Final
Corrective Measures Effectiveness Report
December 2006 Sampling Event
Former Chemical Laundry and
Motor Pool Area 1500, Parcel 94(7)
McClellan
Anniston, Alabama

Prepared for:

Anniston-Calhoun County Fort McClellan Development Joint Powers Authority,
McClellan, Anniston, Alabama

Prepared by:

1601 Blake Street, Suite 200
Denver, Colorado 80202
(303) 572-0200
Fax (303) 572-0202

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LIST OF ABBREVIATIONS AND ACRONYMS

ADEM	Alabama Department of Environmental Management
Army	United States Department of the Army
BCT	Base Realignment and Closure Clean-Up Team
bgs	below ground surface
BRAC	Base Realignment and Closure
CA	*Anniston-Calhoun County Fort McClellan Development Joint Power Authority Facility*, *Cleanup Agreement No. AL4 210 020 562*
CDTF	Chemical Defense Training Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFDP	Center for Domestic Preparedness
cis-1,2-DCE	cis-1,2-dichloroethene
CMER	Corrective Measures Effectiveness Report
CMIP	Corrective Measures Implementation Plan
COC	Constituent of concern
CWM	Chemical warfare material
DO	Dissolved oxygen
DOJ	United States Department of Justice
DQS	*Data Quality Summary*
EBS	*Environmental Baseline Study*
EPA	United States Environmental Protection Agency
ESCA	Environmental Services Cooperative Agreement
ESE	Environmental Science & Engineering, Inc.
FFS	*Focused Feasibility Study, Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)*
FOSET	Finding of Suitability for Early Transfer
FOST	Finding of Suitability for Transfer
Ft/ft	Feet per foot
HI	Hazard index
ILCR	incremental lifetime cancer risk
IT	IT Corporation
JPA	Joint Powers Authority
LUC	Land use control
McClellan	McClellan, Anniston, Alabama
MCL	Maximum contaminant level
MES	Matrix Environmental Services, LLC
µg/l	Microgram per liter
mg/l	Milligram per liter
MNA	Monitored natural attenuation
ORP	Oxidation-reduction potential
Parcel 94(7)	Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
QA	Quality assurance
QAP	*Quality Assurance Plan*
RI	*Draft Remedial Investigation Report, Former Chemical Laundry and*

	Motor Pool Area 1500, Parcel 94(7)
SAIC	Science Applications International Corporation
SAP	*Draft Installation-Wide Sampling and Analysis Plan*
SI	*Site Investigation Report*
Site	Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
SOP	Standard operating procedure
SRA	Streamlined human health risk assessment
SSSL	Site-specific screening level
TCE	Trichloroethene
TDS	Total dissolved solids
TKN	Total kjeldahl nitrogen
TOC	Total organic carbon
trans-1,2-DCE	trans-1,2-dichloroethene
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UST	Underground storage tank
VOC	Volatile organic compounds

1.0 INTRODUCTION

Matrix Environmental Services, L.L.C. (MES) has prepared this Corrective Measures Effectiveness Report (CMER) for groundwater remediation at the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7) [Parcel 94(7)] within McClellan, Anniston, Alabama (McClellan) formerly known as Fort McClellan. Figure 1-1 shows a site map of McClellan and Figure 1-2 the location of Parcel 94(7). This CMER presents results related to the implementation of monitored natural attenuation (MNA) as the remedial action for contaminated groundwater at Parcel 94(7).

This report was prepared on behalf of the Anniston-Calhoun County Fort McClellan Development Joint Powers Authority (JPA). The JPA has assumed from the United States (U.S.) Department of the Army (Army) the responsibility for environmental closure of certain sites at McClellan. Transfer of these sites to the JPA was conducted pursuant to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120(h)(3)(C) which allows federal agencies to transfer contaminated property before all necessary cleanup has taken place. The basis for the continuing effort at these parcels is an Environmental Services Cooperative Agreement (ESCA) between the JPA and the Army originally executed September 2003 (Army, 2003) and amended in September 2005 (Army, 2005) and June 2006. In addition, the JPA has negotiated a Cleanup Agreement (CA), amended November 2005, with the Alabama Department of Environmental Management (ADEM) that describes the responsibilities for completing the investigation and remediation of potentially impacted sites at McClellan (ADEM, 2003a).

1.1 McClellan Site Description and History

McClellan is located in the foothills of the Appalachian Mountains of northeastern Alabama, near the cities of Anniston and Weaver in Calhoun County. McClellan is approximately 60 miles northeast of Birmingham, 75 miles northwest of Auburn, and 95 miles west of Atlanta, Georgia.

The U.S. Government purchased 18,929 acres near Anniston in 1917 for use as an artillery range and a training camp due to the outbreak of World War I. The site was named Camp McClellan in honor of Major General George B. McClellan, a leader of the Union Army during the Civil War. Camp McClellan was used to train troops for World War I from 1917 until the armistice. It was then designated as a demobilization center. Between 1919 and 1929, Camp McClellan served as a training area for active army units and other civilian elements. Camp McClellan was re-designated as Fort McClellan in 1929 and continued to serve as a training area.

In 1940, the government acquired an additional 22,245 acres west of McClellan. This tract of land was named Pelham Range. In 1941, the Alabama Legislature leased approximately 4,488 acres to the U.S. Government to provide an access corridor from the Main Post to Talladega National Forest. This corridor provided access to additional woodlands for training.

The Army operated the Chemical Defense Training Facility (CDTF) at Fort McClellan from 1951 until the school was deactivated in 1973. The CDTF was then reactivated in 1979 and was

closed at the time of base closure in 1999 (Environmental Science & Engineering, Inc. [ESE], 1998). The CDTF offered advanced training in all phases of chemical, biological, and radiological warfare to personnel from all branches of the military.

In 1995, the U.S. Department of Defense announced that Fort McClellan would close by October 1999. The Base Realignment and Closure (BRAC) commission recommended closure of the installation, except for minimum essential land and facilities for a Reserve Component Enclave and essential facilities needed to provide support for the chemical demilitarization operation at Anniston Army Depot. Subsequently, the U.S. Department of Justice (DOJ) requested a transfer of some facilities and training area to their authority for ongoing training exercises. The Army transferred the CDTF and ancillary support facilities to the DOJ in 2000 to establish the Center for Domestic Preparedness (CFDP).

Property that was determined by the Army and ADEM to be suitable for transfer (i.e., "clean property") was transferred to the JPA under a Finding of Suitability for Transfer (FOST). Subsequently, remaining contaminated property was transferred to the JPA under a Finding of Suitability for Early Transfer (FOSET). The basis for the continuing effort at these FOSET parcels is the execution of an ESCA and the CA that describe the responsibilities of all parties in completing the investigation and remediation of potentially environmentally impacted sites at McClellan.

1.2 Purpose and Objectives

The purpose of this CMER is to demonstrate effectiveness of MNA, the selected remedy for groundwater contamination at Parcel 94(7). Objectives for the December 2006 investigation and this CMER included:

- Summarize environmental sampling data from previous investigations and present analytical results for the December 2006 investigation.
- Compare the results of the previous rounds of groundwater sampling to the December 2006 results to evaluate the effectiveness of MNA as a remedy for degradation of chlorinated solvents in groundwater at Parcel 94(7).

1.3 Report Organization

Section 2.0 of this report presents a summary of the environmental setting including location, soil types, geology, and hydrogeology of the parcel. Section 3.0 presents a summary of previous environmental investigations. Section 4.0 describes the activities conducted during the December 2006 investigation, and Section 5.0 presents the results of the December 2006 investigation. Section 6.0 presents the summary, conclusions, and recommendations, and Section 7.0 provides the references cited in this report.

Additional supporting information is provided in Appendices that are provided on CD-ROM with this report. The Appendices include the following:

Appendix A Groundwater Levels and Sample Collection Logs
Appendix B Chains-of-Custody Forms
Appendix C Analytical Data for December 2006 Investigation
Appendix D *Data Quality Summary: Parcel 94(7), Former Chemical Laundry and Motor Pool Area 1500, December 2006 Sampling Event*

2.0 SITE CHARACTERIZATON

The following sections were adapted from the *Draft Remedial Investigation Report, Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)* submitted by IT Corporation (IT, 2002).

2.1 Site Description and History of Parcel 94(7)

Parcel 94(7) is located in the central area of McClellan, along Langley Avenue and south of St. Clair Road (Figure 1-2). Parcel 94(7) was formerly used as a vehicle maintenance facility including three gas stations during World War II (the gas stations are sub-parcels 132[7], 133[7], and 134[7]). The Former Chemical Laundry consisted of the 111th Garment Impregnation Plant and the 317th Garment Impregnation Plant. The garment impregnation facilities reportedly laundered garments to neutralize chemical warfare material (CWM). The garments were also treated to render them relatively impermeable to CWM. Specific garment impregnation procedures are unknown. Impregnation plants reportedly used large volumes of toluene or ethyl alcohol; however, the standard operating procedures (SOPs) for typical impregnation plants describe the use of water, wax, and "chlorinated oil." Parcel 94(7) is currently vacant and will be collectively referred to as the Site. The buildings at the Site have been demolished. Two concrete slab foundations corresponding to the Former Chemical Laundry and Motor Pool Area 1500 remain at the Site along with concrete sumps or grease pits. The remainder of the Site is covered with asphalt pavement (IT, 2002). Proposed future land use of this Site is as a technology and research park as proposed in the Re-Use Plan (EDAW Inc., 1997, as amended by the JPA in June 2005).

2.2 Geology

The geology of McClellan is discussed in the following sections. Information contained in these sections is adapted from previous work performed by IT (2002).

2.3 Regional Geology

Calhoun County includes parts of two physiographic provinces, the Piedmont Upland Province, which is characterized by metamorphosed sedimentary rocks and the Valley and Ridge Province. McClellan lies mainly within the Valley and Ridge Province, which is part of the Appalachian fold-and-thrust structural belt. The fold and thrust belt generally features southeastward-dipping thrust faults with associated minor folding consisting of Paleozoic sedimentary rocks that have been asymmetrically folded and thrust-faulted with major structures and faults striking in a northeast-southwest direction. Geologic contacts in this region generally strike parallel to the faults and repetition of lithologic units is common in vertical sequences. These units, from oldest to youngest, include the Cambrian-aged Chilhowee Group, Shady Dolomite, Rome Formation, Conasauga Formation, and Knox Group, and the Ordovician-aged Newala and Little Oak Limestones, as well as various siltstones, sandstones, shales, dolomites and limestones that are mapped as one, undifferentiated unit in some areas of Calhoun County.

The 39-mile long Jacksonville thrust fault is the most significant structural geologic feature in

the vicinity of McClellan, both for its role in determining the stratigraphic relationships in the area and for its contribution to regional water supplies. The fault is interpreted as a major splay of the Pell City fault, which serves as a fault contact between the bedrock within the McClellan window and the Rome and Conasauga Formations (Osborne and Szabo, 1984). The trace of the Pell City fault marks the boundary between the Pell City thrust sheet and the Coosa deformed belt. The Pell City thrust sheet is exposed between the traces of the Jacksonville and Pell City faults along the western boundary of the McClellan window, and along the trace of the Pell City fault on Pelham Range (Thomas and Neathery, 1982; Osborne et al., 1988). The Coosa deformed belt is a narrow northeast-to-southwest-trending linear zone of complex structure (approximately 90 miles in length) consisting mainly of thin imbricate thrust slices (Thomas and Drahovzal, 1974). An Ordovician-aged sequence comprising the Eden thrust sheet includes an erosional window in the overlying thrust sheet at McClellan. Rocks within the window display complex folding, with the folds being overturned and tight to isoclinal. The carbonates and shales locally exhibit well-developed cleavage (Osborne and Szabo, 1984).

2.3.1 Site-Specific Geology

Bedrock at the Site has been mapped as Ordovician-age Little Oak and Newala Limestones, undifferentiated, and Mississippian/Ordovician-age Floyd and Athens Shale, undifferentiated. An asymmetric anticlinal fold strikes northeast southeast across the parcel and plunges to the southwest (Figure 2-1).

Geologic conditions at the Site have been assessed using monitoring well and soil boring lithologic logs prepared during a previous *Site Investigation* (*SI*) (Science Applications International Corporation [SAIC], 1993) and *Remedial Investigation (RI)* (IT, 2002). The lithologic sequence encountered at the Site consists of an upper interval of residuum 6 to 50 feet thick overlying fractured, weathered limestone. In general, the residuum at the Site is clayey silt with little sand and gravel or silty, sandy clay with little gravel. Bedrock at the Site was encountered at depths ranging from approximately 6 feet below ground surface (bgs) to 50.5 feet bgs. Figure 2-2 shows a cross section location map for Parcel 94(7) (IT, 2003). Figures 2-3 and 2-4 show depictions of Site-specific geologic conditions at Parcel 94(7).

2.3.2 Soil

The soil types of McClellan are discussed in the following sections.

2.3.3 Regional Soil

The soil associations found at McClellan (U.S. Department of Agriculture [USDA], 1961), include:

- **Anniston-Allen, Decatur-Cumberland**. Alluvium, resulting from weathering of older residual soils developed from sandstone, shale and quartzite; deep, well-drained, level to moderately steep soil in valleys underlain by limestone and shale. Subsoil is dark red sandy clay loam. Cumberland and Decatur soils are dark reddish brown gravelly loam developed from weathered limestone.

- **Clarksville-Fullerton.** Well-drained to moderately well-drained stony or cherty soils developed in the residuum of cherty limestone. This association is limited to Pelham Range. The soils are generally dark brown to dark gray-brown silt loam.
- **Rarden-Montevallo-Lehew.** Moderately deep or shallow soils on ridgetops and steep slopes and in local alluvium in draws. Soils are developed from the residuum of shale and fine-grained, micaceous sandstone; reddish brown to dark gray-brown to yellow-brown silt loam, clay or silty clay.
- **Stony Rough Land**. Shallow, steep, and stony soils formed from the weathering of sandstone, limestone, and Talladega Slate. Infiltration is slow; the soils contain many boulders and fragments with clayey residuum. This association underlies a large portion of the Main Post at McClellan.

2.3.4 Site-Specific Soil

Parcel 94(7) soil has been mapped as Anniston and Allen series and the Philo series (IT, 2002). Anniston and Allen gravelly loams (AcC2 and AcD2) consist of strongly acid, deep well drained friable soil that have developed from old local alluvium on foot slopes and fans along the bases of the mountains. The surface horizon is mainly a dark brown or grayish brown gravelly loam, while the subsoil is typically dark red, sandy clay loam. Sandstone and quartizite gravel and cobbles as large as 8 inches in diameter are typically found on the surface and throughout the soil (USDA, 1961).

Along the bank of Ingram Creek, the soil is classified as the Philo and Stendal fine sandy loams (PhA). This mapping unit consists of soil that develops in general alluvium on nearly level bottoms subject to flooding. The Philo series consist of strongly acid, moderately well drained soil that is developing in local and general alluvium. The parent material washed mainly from sandstone and shale but some of it originated from limestone. The surface soil is very dark grayish brown to dark brown fine sandy loam, and the subsoil is dark brown, slightly mottled, fine sandy loam (USDA, 1961).

2.3.5 Hydrogeology

The hydrogeology of McClellan is discussed in the following sections. Information contained in these sections is in part adapted from previous work performed by IT (2002).

2.3.6 Regional Hydrogeology

The hydrogeology of Calhoun County has been investigated by the Geologic Survey of Alabama (Moser and DeJarnette, 1992), the U.S. Geological Survey (USGS) in cooperation with the General Services Administration (Warman and Causey, 1962), and ADEM (Planert and Pritchette, 1989). Groundwater in the vicinity of McClellan occurs in residuum derived from bedrock decomposition along fault zones within fractured bedrock and from the development of karst frameworks. Groundwater flow direction is generally toward major surface water features. However, because of impacts of differential weathering, variable fracturing, and the potential for conduit flow development, the use of surface topography as an indicator for groundwater flow

direction must be used with caution in the area. Groundwater flow direction in areas with well-developed residuum horizons may subtly reflect the surface topography, but it also may exhibit the influence of pre-existing structural fabrics or the presence of perched water horizons on unweathered ledges or impermeable clay lenses.

Precipitation and subsequent infiltration provide recharge to the groundwater flow system in the region. The main recharge areas for the aquifers in Calhoun County are located in the valleys. The ridges generally consist of sandstone, quartzite, and slate which are resistant to weathering, relatively unaffected by faulting, and therefore, relatively impermeable. The ridges have steep slopes and thin to no soil cover, which enhances runoff to the edges of the valleys (Planert and Pritchette, 1989).

The thrust fault zones typical of the county form large storage reservoirs for groundwater. Points of discharge occur as springs, effluent streams, and lakes. Coldwater Spring is one of the largest springs in the State of Alabama, with a discharge of approximately 32 million gallons per day. This spring is the main source of water for the Anniston Water Department, and serves McClellan. The spring is located approximately 5 miles southwest of Anniston and discharges from the brecciated zone of the Jacksonville Fault (Warman and Causey, 1962).

Shallow groundwater at McClellan occurs principally in the residuum developed from Cambrian sedimentary and carbonate bedrock units of the Weisner Formation, Shady Dolomite and locally in lower Ordovician carbonates. The residuum may yield adequate groundwater for domestic and livestock needs but may go dry during prolonged dry weather. Groundwater within the residuum serves as a recharge reservoir for the underlying bedrock aquifers. Bedrock permeability is locally enhanced by fracture zones associated with thrust faults and by the development of solution (karst) features.

Two major aquifers were identified by Planert and Pritchette (1989): the Knox-Shady aquifer and the Tuscumbia-Fort Payne aquifer. The continuity of these aquifers has been disrupted by the complex geologic structure of the region, such that each major aquifer occurs repeatedly in different areas. The Knox-Shady aquifer group occurs over most of Calhoun County and is the main source of groundwater in the county. It consists of the Cambrian-and-Ordovician aged quartzite and carbonates. The Conasauga Formation is the most utilized unit of the Knox-Shady aquifer, with twice as many wells drilled as any other unit (Moser and DeJarnette, 1992).

2.3.7 Site-Specific Hydrogeology

Groundwater in the residuum generally follows the surface topography and flows in a northerly direction from the Site towards Ingram Creek based on the June 2006 measurements shown in Figure 2-5. Groundwater elevation measurements for June 2006 indicated that groundwater flow in bedrock is also in a northerly direction similar to the groundwater flow in the residuum as shown in Figure 2-6.

2.3.8 Surface Hydrology

Surface water draining from the area of the Site flows northeast into Ingram Creek, a tributary of

Cane Creek (Figure 1-2). Ingram Creek is an intermittent stream located approximately 150 to 450 feet northeast of the parcel boundary. The creek channel has been observed to be dry during the summer months. After connecting with Cane Creek, Ingram Creek ultimately flows west into the Coosa River.

3.0 PREVIOUS INVESTIGATIONS

This section summarizes findings of previous investigations conducted at Parcel 94(7). Previous investigations include:

- *Environmental Baseline Study* (*EBS*) and *Site Investigation* (*SI*)
- *Remedial Investigation* (*RI*)
- *Focused feasibility study* (*FFS*)
- 2004 Investigation and *Corrective Measures Implementation Plan* (*CMIP*)
- February 2005 Investigation and CMER
- December 2005 Investigation and CMER
- June 2006 Investigation and CMER

3.1 Environmental Baseline Study and Site Investigation

An *EBS* was conducted to document current environmental conditions of all Fort McClellan property (ESE, 1998) and a background monitoring well was installed at the Site. Subsequently an *SI* was completed in 1998 and fieldwork included a geophysical investigation to identify potential underground storage tanks (USTs) (SAIC, 1993). The geophysical anomalies were investigated and no USTs were found at the Site. During an August 1999 BRAC Cleanup Team (BCT) meeting, it was agreed that no further action was necessary in regard to the USTs.

3.2 Remedial Investigation

An *RI* was performed in two phases and chlorinated solvents were detected in groundwater collected from residuum and bedrock monitoring wells. Based on the *RI* sample collection, volatile organic compounds (VOCs) in groundwater appeared to be centered in the area around monitoring well FTA-94-MW01 for the residuum and monitoring well FTA-94-MW11 for the bedrock. The occurrence of vinyl chloride and cis-1,2-dichloroethene (cis-1,2-DCE), degradation products of trichloroethene (TCE), was generally restricted to these two monitoring wells.

3.3 Focused Feasibility Study

An *FFS* was completed and submitted to ADEM for review. The *FFS* recommended that land use controls (LUCs) coupled with MNA most appropriately addressed the groundwater contamination at Parcel 94(7). This recommendation was based in part on a streamlined human health risk assessment (SRA) performed for groundwater at the Site. The SRA included an estimate of incremental lifetime cancer risk (ILCR) and the hazard index (HI) for non-carcinogenic constituents of concern (COCs) associated with the groundwater using a residential exposure scenario. These calculations indicated that at a concentration equal to the maximum contaminant level (MCL), the combined ILCR for all groundwater constituents of concern (COCs) would fall in the accepted risk management range of 1×10^{-4} to 1×10^{-6} and the

cumulative HI is equal to the maximum acceptable value of 1. Because this risk estimate was based on a residential exposure scenario, it represented the most protective scenario. Accordingly, LUCs coupled with MNA were considered protective of human health because the LUCs would prohibit the development of Parcel 94(7) groundwater as a potable water source, eliminating the potential contaminant exposure pathway for human receptors until MNA effectively reduced COC concentrations into or below the risk management range. Contaminated groundwater does not pose unacceptable risk to ecological receptors (IT, 2003).

ADEM, in their comments on the *FFS* (ADEM, 2003b), concurred with recommendations of the *FFS* to implement LUCs and MNA to address groundwater contamination at the Site. ADEM subsequently agreed that one round of groundwater samples should be collected and analyzed for MNA parameters before implementation of LUCs and MNA (ADEM, 2003c).

3.4 April 2004 Groundwater Sampling and CMIP

One round of groundwater samples was collected in March and April 2004 and a *Final CMIP* (MES, 2006a) was submitted to ADEM to meet the requirement outlined in the *FFS*. Based on the March/April 2004 sample results, the highest concentrations of VOCs were in groundwater samples collected from residuum monitoring well FTA-94-MW01 and bedrock monitoring well FTA-94-MW11. Vinyl chloride and cis-1,2-DCE, both degradation products of TCE, were generally restricted to groundwater collected from these two monitoring wells. Additionally, the concentrations of chlorinated solvents detected in groundwater samples generally declined during the interval since the previous groundwater sampling rounds. For example, TCE was present in residuum groundwater collected from monitoring well FTA-94-MW01 at 53 micrograms per liter (µg/l) in December 2000, but decreased to 11 µg/l by March 2004. Similarly, TCE was present in bedrock groundwater collected from monitoring well FTA-94-MW11 at 75 µg/l in December 2000 but decreased to 34 µg/l by March 2004. An interpretation of the TCE plume showing isoconcentration contours for TCE in residuum and bedrock groundwater in March 2004 is presented in Figures 3-1 and 3-2, respectively. Please note the isoconcentration contours for TCE are shown at the revised site-specific screening levels (SSSLs) (see Section 5.5.3 for further details concerning SSSLs) which differs from the contour concentrations shown in the TCE concentration figures in preceding CMERs.

Groundwater samples were also analyzed for constituents including ethane, ethene, methane, iron, manganese, and inorganic water quality parameters including nitrate and nitrite. The concentrations of these constituents helped identify groundwater where MNA may be successfully implemented. Methane was detected in groundwater from the bedrock monitoring wells and four of the residuum monitoring wells. The maximum concentration was 1,600 µg/l in groundwater collected from bedrock monitoring well FTA-94-MW14. This monitoring well is located upgradient of the contaminated groundwater; however, methane is a product of fermentation of organic material and groundwater at this location contains detectable concentrations of organic carbon. Nitrate and nitrite either were not detected or were present at low concentrations (0.4 milligrams per liter [mg/l] or less). Similarly, the concentrations of sulfate were less than 12 mg/l in groundwater from wells containing elevated concentrations of chlorinated solvents. The presence of methane in the bedrock wells and low or nondetect concentrations of nitrate, nitrite, and sulfate generally indicate that reducing conditions are

present and appropriate for biologically mediated reductive dehalogenation of chlorinated solvents.

3.5 February 2005 Groundwater Sampling and CMER

Groundwater samples were collected in February 2005 and a *CMER* (MES, 2006b) was submitted to ADEM to meet the requirement outlined in the *CMIP* (MES, 2006a). Based on the February 2005 sample results, the highest concentrations of VOCs were in groundwater samples collected from residuum monitoring well FTA-94-MW01 and bedrock monitoring well FTA-94-MW11. The occurrence of vinyl chloride and cis-1,2-DCE, degradation products of TCE, was generally restricted to groundwater collected from bedrock monitoring well FTA-94-MW11. Additionally, the concentrations of chlorinated solvents detected in groundwater samples generally decreased during the interval since the previous groundwater sampling rounds. For example, TCE was present in residuum groundwater collected from monitoring well FTA-94-MW01 at 11 µg/l in March 2004, but decreased to 2.8 µg/l by February 2005. Similarly, TCE was present in bedrock groundwater collected from monitoring well FTA-94-MW11 at 34 µg/l in March 2004 but decreased to 16 µg/l by February 2005.

The maximum concentration of methane in the residuum was 31 µg/l in monitoring well FTA-94-MW07. The maximum concentration of methane in bedrock was 270 µg/l in monitoring well FTA-94-MW14. Nitrate and nitrite either were not detected or were present at low concentrations (0.2 mg/l or less). Similarly, the concentrations of sulfate were less than 12 mg/l in groundwater collected from monitoring wells FTA-94-MW01 and FTA-94-MW11, which contained elevated concentrations of chlorinated solvents, but was as high as 48.4 mg/l in groundwater collected from bedrock monitoring well FTA-94-MW16 where chlorinated solvents were not detected. The presence of methane in groundwater samples collected from the residuum and bedrock monitoring wells, and low or nondetect concentrations of nitrate, nitrite, and sulfate indicated that reducing conditions were present and appropriate for biologically mediated reductive dehalogenation of chlorinated solvents.

3.6 December 2005 Groundwater Sampling and CMER

Groundwater samples were collected in December 2005 and a *CMER* (MES, 2006c) was submitted to ADEM to meet the requirement outlined in the *CMIP* (MES, 2006a). Based on the December 2005 sample results, the highest concentrations of VOCs were in groundwater samples collected from residuum monitoring well FTA-94-MW01 and bedrock monitoring well FTA-94-MW11. Eight VOCs were detected in one or more of the December 2005 groundwater samples including: acetone, benzene, chlorobenzene, cis-1,2-DCE, toluene, trans-1,2-dichloroethene (trans-1,2-DCE), TCE, and vinyl chloride. TCE in residuum groundwater was detected at a maximum concentration of 3.9 µg/l in residuum monitoring well FTA-94-MW01. TCE in bedrock groundwater was detected at a maximum concentration of 18 µg/l in bedrock monitoring well FTA-94-MW11. Vinyl chloride was detected in only one groundwater sample collected from bedrock monitoring well FTA-94-MW11 at an estimated concentration of 2.4 µg/l.

The maximum concentration of methane in groundwater collected from residuum monitoring

wells was 18 µg/l at FTA-94-MW03. The maximum concentration of methane in groundwater collected from bedrock monitoring wells was 870 µg/l at FTA-94-MW14. Nitrate and nitrite either were not detected or were present at low concentrations (less than 0.4 mg/l). Similarly, the concentrations of sulfate were less than 6 mg/l in groundwater collected from monitoring wells FTA-94-MW01 and FTA-94-MW11, which contained elevated concentrations of chlorinated solvents, but were as high as 45.9 mg/l in groundwater collected from monitoring well FTA-94-MW16 where chlorinated solvents were not detected. The presence of methane in groundwater samples collected from the residuum and bedrock monitoring wells, and low or nondetect concentrations of nitrate, nitrite, and sulfate indicated reducing conditions, which was appropriate for biologically mediated reductive dehalogenation of chlorinated solvents.

3.7 June 2006 Groundwater Sampling and CMER

Groundwater samples were collected in June 2006 and a *CMER* (MES, 2006d) was submitted to ADEM to meet the requirement outlined in the *CMIP* (MES, 2006a). Based on the June 2006 sample results, the highest concentrations of VOCs were in the groundwater sample collected from bedrock monitoring well FTA-94-MW11. Nine VOCs were detected in one or more of the June 2006 groundwater samples including: acetone, benzene, carbon disulfide, chlorobenzene, cis-1,2-DCE, toluene, trans-1,2-DCE, TCE, and vinyl chloride. TCE in residuum groundwater was detected at a maximum concentration of 2.5 µg/l in residuum monitoring well FTA-94-MW05. TCE in bedrock groundwater was detected at a maximum concentration of 41 µg/l in bedrock monitoring well FTA-94-MW11 and was identified as an increase in concentration from the previous sampling round. Vinyl chloride was detected in only one groundwater sample collected from bedrock monitoring well FTA-94-MW11 at a concentration of 8.3 µg/l. An interpretation of the TCE plume showing isoconcentration contours for TCE in residuum and bedrock groundwater samples collected during June 2006 is presented in Figures 3-3 and 3-4, respectively. Please note the isoconcentration contours for TCE are shown at the revised SSSLs (see Section 5.5.3 for further details concerning SSSLs) which differs from the contour concentrations shown in the TCE concentration figures in preceding CMERs. As a result, no plume is shown on Figure 3-3 because the TCE concentrations in residuum wells were below the most conservative (i.e., residential) SSSL in June 2006.

The maximum concentration of methane in groundwater collected from residuum monitoring wells was 41 µg/l at FTA-94-MW03. The maximum concentration of methane was 1,200 µg/l in groundwater collected from bedrock monitoring well FTA-94-MW14. The presence of methane in groundwater samples collected from the residuum and bedrock monitoring wells indicated reducing conditions, which was appropriate for biologically mediated reductive dehalogenation of chlorinated solvents. MNA parameters were not collected during this round.

4.0 SUMMARY OF DECEMBER 2006 ACTIVITIES

To meet the recommended actions outlined in the *CMIP* (MES, 2006a) and the previous CMERs (MES, 2006b, 2006c, and 2006d), the following activities were performed during the December 2006 field investigation:

- Measured groundwater levels in nine residuum wells and six bedrock wells.
- Collected groundwater samples from nine residuum and six bedrock wells and analyzed for VOCs, light hydrocarbons, total and dissolved iron and manganese, alkalinity, ammonia, anions (chloride, nitrate, nitrite, and sulfate), total phosphorus, sulfide, total kjeldahl nitrogen (TKN), and total organic carbon (TOC).

The activities performed during this investigation are described in the following subsections.

4.1 Groundwater Sampling

Groundwater samples were collected in accordance with methodology presented in the *Sampling and Analysis Plan* (*SAP* [MES, 2004]). Before groundwater samples were collected, water levels were measured to the nearest hundredth of a foot using a Solinst™ water level indicator and total well depth was measured and recorded. Groundwater samples were collected using a submersible pump. The pump was lowered into the well and positioned at the screened interval. Poly tubing leading from the discharge side of the submersible pump was connected to a flow-through cell equipped with a YSI Model Multiprobe Water Quality Meter. Measurements of field screening data were used to indicate when groundwater quality had stabilized and sampling could begin. Field screening data included pH, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), total dissolved solids (TDS), temperature, pumping rate, water level and volume of groundwater removed. The monitoring well sample collection logs are provided in Appendix A.

Groundwater samples were collected from the well pump outlet after it was identified that the field screening data had stabilized. Laboratory-supplied sample bottles were filled. Sample containers were labeled, placed in a chilled cooler and shipped under chain-of-custody procedures to EMAX Laboratories, Torrance, CA. Figure 4-1 shows the groundwater sampling locations. Table 4-1 presents a summary of groundwater sample station names and analytical parameters. The chain-of-custody forms for the groundwater samples collected during the December 2006 investigation are provided in Appendix B.

4.2 Data Quality Review

MES reviewed the analytical data for the groundwater samples collected in December 2006. The data quality review was performed in accordance with the *Quality Assurance Plan (QAP)* (MES, 2005) to assess compliance with the QA objectives, and to assess hard copy and electronic deliverable consistency and integrity. Appendix C includes the analytical data collected during the December 2006 investigation. The *Data Quality Summary (DQS)* for the December 2006 groundwater samples may be found in Appendix D.

5.0 RESULTS OF DECEMBER 2006 GROUNDWATER SAMPLING

This section discusses the results of the December 2006 investigation at the Site.

5.1 Groundwater Levels

Groundwater elevations measured during the December 2006 groundwater sampling event are presented in Table 5-1. During this investigation, monitoring well FTA-94-MW08 was dry, therefore, no water level measurements were collected at this well. Figure 5-1 shows groundwater elevations and potentiometric surface contour lines for the residuum monitoring wells based on the December 2006 water level measurements. Groundwater in the residuum generally follows the surface topography and flows in a northerly direction from the Site towards Ingram Creek and is consistent with the groundwater elevation measurements from June 2006 (Figure 2-5).

Figure 5-2 shows similar information for the bedrock wells. Groundwater elevation measurements for December 2006 indicated that groundwater flow in bedrock is in a northerly direction, similar to that for groundwater flow in the residuum. This is consistent with the groundwater elevation measurements from June 2006 (Figure 2-6).

5.2 Analytical Data and Data Quality Review

The analytical data for the December 2006 samples are provided in Appendix C. Samples were analyzed for VOCs, total and dissolved iron and manganese, and MNA parameters. MES reviewed the analytical data in accordance with the quality assurance plan *QAP* (MES, 2005). The results of the data quality review for the groundwater samples collected during the December 2006 investigation are presented in the *DQS* in Appendix D. Based on the data quality review, the analytical data generated for this investigation were adequate to fulfill program objectives and were suitable for preparation of this report. A more detailed discussion of the analytical results can be found in the *DQS* (Appendix D).

5.3 Groundwater Field Parameter Results

Measurements of field screening parameters were used to indicate when groundwater quality had stabilized and sampling could begin. Field screening parameters included pH, conductivity, DO, ORP, turbidity, and temperature. The field screening parameters for the groundwater samples are summarized in Table 5-2. Field screening parameter results indicated groundwater sampling was performed in accordance with the *SAP* (MES, 2004).

5.4 Summary of Groundwater Analytical Results

During the December 2006 investigation, groundwater samples were collected from nine residuum wells and six bedrock wells at the Site and analyzed for VOCs and MNA parameters. This section describes the analytical results for the December 2006 groundwater samples.

5.4.1 Volatile Organic Compounds Analytical Results

The analytical results for VOCs detected in the residuum and bedrock groundwater samples are presented in Table 5-3. To simplify the presentation of historical analytical results and facilitate identification of downward or upward trends in compound concentrations, analytical results from previous sampling events are also presented in Table 5-3. Seven VOCs were detected in one or more of the December 2006 groundwater samples including: benzene, carbon disulfide, chlorobenzene, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride. TCE was detected in groundwater collected from residuum monitoring wells: FTA-94-MW01 (4 µg/l), FTA-94-MW03 (0.73 J µg/l), FTA-94-MW05 (1.2 µg/l), and FTA-94-MW07 (0.4 J µg/l); and bedrock monitoring wells FTA-94-MW11 (16 µg/l), FTA-94-MW13 (0.34 J µg/l) and FTA-94-MW14 (0.28 J µg/l). The maximum concentration of TCE was 16 µg/l in groundwater collected from monitoring well FTA-94-MW11. Vinyl chloride was detected in groundwater collected from monitoring wells FTA-94-MW11 (9.7 µg/l) and FTA-94-MW12 (0.28 J µg/l).

5.4.2 Monitored Natural Attenuation Parameter Analytical Results

Groundwater samples collected during the December 2006 investigation were analyzed for ethane, ethene, methane, total and dissolved iron and manganese, chloride, nitrate, nitrite, sulfate, sulfide, total phosphorus, alkalinity, ammonia, TKN and TOC. The concentrations of these constituents help to identify if conditions are suitable for MNA. The analytical results for the MNA parameters are presented in Table 5-3. MNA analytical results from previous sampling events are also presented in Table 5-3.

Methane was detected in groundwater collected from residuum monitoring wells FTA-94-MW02 to FTA-94-MW04, and FTA-94-MW07; and bedrock monitoring wells FTA-94-MW11 to FTA-94-MW14. The maximum concentration of methane in groundwater samples collected from the residuum was 26 µg/l at FTA-94-MW04, and 700 µg/l at FTA-94-MW14 for the bedrock. Monitoring well FTA-94-MW14 is located upgradient of the contaminated groundwater, however, methane is a product of fermentation of organic material and groundwater at this location contains detectable concentrations of organic carbon.

Nitrate and nitrite either were not detected or were present at low concentrations (less than 0.5 mg/l), with the exception of nitrate in residuum monitoring wells FTA-94-MW07 (8.23 mg/l) and FTA-94-MW10 (2.51 mg/l) where VOCs were either nondetect or at very low concentrations. Similarly, the concentrations of sulfate were less than 12 mg/l in groundwater collected from monitoring wells with elevated TCE concentrations.

5.5 Discussion of Analytical Results

An evaluation of the December 2006 analytical results and effectiveness of MNA is discussed in the following subsections.

5.5.1 Evaluation of Sample Results

The December 2006 results were compared to the analytical results from the previous rounds of

sampling. For groundwater collected from the residuum monitoring wells, chemical concentrations in December 2006 were generally comparable or less than chemical concentrations observed in June 2006. The concentration of TCE in groundwater collected from residuum monitoring well FTA-94-MW01 increased slightly from June 2006 (1.1 µg/l) to December 2006 (4 µg/l). TCE concentrations in groundwater collected from residuum monitoring wells FTA-94-MW03 and FTA-94-MW05 decreased from June 2006 (1.2 µg/l and 2.5 µg/l, respectively) to December 2006 (0.73 J µg/l and 1.2 µg/l, respectively).

For groundwater collected from the bedrock monitoring wells, chemical concentrations in December 2006 were generally less than chemical concentrations observed in June 2006. In groundwater collected from the bedrock monitoring well FTA-94-MW11, chemical concentrations for TCE, chlorobenzene, cis-1,2-DCE, and trans-1,2-DCE decreased from June 2006 to December 2006. However, the vinyl chloride concentration in FTA-94-MW11 increased slightly from June 2006 to December 2006.

An interpretation of the TCE plume showing isoconcentration contours for TCE at the revised SSSLs (see Section 5.5.3 for further details concerning SSSLs) is shown in Figure 5-3 for the residuum groundwater samples collected in December 2006 and in Figure 5-4 for the bedrock groundwater samples collected in December 2006. When the interpreted extent of TCE from June 2006 (Figures 3-3 and 3-4) is compared to the December 2006 interpreted extent (Figures 5-3 and 5-4), a reduction of the TCE concentration and plume is observed for the bedrock, and a slight increase of the TCE concentration is observed for the residuum. A general reduction in chlorinated solvents is indicated in Figures 5-5 and 5-6, which show the trend in concentrations of VOCs at residuum monitoring well FTA-94-MW01 and bedrock monitoring well FTA-94-MW11, respectively.

Groundwater collected from clustered monitoring wells was evaluated based on chemical concentrations and vertical hydraulic gradients to assess the potential for vertical migration of chlorinated solvents at the Site. As noted in ITs *RI*, monitoring wells FTA-94-MW11 and FTA-94-MW13 were installed adjacent to well FTA-94-MW01, well FTA-94-MW12 was installed adjacent to well FTA-94-MW03, and well FTA-94-MW16 was installed adjacent to well FTA-94-MW15 to determine the vertical extent of chlorinated VOCs in groundwater at the Site (IT, 2002). Monitoring wells FTA-94-MW01, FTA-94-MW03, and FTA-94-MW15 were completed in the residuum or shallow bedrock; monitoring wells FTA-94-MW11, FTA-94-MW12, and FTA-94-MW16 were completed deeper in the bedrock; and monitoring well FTA-94-MW13 was completed approximately 60 feet deeper than well FTA-94-MW11. Table 5-4 shows the TCE and vinyl chloride concentrations in groundwater collected from each well cluster. Only well cluster FTA-94-MW01/FTA-94-MW11/FTA-94-MW13 had notable concentrations of TCE. Vinyl chloride was detected only in groundwater collected from bedrock wells FTA-94-MW11 and FTA-94-MW12. The TCE concentration in groundwater collected from bedrock well FTA-94-MW11 was higher than in groundwater collected from residuum well FTA-94-MW01 and deep bedrock well FTA-94-MW13 during the December 2006 investigation, as well as during previous investigations. Table 5-5 shows the vertical hydraulic gradients for groundwater at well cluster FTA-94-MW01/FTA-94-MW11/FTA-94-MW13. In December 2006, an upward vertical gradient of -0.00357 feet per foot (ft/ft) was observed between bedrock well FTA-94-MW11 and residuum well FTA-94-MW01, indicating a slight upward movement of groundwater from the

bedrock zone to the residuum. Low magnitude downward vertical gradients were observed from bedrock well FTA-94-MW11 to deep bedrock well FTA-94-MW13 (0.00459 ft/ft), and from residuum well FTA-94-MW01 to deep bedrock well FTA-94-MW13 (0.00214 ft/ft). The slight downward vertical gradient observed between bedrock well FTA-94-MW11 and deep bedrock well FTA-94-MW13 indicate limited potential for downward movement of groundwater from the bedrock zone into the deeper bedrock. However, the lower TCE and vinyl chloride concentrations in groundwater from the deep bedrock relative to the bedrock, and the decreasing concentrations in both the bedrock and deep bedrock over time indicates that MNA is likely occurring in the deep bedrock groundwater zone as well as the bedrock groundwater zone.

5.5.2 Evidence for Natural Attenuation

Natural attenuation refers to naturally occurring processes in soil and groundwater that act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contaminants in those media. These in-situ processes include biotransformation, dispersion, dilution, adsorption, volatilization and chemical or biological stabilization or destruction of contaminants (U.S. Environmental Protection Agency [EPA], 1998).

Biotransformation can often be a dominant process in the natural attenuation of chlorinated solvents. Chlorinated solvent degradation largely occurs by reductive dechlorination (EPA, 1998). Reductive dechlorination is a microbially mediated reaction whereby a chlorine atom on the chlorinated solvent is replaced by a hydrogen atom (Vogel and McCarty, 1987). In many bioremediation processes, an organic contaminant (hydrocarbon) acts as an electron donor and another substance (such as oxygen or nitrate) acts as the electron acceptor. However, during reductive dechlorination, hydrogen acts as the electron donor and halogenated compounds such as chlorinated solvents, act as electron acceptors and thus become reduced.

$$R\text{-}CL + H^{+} + 2\,e^{-} \longrightarrow R\text{-}H + Cl^{-}$$

The site chemistry and the oxidation-reduction potential of a site play an important role in whether reductive dechlorination will occur. Reductive dechlorination will occur only after oxygen and other electron acceptors such as nitrate, nitrite and sulfate have been depleted from the aquifer. Oxygen, nitrate, nitrite and sulfate are more energetically favorable to the microbial population as electron acceptors than chlorinated solvents when hydrogen is the electron donor. In addition, alkalinity is analyzed to measure the buffering capacity of the groundwater, while iron and manganese are used to indicate if anaerobic biological activity is present.

The role of hydrogen as an electron donor during reductive dechlorination is a key factor governing the dechlorination of chlorinated compounds (Carr, C.S. and J.B. Hughes, 1998). Hydrogen is produced in the subsurface by the microbial fermentation of organic compounds including anthropogenic compounds such as petroleum hydrocarbons and natural organic matter. Hydrogen is then used by the dechlorinating bacteria as an electron donor.

The EPA has developed screening protocols for identifying aquifers where natural attenuation is likely occurring. The protocol includes screening criteria for which points are awarded to highlight characteristics that (1) promote anaerobic biodegradation, or (2) are characteristic of

anaerobic biodegradation processes (EPA, 1998). Table 5-6 presents a chart showing the screening criteria and point scoring system for groundwater samples collected during the December 2006 sampling event. The chart was completed for groundwater collected from residuum monitoring well FTA-94-MW01 and from bedrock monitoring well FTA-94-MW11. Concentrations of TCE in groundwater samples collected from FTA-94-MW01 and FTA-94-MW11 are considered representative of TCE concentrations in residuum and bedrock wells, respectively, because the highest concentrations of chlorinated solvents were detected in groundwater collected from these monitoring wells. The results of the screening protocol indicate that there is limited to adequate evidence for MNA in the residuum groundwater and bedrock groundwater. This result is based largely on (1) the presence of daughter products in groundwater including cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, and methane, and (2) the low concentrations of electron accepting anions including nitrate and sulfate.

Because the existing concentrations of TCE are low (< 20 µg/l) evidence for MNA, based on the screening for anaerobic biodegradation processes, would likely be stronger if higher concentrations of chlorinated solvents, including TCE, were present in the groundwater at the Site. MNA daughter products such as methane, ethane and ethene are stoichiometrically related to the starting concentrations of TCE. The low concentrations of TCE in groundwater at the Site minimize the concentrations of daughter products that can be expected to be present in groundwater at the Site. Consequently, despite the presence of daughter products such as methane, points cannot be awarded in the anaerobic biodegradation processes screening criteria because of concentrations that are too low (<0.5 mg/l methane; <0.01 mg/l ethane/ethane).

The downward trend in concentrations of VOCs at residuum monitoring well FTA-94-MW01 (Figure 5-5) and bedrock monitoring well FTA-94-MW11 (Figure 5-6) further supports MNA as an effective means of remediating chlorinated solvents at this Site.

The presence of methane in the residuum and bedrock monitoring wells, and low or nondetect concentrations of nitrate, nitrite and sulfate generally indicate that reducing conditions are present and appropriate for biologically mediated reductive dehalogenation of chlorinated solvents.

The nitrate concentrations in residuum monitoring wells FTA-94-MW07 and FTA-94-MW10 increased from not detected in December 2005 to 8.23 mg/l and 2.51 mg/l, respectively, in December 2006. This may be an indication that the organics have degraded in the groundwater at these locations.

5.5.3 Comparison of Concentrations to Site-Specific Screening Levels

The VOC concentrations detected in groundwater samples were compared to residential, groundskeeper, and construction worker site-specific screening levels (SSSLs) to further evaluate the effectiveness of MNA. The residential, groundskeeper, and construction worker SSSLs presented in this report have been revised from those that were presented in previous reports. The revision of the SSSLs is in response to updated toxicological properties provided in the *Alabama Risk-Based Corrective Action Guidance Manual (ARBCA)* (ADEM, 2006). The revised SSSL values are presented in Table 5-3.

The TCE concentration in residuum monitoring well FTA-94-MW01 (4 µg/l) exceeded the residential SSSL of 3.83 µg/l. The TCE and vinyl chloride concentrations in bedrock monitoring well FTA-94-MW11 (16 µg/l and 9.7 µg/l, respectively) exceeded the residential SSSLs of 3.83 µg/l and 0.0918 µg/l, respectively. The vinyl chloride concentration in bedrock monitoring well FTA-94-MW12 (0.28 J µg/l) exceeded the residential SSSL (0.0918 µg/l). The benzene concentration in bedrock monitoring well FTA-94-MW14 (2.9 µg/l) exceeded the residential SSSL of 0.923 µg/l. No chemical concentrations exceeded their respective groundskeeper or construction worker SSSLs.

Natural attenuation parameters were not compared to SSSLs as many of the constituents do not have SSSLs. As discussed in Section 5.5.2, these constituents were analyzed to monitor the nature of the conditions in the groundwater and evaluate if biological remediation is occurring.

6.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This section summarizes the activities performed during the December 2006 investigation at the Site and presents the major results, conclusions and recommendations. Parcel 94(7) was previously investigated and corrective measures were selected in the *FFS* (IT, 2003). Based on results of the *FFS*, the recommended and approved remedy for the Site was MNA with LUCs. The *CMIP* (MES, 2006a) subsequently was written and recommended implementation of MNA. The December 2006 investigation was performed to meet the recommendations of the *CMIP*.

The purpose of this CMER is to demonstrate continuing effectiveness of MNA, the selected remedy for groundwater contamination at Parcel 94(7). Objectives for the December 2006 investigation and this CMER included:

- Summarize environmental sampling data from previous investigations and present analytical results for the December 2006 investigation.
- Compare the results of the previous rounds of groundwater sampling to the December 2006 groundwater sampling results to evaluate the effectiveness of MNA as a remedy for degradation of chlorinated solvents in groundwater at Parcel 94(7).

6.1 December 2006 Activities

To meet the objectives outlined in the *CMIP* (MES, 2006a) and the previous CMERs (MES, 2006b, 2006c, and 2006d), the following activities were performed:

- Measured groundwater levels in nine residuum wells and six bedrock wells.
- Collected groundwater samples from nine residuum and six bedrock wells using conventional sampling techniques. The groundwater samples were analyzed for VOCs, hydrocarbons, iron, manganese, alkalinity, ammonia, TKN, phosphorus, sulfide, anions, and TOC.
- Reviewed analytical results to assess compliance with QA objectives and to assess hard copy consistency and integrity with electronic data deliverables.

6.2 Results of the December 2006 Investigation

The following conclusions were derived from the December 2006 investigation:

- Groundwater elevations and direction of groundwater flow in the residuum and bedrock were similar in December 2006 to that observed during previous monitoring events. Groundwater in the residuum generally follows the surface topography and flows in a northerly direction from the Site towards Ingram Creek. Similarly, groundwater flows in a northerly direction in bedrock.

- The analytical data generated for this investigation were suitable to fulfill program objectives and for use in preparing this report. A more detailed discussion of the analytical results can be found in the *DQS* (Appendix D).

- Seven VOCs were detected in one or more of the December 2006 groundwater samples including: benzene, carbon disulfide, chlorobenzene, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride. Chemical concentrations in December 2006 were generally less than chemical concentrations observed in June 2006. The concentration of TCE in groundwater collected from residuum monitoring well FTA-94-MW01 increased slightly since June 2006. TCE concentrations in groundwater collected from residuum monitoring wells FTA-94-MW03 and FTA-94-MW05 decreased from June 2006 to December 2006. In groundwater collected from the bedrock monitoring well FTA-94-MW11, chemical concentrations decreased from June 2006 to December 2006, with the exception of vinyl chloride which increased slightly from June 2006 to December 2006.

- The slight downward vertical gradient observed between bedrock well FTA-94-MW11 and deep bedrock well FTA-94-MW13 indicate limited potential for downward movement of groundwater from the bedrock zone into the deeper bedrock. However, the lower TCE and vinyl chloride concentrations in groundwater from the deep bedrock relative to the bedrock, and the decreasing concentrations in both the bedrock and deep bedrock over time indicates that MNA is likely occurring in the deep bedrock groundwater zone as well as the bedrock groundwater zone.

- The VOC concentrations in groundwater were compared to residential, groundskeeper, and construction worker SSSLs (IT, 2000 and ADEM, 2006). The following VOCs had concentrations exceeding their respective residential SSSLs (Table 5-3): TCE in residuum monitoring well FTA-94-MW01, TCE and vinyl chloride in bedrock monitoring well FTA-94-MW11, vinyl chloride in bedrock monitoring well FTA-94-MW12, and benzene in bedrock monitoring well FTA-94-MW14. No chemical concentrations exceeded their respective groundskeeper or construction worker SSSLs.

- Methane continues to be detected in groundwater samples collected from residuum and bedrock monitoring wells. Nitrate and nitrite either were not detected or were present at low concentrations (less than 0.5 mg/l), with the exception of two residuum monitoring wells, FTA-94-MW07 and FTA-94-MW10 where VOCs were either nondetect or at very low concentrations. Similarly, the concentrations of sulfate in the locations with the greatest TCE concentrations were less than 12 mg/l. The presence of methane in groundwater samples collected from the residuum and bedrock monitoring wells, and historically low or nondetect concentrations of nitrate, nitrite, and sulfate generally indicate that reducing conditions are present and appropriate for biologically mediated reductive dehalogenation of chlorinated solvents.

6.3 Conclusions and Recommendations

The December 2006 analytical results support the continuing effectiveness of MNA as the selected groundwater remedy at the Site. This conclusion is supported by the following

observations: (1) lower concentrations of chlorinated solvents in residuum and bedrock compared to historical concentrations, (2) presence of MNA degradation products in groundwater, and (3) favorable reducing conditions in residuum and bedrock groundwater. The continued use of MNA as the groundwater remedy for the Site contamination is expected to further reduce VOC concentrations in groundwater.

The concentrations of chlorinated solvents in groundwater collected from bedrock monitoring well FTA-94-MW11 which increased between December 2005 and June 2006, had decreased from June 2006 to December 2006, with the exception of vinyl chloride. Although vinyl chloride, a daughter product of TCE, was detected at a concentration above the residential SSSL in bedrock monitoring well FTA-94-MW11, this concentration is expected to decrease over time through the continued attenuation of chlorinated solvents.

Based on the information outlined above, the JPA recommends continued use of MNA at this Site. Sampling of VOCs and MNA parameters will continue during the next sampling round in order to further evaluate the effectiveness of MNA at the Site.

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