not right-side up. Therefore, the worker proceeded to reposition the unit correctly. The coils inside the unit were not secured and were freely suspended with outer shell ports. The worker used the extruding coil pipes to grasp the pre-chiller. While turning the pre-chiller on its side, the pipes moved causing the small index fingers of the worker's hands to be pinched with the outer shell. The worker was wearing leather work gloves which greatly reduced the severity of the injury. Unfortunately, the worker was unaware of coils being freely suspended inside the unit. H&S personnel assessed the incident and informed workers to plan activities prior to performing any unfamiliar task. The following Daily Safety Tailgate meeting included discussion of this topic to ensure personnel take the necessary precautions prior to performing any task. In addition, workers were reminded of the importance of wearing the proper PPE on the job. The use of leather gloves ensured the worker did not lose any limbs.

3.8.6 Equipment Inspections

One of the most effective means of preventing incidents or accidents from occurring on a work site is implementing tools to inspect machinery and equipment prior to utilizing these devices. Equipment inspection checklists provide operators with memory jogging reminders of areas and steps to follow for ensuring the safe operation of equipment and machinery. In addition, OSHA mandates the employer to have a competent person to inspect all machinery and equipment prior to each use to make sure it is in safe operating condition [29 CFR 1926.550 (a)(5)].

The following machinery and equipment were inspected daily prior to use:

- Heavy equipment: Front loader, excavator, and manlift
- Machinery: Crane, drill platform, and boilers

The heavy equipment was inspected using a week-long inspection checklist with inspection items listed to ensure safe operation of devices (Appendix N). The operator performed the inspection and checking off each inspection item. Any discrepancy was noted on the log and briefed to the Site Supervisor. H&S personnel were responsible for following up on discrepancies. Items rendering the equipment unsafe were corrected immediately or the equipment was red-tagged. There were no discrepancies during CMI activities at SPCC which resulted in equipment being red-tagged.

A specific crane inspection worksheet was developed by the crane operators based on information found in the manufacturer owner's manual. This inspection addressed items required for safe operating conditions of the crane on site (Appendix O). In addition, items for inspecting the drill platform were placed on the crane inspection worksheet to facilitate inspection procedures. The operator inspected the crane prior to the daily operations. These daily inspections provide early warning signs and assist with scheduling of specialized tasks. An oil leak was noticed during a daily inspection which resulted in a specialized crane mechanic to come on site and rectify the problem.

The final machinery with a checklist were the boilers. A startup inspection worksheet provided operators with step-by-step instructions on the safe startup procedures. The worksheet notes specific safety features to check and operational settings (Appendix P).

3.8.7 Hot Work Permit

Hot work is classified as activities where an open-flame or spark-producing apparatus is used to perform an activity which may produce a flammable atmosphere. These activities include, but are not limited to, welding, cutting, burning, grinding, and related heat-producing jobs.

Several CMI activities involved hot work. The primary hot work activity was hard facing of the auger. This activity was performed daily. Other activities included grinding, cutting and welding metal materials.

Cape Operating Procedures for IRP Sites provided guidance on obtaining a Hot Work Permit on CCAFS. The SSHO contacted Cape Support to schedule an inspection with a Fire Inspector. This notification was performed at least 24 hours in advance. Cape Support personnel would issue a work request number to confirm the appointment. The Fire Inspector would meet the on-site point-of-contact to perform the inspection.

If conditions were acceptable, the Fire Inspector issued a burn permit on the spot. The permit would normally be for a 30-day period. A CCAFS/KSC Welding and Burn Permit (Appendix Q), KSC Form 2-13 indicated the requirements of the permit. As a minimum, dry chemical fire extinguishers at specific locations and fire watch were required. The fire watch involved at least one individual dedicated solely to the look-out and control of stray fires. This individual was required to remain in the immediate area until hot work was completed plus an additional 30 minutes to ensure the risk of a fire was avoided.

3.9 OPERATIONAL WASTE DISPOSAL

The proper management of waste by-products generated during the LDA Project at SPCC, Facility 18003, was the responsibility of the prime contractor, Tetra Tech. All regulated waste streams were managed in accordance with federal, state, and local laws and regulations. In addition, the Tetra Tech. Waste Coordinator utilized the 45th Space Wing's O Plan 19-14, "Waste Petroleum Products and Hazardous Waste Management Plan" and CCAFS Operating Procedures for categorizing, managing, and disposing of wastes generated at SPCC. All waste generated at SPCC resulted directly from CMI activities. These waste streams were categorized into three general waste classes: industrial wastewater, baseline and post-treatment development wastewater, and equipment waste. The waste tracking packages and manifests are presented in Appendix R.

3.9.1 Industrial Wastewater

The primary waste by-product generated was industrial wastewater. Industrial wastewater was produced from two sources: Vapor Conditioning System (knockout tank, pre-chiller, and chiller), and vapor treatment system (FTO). Treatment of industrial wastewater was handled on base utilizing the Trident Industrial Wastewater Treatment Facility off Pier Road (see Figure 1-1). This plant is the primary receiving facility for the disposal of qualifying, IRP generated wastewaters.

Coordination between SGS Utilities, the IRP office, and Tetra Tech resulted in a plan to manage and dispose of industrial wastewater in the most efficient and economical means possible. The final plan involved the use of two 20,000-gallon capacity frac tanks as collection containers with scheduled pick-ups through the SGS Water/Wastewater Supervisor for transport to the Trident Industrial Wastewater Treatment Facility. Prior to commencing remediation activities, Tetra Tech completed a Process Waste Questionnaire (PWQ), Appendix D, describing the projected waste composition, chemical and physical characteristics, and analytical results of similar wastewater. PWQ # CEM040179 was submitted to the SGS Waste Management Group via the IRP office. A Technical Response Package (TRP) was issued on 13 Feb 2006 by SGS to the IRP office. Instructions on how to manage waste stream were detailed in the TRP.

Condensate off-gas water from the knockdown tank and vapor conditioning system was plumbed and treated by the mobile treatment system on site. This system consists of a 950-gallon temporary holding tank and a three-tray stripper to remove VOCs prior to transferring water into the 20,000-gallon frac tanks.

The water was treated for approximately 24 hours. Once treated, the water was discharged into one of the frac tanks. Blowdown water generated from the thermal oxidizer scrubber tower was directly plumbed and pumped into the frac tanks.

Frac tanks were interchangeable to allow continuous collection of industrial wastewater. Once a frac tank reached capacity, samples for VOC concentrations using USEPA Method 8260B, total dissolved solids, pH, fluoride, chloride, and specific gravity were collected in accordance with the USAF Installation Restoration Program 45th Space Wing Facilities Draft Field Sampling Procedures, June 2004. Samples were sent to a contract laboratory for waste determination analysis. All samples collected indicated industrial wastewater generated during CMI activities at SPCC were non-hazardous and therefore within the limits for disposal through the Trident Industrial Wastewater Treatment Facility. Table 3-12 provides a summary of industrial wastewater transported to the Trident Industrial Wastewater Treatment Facility.

Table 3-12. Summary of Industrial Wastewater

IRP Internal Manifest #	Date Sampled	Date Disposed	Waste Determination	Estimated Mass Disposed (lbs)
IRP-06-0001	27 Mar 06	29 Mar 06	Non-Hazardous	167,000
IRP-06-0002	07 Apr 06	12 Apr 06	Non-Hazardous	167,000
IRP-06-004	11 Apr 06	19 Apr 06	Non-Hazardous	167,000
IRP-06-005	19 Apr 06	02 May 06	Non-Hazardous	167,000
IRP-06-006	04 May 06	12 May 06	Non-Hazardous	167,000
IRP-06-008	15 May 06	22 May 06	Non-Hazardous	167,000
IRP-06-009	19 May 06	01 Jun 06	Non-Hazardous	110,000

3.9.2 Baseline and Post-Remediation Development Water

During the baseline phase of flux well installation at Facility 18003, approximately 7,500 gallons of development water were collected. Sample results indicated that levels of vinyl chloride slightly exceeded the toxicity threshold limit as defined in 40 CFR Part 261 Subpart C for USEPA characteristic waste, D043. Tetra Tech personnel worked with the Air Force Program Manager, Trident Industrial Wastewater Treatment Facility officials and SGS Water/Wastewater Supervisor to determine if development water would be accepted for disposal at the Trident Industrial Wastewater Treatment Facility. A PWQ was initiated and sample results provided to the aforementioned personnel. After review, a determination was made that the Trident Industrial Wastewater Treatment Facility could properly treat and dispose of the development water within their respective permit requirements. All parties concurred and the water was removed from the Facility 18003 location within the acceptable time period with appropriate waste disposal forms completed.

Post-remediation development water was collected into two 55-gallon drums and samples taken for determining proper disposal. Toxicity Characteristic Leaching Procedure analysis results showed that none of the USEPA Method 8260 chemicals were above characteristic limits. The control manifest and

45th Space Wing Installation Restoration Program waste tracking form were processed for waste disposition through the IRP office.

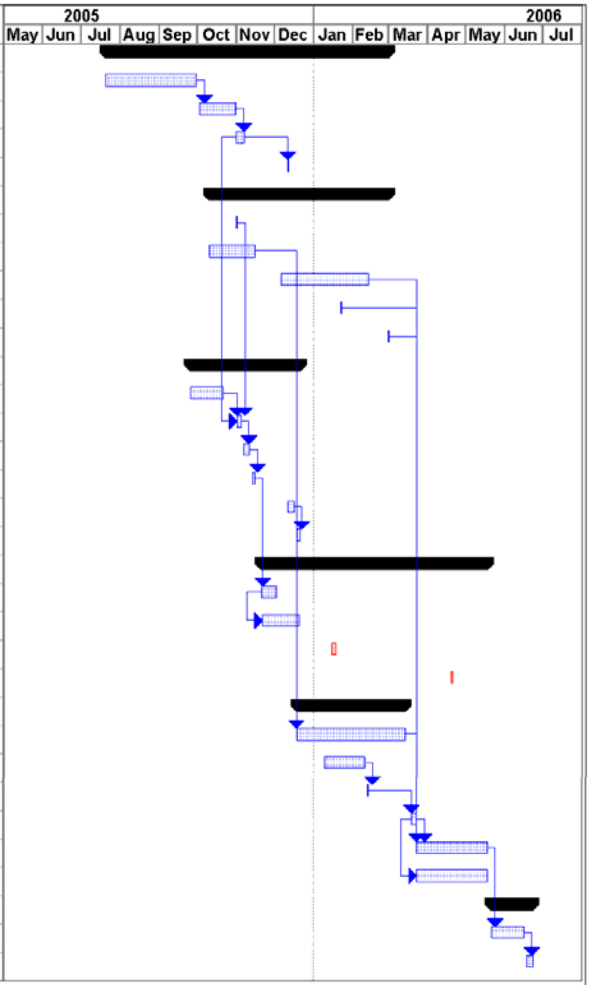
3.9.3 Equipment Waste

The most common waste by-product from equipment operations during CMI activities involved used oil and oil filters. These items are primarily generated from drill platform maintenance activities. Other items included spray paint cans, ethylene glycol, biodegradable hydraulic fluid, and spent absorbent pads. These waste by-products were primarily categorized as “non-hazardous” waste and were segregated based on waste profile into respective 55-gallon drums. Proper disposal procedures were coordinated with IRP personnel.

3.10 TREATMENT TIMELINE

A treatment timeline schedule detailing the work plan, permitting, site preparation, corrective measures implementation, and demobilization activities performed at Facility 18003 is provided in Figure 3-38. The total duration of the field activities (site preparation, corrective measures implementation and demobilization) was approximately 202 work days. Work delays consisted of a total of four days due to two Atlas V rocket launches from space launch complex 41, unanticipated delays in utility connections for the electrical vault and power pole installations, and demobilization delays due to Facility 1381 site preparation activities. Minimal weather delays were experienced during the course of the project.

ID	Task Name	Duration	Start	Finish
1	**Planning, Permitting, and Pre-Construction Submittals**	**154 days**	**Thu 7/21/05**	**Wed 3/1/06**
2	Prepare Work Plan	51 days	Thu 7/21/05	Fri 9/30/05
3	Review Work Plan	20 days	Mon 10/3/05	Mon 10/31/05
4	Revise Work Plan	5 days	Tue 11/1/05	Mon 11/7/05
5	Work Plan approval	1 day	Mon 12/12/05	Mon 12/12/05
6	**Prepare permit requests**	**98 days**	**Tue 10/11/05**	**Wed 3/1/06**
7	Dig Wiavers Issued	1 day	Tue 11/1/05	Tue 11/1/05
8	FAA Permit Issued	26 days	Tue 10/11/05	Tue 11/15/05
9	Process Waste Questionaire Submitted and Technical Review Package Is	47 days	Wed 12/7/05	Mon 2/13/06
10	CCAFS/KSC Welding and Burn Permit Issued	1 day	Mon 1/23/06	Mon 1/23/06
11	Block Dig Waiver Issued	1 day	Wed 3/1/06	Wed 3/1/06
12	**Site Preparation for Facility 18003**	**61 days**	**Mon 9/26/05**	**Wed 12/21/05**
13	Structural demolition at Facility 18003 (by others)	19 days	Mon 9/26/05	Fri 10/21/05
14	Ground Penetrating Radar Survey	3 days	Wed 11/2/05	Fri 11/4/05
15	Trenching for Block Dig Waiver	5 days	Mon 11/7/05	Fri 11/11/05
16	Survey Topography and Sample Locations	2 days	Mon 11/14/05	Tue 11/15/05
17	Site Leveling and Grading	5 days	Mon 12/12/05	Fri 12/16/05
18	Post Grading Survey	3 days	Mon 12/19/05	Wed 12/21/05
19	**Corrective Measures Implementation at Facility 18003**	**124 days**	**Mon 11/21/05**	**Thu 5/18/06**
20	Install flux wells / Pretreatment sampling	9 days	Mon 11/21/05	Fri 12/2/05
21	Laboratory analysis	20 days	Tue 11/22/05	Tue 12/20/05
22	ATLAS V Launch from SLC-41 Delay	3 days	Mon 1/16/06	Wed 1/18/06
23	ATLAS V Launch from SLC-41 Delay	1 day	Thu 4/20/06	Thu 4/20/06
24	**System mobilization and set-up**	**59 days**	**Mon 12/19/05**	**Tue 3/14/06**
25	Mobilization of Remedial Equipment and Utility Connection	59 days	Mon 12/19/05	Tue 3/14/06
26	Electrical Vault Installation	24 days	Tue 1/10/06	Fri 2/10/06
27	Power Available to the Site	1 day	Mon 2/13/06	Mon 2/13/06
28	System checkout, commissionings and test cells	4 days	Mon 3/20/06	Thu 3/23/06
29	Treatment of Facility 18003 source area	39 days	Fri 3/24/06	Thu 5/18/06
30	Process monitoring and analysis	39 days	Fri 3/24/06	Thu 5/18/06
31	**Demobilization**	**24 days**	**Mon 5/22/06**	**Fri 6/23/06**
32	Demobilize Equipment to 1381	19 days	Mon 5/22/06	Fri 6/16/06
33	Final cleanup and post treatment grading	5 days	Mon 6/19/06	Fri 6/23/06



Facilities 18003 and 1381 Corrective Measures Implementation
Cape Canaveral Air Force Station, Florida

Task	▨	Milestone	◆	External Tasks	▭
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 1

Figure 3-38. Treatment Timeline

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4.0 PERFORMANCE SUMMARY

Site investigations conducted during the RFI and in support of the CMS and CMD documented the presence of a groundwater plume with very high dissolved concentrations of TCE (≥ 10 mg/L) suggestive of the presence of DNAPL. The area suspected to contain DNAPL was considered the source of continuing groundwater contamination that flows to the north-northeast. The performance objective was to remove and/or destroy significant contaminant mass (including dissolved, sorbed constituents, and DNAPL) in the identified source area. The following discussion presents a summary of the baseline and post-remediation conditions, and an evaluation of the performance effectiveness of the completed remedial action. As outlined in the Work Plan (Tetra Tech, 2005), the effectiveness of the remedial action will be evaluated by:

- Comparing baseline and post-remediation concentrations of contaminants in soil and groundwater samples from the performance monitoring locations;
- Comparing baseline and post- remediation groundwater mass flux results; and
- Presenting the results from post-remediation monitoring wells to be installed across the site to demonstrate changes in plume concentrations and dimensions.

4.1 BASELINE SAMPLING

Baseline conditions refer to the distribution, frequency, concentration, and mass flux of key VOC chemicals that were present in the treatment area (source zone) or migrating immediately down-gradient of the source zone as interpreted from the results of the baseline soil, groundwater, and groundwater flux sampling. All baseline sampling was conducted prior to the initiation of the remedial action (i.e., in-situ soil mixing with steam, hot air, and ZVI injection). The baseline sampling locations are shown on Figure 4-1. The following baseline sampling was conducted:

- Soil samples were collected at eight locations (SS-01 through SS-08) distributed within the treatment area between November 29 and December 2, 2005. Multiple soil samples were collected at each location at discrete depths using direct push technology (DPT) sampling tools.
- Groundwater samples were collected at nine locations (GW-01 through GW-09) distributed within the treatment area between November 21 and November 28, 2005. Multiple groundwater grab samples were collected at each location at discrete depths using DPT sampling tools.
- Groundwater flux monitoring wells were installed in November 2005; both 1.5 and 2-inch diameter wells were installed. Passive flux meters (PFMs) were installed in the wells during two deployments, one in December 2005 and the other in January 2006. The PFMs were retrieved from the wells after a two or three week period and analyses were performed for VOCs and to estimate the groundwater flow rate and mass flux of VOCs.

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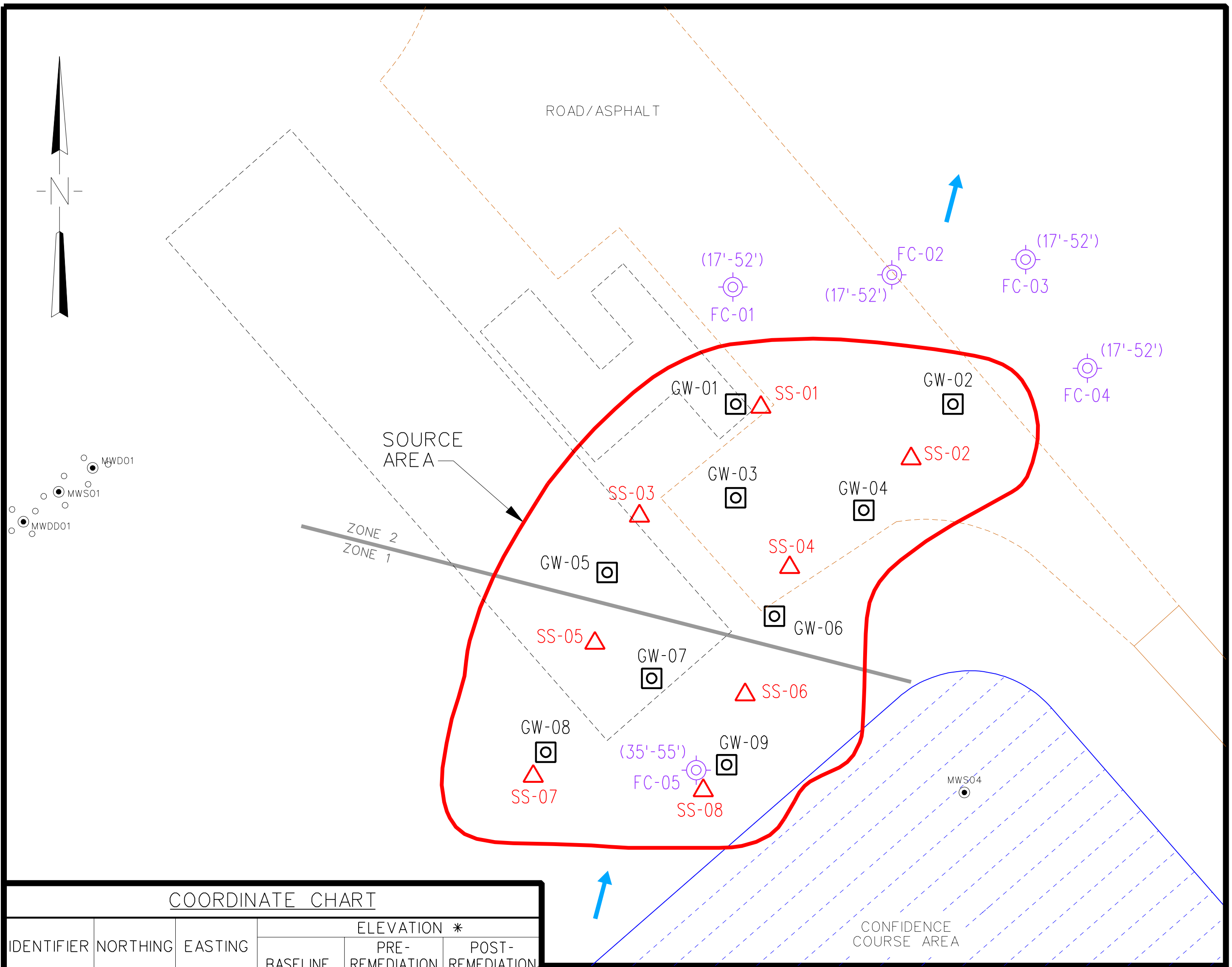

COORDINATE CHART

IDENTIFIER	NORTHING	EASTING	ELEVATION *		
			BASELINE	PRE-REMEDIATION	POST-REMEDIATION
FC-01	1495426	798349	8.1	7.4	▨
FC-02	1495428	798378	8.0	7.6	▨
FC-03	1495431	798403	7.3	7.3	▨
FC-04	1495411	798414	6.8	6.8	▨
FC-05	1495337	798342	8.3	8.3	▨
GW-01	1495404	798350	8.9	7.4	6.9
GW-02	1495404	798390	8.1	7.6	6.8
GW-03	1495387	798350	8.6	7.5	6.8
GW-04	1495385	798373	8.2	7.8	7.2
GW-05	1495373	798326	8.6	7.5	6.7
GW-06	1495365	798357	8.7	7.7	6.8
GW-07	1495353	798334	8.8	7.3	6.7
GW-08	1495340	798315	8.5	7.2	6.2
GW-09	1495338	798348	8.5	7.4	6.8
SS-01	1495403	798354	8.9	7.4	7.0
SS-02	1495394	798382	8.1	7.7	7.7
SS-03	1495383	798332	8.9	7.6	6.6
SS-04	1495374	798360	8.8	7.7	6.8
SS-05	1495360	798324	8.4	7.3	6.4
SS-06	1495350	798351	8.8	7.5	6.8
SS-07	1495335	798312	8.5	7.2	6.0
SS-08	1495333	798344	8.4	7.4	6.6

* ELEVATIONS ARE FEET ABOVE MEAN SEA LEVEL AND ARE APPROXIMATE.

LEGEND

—	DNAPL SOURCE AREA
⊡	GROUNDWATER SAMPLE
(17'-52') ⊙	FLUX CHAMBER (DEPTH BGS)
△	PRE-REMEDIATION SOIL SAMPLE
⊙	EXISTING MONITORING WELL
←	APPROXIMATE GROUNDWATER FLOW DIRECTION

30 0 30

SCALE IN FEET

Tetra Tech Inc.

OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 4-1
BASELINE AND POST-REMEDIATION SAMPLE LOCATIONS

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4.1.1 Baseline Soil Sampling

Baseline soil samples were collected at eight locations, four locations within Source Zone 1 (SZ-1, southern portion of source area) and four locations in SZ-2 (northern portion of source area), as shown in Figure 4-1. All samples were analyzed for VOCs using USEPA Method 8260 and for total iron using USEPA Method 6010. Soil samples were collected at nine depths, 15, 20, 25, 30, 35, 40, 45, 50, and 55 feet bgs, at locations SS-05 through SS-08 in SZ-1. Soil samples were collected at four depths, 15, 20, 25, and 30 feet bgs at locations SS-01 through SS-04 in SZ-2; the scheduled 30 foot sample at SS-04 was inadvertently collected at a depth of 35 feet bgs. Sampling was conducted to greater depths in SZ-1 (i.e., 55 feet bgs) due to the greater depth of source zone contamination in that area. The sampling depth in SZ-2 (i.e., 30 to 35 feet bgs) extended 5 to 10 feet deeper than the maximum depth of LDA penetration (i.e., 25 feet bgs) during subsequent treatment of the area.

A summary of the chemicals detected, number of detections, concentration range, and exceedances of the industrial direct contact and soil leaching to cleanup target levels are provided in Table 4-1. As shown in the table, cDCE, TCE, tDCE, and PCE were the most frequently detected VOCs, and these chemicals were present at the highest concentrations of all VOCs that were detected. As a point of reference, it is noted that three of these VOCs exceeded the industrial direct contact Soil Cleanup Target Level (SCTL) and all four exceeded the leaching SCTL.

Table 4-1. Soil Detection Summary - Baseline Samples

Parameter	No. Detects	No. Samples	Minimum Concentration	Maximum Concentration	Industrial SCTL[(a)]	Leaching SCTL[(a)]
Iron	52	52	1,070	11,300	na	na
cis-1,2-Dichloroethylene	47	52	2.7	240,000	180,000	400
Trichloroethylene	25	52	2.6	850,000	9,300	30
trans-1,2-Dichloroethylene	22	52	2.2	2,040	290,000	700
Tetrachloroethylene	20	52	12.2	157,000	18,000	30
1,1-Dichloroethane	8	52	4.5	294	2.10E+06	400
1,1-Dichloroethylene	7	52	324	1,180	510,000	60
Methylene chloride (b)	6	52	399	10,300	26,000	20
Carbon disulfide	5	52	1.8	204	1.50E+06	5,600
Acetone (c)	1	52	3,760	3,760	6.80E+07	25,000
Vinyl chloride	1	52	3.1	3.1	800	7

All concentration units are µg/kg, except iron which is in mg/kg.
Duplicate samples were not collected during this event.
(a) SCTL shaded if exceeded.
(b) Methylene chloride was detected in 16 additional samples, but noted as a suspected laboratory contaminant.
(c) Acetone was noted as a suspected laboratory contaminant.

4.1.2 Baseline Groundwater Sampling

Baseline groundwater samples were collected at nine locations, three locations within SZ-1 (southern portion of source area) and six locations in SZ-2 (northern portion of source area), as shown in Figure 4-1. All samples were analyzed for VOCs using USEPA Method 8260 and for total iron using USEPA Method 6010. Groundwater samples were collected at six depths, 10, 20, 30, 40, 50, and 60 feet bgs, at locations GW-07 through GW-09 in SZ-1. Groundwater samples were collected at seven depths, 10, 15, 20, 25, 30, 40, and 50 feet bgs, at locations GW-01 through GW-07 in SZ-2. The sampling depth in SZ-1 (60 feet bgs) and in SZ-2 (i.e., 50 feet bgs) extended 5 feet and 25 feet deeper, respectively, than the maximum depth of LDA penetration (i.e., 55 feet and 25 feet bgs, respectively) during subsequent treatment of the areas.

A summary of the chemicals detected, number of detections, concentration range, and exceedances of the GCTLs is provided in Table 4-2. The laboratory analysis reports are presented in Volume IV. As shown in the table, cDCE, TCE, tDCE, and PCE were the most frequently detected VOCs, and these chemicals were present at the highest concentrations of all VOCs that were detected. Hence, the groundwater results are consistent with the soil results.

Table 4-2. Groundwater Detection Summary - Baseline Samples

Parameter	No. Detects	No. Samples	Minimum Concentration	Maximum Concentration	GCTL[(a)]
Iron	60	60	250	76,400	300
cis-1,2-Dichloroethylene	64	66	0.53	582,000	70
Trichloroethylene	41	66	0.52	856,000	3
trans-1,2-Dichloroethylene	37	66	0.57	12,100	100
Tetrachloroethylene	24	66	0.62	19,500	3
1,1-Dichloroethylene	16	66	2	3,020	7
Carbon disulfide	11	66	1	6	700
1,1-Dichloroethane	10	66	3.6	3,570	70
Vinyl chloride	9	66	0.56	2,800	1
1,2-Dichloroethylene (total)	4	66	2	5	na
1,2-Dichloropropane	4	66	1.1	14	5
1,1,1-Trichloroethane	2	66	3100	3190	200
1,2-Dichloroethane	2	66	2	3	3
1,1-Dichloropropene	1	66	--	0.75	na
Acetone	1	66	5.2	5.2	6300
Chloroethane	1	66	--	1	12
Toluene	1	66	--	1	40

All concentration units are μg/L.
No. of detects and samples includes six duplicates; duplicate analysis was not conducted for iron.
(a) GCTL shaded if exceeded.

4.1.3 Baseline Groundwater Mass Flux

Multiple lines of evidence are being used to evaluate the performance of the TCE source area remedial approach via in-situ soil mixing enhanced with steam, hot air, and iron. (See discussion in EnviroFlux, 2006, in Appendix S.) One line of evidence being looked at to measure success or performance is mass flux. There is a measurable amount of contaminant mass output by the source area which ultimately creates the dissolved phase groundwater plume. This output or flux is being measured both baseline and post-remediation to support treatment effectiveness evaluations.

Contaminant flux emanating from the TCE source area is being measured using a passive type device known as a PFM that was installed in wells in and along the down-gradient perimeter of the source area. These PFMs record contaminant flux by measuring the mass of ambient groundwater and contaminant flow per unit area at a measured point in a well screen averaged over a given time period. Based upon this general definition, the units associated with mass flux are determined as:

$$flux = \frac{mass}{area \cdot time} = \left[\frac{M}{L^2 T} \right]$$

where the terms M, L, and T represent the base units of mass, length, and time, respectively. For consistency with common practice, the ambient groundwater flux will be evaluated in terms of the specific discharge or Darcy velocity, which is the volumetric water flux (or flowrate) through a specified cross-sectional area. The resulting units are L/T, Darcy velocity, which will be represented with the units of cm/day. For this performance evaluation the contaminant flux will be discussed in terms of mass flux ($M/(L^2T)$) and represented with the units of ($mg/(m^2day)$) or ($g/(m^2day)$) depending on the magnitude of the observed flux values.

Based upon previous site assessments, the expected contaminants at Facility 18003 are PCE, TCE, and dechlorination products DCE, vinyl chloride, and ethene. The intent, again, is to compare the contaminant mass discharge or flux from the source zone both baseline and post-remediation.

4.1.3.1 Flux Monitoring Network Setup and Baseline Sampling

Flux well installation began on November 21, 2005. Three 1.5-inch pre-packed flux wells were installed when it was determined that a larger diameter well was required for the PFMs. The three 1.5-inch wells were left in place and five 2-inch wells were installed. The three 1.5-inch wells were padded with the 2-inch wells and were finished with 3-foot by 3-foot by 6-foot pads and flush mounted. The network of five 2-inch diameter flux wells (FC-01, FC-02, FC-03, FC-04, and FC-05) was utilized for PFM deployment. Four of the flux wells (FC-01, FC-02, FC-03, and FC-04) were located on the down-gradient perimeter of the source area. These four wells were installed with a screen length of 35 feet from 17 feet to 52 feet bgs and form a control plane for mass discharge estimations. Well FC-05 was located within the source zone. FC-05 was installed with a screen length of 20 feet from 35 feet to 55 feet bgs. PFMs were deployed as 5-foot units with seven PFMs per each down-gradient well (matching the screen length of 35 feet) and four PFMs in the source zone well (matching the screen length of 20 feet). Locations of the flux wells are shown on Figure 4-1. Well Development Records for the flux wells are provided in Appendix T.

Following flux well installation and development, the PFMs were installed in the flux wells. The initial deployment took place December 6 and 7, 2005. Each PFM was successfully deployed with the exception of the final PFM inserted in well FC-01 (from 17 feet to 22 feet bgs). There was considerable resistance when inserting the PFM and it was damaged. Attempts to recover and replace the damaged PFM were unsuccessful, and recovery was delayed until the planned retrieval cycle.

PFM retrieval took place on December 27, 2005 (corresponding to a deployment length of 21 days). During retrieval it was noted that all of the wells except FC-05 had considerable fines present on top of and around the PFMs within the well screen. The presence of fines adversely affects PFM retrieval by increasing the friction between the PFM and the well and adding additional weight above the units, effectively lodging them in place. During retrieval 12 of the PFMs were not recovered, likely due to the presence of fines in the wells.

In order to meet the project objectives, and in the interest of time, a plan was established to re-deploy PFMs using 1.5-inch wells screened over the same depths as the 2-inch wells. The decision to use 1.5-inch wells was based upon availability of resources since three 1.5-inch wells were already previously installed at locations FC-01, FC-02, and FC-03. A new 1.5-inch well was installed at location FC-04. Note that all of the 1.5-inch wells included pre-constructed sand packs on the well screen and thus eliminated or significantly reduced the intrusion of fines. A second PFM deployment and retrieval cycle using the 1.5-inch wells was performed on January 10 and January 25, 2006 (corresponding to a deployment length of 15 days).

4.1.3.2 Baseline Flux Sampling Results

The flux data for the 2-inch and 1.5-inch wells are summarized in Tables 2 and 3 in Appendix S. The data are displayed in Figures 1 and 2 in Appendix S. It should be noted that the units (mg/(m^2day)) are the same as (mg/m^2/day).

In general the trends and magnitudes observed between the two deployments (1.5-inch and 2-inch wells) are comparable. The flux well FC-01 profile for DCE (for which there was no 2-inch data) compares well with the other down-gradient flux wells (FC-02, FC-03, and FC-04). The general trend of high flux in the upper portion of the well that decreases with depth agrees with existing water quality data at the site. The Darcy velocities for the 1.5-inch wells are higher than the 2-inch wells (mean 7.7 cm/day vs 6.4 cm/day) and this is likely a result of differences in convergence or divergence at the well screen or possibly based on the build-up of fines. Based on the data collected to date the 1.5-inch wells appear to provide comparable data in terms of overall flux magnitude. At this point both the 1.5-inch and 2-inch scenarios are being looked at the same; no correct factor has been established.

The contaminant mass flux values measured at the local vertical scale (1.5 foot intervals) can be integrated to find the mass discharge at each well and/or for a transect of wells. Kübert and Finkel (2006) present a review of the methods and errors associated with mass flux integrations. The following equation is used.

$$W_{cp} = \sum_{n=1}^{n_{well}} \left(\sum_{m}^{m_{ver}} F_{n,m} A_{n,m} \right)$$

For analysis of the Facility 18003 data, wells FC-01 through FC-04 were used to form a control plane with a well spacing of 30 feet to evaluate mass flow leaving the source area. The mass discharges for each well are presented in Table 4-3. The total mass discharge (Wcp) sums the individual wells along the transect (FC-01 through FC-04). Based upon PCE, TCE, cis-DCE, and vinyl chloride, approximately 173 grams of VOCs leave the source through this transect per day. The majority of the mass during baseline was cis-DCE from FC-02. Approximately 21 of the 173 grams/day is TCE. Both the total VOC and TCE numbers will be evaluated over time (post-treatment) to measure performance based upon a reduction in mass emitted from the source area.

For FC-05, the flux well placed directly in the source area, the results indicate a significant mass flow. Based upon PCE, TCE, cis-DCE, and vinyl chloride, approximately 191 grams/day of VOCs impacted this flux well. The majority of the mass during baseline was TCE. Approximately 146 of the 191 grams is TCE. Both the total VOC and TCE numbers will be evaluated over time to measure performance based upon a reduction in mass flow in this area. For post-treatment monitoring the flux well (FC-05) will be re-installed.

This data set provides a baseline for comparison following remedial activities at the site.

Table 4-3. Integral estimates of mass discharge at each well and the down-gradient transect

Well	PCE (g/day)	TCE (g/day)	Cis-DCE (g/day)	Vinyl Chloride (g/day)	Ethene (g/day)
FC-01	0.0	20.4	28.3	0.0	0.0
FC-02	0.0	0.0	95.5	0.0	0.0
FC-03	0.0	0.37	19.4	1.60	0.03
FC-04	0.0	0.0	3.87	3.66	0.38
FC-05	24.1	146	21.4	0.01	0.0
Transect W_{cp}	0.0	20.8	147	5.26	0.41

4.2 POST-REMEDIATION SAMPLING

Post-remediation conditions refer to the distribution, frequency, concentration, and mass flux of key VOC chemicals that were present in the treatment area following completion of the in-situ soil mixing with steam, hot air, and ZVI injection that was performed at Facility 18003. Post-remediation soil and groundwater sampling was conducted at the same locations and at the same depths, and using the sample DPT technology and sampling methodology as described above for the baseline sampling (see Section 4.1), with a few exceptions, as follows:

- Soil samples were collected at eight locations (SS-01 through SS-08) distributed within the treatment area on December 19 and 21, 2006. Multiple soil samples were collected at each location at discrete depths using DPT sampling tools.
- Groundwater samples were collected at nine locations (GW-01 through GW-09) distributed within the treatment area between November 13 and December 11 through 19, 2005; a break in sampling between mid-November and early December occurred because of NASA restrictions on site work related to missile launch time frames. Multiple groundwater grab samples were collected at each location at discrete depths using DPT sampling tools.
- The installation of groundwater flux monitoring wells is required to replace the baseline wells that were damaged during the remedial activity. The replacement wells and PFMs will be installed at a future date to provide additional data on the post-remediation groundwater flow rate and mass flux of VOCs.

4.2.1 Post-Remediation Soil Sampling

Post-remediation soil samples were collected at eight locations, four locations within SZ-1, the southern portion of source area, and four locations in SZ-2, the northern portion of source area, as shown in Figure 4-1. All samples were analyzed for VOCs using USEPA Method 8260 and for total iron using USEPA Method 6010. Soil samples were collected at nine depths, 15, 20, 25, 30, 35, 40, 45, 50, and 55 feet bgs, at locations SS-05 through SS-08 in SZ-1. Soil samples were collected at four depths, 15, 20, 25, and 30 feet bgs, at locations SS-01 through SS-04 in SZ-2. As mentioned previously, sampling was conducted to greater depths in SZ-1 due to the greater depth of source contamination in that area, and the sampling depth in SZ-2 extended 5 feet below the depth of LDA penetration (i.e., 30 feet vs. 25 feet)

A summary of the chemicals detected, number of detections, concentration range, and exceedances of the industrial direct contact and soil leaching to cleanup target levels are provided in Table 4-4. As shown in the table, cDCE, TCE, tDCE, and PCE that were the most frequently detected VOCs in the baseline sampling were present in the post-remediation samples, although not at the highest concentrations of all VOCs that were detected. Because of the greater reduction in the maximum concentrations of VOCs that were detected in the post-remediation samples, compared to the baseline samples, the detection limits achieved by the laboratory were significantly lower. As a result, non-target VOCs such as carbon disulfide, and suspected laboratory contaminants such as acetone, were detected at a much greater frequency than in the baseline samples. As a point of reference, it is noted that none of the post-remediation samples contained concentrations of cDCE, TCE, tDCE, or PCE that exceeded the industrial direct contact SCTLs.

Table 4-4. Soil Detection Summary – Post-Remediation Samples

Parameter	No. Detects	No. Samples	Minimum Concentration	Maximum Concentration	Industrial SCTL[(a)]	Leaching SCTL[(a)]
Iron	57	57	1220	20100	na	na
Carbon disulfide	54	57	5.1	143	1.50E+06	5,600
Acetone	51	57	35.1	531	6.8E+07	25,000
cis-1,2-Dichloroethylene	47	57	2.3	14400	180,000	400
Trichloroethylene	43	57	2.8	56.9	9,300	30
Methyl ethyl ketone	40	57	12.1	208	1.1E+08	17,000
Acrolein	11	57	19.5	58.7	300	10
2-Hexanone	8	57	12.5	25.9	130,000	1,400
trans-1,2-Dichloroethylene	8	57	5.4	273	290,000	700
1,1-Dichloroethane	6	57	3.2	36.9	2.1E+06	400
Vinyl chloride	6	57	5.3	166	800	7
1,1-Dichloroethylene	3	57	2.6	18.5	510,000	60
Tetrachloroethylene	2	57	9.8	54.2	18,000	30
Toluene	2	57	3.7	4.9	6.0E+07	500

All concentration units are μg/kg, except iron is mg/kg.
No. of samples and detects includes five duplicates.
[(a)] SCTL shaded if exceeded.

4.2.2 Post-Remediation Groundwater Sampling

Baseline groundwater samples were collected at nine locations, three locations within SZ-1 (southern portion of source area) and six locations in SZ-2 (northern portion of source area), as shown in Figure 4-1. All samples were analyzed for VOCs using USEPA Method 8260 and for total iron using USEPA Method 6010. Groundwater samples were collected at six depths, 10, 20, 30, 40, 50, and 60 feet bgs, at locations GW-07 through GW-09 in SZ-1. Groundwater samples were collected at seven depths, 10, 15, 20, 25, 30, 40, and 50 feet bgs, at locations GW-01 through GW-07 in SZ-2.

A summary of the chemicals detected, number of detections, concentration range, and exceedances of the GCTLs are provided in Table 4-5. As shown in the table, cDCE, TCE, tDCE, and PCE that were the most frequently detected VOCs in the baseline sampling were present in the post-remediation samples, although not at the highest concentrations of all VOCs that were detected. Because of the greater reduction in the maximum concentrations of VOCs that were detected in the post-remediation samples, compared to the baseline samples, the detection limits achieved by the laboratory were significantly lower. As a result, non-target VOCs such as toluene, and suspected laboratory contaminants such as acetone, were detected at a much greater frequency than in the baseline samples.

Table 4-5. Groundwater Detection Summary – Post-Remediation Samples

Parameter	No. Detects	No. Samples	Minimum Concentration	Maximum Concentration	GCTL[(a)]
Iron	64	64	253	908000	300
Acetone	49	64	0.39	16000	6300
cis-1,2-Dichloroethylene	47	64	0.57	52500	70
Toluene	35	64	0.54	26.3	40
Benzene	31	64	0.74	15.8	1
Methyl ethyl ketone	28	64	2.7	3230	4200
trans-1,2-Dichloroethylene	20	64	0.059	1360	100
2-Hexanone	19	64	3.9	238	280
Carbon disulfide	18	64	1	3.5	700
Vinyl chloride	15	64	0.63	2690	1
4-Methyl-2-pentanone	13	64	4	60	na
Trichloroethylene	13	64	0.019	50000	3
1,1-Dichloroethane	11	64	1.4	233	70
Naphthalene	5	64	1.1	2.1	14
1,2-Dichloropropane	4	64	0.89	6.2	5
Methylene chloride	4	64	1.4	56.7	5
Tetrachloroethylene	3	64	4.1	10.4	3
1,1-Dichloroethylene	2	64	7.3	10.6	7
Ethylbenzene	2	64	0.57	0.57	30
m,p-Xylene	2	64	0.52	0.65	20

All concentration units are µg/L.
No. of samples and detects includes seven duplicates.
(a) GCTL shaded if exceeded.

4.2.3 Post-Remediation Groundwater Mass Flux Sampling

The five flux wells that were used during the baseline sampling were either destroyed (FC-05), damaged, or deemed suspect due to nearby operation of the LDA and the effects of temperature increases (FC-01through FC-04). These wells are scoped for replacement at which time PFMs will be installed and sampled to provide additional data on the post-remediation groundwater flow velocity and the flux of any residual VOCs through the aquifer.

4.3 PERFORMANCE EVALUATION

The goal of the remedial action at the SPCC was to reduce the mass of contaminants in the source area. The source area was defined as an area of the aquifer that contained greater than 10 ppm of TCE in the groundwater. Based on data presented in the CMS and CMD reports, the source area was divided into two treatment zones based on the depth of contamination: SZ-1 in the southern portion of the source area that contained targeted contaminant mass to a depth of 55 feet bgs; and SZ-2 that contained targeted contaminant mass to a depth of 25 feet bgs. This section evaluates the performance of the remedial action using four primary metrics, as follows:

- Comparison of the baseline and post-remediation concentrations of TCE and associated chlorinated VOCs in the soil
- Comparison of the baseline and post-remediation concentrations of TCE and associated chlorinated VOCs in the groundwater
- Comparison of changes in the groundwater contaminant flux through the source zone and immediately downgradient
- Document changes in the groundwater plume and the presence/absence of groundwater "source" concentrations at the site based on monitoring well data

As indicated above, the mass removal strategy was based on the concentration of TCE in the groundwater within the source area. In addition, the baseline sample data for soil and groundwater (see Tables 4-1 and 4-2) demonstrated that TCE and associated chlorinated VOCs PCE, cDCE, and tDCE were the primary VOCs present in the source area. Furthermore, the mass removal data presented in Section 5.1 show that these four VOCs accounted for the majority of chemical mass in the source area. Therefore, the data and discussion presented in this section focus on these four "target" VOC contaminants. It should be noted that soil sampling locations SS-02 and SS-04 in SZ-2 were not in treatment cells, but within a 4-foot radius of nearby cells. It should also be noted that post-remediation soil and groundwater DPT samples were collected at one to three depth intervals (i.e., 5 to 15 feet) greater than the depth of treatment in SZ-2. Samples were collected at all of these locations to be consistent with the baseline sampling. However, only samples that were collected from within the LDA treatment cells and depths are used in this performance evaluation. Samples collected at locations or depths that were not directly treated do not provide data on the performance of the technology.

4.3.1 Soil Evaluation

Baseline and post-remediation soil sampling results were presented in Sections 4.1.1 and 4.2.1. The samples were collected at the same locations and depth intervals, with one exception at SS-04, as indicated in Table 4-6. Also noted in the table are the sample intervals at depths greater than the depth of LDA penetration at each sample location.

One measure of performance consists of comparing the concentrations of target VOCs in the soil before and after completion of the remediation. The baseline and post-remediation maximum concentrations of the target VOCs in soil are presented in Table 4-7 and the percent reduction in the maximum concentration is provided. The concentration of iron is also provided in the table as a point of interest related to the injection of ZVI during the remedial action. It should be noted that some of the maximum concentrations presented in Table 4-4 occurred in samples that were not treated; however, the maximums presented in Table 4-7 only include results from treated samples.

Table 4-6. Comparison of Baseline and Post-Remediation Soil Sample Density

Location	Soil Sample Depth, feet								
	15	20	25	30	35	40	45	50	55
SS-01	X	X	X	X					
SS-02	X	X	X	X					
SS-03	X	X	X	X					
SS-04	X	X	X	P	B				
SS-05	X	X	X	X	X	X	X	X	X
SS-06	X	X	X	X	X	X	X	X	X
SS-07	X	X	X	X	X	X	X	X	X
SS-08	X	X	X	X	X	X	X	X	X

X - Samples collected during both sampling events; blank cell indicates not sampled.
B - Baseline only; P - Post-remediation only.
Shading indicates samples not within a treatment cell and/or samples below LDA penetration depth.

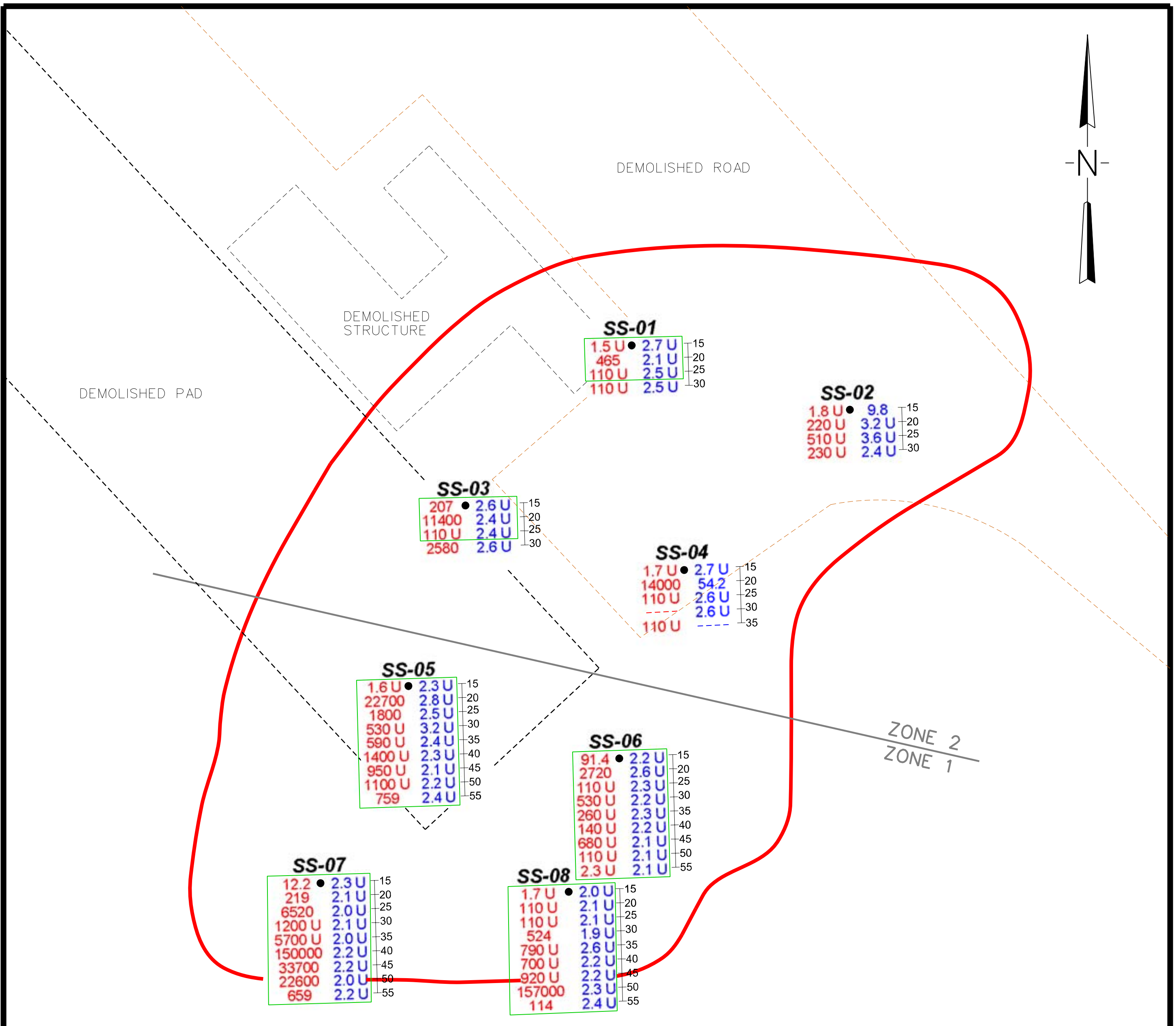
Table 4-7. Comparison of Maximum Concentrations in Soil

Chemical	Baseline Maximum	Post Maximum	Percent Reduction
Tetrachloroethylene	157000	2.7U	>99.99
Trichloroethylene	850000	15	>99.99
cis-1,2-Dichloroethylene	240000	6.5	>99.99
trans-1,2-Dichloroethylene	2040	3.2U	>99.99
Iron	11300	20100	increase

All concentration units are μg/kg, except iron is mg/kg.

As can be seen in Table 4-7, maximum concentrations were reduced by three to five orders of magnitude, and the reduction in maximum concentrations for each of the target VOCs were greater than 99%. A location by location and depth by depth comparison of the reduction in concentrations achieved by the remedial action can be seen in Figures 4-2 through 4-5 that present the baseline and post-remediation concentrations for each target VOC at all depths at each sampling location. Samples that were collected outside of treatment cells or below the depth of LDA penetration are noted on the figures; data from these locations were not used in the performance evaluation.

It was observed that all of the baseline maximum concentrations occurred in SZ-1 (SS-07 and SS-08) at depths between 35 and 50 feet bgs, with the exception of the maximum for tDCE that was found at a depth of 20 feet bgs at SS-04 in SZ-2. However, very high detection limits for tDCE (due to analytical interference from high concentrations of other target VOCs) in SZ-1 suggest that the maximum tDCE concentration was likely to have occurred in SZ-1. A review of the data presented for locations SS-07 and SS-08 in Figures 4-2 through 4-5 reveals the high degree of concentration reduction that was achieved in these areas.



LEGEND

RESULTS WITHIN TREATMENT DEPTH

SOIL DPT LOCATION

POST REMEDIATION SAMPLE RESULTS (SEE NOTE 2)

91.4	2.2 U	15
2720	2.6 U	20
110 O	2.3 U	25
530 U	2.2 U	30
260 U	2.3 U	35 SAMPLE DEPTH SCALE ft/bgs
140 U	2.2 U	40
680 U	2.1 U	45
110 U	2.1 U	50
2.3 U	2.1 U	55

BASELINE SAMPLE RESULTS (SEE NOTE 3)

U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)

20 0 20

SCALE IN FEET

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 15, 20, 25, 30, 35, 40, 45, 50, 55 FEET BELOW GROUND SURFACE (ft/bgs)
5. 35 TO 55 ft/bgs INTERVAL ONLY AT SS-05, SS-06, SS-07, AND SS-08
6. RESULTS ARE mg/kg

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FIGURE 4-2
COMPARISON OF BASELINE AND POST REMEDIATION PCE IN SOIL

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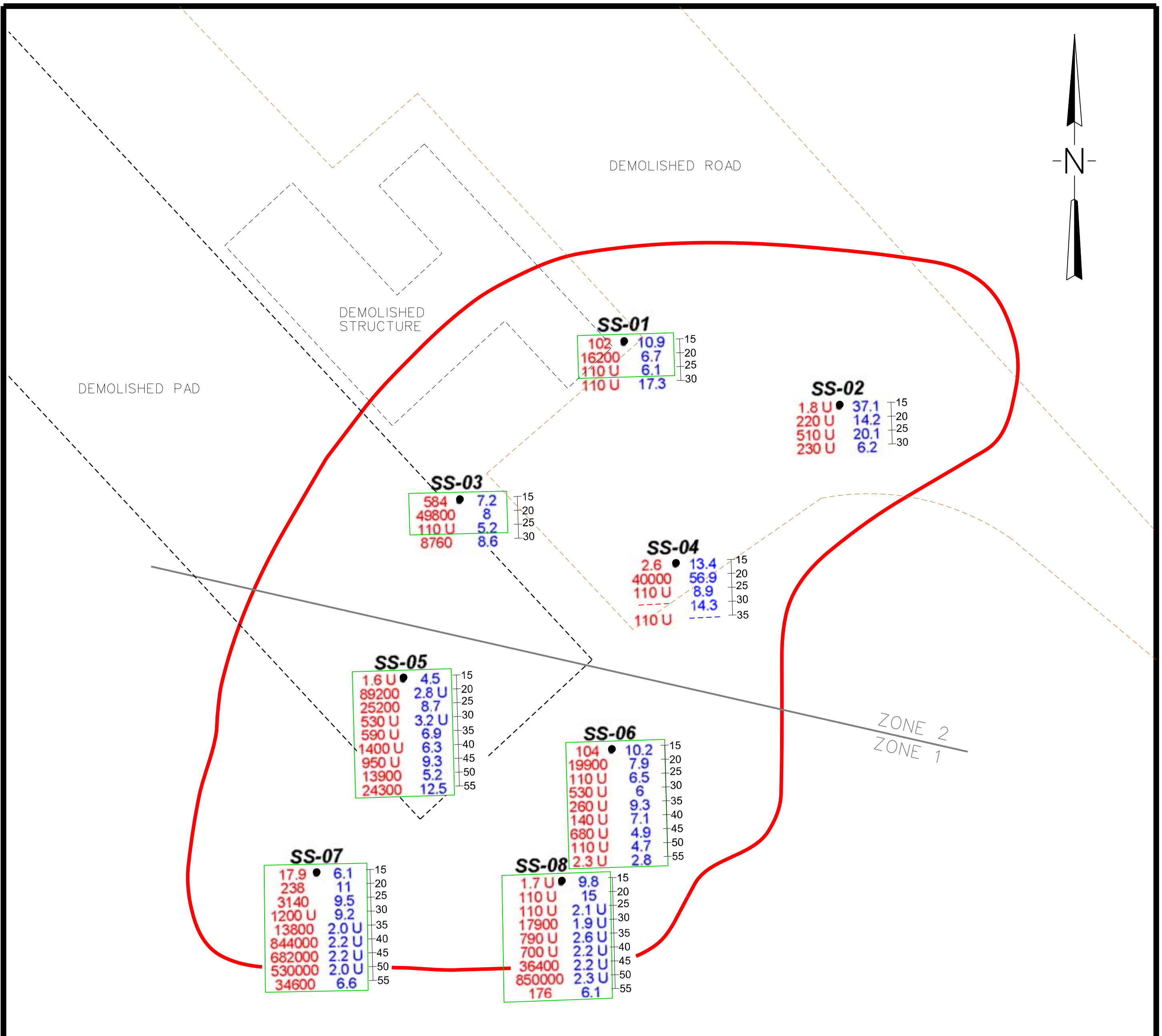

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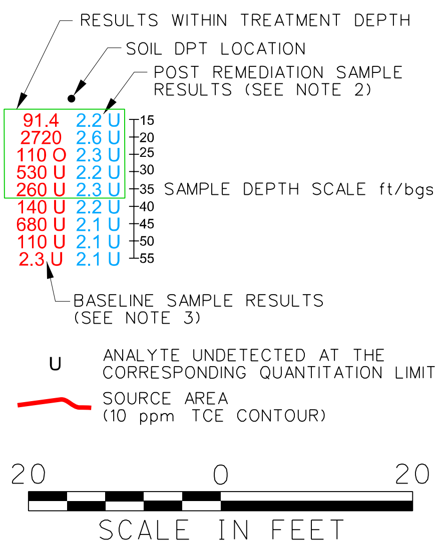

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 15, 20, 25, 30, 35, 40, 45, 50, 55 FEET BELOW GROUND SURFACE (ft/bgs)
5. 35 TO 55 ft/bgs INTERVAL ONLY AT SS-05, SS-06, SS-07, AND SS-08
6. RESULTS ARE mg/kg

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FIGURE 4-3
COMPARISON OF BASELINE AND POST REMEDIATION TCE IN SOIL

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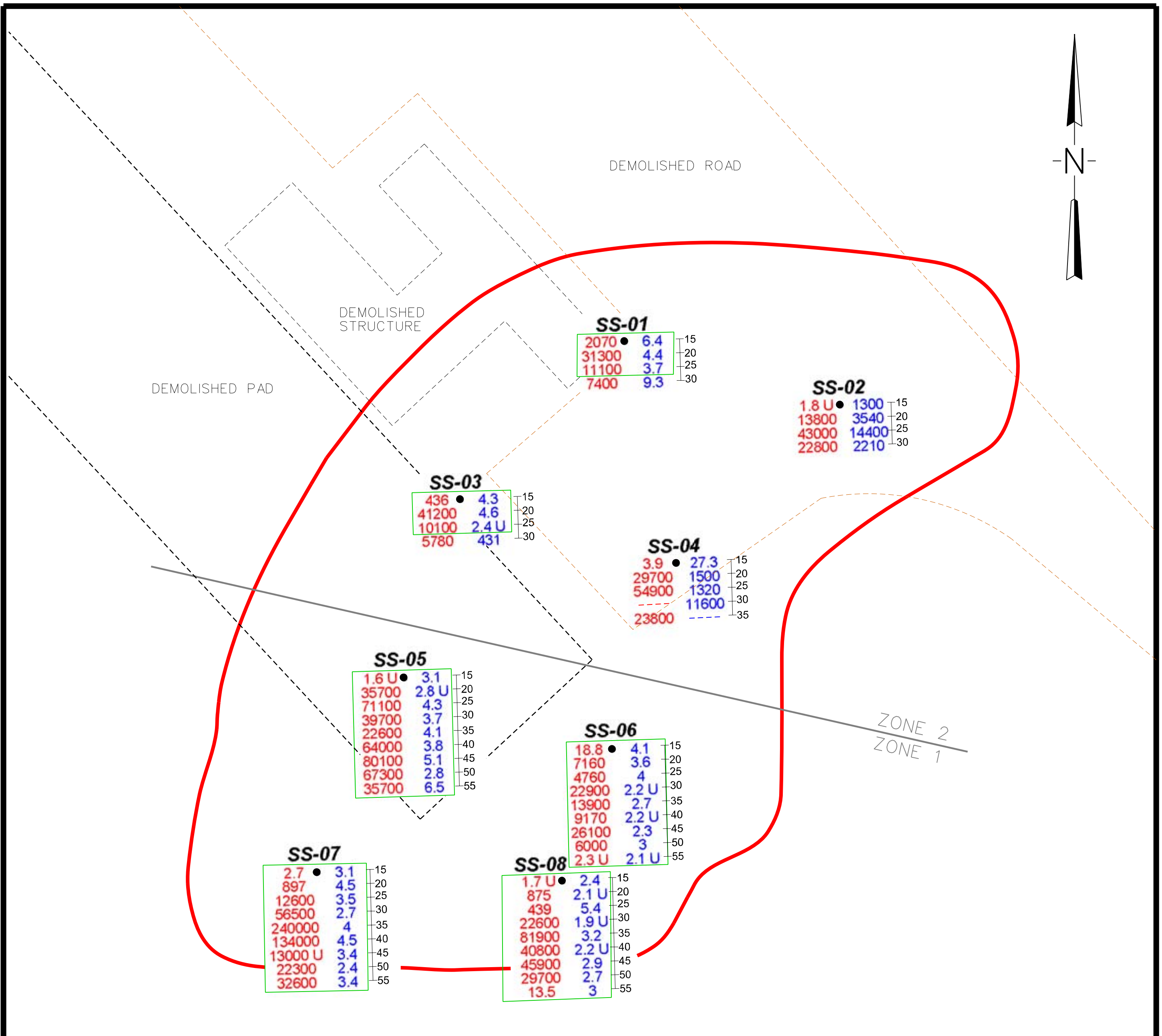

LEGEND

RESULTS WITHIN TREATMENT DEPTH

SOIL DPT LOCATION

POST REMEDIATION SAMPLE RESULTS (SEE NOTE 2)

91.4	2.2 U	15
2720	2.6 U	20
110 O	2.3 U	25
530 U	2.2 U	30
260 U	2.3 U	35 SAMPLE DEPTH SCALE ft/bgs
140 U	2.2 U	40
680 U	2.1 U	45
110 U	2.1 U	50
2.3 U	2.1 U	55

BASELINE SAMPLE RESULTS (SEE NOTE 3)

U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)

20 0 20

SCALE IN FEET

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 15, 20, 25, 30, 35, 40, 45, 50, 55 FEET BELOW GROUND SURFACE (ft/bgs)
5. 35 TO 55 ft/bgs INTERVAL ONLY AT SS-05, SS-06, SS-07, AND SS-08
6. RESULTS ARE mg/kg

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FIGURE 4-4
COMPARISON OF BASELINE AND
POST REMEDIATION
cis-1,2-DCE IN SOIL

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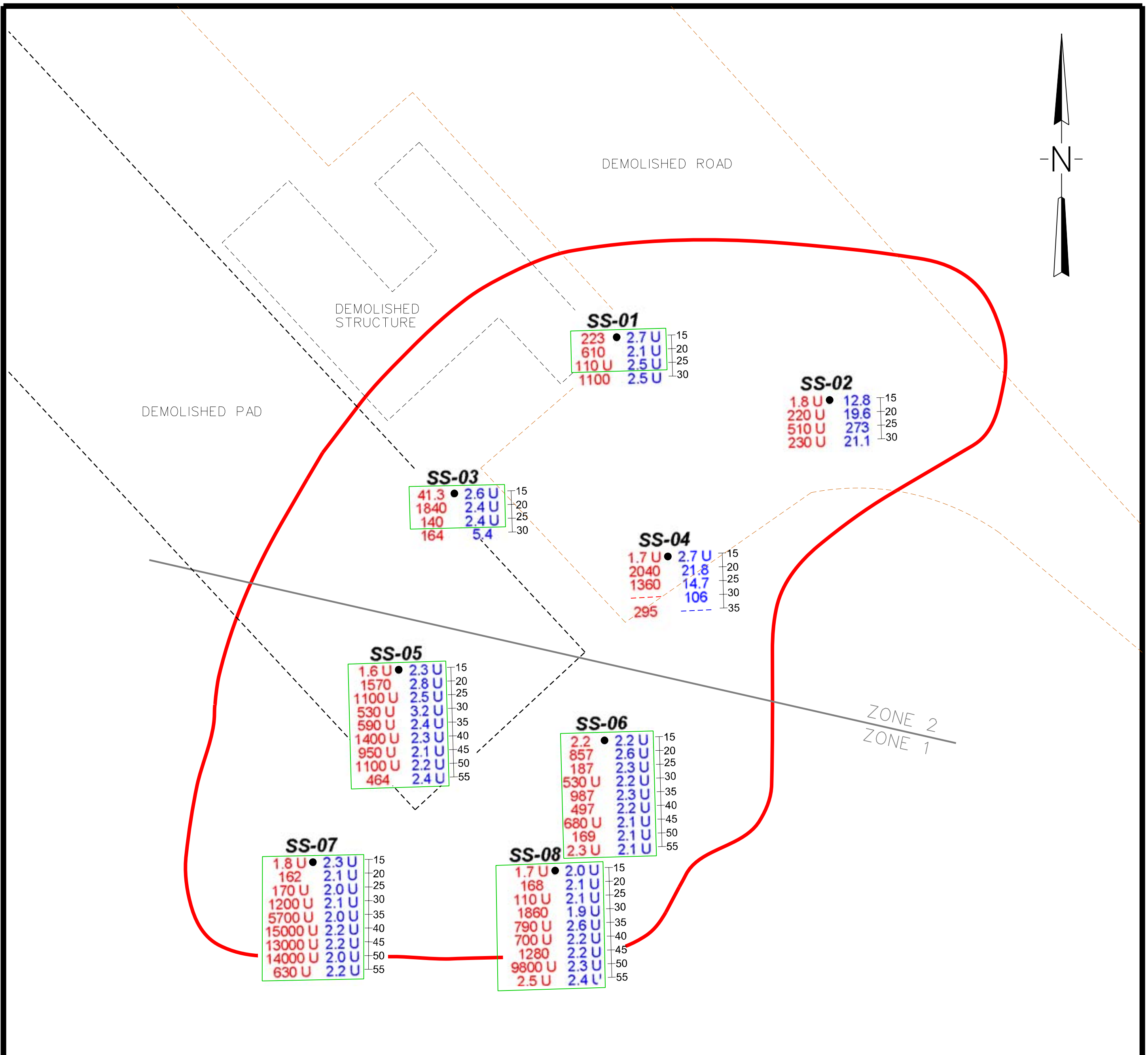

LEGEND

RESULTS WITHIN TREATMENT DEPTH

SOIL DPT LOCATION ●

POST REMEDIATION SAMPLE RESULTS (SEE NOTE 2)

91.4	2.2 U	15
2720	2.6 U	20
110 O	2.3 U	25
530 U	2.2 U	30
260 U	2.3 U	35 SAMPLE DEPTH SCALE ft/bgs
140 U	2.2 U	40
680 U	2.1 U	45
110 U	2.1 U	50
2.3 U	2.1 U	55

BASELINE SAMPLE RESULTS (SEE NOTE 3)

U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)

20 0 20

SCALE IN FEET

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 15, 20, 25, 30, 35, 40, 45, 50, 55 FEET BELOW GROUND SURFACE (ft/bgs)
5. 35 TO 55 ft/bgs INTERVAL ONLY AT SS-05, SS-06, SS-07, AND SS-08
6. RESULTS ARE mg/kg

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FIGURE 4-5
COMPARISON OF BASELINE AND POST REMEDIATION trans-1,2-DCE IN SOIL

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4.3.2 Groundwater Evaluation

Baseline and post-remediation groundwater sampling results were presented in Sections 4.1.2 and 4.2.2. The samples were collected at the same locations and depth intervals, with three exceptions, as indicated in Table 4-8. Also noted in the table are the sample intervals at depths greater than the depth of LDA penetration at each sample location.

Table 4-8. Comparison of Baseline and Post-Remediation Groundwater Sample Density

Location	Groundwater Sample Depth, feet							
	10	15	20	25	30	40	50	60
GW-01	X	X	X	X	X	X	X	
GW-02	X	X	X	X	X	X	X	
GW-03	X	X	X	X	X	X	X	
GW-04	X	X	X	X	X	X	X	
GW-05	X	X	X	X	X	X	X	
GW-06	X	X	X	X	X	X	X	
GW-07	X		B		X	X	X	X
GW-08	B		X		X	X	X	B
GW-09	X		X		X	X	X	X

X - Samples collected during both sampling events; blank cell indicates not sampled.
B - Baseline only; P - Post-remediation only.
Shading indicates samples below LDA penetration depth.

One measure of performance consists of comparing the concentrations of target VOCs in the groundwater before and after completion of the remediation. The baseline and post-remediation maximum concentrations of the target VOCs in groundwater are presented in Table 4-9 and the percent reduction in the maximum concentration is provided. The concentration of iron is also provided in the table as a point of interest related to the injection of ZVI during the remedial action. It should be noted that the post-remediation maximum concentrations for TCE, cDCE, and tDCE occurred in samples below the depth of LDA penetration; however, because only sample data from within the treatment depth is presented in Table 4-9, the post-remediation maximums presented in Table 4-9 are not the same as presented in Table 4-5.

Table 4-9. Comparison of Maximum Concentrations in Groundwater

Chemical	Baseline Maximum	Post Maximum	Percent Reduction
Tetrachloroethylene	19500	10.4	99.95
Trichloroethylene	856000	175	99.98
cis-1,2-Dichloroethylene	582000	28100	95.17
trans-1,2-Dichloroethylene	12100	676	94.41
Iron	76400	908000	increase

All concentration units are μg/L.

As can be seen in Table 4-9, maximum concentrations were reduced by one to three orders of magnitude, and the reduction in maximum concentrations for each of the target VOCs ranged from greater than 99% to 94%. A location by location and depth by depth comparison of the reduction in concentrations achieved by the remedial action can be seen in Figures 4-6 through 4-9 that present the baseline and post-remediation concentrations for each target VOC at all depths at each sampling location. Samples that were collected below the depth of LDA penetration are noted on the figures; data from these locations can not be used in the performance evaluation.

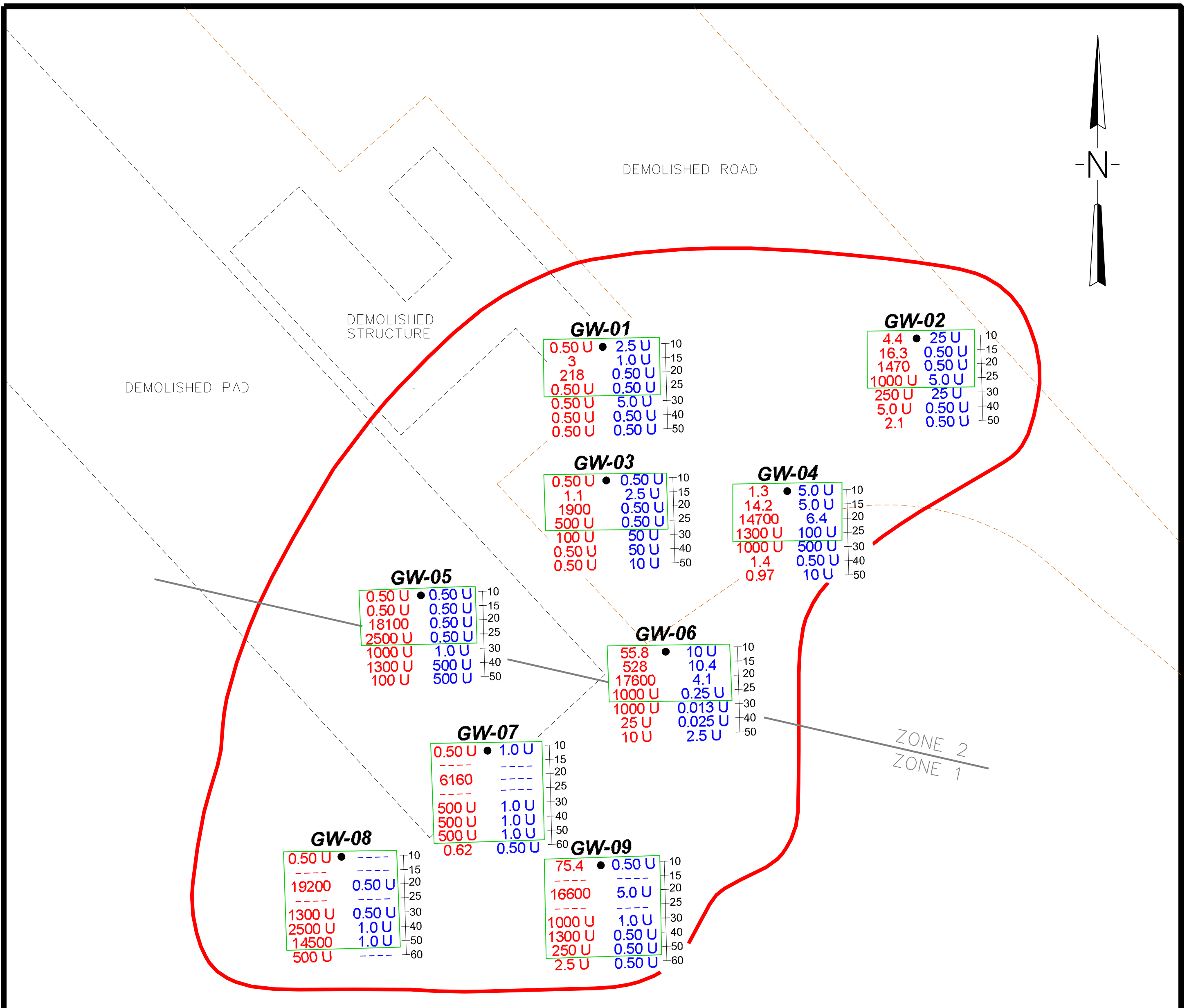
It was observed that all of the baseline maximum concentrations occurred in SZ-1 (GW-08) at depths between 20 and 50 feet bgs, with the exception of the maximum for tDCE that was found at a depth of 25 feet bgs at GW-05 in SZ-2. Unlike the observed tDCE maximum for soil (see Section 4.3.1) the groundwater detection limits for tDCE in SZ-1 do not appear to have biased the location of the maximum concentration. All of the post-remediation maximum concentrations occurred in SZ-2 at location GW-04 (25 feet bgs) and GW-06 (15 and 20 feet bgs); both of these were located along the eastern edge of the central LDA cells (i.e., non-perimeter cells) and at locations where the total treatment time in the cell was typically less (due to lower concentrations and treatment protocols) than cells located in SZ-1.

4.3.3 Groundwater Flux Evaluation

Baseline groundwater flux measurement results were presented in Section 4.1.3. The post-remediation flux measurements will be collected at the same locations and depth intervals within the aquifer. As noted in Section 4.2.3, the flux wells using during the baseline sampling were destroyed or damaged and replacement wells have not been installed to date. The future installation and sampling of the flux wells and PFMs will provide additional data that can be used to monitor the post-remediation groundwater flow velocity and flux of VOCs at the site.

4.3.4 Source Area and Plume Evaluation

Following the completion of the remedial action, multi-chamber monitoring wells were installed at nine locations within the treatment zone. An additional eight 2-inch diameter monitoring wells are scoped to be installed within and around the previously defined source area at the SPCC. Future sampling data from these wells will be used to confirm the DPT groundwater sampling results presented above, to define the presence/absence of the source area following completion of the remedial action, to define the dissolved groundwater plume, and to monitor the long-term impacts of the remedial action on groundwater quality.



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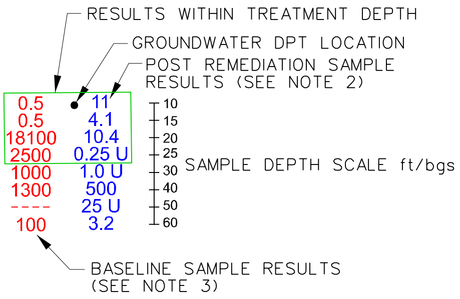
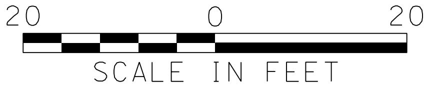


U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)



NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 10, 15, 20, 25, 30, 40, 50, 60 FEET BELOW GROUND SURFACE (ft/bgs)
5. 60ft/bgs INTERVAL ONLY AT GW-07, GW-08, AND GW-09
6. RESULTS ARE $\mu g/L$

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FIGURE 4-6
COMPARISON OF BASELINE AND
POST REMEDIATION PCE IN GROUNDWATER

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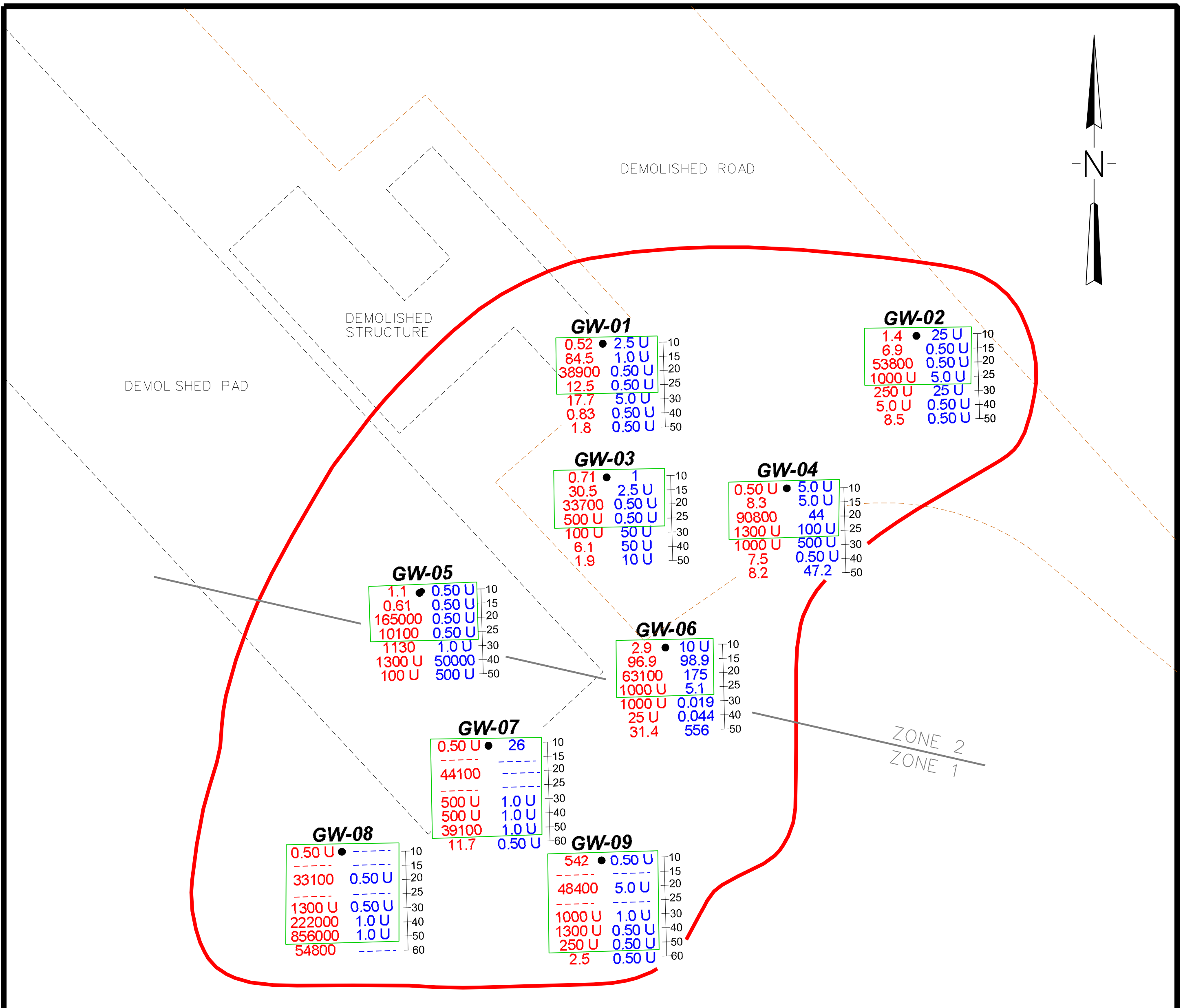

LEGEND

RESULTS WITHIN TREATMENT DEPTH

GROUNDWATER DPT LOCATION

POST REMEDIATION SAMPLE RESULTS (SEE NOTE 2)

0.5	11	10
0.5	4.1	15
18100	10.4	20
2500	0.25 U	25
1000	1.0 U	30
1300	500	40
----	25 U	50
100	3.2	60

SAMPLE DEPTH SCALE ft/bgs

BASELINE SAMPLE RESULTS (SEE NOTE 3)

U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)

20 0 20

SCALE IN FEET

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 10, 15, 20, 25, 30, 40, 50, 60 FEET BELOW GROUND SURFACE (ft/bgs)
5. 60ft/bgs INTERVAL ONLY AT GW-07, GW-08, AND GW-09
6. RESULTS ARE $\mu g/L$

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FIGURE 4-7
COMPARISON OF BASELINE AND
POST REMEDIATION TCE IN GROUNDWATER

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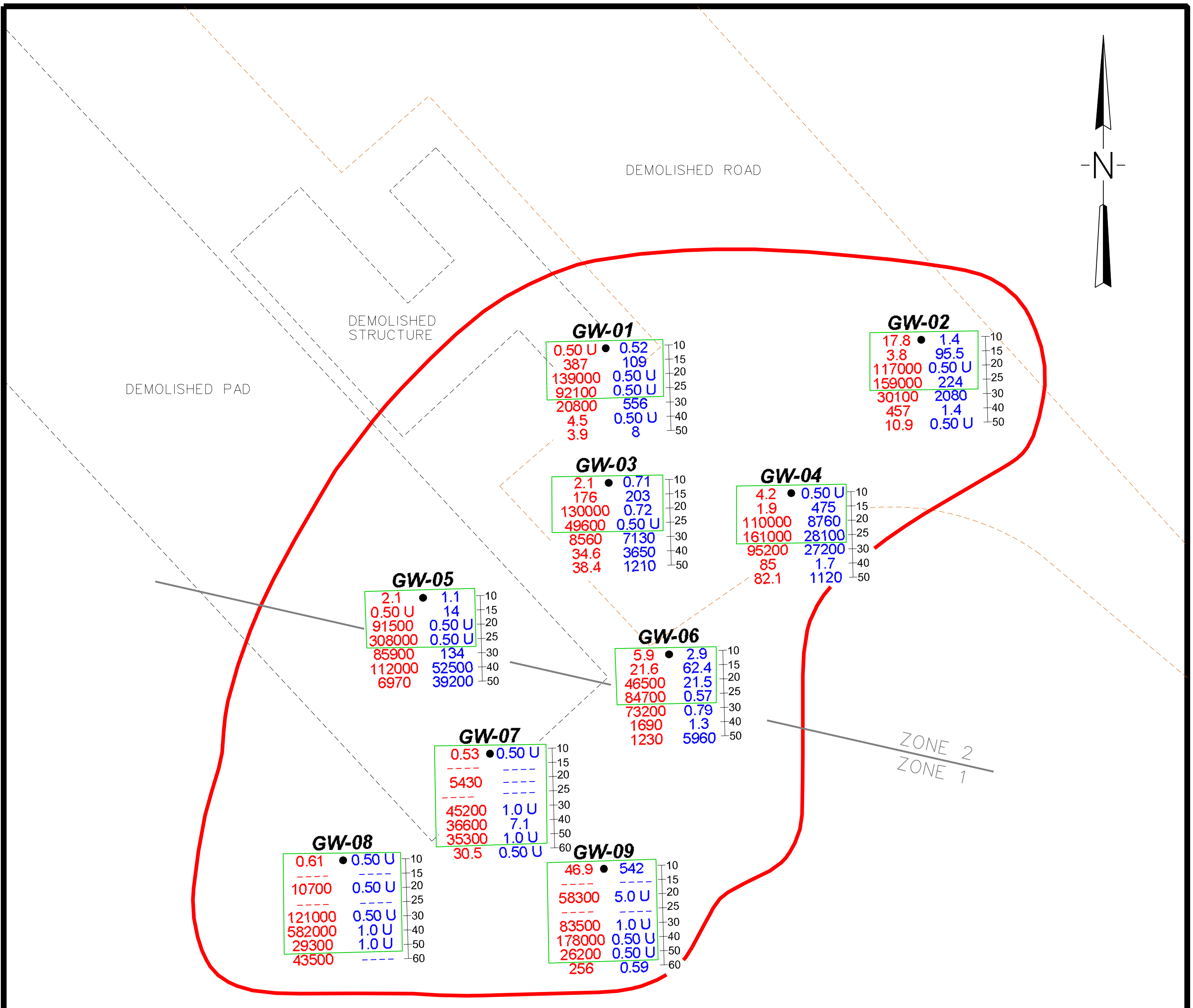

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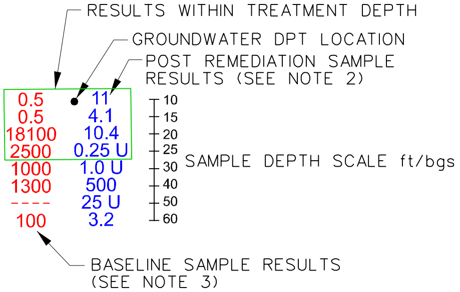

U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

SOURCE AREA (10 ppm TCE CONTOUR)

20 0 20
SCALE IN FEET

NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 10, 15, 20, 25, 30, 40, 50, 60 FEET BELOW GROUND SURFACE (ft/bgs)
5. 60ft/bgs INTERVAL ONLY AT GW-07, GW-08, AND GW-09
6. RESULTS ARE μg/L

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FIGURE 4-8
COMPARISON OF BASELINE AND
POST REMEDIATION cis-1,2-DCE
IN GROUNDWATER

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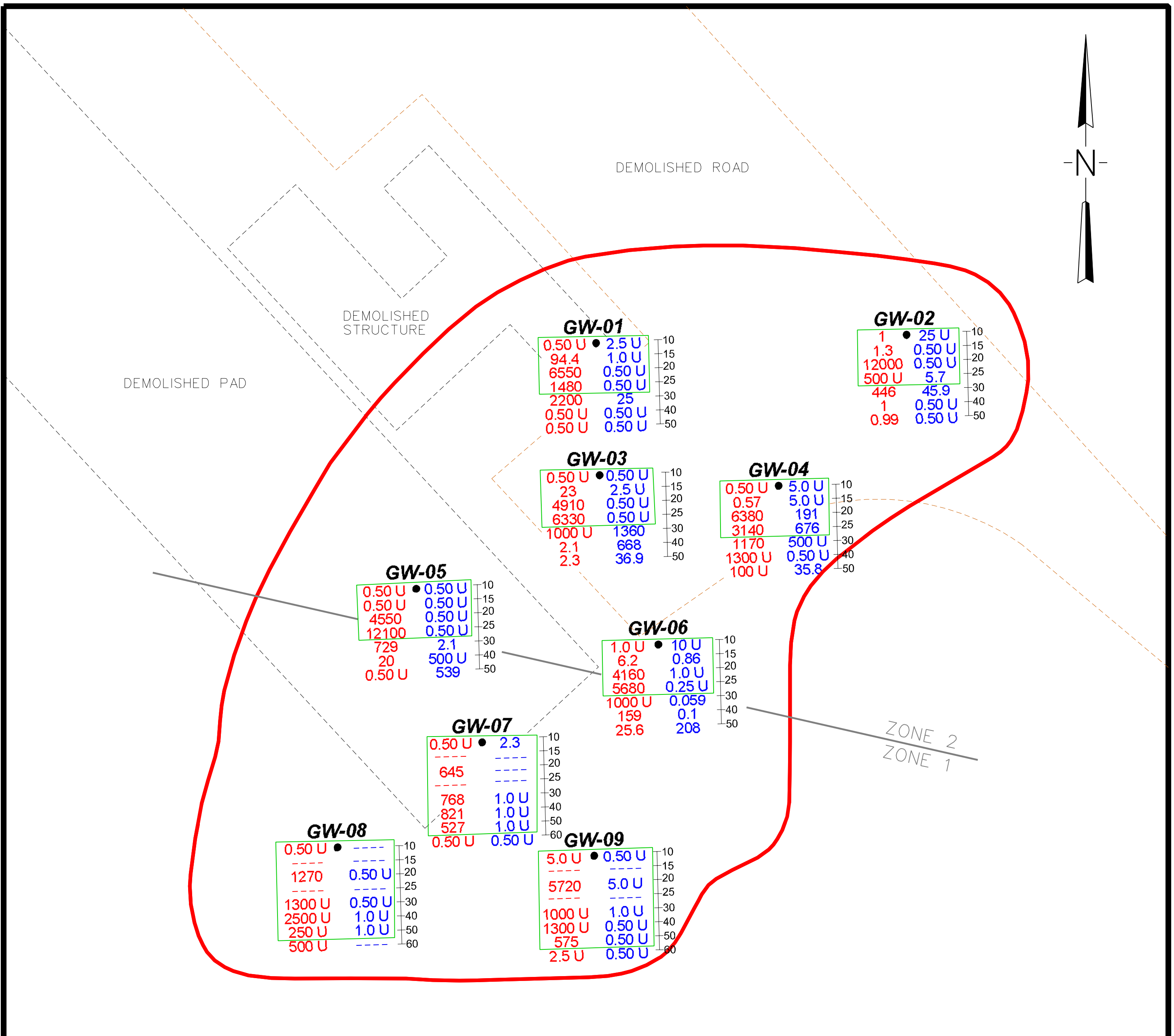

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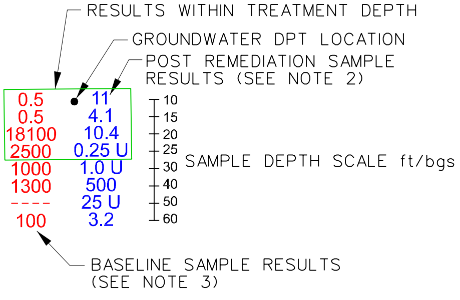
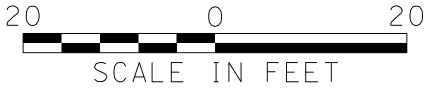


U ANALYTE UNDETECTED AT THE CORRESPONDING QUANTITATION LIMIT

🟥 SOURCE AREA (10 ppm TCE CONTOUR)



NOTES

1. MISSING DATA INDICATES SAMPLE NOT COLLECTED
2. POST-REMEDIATION SAMPLES WERE COLLECTED DEC. 2006
3. BASELINE SAMPLES WERE COLLECTED NOV. 2005
4. SAMPLE DEPTHS ARE: 10, 15, 20, 25, 30, 40, 50, 60 FEET BELOW GROUND SURFACE (ft/bgs)
5. 60ft/bgs INTERVAL ONLY AT GW-07, GW-08, AND GW-09
6. RESULTS ARE $\mu g/L$

Tetra Tech Inc.
OAK RIDGE, TENNESSEE

CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 4-9
COMPARISON OF BASELINE AND
POST REMEDIATION trans-DCE
IN GROUNDWATER

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5.0 CONCLUSIONS

5.1 TECHNOLOGY PERFORMANCE AND REMEDIATION EFFECTIVENESS

This section presents various lines of evidence indicating effective contamination removal efficiencies using the in-situ soil mixing technology with injection of steam, hot air, and ZVI. The cross section profiles presented in Section 3.6 also support the remediation effectiveness using this technology.

5.1.1 Total Mass Removal

A total of 38, 173, and 177 pounds of PCE, TCE, and cis-DCE, respectively, were removed from the source area (i.e., sum of all treatment cells) and these chemicals accounted for 99.6% of the total VOC mass removed. Individually, PCE, TCE, and cis-DCE accounted for 9.8, 44.5, and 45.4%, respectively, of the total VOC mass removed by the remedial action. The total mass removed for each VOC represents all phases that were present in the subsurface (e.g., pure phase, sorbed, dissolved). The trans-DCE, vinyl chloride, and Freon 113 were present in limited areas; however, their total mass represented less than 1% of the total mass removed from the source area. These respective ratios of the VOCs removed are generally consistent with the site characterization data that showed the source area contamination to consist primarily of the more highly oxidized chlorinated VOCs. The total mass removed for each VOC and its percent of total mass removed for SPCC is presented in Table 5-1. The total mass removed for each treatment cell location is presented in Appendix H.

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Table 5-1. Total Mass Removed From Facility 18003

Contaminants	PCE	TCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	Freon 113	Benzene	Toluene	Ethyl-benzene	1,1-DCA	1,1,1-TCA
Mass (lbs)	37.967	173.049	176.518	0.427	0.470	0.377	0.000	0.001	0.000	0.093	0.088
Percent of Total Mass for SPCC	9.76	44.49	45.38	0.11	0.12	0.10	0.00	0.00	0.00	0.02	0.02

Notes:

The mass removal numbers do not account for any fugitive emissions from vapors reaching the surface not captured in the shroud.
The mass removal numbers do not account for any in-situ residual mass breakdown from the ZVI.

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5.1.2 Evaluation of Off-Gas VOC Reduction in a Previously Treated Area

On 18 May 2006, cell BC04 was treated to evaluate the contaminant reduction and mass removal in the previously treated cell locations of BC14, BC16, and BB15. Treatment cell BC04 was treated between the three previously mentioned cells (approximately 27 days after) in the highest contaminated area determined at the site, Figure 2-5 illustrates the location of BC04. The FID concentrations, GC concentrations, and mass removal for treatment cells BC14, BC16, and BB15 are depicted below:

Treatment Cell BC14		
Peak FID Concentration (ppm)	11, 697	
	Peak GC Concentration (ppm)	Mass Removal (lbs)
PCE	1,598	1.948
TCE	14,886	12.485
cis-1,2-DCE	1,110	3.817

Treatment Cell BC16		
Peak FID Concentration (ppm)	12,210	
	Peak GC Concentration (ppm)	Mass Removal (lbs)
PCE	868	2.299
TCE	11,545	15.070
cis-1,2-DCE	3,170	5.988

Treatment Cell BB15		
Peak FID Concentration (ppm)	18,388	
	Peak GC Concentration (ppm)	Mass Removal (lbs)
PCE	2,150	6.467
TCE	22,298	45.770
cis-1,2-DCE	2,239	6.498

Note: Due to the different instruments and calibrations, the GC data at times may be greater than the FID data.

The FID concentrations, GC concentrations, and mass removal for treatment cell BC04 are depicted below:

Treatment Cell BC04		
Peak FID Concentration (ppm)	2,273	
	Peak GC Concentration (ppm)	Mass Removal (lbs)
PCE	0.00	0.00
TCE	7.99	0.005
cis-1,2-DCE	9.01	0.004

Comparing the contaminant data from cells BC14, BC16, and BB15 to the contaminant data from BC04 indicates a great reduction of FID concentrations, GC concentrations, and mass removal. Figure 5-1 illustrates the mass removal comparison between the three previously treated cells and BC04. Therefore, it is evident that the thermal and iron treatment of cells BC14, BC16, and BB15 in the highest contaminated area of the site effectively removed VOCs from the source area.

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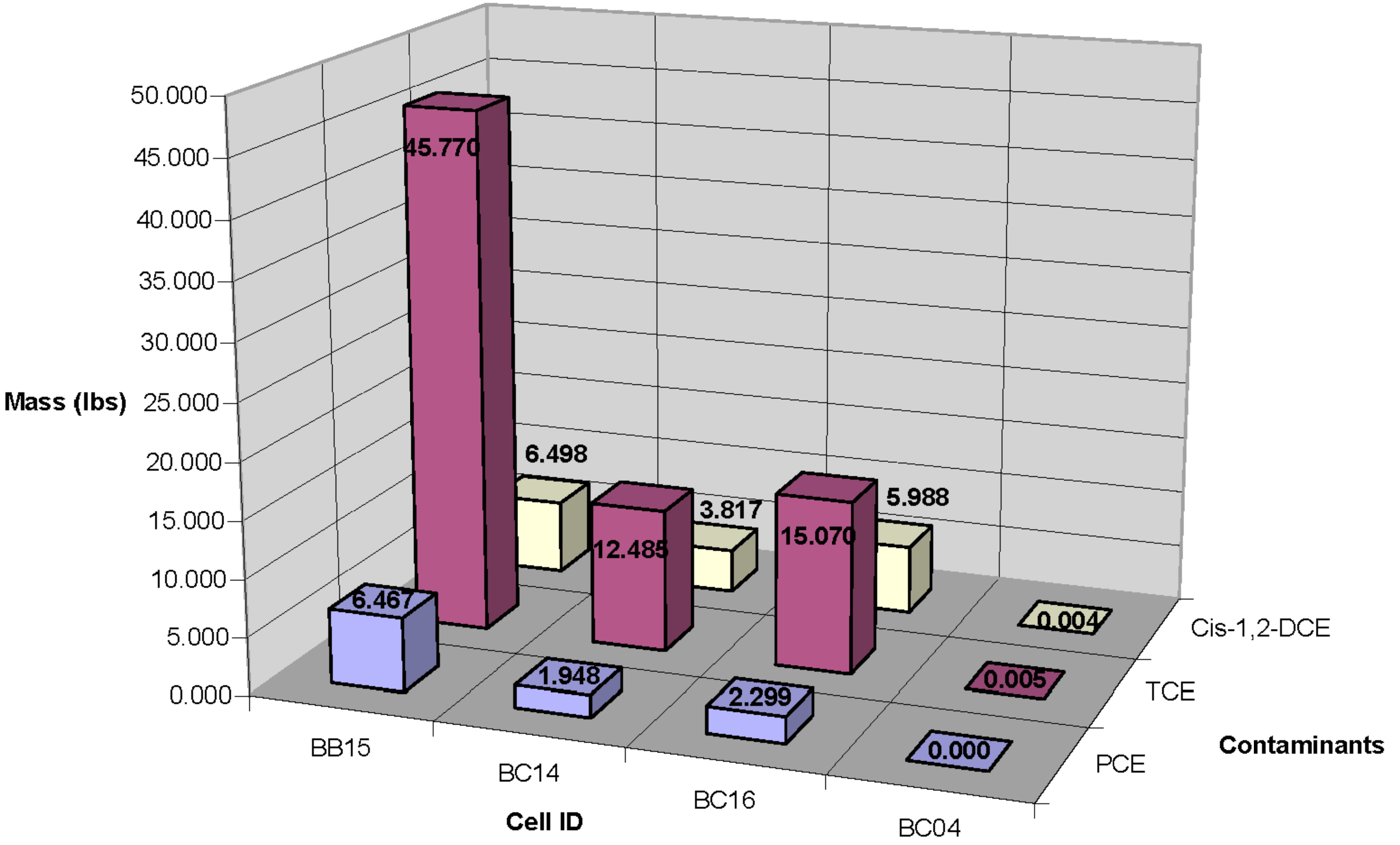

LEGEND
🟦 PCE
🟥 TCE
☐ Cis-1,2-DCE

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CAPE CANAVERAL AIR FORCE STATION
CAPE CANAVERAL, FLORIDA
SPCC (FACILITY 18003)

FIGURE 5-1
PERFORMANCE TEST CELL BC04
BETWEEN BB15, BC14, AND BC16

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5.1.3 Off-Gas VOC Removal Efficiency

Mass removal from the source area is a key indicator of the LDA technology efficiency. It is evident from comparison of the concentration and mass removal profiles presented in Section 3.6.2 (compare Figures 3-22 and 3-28) that high concentrations of VOCs were encountered where high mass removal was achieved; thus, a reduction in the concentration of VOCs in the off-gas is a direct indicator of mass depletion. Based on this correlation, an evaluation was performed to estimate the mass removal efficiency by comparing the maximum concentration of TCE detected during the early passes of the LDA with the maximum concentration detected in the last pass for a given treatment cell; the percent reduction in concentration is deemed an indicator of the mass removal efficiency. TCE represents 44.5% of the total mass removed and was detected at higher concentrations than any other VOC.

For this analysis, the TCE concentration data from the off-gas analysis performed for the 29 cells that lie along Profiles A-A’ and B-B’ were used; these cells include the most highly contaminated treatment cells in the source area at the SPCC site and represent the range of concentrations detected at the site (from highest to lowest). Therefore, the percent reduction achieved in these cells is deemed representative of the entire source area.

The maximum and final TCE concentration data for the selected treatment cells are shown in Table 5-2. Inspection of the data in the maximum column shows a range of maximum detected concentrations from 22,298 to 22 ppm (i.e., non-detect in the gas sample), or a range of three orders of magnitude; these data represent the concentration of TCE during the early to mid passes of the LDA. The final concentration column shows concentrations ranging from 326 to 4.7 ppm and represents the TCE concentration from the final pass of the LDA. The reduction efficiency, excluding cells in which the maximum concentration was zero, ranges from 100 to 64.7% with an average value of 93.7%. A regression analysis of the maximum concentration with the removal efficiency shows no correlation, indicating that the ability of the technology to remove VOCs was not exceeded by the concentrations encountered in the source area.

5.2 TREATMENT COST ANALYSIS

The cost for treatment at SPCC can be broken up into two separate costs: total project cost and cost for thermal treatment per cubic yard. The contract structure for source area treatment utilizing in-situ soil mixing with steam and hot air with ZVI injection included cost for treatment at SPCC and Facility 1381; therefore, cost items such as mobilization and equipment procurement and other direct costs (ODCs) were shared between the two projects. The following sections discuss the two separate cost values for treatment at SPCC.

Table 5-2. TCE Removal Efficiencies in Off-gas

HOLEID	Maximum TCE (ppm)	Final TCE (ppm)	Percent Removal
AW08	0.0	0.0	-
AX09	37.3	0.0	100.0
AY10	37.2	0.0	100.0
AZ11	1653.8	46.3	97.2
BA12	1977.0	257.0	87.0
BC16	11591.8	60.4	99.5
BD17	1775.4	23.9	98.7
BE16	1212.5	16.0	98.7
BF17	223.2	0.0	100.0
BG18	176.3	4.7	97.3
BH17	0.0	0.0	-
BI18	0.0	0.0	-
BJ19	0.0	0.0	-
BK20	0.0	0.0	-
BL21	1957.7	0.0	100.0
BM20	643.0	227.0	64.7
BN21	402.9	16.6	95.9
BC10	0.0	0.0	-
BB11	91.8	16.4	82.1
BB13	5304.4	4.9	99.9
BB15	22298.2	325.7	98.5
BB17	3070.9	47.5	98.5
BB19	476.8	15.7	96.7
BB21	991.7	141.5	85.7
BB23	1242.6	137.4	88.9
BA24	22.7	0.0	100.0
BA26	898.6	170.2	81.1
AZ27	174.5	16.8	90.4
AY28	0.0	0.0	-
Average	**2557.3**	**69.5**	**93.7**

5.2.1 Total Project Cost per Cubic Yard

The total project cost for treatment at SPCC includes the cost for thermally treating the volume of soil as well as all associated project management, construction oversight, survey activities, figure generation, database management, sampling activities, report preparation and finalization, on-site chemist/engineer/health and safety, permitting activities, equipment procurement, travel cost, and iron and fuel cost. Cost not reflected in this total cost includes wastewater disposal cost associated with the removal of the FTO blow-down water off-site and treatment at the base Trident Industrial Wastewater Treatment Facility. The total project cost for treatment of approximately 9,010.5 cubic yards at SPCC was approximately \$3,132,000. Additional funding was procured on 21 July 2005 near the end of treatment at SPCC to treat additional volume at the site. The cost modification was approximately \$336,000, in which approximately 90% (\$303,000) was utilized at the site and the rest was carried over for Facility 1381 source area treatment. Therefore, the total cost for treating the SPCC site was approximately $3,435,000 ($3,132,000 plus approximately $303,000). Comparing the total cost to the total cubic yards treated, this breaks down into a cost of approximately $380 per cubic yard of soil treated at the site.

5.2.2 Thermal Treatment Cost per Cubic Yard

Thermal treatment cost includes only the cost for thermally treating a cubic yard of soil. Items included in this cost are remedial equipment cost, mobilization and demobilization, anticipated down days, site preparation and closure activities. Items not reflected in this thermal treatment cost includes cost of fuel and ZVI. The total cost for thermally treating the 9,010.5 cubic yards of soil was $1,656,000. This breaks down into a cost of approximately $188 per cubic yard of soil treated at the site.

5.3 LESSONS LEARNED

The following section details the observations and lessons learned during the implementation of remedial efforts at SPCC. These observations and lessons learned have been generated from field experience and data analysis in order to optimize system operation for the implementation of in-situ thermal soil mixing with steam and hot air and ZVI injection for Facility 1381 and future projects involving this technology.

5.3.1 Auger Ports

During startup test drilling and active drilling for the first few weeks, it was discovered that the intense steam pressure was rapidly eroding the galvanized steel bushings installed in the auger ports on the grout tube. To alleviate the pressure on the original four ports, an additional three ports (for a total of seven ports on either tube) were installed and the ports were widened on either tube (for a total of 14 ports). In addition, the galvanized steel bushings were replaced with stainless steel bushings which reduced the amount of wear on the bushings and increased the amount of energy input into the treatment cell.

5.3.2 Data Transfer and Wireless Air Card

Data collected during the treatment process were compiled for transfer after completion of the final daily treatment of cells. Transfer of the data was performed through a wireless air card providing Internet access and virtual private network (VPN) access to the Oak Ridge server via cellular signals. Transfer of the data at startup frequently did not occur as scheduled due to the limited coverage of the cellular provider in the SPCC area. Therefore, an extended antenna was procured which improved the signal reception and reduced signal drop before or during the transfer period. For future projects it is recommended to secure wired high-speed data connections via DSL or cable modem, if possible. If not possible, it is recommended to ensure that a wireless Internet service provider maintains a strong coverage signal within the project area.

5.3.3 Iron Storage, Handling and Metering

5.3.3.1 Iron Storage and Clumping

The ZVI consisting of 50 grain mesh was delivered to the site in seven different increments (250 lbs, 500 lbs, 750 lbs, 1000 lbs, 1500 lbs, 2000 lbs, and 3000 lbs) to accommodate the changing iron demands based on depth and FID concentration seen during treatment at the SPCC site and to facilitate efficient batching of the ZVI slurry. The ZVI bags were delivered to the site and covered with 3 millimeter plastic covering to protect the ZVI from the elements. However, during batch preparations on several cells it was discovered that certain bags of ZVI consisted of various sizes of clumps, which was later discovered to have been generated due to rain events and the humid atmosphere. To adjust for these clumps and prevent binding of the mixers and/or pump failure, a smaller batch plant screen was retrofitted to the batch plants and the iron clumps were either broken up to powder or discarded.

To prevent ZVI powder from clumping it is recommended to limit the on-site quantity of ZVI to approximately 30-40 days of treatment and to immediately store the ZVI under protective sheltering (connex boxes, shed, or hangar) once delivered to the site. In addition, it is recommended to instruct the manufacturer to use water-resistant bags and/or provide additional water-resistant wrapping as well as inserting descants within each bag to provide additional moisture protection. As an alternative measure, reducing the number and size variations of the ZVI bags to a bulk delivery /storage/feeding should also improve the process.

5.3.3.2 Iron Metering

During testing and checkout of the remedial equipment prior to treatment at SPCC, several iron batch attempts were made to adequately suspend and inject the ZVI slurry. Two different flow meters were installed to display and record the flow rate of the ZVI slurry during injection but, due to the varying densities of the slurry mixture, the flow meters failed during the testing periods. Due to these flow meter failures, an injection protocol was developed to control the injection of the ZVI through manual manipulation and mechanical controls to ensure an adequately homogeneous distributed iron column.

To ensure precise flow rate injection of the ZVI slurry throughout the entire treatment column and to adequately capture the flow data, it is recommended to procure a flow meter of adequate specifications to handle the varying densities of the ZVI slurry.

5.3.4 Pre-Chiller Unit and Shroud Size

During treatment on Zone 2 cells at SPCC, several cells exhibited dramatic shroud and off-gas pressure and temperature increases due to the amount of steam energy input into a reduced interval. Such a rapid increase in temperature (usually above 160^{o}F) reduced the conditioning efficiency of the VCS that triggered the FTO high inlet temperature alarm and the FTO was shut down. As an example, Zone 2 treatment cell BM28 (Figure 5-2), treated 12 April 2006, exhibited two dramatic temperature increases.

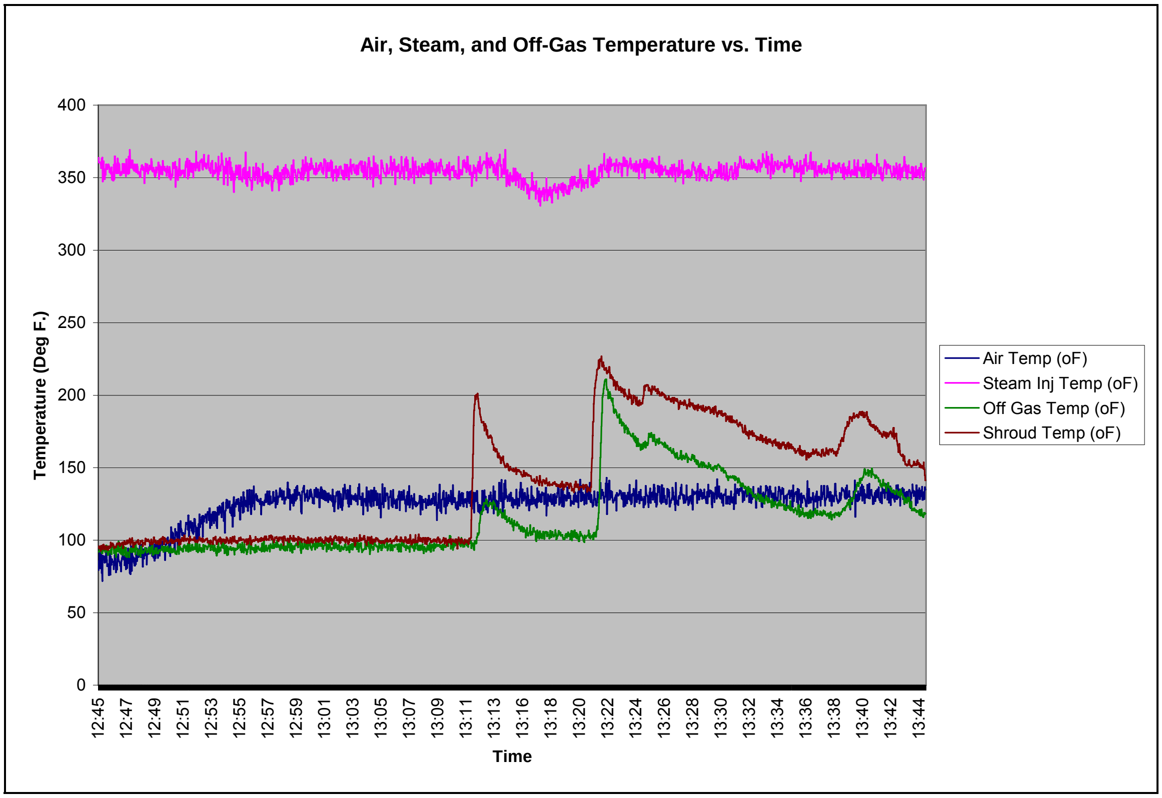

Figure 5-2: Temperature Profile During Treatment on Cell BM28

The first temperature increase was generated during the second pass when the temperature increased from 100^{o}F to 200^{o}F over one foot of treatment at 16 feet bgs. The second temperature increase was generated on the fifth pass, including two focused passes, and increased from 136^{o}F to 226^{o}F over one foot of treatment. In order to increase vapor conditioning efficiency and reduce the amount of FTO failures due to high temperatures, a pre-chiller unit was installed after the knock-out tank and prior to the VCS. The pre-chiller unit reduced the off-gas temperature approximately 10^{o}F in order to satisfy the designed VCS requirement of 160^{o}F while allowing the shroud temperature to reach and maintain at 170^{o}F which suggests hotter temperatures below ground surface and greater remediation. It was also recommended to increase the volume of the shroud to equalize the off-gas stream prior to being sent into the VCS which would reduce or eliminate the dramatic pressure and temperature rises seen when treating shorter intervals. Shroud volume was modified for implementation at Facility 1381.

5.3.5 Subsurface Thermocouple on Kelly Bar

On 10 May 2006 a subsurface thermal investigation was attempted to correlate the temperature profile in a treatment cell to the shroud temperature after two passes in a cell with little or no prior thermal heating. For this investigation, cell BH23 was treated to 55 feet bgs with hot air and steam. A shroud temperature of 160^{o}F was obtained within two passes, upon which the tool was removed. Once removed, a membrane interface probe (MIP) mounted to a GeoProbe drilling rig was drilled to 55 feet bgs, holding every 5 feet bgs for a temperature reading. However, due to a calibration problem with the MIP computer, the readings did not correlate well and the test was cancelled. Thermal treatment on cell BH23 was resumed and completed that same day.

An alternative subsurface thermal investigation was performed on 10 May 2006 by drilling a thermocouple (via GeoProbe) into previously treated cell BB15. BB15 was treated on 21 April 2006 and obtained a maximum shroud temperature of 193°F and a final temperature range of approximately 176°F to 190°F (Figure 5-3).

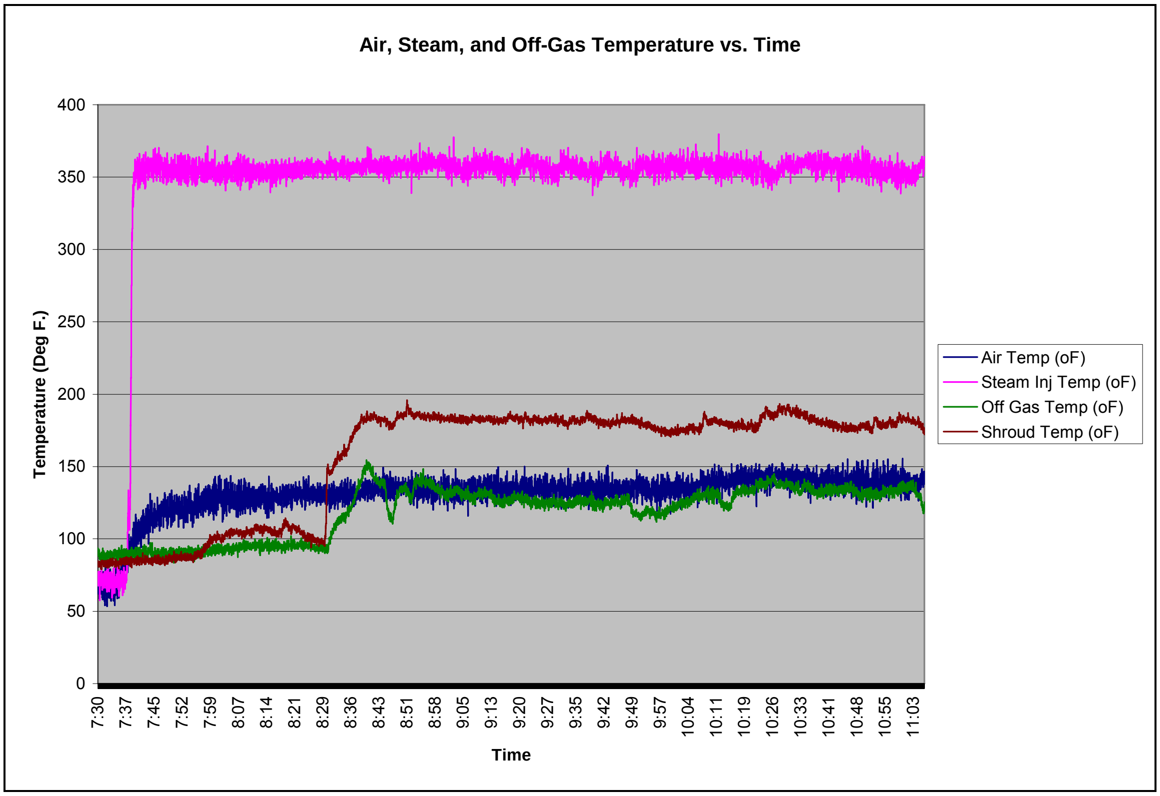

Figure 5-3: Temperature Profile During Treatment on Cell BB15

The thermocouple was connected to a multi-meter with a temperature reading for visual observation at the surface by the operator and was drilled from 10 to 50 feet bgs with an additional 52.5 foot reading. The following depicts the results of the subsurface thermal investigation:

Depth (feet bgs)	Temperature (°F)
10	155
15	163
20	168
25	170
30	173
35	175
40	176
45	174
50	171
52.5	173

Therefore, the investigation depicts an approximate 20 degree difference between the final shroud temperature range (176^{o}F – 190^{o}F) and the subsurface measured temperature range (155^{o}F – 173^{o}F). The decreased temperature range obtained from the investigation may have been generated due to the time difference from the treatment date to the investigation date (19 days) and due to the ZVI slurry injection/water flushing which occurred during the final two passes.

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